

**STUDIES ON STAND PARAMETERS AND NATURAL
REGENERATION STATUS OF SILVER FIR AND
SPRUCE IN HIMACHAL PRADESH**

Thesis

by

Yashpal Sharma

*Submitted in partial fulfilment of the requirements
for the degree of*

MASTER OF SCIENCE

in

**FORESTRY
(SILVICULTURE)**



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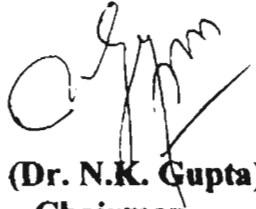
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CERTIFICATE –I

This is to certify that the thesis entitled “**Studies on stand parameters and natural regeneration status of silver fir and spruce in Himachal Pradesh**” submitted in partial fulfillment of the requirement for the award of degree of **MASTER OF SCIENCE in FORESTRY (SILVICULTURE)** to Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni-Solan (H.P.) is a bonafide research work carried out by **Mr. Yashpal Sharma (F-2003-12-M)** 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 investigation have been fully acknowledged.

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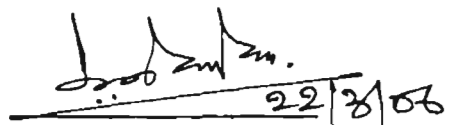

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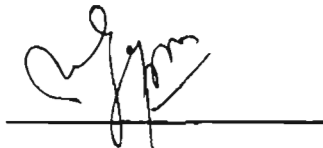
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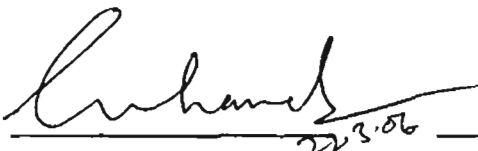

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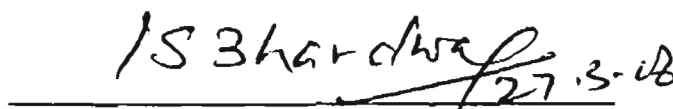
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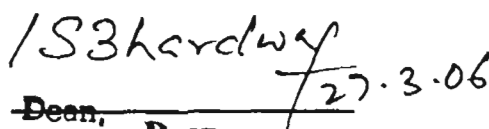
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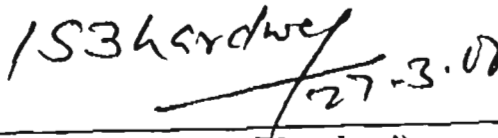
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This is to certify that all the mistakes and errors pointed out by the external examiner have been incorporated in the thesis entitled, “**Studies on stand parameters and natural regeneration status of silver fir and spruce in Himachal Pradesh**” submitted to Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni-Solan (H.P.) by **Mr. Yashpal Sharma (F-2003-12-M)** in partial fulfillment of the requirements for the award of degree of **MASTER OF SCIENCE in FORESTRY (SILVICULTURE)**.



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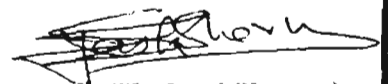
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Needless to mention errors and omissions are mine.

Nauni, Solan,
Dated: Jan 24, 2006


(Yashpal Sharma)

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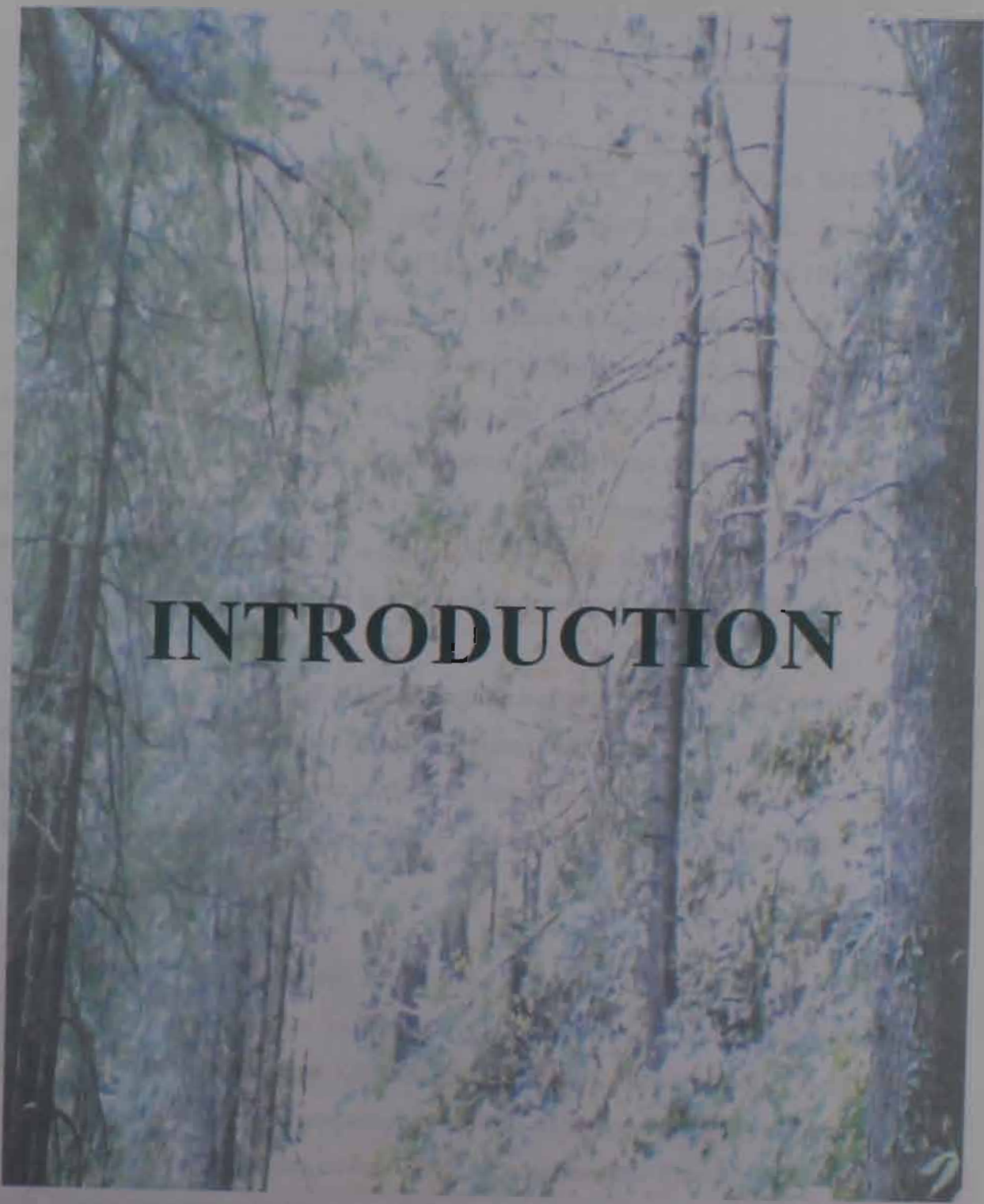
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Chapter 1
INTRODUCTION



INTRODUCTION

Chapter - I

INTRODUCTION

The demand for forest resources is increasing day by day, to fulfill the requirement of ever increasing population throughout the world. Extensive denudation of the forests in past has reduced the vegetation cover of Himalayan watersheds significantly. Urbanization and increase in cattle population has exerted a tremendous pressure on forest causing their shrinkage at much faster rate. In the absence of any land-use regulations has imposed further constraints in the soil and water conservation programmes in ecologically crucial and sensitive hilly areas of the State (Anonymous, 2002). To carryout suitable management programmes for these degrading forest, the knowledge of population structure and regeneration potential of different tree species is of utmost importance (Adhikari, 1996).

Himachal Pradesh has a total geographical area of 55,673 Km², with 3.54 million ha. recorded forest area, which constitutes 63.60% of total geographical area. However, the actual forest cover of the state based on the satellite data of Oct.-Dec., 1998 figures to 13,082 Sq. Km, which constitute 23.50% of geographical area (Anonymous, 2002).

Silver fir (*Abies pindrow*) and spruce (*Picea smithiana*) commonly referred as high level conifers, cover extensive areas in north-west Himalayan states of Himachal Pradesh, Jammu and Kashmir and Uttranchal. They occupy 31% of total area under coniferous forests and account for 49% of the total growing stock in these states. Together these species cover 15640 ha. in Himachal Pradesh (Balu, 2000). These forests are very valuable resource as they play an important role in improving the economy of these states, and help soil and water conservation in catchment areas

of major rivers (Kumar et al., 2002). These species extend throughout the western Himalaya from Afghanistan to Nepal chiefly from 7,000 ft to 12,000 ft, but sometimes descend and are found in cool ravines. Pure stands of silver fir and spruce are rare (Troup, 1921), usually associated with scattered trees of *Cedrus deodara*, *Pinus wallichiana*, *Quercus dilatata*, *Q. semicarpifolia* and *Taxus baccata* (Singh et al., 1987).

In mountainous region marked variation in site factors and vegetation occur due to change in aspect. The greatest difference in microclimate exists between north and south facing slopes (Smith, 1977). Aspect has considerable influence on the altitudinal distribution and growth of the species present. Most tree species reach their lower limits on north facing slope and highest on south facing. Deodar and Kharsu oak are however, mainly on the south faces in most of their altitudinal range while fir and spruce are particularly associated on north faces (Singh, 1998). Himachal has a wide range of altitudes, temperature, precipitation and topography which results in a diversified and rich forest flora varying from northern tropical dry deciduous forests to alpine pastures. The vegetational growth efficiency of the region depends upon the type, quantity and stratification of vegetation. Therefore, to conduct any study on ecology of these areas, a quantitative evaluation of its vegetation becomes a prerequisite.

Successful establishment of crop by natural regeneration follows a series of events that are often difficult for a forester to control. While the number and distribution of seed tree within a stand can be regulated by management. Detailed information about the fate of the seed following dispersal is scarce, thus it is difficult to decide what steps are most critical for the success of regeneration and what management should be used to circumvent the problems (Harmer, 1995).

Natural regeneration of fir has been a problem. These forests have been managed under various systems for helping natural regeneration. In selection

system, lack of adequate light on forest floor, accumulation of thick layer of humus, dense weed growth, poor seed production and grazing are considered responsible for the absence of regeneration. Shelterwood system was introduced in fir forests of Kullu and Seraj forest divisions of Himachal Pradesh but natural regeneration in these forests could not be helped (Dwivedi, 1993).

Being situated at higher elevation in the interiors of the valleys and because of the less demand for fir and spruce these forests were not commercially exploited till the 1st World War, when the demand arose the exploitation of these forests get started. With this a need to evolve the techniques for regenerating these forests was felt. Many experiments and attempts were made towards regenerating these forests, which indicated that natural regeneration in these forests is very scanty and needed to be supplemented by artificial regeneration with proper manipulation of the canopy to admit light, was the only possibility (Singh and Singh, 1987a). These forests were managed under shelterwood system with fixed periodic blocks in the past plans, the commercial felling has created permanent gaps resulting in irregular, understocked forests which were still deficient in regeneration.

There is lot of biotic pressure on these forests by local population and the nomads. The main economy of these people in the mountain region revolves around keeping large herd of sheep, goats and cattle. Transitional movement of herds is still common phenomenon with the change in season. At the start of winter and spring, forests and meadows along migration routes are open for nomadic grazers as well as local communities to graze cattle. To increase the fodder production, people set the forest and grazing ground on fire. This has resulted in loss of regeneration of fire sensitive climax and pre-climax species (Anonymous, 2004).

The regeneration behavior of the species in a forest is determined by its population structure and characterized by the presence of sufficient number of seedlings, saplings and young trees, which indicate successful regeneration of the

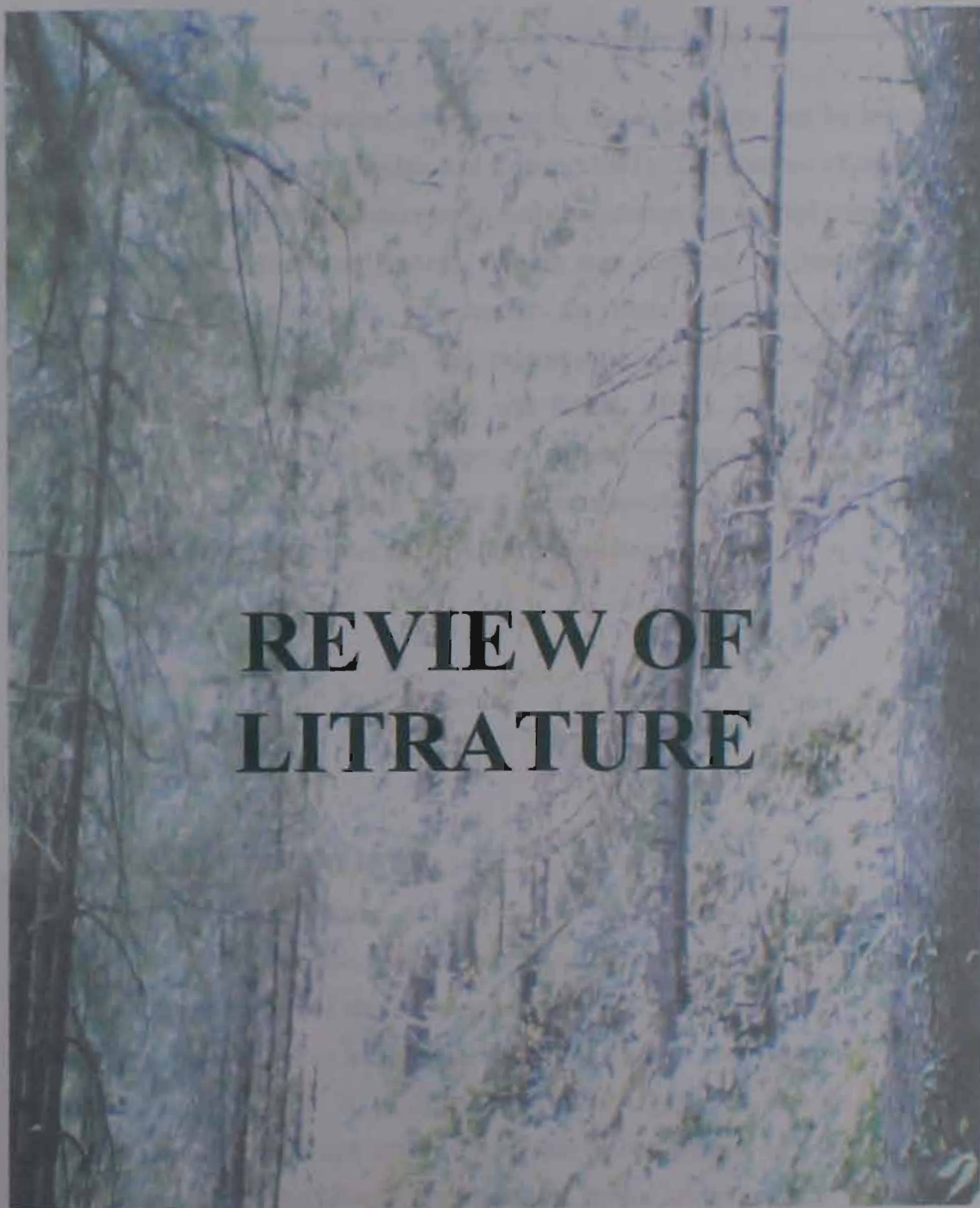
forest tree species. Much information on population structure of individual trees species is now available for low altitude central Himalayan forests (Saxena and Singh, 1985).

Keeping in view the economic and ecological importance along with regeneration problems of these species, the present investigation entitled “Studies on stand parameters and natural regeneration status of silver fir and spruce in Himachal Pradesh” was carried out with following objectives

- To study stand characteristics of fir and spruce
- To study the regeneration status of fir and spruce
- To identify the site specific factors responsible for the regeneration of fir and spruce

Chapter - II

REVIEW OF LITERATURE



REVIEW OF LITRATURE

Chapter - II

REVIEW OF LITERATURE

The regeneration potential of a species in the community can be assessed from its population structure (Auclair and Cottam, 1971). The absence of any land use regulation, urbanization and increase in cattle population has exerted tremendous pressure on forest in Himachal Pradesh, causing their shrinkage at faster rate. To carry out suitable management programmes for these degrading forests, the knowledge of population structure and regeneration potential of different tree species is of utmost importance (Sood and Bhatia, 1991). Hence the present investigation “Studies on stand parameters and natural regeneration status of silver fir and spruce in Himachal Pradesh”, aims at future growth and performance, which has been reviewed in this chapter under following headings.

2.1 Phytosociological study

2.2 Stand characteristics

2.3 Site factors

2.4 Regeneration status

2.1 PHYTOSOCIOLOGICAL STUDY

The floristic composition and phytosociology has long been of principal interest especially for agrostologists and ecologists. The information on the floristic composition remains one of the basic requirements for any such study including classification of ground flora in different systematic types of ecosystems e.g. forest, agriculture, rangeland etc. It is difficult to give information on the floristic composition, stratification and other vegetational characteristics as it varied with season and year. It is also affected by biotic and abiotic components. It is the net result of their interaction which forms a type of community (Whittakar, 1970).

The structure of the forest vegetation along an altitudinal gradient (2550-3600 m) in the Valley of Flowers National Park was studied in Uttar Pradesh by Chandra et al. (1999). And they found that average tree density increased with the altitude, while the average basal area decreased with altitude. The low tree density (338 trees/ha) and high basal area (49.76 m²/ha) in subalpine forest is attributed to high biotic interference and dominance of coniferous species. The indices of tree species diversity and richness decreased with increasing altitude. In terms of shrub density, *Prinsepia utilis* and *Rosa macrophylla* were the dominant shrub species in Himalayan moist upper temperate forest, *R. macrophylla* and *Aster peduncularis* in subalpine forest, and *A. peduncularis*, *Gaultheria trichophylla* and *Ribes glaciale* in subalpine birch forest. Sapling density was highest for *Rhododendron arboreum*, *Taxus wallichiana* and *Syringa emodi* in Himalayan moist upper temperate forest, subalpine forest, and subalpine birch forest respectively.

Rajvanshi et al. (1987) studied the herbaceous under growth on three sites in Nilgiris, for frequency, density, basal area and IVI. Out of 33 species on site-I, 7 were grasses, 3 sedges, 3 ferns, 2 bryophytes and 18 are forbs. On site-II, 7 grasses, 1 sedge, 1 fern, 1 moss and 20 forbs constituted the 30 species. The 14 species on site-III were constituted by 3 grasses, 1 bryophyte and 10 forbs, and they compared the similarity in species composition using similarity index, the site-I and site-II were with lowest similarity (11.1%), site-I and site-III were with 14.8 per cent similarity while site-II and site-III had 48 per cent similarity. Only three species i.e. *Andropogon foulkesii*, *Eupatorium gladulosum* and *Oxalis corniculata* were found common to all the three sites.

Rikhari et al. (1997) made their studies on woody vegetation and regeneration status in a mixed oak forest of Kumaum Himalaya. The results revealed that *Quercus leucotrichophora* in the stands of eastern aspect and *Q. floribunda* in those of north-western aspects had maximum IVI. However, in hill base and of east aspect, *Q. floribunda* remained almost as important as *Q. leucotrichophora*, while in

other stands of eastern aspect *Q. leucotrichophora* showed clear-cut dominance. A similar pattern was evident for *Q. floribunda* on north-western aspect.

Chaturvedi (1994) mentioned that the tropical forest contain maximum number of species then the temperate forest due to more restricted climatic condition and small growing season. The biotic interference has tremendous influence on biodiversity which is directly linked with the reduction of population of both human and livestock.

Studies were conducted by Kaushal et al. (1996) in deodar (*Cedrus deodara*) mixed forests at six locations (Kilba, Shongtong, Kalpa, Riba, Moorang and Thangi) in Himachal Pradesh to study phytosociological attributes, densities (trees, shrubs and herbs), tree parameters (dbh, basal area, height volume and age), nutrient content in green foliage (needles) and litter. Density for deodar trees and for shrubs ranged from 360 to 800 and 2600 to 6600 plants/ha respectively. The mean volume increment varied from 0.33 to 2.88m³/ha (formula volume) and 0.26 to 2.18m³ /ha (local volume tables). The amount of forest litter produced was less at higher altitudes and varied from 2793 to 4860 Kg/ha.

Phytosociological investigation of fir and spruce forests of Chhachpur and Narkanda revealed the difference in vegetation with change in elevation. The IVI value of *Cedrus deodara* was found to be 78.70 and 48.26 in Narkanda and Chhachpur. While IVI values for *Abies pindrow* increased with increase in elevation from 72.06 to 98.99 and 64.84 to 85.64 in Narkanda and Chhachpur, respectively, and these values were highest among all the species. Among herbs *Fragaria indica* was prominent at all the elevations on both the sites. *Trifolium pratense* and *Viola biflora* were the other important species in fir-spruce forests. *Coriaria nepalensis*, *Berberis aristata* and *Zanthoxylum armatum* were prominent shrub species at Narkanda where as *Crataegus crenulata*, *Prinsepia utilis*, *Coriaria nepalensis* and *Cotoneaster microphlla* at Chhachpur (Gupta, 1997).

Pandey and Joshi (1998) carried out phytosociological analysis of data collected from 7 different forest stands, along an altitudinal gradient of 1500-2000 m in Kumaon Himalayas (Utter Pradesh). It was found that *Pinus roxburghii* was the dominant species at lower altitude on eastern and southern aspects and *Quercus leucotrichophora* at higher altitude on northern aspects. The regeneration of deodar was very poor in all stands while, that of *Pinus roxburghii* was better on southern and eastern aspects.

Singh (1998) studied vegetation structure under north and south aspects in the temperate zone of western Himalayas. The species compositions, distribution pattern, diversity concentration of dominance and community coefficient of the forest vegetation were determined under two aspects (north and south facing slopes) in Tirthan valley, Kullu district of Himachal Pradesh. The plant communities in the area are representative of temperate and alpine regions and consist of oak and conifer forests, high altitude mixed forests, alpine, sub alpine and pastures. There was the marked difference in the composition of the trees, shrubs and herbaceous vegetation on the two aspects. The north-facing slope was dominated by *Abies pindrow*, *Picea smithiana* and *Cedrus deodara*, whereas southern aspects were dominated by *Pinus wallichiana*, *Quercus semicarpifolia* and *Rhododendron arboreum*. The density of *Abies pindrow* and *Picea smithiana* were higher on north facing slope than the southern aspects. Only few genera were present on the both aspects, which included *Picea smithiana*, *Abies pindrow* and *Cedrus deodara*.

Singh and Gupta in 1992 reported the result of a phytosociological analysis of ground vegetation carried out in 1984-86 in a compartment in Kotgarh Forest Division, in an area felled since 1970-71, and then closed and planted with silver fir (*Abies pindrow*) and spruce (*Picea smithiana*) in 1984-85. The compartment had a 7-15% slope and N.-NE aspects. The dominant species was *Fragaria indica*, with an Importance Value Index (IVI) of 91.88.

Rolim and Nascimento (1999) studied the species richness, diversity and species-abundance relationships of a tropical forest in the Forest Reserve of Linhares, Espirito Santo State, Brazil, using different sample sizes (1, 2, 4, 8, 16, 32 and 40 ha). The results showed that all 3 of these structural parameters were sensitive to sample size. In the 40-ha sample, the number of species was 143.3% higher than in the 1-ha sample. The differences in the number of species between consecutive samples decreased with increase in sample size. For Shannon's diversity index, the difference between the 40-ha sample and 1-ha sample was only 7.4%. Although there was low variation in the diversity values, there were highly significant differences between samples. In small samples, the lognormal curve showed a truncated shape at the point where, the most of species are represented by few individuals. The truncation indicated that species with very low abundance were not sampled. As the sample size increased, new species were found and existing species changed in abundance. Consequently, the characteristic lognormal distribution curve became more evident, indicating the best representation of species-abundance relationships of the community.

Floristic richness and species diversity were studied in a subtropical humid broadleaved forest ecosystem, 7, 13 and 16 yr after clear felling near Shillong in Meghalaya, India. The numbers of tree species increased from 4 in the 7-yr-old regrowth to 5 and 10 in the 13- and 16-yr-old regrowths, respectively. Comparison of Shannon's diversity index for the tree component showed greater similarity between the 7- and 13-yr-old regrowths, but the 16-yr-old regrowth recorded the highest diversity. On the other hand, the number of herbaceous species declined significantly 33 in the 7-yr-old regrowth to 12 in the 16-yr-old regrowth, so that their diversity index was greater in the 7-yr-old regrowth than in the older regrowths. The diversity of the total community was highest in the 7-yr-old regrowth, declined to a lower level in the 13-yr-old regrowth and increased again in the 16-yr-old regrowth (Arunachalam, 1998).

2.2 STAND CHARACTERISTICS

Suri (1975) had given the regression analysis of data on 97 trees on *Cedrus deodara* (dbh 2 to 38 inches) and 55 trees of *Abies pindrow* (dbh 2 to 24 inches) in Himachal Pradesh and found positive correlation between stem diameter and crown projection area for each species. The curves of number of stems per acre over diameter as predicted by the regression equation and those taken from yield tables were compared for each species and also for *Shorea robusta*. The use of the relation between the variables as a guide to thinning and initial spacing is described and their values for purpose of aerial survey was noted.

Yang et al. (1976) assessed six methods of measuring stand density using stand data viz., trees per unit area, stand density index, stand volume per unit area, spacing index and crown competition factor from *Cryptomeria japonica* plantations. Spacing index and crown competition factor were found to be the most effective being independent of stand age and correlated with volume growth.

Stein (1988) documented an imbalance in size class distribution of ponderosa pine at high elevation on the Paunsaugunt Plateau of southern Utah due to lack of individuals in smaller size classes. Many recent inventories have shown a marked drop in amount of forest land dominated by ponderosa pine with replacement by other species. Fire suppression policies as well as cooler and wetter recent climate, have probably made natural ponderosa pine regeneration difficult and have favoured the more competitive, shade tolerant spruce and fir.

Sood and Bhatia (1991) studied the population structure of tree species in forest around Shimla in Himachal Pradesh, and observed the greater proportion of individual in lower girth classes of *Cedrus deodara*, *Quercus dilatata*, and *Cornus capitata* at site-I, *Cedrus deodara*, *Picea smithiana*, *Quercus dilatata*, *Quercus leucotrichophora* and *Rhododendron arboreum* at site-II and *Quercus leucotrichophora* and *Pinus wallichiana* at site III, representing frequent reproduction while occurrence of only seedling and sapling of *Lyonia ovalifolia*

indicated as recent invader. In all the sites, the number of trees with highest girth classes were negligible, however in saplings number increased with the increase in size class, the number of individuals decreased rapidly in lower size class than bigger ones.

While studying the stand dynamics and regeneration patterns of a pinyon pine forest in east Mexico Segura and Snook (1992) showed that frequency by size class closely approximate a negative exponential distribution, suggesting a balanced and continuous multi-aged condition. Age distribution, however, showed that trees colonized the stand following discrete disturbance events. Significant relationship between size and age occurred among the individual in same stand. Stand structure and regeneration patterns were strongly influenced by natural and human disturbances, particularly a large fire that destroyed most of the forest in 1938.

Information was obtained on the structure, increment and possible utilization of the east Himalayan fir forests in central Bhutan (Burgi and Dorji, 1992). In terms of stems the forests consisted mainly of 83-90% of broad-leaved species (*Rhododendron*, *Betula*, *Prunus* and other species), but inverse was true for basal area and volume which consisted of 72-83 and 86-90% for conifers respectively. Other conifer species present were hemlock (*Tsuga dumosa*) and spruce (*Picea spinulosa*). Annual increment was low 3.2m³/ha on the north facing slope and 2.2m³/ha on south facing slopes.

Studies conducted by Shrivastava (1997) on the management of spruce (*Picea smithiana*) and silver fir (*Abies pindrow*) forests of western Himalayas, which were managed under selection system with 60 cm minimum exploitable diameter and 15 years of felling cycle. There yield is to be regulated by the number of selection trees recruited from lower diameter class to exploitable diameter class during the felling cycle and expressed in percentage. There was a provision of removal of over mature trees to avoid decay. Annual prescribed yield for deodar, kail, spruce and silver fir was fixed at 36, 18 and 900 number of selection trees

which were 35%, 35% and 30% of the total number of selection trees and 32%, 15% and 45% of the annual volume increment of the species respectively.

Sirois (1997) in their studies on distribution and dynamics of balsam fir (*Abies balsamea*) in James Bay area found that balsam fir existed as an isolated population scattered across large expanse of Quebec's boreal forests. At its northern limit, balsam fir was primarily associated with environments that had a low fire frequency, such as coastal lands along James Bay and shores of major hinterland water bodies. Detailed mapping of balsam fir population, stratigraphical study of supporting organic soils, and age structure data of forest stands around Duncan lake with black spruce (*Picea mariana*) and jack pine (*Pinus banksiana*) dominating, constituted the core of the local analysis of balsam fir ecology at its northern limit.

The dynamics of the tree seedling bank was examined by Antos et al. (2000) in old growth, sub alpine spruce and fir (*Picea engelmannii* and *Abies lasiocarpa*) forests in south central British Columbia. The height, basal area and age were determined for seedlings which were up to 149 years old. Regression showed that spruce 1m tall averaged 65 years and fir 92 years old. Age structure indicated that individuals of both species occurred in almost all 5 years age classes. Regression of height and diameter vs. age had high predictability and showed that spruce grew more rapidly than fir.

Glaz (2002) in his studies on characteristics of stand with young natural regeneration in Sudety and Karpaty of different forest stands of varying age of spruce (81-100 years), fir (91-140 years) and beech (80 years and above). He found that natural regeneration is most frequent in the stands of felling age, Results showed no significant correlation between young natural regeneration and the values of the main stand characteristics such as site, age, type of vegetation cover, degree of shelter and basal area.

Glaz and Zajaczkowski (2002) conducted regeneration study in natural forests in Poland to determine the dynamics of natural regeneration based on habitat, age, dbh, basal area, degree of stocking/ stocking rate, vegetation cover, dominant species in shrub layer and degree of shelter. In pine stands they found that natural regeneration was most frequent in the 81-100 year stands growing in the fresh coniferous forest habitat with grass sod cover, birch and juniper as the main species in the shrub layer, with basal area of 25.1 to 30m² /ha (46.77%), 27.23 and 25.47% stocking rate and 52% of degree of shelter. Natural regeneration was most frequent in stands growing in the mountain mixed deciduous forest habitat, age sub classes from IVa to VIa with sod cover, with shrub layer, basal area of 30.1 to 40m²/ha, 20.68 and 18.72% stocking rate and 61% of degree of shelter. While natural stands of fir occur in 91-100 year old stands growing in the mountain forest habitat with weedy ground cover of 67.7% with hazel (*Corylus spp.*) as a dominant species in the shrub layer (44.97%), basal area of 15.1 to 20.0 m²/ha with 36.44% stocking rate and 55% degree shelter.

Agrawal and Patill (1956) studied the problems of regeneration in fir and spruce forests, they noted that fir and spruce seedlings are shade demander in early stages and reproduction of both occurs plentiful at lower elevations under broadleaved trees.

Mishra and Gupta (1993) studied the effect of spacing on stem and crown development on cottonwood at the experimental farm of the University of Horticulture and Forestry, Solan, Himachal Pradesh. Spacing significantly affected all parameters except for degree of crown spread. Height, diameter at breast height, basal area and stem volume increased at increasing spacing while stem length decreased. Crown length, diameter, basal area, surface area and volume, and live crown ratio increased with increasing spacing while crown projection ratio decreased. Significant positive correlations were found between crown surface area and crown volume, stem volume and crown volume, stem volume and crown surface area, stem diameter and live crown ratio, and crown diameter and stem diameter.

Crown efficiency was defined by Assmann as individual tree volume increments per unit of crown projection area, with the hypothesis that, within a given crown class, smaller crowns are more efficient because their ratio between crown surface and horizontal crown projection is higher. Data collected years from 12 loblolly pine (*Pinus taeda*) spacing experiment, established in 1983 at 4 sites in the SE USA, were used to test the hypothesis by taking individual tree height relative to plot dominant height to describe crown class, within-plot, regression showed that crown efficiency decreased with crown size for trees below dominant height. This relationship was much less pronounced than indicated from Assmann's examples, although the crown surface to crown projection ratio behaved in the same way as Assmann had hypothesized. Crown efficiency as well as the crown surface to crown projection area ratio decreased with increasing density. Basal area increment per hectare increased until total crown closure approached 130% and then stayed constant. This major impact of total crown coverage brings into question the usefulness of crown efficiency as an indicator for unit area growth (Sterba and Amateis, 1998).

A comparison was made of the mean growth ring widths at the same cambial age for beech (*Fagus sylvatica*), ash (*Fraxinus excelsior*), Norway spruce (*Picea abies*) and silver fir (*Abies alba*) in a forest near Zurich (Switzerland). The annual ring patterns were analyzed, and compared with the crown condition in 1987. The spruce, beech and ash have maintained a steady or slightly increased mean annual ring increment, this may be the result of modified management and greater spacing or perhaps of fertilizing effects caused by air pollutants. It cannot be estimated how long these increment improvements will persist. In contrast, the increment curve of silver fir has shown sharp decreases since 1956. Beech and ash exhibit identical increment irrespective of the rate of defoliation, whereas spruce and (especially) fir exhibit a lower mean increment when their crowns are damaged. (Kontic et al., 1990).

2.3 SITE FACTORS

Abies ferma and *Tsuga sieboldii* were studied in natural conifer- hardwood forests at Miyazaki by Yurkni and Aragami (1973). The two species were found to grow together and produced abundant seeds every 2-3 years. Most of the seeds germinated in May-July, but died later on and the main cause of death of young seedling was high temperature in summer and frozen soil in winters. Very few conifer seedlings were found in deciduous hardwood stands and were hardly found under conifer stands, where numerous seed trees and undergrowth was present apparently because of lack of sufficient light beneath the canopy and excessive competition from the rhizomes. A lattice experiment on *Abies ferma* showed that the light intensity for initial growth of seedlings was 40-80% of full sunlight.

Parker (1986) studied the environmental and historical factors affecting red and white fir regeneration in ecotonal forests. He used diameter-class distribution of thirty mixed red fir/white fir forests from Yosemite National Park California to examine the pattern of canopy dominance and regeneration mode of these two zonal dominants. He observed that successful regeneration of each species is associated with open canopy and nutrient rich substrates. Red fir regenerates in greater numbers on wider range of sites, but suffers greater mortality than white fir. The pattern of canopy dominance indicates that white fir tolerates canopy closure and dominates on nutrient rich sites in montane forests, whereas red fir is less tolerant of shading and dominates on disturbed, nutrient-poor substrates in sub alpine forests. He concluded that these patterns are interpreted as adaptive response to complex interactions of site factors, disturbance frequency and biotic constraints along an elevation gradient.

Soils and their behavior with respect to natural regeneration of fir and spruce in Narkanda (Himachal Pradesh) were studied (Jha et al., 1984). Although soil formation is governed by podzolization process but the soil profile in poorly regenerated area showed almost negligible eluviations of clay and organic matter due to fairly well developed 'O' horizon. The soils are distinctly acidic, unsaturated and possess low cation exchange capacity. They also found that litter decomposition

in fir and spruce forests releases hydrophobic substances which severely restricted wetting of soil. Therefore, the insufficient moisture content in the soil due to thick layer of humus on the surface affected the process of natural regeneration in fir and spruce in Narkanda.

The influence of site factors on the composition and structure of semi-natural mixed species stands of beech (*Fagus sylvatica*), silver fir (*Abies alba*) and Norway spruce (*Picea abies*) was studied by Abrudan and Mather (1999) in the upper Draganul watershed of north-west Romania. Results of redundancy analysis for beech-conifer stands indicate that *Abies alba* predominates at mid to upper slope positions, on steep gradients and favours southerly aspects. In contrast *Picea abies* was more abundant on frost susceptible lower slopes and damper sites with north-western aspects. A weak ordination with respect to site factors reflected the fact that *Fagus sylvatica* may have been at the upper altitudinal limits of its natural distribution. It was concluded that two species have site requirements that are relatively complementary for both production and the conservation of mixed stands.

Kerr (2000) studied the factors affecting the natural regeneration of Corsican pine (*Pinus nigra*) in Great Britain. It was found that satisfactory natural regeneration of Corsican pine is generally difficult to achieve when compared with Scots pine (*Pinus sylvestris*). However, it is possible if a patient approach is applied. Good seed years occur at an interval of 3-5 years and it is important to initiate operations which will take advantage of these 'mast' years. The bank of advance regeneration can be developed by increasing seed supply, preparing seedbed before seed fall by disturbing organic matter on the soil surface, controlling vegetation and protecting seedlings against browsing.

Hanssen (2003) studied the influence of vegetation cover, humus depth and micro-relief and distance to seed tree edge on natural regeneration of Norway spruce (*Picea abies*) in five clear-cut Bilberry woodland in south-eastern Norway. Most of the regeneration (95%) developed in 1996 after a rich seed year in 1995. The

microhabitat was of crucial importance to seedling establishment. Litter of sphagnum and *Politrichum commune* was good substrate for establishment, while areas dominated by *Deschampsia flexuos*, *Dicranm sp.* and *Pleurozium schreberi* had very few seedlings. Seedling survival after five growing season was slightly better in litter than in sphagnum and other mosses. Increasing humus depth had a positive influence on regeneration probably due to shallow soils at the site. Distance to the seed tree edge had a significant effect on establishment, with more seedlings establishing to the edge.

Light conditions, and the growth rate, stem form and wood quality of planted trees were observed in openings made by group felling in a 31-yr-old stand in Ehime Prefecture in 1961. Light conditions quantified and discussed includes, the relative solar radiation (RSR) in different parts of the opening, the percentage of possible sunshine (PPS) and the diffuse site factor (DSF, the ratio of diffuse radiation at a given site compared with that in the open). Stem growth required an RSR of at least 5%. Regeneration grew fairly well when it was greater than 20% RSR and vigorously when greater than 50% RSR. Trees in the centre of openings generally had the largest stem increment. Growth was highly correlated with RSR and PPS, trees in larger openings grew better than those in smaller openings. Growth was even more highly correlated with DSF. This correlation was independent of opening size and an equation is given showing the relation between relative dbh 10 yr after planting and DSF. (Fujimoto, 1984).

In the main study, on the Oregon coast, scarified plots were established under a 118-year mixed conifer stand thinned to provide a range of canopy densities, and the establishment and growth of seedlings of *Picea sitchensis*, *Tsuga heterophylla*, *Pseudotsuga menziesii* and *Alnus rubra*, from natural seed fall or from sowing, were measured and related to solar radiation. The conifers all became established on mineral soil more readily than *A. rubra*. The intensity of solar radiation (ranging from <10 to nearly 70% of that in the open) had little effect on establishment, but growth in the first season of *P. menziesii* increased with radiation,

and that of the other three species increased with radiation to an optimum, varying with the species from 39 to 50% of that in the open, and then declined, this decline appeared to be related to high soil moisture tension (Ruth, 1968).

Haq (1992) studied the microclimate and natural regeneration of *Abies pindrow* in the moist temperate forests of Pakistan at Kund in 1988-90. These forests have 80% *Abies pindrow*, with the main shrub *Viburnum grandiflorum*. Photosynthetically active radiation (PAR) reaching seedlings was measured under open canopy, and under canopy consisting of trees, *V. grandiflorum* or *V. grandiflorum* + trees, in 1988-89; values were 17-26, 10-31, 1.8-4.5 and 1.4-4.7%, respectively, of those at a completely open site, and varied with season. Mortality rates of 1-3 yr old seedlings were high. For 1-, 2- and 3 years old seedlings observed after 3 years, they were 88, 60 and 70% in the open, and 79, 82 and 69% in the shade, respectively. Survival rates of 4-7 yr old seedlings were less affected in the open. Height growth was slow only 4.7 cm over 3 yr (1.6 cm/yr) in 7-yr-old seedlings.

Roussel (1954) presented the results of measurements of annual growth in *Abies alba* and *Picea abies* in the Levier national forest (Jura). It was noted that fir receiving 25 % radiation made growth equal to that made in the open. Reduction of radiation below this point resulted in decreased growth. A similar decrease in growth was observed in spruce at radiations below 40-50%. At the same summer radiation values a cover of deciduous species is more favourable to growth of coniferous regeneration than a cover of coniferous species.

Sidiyasa (1988) made comparison of soil properties, species composition, sapling and seedling development and diameter distribution of saplings and trees, in 20X20 m plots laid out in stands of *Diospyros celebica* and *Kalappia celebica* in South Sulawesi, Indonesia. Soils under both types of stand were nutrient deficient and acid, with pH ranges of 3.7-3.8 under *D. celebica* and 3.9-4.0 for *K. celebica*. Numbers of individuals at each developmental stage (trees, saplings and seedlings)

were greater in the *K. celebica* stand, and calculation of Jaccard's similarity index confirmed that the developmental stage assemblies were quite different in 2 stands. The species present in each stand type were listed, indicating their stages of development. The average similarity index between the stands was greater than 30%. Regeneration was much greater in the *D. celebica* stand. It is suggested that the presence of certain dominant and co-dominant species could be used to assess the suitability of sites for plantations of these species.

2.4 REGENERATION STATUS

In forest communities of oak-conifer forests has been studied in Bashahr Himalayas by Mohan and Puri (1955). According to them physical and biological environment involved in the development and succession of various forest communities had been worked out in three main climatic climaxes. The presence of conifers in areas was determined by the following factors a) nature of geological slope: oaks were usually dominated on the scarp slope, whereas, the dip slope bore mixed oak/conifer or pure conifer communities, b) nature of secondary deposits resulted in oak climax predominant on secondary soils. Several communities usually predominated on newly laid alluvium; broad leaved deciduous species from communities and on older alluvium conifers with or without deciduous species and c) biotic factors generally destroyed the oak climaxes, by bringing in the conifers on abandoned cultivation.

Chacko (1965) reported that the assessment of regeneration is important in experimental plot with relatively small area. Plot size is the determining factor in negative and positive correlation of the species. It is essential to accept the higher intensity of sampling to get proper results.

Gordon (1970) studied natural regeneration of *Abies concolor* and *Abies mangifera* in north-east California and observed that natural regeneration was abundant with sound seeds, exposed mineral soil and probably some shade in the

first year, since strong insolation, deep litter, competing lower vegetation and long time between good seed year have obstacles to seedling survival and growth.

Regeneration and height growth of planted white spruce (*Picea glauca*) and alpine fir (*Abies lasiocarpa*) seedlings, the growth of competing shrubs and height, diameter and volume growth of spruce and fir up to about 130 years of age were studied on alluvial and aralia sites in the central interior of British Columbia by Eis and Craigdallie (1982). They found that alpine fir regenerated successfully under heavy shrub competition where spruce generally failed and fir growth up to 100 years was better than that of spruce. Spruce maintained its growth longer. They concluded that spruce should be favored where its regeneration can be assured, where shrubs prevent its regeneration, however alpine fir may provide a viable and economical alternative.

Singh and Singh (1987b) reviewed the studies on chir pine forests which occurred extensively in the low to mid montane belt (1000-2000 m amsl) usually as pure forest, but also with *Shorea robusta*, *Toona ciliate* and *Anogeissus latifolia* at low altitude and *Pinus wallichiana*, *cedrus deodara* and *Quercus leucotrichophora* at higher altitude in central Himalayas. The discussion covered environment, palaeoecological aspects, phytosociology, natural regeneration especially in relation to the early successional characteristics of chir pine, biomass productivity, litter fall and decomposition and implications of chir pine expansion.

Singh et al. (1987) studied litter fall and natural regeneration of spruce and silver fir. The data revealed that the litter in such forest is detrimental to natural regeneration of two species.

Sood and Bhatia (1991) studied the population structure and regeneration status of tree species in forest around Shimla in Himachal Pradesh and reported the higher density of seedling and saplings as compared to the other girth classes at site dominated by pure conifers and in the mixed conifer broad-leaved trees. In the sites

the number of tree with higher girth classes were negligible, except for of saplings where the number of individual decreases rapidly at first and then more slowly.

Factors affecting the establishment and recruitment of seedlings of Appalachian endemic *Pinus pungens* were studied in pine-oak forest of dry south-western Mountain in south-western Virginia, United States. It was observed that recruitment of *Pinus pungens* was not limited by seed fall from serotinous cones or by post dispersal seed predation. Total viable seed fall ranged from 35,000 to 69,000 seeds/ha in 1988 and was concentrated in the spring and summer months. Low availability of suitable seedling habitat strongly limited the recruitment of *P. pungens* seedlings. The distribution of habitat variables for *P. pungens* seedlings and random points in the forest overlapped little, indicating that suitable microsites were relatively rare. Seedlings occurred in microsites characterized by shallow pine litter, low ground and canopy covers and larger nearest neighbour distance than occurred at random. Summer drought also contributed to low seedling survivorship, particularly in young seedlings. The result suggested that optimal recruitment and population maintenance of *P. pungens* in pine-oak forest is unlikely in the absence of fire (Williams and Johnson, 1992).

Ram (1991) stated that in case of *Cedrus deodara*, under favourable conditions of snowfall, good seed year, well distributed rainfall, soil conditions in respect of raw humus and weed growth, adequate sunlight under properly opened up crop which may be tended to establish, resulted in profuse natural regeneration. However prolonged dry spell after germination, in May-June, fire and uncontrolled grazing proved disastrous.

Dwivedi (1993) reported that in irregular shelterwood system after seeding felling 50 seed bearer/ha in cooler aspects and 60 trees in hotter aspects, preferably of 40-50 cm or 50-60 cm diameter class be let with a view to help deodar regeneration. When kail forms the pure patches, 30 kail trees/ha on cooler aspect and about 40 trees/ha on hotter aspect be kept as shade bearer. An overhead stratum was

generally removed in 2-3 successive felling. In selection system tree below exploitable diameter were preserved and thinned as and when necessary with the main objective of getting natural regeneration and to get best growth performance.

Gupta (1997) studied the regeneration of fir and spruce forests of Chhachpur and Narkanda areas and found that regeneration of fir on an average was more (687.5/ha) than spruce (312.5/ha) in Narkanda, where as in Chhachpur it was 833.33/ha and 1875.00/ha, respectively. In Narkanda with the increase in elevation the regeneration decreased from 1250/ha to 208.33/ha for fir and for spruce 625/ha to 156.25/ha. The regeneration of fir increased from 625/ha to 1041.67/ha, where as it decreased for spruce from 2083.33/ha to 1666.67/ha with increase in elevation at Chhachpur.

In 2004 Grassi et al. analyzed the distribution and growth of natural regeneration of Norway spruce and silver fir as affected by stand structure and the age structure of all the saplings between 0.2 and 10m in height, in a 30-year-old gap. They found that in both species, natural regeneration was mostly clumped and located at the margin of the gaps. However, fir saplings were more represented in under storey environment as less represented in gaps when compared with spruce. Age structure of natural regeneration in the selected gaps revealed that majority (75%) of saplings appeared after formation of gaps, while regeneration taller than 2m, saplings already present at gap formation predominated. Thus, it was concluded that gap edges represent a preferential regeneration niche.

Chapter - III

MATERIALS AND METHODS

The present investigation entitled "Studies on stand parameters and natural regeneration status of silver fir and spruce in Himachal Pradesh" was carried out in Bashla and Jubbal forest range (Rohru Forest Division) and Kotkhai forest range (Theog Forest Division) of Himachal Pradesh during year 2004-2005. The materials and methods used are described in the following segments.

3.1 STUDY AREA

Present study was carried out in Bashla forest range (Rohru forest division), situated between $31^{\circ}13'5''$ to $31^{\circ}13'55''$ N latitude and $77^{\circ}39'30''$ to $77^{\circ}41'15''$ E longitude, Giri forest in Jubbal forest range (Rohru forest division), $31^{\circ}4'30''$ to $31^{\circ}6'30''$ N latitude and $77^{\circ}32'10''$ to $77^{\circ}33'15''$ E longitude and in Kharapathar area of Kotkhai forest range (Theog forest division) $31^{\circ}7'15''$ to $31^{\circ}8'45''$ N latitude and $77^{\circ}37'10''$ to $77^{\circ}38'10''$ E longitude (Survey of India, Toposheet No. 53 of E/11 1:50,000). The study was mainly confined to fir and spruce forests within the elevation range from 2100 m to 3000 m above mean sea level.

a) Climate

The climate varies a lot depending upon the altitude and aspect. The study area falls in wet temperate zone, however, the northern aspect is more cooler than southern aspect. Precipitation is in the form of rains mainly during rainy season but snowfall occurs during winter months. Seasons are very distinct viz., summer (April to June), monsoon (July to September) and winter (October to March). The parent material consists of shale, schist, micaceous schist and the soil is shallow to deep at different areas but fertile sandy loam. Areas are having gentle to steep slope, draining to Pabber river in Rohru while in Jubbal and Kotkhai the slopes drain into Giri as well as Pabber the tributaries of river Yamuna.

b) Forest types

The forests of study area were having vegetation of temperate nature mainly with the following forest types (Champion and Seth, 1968).

- 12/C₁ - Lower Himalayan temperate forest,
- 12/C_{1b} - Mohru oak forest,
- 12/C₂ - Upper West Himalayan temperate forest,
- 12/2S₁ - Low-level blue-pine forest and
- 13/C₄ - West Himalayan high level dry blue pine forest.

c) Selection of compartments

The details of the selected compartments for the present study under different forest sites are given in table.

Table 1. Details of samples plots taken for study in Rohru and Theog forest divisions.

Forest Division	Forest range	System applied	Compartment	Periodic block (PBs)	Aspect
Rohru (Rohru felling series)	Bashla	Protection working circle	UF-9	Area under protection working circle	North-East
			UF-10		North-East
			UF-9		North-East
Rohru (Jubbhal felling series)	Jubbhal	Indian irregular shelterwood system	Giri-3b	PB-I	Northern
			Giri-4a	PB-I	Northern
			Giri-5b	PB-U	Northern
			Giri-3d	PB-U	Northern
Theog	Kotkhai	-do-	Gahangrri-177	PB-I	North-East
			Nag Tikkar-175	PB-U	North-East

Forests of fir and spruce are managed under Indian irregular shelterwood system. Three plots of 20 m x 20 m each were taken in a stand at three elevation classes (2100-2400 m, 2400-2700 m and 2700-3000 m) in Bashla forest range (Rohru forest division), where the forest was being managed under Protection

Himachal Pradesh (District Map)

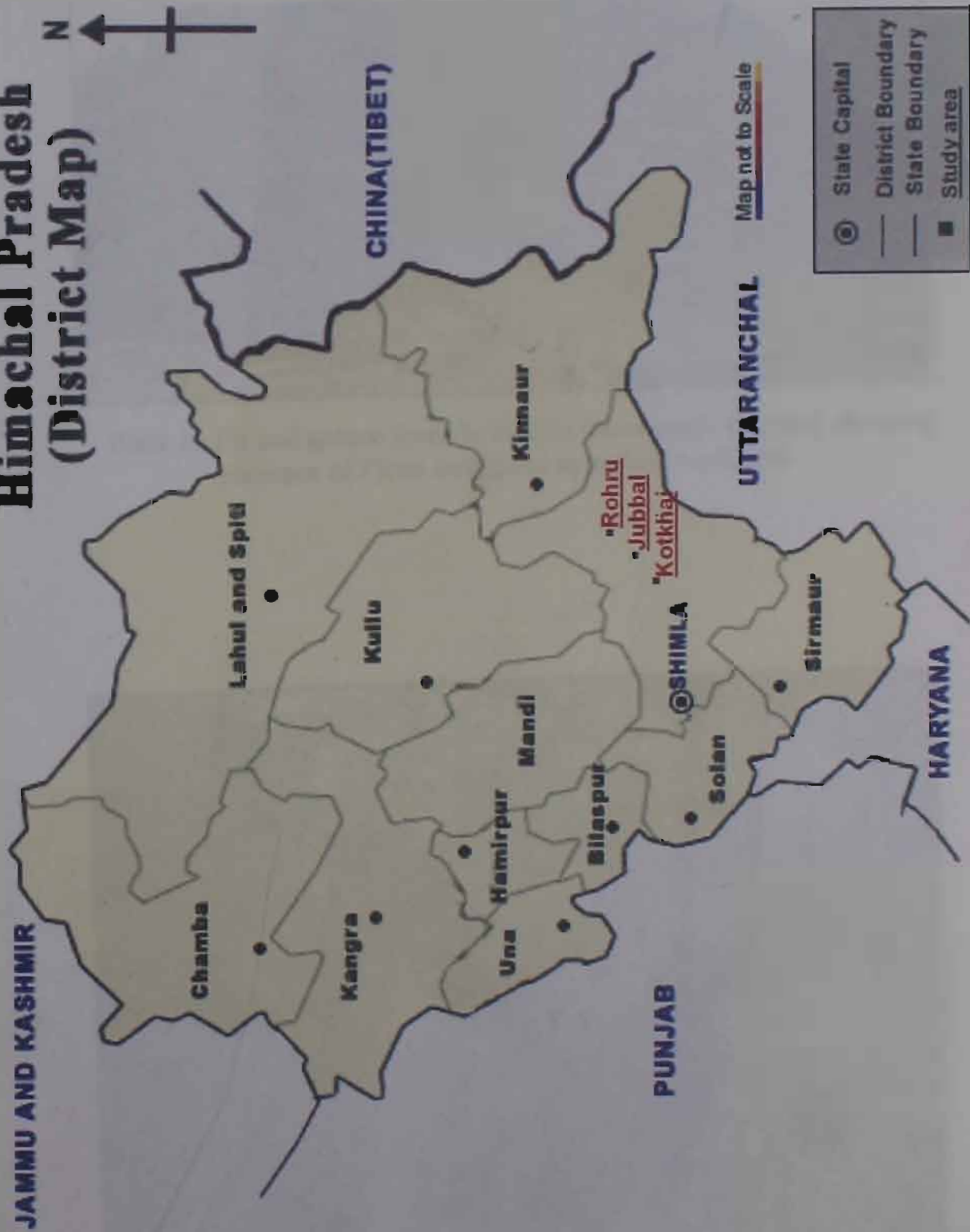


Fig. 1. Map showing study area (Bashla, Jubbal and Kotkhai Forest Ranges)



Plate 1. Fir and spruce forest in Bashla forest range (Rohru), showing presence of *Picea smithiana* at highest elevation.



Plate 2. Fir and spruce forest in Bashla forest range showing higher presence and broader crowns of *Abies pindrow* at lower elevation.



Plate 3. Fir and spruce forest in Jubbal forest range (Rohru Forest Division)



Plate 4. Fir and spruce stand in Jubbal forest range showing low density



Plate 5. Fir and spruce forest in Kotkhai forest range (Theog Forest Division)



Plate 6. Fir and spruce stand in Kotkhai forest range showing different size class trees in the area.

working circle, this forest was not divided into periodic blocks. Whereas, in Jubbal and Kotkhai ranges the forest was under Fir working circle and the area was divided into two periodic blocks, PB-I and PB-unallotted (PB-U). Here sample plots in each periodic block were taken in different elevation classes on the same pattern.

PB-I The PB-I areas are identified for seeding felling and planting

PB-U It is the merger of other periodic blocks into one PB (other than PB-I), and represent the area where salvage and improvement felling are aimed (Shrivatava and Siaguru, 1997).

Protection working circle

This working circle contains the demarcated protected forests, which has not been included in any of the working circle, being either inaccessible due to rock, steep and precipitous terrain or excessive deforestation in the past. They are chiefly important from the protection point of view in preventing denudation and maintaining an equitable flow of water in the streams and rivers which have their source in the hills.

3.2 PHYTOSOCIOLOGICAL STUDIES

The present study on floristic composition was carried out in the sample plots already laid out for growth studies in fir and spruce forests. The observations were recorded for trees in all sample plots of 20 m x 20 m, while for shrub and herbs 5 and 12 plots of 5 m x 5 m and 1 m x 1m were laid out in each tree sample plot, respectively.

The following phytosociological parameters were studied from the basic data viz., number, girth/diameter, height, and basal area collected for different plant communities, using different formulae (Raunkiaer, 1934; Misra, 1968; Menon and Balasubramanyan, 1985).

Percentage frequency (% F)

It is the indicator of number of sample in which the given species occurs, thus express the distribution of various species in the community.

$$\text{Percent frequency (\%F)} = \frac{\text{Number of sampling units in which the species occurred}}{\text{Number of sampling units studied}} \times 100$$

Density (D)

It represents the numerical strength of species in a community calculated as:

$$\text{Density (D)} = \frac{\text{Total number of individuals}}{\text{Total number of quadrates studied}}$$

Basal area

It refers to the ground area actually covered by the stem and calculated by using following relation:

$$\text{Basal area} = \pi d^2/4 \text{ or } g^2/4\pi$$

Where:

d - Diameter

g - Girth

The diameter of trees was measured at breast height with tree caliper (cm), whereas for shrubs and herbs collar diameter (cm) and collar girth (cm), respectively.

Relative basal area, relative density and relative frequency

These parameters were obtained from the percent frequency, density and basal area according to procedure given by Phillips (1959).

$$\text{Relative basal area (RBA)} = \frac{\text{Total basal area of the species}}{\text{Total basal area of all the species}} \times 100$$

$$\text{Relative density (RD)} = \frac{\text{No. of individuals of the species}}{\text{No. of individual of all species}} \times 100$$

$$\text{Relative frequency (RF)} = \frac{\text{No. of occurrence of the species}}{\text{No. of occurrence of all species}} \times 100$$

Importance value index (IVI)

The IVI, which is an integrated measure of the relative frequency, relative density and relative basal area, was calculated for all species of trees shrubs and herbs separately for different elevation classes in study area under Bashla forest range (Rohru), whereas, in Jubbal and Kotkhai forest ranges in each periodic block at different elevation as:

$$\text{IVI} = \text{Relative basal area (RBA)} + \text{Relative density (RD)} + \text{Relative frequency (RF)}$$

Similarity index (SI)

It expresses the ratio of common species to all species found in the vegetation and is determined by the method given by Sorenson (1948).

$$\text{SI} = \frac{\text{No. of common species in two stands (relives) i.e. A and B}}{\frac{1}{2} (\text{Total number of species in stand A} + \text{stand B})} \times 100$$

Shannon index of general diversity (\bar{H})

Species diversity is determined by Shannon's index of general diversity and was calculated by using Margalef formulae Odum, 1971).

$$\bar{H} = -\sum (ni/N) \log (ni/N)$$

Where:

- ni - Importance value of each species
N - Total importance value

3.3 ESTIMATION OF STAND CHARACTERISTICS

Individual tree measurement

Tree falling in each sample plot were enumerated to determine the stand density as number of plants per hectare.

Age of the main crop

The age of the trees was measured by taking out a cylindrical column of wood at 1.37 m above ground with the help of Pressler's increment borer and counting the annual rings, which corresponds to the age of the tree. However, for missing and higher diameter class trees (bigger than the size of increment borer), the age was estimated using linear relationship equation as

$$y = a + bx$$

Where:

- y – Age of the tree (years)
- x – Diameter at breast height (cm)
- a – Intercept
- b – Slope of the line

Diameter at breast height

The mean two diameter measurements of each stem over bark was taken at right angle to each other at 1.37 m above ground with the help of tree calliper.

Tree height

Total height of the standing tree is the straight line distance from the tip of the leading shoot to the ground level, usually measured on slopes from the uphill side of the tree (Chaturvedi and Khanna, 1982). The height of the tree was measured with the help of Ravi Multimeter and expressed in meters.

Crown width

The crown width was measured in two directions (North-south and East-west) and average was calculated as suggested by Assmann (1970) and Chaturvedi and Khanna (1982).

$$CW = \frac{D_1 + D_2}{2}$$

Where:

CW - Crown width (m)

D_1 - First measured crown diameter in meters

D_2 - Second measured crown diameter right angle to the first measurement in meters

Volume of standing trees

Volume of standing trees per hectare was calculated by multiplying the total number of trees per hectare with the mean diameter class volume in which the trees felled, by using the local volume table of the of the area available with the forest department.

Crown projection ratio

It is the ratio which states that by how many times the crown diameter is larger than the stem diameter (Assmann, 1970)

$$\text{Crown projection ratio} = b/d$$

Where:

b - Crown width

d - Stem diameter at breast height

3.4 SITE FACTORS

Solar radiation (influx)

Relative light illumination under selected sample plots was recorded by lux meter under and outside the canopy during day time and the value in percentage of light intensity under the canopy to that in open was calculated as under (Rao, 1998).

$$\text{Solar influx (\%)} = \frac{\text{Total solar radiation beneath the canopy}}{\text{Total solar radiation in open}} \times 100$$

Organic matter layer

It was measured as depth of the column from the top of humus layer to the point under humus where soil exists

Soil pH

It was measured with the help of pH meter, the ratio of soil to water was taken as 1 : 2.5.

3.5 REGENERATION SURVEY

The regeneration survey in fir and spruce forests in Bashla range was done in all major plots (sample plots for trees) at different elevations, while in case of Jubbal and Kotkhai ranges regeneration survey was conducted in each periodic block at different elevations by laying quadrates of 2 m x 2 m (4 sq m), 2500 established plants per hectare were desired to express satisfactory regeneration. The quadrate was considered fully stocked when it contained one established plant (Chacko, 1965)

Each sampling unit had 9 recording unit of 2 m x 2 m quadrate. The survey was conducted for recruits (r) which may be defined as current years seedlings, unestablished regeneration (u) seedling other then recruits which has not established and height less then 2 m, here 4 unestablished plants were taken equivalent to one established plant and established regeneration (e) having height more then 2 m.

Data recording

The regeneration data collection of fir and spruce stands was done on the basis of number of individual occurring at seedling, sapling and pole stage in each quadrate. The height of established and unestablished regeneration was also measured for the assessment of regeneration (Champion, 1935)

Regeneration assessment

The data thus collected was analyzed using formulae given by Chacko (1965) as follows:

$$\text{Recruits (r)/ha} = 2500 \sum_{i=1}^n ri/m$$

$$\text{Unestablished (u)/ha regeneration} = 2500 \sum_{i=1}^n u_i/m$$

$$\text{Established (e)/ha regeneration} = 2500 \sum_{i=1}^n e_i/m$$

Where:

- n - Number of sampling units
- m - Total number of recording units in the survey
- ri - Total number of recruits in each sampling unit
- ui - Total number of unestablished plants in each sampling unit
- ei - Total number of established plants in each sampling unit

$$\text{Weighted average height (m)} = \frac{\text{Total height of unestablished regeneration} + (\text{Number of established plants} \times \text{establishment height})}{\text{Total unestablished plants} + \text{Total established plants}}$$

On the above estimates following indices were calculated :

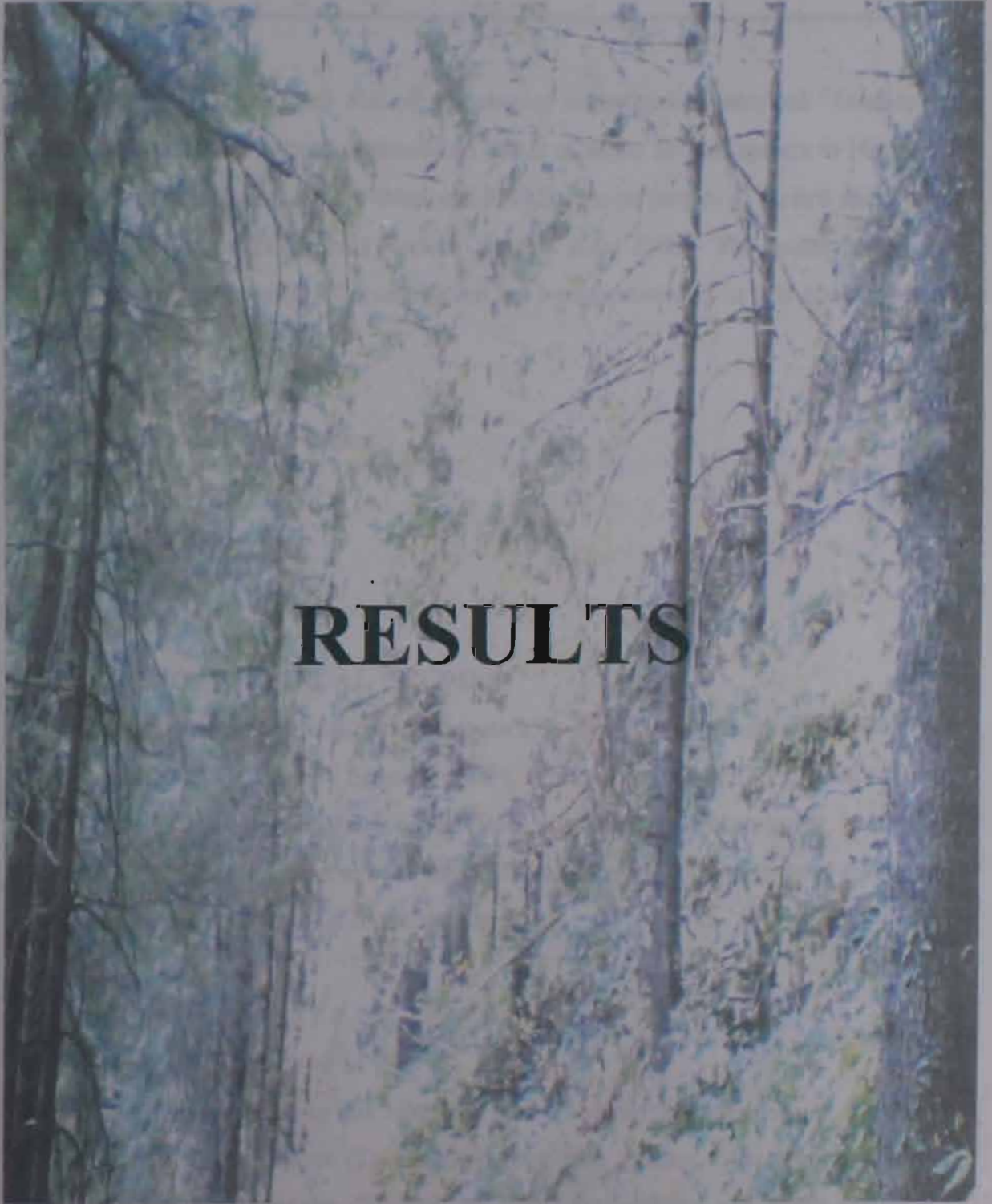
$$\text{Establishment index (I}_1\text{)} = \frac{\text{Weighted average height}}{\text{Establishment height}}$$

Stocking index (I₂)

$$= \frac{1}{2500} \left[\frac{\text{Unestablished regeneration/ha} + \text{established regeneration/ha}}{4} \right]$$

$$\text{Established stocking percent} = 100 (I_1 \times I_2)$$

Chapter 12
EXPERIMENTAL PROCEDURES



RESULTS

Chapter - IV

EXPERIMENTAL RESULTS

The results emerged out of the present investigation entitled “Studies on stand parameters and natural regeneration status of silver fir and spruce in Himachal Pradesh” conducted in Bashla, Jubbal and Kotkhai forest ranges of Rohru and Theog Forest Division of Himachal Pradesh during 2004-2005. The salient findings obtained during the course of investigation are being presented in this chapter under following heads:

- 4.1 Phytosociological studies
- 4.2 Stand characteristics
- 4.3 Site factors
- 4.4 Regeneration studies

4.1 PHYTOSOCIOLOGICAL STUDIES

The phytosociological parameters such as density (D), basal area (BA), per cent frequency (%F), relative frequency (RF), relative frequency (RF), relative basal area (RBA) and importance value index (IVI), similarity & dissimilarity index and Shannon's diversity index have been tabulated in tables 20 to 38 for three elevations of Bashla, Jubbal and Kotkhai forest ranges.

4.1.1 BASHALA FOREST RANGE

i) Elevation class 2100-2400 m

The data collected in this elevation class revealed the presence of 8 tree, 11 shrubs and 28 herb species (Table-2). Among tree species, *Abies pindrow* was having maximum dominance, followed by *Pinus wallichiana* and *Picea smithiana* with IVI 135.23, 39.46 and 25.28, respectively. The *Cedrus deodara* recorded the

minimum value of IVI (12.01). In shrubs *Sarcococca saligna* was the dominant species followed by *Lonicera acuminata* and *Viburnum cotinifolium* with IVI of 57.56, 42.64 and 41.44, respectively, whereas, *Elaeagnus parviflora* was reported for lowest IVI value (3.46). Under herbs *Viola pilosa* was having maximum dominance followed by *Fragaria vesca* and *Trifolium pratense* with 44.85, 35.28 and 23.28 IVI respectively, *Hypericum perforatum* observed the lowest value of IVI (0.57).

The total basal area of the trees was 258367.5 cm²/ha with maximum contribution of 151930.42 cm²/ha by *Abies pindrow*, whereas the total basal area of shrubs and herbs accounted to 21270.93cm²/ha and 106302.78 cm²/ha for which the share of *Sarcococca saligna* and *Viola pilosa* was 28.24 and 27.03%, respectively.

ii) Elevation class 2400-2700 m

The data tabulated in table-3 revealed that out of 4 tree species *Picea smithiana* was dominating with maximum IVI value of 117.08, which was contributed by relative basal area of 62.10% resulting from basal area 271086.83 cm²/ha, followed by *Abies pindrow* with maximum density of 116.67/ha, relative density 35.01 and an IVI value of 95.83, whereas *Cedrus deodara* showed minimum presence with 24.96 IVI.

Out of total 10 shrub species *Rosa macrophylla* had highest value of all phytosociological parameters with IVI value of 135.65, whereas rare species was *Deutzia compacta* with lowest IVI (4.56). The area presented 32 herb species, where *Fragaria vesca* was dominant species, followed by *Trifolium pratense* with IVI value of 72.45 and 45.50, respectively. The minimum IVI value of 0.43 was found in case of *Polygonum vacciniifolium*. The total basal area for trees was 436565.50 cm²/ha, 37902.40 cm²/ha for shrubs and for herbs it was 255493.89 cm²/ha.

iii) Elevation class 2700-3000 m

The data presented in table-4 indicated 5 trees, 6 shrubs and 31 herbs in this elevation class. Among trees *Picea smithiana* had maximum basal area of 461168.25

Table 2. Floristic composition in Bashla forest range at an elevation of 2100-2400 m

Species	Average D/ha	BA/ha cm ²	% F	RD	RBA	RF	IVI
Trees							
<i>Abies pindrow</i>	150.00	151930.42	100.00	51.43	58.80	25.00	135.23
<i>Picea smithiana</i>	41.67	6875.42	33.33	14.29	2.66	8.33	25.28
<i>Pinus wallichiana</i>	41.67	21973.58	66.67	14.29	8.50	16.67	39.46
<i>Prunus prostrata</i>	25.00	14343.25	66.67	8.57	5.55	16.67	30.79
<i>Juglans regia</i>	8.33	6698.67	33.33	2.86	2.59	8.33	13.78
<i>Aesculus indica</i>	8.33	50658.67	33.33	2.86	19.61	8.33	30.80
<i>Populus ciliata</i>	8.33	3768.00	33.33	2.86	1.46	8.33	12.65
<i>Cedrus deodara</i>	8.33	2119.50	33.33	2.86	0.82	8.33	12.01
Total		258367.50					
Shrubs							
<i>Berberis aristata</i>	186.67	448.00	26.67	7.53	2.11	8.89	18.52
<i>Cotoneaster bacillaris</i>	26.67	442.93	6.67	1.08	2.08	2.22	5.38
<i>Daphne cannabina</i>	213.33	2454.67	26.67	8.60	11.54	8.89	29.03
<i>Desmodium elegans</i>	213.33	1569.87	40.00	8.60	7.38	13.33	29.32
<i>Deutzia compacta</i>	106.67	1445.60	20.00	4.30	6.80	6.67	17.76
<i>Elaeagnus parviflora</i>	26.67	33.87	6.67	1.08	0.16	2.22	3.46
<i>Lonicera acuminata</i>	373.33	2085.33	53.33	15.05	9.80	17.78	42.64
<i>Prinsepia utilis</i>	80.00	4335.20	13.33	3.23	20.38	4.44	28.05
<i>Rosa macrophylla</i>	266.67	1059.47	33.33	10.75	4.98	11.11	26.84
<i>Sarcococca saligna</i>	506.67	6006.67	26.67	20.43	28.24	8.89	57.56
<i>Viburnum cotinifolium</i>	480.00	1389.33	46.67	19.35	6.53	15.56	41.44
Total		21270.93					

(Contd....)

Species	Average D/ha	BA/ha cm ²	% F	RD	RBA	RF	IVI
Herbs							
<i>Adiantum venustum</i>	67500.00	952.78	25.00	8.05	0.90	4.11	13.06
<i>Arisaema intermedium</i>	6944.44	3963.89	25.00	0.83	3.73	4.11	8.67
<i>Bistorta amplexicaulis</i>	19166.67	2475.00	25.00	2.29	2.33	4.11	8.72
<i>Carpesium cernuum</i>	3611.11	686.11	13.89	0.43	0.65	2.28	3.36
<i>Agrostes spp.</i>	7222.22	444.44	13.89	0.86	0.42	2.28	3.56
<i>Cynoglossum glochidiatum</i>	555.56	200.00	2.78	0.07	0.19	0.46	0.71
<i>Cyperus aristatus</i>	82777.78	7363.89	22.22	9.88	6.93	3.65	20.46
<i>Dichanthium annulatum</i>	20277.78	2211.11	2.78	2.42	2.08	0.46	4.96
<i>Dryopteris nigropaleacea</i>	49444.44	8794.44	44.44	5.90	8.27	7.31	21.48
<i>Prunella vulgaris</i>	13888.89	1305.56	8.33	1.66	1.23	1.37	4.26
<i>Fragaria vesca</i>	135277.78	12575.00	44.44	16.14	11.83	7.31	35.28
<i>Galium aparine</i>	77500.00	5958.33	30.56	9.25	5.61	5.02	19.88
<i>Geranium wallichianum</i>	2500.00	400.00	5.56	0.30	0.38	0.91	1.59
<i>Ganaphalium affine</i>	833.33	88.89	2.78	0.10	0.08	0.46	0.64
<i>Hedera helix</i>	10833.33	777.78	33.33	1.29	0.73	5.48	7.50
<i>Hypericum perforatum</i>	277.78	88.89	2.78	0.03	0.08	0.46	0.57
<i>Onychium contignum</i>	32222.22	2675.00	2.78	3.84	2.52	0.46	6.82
<i>Origanum vulgare</i>	3055.56	752.78	5.56	0.36	0.71	0.91	1.99
<i>Oxalis corniculata</i>	9166.67	552.78	2.78	1.09	0.52	0.46	2.07
<i>Perotis latifolia</i>	85833.33	5286.11	63.89	10.24	4.97	10.50	25.72
<i>Polygonum vacciniifolium</i>	833.33	88.89	2.78	0.10	0.08	0.46	0.64
<i>Rumax nepalensis</i>	1111.11	705.56	5.56	0.13	0.66	0.91	1.71
<i>Salvia glutinosa</i>	8611.11	5286.11	44.44	1.03	4.97	7.31	13.31
<i>Sanicula europea</i>	16111.11	3630.56	33.33	1.92	3.42	5.48	10.82
<i>Strobilanthes alatus</i>	15000.00	1950.00	41.67	1.79	1.83	6.85	10.47
<i>Trifolium pratense</i>	106944.44	6808.33	25.00	12.76	6.40	4.11	23.28
<i>Urtica dioica</i>	3055.56	1547.22	11.11	0.36	1.46	1.83	3.65
<i>Viola pilosa</i>	57500.00	28733.33	66.67	6.86	27.03	10.96	44.85
Total		106302.78					

D - Density
F - Frequency
RD - Relative density
IVI - Importance value index

BA - Basal area
RF - Relative frequency
RBA - Relative basal area

Table 3. Floristic composition in Bashla forest range at an elevation of 2400-2700 m

Species	Average D/ha	BA/ha cm ²	% F	RD	RBA	RF	IVI
Trees							
<i>Abies pindrow</i>	116.67	134575.67	100.00	35.01	30.83	30.00	95.83
<i>Picea smithiana</i>	83.25	271086.83	100.00	24.98	62.10	30.00	117.08
<i>Pinus wallichiana</i>	91.67	20161.50	100.00	27.51	4.62	30.00	62.13
<i>Cedrus deodara</i>	41.67	10741.50	33.33	12.50	2.46	10.00	24.96
Total		436565.50					
Shrubs							
<i>Berberis aristata</i>	188.00	2641.07	26.67	8.01	6.97	9.30	24.28
<i>Cotoneaster bacillaris</i>	240.00	1492.53	26.67	10.22	3.94	9.30	23.46
<i>Daphne cannabina</i>	106.67	974.40	13.33	4.54	2.57	4.65	11.76
<i>Desmodium elegans</i>	53.33	191.20	13.33	2.27	0.50	4.65	7.43
<i>Deutzia compacta</i>	26.67	416.27	6.67	1.14	1.10	2.33	4.56
<i>Lonicera acuminata</i>	346.67	6476.00	53.33	14.76	17.09	18.60	50.45
<i>Prinsepia utilis</i>	53.33	409.60	13.33	2.27	1.08	4.65	8.00
<i>Rosa macrophylla</i>	1093.33	22309.33	86.67	46.56	58.86	30.23	135.65
<i>Sarcococca saligna</i>	53.33	212.53	13.33	2.27	0.56	4.65	7.48
<i>Viburnum cotinifolium</i>	186.67	2779.47	33.33	7.95	7.33	11.63	26.91
Total		37902.40					

(Cont....)

Species	Average D/ha	BA/ha cm ²	% F	RD	RBA	RF	IVI
Herbs							
<i>Adiantum venustum</i>	47222.22	355.56	19.44	2.43	0.14	2.48	5.05
<i>Agrimonia eupatorium</i>	10000.00	1800.00	30.56	0.51	0.70	3.90	5.12
<i>Ajuga bracteosa</i>	5277.78	3219.44	8.33	0.27	1.26	1.06	2.60
<i>Arisaema intermedium</i>	7500.00	4441.67	30.56	0.39	1.74	3.90	6.03
<i>Aster albescens</i>	1388.89	88.89	11.11	0.07	0.03	1.42	1.52
<i>Bistorta amplexicaulis</i>	45833.33	7669.44	47.22	2.36	3.00	6.03	11.39
<i>Bupleurum candollii</i>	2777.78	300.00	13.89	0.14	0.12	1.77	2.03
<i>Calamintha umbrosa</i>	1111.11	200.00	2.78	0.06	0.08	0.35	0.49
<i>Carpesium cernuum</i>	1666.67	155.56	11.11	0.09	0.06	1.42	1.57
<i>Cnicus argyreaanthus</i>	3611.11	755.56	13.89	0.19	0.30	1.77	2.25
<i>Cynoglossum glochidiatum</i>	4166.67	752.78	5.56	0.21	0.29	0.71	1.22
<i>Cyperus aristatus</i>	158055.56	14752.78	47.22	8.13	5.77	6.03	19.93
<i>Dichanthium arnulatum</i>	235555.56	18366.67	41.67	12.12	7.19	5.32	24.63
<i>Desmodium elegans</i>	3055.56	250.00	8.33	0.16	0.10	1.06	1.32
<i>Dryopteris nigropaleacea</i>	81944.44	15527.78	50.00	4.22	6.08	6.38	16.68
<i>Origanum vulgare</i>	2500.00	200.00	2.78	0.13	0.08	0.35	0.56
<i>Fragaria vesca</i>	451388.89	94958.33	94.44	23.22	37.17	12.06	72.45
<i>Galium aparine</i>	116666.67	13247.22	47.22	6.00	5.18	6.03	17.22
<i>Galinsoga parviflora</i>	58055.56	1611.11	5.56	2.99	0.63	0.71	4.33
<i>Geranium wallichianum</i>	9722.22	1263.89	25.00	0.50	0.49	3.19	4.19
<i>Hedera helix</i>	1944.44	352.78	2.78	0.10	0.14	0.35	0.59
<i>Impatiens micranthemum</i>	8333.33	2163.89	19.44	0.43	0.85	2.48	3.76
<i>Onychium contignum</i>	104444.44	6750.00	19.44	5.37	2.64	2.48	10.50
<i>Perotis latifolia</i>	109444.44	4400.00	38.89	5.63	1.72	4.96	12.32
<i>Polygonum vacciniifolium</i>	833.33	88.89	2.78	0.04	0.03	0.35	0.43
<i>Prunella vulgaris</i>	16944.44	3430.00	19.44	0.87	1.34	2.48	4.70
<i>Ranunculus adoxifolius</i>	18888.89	1419.44	19.44	0.97	0.56	2.48	4.01
<i>Salvia glutinosa</i>	13888.89	4422.22	38.89	0.71	1.73	4.96	7.41
<i>Seligenella spp.</i>	12500.00	552.78	5.56	0.64	0.22	0.71	1.57
<i>Strobilanthes alatus</i>	6944.44	733.33	16.67	0.36	0.29	2.13	2.77
<i>Trifolium pratense</i>	389444.44	43302.78	66.67	20.04	16.95	8.51	45.50
<i>Valeriana jatamansi</i>	12500.00	7961.11	16.67	0.64	3.12	2.13	5.89
Total		255493.89					

D - Density
F - Frequency
RD - Relative density
IVI - Importance value index

BA - Basal area
RF - Relative frequency
RBA - Relative basal area

Table 4. Floristic composition in Bashla forest range at an elevation of 2700-3000 m

Species	Average D/ha	BA/ha cm ²	% F	RD	RBA	RF	IVI
Trees							
<i>Picea smithiana</i>	200.00	461168.25	100.00	80.00	94.46	42.86	217.32
<i>Abies pindrow</i>	8.33	6698.67	33.33	3.33	1.37	14.29	18.99
<i>Taxus baccata</i>	16.67	8194.33	33.33	6.67	1.68	14.29	22.63
<i>Pinus wallichiana</i>	16.67	7019.25	33.33	6.67	1.44	14.29	22.39
<i>Prunus prostrata</i>	8.33	5128.67	33.33	3.33	1.05	14.29	18.67
Total		488209.17					
Shrubs							
<i>Berberis aristata</i>	80.00	241.87	20.00	5.45	1.65	10.00	17.10
<i>Cotoneaster bacillaris</i>	106.67	1176.27	20.00	7.27	8.02	10.00	25.29
<i>Desmodium elegans</i>	53.33	248.53	13.33	3.63	1.69	6.67	11.99
<i>Lonicera acuminata</i>	188.00	1316.80	40.00	12.81	8.98	20.00	41.79
<i>Rosa macrophylla</i>	906.67	8430.80	80.00	61.76	57.49	40.00	159.26
<i>Viburnum cotinifolium</i>	133.33	3249.07	26.67	9.08	22.16	13.33	44.57
Total		14663.33					

(Cont....)

Herbs	Average D/ha	BA/ha cm ²	% F	RD	RBA	RF	IVI
<i>Adiantum venustum</i>	47500.00	355.56	11.11	5.22	0.28	1.84	7.34
<i>Agrimonia eupatorium</i>	3888.89	900.00	13.89	0.43	0.70	2.30	3.43
<i>Anaphalis busa</i>	1666.67	400.00	5.56	0.18	0.31	0.92	1.42
<i>Arisaema intermedium</i>	6944.44	3383.33	38.89	0.76	2.63	6.45	9.85
<i>Aster albescens</i>	3333.33	333.33	13.89	0.37	0.26	2.30	2.93
<i>Bistorta amplexicaulis</i>	76111.11	7783.33	50.00	8.37	6.05	8.29	22.71
<i>Bupleurum candollii</i>	1388.89	177.78	5.56	0.15	0.14	0.92	1.21
<i>Calamintha umbrosa</i>	2222.22	400.00	5.56	0.24	0.31	0.92	1.48
<i>Carpesium cernuum</i>	3055.56	600.00	13.89	0.34	0.47	2.30	3.11
<i>Agrostes spp.</i>	1111.11	1416.67	2.78	0.12	1.10	0.46	1.68
<i>Cynoglossum glochidiatum</i>	3055.56	2700.00	8.33	0.34	2.10	1.38	3.82
<i>Cyperus aristatus</i>	151111.11	17927.78	38.89	16.61	13.94	6.45	37.00
<i>Dryopteris nigropaleacea</i>	36944.44	6375.00	33.33	4.06	4.96	5.53	14.55
<i>Onychium contiguum</i>	7500.00	805.56	2.78	0.82	0.63	0.46	1.91
<i>Fragaria vesca</i>	230277.78	21866.67	63.89	25.31	17.00	10.60	52.92
<i>Galium aparine</i>	118611.11	8433.33	58.33	13.04	6.56	9.68	29.27
<i>Geranium wallichianum</i>	4166.67	422.22	13.89	0.46	0.33	2.30	3.09
<i>Ganaphalium affine</i>	833.33	88.89	2.78	0.09	0.07	0.46	0.62
<i>Habenaria pectinata</i>	2777.78	466.67	11.11	0.31	0.36	1.84	2.51
<i>Impatiens micranthemum</i>	1944.44	552.78	5.56	0.21	0.43	0.92	1.57
<i>Iris kumaonensis</i>	8333.33	4033.33	22.22	0.92	3.14	3.69	7.74
<i>Perotis latifolia</i>	33333.33	844.44	19.44	3.66	0.66	3.23	7.55
<i>Aconogonum alpinum</i>	19444.44	6925.00	19.44	2.14	5.38	3.23	10.75
<i>Potentilla nepalensis</i>	1388.89	316.67	11.11	0.15	0.25	1.84	2.24
<i>Ranunculus adoxifolius</i>	5000.00	4250.00	19.44	0.55	3.30	3.23	7.08
<i>Roscoea capitata</i>	21111.11	7280.56	25.00	2.32	5.66	4.15	12.13
<i>Rumax nepalensis</i>	1111.11	400.00	5.56	0.12	0.31	0.92	1.35
<i>Salvia glutinosa</i>	11111.11	5597.22	33.33	1.22	4.35	5.53	11.10
<i>Trifolium pratense</i>	85833.33	9133.33	27.78	9.44	7.10	4.61	21.15
<i>Urtica dioica</i>	4722.22	2088.89	8.33	0.52	1.62	1.38	3.53
<i>Viola pilosa</i>	13888.89	12341.67	11.11	1.53	9.60	1.84	12.97
Total		128600.00					

D - Density
F - Frequency
RD - Relative density
IVI - Importance value index

BA - Basal area
RF - Relative frequency
RBA - Relative basal area

cm²/ha, relative density (80.00), relative frequency (42.86) and IVI (217.32). The lowest value for relative density 3.33 was recorded for both *Abies pindrow* and *Prunus prostrata*. *Taxus baccata* and *Pinus wallichiana* had equal relative density (6.67) and percentage frequency (33.33), while minimum basal area (5128.67 cm²/ha) and relatively 1.05% of the total basal was recorded for *Prunus prostrate*.

Among 6 shrubs species *Rosa macrophylla* showed maximum value for basal area (8430.80 cm²/ha), percentage frequency (80%), relative density (61.76), relative basal area (57.49), relative frequency (40.00) and IVI (159.26), while *Desmodium elegans* with minimum value of IVI (11.99). The total basal area for shrub species in this elevation class was 14663.33 cm²/ha. Among 31 herbs, *Fragaria vesca* showed maximum values 25.31, 17.00, 10.60 and 52.92 for relative density, relative basal area, relative frequency, and IVI, respectively. The next dominant species were *Cyperus aristatus* and *Galium aparine* with IVI values of 37.00 and 29.27, respectively. The total basal area of the herbaceous vegetation was found to be 128600.0 cm²/ha.

4.1.2 JUBBAL FOREST RANGE

4.1.2a PB-I

i) Elevation class 2100-2400 m

In this elevation class 3 tree, 7 shrub and 18 herb species were observed, with total basal area of 326354.63, 6448.80 and 110112.50 cm²/ha respectively (Table-5). Among trees maximum dominance was of *Pinus wallichiana* with IVI value of 124.63 followed by *Picea smithiana* (111.48), whereas minimum IVI (63.89) was observed in case of *Cedrus deodara*. Among shrub species maximum IVI (92.27) was found in case of *Berberis aristata* followed by *Wikstroemia canescens* and *Rosa macrophylla* with IVI value of 77.46 and 61.27, respectively. The minimum IVI (10.91) was recorded for *Rhamnus purpurens*. In case of herbs, maximum dominance was found for *Cyperus aristatus* followed by *Fragaria vesca* and *Dryopteris nigropaleacea* with IVI of 44.55, 43.93 and 33.47, respectively. The lowest IVI value of 0.94 was of *Rumax nepalensis*.

ii) Elevation class 2400-2700 m

The tabulated data for this elevation class of PB-I areas of Jubbal forest range (Table-6), showed that the maximum average density (237.50) and relative density (52.78) for *Picea smithiana*, with 100% frequency and 65245.50 cm²/ha basal area but the maximum IVI (134.73) and basal area (142736.25 cm²/ha) contributing 65.29% to the total basal area of 218632.50 cm²/ha was recorded for *Pinus wallichiana*, whereas the minimum IVI (20.20) was recorded for *Abies pindrow*.

Out of total 6 shrubs most dominant species was *Lonicera angustifolia* having highest value (103.03) of IVI, it also accounted for maximum average density (640 plants/ha), basal area (4584.4 cm²/ha), per cent frequency (70%), relative density (34.78), relative basal area (40.25) and relative frequency (28.0), with minimum presence of *Cotoneaster bacillaries*. Among herb species most dominant species was *Trifolium pratense* followed by *Fragaria vesca* and *Galium aparine* with IVI value of 46.21, 40.95 and 27.31, respectively, while rare species was *Carpesium cernuum* with lowest IVI of 0.98.

iii) Elevation class 2700-3000 m

From the data given in table-7 pertaining to elevation class 2700-3000 m in PB-I it is clear that the elevation class contained 3 tree, 6 shrub and 19 herb species. Among trees *Abies pindrow* was recorded for maximum dominance with an IVI of 192.35 which was followed by *Picea smithiana* (75.88) and *Pinus wallichiana* (31.77), respectively. The total basal area for trees was 454152.95 cm²/ha with maximum contribution (65.27%) of *Abies pindrow*. Among shrubs, *Viburnum cotinifolium* was the most dominant followed by *Cotoneaster bacillaris* with an IVI of 97.67 and 93.00, respectively. Out of the total basal area 21950.80 cm²/ha for shrubs the maximum contribution was of *Cotoneaster microphylla* (37.18%) followed by *Cotoneaster bacillaris* (30.50%) and *Viburnum cotinifolium* (26.83%). Among herbs maximum dominance was observed for *Fragaria vesca* followed by *Geranium wallichianum* and *Viola pilosa* with IVI value of 82.31, 43.91 and 30.93, respectively.

Table 5. Floristic composition in Jubbal forest range at an elevation of 2100-2400 m (PB-I)

Species	Average D/ha	BA/ha cm ²	% F	RD	RBA	RF	IVI
Trees							
<i>Picea smithiana</i>	200.00	152645.88	100.00	31.37	46.77	33.33	111.48
<i>Pinus wallichiana</i>	362.50	112378.88	100.00	56.86	34.43	33.33	124.63
<i>Cedrus deodara</i>	75.00	61329.88	100.00	11.76	18.79	33.33	63.89
Total		326354.63					
Shrubs							
<i>Berberis aristata</i>	480.00	2226.80	70.00	28.57	34.53	29.17	92.27
<i>Cotoneaster bacillaris</i>	160.00	594.80	30.00	9.52	9.22	12.50	31.25
<i>Lonicera acuminata</i>	80.00	80.40	20.00	4.76	1.25	8.33	14.34
<i>Rhamnus purpurens</i>	80.00	127.60	10.00	4.76	1.98	4.17	10.91
<i>Rosa macrophylla</i>	200.00	2108.80	40.00	11.90	32.70	16.67	61.27
<i>Viburnum cotinifolium</i>	40.00	384.00	10.00	2.38	5.95	4.17	12.50
<i>Wikstroemia canescens</i>	640.00	926.40	60.00	38.10	14.37	25.00	77.46
Total		6448.80					
Herbs							
<i>Adiantum venustum</i>	18750.00	66.67	8.33	2.00	0.06	1.16	3.21
<i>Arisaema intermedium</i>	4166.67	2625.00	25.00	0.44	2.38	3.47	6.30
<i>Bistorta amplexicaulis</i>	7916.67	862.50	20.83	0.84	0.78	2.89	4.52
<i>Cyperus aristatus</i>	202083.33	14529.17	70.83	21.53	13.20	9.83	44.55
<i>Dryopteris nigropaleacea</i>	94166.67	16266.67	62.50	10.03	14.77	8.67	33.47
<i>Onychium contiguum</i>	94166.67	6204.17	50.00	10.03	5.63	6.94	22.60
<i>Fragaria vesca</i>	146666.67	20350.00	70.83	15.62	18.48	9.83	43.93
<i>Galium aparine</i>	42916.67	2245.83	45.83	4.57	2.04	6.36	12.97
<i>Geranium wallichianum</i>	9583.33	995.83	25.00	1.02	0.90	3.47	5.39
<i>Hedera helix</i>	8750.00	666.67	25.00	0.93	0.61	3.47	5.01
<i>Impatiens micranthemum</i>	7083.33	962.50	12.50	0.75	0.87	1.73	3.36
<i>Perotis latifolia</i>	91250.00	4458.33	54.17	9.72	4.05	7.51	21.28
<i>Prunella vulgaris</i>	32916.67	5008.33	45.83	3.51	4.55	6.36	14.41
<i>Rumax nepalensis</i>	833.33	300.00	4.17	0.09	0.27	0.58	0.94
<i>Salvia glutinosa</i>	4166.67	2154.17	20.83	0.44	1.96	2.89	5.29
<i>Strobilanthes dalhousianus</i>	50416.67	7216.67	79.17	5.37	6.55	10.98	22.91
<i>Trifolium pratense</i>	87500.00	11545.83	29.17	9.32	10.49	4.05	23.85
<i>Viola spp.</i>	35416.67	13654.17	70.83	3.77	12.40	9.83	26.00
Total		110112.5					

D - Density
 F - Frequency
 RD - Relative density
 IVI - Importance value index

BA - Basal area
 RF - Relative frequency
 RBA - Relative basal area

Table 6. Floristic composition in Jubbal forest range at an elevation of 2400-2700 m (PB-I)

Species	Average D/ha	BA/ha cm ²	% F	RD	RBA	RF	IVI
Trees							
<i>Abies pindrow</i>	12.5	1658.38	50	2.78	0.76	16.67	20.20
<i>Picea smithiana</i>	237.5	65245.50	100	52.78	29.84	33.33	115.95
<i>Pinus wallichiana</i>	162.5	142736.25	100	36.11	65.29	33.33	134.73
<i>Cedrus deodara</i>	37.5	8992.38	50	8.33	4.11	16.67	29.11
Total		218632.51					
Shrubs							
<i>Berberis aristata</i>	280	676.4	50	15.22	5.94	20.00	41.16
<i>Cotoneaster bacillaris</i>	80	414	10	4.35	3.63	4.00	11.98
<i>Lonicera angustifolia</i>	640	4584.4	70	34.78	40.25	28.00	103.03
<i>Prinsepia utilis</i>	80	464.8	20	4.35	4.08	8.00	16.43
<i>Rosa macrophylla</i>	480	2524.4	60	26.09	22.16	24.00	72.25
<i>Viburnum cotinifolium</i>	280	2726.8	40	15.22	23.94	16.00	55.16
Total		11390.8					

(Cont....)

Species	Average D/ha	BA/ha cm ²	% F	RD	RBA	RF	IVI
Herbs							
<i>Adenocaulon bicolor</i>	2083.33	166.67	8.33	0.33	0.19	1.53	2.05
<i>Adiantum venustum</i>	15833.33	266.67	8.33	2.51	0.30	1.53	4.34
<i>Anemone rivularis</i>	833.33	300.00	4.17	0.13	0.34	0.76	1.24
<i>Arisaema intermedium</i>	5416.67	3300.00	25.00	0.86	3.76	4.58	9.20
<i>Carpesium cernuum</i>	416.67	133.33	4.17	0.07	0.15	0.76	0.98
<i>Cyperus aristatus</i>	51250.00	3070.83	29.17	8.12	3.50	5.34	16.96
<i>Dichanthium annulatum</i>	7500.00	166.67	8.33	1.19	0.19	1.53	2.90
<i>Elsholtzia flava</i>	11250.00	8037.50	33.33	1.78	9.16	6.11	17.05
<i>Dryopteris nigropaleacea</i>	25416.67	3283.33	29.17	4.03	3.74	5.34	13.11
<i>Onychium contignum</i>	24583.33	2487.50	12.50	3.89	2.84	2.29	9.02
<i>Fragaria vesca</i>	119583.33	8591.67	66.67	18.94	9.80	12.21	40.95
<i>Galium aparine</i>	86250.00	5275.00	41.67	13.66	6.01	7.63	27.31
<i>Geranium wallichianum</i>	10833.33	1033.33	33.33	1.72	1.18	6.11	9.00
<i>Halenia elliptica</i>	1250.00	133.33	4.17	0.20	0.15	0.76	1.11
<i>Hedera helix</i>	4583.33	266.67	12.50	0.73	0.30	2.29	3.32
<i>Impatiens sulcata</i>	2916.67	300.00	4.17	0.46	0.34	0.76	1.57
<i>Oxalis corniculata</i>	36666.67	733.33	12.50	5.81	0.84	2.29	8.93
<i>Perotis</i>	14166.67	641.67	12.50	2.24	0.73	2.29	5.27
<i>Prunella vulgaris</i>	14166.67	2208.33	41.67	2.24	2.52	7.63	12.40
<i>Rumax nepalensis</i>	10000.00	6804.17	25.00	1.58	7.76	4.58	13.92
<i>Salvia glutinosa</i>	4166.67	2020.83	20.83	0.66	2.30	3.82	6.78
<i>Senecio chrysanthemoides</i>	1250.00	166.67	8.33	0.20	0.19	1.53	1.91
<i>Strobilanthes dalhousianus</i>	6666.67	829.17	8.33	1.06	0.95	1.53	3.53
<i>Trifolium pretense</i>	136250.00	16245.83	33.33	21.58	18.52	6.11	46.21
<i>Urtica dioica</i>	17500.00	10637.50	29.17	2.77	12.13	5.34	20.24
<i>Viola spp.</i>	20416.67	10612.50	29.17	3.23	12.10	5.34	20.68
Total		87712.5					

D - Density
F - Frequency
RD - Relative density
IVI - Importance value index

BA - Basal area
RF - Relative frequency
RBA - Relative basal area

Table 7. Floristic composition in Jubbal forest range at an elevation -2700-3000 m (PB-1)

Species	Average D/ha	BA/ha cm ²	% F	RD	RBA	RF	IVI
Trees							
<i>Abies pindrow</i>	462.50	296406.75	100	77.08	65.27	50	192.35
<i>Picea smithiana</i>	112.50	145922.07	50	18.75	32.13	25	75.88
<i>Pinus wallichiana</i>	25.00	11824.13	50	4.17	2.60	25	31.77
Total		454152.95					
Shrubs							
<i>Berberis aristata</i>	160.00	200.80	20.00	8.33	0.91	8.33	17.58
<i>Cotoneaster bacillaris</i>	640.00	6694.80	70.00	33.33	30.50	29.17	93.00
<i>Cotoneaster microphylla</i>	160.00	8161.60	20.00	8.33	37.18	8.33	53.85
<i>Lonicera angustifolia</i>	80.00	130.40	20.00	4.17	0.59	8.33	13.09
<i>Rosa macrophylla</i>	160.00	872.80	30.00	8.33	3.98	12.50	24.81
<i>Viburnum cotinifolium</i>	720.00	5890.40	80.00	37.50	26.83	33.33	97.67
Total		21950.8					
Herbs							
<i>Adenocaulon bicolor</i>	3333.33	466.67	12.50	0.93	0.83	2.75	4.51
<i>Adiantum venustum</i>	8750.00	166.67	8.33	2.44	0.30	1.83	4.57
<i>Selinum tenuifolium</i>	17500.00	1629.17	45.83	4.88	2.90	10.09	17.87
<i>Arisaema intermedium</i>	6666.67	2516.67	29.17	1.86	4.48	6.42	12.76
<i>Carpesium cernuum</i>	1666.67	166.67	8.33	0.46	0.30	1.83	2.60
<i>Cyperus aristatus</i>	10833.33	466.67	12.50	3.02	0.83	2.75	6.60
<i>Dichanthium annulatum</i>	6250.00	166.67	8.33	1.74	0.30	1.83	3.87
<i>Dryopteris nigropaleacea</i>	15000.00	1033.33	25.00	4.18	1.84	5.50	11.52
<i>Onychium contignum</i>	21250.00	2337.50	12.50	5.92	4.16	2.75	12.83
<i>Fragaria vesca</i>	162500.00	12037.50	70.83	45.30	21.41	15.60	82.31
<i>Geranium wallichianum</i>	20416.67	15295.83	50.00	5.69	27.21	11.01	43.91
<i>Halenia elliptica</i>	10833.33	1895.83	33.33	3.02	3.37	7.34	13.73
<i>Prunella vulgaris</i>	3750.00	400.00	12.50	1.05	0.71	2.75	4.51
<i>Rumax hastatus</i>	3750.00	1958.33	16.67	1.05	3.48	3.67	8.20
<i>Salvia glutinosa</i>	1250.00	562.50	8.33	0.35	1.00	1.83	3.18
<i>Senecio chrysanthemoides</i>	3750.00	1033.33	25.00	1.05	1.84	5.50	8.39
<i>Trifolium pretense</i>	33333.33	2029.17	20.83	9.29	3.61	4.59	17.49
<i>Viola pilosa</i>	21250.00	9416.67	37.50	5.92	16.75	8.26	30.93
<i>Viola spp.</i>	6666.67	2637.50	16.67	1.86	4.69	3.67	10.22
Total		56216.67					

D - Density
 F - Frequency
 RD - Relative density
 IVI - Importance value index

BA - Basal area
 RF - Relative frequency
 RBA - Relative basal area

The total basal area for all the herbs was found to be 56216.67 cm²/ha with maximum contribution of *Geranium wallichianum* (27.21%) followed by *Fragaria vesca* (21.41%).

4.1.2b PB-U (Unalloted)

i) Elevation class 2100-2400 m

Table-8 represents the floristic composition in PB-U area in Jubbal forest range for 2100-2400m elevation class which reveals that among three tree species *Picea smithiana* was dominating with maximum IVI value (151.20) followed by *Cedrus deodara* (88.55), whereas, minimum IVI value (60.25) for *Pinus wallichiana*, similar pattern was observed for these species related to density and basal area, however frequency for all the species was equal.

Out of total eight shrub species maximum IVI was recorded for *Berberis aristata* (77.98), although relative basal area was recorded maximum for *Rosa moschata* which was second dominant species in the area with IVI value of 51.23. Moreover, the least dominant was *Cotoneaster microphylla* with 8.77 IVI value, which was due to lowest frequency, density and basal area. Among eighteen herb species recorded in the area maximum IVI (49.60) was found in case of *Cyperus aristatus* with relative density of 23.70, which was followed by *Viola spp.* with IVI, relative frequency and relative basal area of 44.28, 11.36 and 25.34, respectively. However, minimum IVI (1.60) was recorded of *Bistorta amplexicaulis*.

ii) Elevation class 2400-2700 m

Table-9 pertaining to PB-U in elevation class 2400-2700m in Jubbal forest range indicated that *Picea smithiana* was dominant among five tree species with value 95.72 of IVI, followed by *Pinus wallichiana* (79.46), however both species showed equal value for relative density (33.33) and relative frequency (22.22), whereas *Juglans regia* was found as associated species with minimum value for these parameters. The total basal area of the trees was 310085.38 cm²/ha. Among four shrubs most dominant species was *Viburnum cotinifolium* having highest value

(148.65) of IVI followed by *Rosa macrophylla* (108.38), while minimum (15.96) IVI was of *Berberis aristata*.

Among twenty three herb species recorded in the area the most dominant species on the basis of IVI was *Fragaria vesca* (52.85) followed by *Trifolium pratense* (30.72), however maximum basal area was found in case of *Arisaema intermedium* (10929.17 cm²/ha), whereas, *Dichanthium annulatum* encountered minimum with IVI value of (1.47).

iii) Elevation class 2700-3000m

Table-10 shows the floristic composition of trees, shrubs and herbs for elevation class 2700-3000 m in PB-U areas of Jubbal forest range, where only two tree species were recorded namely *Abies pindrow* and *Picea smithiana* with IVI value 261.05 and 38.95 respectively, which reveals that *Abies pindrow* was almost in pure form with 902810.00 cm²/ ha of basal area. Among four shrub species maximum IVI was recorded for *Viburnum cotinifolium* i.e. 157.61 and was followed by *Skimmia anquetilia* with 108.25 IVI, this species was also recorded for maximum basal area (8996.80 cm²/ha). However, the most rare species in this area was *Berberis aristata* with 28.8 cm²/ha basal area out of the total basal area of 14224.0 cm²/ha of all the shrub species.

Out of the twenty two herbs *Fragaria vesca* was the most dominant species with 56.44, IVI, 13.29, relative frequency and 26.49 relative density followed by *Viola spp.* in dominance on the basis of IVI, which was 37.39. The relative basal area was recorded maximum 25.07% for *Viola spp.* out of total basal area of 69908.33 cm²/ha.

4.1.3 KOTKHAI FOREST RANGE

4.1.3a PB-I

i) Elevation class 2100-2400 m

In case of PB-I (Table-11) for an elevation class 2100-2400m in Kotkhai range the results related to floristic composition revealed that maximum average

Table 8. Floristic composition in Jubbal forest range at an elevation of 2100-2400 m (PB-U)

Species	Average D/ha	BA/ha cm ²	% F	RD	RBA	RF	IVI
Trees							
<i>Picea smithiana</i>	337.50	183926.00	100.00	56.25	61.62	33.33	151.20
<i>Pinus wallichiana</i>	100.00	30606.00	100.00	16.67	10.25	33.33	60.25
<i>Cedrus deodara</i>	162.50	83965.75	100.00	27.08	28.13	33.33	88.55
Total		298497.75					
Shrubs							
<i>Berberis aristata</i>	400.00	914.40	60.00	29.41	20.00	28.57	77.98
<i>Cotoneaster bacillaris</i>	120.00	283.60	20.00	8.82	6.20	9.52	24.55
<i>Cotoneaster microphylla</i>	40.00	48.80	10.00	2.94	1.07	4.76	8.77
<i>Lonicera angustifolia</i>	240.00	226.40	40.00	17.65	4.95	19.05	41.65
<i>Prinsepia utilis</i>	40.00	113.20	10.00	2.94	2.48	4.76	10.18
<i>Rosa macrophylla</i>	200.00	767.60	30.00	14.71	16.79	14.29	45.78
<i>Rosa moschata</i>	40.00	1990.40	10.00	2.94	43.53	4.76	51.23
<i>Wikstroemia canescens</i>	280.00	228.40	30.00	20.59	4.99	14.29	39.87
Total		4572.8					
Herbs							
<i>Adiantum venustum</i>	21250.00	66.67	8.33	2.30	0.06	1.14	3.50
<i>Dryopteris nigropaleacea</i>	80416.67	10283.33	54.17	8.70	9.47	7.39	25.55
<i>Arisaema intermedium</i>	6250.00	2787.50	29.17	0.68	2.57	3.98	7.22
<i>Bistorta amplexicaulis</i>	2500.00	208.33	8.33	0.27	0.19	1.14	1.60
<i>Cyperus aristatus</i>	219166.67	23795.83	29.17	23.70	21.92	3.98	49.60
<i>Dichanthium annulatum</i>	12500.00	433.33	8.33	1.35	0.40	1.14	2.89
<i>Fragaria vesca</i>	90000.00	9291.67	54.17	9.73	8.56	7.39	25.68
<i>Galium aparine</i>	95000.00	6166.67	79.17	10.27	5.68	10.80	26.75
<i>Geranium wallichianum</i>	39166.67	2400.00	66.67	4.24	2.21	9.09	15.54
<i>Hedera helix</i>	27500.00	2000.00	50.00	2.97	1.84	6.82	11.63
<i>Onychium contiguum</i>	65000.00	4033.33	58.33	7.03	3.71	7.95	18.70
<i>Perotis</i>	72083.33	3166.67	62.50	7.80	2.92	8.52	19.24
<i>Prunella vulgaris</i>	7916.67	995.83	25.00	0.86	0.92	3.41	5.18
<i>Salvia glutinosa</i>	2083.33	962.50	8.33	0.23	0.89	1.14	2.25
<i>Strobilanthes dalhousianus</i>	90416.67	11883.33	70.83	9.78	10.94	9.66	30.38
<i>Trifolium pratense</i>	15000.00	1058.33	8.33	1.62	0.97	1.14	3.73
<i>Viola spp.</i>	70000.00	27516.67	83.33	7.57	25.34	11.36	44.28
Miscellaneous species	8333.33	1525.00	29.17	0.90	1.40	3.98	6.28
Total		108575.00					

D - Density
 F - Frequency
 RD - Relative density
 IVI - Importance value index

BA - Basal area
 RF - Relative frequency
 RBA - Relative basal area

Table 9. Floristic composition in Jubbal forest range at an elevation of 2400-2700 m (PB-U)

Species	Average D/ha	BA/ha cm ²	% F	RD	RBA	RF	IVI
Trees							
<i>Picea smithiana</i>	87.50	124540.50	100.00	33.33	40.16	22.22	95.72
<i>Pinus wallichiana</i>	87.50	74123.75	100.00	33.33	23.90	22.22	79.46
<i>Cedrus deodara</i>	37.50	36198.38	100.00	14.29	11.67	22.22	48.18
<i>Prunus prostrata</i>	37.50	63879.50	100.00	14.29	20.60	22.22	57.11
<i>Juglans regia</i>	12.50	11343.25	50.00	4.76	3.66	11.11	19.53
Total		310085.38					
Shrubs							
<i>Berberis aristata</i>	80	92.4	20	4.88	0.55	10.53	15.96
<i>Lonicera angustifolia</i>	160	1124.4	20	9.76	6.74	10.53	27.02
<i>Rosa macrophylla</i>	800	3798.4	70	48.78	22.75	36.84	108.38
<i>Viburnum cotinifolium</i>	600	11678.8	80	36.59	69.96	42.11	148.65
Total		16694					

(Cont....)

Species	Average D/ha	BA/ha cm ²	% F	RD	RBA	RF	IVI
Herbs							
<i>Adenocaulon bicolor</i>	6666.67	800.00	20.83	1.06	1.25	3.65	5.96
<i>Adiantum venustum</i>	80833.33	1095.83	16.67	12.86	1.72	2.92	17.50
<i>Agrimonia eupatorium</i>	10833.33	2725.00	20.83	1.72	4.27	3.65	9.64
<i>Selinum tenuifolium</i>	2916.67	158.33	16.67	0.46	0.25	2.92	3.63
<i>Arisaema intermedium</i>	11666.67	10929.17	41.67	1.86	17.13	7.30	26.28
<i>Bistorta amplexicaulis</i>	1666.67	600.00	8.33	0.27	0.94	1.46	2.67
<i>Cyperus aristatus</i>	48333.33	2833.33	20.83	7.69	4.44	3.65	15.78
<i>Dichanthium annulatum</i>	3333.33	133.33	4.17	0.53	0.21	0.73	1.47
<i>Dryopteris nigropaleacea</i>	32500.00	4383.33	33.33	5.17	6.87	5.84	17.88
<i>Onychium contiguum</i>	44166.67	3283.33	16.67	7.03	5.15	2.92	15.09
<i>Fragaria vesca</i>	145416.67	9175.00	87.50	23.14	14.38	15.33	52.85
<i>Galium aparine</i>	36666.67	3370.83	45.83	5.84	5.28	8.03	19.15
<i>Geranium wallichianum</i>	8750.00	1358.33	12.50	1.39	2.13	2.19	5.71
<i>Halenia elliptica</i>	5833.33	800.00	25.00	0.93	1.25	4.38	6.56
<i>Hedera helix</i>	5833.33	866.67	16.67	0.93	1.36	2.92	5.21
<i>Oxalis corniculata</i>	47916.67	1033.33	16.67	7.63	1.62	2.92	12.17
<i>Prunella vulgaris</i>	12916.67	2158.33	33.33	2.06	3.38	5.84	11.28
<i>Rumex nepalensis</i>	2500.00	962.50	12.50	0.40	1.51	2.19	4.10
<i>Salvia glutinosa</i>	4166.67	2716.67	20.83	0.66	4.26	3.65	8.57
<i>Senecio chrysanthemoides</i>	2500.00	566.67	12.50	0.40	0.89	2.19	3.48
<i>Trifolium pratense</i>	94583.33	5804.17	37.50	15.05	9.10	6.57	30.72
<i>Urtica dioica</i>	5000.00	2187.50	12.50	0.80	3.43	2.19	6.41
<i>Viola spp.</i>	13333.33	5870.83	37.50	2.12	9.20	6.57	17.89
Total		63812.5					

D - Density
 F - Frequency
 RD - Relative density
 IVI - Importance value index

BA - Basal area
 RF - Relative frequency
 RBA - Relative basal area

Table 10. Floristic composition in Jubbal forest range at an elevation of 2700-3000 m (PB-U)

Species	Average D/ha	BA/ha cm ²	% F	RD	RBA	RF	IVI
Trees							
<i>Abies pindrow</i>	525.00	873127.13	100.00	97.67	96.71	66.67	261.05
<i>Picea smithiana</i>	12.50	29682.88	50.00	2.33	3.29	33.33	38.95
Total		902810.00					
Shrubs							
<i>Berberis aristata</i>	40	28.8	10	6.25	0.20	10	16.45
<i>Cotoneaster microphylla</i>	40	204	10	6.25	1.43	10	17.68
<i>Skimmia anquetilia</i>	160	8996.8	20	25	63.25	20	108.25
<i>Viburnum cotinifolium</i>	400	4994.4	60	62.5	35.11	60	157.61
Total		14224					

Species	Average D/ha	BA/ha cm ²	% F	RD	RBA	RF	IVI
Herbs							
<i>Adenocaulon bicolor</i>	6250.00	1229.17	20.83	1.13	1.76	3.16	6.05
<i>Adiantum venustum</i>	55833.33	733.33	12.50	10.11	1.05	1.90	13.06
<i>Selinum tenuifolium</i>	11666.67	1562.50	37.50	2.11	2.24	5.70	10.04
<i>Dryopteris nigropaleacea</i>	16666.67	1229.17	20.83	3.02	1.76	3.16	7.94
<i>Arisaema intermedium</i>	14166.67	8700.00	54.17	2.57	12.44	8.23	23.24
<i>Bistorta amplexicaulis</i>	6250.00	1095.83	25.00	1.13	1.57	3.80	6.50
<i>Carpesium cernuum</i>	833.33	133.33	4.17	0.15	0.19	0.63	0.97
<i>Cyperus aristatus</i>	27916.67	1200.00	25.00	5.06	1.72	3.80	10.57
<i>Fragaria vesca</i>	146250.00	11645.83	87.50	26.49	16.66	13.29	56.44
<i>Galium aparine</i>	47083.33	2562.50	41.67	8.53	3.67	6.33	18.52
<i>Geranium wallichianum</i>	15833.33	1962.50	33.33	2.87	2.81	5.06	10.74
<i>Halenia elliptica</i>	12916.67	1733.33	50.00	2.34	2.48	7.59	12.41
<i>Hedera helix</i>	1250.00	133.33	4.17	0.23	0.19	0.63	1.05
<i>Perotis latifolia</i>	7916.67	300.00	4.17	1.43	0.43	0.63	2.50
<i>Prunella vulgaris</i>	8750.00	1066.67	20.83	1.58	1.53	3.16	6.28
<i>Rumax hastatus</i>	6666.67	4208.33	33.33	1.21	6.02	5.06	12.29
<i>Salvia glutinosa</i>	833.33	266.67	8.33	0.15	0.38	1.27	1.80
<i>Selinum tenuifolium</i>	59166.67	2391.67	29.17	10.72	3.42	4.43	18.57
<i>Senecio chrysanthemoides</i>	13750.00	5587.50	54.17	2.49	7.99	8.23	18.71
<i>Trifolium pratense</i>	51250.00	3079.17	29.17	9.28	4.40	4.43	18.12
<i>Viola spp.</i>	29583.33	17525.00	45.83	5.36	25.07	6.96	37.39
Miscellaneous species	11250.00	1562.50	16.67	2.04	2.24	2.53	6.80
Total		69908.33					

D - Density
F - Frequency
RD - Relative density
IVI - Importance value index

BA - Basal area
RF - Relative frequency
RBA - Relative basal area

Table 11. Floristic composition in Kotkhai forest range at an elevation of 2100-2400 m (PB-1)

Species	Average D/ha	BA/ha cm ²	% F	RD	RBA	RF	IVI
Trees							
<i>Picea smithiana</i>	37.50	87625.75	100.00	15.00	38.66	28.57	82.23
<i>Quercus spp.</i>	112.50	119496.75	100.00	45.00	52.72	28.57	126.29
<i>Taxus baccata</i>	37.50	9714.50	50.00	15.00	4.29	14.29	33.57
<i>Cedrus deodara</i>	25.00	3071.38	50.00	10.00	1.35	14.29	25.64
<i>Pinus wallichiana</i>	37.50	6774.50	50.00	15.00	2.99	14.29	32.27
Total		226682.88					
Shrubs							
<i>Berberis aristata</i>	440.00	929.60	70.00	42.31	5.57	43.75	91.62
<i>Daphne cannabina</i>	160.00	490.40	20.00	15.38	2.94	12.50	30.82
<i>Lonicera angustifolia</i>	80.00	235.60	10.00	7.69	1.41	6.25	15.35
<i>Prinsepia utilis</i>	120.00	6261.20	30.00	11.54	37.49	18.75	67.77
<i>Viburnum cotinifolium</i>	240.00	8786.00	30.00	23.08	52.60	18.75	94.43
Total		16702.80					

(Cont....)

Species	Average D/ha	BA/ha cm ²	% F	RD	RBA	RF	IVI
Herbs							
<i>Adiantum venustum</i>	65833.33	733.33	12.50	8.69	0.80	2.11	11.60
<i>Agrimonia eupatorium</i>	29166.67	6204.17	50.00	3.85	6.74	8.45	19.04
<i>Dryopteris nigropaleacea</i>	15833.33	2487.50	16.67	2.09	2.70	2.82	7.61
<i>Arisaema intermedium</i>	5000.00	2187.50	20.83	0.66	2.38	3.52	6.56
<i>Bistorta amplexicaulis</i>	15833.33	2095.83	33.33	2.09	2.28	5.63	10.00
<i>Bistorta spp.</i>	107916.67	7829.17	41.67	14.24	8.50	7.04	29.78
<i>Fragaria vesca</i>	177916.67	16958.33	75.00	23.47	18.41	12.68	54.56
<i>Galium aparine</i>	104583.33	12837.50	50.00	13.80	13.94	8.45	36.19
<i>Geranium wallichianum</i>	3750.00	433.33	8.33	0.49	0.47	1.41	2.37
<i>Halenia elliptica</i>	2500.00	266.67	8.33	0.33	0.29	1.41	2.03
<i>Hedera helix</i>	3333.33	300.00	12.50	0.44	0.33	2.11	2.88
<i>Impatiens sulcata</i>	5416.67	937.50	20.83	0.71	1.02	3.52	5.25
<i>Onychium contiguum</i>	37500.00	3845.83	8.33	4.95	4.18	1.41	10.53
<i>Perotis latifolia</i>	32500.00	1304.17	25.00	4.29	1.42	4.23	9.93
<i>Prunella vulgaris</i>	17500.00	1758.33	29.17	2.31	1.91	4.93	9.15
<i>Rumax hastatus</i>	2083.33	1358.33	8.33	0.27	1.47	1.41	3.16
<i>Salvia glutinosa</i>	21250.00	10175.00	58.33	2.80	11.05	9.86	23.71
<i>Strobilanthes dalhousianus</i>	34583.33	5833.33	33.33	4.56	6.33	5.63	16.53
<i>Trifolium pratense</i>	44166.67	2391.67	20.83	5.83	2.60	3.52	11.95
<i>Urtica dioica</i>	2916.67	1262.50	12.50	0.38	1.37	2.11	3.87
<i>Viola spp.</i>	28333.33	10895.83	45.83	3.74	11.83	7.75	23.32
Total		92095.83					

D - Density
F - Frequency
RD - Relative density
IVI - Importance value index

BA - Basal area
RF - Relative frequency
RBA - Relative basal area

density (112.50/ha), basal area (119496.75 cm²/ha), relative density (45.00), relative basal area of 52.72 and IVI (126.29) was recorded for *Quercus spp.* followed by *Picea smithiana* with an IVI of 82.23. *Cedrus deodara* was associated with lower value for these parameters. The total basal area for trees was 226682.88 cm²/ha with maximum contribution of *Quercus spp.*

Out of total 5 shrub species the dominant species based on IVI was *Viburnum cotinifolium* (94.43) followed by *Berberis aristata* (91.62). Whereas *Lonicera angustifolia* showed lowest IVI (15.35). Among 31 herb species recorded in the area *Fragaria vesca* was the dominant followed by *Bistorta spp.* and *Salvia glutinosa* with IVI 54.56, 29.78 and 23.71, respectively. The minimum value for IVI was for *Halenia elliptica* (2.03).

ii) Elevation class 2400-2700 m

The data in table-12 pertaining to PB-I for Kotkhai range revealed the presence of 7 trees, 2 shrubs and 20 herb species. The maximum dominance was observed of *Abies pindrow* among trees with IVI as 83.01 followed by *Quercus spp.*, *Pinus wallichiana* and *Picea smithiana* with IVI value of 78.04, 31.59 and 30.43, respectively, whereas least value (18.86) was recorded for *Taxus baccata*. Among shrub species *Viburnum cotinifolium* was the dominant species with respect to *Berberis aristata* with IVI value of 232.36 and 67.64, respectively. In case of herbs maximum dominance was observed for *Fragaria vesca* followed by *Cyperus aristatus* and *Galium aparine* with 72.35, 27.89 and 25.82 IVI, respectively, while *Carpesium cernuum* and *Geranium wallichianum* were having equal and lowest value (0.89) of IVI.

iii) Elevation class 2700-3000 m

The phytosociological data presented (Table-13) for Kotkhai in PB-I areas indicated the presence of two tree species *Abies pindrow* and *Quercus spp.* with 93.22 and 106.78 IVI value. The total basal area for tree species was recorded to be 357048.38 cm²/ha with 73.53% contribution for *Abies pindrow*.

In case of shrubs the phytosociological attributes revealed that *Berberis aristata* with IVI value of 94.28 as the dominant species followed by *Rosa macrophylla*, *Lonicera angustifolia* and *Viburnum cotinifolium* with IVI value of 70.64, 63.07 and 51.66, respectively. In case of herbs *Fragaria vesca* showed maximum dominance followed by *Galium aparine* with IVI of 99.19 and 48.53, respectively. *Rumex hastatus* was reported for lowest IVI (1.15). The total basal area of the herbs was reported to be 59383.33 cm²/ha

4.1.3b PB-U (Unallotted)

i) Elevation class 2100-2400 m

The table-14 represented the phytosociological data for Kotkhai forest range for elevation class 2100-2400 m in PB-U and reveals that out of 3 tree species present, the habitat was dominated by *Pinus wallichiana* followed by *Quercus spp.* with 213.10 and 57.34 IVI value, respectively. Whereas the lowest value for IVI was recorded for *Picea smithiana* (29.56). Among total 4 shrub species in the area *Prinsepia utilis* was dominating followed by *Daphne cannabina* with IVI of 129.07 and 103.81, respectively. The lowest value for IVI was recorded for *Rosa macrophylla* (10.87) due to lowest values for relative frequency, relative density and relative basal area. Among 23 herb species present in the area, it was found that *Cyperus aristatus* was the dominant species followed by *Galium aparine* and *Fragaria vesca* with 81.92, 24.39 and 20.04 IVI, respectively. The lowest IVI value of 1.26 was recorded for *Urtica dioica*.

ii) Elevation class 2400-2700 m

In this elevation class in PB-U for Kotkhai forest range the result in table 15 revealed that among 3 tree species *Cedrus deodara* had maximum average density (275 trees/ha), basal area (182720.0 cm²/ha), relative density (52.38), relative basal area (61.91) and IVI (147.62). The other two species present *Picea smithiana* and *Pinus wallichiana* had IVI 80.60 and 71.78, respectively. All the species present in the area represented equal relative frequency of 33.33%. The total basal area for the trees was 295147.88 cm²/ha with maximum contribution of 61.91% by *Cedrus deodara*.

Table 12. Floristic composition in Kotkhai forest range at an elevation of 2400-2700 m (PB-1)

Species	Average D/ha	BA/ha m ²	% F	RD	RBA	RF	IVI
Trees							
<i>Abies pindrow</i>	150.00	73378.25	50.00	42.86	25.87	14.29	83.01
<i>Picea smithiana</i>	25.00	25522.38	50.00	7.14	9.00	14.29	30.43
<i>Quercus spp.</i>	100.00	99803.13	50.00	28.57	35.19	14.29	78.04
<i>Cedrus deodara</i>	25.00	18378.88	50.00	7.14	6.48	14.29	27.91
<i>Taxus baccata</i>	12.50	2835.88	50.00	3.57	1.00	14.29	18.86
<i>Juglans regia</i>	25.00	24776.63	50.00	7.14	8.74	14.29	30.16
<i>Pinus wallichiana</i>	12.50	38945.88	50.00	3.57	13.73	14.29	31.59
Total		283641.00					
Shrubs							
<i>Viburnum cotinifolium</i>	360.00	5410.40	50.00	75.00	85.93	71.43	232.36
<i>Berberis aristata</i>	120.00	885.60	20.00	25.00	14.07	28.57	67.64
Total		6296.00					

(Cont....)

Species	Average D/ha	BA/ha m ²	% F	RD	RBA	RF	IVI
Herbs							
<i>Adiantum venustum</i>	95416.67	966.67	66.67	11.30	0.86	10.74	22.90
<i>Agrimonia eupatorium</i>	13333.33	1829.17	33.33	1.58	1.63	5.37	8.58
<i>Arisaema intermedium</i>	11666.67	7308.33	37.50	1.38	6.51	6.04	13.93
<i>Bistorta amplexicaulis</i>	20000.00	2829.17	41.67	2.37	2.52	6.71	11.60
<i>Carpesium cernuum</i>	833.33	133.33	4.17	0.10	0.12	0.67	0.89
<i>Cnicus argyraeanthus</i>	833.33	529.17	4.17	0.10	0.47	0.67	1.24
<i>Cyperus aristatus</i>	111250.00	8229.17	45.83	13.18	7.33	7.38	27.89
<i>Dryopteris nigropaleacea</i>	46250.00	4316.67	29.17	5.48	3.85	4.70	14.02
<i>Fragaria vesca</i>	259583.33	31637.50	83.33	30.75	28.18	13.42	72.35
<i>Galium aparine</i>	98750.00	7562.50	45.83	11.70	6.74	7.38	25.82
<i>Geranium wallichianum</i>	833.33	133.33	4.17	0.10	0.12	0.67	0.89
<i>Impatiens sulcata</i>	31250.00	5275.00	66.67	3.70	4.70	10.74	19.14
<i>Onychium contiguum</i>	84166.67	8862.50	25.00	9.97	7.89	4.03	21.89
<i>Phragmites carca</i>	9166.67	2125.00	4.17	1.09	1.89	0.67	3.65
<i>Prunella vulgaris</i>	2916.67	100.00	12.50	0.35	0.09	2.01	2.45
<i>Rumax hastatus</i>	416.67	529.17	4.17	0.05	0.47	0.67	1.19
<i>Salvia glutinosa</i>	17500.00	15662.50	50.00	2.07	13.95	8.05	24.08
<i>Trifolium pratense</i>	9166.67	529.17	4.17	1.09	0.47	0.67	2.23
<i>Urtica dioica</i>	3333.33	2454.17	8.33	0.39	2.19	1.34	3.92
<i>Viola spp.</i>	27500.00	11254.17	50.00	3.26	10.02	8.05	21.34
Total		112266.67					

D - Density
F - Frequency
RD - Relative density
IVI - Importance value index

BA - Basal area
RF - Relative frequency
RBA - Relative basal area

Table 13. Floristic composition in Kotkhai forest range at an elevation of 2700-3000 m PB-1

Species	Average D/ha	BA/ha cm ²	% F	RD	RBA	RF	IVI
Trees							
<i>Abies pindrow</i>	287.50	262524.25	100.00	69.70	73.53	50.00	193.22
<i>Quercus spp.</i>	125.00	94524.13	100.00	30.30	26.47	50.00	106.78
Total		357048.38					
Shrubs							
<i>Rosa macrophylla</i>	440.00	2092.80	50.00	29.73	17.10	23.81	70.64
<i>Lonicera angustifolia</i>	360.00	1245.60	60.00	24.32	10.18	28.57	63.07
<i>Viburnum cotinifolium</i>	280.00	2258.40	30.00	18.92	18.46	14.29	51.66
<i>Berberis aristata</i>	320.00	5978.00	50.00	21.62	48.85	23.81	94.28
<i>Cotoneaster microphylla</i>	80.00	662.40	20.00	5.41	5.41	9.52	20.34
Total		12237.20					
Herbs							
<i>Ajuga bracteosa</i>	2083.33	1358.33	12.50	0.43	2.29	2.52	5.24
<i>Anemone rivularis</i>	8750.00	1066.67	37.50	1.82	1.80	7.56	11.18
<i>Selinum tenuifolium</i>	29583.33	3054.17	50.00	6.17	5.14	10.08	21.40
<i>Dryopteris nigropaleacea</i>	7500.00	829.17	4.17	1.56	1.40	0.84	3.80
<i>Arisaema intermedium</i>	5833.33	3866.67	37.50	1.22	6.51	7.56	15.29
<i>Bistorta amplexicaulis</i>	5000.00	2691.67	16.67	1.04	4.53	3.36	8.94
<i>Carpesium cernuum</i>	1666.67	266.67	8.33	0.35	0.45	1.68	2.48
<i>Fragaria vesca</i>	220833.33	20079.17	95.83	46.05	33.81	19.33	99.19
<i>Galium aparine</i>	110416.67	7162.50	66.67	23.02	12.06	13.45	48.53
<i>Geranium wallichianum</i>	10833.33	1537.50	29.17	2.26	2.59	5.88	10.73
<i>Halenia elliptica</i>	2916.67	529.17	4.17	0.61	0.89	0.84	2.34
<i>Hedera helix</i>	2916.67	300.00	12.50	0.61	0.51	2.52	3.63
<i>Perotis latifolia</i>	2500.00	133.33	4.17	0.52	0.22	0.84	1.59
<i>Prunella vulgaris</i>	3750.00	900.00	12.50	0.78	1.52	2.52	4.82
<i>Rumax hastatus</i>	416.67	133.33	4.17	0.09	0.22	0.84	1.15
<i>Salvia glutinosa</i>	4166.67	2566.67	12.50	0.87	4.32	2.52	7.71
<i>Trifolium pratense</i>	28750.00	1129.17	12.50	5.99	1.90	2.52	10.42
<i>Viola pilosa</i>	25000.00	8079.17	50.00	5.21	13.61	10.08	28.90
<i>Viola spp.</i>	6666.67	3700.00	25.00	1.39	6.23	5.04	12.66
Total		59383.33					

D - Density
 F - Frequency
 RD - Relative density
 IVI - Importance value index

BA - Basal area
 RF - Relative frequency
 RBA - Relative basal area

Table 14. Floristic composition in Kotkhai forest range at an elevation of 2100-2400 m (PB-U)

Species	Average D/ha	BA/ha cm ²	% F	RD	RBA	RF	IVI
Trees							
<i>Pinus wallichiana</i>	262.50	273602.13	100.00	87.50	75.60	50.00	213.10
<i>Picea smithiana</i>	12.50	1436.63	50.00	4.17	0.40	25.00	29.56
<i>Quercus spp.</i>	25.00	86873.25	50.00	8.33	24.00	25.00	57.34
Total		361912					
Shrubs							
<i>Daphne cannabina</i>	360.00	1666.00	80.00	36.00	20.75	47.06	103.81
<i>Prinsepia utilis</i>	360.00	5112.00	50.00	36.00	63.66	29.41	129.07
<i>Lonicera angustifolia</i>	240.00	1172.40	30.00	24.00	14.60	17.65	56.25
<i>Rosa macrophylla</i>	40.00	79.60	10.00	4.00	0.99	5.88	10.87
Total		8030					
Herbs							
<i>Adenocaulon bicolor</i>	3333.33	400.00	12.50	0.33	0.33	2.10	2.76
<i>Adiantum venustum</i>	44583.33	466.67	12.50	4.36	0.39	2.10	6.85
<i>Agrimonia eupatorium</i>	3750.00	962.50	12.50	0.37	0.81	2.10	3.27
<i>Dryopteris nigropoleacea</i>	20416.67	3916.67	16.67	2.00	3.28	2.80	8.07
<i>Arisaema intermedium</i>	10833.33	12108.33	33.33	1.06	10.13	5.59	16.78
<i>Bistorta amplexicaulis</i>	16250.00	1525.00	20.83	1.59	1.28	3.50	6.36
<i>Carpesium cernuum</i>	2916.67	433.33	8.33	0.29	0.36	1.40	2.05
<i>Cnicus argyreaanthus</i>	1250.00	829.17	4.17	0.12	0.69	0.70	1.52
<i>Cyperus aristatus</i>	393333.33	36916.67	75.00	38.45	30.88	12.59	81.92
<i>Dichanthium annulatum</i>	18750.00	733.33	12.50	1.83	0.61	2.10	4.54
<i>Fragaria vesca</i>	83333.33	4183.33	50.00	8.15	3.50	8.39	20.04
<i>Galium aparine</i>	96666.67	6995.83	54.17	9.45	5.85	9.09	24.39
<i>Geranium wallichianum</i>	21666.67	3583.33	41.67	2.12	3.00	6.99	12.11
<i>Hedera helix</i>	5416.67	700.00	16.67	0.53	0.59	2.80	3.91
<i>Onychium contiguum</i>	87500.00	7791.67	29.17	8.55	6.52	4.90	19.97
<i>Perotis latifolia</i>	67500.00	1866.67	37.50	6.60	1.56	6.29	14.45
<i>Prunella vulgaris</i>	10416.67	1295.83	29.17	1.02	1.08	4.90	7.00
<i>Rumax hastatus</i>	3750.00	2020.83	16.67	0.37	1.69	2.80	4.85
<i>Salvia glutinosa</i>	6666.67	5133.33	25.00	0.65	4.29	4.20	9.14
<i>Strobilanthes dalhousianus</i>	2916.67	266.67	8.33	0.29	0.22	1.40	1.91
<i>Trifolium pratense</i>	80000.00	4279.17	33.33	7.82	3.58	5.59	16.99
<i>Urtica dioica</i>	1250.00	529.17	4.17	0.12	0.44	0.70	1.26
<i>Viola spp.</i>	40416.67	22612.50	41.67	3.95	18.91	6.99	29.86
Total		119550					

D - Density
 F - Frequency
 RD - Relative density
 IVI - Importance value index

BA - Basal area
 RF - Relative frequency
 RBA - Relative basal area

Table 15. Floristic composition in Kotkhai forest range at an elevation of 2400-2700 m (PB-U)

Species	Average D/ha	BA/ha cm ²	% F	RD	RBA	RF	IVI
Trees							
<i>Picea smithiana</i>	125.00	69221.38	100.00	23.81	23.45	33.33	80.60
<i>Cedrus deodara</i>	275.00	182720.00	100.00	52.38	61.91	33.33	147.62
<i>Pinus wallichiana</i>	125.00	43206.50	100.00	23.81	14.64	33.33	71.78
Total		295147.88					
Shrubs							
<i>Berberis aristata</i>	80.00	159.20	20.00	4.88	4.53	9.52	18.93
<i>Cotoneaster microphylla</i>	800.00	2088.80	70.00	48.78	59.45	33.33	141.56
<i>Daphne cannabina</i>	40.00	156.00	10.00	2.44	4.44	4.76	11.64
<i>Lonicera angustifolia</i>	320.00	471.20	60.00	19.51	13.41	28.57	61.49
<i>Prinsepia utilis</i>	40.00	258.00	10.00	2.44	7.34	4.76	14.54
<i>Rosa macrophylla</i>	360.00	380.40	40.00	21.95	10.83	19.05	51.83
Total		3513.6	210				
Herbs							
<i>Adenocaulon bicolor</i>	9166.67	1400.00	33.33	1.22	1.70	5.00	7.92
<i>Adiantum venustum</i>	71666.67	608.33	20.83	9.53	0.74	3.13	13.40
<i>Agrimonia eupatorium</i>	3333.33	266.67	8.33	0.44	0.32	1.25	2.02
<i>Arisaema intermedium</i>	7500.00	2983.33	37.50	1.00	3.62	5.63	10.24
<i>Bistorta amplexiculis</i>	10833.33	1600.00	37.50	1.44	1.94	5.63	9.01
<i>Carpesium cernuum</i>	5000.00	1166.67	20.83	0.67	1.42	3.13	5.21
<i>Cyperus aristatus</i>	83750.00	3225.00	50.00	11.14	3.92	7.50	22.56
<i>Dichanthium annulatum</i>	33750.00	1529.17	25.00	4.49	1.86	3.75	10.10
<i>Dryopteris nigropaleacea</i>	30833.33	1791.67	20.83	4.10	2.18	3.13	9.40
<i>Fragaria vesca</i>	148750.00	12754.17	66.67	19.79	15.48	10.00	45.27
<i>Galium aparine</i>	95833.33	7950.00	62.50	12.75	9.65	9.38	31.78
<i>Geranium wallichianum</i>	4166.67	466.67	12.50	0.55	0.57	1.88	3.00
<i>Halenia elliptica</i>	13333.33	2270.83	37.50	1.77	2.76	5.63	10.16
<i>Hedera helix</i>	8333.33	941.67	33.33	1.11	1.14	5.00	7.25
<i>Onychium contiguum</i>	30833.33	2983.33	16.67	4.10	3.62	2.50	10.22
<i>Oxalis corniculata</i>	9583.33	133.33	4.17	1.27	0.16	0.63	2.06
<i>Perotis latifolia</i>	40416.67	1266.67	29.17	5.38	1.54	4.38	11.29
<i>Rumax nepalensis</i>	2083.33	929.17	16.67	0.28	1.13	2.50	3.91
<i>Salvia glutinosa</i>	6250.00	2945.83	20.83	0.83	3.58	3.13	7.53
<i>Selinum tenuifolium</i>	5833.33	833.33	20.83	0.78	1.01	3.13	4.91
<i>Trifolium pratense</i>	80416.67	6529.17	33.33	10.70	7.93	5.00	23.63
<i>Urtica dioica</i>	833.33	433.33	8.33	0.11	0.53	1.25	1.89
<i>Viola spp.</i>	46666.67	26229.17	41.67	6.21	31.84	6.25	44.30
Miscellaneous species	2500.00	1129.17	8.33	0.33	1.37	1.25	2.95
Total		82366.67					

D - Density
 F - Frequency
 RD - Relative density
 IVI - Importance value index

BA - Basal area
 RF - Relative frequency
 RBA - Relative basal area

Among shrub species, most dominant species was *Cotoneaster microphylla* having highest value (141.56) for IVI, followed by *Lonicera angustifolia* (61.49) and *Rosa macrophylla* (51.83). The total basal area for shrub species was recorded to be 3513.6 cm²/ha. In case of herbs total number of species recorded were 24, out of which *Fragaria vesca* showed highest value for relative density (19.79), relative frequency (10.00) and IVI (45.27) followed by *Viola spp.* with IVI value of 44.30, which showed maximum basal area 26229.17 cm²/ha out of the total 82366.67 cm²/ha to the tune of 31.84%

iii) Elevation Class 2700-3000 m

Phytosociological data given in table 16 for different plant species under elevation class 2700-3000m in PB-U for Kotkhai shows the dominance for *Abies pindrow* among six tree species with IVI value (140.22), basal area (185724.13 cm²/ha average density of 187.5/ha, whereas the minimum IVI of 18.56 was observed for *Quercus spp.* The total basal area of tree species was recorded to be 322868.75 cm²/ha.

The maximum IVI of 82.32 was recorded for *Viburnum cotinifolium* followed by *Berberis aristata* (69.17) and *Cotoneaster microphylla* (63.89). *Berberis aristata*, *Cotoneaster microphylla*, *Rosa macrophylla* recorded same value for average density i.e. 160 plants/ha. And minimum (14.83) IVI was recorded in case of *Sarcococca saligna*. Total basal area recorded for all species was 16572.80 cm²/ha, where *Viburnum cotinifolium* showed the maximum basal area contribution of 8118.00 cm²/ha. In case of herbs, 28 species were recorded, with maximum IVI of 71.22 accounted for *Trifolium pratense* due to high value for all the phytosociological parameters, followed by *Fragaria vesca* (54.24). The lowest IVI (0.91) was recorded for *Impatiens sulcata*.

4.1.4 SIMILARITY INDEX

4.14a BASHLA FOREST RANGE

The data of number of species present in different elevations was used to find similarity among of trees, shrubs and herbs separately (Table-17). The similarity in vegetation calculated in percent was found to be 66.67% between lowest and the middle elevation class and the middle and the highest elevation class, while the

similarity between lowest and highest elevation class was 61.54% in case of trees. In shrubs maximum similarity (95.24%) was between lowest and middle elevation class followed by middle and highest elevation class (75%), whereas it was minimum (70.59%) between lowest and highest elevation class. And in herbs maximum similarity was between lowest and middle elevation class followed by lowest and highest elevation class and then middle and highest elevation class i.e. 66.67, 64.41 and 63.49 per cent, respectively in Bashla forest range.

4.1.4b JUBBAL FOREST RANGE

In Jubbal forest range (Table-18) similarity for trees was equal in all elevation classes i.e. 66.67%, while in case of shrubs maximum similarity (76.92) was observed between middle and highest elevation class followed by lowest and middle elevation class (70.59%) and least in lowest x highest elevation class (66.67%). In case of herbs, the similarity of species between elevation classes was very narrowly different, which varied between 65.22 to 69.39 per cent.

4.1.4c KOTKHAI FOREST RANGE

The data in table-19 referring to Kotkhai range shows that maximum similarity in trees was found in elevation class 2400-2700m and 2700-3000 m followed by 2100-2400 x 2400-2700m and then 2100-2400 m and 2700-3000 m elevation class with respective values of 92.13, 83.33 and 72.73 per cent. In case of shrubs highest species similarity (92.31%) was found between 2100-2400 m x 2400-2700 m elevation class followed by 2400-2700m x 2700-3000 m elevation class (76.92%) and then by 2100-2400 m x 2700-3000 m elevation class (66.67%), whereas in case of herbs maximum similarity (85.71) was found between middle and highest elevation class followed by lowest and highest and then by lowest and middle elevation class with similarity of 80.70 and 79.31, respectively.

4.1.5 SHANNON'S INDEX FOR DIVERSITY

4.1.5a BASHLA FOREST RANGE

To show the species richness the Shannon's diversity index was calculated from IVI value separately on the basis of elevation class for trees shrubs and herbs

Table 16. Floristic composition in Kotkhai forest range at an elevation of 2700-3000 m (PB-U)

Species	Average D/ha	BA/ha cm ²	% F	RD	RBA	RF	IVI
Trees							
<i>Abies pindrow</i>	187.50	185724.13	100.00	57.69	57.52	25.00	140.22
<i>Picea smithiana</i>	37.50	26299.38	100.00	11.54	8.15	25.00	44.68
<i>Quercus spp.</i>	12.50	7153.38	50.00	3.85	2.22	12.50	18.56
<i>Taxus baccata</i>	50.00	38062.88	50.00	15.38	11.79	12.50	39.67
<i>Juglans regia</i>	12.50	9429.88	50.00	3.85	2.92	12.50	19.27
<i>Pinus wallichiana</i>	25.00	56199.13	50.00	7.69	17.41	12.50	37.60
Total		322868.75					
Shrubs							
<i>Berberis aristata</i>	160.00	3637.20	30.00	22.22	21.95	25.00	69.17
<i>Cotoneaster microphylla</i>	160.00	4143.20	20.00	22.22	25.00	16.67	63.89
<i>Lonicera angustifolia</i>	80.00	164.80	10.00	11.11	0.99	8.33	20.44
<i>Rosa macrophylla</i>	160.00	353.60	30.00	22.22	2.13	25.00	49.36
<i>Sarcococca saligna</i>	40.00	156.00	10.00	5.56	0.94	8.33	14.83
<i>Viburnum cotinifolium</i>	120.00	8118.00	20.00	16.67	48.98	16.67	82.32
Total		16572.8					

(Contd....)

Species	Average D/ha	BA/ha cm ²	% F	RD	RBA	RF	IVI
<i>Adenocaulon bicolor</i>	1250.00	133.33	4.17	0.15	0.12	0.74	1.01
<i>Adiantum venustum</i>	37083.33	308.33	8.33	4.49	0.28	1.47	6.23
<i>Anemone rivularis</i>	6250.00	1691.67	20.83	0.76	1.51	3.68	5.95
<i>Selinum tenuifolium</i>	3333.33	333.33	8.33	0.40	0.30	1.47	2.17
<i>Dryopteris nigropaleacea</i>	21250.00	4462.50	20.83	2.57	3.99	3.68	10.24
<i>Arisaema intermedium</i>	5416.67	4041.67	12.50	0.66	3.62	2.21	6.48
<i>Bistorta amplexicaulis</i>	2083.33	733.33	12.50	0.25	0.66	2.21	3.11
<i>Carpesium cernuum</i>	7083.33	2820.83	8.33	0.86	2.52	1.47	4.85
<i>Cnicus argyraeanthus</i>	1666.67	1925.00	8.33	0.20	1.72	1.47	3.39
<i>Cyperus aristatus</i>	20000.00	1129.17	12.50	2.42	1.01	2.21	5.64
<i>Dichanthium annulatum</i>	17916.67	600.00	8.33	2.17	0.54	1.47	4.18
<i>Elsholtzia flava</i>	11666.67	6283.33	12.50	1.41	5.62	2.21	9.24
<i>Fragaria vesca</i>	197916.67	17420.83	83.33	23.95	15.58	14.71	54.24
<i>Galium aparine</i>	95833.33	7075.00	54.17	11.60	6.33	9.56	27.49
<i>Geranium wallichianum</i>	6250.00	1200.00	16.67	0.76	1.07	2.94	4.77
<i>Halenia elliptica</i>	12916.67	1495.83	29.17	1.56	1.34	5.15	8.05
<i>Hedera helix</i>	5000.00	866.67	16.67	0.61	0.78	2.94	4.32
<i>Impatiens sulcata</i>	416.67	133.33	4.17	0.05	0.12	0.74	0.91
<i>Onychium contignum</i>	29166.67	2416.67	8.33	3.53	2.16	1.47	7.16
<i>Oxalis corniculata</i>	27500.00	1341.67	8.33	3.33	1.20	1.47	6.00
<i>Prunella vulgaris</i>	11250.00	1995.83	29.17	1.36	1.79	5.15	8.29
<i>Rumax hastatus</i>	5833.33	2391.67	25.00	0.71	2.14	4.41	7.26
<i>Salvia glutinosa</i>	8333.33	4604.17	25.00	1.01	4.12	4.41	9.54
<i>Senecio chrysanthemoides</i>	1250.00	829.17	4.17	0.15	0.74	0.74	1.63
<i>Trifolium pratense</i>	261666.67	30237.50	70.83	31.67	27.05	12.50	71.22
<i>Urtica dioica</i>	2916.67	829.17	8.33	0.35	0.74	1.47	2.57
<i>Viola spp.</i>	24583.33	14183.33	41.67	2.98	12.69	7.35	23.02
Miscellaneous	416.67	300.00	4.17	0.05	0.27	0.74	1.05
Total		111783.33					

D - Density
F - Frequency
RD - Relative density
IVI - Importance value index

BA - Basal area
RF - Relative frequency
RBA - Relative basal area

Table 17. Similarity index for trees, shrubs and herbs between different elevations in Bashla forest range

Similarity Dissimilarity		2100-2400 m	2400-2700 m	2700-3000 m
		Trees	2100-2400 m	-
2400-2700 m	33.33		-	66.67
2700-3000 m	38.46		33.33	-
Shrubs	2100-2400 m	-	95.24	70.59
	2400-2700 m	4.76	-	75.00
	2700-3000 m	29.41	25.00	-
Herbs	2100-2400 m	-	66.67	64.41
	2400-2700 m	33.33	-	63.49
	2700-3000 m	35.59	36.51	-

Table 18. Similarity index for trees, shrubs and herbs between different elevations in Jubbal forest range

Similarity Dissimilarity		2100-2400 m	2400-2700 m	2700-3000 m
		Trees	2100-2400 m	-
2400-2700 m	33.33		-	66.67
2700-3000 m	33.33		33.33	-
Shrubs	2100-2400 m	-	70.59	66.67
	2400-2700 m	29.41	-	76.92
	2700-3000 m	33.33	23.08	-
Herbs	2100-2400 m	-	69.39	65.22
	2400-2700 m	30.61	-	69.09
	2700-3000 m	34.78	30.91	-

Table 19. Similarity index for trees, shrubs and herbs between different elevations in Kotkhai forest range

Similarity Dissimilarity		2100-2400 m	2400-2700 m	2700-3000 m
		Trees	2100-2400 m	-
2400-2700 m	16.67		-	92.31
2700-3000 m	27.27		7.69	-
Shrubs	2100-2400 m	-	92.31	66.67
	2400-2700 m	7.69	-	76.92
	2700-3000 m	33.33	23.08	-
Herbs	2100-2400 m	-	79.31	80.70
	2400-2700 m	20.69	-	85.71
	2700-3000 m	19.30	14.29	-

(Table-20). Data in the table indicate maximum diversity for trees (0.74) and shrubs (0.96) in elevation class 2100-2400 m while for herbs maximum diversity (1.25) was found in elevation class 2700-3000 m. The minimum diversity for trees (0.42) and shrubs (0.61) was recorded in elevation class 2700-3000 m, whereas for herbs (1.18) in middle elevation class in Bashla forest range.

4.1.5b JUBBAL FOREST RANGE

In Jubbal under PB-I and PB-U (Table-21) maximum diversity of 0.65 and 0.49, respectively was found in elevation class 2400-2700 m, whereas minimum for PB-I (0.17) and PB-U (0.36) was at an elevation of 2700-3000 m. The maximum diversity index value for shrubs were 0.73 and 0.83 at 2100-2400 m elevation under PB-I and PB-U, whereas, the maximum value of 0.67 and 0.45 were obtained for PB-I and PB-U at 2700-3000 m elevation. The maximum diversity for herbs was recorded in 2400-2700 m elevation class i.e. 1.23 for both the periodic blocks.

4.1.5c KOTKHAI FOREST RANGE

In Kotkhai maximum diversity for trees was observed in middle elevation class for PB-I (0.78) followed by PB-U (0.66) highest elevation, however the lowest diversity value of 0.28 at 2700-3000m elevation and 0.34 at 2100-2400m elevation in PB-I and PB-U was observed, respectively (Table-22). In case of shrubs, maximum diversity in PB-U (0.72) was at an elevation of 2700-3000 m with minimum (0.51) in lowest elevation (2100-2400 m) class. In PB-I maximum value was 0.66 in highest elevation class, while minimum was 0.23 in middle elevation class. For herbs, maximum (1.22) value for diversity was recorded in PB-U in 2400-2700 m elevation class and minimum (0.99) in PB-I for highest elevation class.

4.2 STAND CHARACTERISTICS

4.2.1 BASHLA FOREST RANGE

The growing stock studies in Bashla showed trees of different diameter classes ranging from 10–20 cm to 100 cm and above of fir and spruce in different elevation classes (Table-23). The average dbh and height showed increasing trend

from 14.35-83.00 cm and 16-40 m at 2100-2400 m elevation class, where the diameter classes 40-50 cm 50-60 cm and 70-80 cm were missing. Maximum average number of trees (125/ha) was found in lowest (10-20 cm) diameter class, whereas, minimum (8.33/ha) were found in 30-40 cm and 60-70 cm diameter classes. The maximum basal area (9.02 m²/ha) and volume (170.0 m³/ha) was found in 80-90 cm diameter class, Average crown width was maximum (6.4 m) in 80-90 cm, with maximum total crown cover (16.94 %) in 10-20 cm diameter class.

In middle elevation class (2400-2700 m) the maximum number of trees (91.67/ha) was recorded in 10-20 cm diameter class, but maximum basal area (24.15 m²/ha) and volume (182.00 m³/ha) in diameter class 100 cm and above, which also recorded maximum average crown width (7.78 m). Total crown percentage of fir and spruce was 40.71% out of which maximum (10.07) was of 10-20 diameter class trees (Table-23). The trees from 50-90 cm diameter classes (four classes) were not available in the forest. In the elevation class 2700-3000 m, average number of 16.67/ha trees were available from 20-30 cm to 8.33/ha in 80-90 cm diameter class, with maximum number of 50 trees/ha in diameter class 30-40 cm and 40-50 cm. Maximum basal area 14.35 m² for diameter class 60-70 cm with total volume 229.17 m³/ ha. Average crown width was maximum 11.25m in highest diameter class i.e. 80-90 cm. The total area of the ground covered by the crowns of fir and spruce was 87.92 % out of which 25.63 % was contributed by 60-70 cm diameter class trees.

4.2.2 JUBBAL FOREST RANGE

4.2.2a PB-I

The stand characteristic in Jubbal forest range for PB-I area are presented in table 24 indicates that in elevation class 2100-2400m, the maximum number of trees (62.5/ha) was recorded in 10-20cm diameter class. However, the highest total basal area (6.04 m²/ ha) and total volume (65.85 m³/ ha) for 40-50 cm diameter class. The average crown width was maximum (6.05 m) for 50-60 cm diameter class. Fir and spruce covered 39.11% of the ground area with the maximum coverage of 10.56 % by 40-50 cm diameter class.

Table 20. Shannon diversity index (\bar{H}) values for different components in Bashla forest range at different elevations

Component	Elevation (m)		
	2100-2400	2400-2700	2700-3000
Trees	0.74	0.55	0.42
Shrubs	0.96	0.76	0.61
Herbs	1.24	1.18	1.25

Table 21. Shannon diversity index (\bar{H}) values for different components in Jubbal forest range at different elevations

Component	Elevation (m)					
	2100-2400		2400-2700		2700-3000	
	PB-I	PB-U	PB-I	PB-U	PB-I	PB-U
Trees	0.46	0.45	0.49	0.65	0.36	0.17
Shrubs	0.73	0.83	0.69	0.47	0.67	0.45
Herbs	1.11	1.10	1.23	1.23	1.11	1.19

Table 22. Shannon diversity index (\bar{H}) values for different component in Kotkhai forest range at different elevations

Component	Elevation (m)					
	2100-2400		2400-2700		2700-3000	
	PB-I	PB-U	PB-I	PB-U	PB-I	PB-U
Trees	0.61	0.34	0.78	0.45	0.28	0.66
Shrubs	0.63	0.51	0.23	0.62	0.66	0.72
Herbs	1.17	1.13	1.10	1.22	0.99	1.16

Table 23. Class-wise average diameter effect on basal area, total standing volume, crown width and crown area of fir and spruce at different elevations in Bashla forest range

Diameter class (cm)	Average dbh (cm)	Height (m)	No. of trees/ha	Total BA/ha (m ²)	Total Vol./ha (m ³)	Average crown width (m)	Total Crown Cover (%)
Elevation-2100-2400 m							
10-20.	14.35	16.00	125.00	2.07	10.00	4.03	16.94
20-30	23.75	25.00	33.33	1.49	10.00	5.05	7.16
30-40	36.00	23.00	8.33	0.85	6.00	3.75	0.92
60-70	61.00	32.00	8.33	2.44	41.00	5.70	2.13
80-90	83.00	40.00	16.67	9.02	170.00	6.40	5.36
Total			191.67	15.87	237.00		32.51
Elevation-2400-2700 m							
10-20.	15.12	13.00	91.67	1.73	7.67	3.65	10.07
20-30	26.75	20.50	33.33	1.89	10.33	4.53	5.46
30-40	38.00	21.00	16.67	1.89	12.00	6.43	5.41
40-50	45.50	23.00	33.33	5.43	53.17	5.73	8.64
90-100	91.00	41.00	8.33	5.42	107.08	7.00	3.21
100+	135.00	49.00	16.67	24.15	182.00	7.78	7.92
Total			200.00	40.51	372.25		40.71
Elevation-2700-3000 m							
20-30	24.50	18.0	16.67	0.79	5.33	4.88	3.11
30-40	33.10	16.0	50.00	4.32	35.17	5.62	12.53
40-50	43.33	25.0	50.00	7.40	79.00	6.30	15.63
50-60	52.50	25.0	16.67	3.61	50.33	7.88	8.12
60-70	66.20	31.0	41.67	14.35	229.17	8.80	25.63
70-80	75.00	32.0	25.00	11.07	182.50	8.54	14.62
80-90	88.00	39.0	8.33	5.07	77.92	11.25	8.28
Total			208.33	46.61	659.42		87.92

Table 24. Class-wise average diameter effect on basal area, total standing volume, crown width and crown area of fir and spruce in Jubbal forest range at different elevations in PB-1

Diameter class (cm)	Average dbh (cm)	Height (m)	No. of trees/ha	Total BA/ha (m ²)	Total Vol./ha (m ³)	Average crown width (m)	Crown cover (%)
Elevation-2100-2400 m							
10-20.	15.39	11.40	62.50	1.19	6.63	3.85	7.35
20-30	23.83	20.33	37.50	1.69	13.69	5.47	8.87
30-40	34.16	22.67	37.50	3.49	34.43	5.42	8.74
40-50	45.16	23.67	37.50	6.04	65.85	5.98	10.56
50-60	53.00	26.00	12.50	2.76	36.23	6.05	3.59
Total			187.50	15.17	156.83		39.11
Elevation- 2400-2700 m							
10-20.	13.83	10.73	175.00	2.7125	20.16	3.97	19.13
20-30	23.08	17.40	62.50	2.69	22.81	5.39	14.64
30-40	36.00	16.00	12.50	1.28	11.48	5.25	2.71
Total			250.00	6.6750	54.45		36.48
Elevation- 2700-3000 m							
10-20.	16.47	13.13	187.50	3.94	44.06	4.04	24.91
20-30	24.18	15.40	187.50	9.38	94.94	4.86	33.95
30-40	33.17	21.00	87.50	7.66	93.30	5.22	19.97
40-50	44.58	26.67	75.00	11.78	131.93	5.61	18.77
60-70	60.17	27.33	37.50	10.65	162.53	7.60	17.19
Total			575.00	43.41	526.75		114.79

In elevation class 2400-2700 m fir and spruce trees of only three diameter classes (10-20 cm to 30-40 cm) were present with maximum number of trees (175/ha) in lowest (10-20 cm) diameter class (Table-24). The maximum basal area (2.71 m²/ha) and volume (22.81 m³/ha) was recorded in diameter class 10-20 cm and 20-30 cm, respectively. The average crown width was maximum 5.39 m in 20-30 cm diameter class. The total crown cover of fir and spruce was 36.48 % with maximum contribution of 19.13% by 10-20 cm diameter class. In highest elevation class (2700-3000m), the trees of 10-20 cm to 60-70cm diameter classes were available except one diameter class i.e. 50-60 cm. The equal and highest number of trees (187.50/ha) were found in 10-20 cm and 20-30 cm diameter classes. The maximum basal area (11.78 m²/ha) and maximum volume (162.53 m³/ha) was recorded in diameter class 40-50 cm and 60-70 cm, respectively. The maximum average crown width (7.60 m) was in 60-70 cm diameter class. The total percentage crown cover of fir and spruce was (114.79%) with maximum contribution 33.95 % by 20-30 cm diameter class.

4.2.2b PB-U (Unallotted)

In PB-U (Table-25) in Jubbal forest range the average dbh and average height showed increasing trend with increasing diameter class. In lowest elevation class (2100-2400m) maximum number of trees (150/ha) was found in diameter class 20-30 cm, although maximum basal area and total volume 8.30 m²/ha and 91.80 m³/ha, respectively was found in 30-40 cm diameter class. The average crown width showed increasing trend from 4.58m to 5.78 m with increase in diameter class. The percentage crown cover for fir and spruce was maximum (33.12%) in 20-30 cm diameter class out of the total coverage of 74.14 per cent.

In second elevation class (2400-2700 m) the trees of fir and spruce were present in three diameter classes i.e. 20-30 cm, 30-40 cm and 70-80 cm. Out of the total 87.50 tree/ha of fir and spruce equal number (37.50/ha) were of 20-30 cm and 30-40 cm diameter classes. Out of the total basal area of 12.46 m²/ha and volume of (123.91 m³/ha) the maximum contribution of 6.13 m²/ha and 75.80 m³/ha was from

70-80 cm diameter class. The maximum average crown width of 9.35 m and out of the total crown cover of 35.24% of fir and 14.26% of spruce contributed to 30-40 cm diameter class.

The data represented in table 25 for highest elevation class indicates the presence of 8-diameter classes from 10-20 cm to 80-90 cm with variable number of trees in each diameter class. Highest number of 125 trees followed by 112.5 and 87.5 per hectare were recorded in 50-60 cm, 10-20 cm and 20-30 cm diameter class, respectively. However, the basal area was maximum 29.13 followed by 26.87 in 50-60 cm and 70-80 cm diameter class. These two-diameter classes as contributed 27.29% and 20.46% crown cover to the total crown coverage value of 106.12% of the area.

4.2.3 KOTKHAI FOREST RANGE

4.2.3a PB-I

The trees of fir and spruce were represented in 3, 4 and 5 diameter classes in lowest, middle and highest elevation classes respectively. The growing stock studies of PB-I areas in Kotkhai range revealed that in the lowest elevation class (2100-2400 m) fir and spruce trees were present in three diameter classes i.e. 10-20 cm, 20-30 cm and 60-70 cm. Among these diameter classes equal number of 25 trees/ha were found in 10-20 cm and 60-70 cm diameter classes, with minimum of 12.5/ha in 20-30 cm diameter class. Out of the total basal area (8.79 m²/ha) and total volume (115.56 m³/ha), maximum 7.80 m²/ha and 108.35 m³/ha, respectively was the share of 60-70 cm diameter class. There was increase in average crown width per tree from 4.05 m to 6.40 m with increase in diameter class. The total crown cover percentage of fir and spruce was 14.35% with maximum 8.43% by 60-70 cm diameter class.

In second elevation class (2400-2700 m) the maximum number of trees (112.50/ha) was recorded for 20-30 cm diameter class, this diameter class also recorded maximum basal area of 5.06 m²/ha, volume of 61.55 m³/ha and 15.21 %

Table 25. Class-wise average diameter effect on basal area, total standing volume, crown width and crown area of fir and spruce in Jubbal forest range at different elevations in PB-U

Diameter class (cm)	Average dbh (cm)	Height (m)	No. of trees/ha	Total BA/ha (m ²)	Total Vol./ha (m ³)	Average crown width (m)	Crown cover (%)
Elevation-2100-2400 m							
10-20.	17.21	14.00	87.50	2.06	9.28	4.58	14.65
20-30	24.71	20.08	150.00	7.50	54.75	5.25	33.12
30-40	32.44	21.88	100.00	8.30	91.80	5.78	26.36
Total			337.50	17.86	128.45		74.14
Elevation-2400-2700 m							
20-30	28.17	19.67	37.50	2.36	13.69	6.48	12.40
30-40	36.67	24.00	37.50	3.98	34.43	6.90	14.26
70-80	79.00	32.00	12.50	6.13	75.80	9.35	8.58
Total			87.50	12.46	123.91		35.24
Elevation-2700-3000 m							
10-20.	15.00	14.67	112.50	1.5200	26.44	3.47	11.15
20-30	25.29	20.00	87.50	4.3700	50.49	4.37	13.75
30-40	34.00	26.33	37.50	3.410	40.91	4.85	7.11
40-50	43.42	30.00	75.00	11.170	131.93	5.41	17.45
50-60	54.44	34.94	125	29.13	331.54	6.11	27.29
60-70	61.50	32.50	25.00	7.420	91.28	5.15	5.21
70-80	74.00	33.60	62.50	26.870	303.06	6.39	20.46
80-90	83.00	33.00	12.50	6.760	68.89	6.15	3.71
Total			537.50	90.65	1044.53		106.12

crown cover, however, maximum average crown width (6.65 m) was found in 40-50 cm diameter class out of the total crown cover of 24.74% for fir and spruce trees.

Similarly in highest elevation class in table 26 out of the total 287.5 trees/ha maximum number of trees (125/ha) was found in 20-30 cm diameter class, although maximum basal area 8.49 m²/ha and volume 95.46 m³/ha was found in 30-40 cm diameter class. The maximum crown width (7.80 m) was recorded for highest (50-60 cm) diameter class. The percentage crown cover of fir and spruce for this elevation was 52.58%, and the maximum contribution was 18.47% by 20-30 cm followed by 15.43% of 30-40 cm diameter class.

4.2.3b PB-U (Unallotted)

Table-27 represents the data pertaining to growing stock in Kotkhai forest range for three elevation classes. From the table it can be seen that in lowest elevation class (2100-2400 m) fir and spruce was found only in one diameter class i.e. 10-20 cm, with total basal area of 0.15 m²/ha, volume of 1.33 m³/ha and percentage crown cover of 1.04. The trees of higher diameter classes were absent. As we move to higher elevation classes, the number of diameter classes containing trees of fir and spruce also increased. In elevation class 2400-2700 m three diameter classes of 10-20 cm, 20-30 cm and 40-50 cm were found. Out of the total 125 trees/ha of fir and spruce maximum 75 trees/ha were of 20-30 cm diameter class. The maximum basal area (3.55 m²/ha) and total volume (43.90 m³/ha) was found in 40-50cm diameter class. The percentage crown cover of fir and spruce for the area was 31.54, with maximum (21.10%) share of 20-30 cm diameter class.

In the elevation class 2700-3000 m there were 5 diameter classes. Out of the total 225 tree/ha the maximum number of trees (62.50/ha) were present in two diameter classes i.e. 10-20 cm and 40-50 cm. The diameter class 40-50 cm also recorded maximum total basal area (9.09 m²/ha) and total volume (109.90 m³/ha). The average crown width was maximum (5.81m) in 20-30 cm. The total crown

cover of fir and spruce was 47.97% in this elevation out of which 40-50 cm diameter class trees contributed 14.50% of the crown area (Table-27).

On the basis of projected age through regression equations developed for *Abies pindrow* Bashla ($y = 21.03 + 1.47x$), Jubbal ($y = 9.67 + 2.47x$) and Kotkhai ($y = 36.09 + 1.10x$), whereas, for *Picea smithiana*, Bashla ($y = 21.56 + 1.30x$), Jubbal ($y = 8.21 + 1.73x$) and Kotkhai ($y = 18.47 + 1.20x$) it was found that diameter growth of fir was slow in Kotkhai followed by Jubbal and Bashla in the initial stage. However, the time taken to reach the diameter girth of 90-100 cm was in the order of Jubbal > Bashla > Kotkhai. The age was almost equal in the diameter class of 40 – 50 cm in Bashla and Kotkhai, whereas for spruce the results indicated that the growth was similar in order except in Bashla where lowest diameter class took maximum time as compared to Kotkhai and Jubbal. It was also observed that fir took more time than spruce to achieve the same diameter growth (Appendix I).

4.3 SITE FACTORS

The impact of different forest conditions like soil pH, depth of organic matter, solar radiation, crown cover of fir-spruce and its associates as well as crown projection ratio on regeneration of fir and spruce and their associate species was studied for Bashla, Jubbal and Kotkhai forest ranges of Himachal Pradesh and results are as under.

4.3.1 BASHLA FOREST RANGE

From table-28 it can be revealed that maximum stocking per cent for fir and spruce and for other species was found in elevation class 2400-2700 m, where the pH value was 6.43 slightly acidic then other two elevation classes, the depth of organic matter was also minimum (3.5 cm), whereas, the solar radiation of 12.34% and 59.84% crown cover value of the middle class was in between the values of other two elevation classes. The crown projection ratio of 16.42 and 27.74 for fir & spruce and for the associated species was recorded, whereas minimum regeneration was found at highest elevation class, where pH was less acidic, the depth of organic matter was maximum (8.00 cm). The percentage solar radiation value under canopy

Table 26. Class-wise average diameter effect on basal area, total standing volume, crown width and crown area of fir and spruce in Kotkhai at different elevations in PB-1

Diameter class (cm)	Average dbh (cm)	Height (m)	No. of trees/ha	Total BA/ha (m ²)	Total Vol./ha (m ³)	Average crown width (m)	Crown cover (%)
Elevation-2100-2400 m							
10-20.	16.50	14.00	25.00	0.55	2.65	4.05	3.32
20-30	21.00	17.00	12.50	0.44	4.56	5.15	2.60
60-70	63.00	27.00	25.00	7.80	108.35	6.40	8.43
Total			62.50	8.79	115.56		14.35
Elevation-2400-2700 m							
10-20.	14.50	9.00	25.00	0.42	5.88	3.35	2.24
20-30	24.38	17.00	112.50	5.06	61.55	4.27	15.21
30-40	32.50	22.00	25.00	2.08	27.28	3.88	2.95
40-50	45.00	24.00	12.50	1.99	21.95	6.65	4.34
Total			175.00	9.54	116.65		24.74
Elevation-2700-3000 m							
10-20.	14.00	9.00	12.50	0.19	2.94	3.65	1.31
20-30	25.00	17.20	125.00	6.25	72.13	4.27	18.47
30-40	35.00	24.57	87.50	8.49	95.46	4.71	15.43
40-50	45.63	27.25	50.00	8.20	87.95	5.31	11.40
50-60	57.00	25.00	12.50	3.19	32.81	7.80	5.97
Total			287.50	26.31	291.29		52.58

Table 27. Class-wise average diameter effect on basal area, total standing volume, crown width and crown area of fir and spruce in Kotkhai at different elevations in PB-U

Diameter class (cm)	Average dbh (cm)	Height (m)	No. of trees/ha	Total BA/ha (m ²)	Total Vol./ha (m ³)	Average crown width (m)	Crown cover (%)
Elevation-2100-2400 m							
10-20.	12.10	18.00	12.50	0.15	1.33	3.25	1.04
Elevation-2400-2700							
10-20.	14.25	11.00	25.00	0.40	2.65	4.30	3.64
20-30	22.28	18.33	75.00	3.00	27.38	5.97	21.10
40-50	42.50	28.00	25.00	3.55	43.90	5.75	6.80
Total			125.00	6.95	73.93		31.54
Elevation-2700-3000 m							
10-20.	13.56	10.00	62.50	0.94	13.08	4.29	9.16
20-30	27.07	19.17	50.00	2.93	26.20	5.81	13.29
30-40	36.63	20.33	37.50	3.98	40.91	5.37	8.52
40-50	42.89	20.00	62.50	9.09	109.90	5.38	14.50
50-60	62.50	21.00	12.50	3.84	32.81	5.05	2.50
Total			225.00	20.78	222.90		47.97

Table 28. Effect of site conditions on the regeneration at different elevations in Bashla forest range

Elevation class	Established Stocking percent		pH	Organic matter layer (cm)	Solar radiation (Lux)		Under canopy Solar Radiation (%)	Crown cover (%)	Crown Projection ratio (b/d)	
	Fir & Spruce	Associated species			Outside canopy	Under canopy			Fir & Spruce	Associated species
2100-2400	20.87	6.35	6.54	5.33	6750.00	703.18	10.34	58.02	24.84	20.64
2400-2700	22.00	11.11	6.43	3.50	7050.00	869.14	12.34	59.84	16.42	27.74
2700-3000	0.00	1.19	6.57	8.00	7353.30	1257.22	17.13	103.01	19.39	21.24

Table 29. Effect of site conditions on the regeneration at different elevations in Jubbal forest range

Elevation class	Established Stocking percent		pH	Organic matter layer (cm)	Solar radiation (Lux)		Under canopy Solar Radiation (%)	Crown cover (%)	Crown projection ratio (b/d)	
	Fir & Spruce	Associated species			Outside canopy	Under canopy			Fir & Spruce	Associated species
PB-I										
2100-2400	3.38	25.63	6.58	4.25	6820.00	689.50	10.09	143.14	19.20	22.56
2400-2700	29.75	5.56	6.50	5.75	6890.00	750.67	10.83	105.10	28.52	21.73
2700-3000	8.23	0.00	6.12	8.75	6660.00	515.00	7.74	119.304	18.80	20.04
PB-U										
2100-2400	9.23	27.76	6.55	4.75	6250.00	649.00	10.44	104.97	21.20	24.40
2400-2700	9.60	5.17	6.39	6.00	6730.00	835.00	11.83	107.47	19.42	22.31
2700-3000	0.00	0.00	6.43	11.50	6635.00	529.17	7.89	106.12	13.59	-

Table 30. Effect of site conditions on the regeneration at different elevations in Kotkhai forest range

Elevation class	Established Stocking percent		pH	Organic matter layer (cm)	Solar radiation (lux)		Under canopy Solar Radiation (%)	Crown cover (%)	Crown projection ratio (b/d)	
	Fir & Spruce	Associated species			Outside canopy	Under canopy			Fir & Spruce	Associated species
PB-1										
2100-2400	0.45	1.46	6.18	5.25	6610.00	494.00	7.49	43.59	17.53	24.33
2400-2700	0.85	11.11	6.48	4.75	6775.00	557.86	8.20	53.59	16.77	15.77
2700-3000	3.76	1.29	6.30	9.25	7615.00	873.25	11.5	66.67	15.35	12.57
PB-U										
2100-2400	5.56	4.81	6.36	3.75	6745.00	604.09	8.85	153.63	26.86	12.26
2400-2700	0.72	32.87	6.51	5.75	6765.00	668.88	9.94	113.76	25.37	25.86
2700-3000	4.24	1.56	6.65	7.25	7400.00	810.73	11.00	67.49	19.57	13.39

was minimum of 10.34, with minimum crown cover of 58.02%. However, outside canopy and under canopy the solar radiation increased with increase in the elevation from 6750 to 7353.30 and 703.18 to 1257.22 lux, respectively. The crown projection ratio recorded for fir and spruce and for their associates species was 19.39 and 21.24, respectively.

4.3.2 JUBBAL FOREST RANGE

In Jubbal forest range maximum regeneration 29.75% of fir and spruce was recorded in PB-I at an elevation of 2400-2700 m, where the pH value was 6.5 (Table-29). The percentage solar radiation under storey was 10.83 and crown cover of 105.10%, the crown projection was maximum (28.52) for fir & spruce and second highest (21.71) for the associate species, while the established regeneration for other species was only 5.56%. The minimum (3.38%) established regeneration of fir and spruce was found in elevation class 2100-2400 m, whereas the value for the other species was maximum (25.63%). In lowest elevation class pH and depth of organic matter was 6.58 and 4.25 cm, respectively. Whereas, the solar radiation was 10.09% with 143.14% crown cover. The total solar radiation in open was 6820, 6890 and 6660 lux, whereas under canopy the values were 689.5, 750.67 and 575.0 lux at lower, middle and highest elevation, respectively. The crown projection ratio was 19.2 for fir & spruce, while for other species value of 22.56 was recorded slightly higher to other elevations. The established regeneration of fir and spruce in PB-U (Table-29) was maximum (9.60) in 2400-2700 m, which was almost equal (9.23) in 2100-2400 m elevation class, however, regeneration was totally absent in 2700-3000 m elevation class.

The maximum regeneration of the species other than fir and spruce was in lowest elevation class. The pH value was 6.55 and 6.39 in lowest and in middle elevation class, where the depth of organic matter was 11.5 cm at 2700-3000m elevation followed by 6.0 cm and 4.75 cm in middle and the lower most elevation, respectively. Solar radiation, crown cover, crown projection ratio for fir and spruce, as well as for other species, was nearly equal in lower and middle elevation classes. The elevation 2700-3000 m was devoid of regeneration of any kind, where

maximum presence of fir and spruce was recorded (Table-25). The solar radiation outside the canopy was maximum (6730lux) in 2400-2700 m elevation followed by highest and lowest elevations with values of 6635.0 and 6250.0 lux, respectively. The values under canopy varied from 529.17 to 835.0 lux in highest and middle elevation class, however, it was in between (649.0 lux) in lowest elevation class.

4.3.3 KOTKHAI FOREST RANGE

The data given in table-30 pertaining to regeneration in Kotkhai forest range revealed that in middle elevation, maximum 11.11 and 32.87% established stocking was observed for species other than fir and spruce in PB-I and PB-U, respectively. The maximum established regeneration of fir and spruce was obtained in PB-U at lowest elevation with value of 5.56%. The pH value was acidic throughout the distribution. The depth of organic matter was maximum 9.25 and 7.25 cm in highest elevation (2700-3000 m) in both PB-I and PB-U, respectively. The under canopy solar radiation was lowest in 2100-2400 m elevation class and increased with increase in elevation from 7.49 to 11.50% in PB-I and 8.85 to 11.00% in PB-U. However, the crown cover was more in unallotted as compared to PB-I. Whereas the crown projection ratio was 16.77 and 15.77 in PB-I and 25.37 and 25.86 in PB-U for fir and spruce and other associates, respectively. The solar radiation outside the canopy increased with increase in elevation with value 6610.0, 6775.0 and 7615.0 lux. Whereas, under canopy values were 494.0, 557.86 and 873.25 lux for lowest, middle and highest elevation in PB-I. The trend for PB-U remained same where the solar radiation under canopy varied from 604.09 to 810.73 and outside canopy 6745.0 to 7400.0 lux in lower to highest elevation class. In general for all the sites the regeneration status showed increasing trend with increase in crown projection ratio for fir and spruce as well as for associated species.

4.4 REGENERATION STUDIES

4.4A Regeneration Components

In the present investigation regeneration studies were carried out on recruits, unestablished and established regeneration in three sites viz., Bashla and Jubbal

forest range (Rohru forest division) and Kotkhai forest range (Theog forest division) at three different elevation classes and available periodic blocks.

4.4A.1 BASHLA FOREST RANGE

Table-31 represents the regeneration status of fir and spruce in Bashla range of Rohru forest division. The results of elevation class 2100-2400 m revealed maximum number of recruits for *Pinus wallichiana* (462.96/ha), while number of recruits for *Abies pindrow* and *Picea smithiana* were 185.18/ha and 277.78/ha, respectively. Similarly the maximum number of unestablished plants was recorded for *Pinus wallichiana* 925.93/ha. Whereas, in case of *Abies pindrow* and *Picea smithiana* the number was 462.96/ha and 370.37/ha respectively. The established regeneration was recorded as 370.37/ha, for both *Abies pindrow* and *Picea smithiana* and 92.54/ha for *Cedrus deodara*.

In second elevation class (2400-2700 m) maximum recruits (833.33/ha) of *Abies pindrow* were found, followed by *Pinus wallichiana* (555.56/ha), whereas in case of *Picea smithiana* it was 185.18/ha. Maximum unestablished plants were recorded for *Picea smithiana* (3240.74/ha), followed by *Abies pindrow* (1296.36/ha) and *Pinus wallichiana* (833.33/ha). The established regeneration was recorded maximum for *Picea smithiana* (277.78/ha) followed by *Pinus wallichiana* (185.18/ha) and *Cedrus deodara* (92.54/ha).

Moreover, in highest elevation class (2700-3000 m) only recruits for *Picea smithiana* (370.37/ha) and *Pinus wallichiana* (185.18/ha) were found. The artificial regeneration of broad-leaved was present in the area. The established regeneration was totally absent (Table-31).

4.4A.2 JUBBAL FOREST RANGE

4.4A.2a PB-I

The regeneration status of fir and spruce in Jubbal forest range at different elevations under PB I (Table-32) reveals that maximum number (4166.67) of

recruits were found in case of *Abies pindrow* at highest elevation. At 2100-2400 m maximum number of recruits were found in case of *Pinus wallichiana* (694.44/ha) followed by *Picea smithiana* (416.67/ha) and minimum for *Cedrus deodara* (138.89/ha). Whereas, number of unestablished plants were maximum for *Picea smithiana* (1111.11/ha) followed by *Cedrus deodara* (972.22/ha) and minimum for *Quercus spp.* (138.89/ha), while *Cedrus deodara* was the only species which showed the established regeneration (555.56/ha) at lowest elevation class.

In second elevation class (2400-2700m) only *Picea smithiana* and *Pinus wallichiana* were among regenerating species with 138.89/ha and 277.78/ha recruits and 833.33/ha and 138.89/ha established plant, respectively, while unestablished plants of only *Picea smithiana* (555.56/ha) were present.

Number of recruits at highest elevation class for *Abies pindrow*, *Picea smithiana*, and *Pinus wallichiana* were 4166.67/ha, 694.44/ha and 138.89/ha, respectively. The unestablished plants 555.56/ha of only *Abies pindrow* were present. The equal established regeneration of 138.89/ha were observed for *Abies pindrow* and *Picea smithiana*.

4.4A.2b PB-U (Unallotted)

In table-33 regeneration of fir and spruce in Jubbal forest range at different elevations under PB-U is presented according to which the equal number of recruits at first elevation class for *Picea smithiana* and *Pinus wallichiana* were 277.78/ha and 138.89/ha for *Juglans regia*. The unestablished plants (138.89/ha) each for *Picea smithiana* and *Pinus wallichiana*, while maximum established regeneration was recorded for *Cedrus deodara* (277.78/ha), whereas, established regeneration of 277.78/ha and 694.44/ha was observed for *Picea smithiana* and *Pinus wallichiana* respectively in lowest elevation class.

In second elevation class (2400-2700m) recruits of only *Picea smithiana* (694.44/ha) were present. This species also recorded equal and maximum number

Table 31. Regeneration status of Fir and Spruce forests in Bashla forest range at different elevations

Parameters	r/ha	u/ha	$\bar{h}t$ (cm)	e/ha	$\bar{H}t$ (cm)
Species	Elevation-2100-2400 m				
<i>Abies pindrow</i>	185.18	462.96	17.40	370.37	365.00
<i>Picea smithiana</i>	277.78	370.37	43.75	370.37	225.00
<i>Pinus wallichiana</i>	462.96	925.93	29.60	-	-
<i>Cedrus deodara</i>	185.18	92.59	120.00	92.54	220.00
<i>Aesculus indica</i>	277.78	92.59	65.00	-	-
<i>Quercus spp.</i>	-	277.78	70.00	-	-
Total	1388.88	2222.22	345.75	833.28	810.00
	Elevation-2400-2700 m				
<i>Abies pindrow</i>	833.33	1296.30	22.64	-	-
<i>Picea smithiana</i>	185.18	3240.74	85.31	277.78	288.33
<i>Pinus wallichiana</i>	555.56	833.33	66.33	185.18	220.00
<i>Cedrus deodara</i>	92.59	185.18	95.00	92.54	240.00
<i>Aesculus indica</i>	185.18	277.78	26.00	-	-
Total	1851.84	5833.33	295.28	555.50	748.33
	Elevation-2700-3000 m				
<i>Picea smithiana</i>	370.37	-	-	-	-
<i>Pinus wallichiana</i>	185.18	-	-	-	-
<i>Robinia pseudocasia</i>	-	277.78	18.00	-	-
<i>Aesculus indica</i>	-	185.18	46.00	-	-
<i>Juglans regia</i>	-	92.59	40.00	-	-
<i>Populus ciliata</i>	-	92.59	60.00	-	-
Total	555.55	648.14	164.00	-	-

r - recruits

u - unestablished regeneration

e - established regeneration

$\bar{h}t$ - average height of unestablished regeneration

$\bar{H}t$ - average height of established regeneration

Table 32. Regeneration status of Fir and Spruce forests in Jubbal forest range at different elevations under PB-I

Parameters	r/ha	u/ha	$\bar{h}t$ (cm)	e/ha	$\bar{H}t$ (cm)
Species	Elevation-2100-2400 m				
<i>Picea smithiana</i>	416.67	1111.11	60.88	-	-
<i>Pinus wallichiana</i>	694.44	555.56	95.75	-	-
<i>Cedrus deodara</i>	138.89	972.22	110.00	555.56	207.50
<i>Quercus spp.</i>	-	138.89	25.00	-	-
Total	1250.00	2777.78	291.63	555.56	207.50
Species	Elevation-2400-2700 m				
<i>Picea smithiana</i>	138.89	555.56	82.50	833.33	266.67
<i>Pinus wallichiana</i>	277.78	-	-	138.89	320.00
Total	416.67	555.56	82.50	972.22	586.67
Species	Elevation-2700-3000 m				
<i>Abies pindrow</i>	4166.67	555.56	10.25	138.89	900.00
<i>Picea smithiana</i>	694.44	-	-	138.89	240.00
<i>Pinus wallichiana</i>	138.89	-	-	-	-
Total	5000.00	555.56	10.25	277.78	1140

Table 33. Regeneration status of Fir and Spruce forests in Jubbal forest range at different elevations under PB- U (unallotted)

Parameters	r/ha	u/ha	$\bar{h}t$ (cm)	e/ha	$\bar{H}t$ (cm)
Species	Elevation-2100-2400 m				
<i>Picea smithiana</i>	277.78	138.89	43.00	277.78	250.00
<i>Pinus wallichiana</i>	277.78	138.89	48.00	694.44	246.00
<i>Cedrus deodara</i>	-	277.78	165.00	-	-
<i>Juglans regia</i>	138.89	-	-	-	-
Total	694.45	555.56	256.00	972.22	496.00
Species	Elevation-2400-2700 m				
<i>Picea smithiana</i>	694.44	277.78	76.50	277.78	295.00
<i>Pinus wallichiana</i>	-	138.89	70.00	138.89	220.00
<i>Cedrus deodara</i>	-	138.89	70.00	-	-
Total	694.44	555.56	216.50	416.67	515.00
Species	Elevation-2700-3000 m				
<i>Abies pindrow</i>	3055.56	-	-	-	-
Total	3055.56	-	-	-	-

r - recruits

u - unestablished regeneration

e - established regeneration

$\bar{h}t$ - average height of unestablished regeneration

$\bar{H}t$ - average height of established regeneration

(277.78/ha) of established and unestablished plants, whereas, third elevation class was devoid of established and unestablished plants, however, 3055.56/ha recruits of *Abies pindrow* were observed in this elevation class.

4.4A.3 KOTKHAI FOREST RANGE

4.4A.3a PB-I

The data from table-34 on regeneration status of fir and spruce Kotkhai forest range at different elevations in PB-I indicated equal number of recruits of *Pinus wallichiana* and *Quercus spp.* i.e. 416.67/ha at 2100-2400m elevation class. The maximum number of unestablished plants of *Quercus spp.* (833.33/ha) followed by *Picea smithiana* and *Cedrus deodara* with equal number (277.78/ha), however minimum value of 138.89/ha was recorded for *Pinus wallichiana*. While the established regeneration was absent of all the species in this elevation range. In second elevation (2400-2700m) maximum and equal recruits 555.56/ha were recorded for *Abies pindrow* and *Pinus wallichiana* but the minimum 138.89/ha was of *Picea smithiana*. The unestablished plants 277.78/ha and 138.89/ha were recorded for *Abies pindrow* and *Picea smithiana* respectively, however, *Pinus wallichiana* was the only species which showed the established regeneration with value of 277.78/ha.

In third elevation class 2700-3000m *Quercus spp.* showed maximum number of recruits and unestablished plants 833.33/ha and 1666.67/ha, respectively. *Picea smithiana* had only unestablished plants (138.89/ha), whereas, while in case of *Abies pindrow* number of recruits, unestablished plants and established plants were 694.44, 138.89 and 138.89 per hectare, respectively (Table-34).

4.4A.3bPB-U (Unallotted)

Table-35 indicates regeneration status of fir and spruce forests for PB unallotted for Kotkhai forest range. In elevation class 2100-2400 m recruits (1111.11/ha) of only *Pinus wallichiana* were present. The unestablished regeneration was recorded for *Pinus wallichiana* 138.89/ha and 277.78/ha for

Cedrus deodara. While established regeneration was found equal (138.89/ha) for both *Picea smithiana* and *Pinus wallichiana*.

In second higher elevation (middle) class *Picea smithiana* and *Cedrus deodara* recorded 416.67 and 277.78/ha number of recruits, while unestablished plants were maximum of *Cedrus deodara* (694.44/ha), whereas, *Picea smithiana* and *Pinus wallichiana* were having equal (277.78/ha) number of unestablished plants. The number of established plants were 694.44/ha and 138.89/ha of *Cedrus deodara* and *Pinus wallichiana*, respectively.

At highest elevation class (2700-3000 m) number of recruits 555.56/ha of *Abies pindrow* and 277.78/ha of *Pinus wallichiana* were present. The unestablished plants recorded were equal (138.89) of *Abies pindrow* and *Picea smithiana*. Whereas, 555.56/ha for *Pinus wallichiana*.

4.4B REGENERATION ESTABLISHMENT AND STOCKING

Weighted average height, establishment index and stocking index was calculated for different regenerating tree species for forest stands with respect to its three elevation classes under Bashla, Jubbal and Kotkhai forest ranges to access its established stocking per cent.

4.4B.1 BASHLA FOREST RANGE

The total established stocking percent (Table-36) was maximum 33.11 in middle followed by lower 27.21 and 1.19 in highest elevation class. At lowest and middle elevation the maximum established stocking percent was 11.28 and 20.53 of *Picea smithiana* followed by *Abies pindrow* (9.58) at lowest elevation and *Pinus wallichiana* (7.13) in middle elevation.

i) *Abies pindrow*

The perusal of data given in table-36 for regeneration establishment and stocking in Bashla indicated that weighted average height for *Abies pindrow* was

Table 34. Regeneration status of Fir and Spruce forests in Kotkhai forest range at different elevations under PB-I

Parameters	r/ha	u/ha	$\bar{h}t$ (cm)	e/ha	$\bar{H}t$ (cm)
Species	Elevation-2100-2400 m				
<i>Picea smithiana</i>	-	277.78	32.50	-	-
<i>Pinus wallichiana</i>	416.67	138.89	23.00	-	-
<i>Cedrus deodara</i>	-	277.78	50.50	-	-
<i>Quercus spp.</i>	416.67	833.33	14.33	-	-
Total	833.34	1527.78	120.33	-	-
Species	Elevation-2400-2700 m				
<i>Abies pindrow</i>	555.56	277.78	31.50	-	-
<i>Picea smithiana</i>	138.89	138.89	60.00	-	-
<i>Pinus wallichiana</i>	555.56	-	-	277.78	215.00
<i>Cedrus deodara</i>	416.67	-	-	-	-
Total	1666.68	416.67	91.50	277.78	277.78
Species	Elevation-2700-3000 m				
<i>Abies pindrow</i>	694.44	138.89	12.00	138.89	320.00
<i>Picea smithiana</i>	-	138.89	12.00	-	-
<i>Quercus spp.</i>	833.33	1666.67	15.50	-	-
Total	1527.77	1944.45	39.50	1983.95	3967.90

Table 35. Regeneration status of Fir and Spruce forests in Kotkhai forest range at different elevations under PB-U (unallotted)

Parameters	r/ha	u/ha	$\bar{h}t$ (cm)	e/ha	$\bar{H}t$ (cm)
Species	Elevation-2100-2400 m				
<i>Picea smithiana</i>	-	-	-	138.89	230.00
<i>Pinus wallichiana</i>	1111.11	138.89	55.00	138.89	200.00
<i>Cedrus deodara</i>	-	277.78	27.50	-	-
Total	1111.11	416.67	82.50	277.78	430.00
Species	Elevation-2400-2700 m				
<i>Picea smithiana</i>	416.67	277.78	52.50	-	-
<i>Pinus wallichiana</i>	-	277.78	61.50	138.89	240.00
<i>Cedrus deodara</i>	277.78	694.44	127.00	694.44	292.00
Total	694.45	1250.00	241.00	833.33	532.00
Species	Elevation-2700-3000 m				
<i>Abies pindrow</i>	555.56	138.89	35.00	-	-
<i>Picea smithiana</i>	-	138.89	30.00	-	-
<i>Pinus wallichiana</i>	277.78	555.56	56.25	-	-
Total	833.34	833.34	121.25	-	-

r - recruits

u - unestablished regeneration

e - established regeneration

$\bar{h}t$ - average height of unestablished regeneration

$\bar{H}t$ - average height of established regeneration

Table 36. Regeneration establishment and stocking data for different tree species in Fir and Spruce forests in Bashla

Species	Weighted average height (cm)	Establishment index (I ₁)	Stocking index (I ₂)	Established Stocking percent (100xI ₁ x I ₂)
Elevation-2100-2400 m				
<i>Abies pindrow</i>	98.56	0.49	0.194	9.58
<i>Picea smithiana</i>	121.88	0.61	0.185	11.28
<i>Cedrus deodara</i>	160.00	0.80	0.046	3.70
<i>Pinus wallichiana</i>	29.60	0.15	0.093	1.37
<i>Aesculus indica</i>	65.00	0.33	0.009	0.30
<i>Quercus spp.</i>	70.00	0.35	0.028	0.97
Total	545.03	2.73	0.556	27.21
Elevation-2400-2700 m				
<i>Abies pindrow</i>	22.64	0.11	0.130	1.47
<i>Picea smithiana</i>	94.37	0.47	0.435	20.53
<i>Pinus wallichiana</i>	90.64	0.45	0.157	7.13
<i>Aesculus indica</i>	26.00	0.13	0.028	0.36
<i>Cedrus deodara</i>	130.00	0.65	0.056	3.61
Total	363.65	1.82	0.806	33.11
Elevation-2700-3000 m				
<i>Robinia pseudoacacia</i>	18.00	0.09	0.028	0.25
<i>Aesculus indica</i>	51.00	0.26	0.019	0.47
<i>Juglans regia</i>	40.00	0.20	0.009	0.19
<i>Populus ciliata</i>	60.00	0.30	0.009	0.28
Total	169.00	0.85	0.065	1.19

maximum (98.56 cm) in lowest elevation class (2100-2400 m) followed by middle elevation class with the value of 22.64 cm. However highest elevation class (2700-3000 m) showed complete absence of regeneration for this species. The establishment index varied from 0.11 to 0.49 while stocking index from 0.13 to 0.19 in middle to lower elevation class, respectively. The establishment stocking per cent was highest (9.58) in first elevation class, while minimum of 1.47 in second elevation class.

ii) *Picea smithiana*

In case of *Picea smithiana* maximum weighted average height (121.88 cm) was recorded for lowest elevation class with establishment index value of 0.61 and stocking index 0.185 whereas, in 2400-2700m elevation class the maximum stocking index (0.435) and established stocking per cent (20.53) was recorded. The highest elevation class was devoid of the regeneration of the species.

iii) *Cedrus deodara*

The regeneration study in all elevation classes showed the maximum weighted average height of 160 cm in first elevation class with establishment index of 0.80, stocking index of 0.046 and establishment stocking per cent of 3.70. The establishment stocking per cent of this species was 3.61 in middle elevation class. At 2700-3000 m elevation the regeneration of *Cedrus deodara* was totally absent.

iv) *Pinus wallichiana*

The regeneration of this species was in lowest and middle elevation classes. The established stocking per cent of *Pinus wallichiana* with value 7.13 was more in second elevation class as compare to lowest elevation class with value of 1.37. The value of weighted average height (90.64 cm), establishment index (0.45) and stocking index (0.157) was higher in middle elevation class with no trace of its regeneration in third elevation class.

v) *Aesculus indica*

Aesculus indica was present very less in all the three elevation classes, although in third elevation class (2700-3000m) it was artificially planted, where established stocking per cent (0.47) was better as compare to the other elevation classes.

vi) *Quercus spp.*

It was found only in lowest elevation class with the weighted average height (70.00 cm), establishment index of 0.35, stocking index (0.028) and 0.97 per cent established stocking.

Robinia pseudoacacia, *Juglans regia* and *Populus ciliata* shown in the table had 0.25, 0.19 and 0.28 values of establishment stocking per cent in sequence which represents the artificial regeneration only.

4.4B.2 JUBBAL FOREST RANGE

4.4B.2a PB-I

The weighted average height, establishment index, stocking index and established stocking per cent was calculated for all the species recorded in all regeneration units at different elevation in PB-I (Table-37). The highest establishment stocking per cent (35.31) was obtained in middle elevation contributed by *Picea smithiana* and *Pinus wallichiana* (29.75 and 5.56). In the lower elevation total established stocking per cent was 29.01 mainly contributed by *Cedrus deodara* (22.80%) followed by *Picea smithiana* (3.38%). At highest elevation class, the total established stocking per cent was 8.23 contributed by *Abies pindrow* (2.68%) and *Picea smithiana* (0.56). The species wise findings are as under.

i) *Abies pindrow*

The *Abies pindrow* regeneration was recorded only in highest elevation class (2700-3000 m) as revealed from table-37. The weighted average height of

Table 37. Regeneration Establishment and stocking data for different tree species in Fir and Spruce forests in Jubbal in PB-I

Species	Weighted average height (cm)	Establishment index (I ₁)	Stocking index (I ₂)	Established Stocking percent (100xI ₁ x I ₂)
Elevation-2100-2400 m				
<i>Picea smithiana</i>	60.88	0.30	0.111	3.38
<i>Cedrus deodara</i>	142.73	0.71	0.319	22.80
<i>Pinus wallichiana</i>	95.75	0.48	0.056	2.66
<i>Quercus spp.</i>	25.00	0.13	0.014	0.17
Total	324.35	1.62	0.500	29.01
Elevation-2400-2700 m				
<i>Picea smithiana</i>	153.00	0.77	0.389	29.75
<i>Pinus wallichiana</i>	200.00	1.00	0.056	5.56
Total	353.00	1.77	0.444	35.31
Elevation-2700-3000 m				
<i>Abies pindrow</i>	48.20	0.24	0.111	2.68
<i>Picea smithiana</i>	200.00	1.00	0.056	5.56
Total	248.20	1.24	0.167	8.23

Table 38. Regeneration Establishment and stocking data for different tree species in Fir and Spruce forests in Jubbal in PB-U

Species	Weighted average height (cm)	Establishment index (I ₁)	Stocking index (I ₂)	Established Stocking percent (100xI ₁ x I ₂)
Elevation-2100-2400 m				
<i>Cedrus deodara</i>	165.00	0.83	0.028	2.29
<i>Pinus wallichiana</i>	174.67	0.87	0.292	25.47
<i>Picea smithiana</i>	147.67	0.74	0.125	9.23
Total	487.33	2.44	0.444	36.99
Elevation-2400-2700 m				
<i>Picea smithiana</i>	138.25	0.69	0.139	9.60
<i>Cedrus deodara</i>	70.00	0.35	0.014	0.49
<i>Pinus wallichiana</i>	135.00	0.68	0.069	4.69
Total	343.25	1.72	0.222	14.77

regeneration was 48.20 cm. The value of establishment index was found to be 0.24 and stocking index 0.111 with 2.68% established stocking.

ii) *Picea smithiana*

The data pertaining to this species in the table-37 indicates the maximum weighted average height of 200 cm in third elevation class (2700-3000 m), with establishment index of 1.00. However, maximum stocking index (0.389) and established stocking per cent of 29.75 was recorded in middle elevation class. Minimum stocking per cent (3.38) was observed in lowest elevation class.

iii) *Cedrus deodara*

The regeneration of *Cedrus deodara* was only found in lowest elevation class with maximum weighted average height (142.73 cm), establishment index (0.71), stocking index (0.319), and established stocking per cent of 22.80 among all the species except *Picea smithiana* in middle elevation class.

iv) *Pinus wallichiana*

The regeneration for this species was recorded up to 2700 m. The maximum weighted average height (200 cm), establishment index (1.00), stocking index (0.56) and established stocking per cent of 5.56 were observed in middle elevation class 2400-2700.

v) *Quercus spp.*

The regeneration of this species was recorded only in lowest elevation class, with very less weighted average height of 25.00 cm and (0.17) established stocking per cent among all the species at different elevations studied at different elevations studied under Jubbal forest range in PB-I.

4.4.2b PB- U (Unallotted)

The regeneration establishment and stocking data (Table-38) for different elevations under unallotted periodic blocks indicated that regeneration was totally

absent for all the species at highest elevation (2700-3000 m). In lowest and the middle elevations *Pinus wallichiana*, *Cedrus deodara* and *Picea smithiana* regeneration was obtained. The regeneration of *Abies pindrow* was totally absent. Total established stocking per cent in lower and mid elevation was obtained 36.99 and 14.77% respectively. The established stocking per cent in *Pinus wallichiana* was highest with 25.47 in lower elevation, whereas at mid elevation *Picea smithiana* showed maximum 9.60 established stocking per cent, while *Pinus wallichiana* was second at middle elevation with 4.69 per cent value, the *Cedrus deodara* remained in third position in both the elevations. The result for different are detailed as under.

i) *Picea smithiana*

In case of *Picea smithiana* maximum stocking per cent of 9.60 and stocking index of 0.139 was recorded in middle elevation class, while the weighted average height (147.67 cm) and establishment index (0.74) was recorded with stocking per cent of 9.23 at lowest elevation class i.e. 2100-2400 m.

ii) *Cedrus deodara*

The weighted average height was maximum (165.00 cm) in lowest elevation class, with maximum establishment index (0.83) and stocking per cent (2.29) as compared to middle elevation class, where the corresponding values were 70 cm, 0.35, 0.014 and 0.49 quite low and there was no regeneration in highest elevation class.

iii) *Pinus wallichiana*

Pinus wallichiana showed (Table-38) the maximum established stocking per cent (25.47) among all the species. The maximum average height was 174.67 cm in lowest elevation class as compared to mid elevation class (135 cm). The established stocking per cent was quite low (4.69%) less than that of *Picea smithiana*, however, more than *Cedrus deodara* in second elevation class.

4.4B.3 KOTKHAI FOREST RANGE

4.4B.3a PB-I

The perusal of data (Table-39) represents the regeneration stocking data for Kotkhai range in PB-I areas, which reveals that maximum value of 11.97, established stocking per cent was obtained in middle elevation class followed by 2700-3000 m elevation class. The maximum regeneration 11.11% was of *Pinus wallichiana* in middle elevation, whereas 3.68% for *Abies pindrow* in highest elevation.

i) *Abies pindrow*

Abies pindrow regeneration was only in middle and highest elevation class. The weighted average height was (106.00 cm) highest in elevation class 2700-3000 m. The values of 0.53, .069 and 3.68 for establishment index, stocking index and established stocking per cent were obtained in highest elevation as compared to middle elevation where there values were 0.16, 0.028 and 0.44%, respectively.

ii) *Picea smithiana*

The presence of *Picea smithiana* regeneration was in all the elevation classes under study. The maximum average height (60.00 cm), establishment index (0.30) was in second elevation class, while maximum stocking index (0.028) and established stocking per cent (0.45) was recorded in lowest elevation class.

iii) *Cedrus deodara*

Cedrus deodara was found only in first elevation class in this forest stand, with weighted average height, establishment index, stocking index and established stocking per cent values of 50.50 cm, 0.25, 0.028 and 0.70 per cent, respectively.

iv) *Pinus wallichiana*

Pinus wallichiana regeneration was recorded in first two elevation classes, although it was absent in highest elevation class. The maximum weighted average height (200.00 cm), establishment index (1.00), stocking index (0.111) and

established stocking per cent (11.11) for this species were recorded in middle elevation class.

v) *Quercus spp.*

The regeneration for *Quercus spp.* was found for first and the highest elevation class, with maximum average height (15.50 cm), establishment index (0.08), stocking index (0.167) and stocking per cent of 1.29 in highest elevation class

4.4B.3b PB-U (Unallotted)

The data given in table-17 reveals that the total maximum established stocking percent (33.59) was obtained in mid-elevation class, mainly contributed by *Cedrus deodara* (28.39) followed by *Pinus wallichiana* (4.49). At lower elevation for the total 10.36%, *Picea smithiana* contributed 5.56, while *Pinus wallichiana* contributed 4.43%. However in highest elevation class 3.99% was contributed by *Picea smithiana* and 1.56 by *Pinus wallichiana* to the total of 5.80% established stocking per cent. The data pertaining to different species is given as under.

i) *Abies pindrow*

Abies pindrow regeneration was found only in highest elevation class, with weighted average height of 35 cm, establishment index of 0.18, stocking index value of 0.014 and 0.24 established stocking per cent.

ii) *Picea smithiana*

The regeneration for this species was present in lower, middle and higher elevations i.e. 2100-3000 m, with maximum established stocking per cent (5.56) in lowest elevation class followed by 3.99 in 2700-3000 m elevation class and minimum of 0.72 in middle elevation class. The maximum weighted average height (200 cm), establishment index (1.00) and stocking index (0.056) was obtained in lowest elevation class.

Table 39. Regeneration Establishment and stocking data for different tree species in Fir and Spruce forests in Kotkhai in PB-I

Species	Weighted average height (cm)	Establishment index (I ₁)	Stocking index (I ₂)	Established Stocking percent (100xI ₁ xI ₂)
Elevation-2100-2400 m				
<i>Picea smithiana</i>	32.50	0.16	0.028	0.45
<i>Cedrus deodara</i>	50.50	0.25	0.028	0.70
<i>Pinus wallichiana</i>	23.00	0.12	0.014	0.16
<i>Quercus spp.</i>	14.33	0.07	0.083	0.60
Total	120.33	0.60	0.153	1.91
Elevation-2400-2700 m				
<i>Picea smithiana</i>	60.00	0.30	0.014	0.42
<i>Abies pindrow</i>	31.50	0.16	0.028	0.44
<i>Pinus wallichiana</i>	200.00	1.00	0.111	11.11
Total	291.50	1.46	0.153	11.97
Elevation-2700-3000 m				
<i>Abies pindrow</i>	106.00	0.53	0.069	3.68
<i>Picea smithiana</i>	12.00	0.06	0.014	0.08
<i>Quercus spp.</i>	15.50	0.08	0.167	1.29
Total	133.50	0.67	0.250	5.06

Table 40. Regeneration Establishment and stocking data for different tree species in Fir and Spruce forests in Kotkhai in PB-U

Species	Weighted average height (cm)	Establishment index (I ₁)	Stocking index (I ₂)	Established Stocking percent (100xI ₁ xI ₂)
Elevation-2100-2400 m				
<i>Picea smithiana</i>	200.00	1.00	0.056	5.36
<i>Pinus wallichiana</i>	127.50	0.64	0.069	4.43
<i>Cedrus deodara</i>	27.50	0.14	0.028	0.38
Total	355.00	1.78	0.153	10.36
Elevation-2400-2700 m				
<i>Picea smithiana</i>	52.00	0.26	0.028	0.72
<i>Cedrus deodara</i>	163.50	0.82	0.347	28.39
<i>Pinus wallichiana</i>	107.67	0.54	0.083	4.49
Total	323.17	1.62	0.458	33.59
Elevation-2700-3000 m				
<i>Abies pindrow</i>	35.00	0.18	0.014	0.24
<i>Picea smithiana</i>	115.00	0.58	0.069	3.99
<i>Pinus wallichiana</i>	56.25	0.28	0.056	1.56
Total	206.25	1.03	0.139	5.80

iii) *Pinus wallichiana*

The regeneration of *Pinus wallichiana* was present in all the elevation classes from 2100-3000 m. The maximum weighted average height (127.50 cm) and establishment index (0.64) was found in lowest elevation class. However, maximum stocking index of 0.083 and established stocking per cent of 4.49 was found in middle elevation class.

iv) *Cedrus deodara*

The regeneration study of *Cedrus deodara* revealed its presence in lower and middle elevation but maximum regeneration took place in elevation class 2400-2700 m with established stocking per cent of 28.39. The maximum value for weighted average height 163.50 cm, establishment index (0.82) and stocking index (0.347) was also recorded in second elevation class.

Chapter IV
DISCUSSION



DISCUSSION

Chapter - V

DISCUSSION

The results obtained from the present study has been discussed in this chapter to establish cause and affect relationship among various parameters studied to draw logical information in the light of available literature in the following headings.

5.1 PHYTOSOCIOLOGICAL STUDIES

The results of floristic composition study reveals that total number of species decreased in Bashla from 47 to 42 and in PB-I from 31 to 26 in Kotkhai forest range, whereas, increased in PB-U from 30 to 40 with increase in diameter (Table-2 to 16). The number of tree species in Jubbal in all elevations classes except PB-U in middle elevation was less as compared to corresponding elevation classes in Bashla and Kotkhai forest ranges. The minimum number of two tree species was present in highest elevation class in Kotkhai (PB-I) and Jubbal (PB-U) as compared to higher number of individuals under trees, shrubs and herbs in all the sites. The decrease in number from lower elevation to higher was due to variation in climatic condition towards the lower temperature and smaller growth period. The results are in accordance with the study of Joshi et al. (1986). The lower elevation in Bashla forest showed more presence of fir as compared to other species. This can be attributed to the less solar radiation outside canopy and microclimatic condition favorable for the growth of fir. Kumar et al. (2005) recorded the maximum number of trees and shrubs on the undisturbed sites, which is quite similar to the conditions of Bashla forest (under protection working circle) as well as PB-U areas in Kotkhai and Jubbal).

The total number of trees as well as IVI value of *Abies pindrow* decreased with increase in elevation class in Bashla forest range from 150 trees/ha to 8.33 tree/ha and 135.23 to 18.99 IVI value (Table-2 to 4). Whereas in contrast the dominance of *Picea smithiana* increased from lower to higher elevation class with IVI value of 25.28 to 217.32, respectively. This variation is due to microclimatic conditions and poor exposure to sunlight at lower elevation (Table-28) and gaps at higher elevation as the density was less and small diameter classes contained more trees (Table-23). The number of species associated with fir and spruce are also more at lower elevation since the microclimatic conditions became favorable for the growth and development of associated species at lower elevation (Spurr and Barnes, 1980). These results were also supported by the studies conducted by Rawat et al. (1989) and Singh et al. (1994) regarding the more frequent presence of dominant and co-dominant species than the other associates in the natural zone of tree distribution. The occurrence of *Picea smithiana* and *Pinus wallichiana* is more on exposed and drier aspect at different elevations (Inayatullah and Ticku, 1965), whereas, the presence of broadleaved species decreased with the presence of *Picea smithiana*, which resulted in lower dominance of fir and spruce forests. Similar findings were given by Dhani and Panwar (1999), regarding the occurrence of *Quercus dilatata* a moisture loving species on northern aspect. Further persistent increase in *Quercus spp* resulted in the decrease of main crop of deodar (Singh et al., 1987).

In Jubbal, the lowermost elevation was devoid of *Abies pindrow* whereas, it showed the presence with IVI value of 20.20 least among all tree species in middle elevation (Table-6) and dominant in uppermost elevation class with IVI 192.35 among 3 tree species present (Table-7). Similar trend was followed under PB-U except the higher presence of *Abies pindrow* in 2700-3000 m elevation with maximum IVI of 261.05 as compared to its associate *Picea smithiana*, with IVI value of 38.95 (Table-10). The tree species were less indicative of favorable conditions for fir and spruce growth at lower elevation.

In Kotkhai forest range *Abies pindrow* was absent in lowermost elevation class where the maximum dominance was of *Quercus spp* (126.29) followed by *Picea smithiana* 82.23 IVI in PB-I but the presence of *Abies pindrow* was higher in middle and highest elevation with 83.01 and 193.22 IVI followed by *Quercus spp* with IVI 78.04 and 106.78, respectively. The total basal area for trees increased from lowest to highest elevation class in all the three sites except in PB-U areas in Kotkhai, where the maximum basal area 361912.00 cm²/ha followed by 295147.88 cm²/ha and 322868.75 cm²/ha in low, mid and highest elevation classes, respectively, (Table-14 to 16). This can be attributed to more number of trees in higher diameter class than at lower ones (Table-27). In PB-U (Table 14-15) lowermost elevation was dominated by *Pinus wallichiana* followed by *Quercus spp* and *Picea smithiana* with 213.10, 57.34 and 29.56, respectively, whereas the middle elevation was dominated by *Cedrus deodara* followed by *Picea smithiana*. *Abies pindrow* was present only in highest elevation class where it showed the dominance with 140.22 value of IVI (Table-16).

Maximum shrubs were observed in Bashla forest range where the number of species decreased from lower elevation (11) to higher elevation (6) subsequently, while in Jubbal and Kotkhai maximum 8 and 6 shrub species were found in PB-U at lowest elevation and middle elevation class, respectively. This can be attributed to the growth of shrubs in exposed gaps created in old felling operations and allocation of these forests under protection working circle to avoid excessive damage, except to meet the limited need of local population. These studies are in line with the findings of Chandra et al. (1999) regarding the dominance of shrubs in Himalayan temperate forests between 2550-3000 m. As regards the number of shrub species, Kotkhai PB-I observed least number of shrubs (2) in middle elevation class, which can be attributed to poor light conditions (Table-30) and poor regeneration conditions (Table-30). This can be attributed to the presence of large number of tree species (7) with higher density (Table-12), while shrub density was less (480/ha). Our results are in accordance to the study conducted by Rikhari et al. (1991) in which they found

that with increased richness in tree species leads to the reduction in the presence of shrubs.

In Jubbal forest range the presence of shrub species was almost equal in all elevation classes in PB-I with *Berberis aristata* > *Wikstroemia canescens* > *Rosa macrophylla* > *Viburnum continifolium* but in the highest elevation the sequence of dominance was *Viburnum continifolium* > *Cotoneaster bacillaries* > *Cotoneaster microphylla* (Table-5 to 7). In Bashla forest range total herbaceous species recorded were 28, 32 and 31 from lowest to highest elevation classes. *Viola pilosa* (44.85) was dominating followed by *Fragaria vesca* (35.28) and *Perotis latifolia* (25.72) in lowest elevation class. In middle and highest elevation class the dominance was of *Fragaria vesca* > *Trifolium pratense* > *Dicanthium annulatum* and *Fragaria vesca* > *Cyperus aristatus* > *Galium aparine* (Table-2 to 4)

In Jubbal forest range herbaceous vegetation showed the presence of highest number of 26 and 23 in middle elevation class in PB-I and PB-U (Table 6 & 9). About equal dominance of *Cyperus aristatus* (44.55) and *Fragaria vesca* (43.93) at lowest elevation class in PB-I, whereas in middle *Trifolium pratense* > *Fragaria vesca* > *Galium aparine* but at highest elevation class *Fragaria vesca* > *Geranium wallichinum* > *Viola spp* based on IVI (Table 5-7).

In lowest elevation class, *Cyperus aristatus* was the dominant species with IVI value of 49.60 followed by *Viola spp.* (44.28) and *Strobilanthus dalhousianus* (30.38) under PB-U, and in middle and higher elevation classes *Fragaria vesca* > *Trifolium pratense* > *Ariseama intermedium* and *Fragaria vesca* > *Viola spp* > *Ariseama intermedium*. The results of the study are similar to the study conducted by Gupta (1997) concerning species composition. However, there is slight variation in the dominance of the species, it can be attributed to variation in aspect, management and grazing. Since the biotic factors interfere the dominance of plant species (Chandra et al., 1999).

In Kotkhai, the presence of herbaceous vegetation was higher (28) in highest elevations under PB-U areas, where the growth is unrestricted and conditions became favorable for the growth of herbaceous vegetation in the beginning (Table-14 to 16). Whereas, the number of herbaceous vegetation was almost equal in PB-I ranging from 19 to 21. The site was dominated by *Fragaria vesca* (54.56, 72.35 and 99.19) in all the elevation classes with highest IVI value from lowest to highest elevation class followed by *Bistorta spp.*, *Cyprus aristatus* and *Galium aparine* at lower middle and highest elevation class on the basis of IVI value (Table-11 to 13). In PB-U at lowest elevation the sequence of dominance was *Cyprus aristatus* > *Galium aparine*. In addition, *Fragaria vesca* > *Viola spp* > *Galium aparine* in middle elevation. However, at highest elevation class *Trifolium pratense* > *Fragaria vesca* > *Galium aparine*. The variation in number of species and dominance may be attributed to the change in microclimatic conditions due to upper canopy trees combination and shrub species present in the area. The results are in accordance to the indication regarding the change in climatic conditions with elevation, aspect and phytosociological association of different strata of vegetation (Khanna, 2001). Kumar et al. (2005) also observed the increase in diversity with change in climatic conditions due to various abiotic and biotic factors. In general the similarity among tree vegetation was higher between middle and highest elevation, whereas among shrubs, lower x middle but herbs species were almost similar in all elevation classes.

In Bashla the similarity (Table-17) for trees between lower x middle and middle x elevation highest was equal with 66.67% and for lowest x highest elevation was less and among shrubs it was maximum with 95.24% between lower and middle elevation class and in herbs it was nearly same although highest again for lowest and middle elevation class. Which is also evident from the study of Kumar et al. (2005) that similarity increases with reduction in biotic interference.

In Jubbal, similarity (Table-18) for trees between different elevation classes was equal whereas for shrubs and herbs minimum similarity observed was between 2100-2400 m x 2700- 3000 m elevation class. Whereas the maximum similarity was

recorded between middle and highest elevation class for shrubs and lowest x middle elevations for herbs, which is the indication of the impact of elevation on climatic conditions and association of the species as the variation was less in middle elevation class (Table 6 & 9).

In Kotkhai, maximum similarity in tree vegetation observed was between middle and highest elevation class (Table-19). However, overall similarity was more than 72.73% between different elevations, indicative of uniform distribution of trees. The higher similarity index generally above 50% in stands exhibit fairly uniform composition of the forest (Rikhari et al., 1991). While the similarity value for shrubs remained low between lowest and highest elevation class, but lower x middle class similarity was highest. The herbaceous vegetation was less similar in lower and middle elevation class but the similarity was more between middle and highest elevation class. These results are in line with the findings of Gupta (1997).

The diversity among trees decreased with increase in elevation in Bashla, PB-I and PB-U of Jubbal and PB-I of Kotkhai forest, however, diversity increased with increase in elevation in PB-U under Kotkhai forests. In case of shrubs the diversity decreased with increase in elevation in Bashla and Jubbal forest sites but in Kotkhai in both PB-I and PB-U the diversity increased with elevation indicative of biotic interference. In case of herbs the diversity was maximum in middle elevation in Jubbal, however in other forests no definite pattern was observed, but the variation was narrow. Regarding the diversity in species based on composition of trees, shrubs and herbs in different elevation classes and management system. The individual species with maximum IVI as well as concentration of dominance have maximum diversity (Singh, 1998). On an average the diversity index value was least in trees which was followed by shrubs and herbs in increasing order in all the sites. In Bashla, diversity decreased with increase in elevation class. Whereas, in other forests the value remained lower for middle elevation. The results are in accordance with the findings of Marpa (2005) and Chand (2004).

5.2 STAND CHARACTERISTICS

It is evident from the table 23 to 27 that different tree parameters like average diameter, average height and average crown width in general showed higher value for highest diameter class in all elevation classes and available periodic blocks. It is in accordance with the study on *Acacia catechu* by Singh, 2002; similar results were also reported in *Cedrus deodara* by Singh (2004). In Bashla forest range trees were found in diameter class ranging from 10-20 cm -100 cm and above classes, in Jubbal forest range from 10-20 cm to 80-90 cm, whereas in Kotkhai from 10-20 cm to 60-70 cm diameter class trees were present in the three elevation classes and available periodic blocks with the absence of some tree diameter class at different elevations in Bashla, Jubbal and Kotkhai forest ranges, which may be attributed to the removal of trees in the past for packing cases to fulfill the petty requirement of local population. Stein (1988) also reported the decrease in main species with replacement by other species due to impact of biotic and abiotic factors.

In general the total number of trees per hectare for fir and spruce increased with increase in elevation class from lowest to highest elevation class for the three sites (Table 23-27), which also resulted in increased percent crown cover except in Jubbal where middle elevation recorded least value. The presence of less number of trees of fir and spruce at lower elevation and higher number in higher elevation class may be because of its natural zone of occurrence and preferred habitat lies at higher altitude whereas lower altitude was preferred by other associates like *Pinus wallichiana*, *Cedrus deodara*, etc which is indicated by the floristic composition, where the presence of *Pinus wallichiana* (Table-5), *Cedrus deodara* (Table-15), *Quercus spp* (Table-11) and other associates were more in number than the main species. The results are also supported by (Veillon, 1965). The presence of irregular number of trees in diameter class at different elevations may be due to the ban on green felling, thinning and improvement fellings as well as more regeneration in past.

The average height of the trees increased with increase in diameter class, however, there was no marked trend for this parameter in different diameter classes with change in elevation class and periodic block. The least height of 9 m was observed for 10-20cm diameter class in the middle and higher elevation in PB-I under Kotkhai range, which can be attributed to the higher presence of *Abies pindrow* in 2400-2700m and absence of *Picea smithiana* in 2700-3000m (Table-13).

Total basal area of fir and spruce increased with increase in the elevation class of the tree in all the three sites and available PBs with maximum basal area of 90.65 m²/ha, for 2700-3000m elevation class in PB-U (Table-25) in Jubbal forest range, which was due to increase in number of trees for fir and spruce with increase in elevation class. Similarly, trend for increase in basal area with increase in elevation class was found when total basal area for all the species was compared.

Total standing volume for fir and spruce followed the same trend as that of basal area (Table 26 & 27). The volume increased with increase in average diameter, average height and number of trees and change in the elevation class from 2100-2400 m to 2700-3000m. This can be attributed to the presence of appreciable number of trees in higher diameter class since diameter is important variable in volume estimation (Fatima and Hussain, 1984).

The growth of fir was slow as compared to spruce in all the diameter classes and forest sites except in Jubbal, where the diameter growth of spruce was slow then fir in Bashla after the age of about 86 years in diameter class 40-50 cm, the results are in line with the findings of Troup (1921). The regression equation of height and diameter with age developed by Antos et al. (2000) for fir and spruce showed that spruce grew more rapidly than fir.

REGENERATION AND SITE FACTOR STUDIES

The presence of recruits of fir increased with increase in elevation, whereas, unestablished regeneration of spruce increased with elevation in Bashla forest range

(Table-31). However, both the species had equal number of established plants at lowest elevation. But established plants of spruce were recorded comparatively less at middle elevation. The established stocking per cent was maximum 22.00 in middle elevation followed by lower elevation where it was 20.87, whereas no regeneration was observed at highest elevation class for fir & spruce, and their associated species also followed same pattern with 11.11, followed by 6.35 and 1.19% in middle, lower and highest elevation, respectively (Table-28), similar results were obtained for fir regeneration from lower to higher elevation in Narkanda (Gupta, 1997). The middle elevation class were found to have least depth of organic matter (3.5 cm), whereas at highest elevation the depth of organic matter was 8 cm since at higher elevation temperature responsible for decomposition is low. The crown projection ratio was maximum for associated species in contrast to the lowest for fir and spruce in middle elevation class. The higher projection ratio (24.84) was observed for fir and spruce in lowest elevation class, where per cent solar radiation was minimum (10.34). In the elevation classes where per cent solar radiation was higher supported the regeneration of the tree species as evident from table 28-30. Similar trend was observed in Jubbal forest range and to some extent in Kotkhai also. In general, higher solar radiation per cent indicated the higher regeneration up to middle elevation but the low crown cover. The poor regeneration at higher elevation can be attributed to higher organic matter accumulation. These results are also supported by Jha et al. (1984) and Singh et al. (1987)

In Jubbal forest range both in PB-I and PB-U the total regeneration in middle elevation class was higher for fir and spruce (29.75 and 9.60 respectively) whereas, at lower elevation in both periodic blocks the associated species contributed more to established stocking percent (Table-29). The presence of fir was nil in lower and middle elevation classes in PB-I and PB-U. The highest elevation class in PB-U contained only recruits whereas, PB-I showed unestablished as well as established regeneration. the regeneration of spruce decreased with increase in elevation in PB-I but increased in PB-U from lower to middle elevation class (Table 32 & 33) Agarwal and Patil (1956) observed that regeneration of fir and spruce was plentiful at lower

elevation under broad leaved trees, which supports the results of the investigation as number of broadleaved associate species are more on lower elevation classes (Table 2-16). The highest elevation in PB-I had only 8.23 per cent of established stocking. In general, the depth of organic matter is having indirect relationship with the established stocking per cent (Singh, 1983). The low crown cover 105.10 per cent in PB-I showed higher regeneration establishment of fir and spruce as well as the total regeneration of all the species. The percent crown cover was minimum which resulted higher under canopy solar radiation (750.67 lux) to reach forest ground. Similar results were obtained for natural regeneration studies of *Abies concolor* and *Abies mangifica* by Gordon (1970) and Ram Parkash (1991) for *Cedrus deodara* regeneration.

In Kotkhai forest range the fir recruits and unestablished regeneration was absent in lowest and middle elevation class in PB-U and lowest elevation in PB-I, whereas, established regeneration was absent in PB-U and in middle elevation of PB-I (Table-34 to 35). The regeneration of spruce was in all the elevation classes in both the PBs. In general the total regeneration was very less for all the species including fir and spruce ranging from 1.91 to 11.97 and 5.80 to 10.36 in PB-I and PB-U (Table-39 to 40) except in middle elevation of PB-U. The maximum fir and spruce regeneration of 5.56 per cent was observed in lowest elevation class followed by 4.24 per cent in highest elevation class and the associated species showed maximum regeneration of 32.87 per cent in PB-U and 11.11 per cent in PB-I at middle elevation (Table-30). Whereas middle elevation class in PB-U had maximum crown projection ratio, indicative of wide crowns due to open spaces, which is evident from low value of under canopy solar radiation helpful for improvement in regeneration. In general solar radiation increased with the increase in elevation in all sites. However, the trend (Fig 2 to 4) of under canopy radiation (%) increased with elevation in both PB-I and PB-U in Jubbal and Kotkhai forest range and pH ranged between 6.43 to 6.55, which is almost equal in all elevation classes where the regeneration was found to be maximum.

Fig. 2. Percentage solar radiation(%) & Crown projection ratio w.r.t. Elevation change (Bashla forest Range)

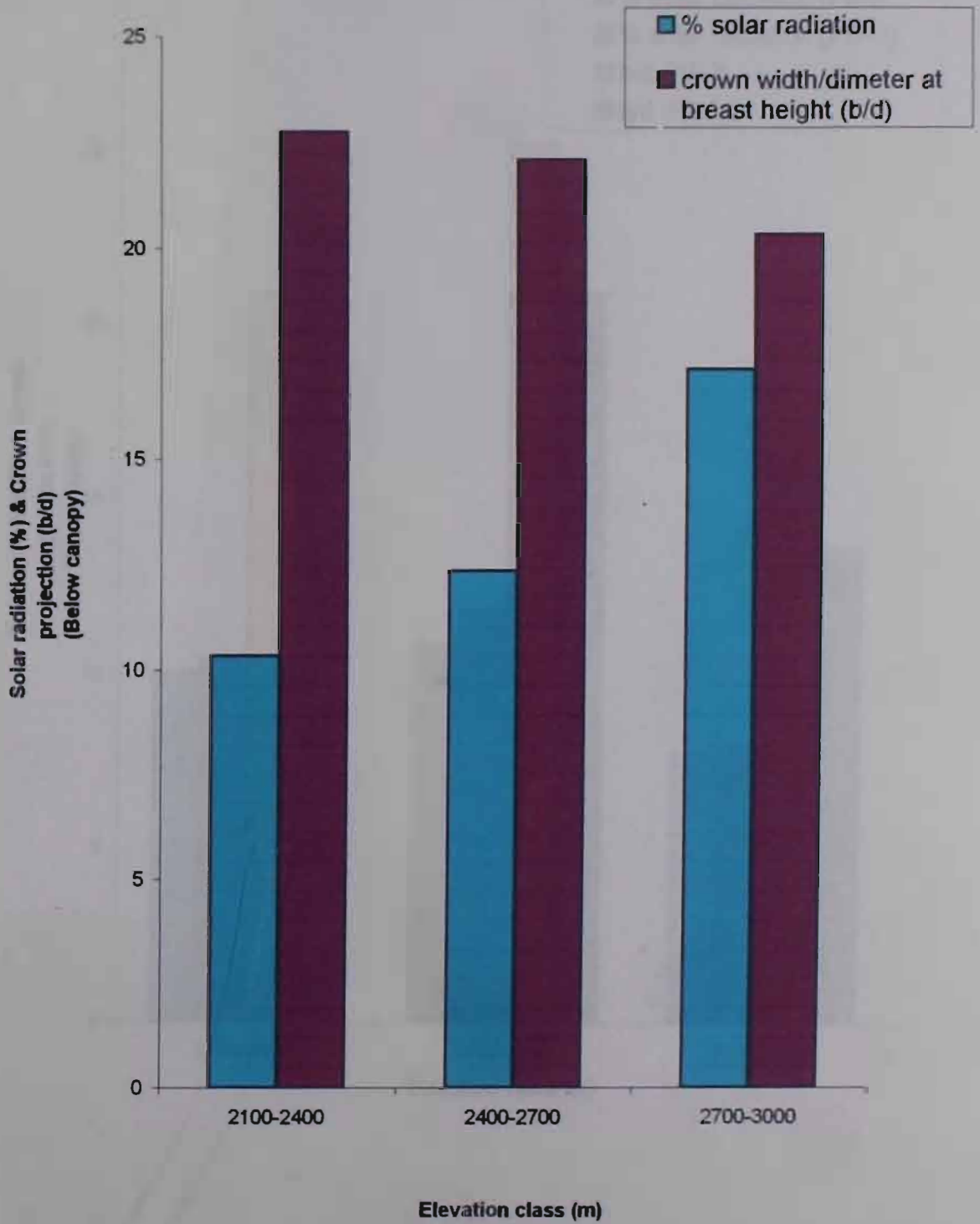


Fig. 3. Percentage solar radiation & Crown projection ratio w.r.t. elevation change (Jubbal forest range)

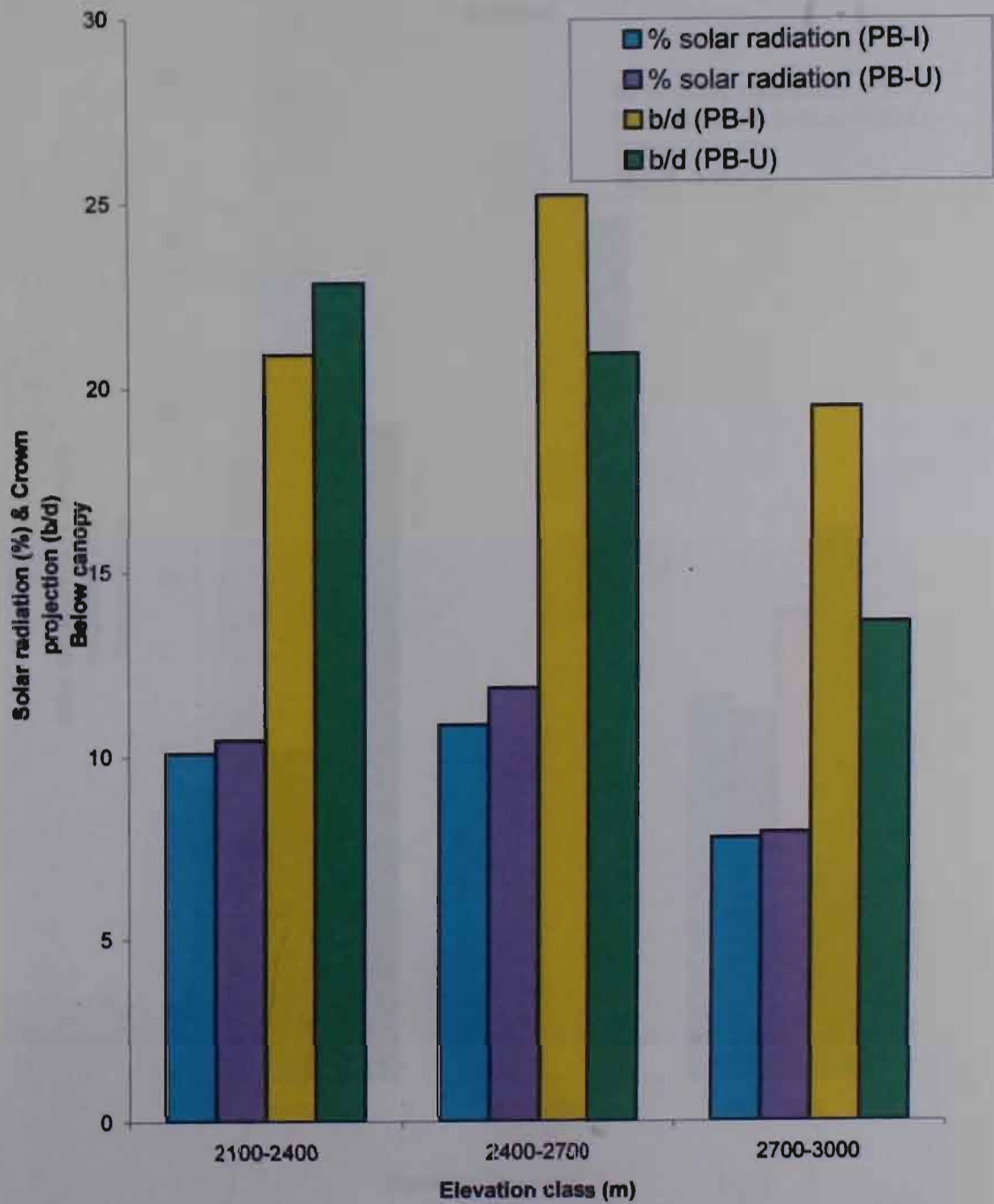
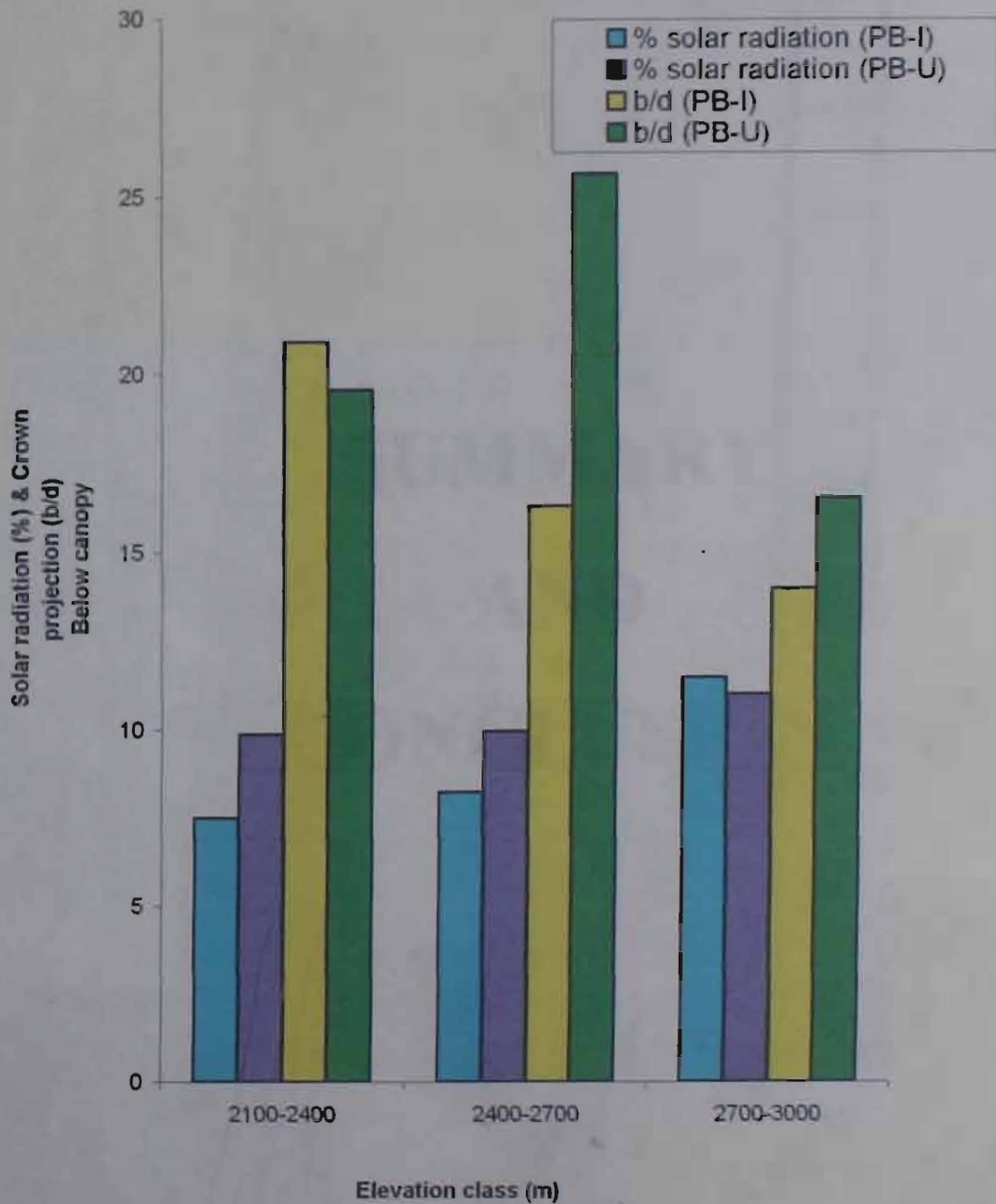
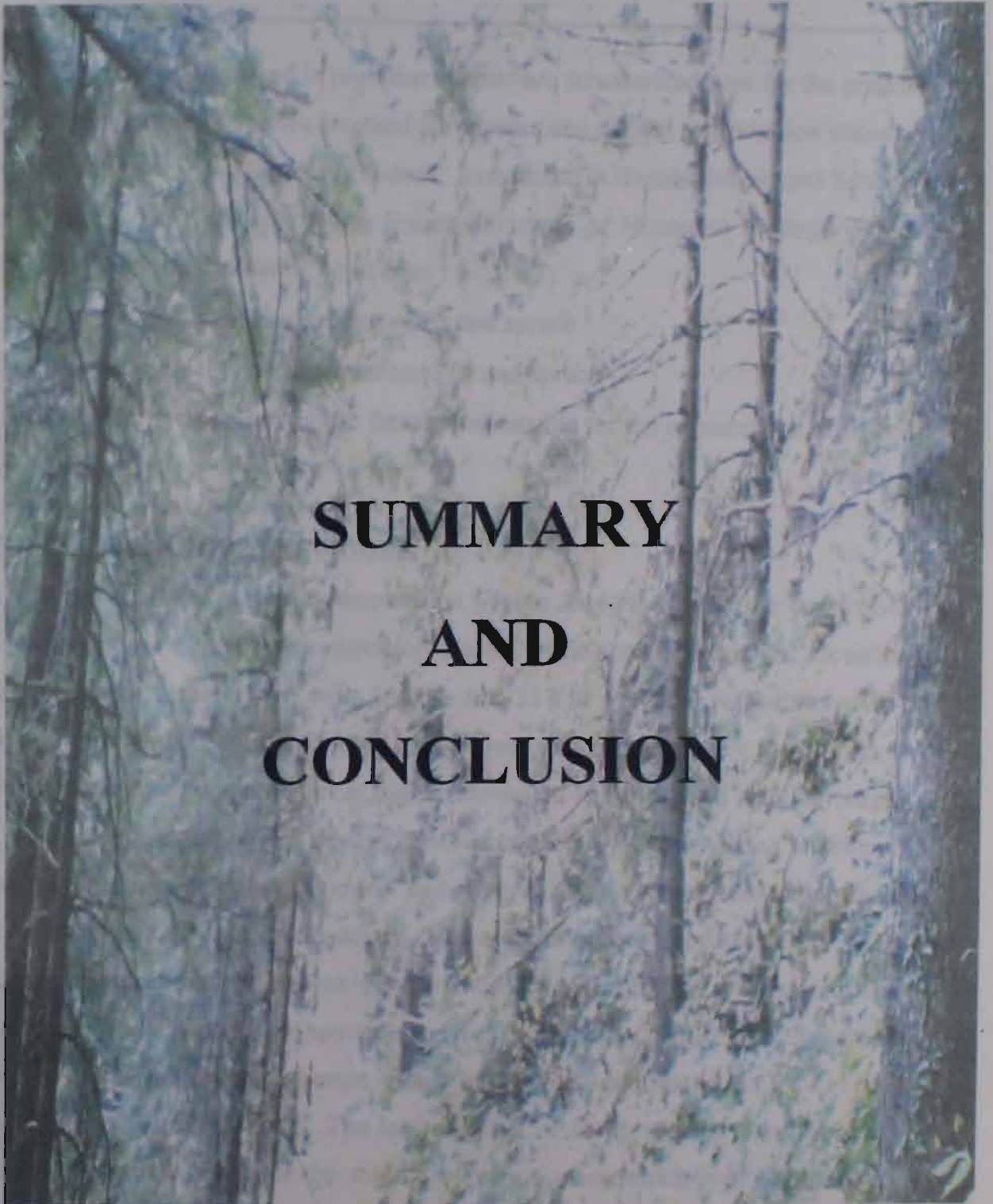


Fig. 4. Percentage solar radiation and Crown projection ratio w.r.t. Elevation change (Kotkhai)



CHAPTER - VI

SUMMARY AND CONCLUSION



**SUMMARY
AND
CONCLUSION**

Chapter - VI

SUMMARY AND CONCLUSION

The results discussed in previous chapter are summarized here for the present investigation entitled “Studies on stand parameters and natural regeneration status of silver fir and spruce in Himachal Pradesh”, conducted in Bashla, Jubbal and Kotkhai forest ranges of Rohru and Theog Forest Divisions of Himachal Pradesh during 2004-2005, with the following objectives :

- To study stand characteristics of fir and spruce
- To study the regeneration status of fir and spruce
- To identify the site specific factors responsible for the regeneration of fir and spruce

PHYTOSOCIOLOGICAL STUDIES

The results of floristic composition (Table 2-16) indicated the dominance of *Abies pindrow* on the lower elevation classes while spruce on highest elevation class in Bashla forest range with 135.23 and 217.32 of IVI, respectively. The variation may be due to microclimatic conditions and poor exposure to sunlight at lower elevation and created gaps at higher elevation. In Jubbal and Kotkhai ranges the lower elevation class was devoid of *Abies pindrow*, whereas *Picea smithiana*, *Pinus wallichiana*, *Cedrus deodara* and *Quercus spp.* were among dominant species at lower and middle elevations. However, at highest elevation class *Abies pindrow* was dominating in both PB-I and PB-U in Jubbal as well as Kotkhai forest range. In case of PB-I *Quercus spp.* were dominating (126.29) in the lowest elevation range in Kotkhai, whereas, *Pinus wallichiana* dominated the PB-U areas with highest IVI value 213.10. The least number of shrub species were recorded i.e. 2 in PB-I in Kotkhai for the middle elevation class which was attributed to poor light and growth conditions. However, the maximum number of shrubs i.e. 11 was recorded in Bashla forest range in the lowest elevation class. On the basis of IVI value for shrubs *Sarcococca saligna* was found dominant in lowest elevation

in Bashla forest indicating favourable conditions for the growth of deodar but the presence of *Abies pindrow* was maximum, whereas, in upper elevation *Rosa macrophylla* was dominant followed by *Viburnum cotinifolium*. However, in Jubbal *Viburnum cotinifolium* was dominant in middle and highest elevation under PB-I and PB-U, respectively followed by *Rosa macrophylla*.

In Kotkhai *Viburnum cotinifolium* was dominant at lower and middle elevation in PB-I but in highest elevation of PB-U, which is indicative of favorable conditions for the growth of these species. Among 28 herb species in this forest *Viola pilosa* was dominating followed by *Fragaria vesca* and *Perotis latifolia*. But from 2400 m to 3000 m i.e. in two elevations (2400-2700 m & 2700-3000 m) *Fragaria vesca* was the dominant species with IVI value of 72.45 and 52.92, respectively.

For PB-I and PB-U areas in Jubbal forest range recorded number of herb species was 26 and 23 in middle elevation class. *Cyperus aristatus* was found to be dominant in lowest elevation class, whereas, in middle and highest elevation class *Fragaria vesca* was dominating in both periodic blocks. In Kotkhai, the elevation classes 2700-3000 m in PB-U the number of herbaceous species was higher (28) among all the elevations and periodic blocks, where the growth was unrestricted and conditions became favourable for the growth of herbaceous vegetation. The site was dominated by *Fragaria vesca* for PB-I in all elevation classes followed by *Bistorta spp.*, *Cyperus aristatus* and *Galium aparine* from lowest to highest elevation class, respectively. The similarity for trees between lower x middle and middle x highest elevation class was equal (66.67% and for lowest x highest elevation class was 61.54%. Among shrubs, it was maximum (95.24%) between lowest x middle elevation class and in case of herbs nearly equal similarity among the species present in the different elevations were observed in Bashla forest. In Jubbal similarity for all elevation was equal for trees, however, for shrubs and herbs minimum similarity of species was observed between lowest x highest elevation classes, whereas, maximum was between middle x highest elevation class for both shrubs and herbs.

The maximum similarity for tree vegetation in Kotkhai was recorded between middle x highest elevation class. However, overall similarity of the area for trees, shrubs and herbs was above 66.67%, which indicates uniform distribution of the vegetation. The conditions of overlapping composition of the vegetation and similar climatic conditions give higher similarity in vegetation.

The diversity in species based on composition of trees, shrubs and herbs in different elevation classes and management system. On an average the diversity index value was least in the trees which was followed by shrubs and herbs in increasing order in all the sites.

STAND CHARACTERISTICS

The growth and standing volume of fir and spruce among different stands (Table 23-27) showed increasing trend in average diameter, average height, average crown width with increase in diameter for all the diameter classes i.e. maximum value for highest diameter class in each site. In Bashla forest range trees were found in diameter classes ranging from 10-20 cm to 100 cm & above, in Jubbal forest range from 10-20 to 80-90 cm, whereas, in Kotkhai range, trees from 10-20 cm to 60-70cm diameter class were present in all the elevation classes (3 classes) ranging from 2100-3000 m above mean sea level. However, some of different classes were absent in the stand.

In general the total number of trees of fir and spruce increased with increase in elevation class from lowest to highest (Table 23-27), which resulted an increase in per cent crown cover except in Bashla for middle elevation class. In addition, there was an increase in total basal area of fir and spruce as we move up from lower elevation to highest elevation class. Among all the sites and available periodic blocks maximum basal area of 90.65 m²/ha was recorded in PB-U of Jubbal forest range at an elevation of 2700-3000 m. The total standing volume of fir and spruce followed the same trend as that of basal area. The volume increased with increase in

average diameter, average height and number of trees from lowest to highest elevation class.

REGENERATION AND SITE FACTOR STUDIES

The results of regeneration site factor studies of fir and spruce forests summarized from table 36-40 and the regeneration in these forests was found poor in all the sites in Bashla 33.11 % regeneration stocking was observed in middle elevation class. The maximum stocking of established regeneration of 36.99 % in PB-U of Jubbal forest range at an elevation class of 2100-2400 m, where the major contribution was of *Pinus wallichiana* (25.47%), followed by 35.31 % in PB-I in middle elevation. Whereas, in maximum regeneration (33.59) was found for PB-U in Kotkhai. Among three elevation classes minimum regeneration was recorded in highest elevation class for all the sites. The stocking of established regeneration was less than 15% of all the tree species, where the thick layer of organic matter was present ranging from minimum 7.25 cm in Kotkhai forest range (PB-U) to 11.50 cm in Jubbal forest range (PB-U) in highest elevation class. The crown projection for fir and spruce ranged from 13.59 in PB U at highest to 28.52 for PB-I in Jubbal at middle elevation, which indicated the open spaces for good crown development. While, for associated species minimum crown projection was recorded 12.26 in PB U areas of Kotkhai range at lowest elevation class to maximum 27.74 in Bashla range in middle elevation.

The pH value was acidic in fir and spruce forests in all sites and elevations (Table 28 to 30). The value of pH ranged from 6.12 at 2700-3000m elevation in Jubbal for PB-I to highest 6.65 for PB-U for Kotkhai range at highest elevation. The percentage solar radiation showed positive impact on regeneration in general. The regeneration was more with higher percentage of solar radiation up to middle elevation. The lower amount of solar radiation also had impact on the presence of *Abies pindrow* at lower elevation with regard to its associates which occupy otherwise lower heights.

COCLUSION

The present Investigation entitled "Studies on stand parameters and natural regeneration status of silver fir and spruce in Himachal Pradesh" can be concluded as:

- The phytosociology of the area revealed that among trees fir and spruce dominated most of the sites followed by Kail and deodar.
- The most dominant shrub species recorded for different stands in the present studies were *Rosa macrophylla*, *Cotoneaster bacillaris*, and *Viburnum cotinifolium*.
- In case of herb *Fragaria vesca* dominated most of the sites with maximum IVI value, the other species which were found in dominant form were *Trifolium pratense*, *Cyperus aristatus* and *Viola* spp.
- The maximum similarity for trees was observed between highest x middle elevation in Kotkhai, for shrubs in lowest x middle elevation class in Bashala and for herbs in middle x highest elevation in Kotkhai. Similarity index value was more than 60 per cent for all trees, shrubs and herbs indicating comparable uniformity in the vegetation.
- The maximum diversity for tree was observed in Kotkhai at an elevation of 2400-2700 m in PB-I, for shrubs and herbs in Bashla for lowest and highest elevation class.
- With increase in elevation class there was increase in number of trees, total basal area, total volume and crown cover of the trees of fir and spruce which is indicative of optimum condition at higher elevation better growth of fir and spruce forests.
- Age have profound effect on diameter of trees as it was observed that higher density of tree resulted in less then expected diameter. Reverse was true in case of sparse vegetation for both the species.

- The per cent solar radiation increased with decrease in crown cover at lower elevations resulted in higher crown projection ratio. Whereas, organic matters layer increased with increase in elevation.
- At highest elevation, the established stocking percentage for regeneration was scanty while the middle elevation supported regeneration of fir and spruce.
- The regeneration of associated species of fir and spruce showed increasing trend with the increase in their respective crown projection ratio.



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Chapter - VII

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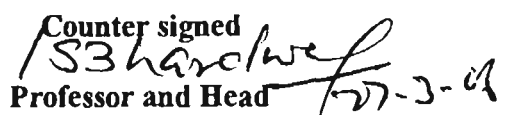
Title of Thesis	:	Studies on stand parameters and natural regeneration status of silver fir and spruce in Himachal Pradesh
Name of the Student	:	Yashpal Sharma
Admission Number	:	F-2003-12-M
Major Advisor	:	Dr. N.K. Gupta
Major Field	:	Silviculture
Minor Field (s)	:	i) Tree Improvement ii) Soil science
Degree Awarded	:	M.Sc. Silviculture
Year of Award of Degree	:	2006
No. of Pages in Thesis	:	83 + II
No. of words in Abstract	:	419

ABSTRACT

The present investigation entitled "Studies on stand parameters and natural regeneration status of silver fir and spruce in Himachal Pradesh" was carried out in Bashla, Jubbal and Kotkhai forest ranges (District Shimla) of Himachal Pradesh from 2100-3000 m a.m.s.l. In the study three plots of 20m x 20m were taken for trees at three elevation class i.e. 2100-2400 m, 2400-2700 m and 2700-3000 m in each stand and within which 5 quadrates of 5 m x 5 m, 12 quadrates of 1 m x 1 m and 9 quadrates of 2 m x 2 m were selected for the study of shrubs, herbs and regeneration. The floristic composition studies revealed that among trees *Abies pindrow* and *Picea smithiana* dominated most of the sites. The maximum dominance of *Abies pindrow* (261.05 IVI) and *Picea smithiana* (217.32 IVI) was found, at highest elevation of Jubbal forest range in PB-U and Bashla forest range, respectively. The dominant shrub species in study area were *Sarcococca saligna*, *Rosa macrophylla*, *Berberis aristata*, *Lonicera angustifolia* *cotoneaster bacillaries*, *Viburnum cotinifolium*, while for herbs most dominant were *Fragaria vesca*, *Trifolium pratense* and *Cyperus aristatus*. The similarity index value was more than 60% for all the three components (tree, shrubs and herbs) indicating uniformity in vegetation. The maximum diversity was observed between herbs followed by shrubs and trees. The result obtained for various fir & spruce parameters viz., average diameter, average height, average crown width showed increasing trend from lower to higher diameter classes in all sites. The presence of trees in different elevation classes showed increasing trend from lower to highest elevation. The maximum number of fir and spruce trees 575/ha were found in PB-I at highest elevation class in Jubbal. Total basal area, volume and crown cover also showed increasing trend from lowest to highest elevation class. Maximum basal area (90.65 m²/ha) and volume (1044.53 m³/ha) was found in highest elevation class of Jubbal forest in PB-I. The regeneration increased with increase in elevation, total radiation, crown projection ratio and normal (about 100%) crown cover. The low regeneration was obtained at highest elevation where there was thick layer of organic matter and higher light intensity. The higher projection ratio of associated species resulted in better regeneration. The over all regeneration status of these forests was less than 36 % showing the general trend of regeneration as *Pinus wallichiana* > *Picea smithiana*. Whereas the regeneration of *Abies pindrow* was poor and that can be due to the non fulfillment of the optimum requirements for the regeneration of the species at higher elevation.

Signature of Major Advisor


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Marital status Single

Personal profile

I am reliable, well organized and used to working on my own initiative. I am able to prioritize my workload. I am comfortable working on my own or as part of team.

Education

Year	Certificate / degree
Jan 2003	B.Sc. in Forestry from Dr Y.S. Parmar University of Horticulture and Forestry, Solan (H.P.)
March 1997	Senior Secondary (plus two) from H.P. board
July 1995	Matriculation (I.C.S.E. Board)

Whether sponsored by some state / Central Govt./Univ./SAARC : No

Scholarship/Stipend/Fellowship, any other financial assistance received during the study period : M.Sc. - University Stipend


(Yashpal Sharma)



APPENDICES

Appendix- I

Projected age for different diameter class in Bashla, Jubbal and Kotkhai ranges

DBH Class	Age (years)		
	Bashla	Jubbal	Kotkhai
	<i>Abies pindrow</i>		
10-20.	43.08	46.81	52.59
20-30	57.78	71.51	63.59
30-40	72.48	96.21	74.59
40-50	87.18	120.91	85.59
50-60	101.88	145.61	96.59
60-70	116.58	170.31	107.59
70-80	131.28	195.01	118.59
80-90	145.98	219.71	129.59
90-100	160.68	244.41	140.59
	<i>Picea smithiana</i>		
10-20.	41.06	34.16	36.47
20-30	54.06	51.46	48.47
30-40	67.06	68.76	60.47
40-50	80.06	86.06	72.47
50-60	93.06	103.36	84.47
60-70	106.06	120.66	96.47
70-80	119.06	137.96	108.47
80-90	132.06	155.26	120.47
90-100	145.06	172.56	132.47

Regression equation and R^2 values used for tree age in Bashla, Jubbal and Kotkhai ranges

Abies pindrow

Bashla $y = 21.03 + 1.47x$ and $R^2 = 0.896$

Jubbal $y = 9.67 + 2.47x$ and $R^2 = 0.827$

Kotkhai $y = 36.09 + 1.10x$ and $R^2 = 0.838$

Picea smithiana

Bashla $y = 21.56 + 1.30x$ and $R^2 = 0.873$

Jubbal $y = 8.21 + 1.73x$ and $R^2 = 0.915$

Kotkhai $y = 18.47 + 1.20x$ and $R^2 = 0.838$

Where,

y = tree age (dependent variable)

x = diameter at breast height (independent variable)

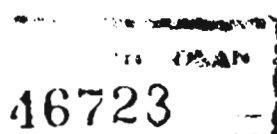
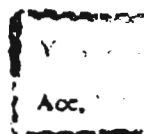
a = y-intercept

b = slope of the line

Appendix- II

Total number of species for trees shrubs and herbs in Bashla, Jubbal and Kotkhai forest ranges at different elevation classes and available periodic blocks

Bashla forest range						
Component	Elevation class					
	2100-2400 m		2400-2700 m		2700-3000 m	
Trees	8		4		5	
Shrubs	11		10		6	
Herbs	28		32		31	
Total	47		46		42	
Jubbal forest range						
Component	Elevation class					
	2100-2400 m		2400-2700 m		2700-3000 m	
	PB-I	PB-U	PB-I	PB-U	PB-I	PB-U
Trees	3	3	4	5	3	2
Shrubs	7	8	6	4	6	4
Herbs	18	18	26	23	19	22
Total	28	29	36	32	28	28
Kotkhai forest range						
Component	Elevation class					
	2100-2400 m		2400-2700 m		2700-3000 m	
	PB-I	PB-U	PB-I	PB-U	PB-I	PB-U
Trees	5	3	7	3	2	6
Shrubs	5	4	2	6	5	6
Herbs	21	23	20	24	19	28
Total	31	30	29	33	26	40



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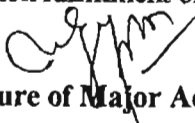
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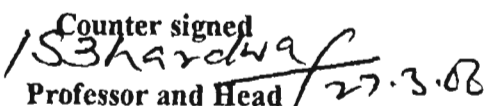
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