STRUCTURAL AND FUNCTIONAL STUDIES OF WOODY ELEMENTS OF BETULA FOREST IN SANGLA VALLEY OF HIMACHAL PRADESH

Thesis

by

AASIF ALI

Submitted in partial fulfilment of the requirements for the degree of

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COLLEGE OF FORESTRY
Dr Yashwant Singh Parmar University
of Horticulture and Forestry, Nauni
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2011

FRONTISPIECE

Betula utilis

DEDICATED

TO

MY PARENTS

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CERTIFICATE-I

This is to certify that the thesis entitled, **"Structural and Functional Studies of Woody Elements of Betula Forests in Sangla Valley of Himachal Pradesh"**, submitted in partial fulfilment of the requirements for the award of degree of **DOCTOR OF PHILOSOPHY** in **FORESTRY (TREE IMPROVEMENT AND GENETIC RESOURCES)** to Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.) is a record of bonafide research work carried out by **Mr. Aasif Ali (F-2007-03-D)** under my guidance and supervision. No part of this thesis has been submitted for any other degree or diploma.

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

Place: Nauni, Solan **(Dr. Rajan Bawa)**
Dated: **Chairman**
Advisory Committee

CERTIFICATE-II

This is to certify that the thesis entitled, **"Structural and Functional Studies of Woody Elements of Betula Forests in Sangla Valley of Himachal Pradesh",** submitted by **Mr. Aasif Ali (F-2007-03-D)** to Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.), in partial fulfilment of the requirements for the award of degree of **DOCTOR OF PHILOSOPHY** in **FORESTRY (TREE IMPROVEMENT AND GENETIC RESOURCES)** has been approved by the Student's Advisory Committee after an oral examination of the same in collaboration with the external examiner.

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This is to certify that all the mistakes and errors pointed out by the external examiner have been incorporated in the thesis entitled, **"Structural and Functional Studies of Woody Elements of Betula Forests in Sangla Valley of Himachal Pradesh",** submitted to Dr Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.) by **Mr. Aasif Ali (F-2007-03-D)** in partial fulfilment of the requirements for the award of degree of **DOCTOR OF PHILOSOPHY** in **FORESTRY (TREE IMPROVEMENT AND GENETIC RESOURCES).**

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(In the name of Allah, the most Beneficent and the most Merciful)

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Needless to say errors and omissions are mine.

Place : Nauni, Solan
Date : July 21 , 2011 **(Aasif Ali)**

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Chapter-1

INTRODUCTION

The evolution of man has been in-extricably linked with the tangible and intangible benefits flowing from forests. However, the focus of attention has always remained on material benefits from the natural resource. The phenomenal pressure of ever rising population, urbanization and industrialization has resulted in over exploitation of the natural forests, reducing the forest cover of India from about 40 per cent in 1952 to 23.84 per cent at present (Anonymous, 2009). This is markedly low as we need to have at least 33 per cent forest cover in the country as per National Forest Policy, 1988. The rate of deforestation is as high as 2.8 per cent, which is quite high as compared to 0.007 per cent per annum recorded for the past century (Anonymous, 1999). The situation of forest resource in Himachal Pradesh is no different. The total geographical area of state is about 55,673 km^2 of which the total forest cover is 27.50 per cent (15,306 km^2) as against the required 66 per cent recommended by National Forest Policy for the hilly areas (Anonymous, 2009).

Indian Himalayas spreads approximately 2,500 km from northwest to southeast along with its extension in northeastern parts of India with a breadth ranging from 250 to 450 km. The impact of terrain, diversity and altitudinal variation with concurrent changes in temperature and precipitation has created unique ecosystems of diverse habitats and species association, one of the richest in the world. The ecological changes and diversity at any place in the Himalayas is determined by the interactions of vertical, transverse and longitudinal axis (Gaston *et al.*, 1981). The vertical axis by the altitude is dependent on the effect of temperature and moisture, the traverse axis cutting across the main land is determined by topography causing decreased annual precipitation and extreme temperature fluctuations between front and inner ranges. The longitudinal axis parallel to the ranges is determined by a general geographical trend of decreasing monsoon precipitation and increasing winter snowfall from southeast to northeast. A greater variation in aspect, slope and altitudinal zonation has resulted in abrupt changes in plant communities and as such, small areas may comprise a variety of habitat types (Verma, 2000).

Biodiversity has become more and more popular topic within the discussion of sustainability in the last decade, though the maintenance of diversity of forest ecosystems requires many years, especially stressed upon even in the Rio declaration and renewed by the Lisbon conference in 1998. Biodiversity is the sum total of plants, animals and microorganisms existing as an interacting system in a given habitat. It exists on earth in eight broad realms with 193 biogeographical provinces (Udvardy, 1984). Each geographical province is composed of ecosystems which are constituted by communities of living specks existing in an ecological region. At the global level about 16,04,000 species of plants, animals and microorganisms have been described so far. However, it is estimated that there are around 17,98,000 species (WCMC, 1992). These species exist on land, fresh water and in marine habitats or occur as symbionts in mutualistic and in parasitic state with other organisms. Biodiversity can be assessed at three broad levels, viz., genetic variation with in species (number of individuals with in a species), the variety of species with in a habitat and the variety of habitats on ecosystems or planet (Flint, 1991). Since biodiversity functions at different levels and on it depends the stability of climate, water, soil, air and over all health of the biosphere at large, it is also the source of species on which human race depends for food, fodder, fuel, fiber, shelter, medicines, etc.

Phytosociology basically deals with the study of composition, distribution, development of vegetation and environmental relationships of plant communities (Brenner, 1952; Christensen *et al.*, 1959 and Hofmann, 1999). Plants typically occur together in repeating groups of associated plants called communities and are best described by observing the identity and growth form of the most abundant and the largest species or the most characteristic species of the particular community (Tansley, 1935 and Whittakar, 1970). In geo-botany, phytosociology is also known as sociologic geo-botany, vegetation science, plant sociology or synecology (community ecology). No doubt the species diversity is higher in the rain forests and there are far more species per unit area in total in the tropics, yet the Himalayan environment is more diverse at levels of biological organization higher in species, genera, family, habitats and ecosystems. Perhaps no other life zone contains so much variation between habitats and ecosystem (Beta diversity) as the Himalayas. It has a striking zonation of natural vegetation besides occurrence of endemic species found occurring with in narrow ranges. The occurrence of species in narrow ranges is more pronounced due to micro-variations in altitude, climate, soil and vegetation over very short distance.

The two major aspects of an ecosystem are, the structure and the function. By the structure we mean (i) the composition of the biological community including species, number, biomass, life history and distribution in space etc., (ii) the quantity and distribution of the non-living materials, such as nutrients, water etc., and (iii) the range, or gradient of the conditions of the existence, such as temperature, light etc. By function we mean (i) the rate of biological energy flow i.e., the production and respiration rates of the community, (ii) rate of materials or nutrient cycles, and (iii) biological or ecological regulation including both regulation of organisms by environment (photoperiodism etc.) and regulation of environment by the organism, (nitrogen fixing organisms etc.). Thus, in any ecosystem, structure and function (rate function) are studied together.

Betula utilis D. Don., commonly known as birch in English and Bhojpattar in Hindi belongs to family Betulaceae. It is a moderate sized deciduous tree up to 20 m tall or often mere shrub on higher elevations forming the upper most limit and successional climax of the vegetation in tree line. The bark is smooth, reddish brown with whitish, linear, horizontal, lenticles, which was used as paper in China. Leaves are stalked, 5 to10 cm long, ovate, unequally serrate, acute, slightly hairy along the mid ribs. The tree is found in higher reaches of the inner Himalayas starting from Bhutan westwards, chiefly at an altitude between 3,000 to 4,500 m amsl. But sometimes it descends sporadically as low as 2,500 m and even 2,000 m in the Kishenganga valley of Kashmir (Troup, 1921). Northwards, it extends to China and western Tibet. It is usually found associated with *Abies pindrow, Quercus semecarpifolia, Pyrus lanat* and *P. foliolosa*. It has a gregarious growth nature and makes the upper limit of tree vegetation on the uplands of the inner western Himalayas below the snow line begins. The birch forests occur on open exposed tracts which are under snow throughout the greater part of the winter. It is the only broadleaved angiosperm tree species in the Himalayas which dominates an extensive area at subalpine altitudes (Zobel and Singh, 1997). *Betula* spp. possess high freezing tolerance (Sakai and Larcher, 1987) which enables them to form tree line in the Himalayas (Zobel and Singh, 1997 and TISC, 2002) as well as in the Scandinavian region (Cairns and Moen, 2004). The tree is a strong light demander. The young crops spring upon bare ground exposed by the scouring of snow or on the accumulation of earth and rock debris. The birch forests themselves are subjected to constant erosion and scouring by snow and the upper reaches of the snow-fed torrents are often piled up with the white trunks of the birch trees, which have been swept down by the sliding and melting snow. In some localities extensive damage is done to the birch forests by nomadic graziers and local residents, who lop and fell the tree for fodder and fuelwood and have been responsible for the clearance of large tracts of forests. The excessive striping of the bark for decorative paper making and other purposes also accounts for the death of many trees.

The betula has poor survival due to biotic interference like grazing, and trampling, infrequent seed years, accumulation of humus and weed growth, etc. Furthermore, the slow initial growth hampers its establishment and development in the natural habitat, threatening the very existence of species in this country. Management and improvement of the existing stock thus requires the knowledge of population structure, composition and regeneration potential of species for its overall growth and development.

Keeping in view the ecological importance, the present investigation entitled, "Structural and Functional Studies of Woody Elements of Betula Forests in Sangla Valley of Himachal Pradesh", has been carried out with the following main objectives:

i) To study the structural parameters.
ii) To evaluate the functional aspects.
iii) To study the soil characteristics.
iv) To study the natural regeneration status of *Betula utilis*.

Chapter-2

REVIEW OF LITERATURE

The information pertaining to the present study has been reviewed in the light of work done on various high altitude species in India and abroad. The important information and investigations related to present work has been described in this chapter under the following main headings:

- Phytosociological studies
- Phenological studies
- Natural regeneration studies

2.1 Phytosociological Studies

Phytosociology basically deals with the study of composition, distribution, development of vegetation and environmental relationships of plant communities (Brenner, 1952; Christensen *et al.*, 1959 and Hofmann, 1999). Plants typically occur together in repeating groups of associated plants called communities and are best described by observing the identity and growth form of the most abundant and the largest species or the most characteristic species of the particular community (Tansley, 1935 and Whittakar, 1970). In geo-botany, phytosociology is also known as sociologic geo-botany, vegetation science, plant sociology or synecology (community ecology).

Dhaulkhandi *et al.* (2008) reported the regeneration potential and community structure of natural forest site in Gangotri, Uttarakhand. A total of seven tree species were recorded from the site. Among the trees, *Picea smithiana* was the dominant and *Cedrus deodara* was found as the co-dominant species. However, the highest (240 trees/ha) density was reported for *Pinus wallichiana*, while least number of individuals (30 trees/ha each) were recorded for *Acer caesium* and *Pinus wallichiana*. In tree layer, most of the species (65.16%) were distributed contagiously and few (34.84%) were distributed randomly. However, none of the species showed regular distribution pattern. They also reported that as far as regeneration status was concerned, 71.4 per cent species showed good regeneration, 14.3 per cent species were facing the problem of poor regeneration, while only 14.3 per cent species were not regenerating properly.

Kumar and Thakur (2008) studied the effect of forest fire on woody vegetation and regeneration behaviour in chir pine (*Pinus roxburghii*) forest in Solan Forest Division of H.P. Fire affected sites were surveyed for floristic composition, density, basal area, importance value index (IVI), abundance frequency ratio (A/F), Shannon Weaver Index, Simpson's Index of dominance (Cd), species richness (d), Sorenson index (S) and natural regeneration potential of tree and shrubs. Fire resistant species were observed more in selected chir pine forests. No consistent trend was observed for density, basal area, IVI, H', Sorenson's Index of Similarity between fire affected and control sites for trees. Density and basal area in fire affected sites were lesser than control sites for shrubs.

Rohit and Neelam (2008) investigated the population size, dominance and the diversity of tree species of Akashkamini valley. Four forest stands within an altitudinal range of (1500-1800 m) were selected for the study. The study reveals that *Quercus leucotricophora* was the most dominant species of stand I (1500 m) and stand IV (1800 m) with maximum IVI values of 137.94 and 57.88, respectively. Maximum population size (863 trees/ha) was recorded in stand I (1500 m) for the tree species *Quercus leucotricophora*. The total basal area varied between 16.15 to 41.51 m^2/ha. Shannon Wiener diversity index ranged between 1.35 to 1.98. Concentration of dominance showed inverse trend to diversity index. D-D curves showed log normal distribution irrespective of sites and growth forms.

Dwivedi *et al.* (2008) carried out phytosociological investigations of a community managed forest in a micro watershed located in the Western Himalayas to analyze the composition of trees on different topo sequences. *Grewia optiva* was found widely distributed and dominating at hill top and valley sites with IVI of 12 and 52.58, respectively, whereas *Bauhinia veriegata* with IVI value of 13.47 on hill slopes. The highest relative density values were also recorded by *Grewia optiva* on hill top (18.58) and valley sites (20.58) and *Bauhinia variegata* on hill slopes (15.79). On the whole, species diversity was higher on slopes (2.98) as compared to valley areas (2.68) and hill top (2.62). The overall dominance of *Grewia optiva* and *Bauhinia veriegata* in community managed micro watershed in the region is because these trees are used for fodder and hence propagated and protected too.

A phytosociological study was made by Anup and Sharma (2008) of *Populus euphratica* community in the Trans Himalayas of Ladakh, Jammu and Kashmir. The vegetation forms a high altitude riverine forest with low species diversity (H'=0.8569) and high concentration of dominance (Cd=0.5162). In the upper layer *Populus euphratica* dominated the association with importance value index (IVI) of 219.26, while in the middle layer *Berberis ulicina* was the dominant species (IVI=57.33).

Verma *et al*. (2008) evaluated the plant diversity and growth forms in alpine pasture of Talra Wildlife Sanctuary of District Shimla, Himachal Pradesh, India during August 2003. A total of 75 species of plants, comprising of 7 grasses, 4 sedges, 4 leguminous forbs and 60 non-leguminous forbs were recorded from the area. On the basis of importance value index (IVI), *Sibbaldia cuneata* was found to be the dominant species followed by *Geum elatum, Ligularia amplexicaulis, Primula denticulata* and *Saxifraga parnassifolia*. The distribution of all the plant species was contagious. The index of dominance was 0.036 and the index of diversity was 5.386. The contribution of tall forbs, short forbs, cushioned and spreading forbs in the alpine pasture was 29.33, 54.66 and 16.0 per cent, respectively.

A study was conducted by Thakur *et al.* (2007) in the zone of occurrence (900-2200 m amsl) in three elevation ranges of chir pine (*Pinus roxburghii*) forests in Himachal Pradesh. The results revealed that lower Himalayan chir pine forests showed less diverse tree species, having *Quercus leucotrichophora* as the dominant followed by *Pyrus pashia*. More diversity in the case of shrubs as compared to that of the Shiwalik chir pine forest was observed. The results of this study revealed that floristic dynamics, dominance and the distribution of woody species changed with the change in aspect and altitude.

The Nubra valley of Ladakh (Jammu and Kashmir) constitutes a part of the Indian cold desert in Trans Himalayas. The life forms of the flora of Nubra valley (including pteridophytes, gymnosperms and angiosperms) belonging to 65 families, 257 genera and 439 species have been studied. The biological spectrum has been compared with that of Raunkiaer's normal spectrum. Therophytes were found to have the highest percentage of species in the area. The thero-hemi-cryptophytic phytoclimate of the area is characteristic of cold alpine zones (Nagar and Ahmed, 2007).

Lanker (2007) studied edapho-ecological characteristics and regeneration status of yew in Kotgarh, Chopal and Theog Forest Divisions of Himachal Pradesh. The floristic study revealed that among trees, *Picea smithiana* and *Abies pindrow* dominated in most of the sites, while among shrubs, *Viburnum continifolium, Rosa macrophylla, Cotoneaster bacillaris* and *Berberis aristata* were the major species. Similarly, Sharma (2006) found that maximum dominance of *Abies pindrow* (261.05 IVI) occuried at high elevation of Jubbal Forest (PB-U) and Bashla Forest.

A study by Pant and Samant (2007) conducted in biodiversity rich Mornaula Reserve Forest between an altitude range of 1,500 to 2,200 m amsl to analyse the structure, composition of the forest communities including richness of economically important, native, endemic and rare-endangered species to prioritize communities for conservation. A total of 123 sites were sampled. For each site, habitat characteristics, altitude and dominant species have been given. From the sampled sites, 289 species (37 trees, 37 shrubs and 215 herbs) and 31 forest communities have been recorded. The density of trees ranged from 340 to 2,438 individuals/ha and total basal area from 19.52 to 234.31 individuals/m^2. The densities of saplings ranged from 340 to 2,277 individuals/ha and seedlings 266 to 1,571 individuals/ha; shrubs 357 to 1,156 individuals/ha and herbs 21.73 to 431.04 individuals/m^2. The richness of the trees ranged from 3 to 27, shrubs 8 to 36, herbs 17 to 145, seedlings 3 to 22 and saplings 2 to 21. Species diversity for trees ranged from 0.99 to 2.93, for seedlings 0.86 to 2.65, for saplings 0.44 to 2.78, in case of shrubs 1.94 to 4.43 and for herbs it was between 1.42 to 4.66. These recorded values were almost comparable with the studies conducted in sub-tropical, temperate and sub-alpine regions of the western Himalayas. In some cases the values were slightly higher than the reported values. The communities have been prioritized for conservation based on the species richness, nativity, endemism, economically important and rare-endangered species. Among, all the prioritized communities, *Rhododendron arboreum* community supported maximum species including native, endemic, economically important and rare-endangered species. In view of the high socio-economic and conservation values of the identified communities, monitoring of these communities at least for a period of five years and development of appropriate strategy and action plan for the conservation and management have been suggested.

Sati (2006) examined the forest diversity and degradation of forest in the Pindar Basin of Uttaranchal Himalaya and suggested the management of forest resources in the fragile mountain terrain, as sustainable management schemes for forests have become increasingly important and timely, because these areas have come under serious exploitation and constant threat of disintegration, following the depletion of forest. The natural hazards and man-induced activities, both were equally responsible for depletion of forest in mountain areas, while the mountains supported the highest biodiversity of fauna and flora. In the Pindar Basin, four zones of forests exist according to altitudes. These zones are characterized by eucalyptus and *Dendrocalamus* spp in the low lying region, pine trees in the mid altitude, coniferous forests along with oak in the temperate zone and extensive alpine meadows. The basin is rich in forest resources particularly in temperate coniferous forest. Proper management of forest could not take place due to high inaccessibility of forest cover areas on the one hand and over utilization of forest resources, on the other.

Fortney (2006) revealed that plant communities in West Virginia wetlands were highly diverse because of variability in topography, substrate characteristics and water quality. Forested communities were commonly associated with streams and rivers as either bottomland overflow or swamp wetlands. While *Acer saccharinum* and *A. negundo* were frequent dominants at low elevations. *Picea rubens*, *Tsuga canadensis* and *Betula allegheniensis* dominated the higher elevations.

Kala (2006) reported plant community composition and species diversity in the Valley of Flowers and Khiron Valley of the Uttarakhand Himalayas using stratified random quadrates of 0.25 m^2. TWINSPAN was used for identifying the plant communities and Shannon Wiener Index (H') was used for species diversity. The central valley portion in the Valley of Flowers that falls between 3,300 to 3,700 m elevations supported nine plant communities, whereas the Khiron Valley, located at similar elevation supported only seven plant communities. In the Valley of Flowers, species diversity was higher (H'=2.93) than the Khiron Valley (H'=2.77). Plant species diversity decreased with elevation in both protected and unprotected alpine meadows.

Joshi and Samant (2004) studied the buffer zone of Nanda Devi Biosphere Reserve. Seventy six woody species (trees: 24, shrubs: 52) and 13 forest communities have been recorded between 2,300 to 3,800 m amsl. Tree density ranged from 533 to 1,220 individuals/ha, tree basal area from 14.68 to 80.28 m^2/ha and shrub density from 1,490 to 6,695 individuals/ha. The mean density of trees was significantly lower in temperate forests in comparison to sub-alpine forests. Richness of trees ranged from 3 to 18 and for shrubs from 5 to 29. Species diversity (H') of trees ranged from 0.45 to 2.08 and shrubs from 0.90 to 3.14. In the temperate zone, species richness and altitude had significant positive correlations, whereas in the sub-alpine zone the two variables were negatively correlated. The native species were more in the area (>65% species) and in communities (>70% species) and was highest for the *Picea smithiana-Pinus wallichiana* mixed community, whereas the maximum numbers of natives and endemic species were recorded in the *Pinus wallichiana* community. The density and richness of non-natives were found to be significantly lower in comparison to the natives. Economic importance and conservation value of the communities were also assessed and communities prioritized.

Gautam and Webb (2001) on the other hand analyzed the effect of plantation size, aspect and canopy closure on species richness and stem density in pine species and concluded that natural forest had greater species richness and stem density than plantation. They also found that northern aspect plantation had greater richness and stem density than southern aspect plantations but the plantation size had no significant effect on diversity or stem density.

Similarly, Lee *et al.* (2000) investigated the vegetational composition of the central part of Taiwan from 2,500 m to 3,952 m amsl. The main vegetation types included alpine grassland, Taiwan hemlock (*Pinus taiwanensis*), Taiwan yew (*Taxus sumatrana*), Formosan red cypress (*Chamaeyparis formosensis*), Taiwan spruce (*Picea morrisonicola*), Taiwan fir (*Abies kawakamii*), high montain juniper

(*Juniperus squamata*) and alpine tundra. The dominant tree species was however, found to be Taiwan hemlock with DBH ranging from 5 to 230 cm and age between 20 to 950 yr.

Fischer (2000) surveyed the vegetation and phytosociological relations on calcareous steeps slopes in the northern lower Alps. The study revealed that beech trees formed the upper canopy, yew the secondary tree canopy and the ground strata was dominated by grass species. Shamet *et al.* (1999) on the other hand investigated structural and propagation aspects in *Taxus baccata*, a rare conifer found in fir-kharsu oak forests. The study revealed higher relative density (14.7), relative frequency (16.22) and relative basal area (3.0) in fir forest followed by kharsu-oak and deodar forests.

Bist (2000) attempts to show the impact of changes in forest cover in one of India's Biosphere Reserves - the Nanda Devi Biosphere Reserve. This reserve was constituted by the Government of India in February 1998 to conserve the biodiversity and integrity of plants, animals and microorganisms in their totality as part of the wider natural ecosystem to safeguard the genetic diversity of the species and to improve the socioeconomic conditions of the people living in and around the reserves. The vegetation analysis was based on visual interpretation of thematic mapper (TM) and ERS satellite imagery for the period 1988-96, which depicted that the forest cover has increased over the study period.

Chandra *et al.* (1999) while working on sub alpine forests reported that average tree density increases even with the altitudes, whereas average basal area and species diversity was found to decrease with increase in altitude. They attributed low tree density (288 trees/ha) and high basal area (49.7m^2/ha) to high biotic pressure in the area.

Hofmann (1999) described association tables, distribution, structure, floristic composition, site factors and phytogeography. The yew was here a tree of the thermophilous beech forests growing on limestone with its optimum in the Saslerio Taxetum, regarded as a regional association.

Singh (1998) conducted vegetational survey under two aspects in the Tirthan valley of Kullu district of Himachal Pradesh. The plant communities in the area were found to have a marked difference in the composition on two aspects. The northern aspect was dominated by *Abies pindrow, Picea smithiana* and *Cedrus deodara*, whereas the southern aspects were dominated by *Pinus wallichiana*, *Quercus semecarpifolia* and *Rhododendron arborium*. The density of *Abies pindrow* and *Picea smithiana* were higher on north facing slope than on southern aspect.

Similarly, Pandey and Joshi (1998) analyzed the phytosociology of forest stands located along an altitudinal gradient of 1,500 to 2,000 m amsl in the Kumaun Himalayas. Based on IVI values, chir pine, deodar mixed with chir pine, chir pine mixed with oak, oak and oak dominated mixed broad leaved communities were identified. Chir pine was the dominant species at lower altitudes on the eastern and southern aspects, while oak (*Quercus leucotrichophora*) dominated the higher altitudes of the northern aspect.

The species composition, distribution pattern, diversity, concentration of dominance and community coefficients of the forest vegetation were determined fewer than two aspects (north and south facing slopes) in the Tirthan valley, in Kullu district, Himachal Pradesh by Singh (1998). The plant communities in the area are representative of temperate and alpine regions and consist of oak (*Quercus* spp) and coniferous forests, high altitude mixed forests and alpine to sub-alpine pastures. There was a marked difference in the composition of tree, shrub and herbaceous species on the two aspects. The north facing slope was dominated by *Abies pindrow, Picea smithiana* and *Cedrus deodara*, whereas the southern aspect was mainly dominated by *Pinus wallichiana, Quercus semecarpifolia* and *Rhododendron arboreum*. The densities of

Abies pindrow and *Picea smithiana* were higher on the north facing slope than the southern aspect. The species diversity of north and south facing slopes were 0.638 and 0.208, respectively. Only a few genera were present on both the aspects including tree species of *Picea, Cedrus* and *Abies*.

Samant *et al*. (1998) studied the biodiversity of the Askot Wildlife Sanctuary in the Kumaun Himalaya and analysed the data for landscape, faunal and floral diversity. The forest and pasture land, ideal habitats for the flora and fauna, covered nearly 52 and 12 per cent, respectively, of the total area. Plant diversity was represented by 1,262 species of vascular plants (angiosperms 1112, gymnosperms 7, pteridophytes 143 taxa). Diversity of the species within families, genera, habitats, communities and along vertical gradient zones was also analysed. Maximum diversity existed in the family Orchidaceae (120 taxa), the genus Polystichum (13 taxa), the altitude zone of 1,001 to 2,000 m (860 taxa), the forest habitat (623 taxa) and the ban oak (*Quercus leucotrichophora*) community (92 taxa). Seventyone families were found to be monotypic. Similarity the species composition within the habitats indicated maximum similarity in areas of shrubberies and alpine meadows/slopes (71.65%) and exposed open/grassy slopes and shady moist places (47.32%). A total of 432 (34.2%) taxa are native to the Indian Himalayas, of which 24 are endemic and 235 are near endemic, with 65.8 per cent of taxa represented in the neighbouring areas and other regions of the globe. Ten taxa occurring in the Sanctuary area have been already recorded in the Red Data Book of Indian Plants.

Mehta *et al*. (1997) studied species composition, distribution pattern, diversity, concentration of dominance and community coefficient. In the shrub stratum, *Berberis asiatica* and *Rhus parviflora* dominated in burnt protected sites and within the shrubs *Berberis asiatica* was dominant on unburnt grazed and unburnt protected sites. The sapling stratum followed the opposite trend to the tree stratum.

Rikhari *et al.* (1997) on the other hand conducted studies on tree vegetation in a mixed oak forest in Kumaon Himalaya. The results revealed the dominance of *Quercus leucotrichophora* on eastern aspect and *Q. floribunda* on northwestern aspect. However, at hill base and eastern aspect, *Q. floribunda* remained as dominant, while in other stands of eastern aspect, *Q. leucotrichophora* showed dominance.

Similarly, Kaushal *et al*. (1996) revealed that the deodar tree parameters, viz., dbh, basal area, height, age, volume, MAVI and phytosociological attributes like tree, shrub and herb densities were comparatively higher at lower altitude than the upper altitudes.

Gupta (1996) on the other hand, worked on phytosociology, biomass and regeneration studies of fir-spruce forests at Chhachpur and Narkanda forests. It was found that *Cedrus deodara* had an IVI value of 78.70 and 48.26 in Narkanda and Chhachpur, respectively. The value for *Abies pindrow* increased with the increase in elevation in both the localities.

Singh *et al.* (1994) investigated phytosociological attributes and resource utilization on the south-eastern slopes of Shimla town (H.P.) with slopes of 30^0 to 45^0 and altitude ranging from 1,700 to 2,400 m amsl. *Pinus roxburghii* was found to be the dominant species at site I (slope 30^0 - 35^0, altitude 1700-2000 m), *Cedrus deodara* dominated site II (slope 35^0-40^0, altitude 1900-2400 m) and site III (slope 35^0-45^0, altitude 1900-2300 m). On the basis of IVI values, *Quercus incana* was however, recorded as co-dominant in all the sites. A gradual decrease in basal cover of trees from top to bottom on different slopes was also noticed at site II, while the pattern was irregular at site I and III.

A study was conducted by Lata and Bisht (1991) at eight forests patches varying in altitude (1700-2500 m amsl) and slope in moist temperate forest at Pauri in the Garhwal Himalaya. Four sites were dominated by *Quercus leucotrichophora* and two sites each by *Cupressus torulosa* and *Pinus roxburghii.* The maximum number of species and total basal cover of forest (7125.02 $cm^2/100m^2$) were recorded at 2,500 m amsl (site VIII). Concentration of dominance varied from 0.2139 to 0.5478 and 0.2148 to 0.5845 on the basis of total basal cover and density, respectively. *Rubus* and *Berberis* species were the most common among seven shrub species.

Kim (1988) working on South Korean forested Islands and divided them into three types of forest vegetation, viz., broad leaved deciduous forest, evergreen coniferous forest (*Taxus cuspidata* var. *latifolia/Pinus parviflora*) and broad leaved evergreen forest (*Persea thumbergi* and *Acer okamotoanum*). The distribution patterns were illustrated by the ratio of evergreen and broadleaved species and the warmth index according to altitudinal changes.

Singh *et al*. (1987) on the other hand made a vegetational analysis of the forests near Nainital in Uttarakhand. The phyto-sociological analysis showed that it represented three major forest types of *Quercus floribunda* forests (dominant species *Q. floribunda* and *Q. leucotrichophora*), *Cedrus deodara* forest (dominant species *C. deodara and Q. floribunda*) and mixed oak-conifer forest (dominant species *Q. floribunda and Cupressus torulosa).*

Christensen *et al.* (1959) investigated the species composition of forests based on 108 stands. The most important trees were *Larix laricina* and Picea *mariana* on the wet and most acidic sites, *Thuja occidentalis, Abies balsamea* and *Fraxinus nigra* on intermediate sites, while *Tsuga canadensis, Betula lutea* and *Acer saccharum* were found on the nearly mesic sites.

Similarly, Maycocock (1955) investigated a coniferous community in the Algonquin Park area, Ontario, Canada situated in a broad ecotonal belt between the northern boreal and southern deciduous forests. White spruce, white pine and balsam fir were the dominant tree species which enabled this type to be labeled as picea-pinus-abies association.

Similarly, Puri and Mohan (1955) conducted successional studies in Bushahar Himalaya and reported that in high altitude of 2,240 to 2,660 m, there existed stable climax forests in the form of pure *Quercus semecarpifolia* and all other communities were at developmental stages tending to progress towards oak climax. He concluded that the persistence of several communities in a more or less semi permanent stage was due to the aspect, nature of the soil and biotic conditions.

2.2 Phenological Studies

The descriptive study of the behavioral characteristic of organism in relation to their environment is termed as phenology. Phenometry being the quantitative measure of the life cycle or specific phenophases and their value with regard to ecosystem analysis lies particularly in the understanding that they provide information of the plant's responses to climate. Phenology is generally described as an art of observing the phases of the life cycle or the activities of the organism as they occurred through the year. These studies permit a calendar to be constructed for the vegetative activity of the plants especially the periods of leaf shedding, flowering and fruiting superimposed on civil calendar. The study of leafing, fruiting and flowering is a prerequisite for study on the reproductive biology and breeding system of species (Leith, 1970).

Kala (1999) recorded the phenology of alpine plants in the sub-alpine and alpine zones of the Valley of Flowers National Park and Hemkund, in Chamoli District, Uttarakhand. Transects were laid in both the areas and monitored for phenology at 30 days intervals. A total of 95 flowering plant species were found on the transects, of which 84 per cent were forbs, 14 per cent were evergreen shrubs and under shrubs, while remaining 2 per cent were grasses and sedges. The vegetative phase depicted peak in June and from the same month the flowering phase also increased in the valley. July and August were the best months for flowering. The prominent vegetative phase peaked earlier (in June) in the cushion forming forbs than in other forms of plants. The growing season was longest at lower altitudes and decreased with increasing altitude from subalpine forest to alpine meadows.

Phenology and floral biology of *Acer caesium* from the Kumaun Central Himalaya were studied in relation to leaf sprouting, flowering and anthesis, fruit setting, development and retention and leaf and fruit drop. The total period of flowering for the species was 48 days. The average fruit setting was 88.84 per cent in 1994, 20 days after pollination, but only 75.96 per cent 50 days after pollination. Leaf drop and fruit drop starts in October and natural regeneration by seeds took place in the next monsoon (Semalty and Sharma, 1996).

Joshi *et al.* (1994) highlighted the changes in species composition, life form, growth form and leaf phenology of herbaceous layers in response to changes in the extent of tree cover and associated variations in edaphic conditions between 1,600 and 2,000 m altitude at Nainital in the Central Himalayas. Three adjacent sites were selected with different degrees of deforestation, viz., ban oak (*Quercus leucotrichophora*) forest; partly deforested ban oak/chir pine (*Pinus roxburghii*) forest and deforested open grassland with a few scattered ban oaks. The flora was phanerophytic at the forested site, therophytic at the partly deforested site and hemigeophytic at the deforested site. Forbs formed the dominant growth forms on the forested site, while at the partly deforested and deforested sites grasses and sedges in combination with short forbs and tall forbs, respectively, predominated. Observations on leaf phenology indicated that of the total number (44) of herb species, 68 per cent initiated growth during the rainy season and the rest during the summer season. Periods of photosynthetic activity were longer for summer initiated species than for the rainy season initiated species.

Rawal *et al.* (1991) made a study in 1988 and 1989 on the phenology (leaf flushing, flowering, fruiting and leaf fall) of tree layer species from the timber line of Kumaun. Deciduous tree species made up 66 per cent of the timber line vegetation. Leaf flushing occurred from the end of March to the middle of June. Comparison was made between the lower Himalayan forests of Kumaun. The study supported the view that the intense fluctuations in environmental conditions determine the onset of different growth activities within the short growing season.

Ansari (1989) studied the phenology of 726 angiosperms (woody, categorized as trees, erect shrubs, climbing parasitic shrubs and herbaceous) in the forest in Uttar Pradesh. Flowering data was tabulated for each species category and separately for 17 of the more important species (mainly trees). The data related to climatic factors (rainfall and temperature). The flowering period of woody plants was maximum during March to April, while herbaceous plants showed maximum flowering during July to September.

Phenological events are also influenced by the biotic influences of associated species as well as by the climatic and edaphic conditions. Various climatic factors stand density (light) and site quality influences the flowering and fruiting of teak, e.g., shallow soils induce early flowering (Hedegart *et al.,* 1975).

The studies of Frankie *et al.* (1974) provide examples of the two adaptive strategies, firstly dry season leaf fall with wet season flushing and secondly dry season leaf fall with dry season flushing. Studies in tropical forestry have revealed massive dry season flowering. They also found twice as many seasonally flowering species in bloom in the dry season as compared to the wet season.

Since trees are subjected to different environmental conditions depending upon their position, Frankie *et al.* (1974) and Medway (1972) described several type of variations in the timing and duration of leaf, flower and fruit production. According to them, the northern collection started growth first, gradually followed by more southerly sources and plants from the most southern reaches of the range started growth last in the case of sugar maple (*Acer saccharum* Marsh.). Some other species showed reversed trend, i.e., trees from southern sources flushed first which were gradually followed by those from northerly sources.

The main approach in phenology is to establish average calendar dates with specific phenological events, which is known as bench marking. This has got much value in productivity studies also. The phenologists select the beginning or the end of phenophases or any distinguishable phase in the life cycle of plants in which changes occur in a short period of time. Some phenologists consider the entire community as a unit and describe the seasonal changes as phenophases. The way in which the entire sequence of phenophases occurs around the year is called the phenodynamics and the elaboration this for all the species in one community entering in a given phenophases is termed as the phenological spectrum. There are many aspects of productivity, which can be categorized, predicted and evaluated on the basis of phenological attributes (Leith, 1970).

Alternate year or irregular flowering has been demonstrated for certain species in the tropics by Ashton (1969) and Janzen (1970).

Mehar-Homji (1964) is of the opinion that to judge the characteristics of aridity or humidity of a region, five criteria can be proposed, viz., climate, ephemonic, floristic, vegetational and the agronomic. In *Bothriochloa decipins* flowering becomes progressively late with decreasing latitudes.

Heslop Harrison (1961) has reported no apparent relationship between latitude of origin and flowering time for *Bothriochoa decipiens* and many short day plants. He also reported that the floral initiation was controlled photo periodically. He further stated that short days promote femaleness and long days maleness. Origin of late flowering and obligate short day responsiveness are linked and probably represent the original behaviour pattern of species (Emergy and Brown, 1958). Heinrich (1976) found native spiraea along with little year-to-year variation in flowering times. Lindsey and Newman (1956) and Jackson (1966) gave the concept that phenological progression followed cumulative heat sums. Wang (1960) presented an interesting historical account of development of phenological observations and the thermal index and evaluated their performances. Flower and Tiedemann (1980) studied the phenology of two under story species and found that phenological phases related well to the temperature but poorly to calendar date or soil moisture.

Climatic forces appear to be the most important in controlling the variations in the time of occurrence of phenological phenomena (Krishnaswamy and Mathauda, 1954). They believe that fluctuations in dates of occurrence of the three phenospheres can in most cases be correlated with parallel changes in the main climatic forces. The measure and the direction of influence of the latter vary with the species and the species in question. Higher mean temperature in the short period, preceding the normal date of occurrence of the phenomenon tends to advance new leafing and flowering. Low rainfall and low relative humidity also appear to exercise a similar influence, though it may be marked in some cases. Low temperature, high rainfall and humidity have an opposite effect. High temperature appears to quicker fruit ripening in *Toona ciliata* and probably in *Shorea robusta* too. High rainfall and high humidity also appear to advance fruit ripening in certain cases. This is in contrast with these two factors on new leafing and flowering where they show an opposite tendency. Fruit ripening in the case of *Dalbergia sissoo* and *Mangifera indica* does not show any clear relationship with temperature, rainfall or humidity. Frankie *et al.* (1974) found that precipitation pattern is meaningful for fruit development besides several other biotic and abiotic factors, which may also be involved.

2.3 Natural Regeneration Studies

Majila and Kala (2010) studied the forest structure and regeneration along the altitudinal gradient in the Binsar Wildlife Sanctuary of Uttarakhand Himalayas in India. Stratified random sampling of tree species was done by placing minimum 15 quadrats (10x10) m at each aspect and altitude. The results reveal that along the altitudinal gradient there were three types of forest communities in the Sanctuary, viz., chir pine (*Pinus roxburghii*), oak-chir pine (*Quercus leucotrichophora* and *Pinus roxburghii*) and oak (*Quercus floribunda* and *Quercus leucotrichophora*). The regeneration of chir pine was best at lower altitude on south and east aspects, which indicated that it mostly regenerated on warm and dry slopes. In general, the regeneration potential in most of the tree species declined with the altitude. The density of saplings and seedlings also represented the dominant species at each altitudinal range, which indicated the cyclic regeneration of forests in the Sanctuary area.

Upadhaya *et al*. (2009) studied the population structure and regeneration ecology of *Ilex khasiana* at five representative natural populations, viz., Mylliem (Population - I), Upper Shillong (Population - II), Shillong Peak (Population - III), Laitkor (Population - IV) and Nongpiyur (Population - V) to probe into the responsible affecting factors for its population structure and regeneration ability in these populations. Experimental observation under three controlled light conditions (full sunlight, intermediate sunlight and low sunlight) showed that the growth status and survival rates of seedlings under intermediate and low light were better than those under the high light condition. The density-diameter distribution in population of adult trees (>5 cm dbh) exhibited a typical character of regenerating population. A higher seedling mortality rate in natural populations of *Ilex khasiana* was most probably due to increase in light intensity followed by vegetation destruction and other anthropogenic disturbances that caused opening of forest canopy. The findings of the study are of immense value in formulating appropriate conservation measures for the species.

Dhaulkhandi *et al*. (2008) reported the regeneration potential and community structure of natural forest site in Gangotri, Uttarakhand. A total of seven tree species were recorded from the site. Among the trees, *Picea smithiana* was the dominant and *Cedrus deodara* was found co-dominant species. However, the highest (240 trees/ha) density was reported for *Pinus wallichiana,* while least number of individuals (30 trees/ha) were recorded for *Acer caesium* and *Pinus wallichiana*. In tree layer the most of the species (65.16%) were distributed contagiously and few (34.84%) were distributed randomly. However, none of the species showed regular distribution pattern. *Artemesia gamillinea* and *Cotoneaster gilgitansis* were the most and least dominant shrub species, respectively. All species of shrub layer were distributed contagiously (100%). In the seedling stage, maximum number was observed for *Pinus wallichiana* (1080 seedling/ha) followed by *Picea smithiana* (1040 seedling/ha) as compared to *Pinus wallichiana* (520 sapling/ha). As far as regeneration status was concerned, 71.4 per cent species showed good regeneration, 14.3 per cent species were facing the problem of poor regeneration and only 14.3 per cent species were not regenerating.

The results of study conducted by Semwal *et al.* (2008) on structure, composition, diversity and regeneration status of different forest types in a moist temperate region of Garhwal revealed that overall diversity increased in *Pinus* spp dominated sites, which were characterized by more open canopies with scattered trees interspersed with young trees, shrub and herb species compared to *Quercus* spp forests with a dense crown cover. A direct proportional relationship between tree cover and the diversity of sub stratum vegetation was found to increase with increasing tree canopy cover. Tree density showed strong correlations with the densities of seedlings and poles. The observations suggest that conversion of saplings to tree strata is a crucial factor to ensure good regeneration of species.

A study by Bahar *et al.* (2008) revealed that fire had beneficial effect at seedling stage but high incidence of fire every year leads to death of natural regeneration of chir pine. They also found that the dormant buds of chir pine seedling sprouted after fire incidence.

A study by Balwant *et al*. (2007) provides ecological information on the phenology; relative density and average height; and regeneration, conservation and management status of *Cedrus deodara*, *Pinus roxburghii* and *Quercus leucotrichophora* in Western Himalayas. The results indicated that *Cedrus deodara* is highly dense and well regenerated, while the growth and establishment of *Pinus roxburghii* and *Quercus leucotrichophora* were affected by intense biotic pressure.

Distribution and community structure of *Betula utilis* forest in a trans Himalayan dry valley was studied in Manang (central Nepal) with the major focus on regeneration. In general, *Betula utilis* was regenerating, as evident from a reverse J-shaped density-diameter curve for pure *Betula utilis* forest forming the tree line was mature and mixed *Betula utilis* forest at lower elevations was young. However, the distribution of seedlings and saplings was spatially heterogeneous and appeared to depend on canopy cover. The stands with highest seedling and sapling densities of *Betula utilis* had no trees. Betula seedlings were absent where the tree density and basal area (BA) exceeded 20 stems/100 m^2 and 1.0 per cent, respectively (Shrestha *et al.* 2007).

Gupta (2007) investigated the natural regeneration status of silver fir and spruce in Kullu, Rajgarh and Kotgarh Forest Divisions of Himachal Pradesh and reported that over all regeneration was better at Kullu (91.68%), followed by Kotgarh (74.69%) and Rajgarh (72.47%) forests.

Studying the natural regeneration status of *Taxus baccata* in Kotgarh, Theog and Chopal Forest Divisions, Lanker (2007) reported the total absence of established regeneration in the study areas. Sharma (2006) on the other hand reported poor status of fir and spruce natural regeneration in all selected sites of Jubbal forest range. He reported a maximum 33.11 per cent established stocking in middle elevation, while minimum value was recorded for higher elevation.

A study by Wangda and Ohsawa (2006) characterized the structure and regeneration dynamics of dominant tree species along altitudinal gradient in dry valley slopes of the Bhutan Himalayas. In general, regeneration pattern of major dominant species shifted from inverse J (lower altitudes), to sporadic (mid altitudes) and to uni modal type upper altitudes corresponding to three regeneration trends, viz., invasive at the lower, warm, dry forest under relatively strong human disturbances; stable/balanced at the mid altitude, in a relatively stable, mature moist evergreen broadleaved forest with gap regeneration; and poor/low regeneration at the upper, cool, humid conifer forest with a continuously cattle grazed under storey. They suggested to prevent excessive exploitation of dry pine forest of lower valley bottom and to control cattle grazing at higher altitudes.

Abhilash *et al*. (2005) studied *Nageia wallichiana* species to assess the abundance and diversity of seedling regeneration in natural habitat of Goodrical Reserve Forest. Based on the distribution pattern, *Nageia wallichiana* showed contagious distribution, while most of the other species exhibited preponderance of random distribution.

Shamet and Gupta (2005) while investigating *Taxus baccata* in the Bagi, Tikker and Chunjur forests of Shimla Forest Circle, reported that natural regeneration was very poor in all the selected three sites. The highest established regeneration of 1,250/ha was reported in Chunjar forest, whereas, the same was found to be totally absent in Bagi and Tikkar forests. Similarly, Singh (2004) working with *Cedrus deodara* species revealed regeneration status of recruits as 416.6/ha and unestablished regeneration of 1388.8/ha in PB I area of Shimla forest. However, the maximum number of recruits and established plants were recorded on northern aspect at 2,000 m amsl.

Similarly, Rikhari *et al.* (2000) revealed that poor regeneration of *Taxus baccata* was not only due to excessive harvesting or removal, but also due to other factors like extremely slow growth, poor seed germination, unrestricted grazing, accumulation of raw humus and unsatisfactory light condition.

Garcia *et al.* (2000) investigated the effect of herbivores and the protective role of dense shrub under storey on the regeneration ability of the yew at Sierra Nevada in Spain. The estimated density of the yew in the study plot was 287.9 individual/ha, with more than 90 per cent being juveniles (seedlings and saplings), which were mostly located under fleshy fruited shrubs. Saplings, however, suffered serious herbivore damage when unprotected by shrubs.

Giertych (2000) on the other hand, studied the factors determining natural regeneration of yew (*Taxus baccata*) in Kornik Arboretum and reported that the survival of yew was best under lose canopies, moderate shade and low pH soils.

Similarly, Rajwar *et al.* (1999) studied the density of seedling and sapling in ten forest sites with three stands each consisting of three elevation types of *Quercus leucotrichophora - Pinus roxburghii* (1800-2000 m), *Q. leucotrichophora* (2000-2200 m) and *Q. floribunda* (2200-2400 m) stands. In these forests, the density ranged from 2.64 to 7.73 saplings/25 m^2, while it was 5.28 to 14.52 for seedling/25 m^2. Similarly, on the basis of regeneration potential, sites I to III were dominated by *Q. floribunda*, sites IV to VIII and site X by *Q. leucotrichophora* and site IX by *Pinus roxburghii*. Most of the species were found to be continuously distributed.

Feller (1998) studied the natural regeneration of subalpine fir (*Abies lasiocarpa*) and Engleman spruce (*Picea englemannii*) in Engleman forest of south central British Columbia. The influence of seedbed light and competing vegetation on germination, seedling survival and growth were investigated. He found that seedling survival and growth generally did not differ between site types and were little influenced by competing residue. The number of living fir seedlings increased as the amount of light increased, whereas partial shade benefited survival of spruce seedling.

Gupta (1996) investigated the regeneration of fir and spruce and reported that regeneration of fir (687.5/ha) on an average was more as compared to the spruce (312.50/ha) in Narkanda (Theog Forest Division). In contrast, however, the regeneration of spruce (1875.00/ha) was found to be more than fir (833.33/ha) at Chhachpur (Jubbal Forest Division). The investigation also revealed that regeneration decreased with the increase in elevation from 1,250/ha to 208.33/ha for fir and from 625/ha to 156.25/ha for spruce at Narkanda, while it increased with increase in elevation in fir from 625/ha to 1041.67/ha and decreased for spruce from 2,083/ha to 1,666.67/ha at Chhachpur.

Seildling and Constien (1998) investigating yew regeneration near Berlin in Germany revealed 589 seedlings in 73 ha forest with highest seedling density close to forest border and in young-moderate old pine stand.

Sood and Bhatia (1991) reported higher density of seedlings and saplings in three selected forest sites dominated by conifers. They indicated better regeneration in site III (*Cedrus deodara-Pinus roxburghii*) and mixed conifer and broad leaved in site II (*Quercus* spp., *Picea smithiana* and *Pinus wallichiana*) than at the site dominated by pure broad leaved species in site I (*Quercus leucotrichophora-Rhododendron arboreum*). The occurrence of greater proportion of individuals in lower girth classes of *Cedrus deodara*, *Q. dilatata* and *Cornus capitata* at site I; *C. deodara*, *P. smithiana, Q. dilatata, Q. leucotrichophora* and *R. arboretum* at site II and *C. deodara, Q. leucotrichophora* and *P. wallichiana* at site III represented frequent regeneration.

Similarly, Kopp (1991) studied *Taxus baccata* in the natural reserve yew forest at Gottingen and made observations regarding natural regeneration, i.e., appearance, seedling mortality and health condition of new seedlings. The decisive factors for successful natural regeneration of the species were adequate light and effective fencing against hares. Though a steady number of yew seedlings persist by eliminating browsing without opening up the canopy, their growth was found to be severely depressed. Thus, to ensure vigorous natural regeneration of yew, both fencing and opening up of the canopy was required.

Silas *et al.* (1987) analysed the pine-oak communities for structural changes and found the composition of vegetative cover at different altitudes in Pauri Garhwal. The species distribution was markedly distinct, which followed the normal Raunkier's pattern with slight variation in the species, but the number of species in different forests was different.

Singh (1983) reported that regeneration of *Abies pindrow* in Jammu and Kashmir was deficient and that the reasons for this could be seed scarcity, unrestricted grazing, accumulation of raw humus, unsatisfactory light conditions, excessive moisture, drought and unwanted undergrowth.

McNeil and Thomson (1982) found that regeneration of sitka spruce on mineral soil surface gave better survival than those of peat covered with needle litter. Similarly, Sorg (1980) while working with sub-alpine spruce reported that the amount of regeneration decreased with the increase in altitude and increased with increasing slope and pH value of top humus layer.

Natural regeneration in many coniferous species depends upon seedling and site conditions prevailing in the area. Gordon (1970) studied the status of natural regeneration of *Abies concolor* and *A. magnifica* in northeast California and proved that natural regeneration was abundant with sound seed, exposed mineral soil and some shade. However, strong insulation, deep litter, competing lower vegetation and long seed years create obstructions to seedling survival and growth.

Nobel and Alexender (1970) on the other hand, reported that weather, aspect and seed bed condition controls the progress of natural regeneration of Engelmann spruce. On northern aspect with some shade, a small clear cut opening of one to two ha create conditions for successful regeneration, while on southern aspect, good regeneration was not possible as shade was absolutely essential for its survival.

Inayatullah and Ticku (1965) investigated the plant communities in the Kashmir valley zone and coniferous forest zone. In the valley, regeneration was hampered by a dense undergrowth of *Parrotia* spp*,* while in the outer ranges, regeneration was generally satisfactory. Whenever conditions become drier, *Pinus wallichiana* regenerate and eventually the young crop of *P. wallichiana* created conditions conductive to *Cedrus deodara* regeneration and a mixed crop of *C. deodara* and *P. wallichiana* resulted. However, wherever conditions become moist, *C. deodara* thrived well and finally ousted *P. wallichiana* from the area.

Similarly, Chacko (1965) reported that the assessment of regeneration was important in experimental plots and that plot size was the determining factor in negative and positive correlation of species. It was, therefore, essential to use higher intensity of sampling to get accurate results. Singh (1948) studied the fir forests of the Pir Panjal (Kashmir) region and noticed profuse natural regeneration in the species attributed to ideal geological, topographical and soil conditions.

Troup (1921) while working on regeneration of silver fir and spruce in Chakrata forests revealed that heavy opening of canopy and dense weed growth inhibited regeneration in the species. Light felling followed by cutting and burning of bush growth was favoured to induce regeneration in the species.

Pengshalin *et al.* (2006) reported that temperature, light intensity and precipitation were the main climatic factors affecting the growth and distribution of *Taxus* spp as it preferred acid and fertile soils and a gentle than a steep slope.

Jayen *et al.* (2006) on the other hand, studied the success of regeneration in the boreal forest of north west Quebec, Canada and reported that seedlings preferentially established on mineral soil and that woody debris seemed to be a good substrate for germination and survival. Seedlings established more frequently and grew better where thickness of residual organic matter was the lowest.

Zu Yuan Gang *et al.* (2006) revealed that yew in Heilongjiang province, China, was mainly distributed under the main storey of natural mixed forest of conifer and broadleaved species. The soil moisture content of the yew site was higher (40%-60%), while pH value of soil was relatively lower (4.7-5.5). They summarized that the population structure of yew was not rational rather belonged to the degeneration type.

Similarly, Filipiak and Komisarek (2005) investigated the physico-chemical properties of soil in silver fir stands in south west part of Poland. They observed that potassium content in soil and the regeneration of silver fir in the area was statistically significant. Boratynski *et al*. (2001) revealed that the increment of height in yew was greater under less density of beech – fir (*Betula* spp and *Abies* spp) stand under which the species grew.

Verma *et al.* (2003) reported that dominance index was lower while diversity index was higher for ground flora under forest, while compared to the area outside the forest. The ground flora under forest has higher diversity index (4.534) than area outside the forest (3.148). The index of dissimilarity between forest and outside the forest was high indicating a significant degree of dissimilarity in ground flora species. Forest soil showed high fertility status as compared to area outside the forest.

Giertych (2000) studied the factors determining natural regeneration of yew plants in the Kornik Arboretum in Poland and reported that yew survival near the trunk was better under lose canopies in moderate shade and low pH soils.

Similarly, Sera *et al.* (2000) investigated the effect of climatic and pollution stress, soil substrate, mosses and dominant herb species on natural growth and development of mountain Norway spruce seedlings in

Slovakia and concluded that most of the seedlings were germinating and growing well under litter cover. The least favourable condition, however, was observed in areas dominated by grass species.

Dlaci *et al.* (2000) investigated the regeneration of Norway spruce (*Picea abies*) in the Julian Alps, Slovenia. The successful regeneration was found in plots with more podzolized soils, higher content of organic matter, sparse ground vegetation cover and more diffuse site factors.

Abrudan and Mather (1999) studied the influence on composition and structure of semi-natural mixed species stand of beech (*Fagus sylvatica*), silver fir (*Abies alba*) and Norway spruce (*Picea abies*) in upper Draganul watershed area of North-west Romania. They observed that *Abies alba* predominate at a mid to upper slopes on steep gradients and favours southern aspects. In contrast, *Picea abies* was more abundant on frost susceptible lower slopes on northwestern aspects.

Similarly, Chandra *et al.* (1999) studied the structure of the forest vegetation along an altitudinal gradient in the valley of Flowers, National Park and two other sites in its vicinity. Three major vegetation types, viz., Himalayan moist upper temperate forest (dominated by *Acer caesium, Rhododendron arboreum, Corylus jacauemontii, Pyrus vessica, Juglans regia*), sub-alpine fir forest (dominated by *Abies pindrow, Taxus wallichiana*) and sub-alpine birch forest (dominated by *Betula utilis*) were identified on the basis of importance value index (IVI).

Walter *et al.* (1998) carried out studies on *Picea abies* and *Abies alba* stands in Black Forest to determine the distribution of brambles (*Rupus* spp) in relation to soil type and vegetation and also the effect of brambles on the growth of *A. alba* natural regeneration. They found that the ground cover by brambles depend on the amount of light and also correlated favourably with the type of humus. Thick surface layer of humus reduced the degree of bramble cover but not its occurrence.

Similarly, Rikhari (1998) while studying the stand structure, canopy density, regeneration and conservation strategy for *Taxus baccata* (sub-species *wallichiana*) found that the number of trees, saplings and seedlings varied amongst plots. Leaf area index and canopy volume increased with increasing circumference and breast height. Since it is a very slow growing tree with poor regeneration, the extent of canopy damage was likely to have serious consequence on biomass yield, plant survival and natural regeneration by affecting seedling growth.

Bailey and Liegeal (1998) studied Pacific yew (*Taxus bravifolia*) and reported that growth and reproduction patterns were important in the long term viability of yew populations. The investigation confirmed and quantified some qualitative observation of yew tree like size and age distributions.

Prajapati (1997) on the other hand studied the regeneration status of evergreen and semi-evergreen species in north Canara forest comprising five divisions namely Haliyal, Yellapur, Kanwar, Honnavar and Sirsi divisions. The analysis showed that the established regeneration as percentage of total regeneration varied from 4.17 to 14.94 in moist deciduous forest and from 14.94 to 21.95 in evergreen/semi-evergreen forests. However, the comparison of field data with the standard showed that the regeneration in the strata was highly inadequate, i.e., forests were not regenerating at the rate they should have been because of the heavy biotic pressure.

Similarly, Seildling and Constien (1998) investigated yew regeneration in Grunewald Forest area, near Berlin, Germany and observed that removal of *Prunus serotina* followed by thinning of pine resulted in increased growth of yew seedlings, thus indicating the importance of light for the species.

Adhikari *et al.* (1995) studied the structure and functioning of three different forest communities, viz., horse chestnut (*Aesculus indica*), silver fir (*Abies pindrow*) and kharsu oak (*Quercus semecarpifolia*) forests in a high altitude region of central Himalaya. Tree density was found to be 280, 355 and 480 stems/ha and total basal cover 76, 106 and 73 m^3/ha, respectively.

Singhal and Soni (1992) studied vegetation types of eight sites in Massoori for quantitative characters, viz., frequency, density, abundance, mean basal area/tree and total basal area of ten major tree species. The data was correlated with soil characteristics and mean annual increment for each forest type. Deodar forest was found to have the highest mean annual increment as compared to chir and oak forests. Niemann (1992) studied the influence of light on yew natural regeneration and protection from excessive browsing damage. He observed that careful and repeated opening up of the main stand would preserve yew trees and also create conditions favourable for vigorous natural regeneration of the species. Similarly, Gensac (1989) studied the colonization of spruce (*Picea abies*) seedlings in the Savoy Alps, France and reported that soil conditions in which spruce regeneration was favourable were mainly skeletal, acid, sandy soils and poor in organic matter.

Singh *et al.* (1987) investigated the relation of litter fall and natural regeneration of spruce and silver fir in Kotgarh forests of Himachal Pradesh and reported that the litter in the forest was detrimental to natural regeneration of both the species.

Similarly, Jha *et al*. (1984) studied the regeneration in fir and spruce forests in Narkanda forest and showed almost negligible eluviations of clay and organic matter in the soil profile. They reported that litter decomposition released some hydrophobic substances, which severely restrict wetting of the soil in the forests. Therefore, the insufficient moisture content in the soil due to thick layer of humus on the surface badly affected the process of natural regeneration in fir and spruce forests.

Similarly, Korpel and Paule (1976) studied the stand structure and composition in a mixed stand near *Banska Bystrica* (Slovakia), where yew

(*Taxus baccata*) reached its greatest abundance in Europe. The stand had been naturally regenerated eighty years earlier and was dominated by Beech (*Fagus sylvatica*) accompanied by spruce and fir. Yew formed an under storey with density of 167 stems/ha accounting for 13.6 per cent of the basal area but only 3.9 per cent ($15m^3$/ha) of the volume of the stand.

Richardson (1975) on the other hand summarized the results of a series of regeneration surveys throughout Newfoundland and Labrador and reported that after fire, regeneration of *Abies balsmea* was virtually absent, but *Picea marina* regenerated without difficulty if satisfactory seed source and seed beds were present. Colaona and Giannini (1971) revealed that air humidity had an important effect on germination of *Abies alba, Epilobium augustifolium* and *Rubus hirtus* seeds. They also found that the presence of a surface layer of litter or moss was unfavourable to their early growth.

Hosely (1936) investigated the results obtained in *Picea abies* and concluded that the species from northern sources excelled in growth rate than those from the central Europe. He further reported that diameter of the trees was more closely correlated with latitude than that of height.

Chapter-3

MATERIALS AND METHODS

The present investigation entitled, “Structural and Functional Studies of Woody Elements of Betula Forest in Sangla Valley of Himachal Pradesh”, was carried out in betula bearing forests at Sangla Valley of Himachal Pradesh during the year 2008-2010. The material and methods used for the study are described in the following paragraphs.

3.1 STUDY AREA

Present study was carried in the Sangla valley which is nested in the Kinnaur district of Himachal Pradesh located between latitude $31^{0}06'$ N to $31^{0}30'$ N and longitude $78^{0}10'$E to $79^{0}00'$ E (FSI, Mapsheet Number 53I7). The study was mainly confined to *Betula utilis* bearing forests within the elevation range from 3,000 m to 3,900 m amsl distributed mainly in west Himalayan sub-alpine birch/fir forests ($14/C_1$), Birch-Rhododendron scrub forests ($15/C_1$) and Deciduous alpine scrub ($15/C_2$) forest types as per Champion and Seth (1968). The valley comprises a number of small watersheds which find their way into the Baspa River. The hamlets are scattered all along the valley. The strips of cultivable lands in valley vary from a few hectares to a few kilometers. The upper most part of the mountain peaks are usually covered by perpetual snow cover. A major part of the valley remains cut-off from other parts of the state due to heavy snowfall during winter period. The rocks in the valley varied in age from Precambrian to perm carboniferous. Schists, gneisses, granites, quartzites, phyllites, conglongrates, quartzites slate, dolomite and limestone are the major rock types. Rocks have been highly exposed along the Karchham-Sangla road. Soil type is sandy to sandy loam and is highly fragile (Fig. 1).

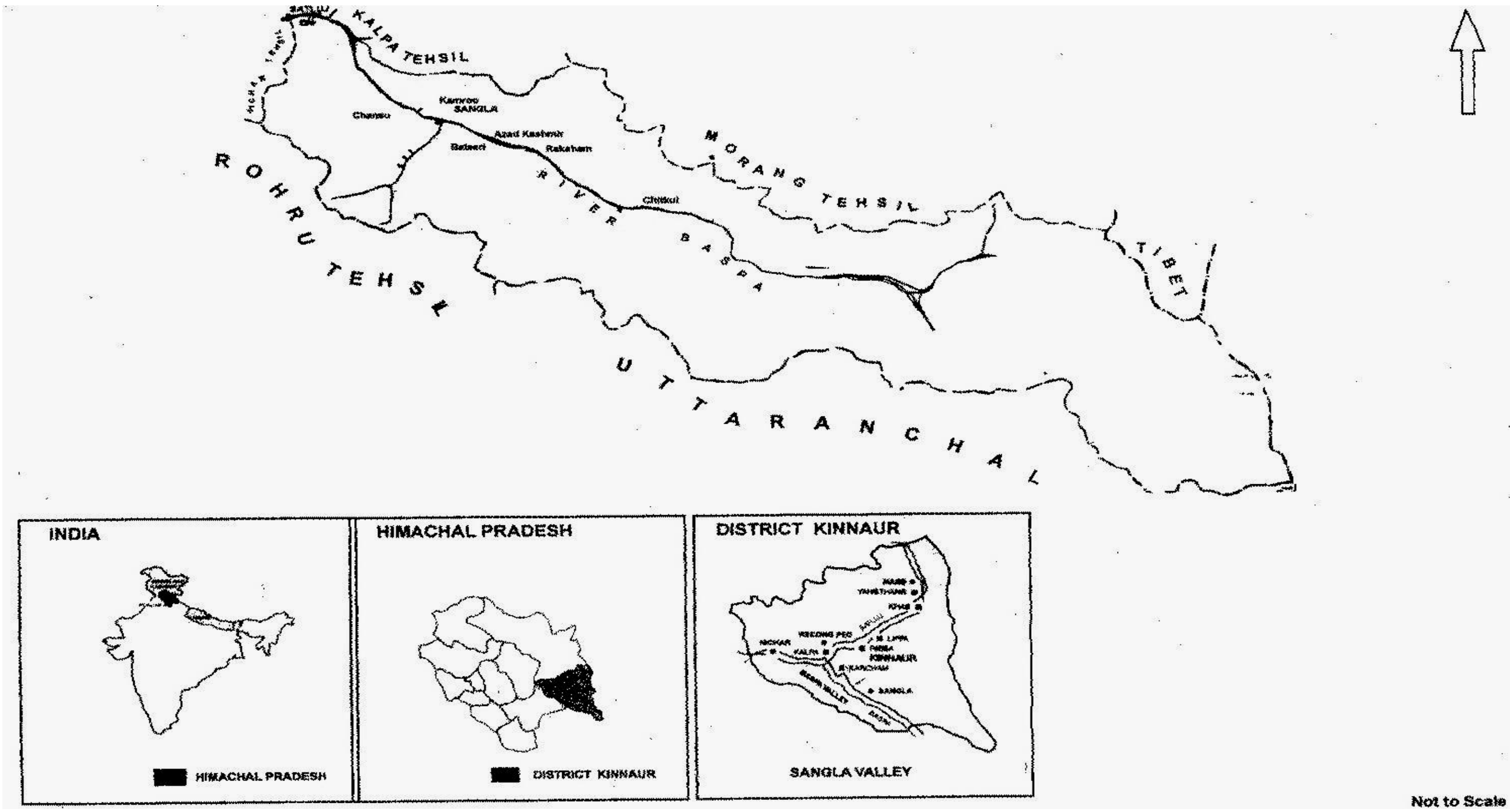


Fig. 1: Map depicting location of HP, Kinnaur, Sangla valley and study site.

3.2 Climate

There are four major seasons, viz., spring starts from middle of March and lasts till mid May, summer from mid May to mid September, autumn from mid September to November and winter season from December to March. Summer is quite mild and with the onset of monsoon rains, there is a gradual decline in atmospheric temperature. After the receding of monsoon, the mercury drops further thus winter sets in. The period from November to March is the coldest.

3.3 Site Selection

The selection of the site was carried out on the basis of presence of *Betula utilis stands* for the study purpose. The study area selected ranged between 3,000 to 3,900m amsl. Since the terrain was highly undulating and it was not possible to cline at many places. Thus the complete area was horizontal (H) divided into three elevations, viz., lower zone (3,000 to 3,300 m), middle zone (3,300 to 3,600 m) and upper zone (3,600 to 3,900 m). these three horizontal (H) zones were further divided into five vertical (V) zones as depicted below. Thus 15 compartments were marked. Sampling was carried out in each compartment as depicted below.

	V1	**V2**	**V3**	**V4**	**V5**
H3 **Upper Elevation** **(3,600-3,900 m)**	**Q11**	**Q12**	**Q13**	**Q14**	**Q15**
H2 **Middle Elevation** **(3,300-3,600 m)**	**Q6**	**Q7**	**Q8**	**Q9**	**Q10**
H1 **Lower Elevation** **(3,000-3,300 m)**	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**

The following parameters were studied.

i. **Floristic Composition**
ii. **Phenology**
iii. **Phytosociological Studies**
iv. **Soil Characteristics**
v. **Plant Chemicals**

The study on phytosociology and floristic composition was carried out in the sample plots laid out in Betula bearing forests. The observations were recorded for woody elements, viz., trees and shrubs in all sample plots.

The data for following phytosociological parameters were collected, viz., number of species, number of individuals of each species, girth/diameter, height and basal area fallowing different formulae as proposed by Raunkiaer, 1934; Misra, 1968 and Menon and Balasubramanyam, 1985. Quadrate size (10 x 100 m) was estimated through species area curve and five quadrate per elevation were studied.

Percentage Frequency (%F)

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

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

$$\text{Abundance (A)} = \frac{\text{Number of individuals of a species}}{\text{Number of sampling units of occurrence}}$$

Density (D)

It represents the numerical strength of species in a community and is 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

Basal area: = $\pi d^2/4$ or $g^2/4\pi$

Where

d = Diameter
g = Girth

Relative Basal Area, Relative Density and Relative Frequency

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

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

$$\text{Relative density (RD)} = \frac{\text{Number of individuals of the species}}{\text{Number of individuals of all species}} \times 100$$

$$\text{Relative frequency (RF)} = \frac{\text{Number of occurrence of the species}}{\text{Number of occurrence of all species}} \times 100$$

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 and shrubs separately for different elevation classes in study areas of all the three forests.

IVI = Relative basal area (RBA) + Relative Density (RD) + Relative Frequency (RF)

Similarity Index

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

$$SI = \frac{\text{Number of common species in two stand (relives)}}{\text{½ (Total number of species in stand A + stand B)}} \times 100$$

Shannon Index of General Diversity ($\overline{H}$)

Species diversity is determined by Shannon's Index of general diversity and was calculated by using Margalef formula (Odum, 1971)

$$\overline{H} = - \sum (ni/N) \text{ Log } (ni/N)$$

Where

ni – Importance value of each species

N – Total importance value

The Index of Dominance

The index of dominance (C) of the community was calculated by Simpson's Index (Simpson, 1949):

$$\lambda = [(n\,i\,/N)^2$$

where, λ = Index of dominance,

n i and N being the same as in Shannon index of general diversity.

Species Richness

Margalef Index was calculated using a formula given by Margalef (1958):

$$SR = s - 1/ \log n$$

where, s is the no. of species, n is the no. of individuals.

Evenness Index

The Evenness Index of the community was calculated following Pielou (1966):

$$P = Hi / \log S.$$

where, Hi is the Shannon Index of diversity and S is the number of species.

Estimation of Stand Characteristics

Identification of Species and its Associates

All the trees falling under each sample plot were identified before going for further estimations.

Individual Tree Measurement

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

Diameter

For trees, diameter at breast height was measured and the mean of two diameter measurements (east-west and north-south) of each stem over bark was taken at right angles to each other at 1.37 m above ground with the help of tree calipers. In case of shrubs, seedlings, saplings, the basal diameter at ground level was measured at two different directions (east-west and north-south) and mean considered for calculations.

Tree Height

Total height of 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 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:

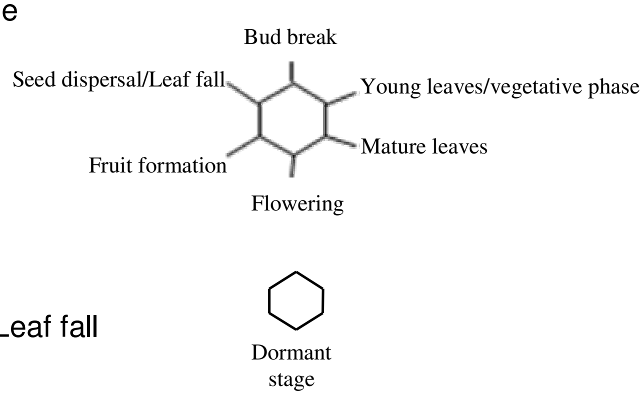
CW = Crown width (m)
D_1 = First measured crown diameter (m)
D_2 = Second measured crown diameter at right angle to the first measurement (m)

Phenological Behaviour

Different phenological stages of Betula forests were studied after one month interval for a period of one year starting from March 2009 to February 2010.

In the present study, six different phenophases were recorded which are as under

- New leaf flush (bud break)
- Vegetative phase
- Mature leaf
- Flowering
- Seed formation
- Seed dispersal/Leaf fall
- Dormant



Regeneration Survey

The regeneration survey was carried out in all the sample plots in all the selected sites at each elevation. In each major sample plot (10x100 m), twenty quadrates of size 2 x 2m were laid down. A number of 2,500 established plant per hectare was considered to express satisfactory regeneration. Similarly, the quadrate was considered fully stocked when it contained at least one established plant (Chacko, 1965).

The survey was conducted for recruits (defined as current years seedlings), unestablished regeneration (seedling other than recruits which has not yet established and the height was less than 2 m); here four unestablished plants were taken equivalent to one established plant and established regeneration having height of more than 2 m.

The regeneration data for *Betula utilis* and associated species was collected on the basis of number of individuals occurring at seedling, sapling and pole stage in each quadrate. The height of unestablished plants was also measured for the assessment of regeneration (Champion, 1935).

Regeneration Assessment

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

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

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

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

Where

n = Number of sampling units

m = Total number of recording units in 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

$$\text{Weighted Average Height (m)} = \frac{\text{Total height of unestablished regeneration + (Number of established plants x establishment height)}}{\text{Total unestablished plants + total established plants}}$$

On the basis of above estimates following indices were calculated:

$$\text{Establishment Index } (I_1) = \frac{\text{Weighted average height}}{\text{Establishment height}}$$

$$\text{Stocking Index } (I_2) = 1/2500 \times \frac{\text{Unestablished regeneration/ha}}{4} + \text{Established regeneration/ ha}$$

Established Stocking (%) $= 100 (I_1 \times I_2)$

Regeneration Success (%) = Stocking index (I_2) X 100

Site Characteristics

Solar Influx

Light illumination was recorded by lux meter under and outside the Betula canopy in selected forest sites at various elevations separately during day time and the value in percentage of light intensity under canopy to that in the open was calculated as under (Rao, 1998).

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

Photosynthesis Studies

The photosynthetic rate of Betula plants was measured with the help of LCA4 portable photosynthesis system (ADC.UK.). The portable pre-programmed system included a leaf chamber, incorporated with humidity, temperature and PAR sensors. The measurements for photosynthesis were made between 10:00 to 13:00 hours. The instrument was carried to the field with all the accessories and attachments. The leaf was enclosed in the leaf chamber and a record was taken. The leaf was then removed from the leaf chamber, which was replaced by a new leaf sample. For each reading a fully expanded leaf was enclosed and the same procedure was followed for each sample. Leaves from each plant were randomly selected for studying the photosynthesis. The following parameters were recorded.

- Solar radiations
- Leaf temperature

- Relative humidity
- CO_2 entering in the chamber and CO_2 passing out of the chamber
- Photosynthesis
- Transpiration rate

Water Use Efficiency (WUE)

Water use efficiency was calculated on the basis of data recorded for photosynthesis and transpiration as under:

$$\text{WUE} = \frac{\text{Number of molecules of } CO_2 \text{ fixed}}{\text{Number of molecules of } H_2O \text{ transpired}}$$

Soil and Plant Nutrients

Soil Samples

The soil samples were collected in moisture boxes from both the elevations at all the selected sites. The soil samples were collected from two depths, i.e., 0-15 cm and 15-30 cm. One composite soil sample was taken from each sample plot for each depth making the total four number of soil samples per elevation for single depth range. The fresh weight and then the oven dried readings were taken for these soil samples. The samples were properly labelled and stored in polythene bags for their subsequent analysis.

Soil Analysis

Soil and plant samples were analyzed in laboratory for different physico-chemical properties:

Physical Properties

- **Per cent soil moisture**

It was obtained by using the formula

$$\text{Per cent moisture} = \frac{\text{Weight of moist soil – oven dry weight}}{\text{oven dry weight}} \times 100$$

- **Organic Matter Layer**

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

- **Bulk Density (BD)**

Bulk density or apparent specific gravity of the soil is defined as the mass of a unit volume of soil bulk including pore space. Bulk density was calculated as following (Singh *et al.*, 1986):

$$\text{Bulk density} = \frac{W_2 - W_1}{V} \quad gm/cm^3$$

Where,

W_1 = Weight of empty bottle

W_2 = Weight of bottle and soil

V = Volume of soil/water needed to fill the bottle

- **Particle Density (PD)**

Mass of a unit volume of soil solid is called particle density. It was determined by measuring the mass and volume of soil solids as following (Singh *et al.*, 1986):

$$\text{Particle density} = \frac{10}{[W2 + 10] - W3} \quad gm/cm^3$$

Where,

W_1 = Weight of empty pycnometer (RD bottle)
W_2 = Weight of empty RD bottle + water
W_1 = Weight of RD bottle + water + soil
Weight of soil taken = 10g

- **Porosity (%)**

Porosity of the soil is the fraction of soil volume not occupied by soil particle. It can be measured with the help of bulk density and particle density as (Richards, 1968):

$$\text{Porosity (\%)} = 100 - \frac{\text{Bulk density}}{\text{Particle Density}} \times 100$$

- **Chemical Properties**

  - Soil pH was determined by 1:2.5 water suspensions method (Jackson, 1973).
  - Organic carbon was determined by wet digestion method of Walkley and Black (1954).
  - Available N was determined by alkaline permanganate method of Subbiah and Asija (1956).
  - Available P was determined by $SnCl_2$ reduced phosphomolybdate complex in HCl system (Jackson, 1973).
  - Available K was determined by flame photometer method.

Correlation Studies

Karl Pearson's (simple) correlation coefficient was worked out as per Panse and Sukhatme (1967)

$$rxy = \frac{COV(x, y)}{\sqrt{Vx \times Vy}} \times 100$$

Where rxy = Simple correlation between x and y

Vx = Variance of characters x

Vy = Variance of characters y

Chapter-4

EXPERIMENTAL RESULTS

The results emanating from the present investigation entitled, "Structural and Functional Studies of Woody Elements of Betula Forest in Sangla Valley of Himachal Pradesh", conducted in selected Betula bearing forests of Sangla Valley of Himachal Pradesh during 2009-10 are described in this chapter. The salient findings obtained during the course of investigation are being presented under following headings:

4.1 Floristic composition

4.2 Phenological studies

4.3 Phytosociological studies

4.4 Regeneration studies

4.5 Soil studies

4.6 Plant nutrients

4.7 Photosynthetic activities

4.1 Floristic Composition

In the entire study area where the quadrates were laid at three elevations in Sangla valley, a total of 6 tree species and 14 shrub species were recorded. All the tree and shrub species were present in the lower elevation. In the middle elevation, 5 tree species and 8 shrub species were recorded, whilein the upper most elevation, only 4 tree species and 6 shrub species were present (Table 1). Thus depicting that as the latitude increases, there is reduction in the total number of woody species. *Juglans regia* was found to occur only at lower elevation whereas *Juniperus macropoda* was recorded at lower and middle elevations only (Table 1).

Table 1: Floristic diversity of woody elements in Sangla valley.

Species	Sangla Valley		
	Lower Elevation	Middle Elevation	Upper Elevation
Trees			
Abies pindrow	■	■	■
Betula utilis	■	■	■
Juglans regia	■		
Juniperus macropoda	■	■	
Picea smithiana	■	■	■
Pinus wallichiana	■	■	■
Shrubs			
Berberis aristata	■	■	■
Cotoneaster baccillaris	■	■	■
Desmodium tiliaefolium	■		
Indigofera gerardiana	■	■	
Juniperus recurva	■	■	■
Prinsepia utilis	■	■	■
Rhamanus triqetrus	■	■	
Rosa macrophylla	■	■	■
Viburnum cotonifolium	■	■	■
Total	15	13	10

Where ■ : depicts presence.

4.2 Phenological Studies

Phenology is generally described as the art of observing the life cycle phases or the activities of the organism as they occur through the year as we can say that the descriptive study of the behavioral characteristics of organism in relation to their environment is termed as

Table 3: Phenophases observed for different woody elements in middle elevation (3300-3600m) in the study area.

Species	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Trees												
Abies pindrow												
Betula utilis												
Juniperus macropoda												
Picea smithiana												
Pinus wallichiana												
Shrubs												
Berberis aristata												
Cotoneaster baccillaris												
Indigofera gerardiana												
Juniperus recurva												
Prinsepia utilis												
Rhamanus triqetrus												
Rosa macrophylla												
Viburnum continifolium												

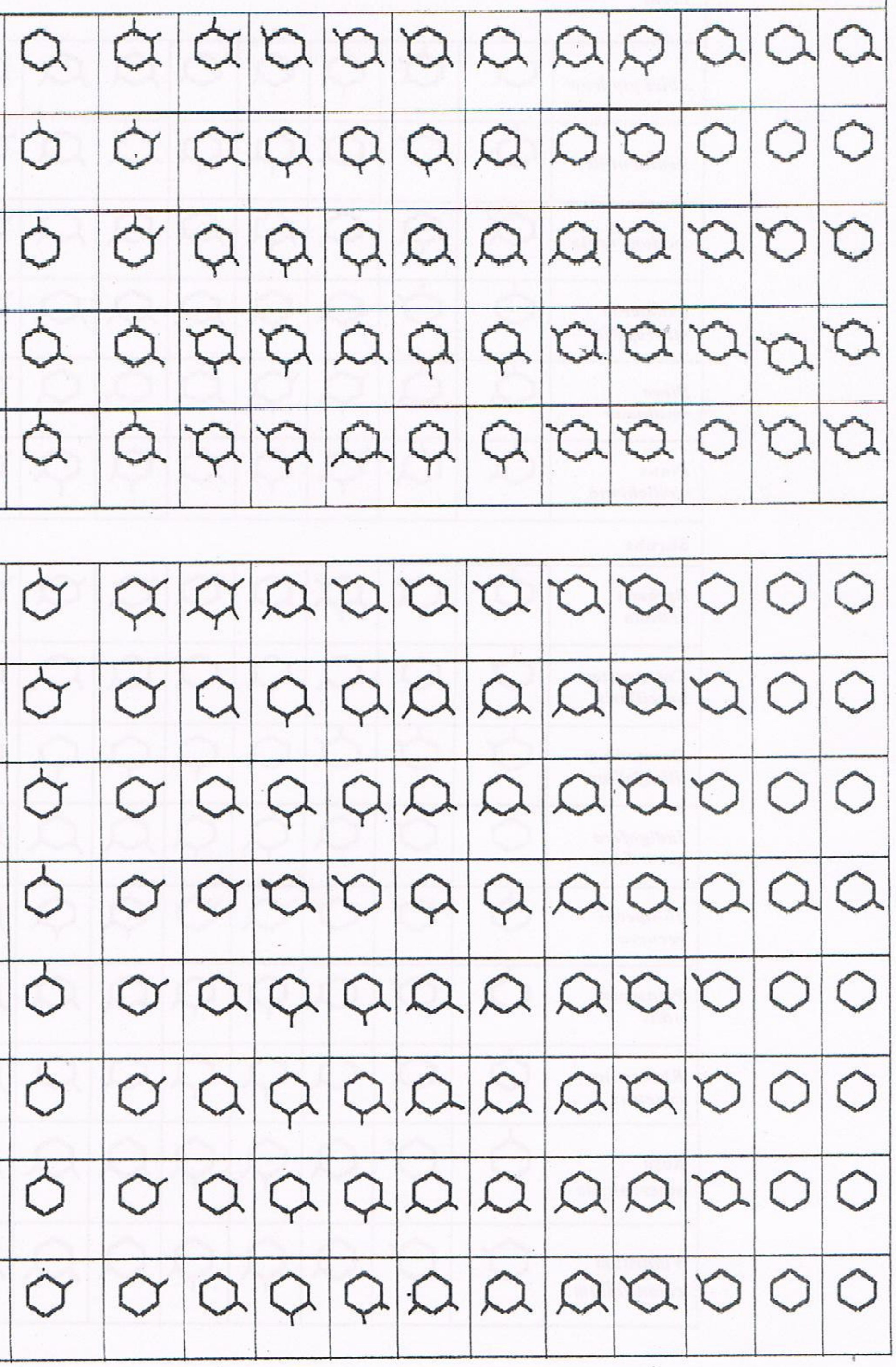
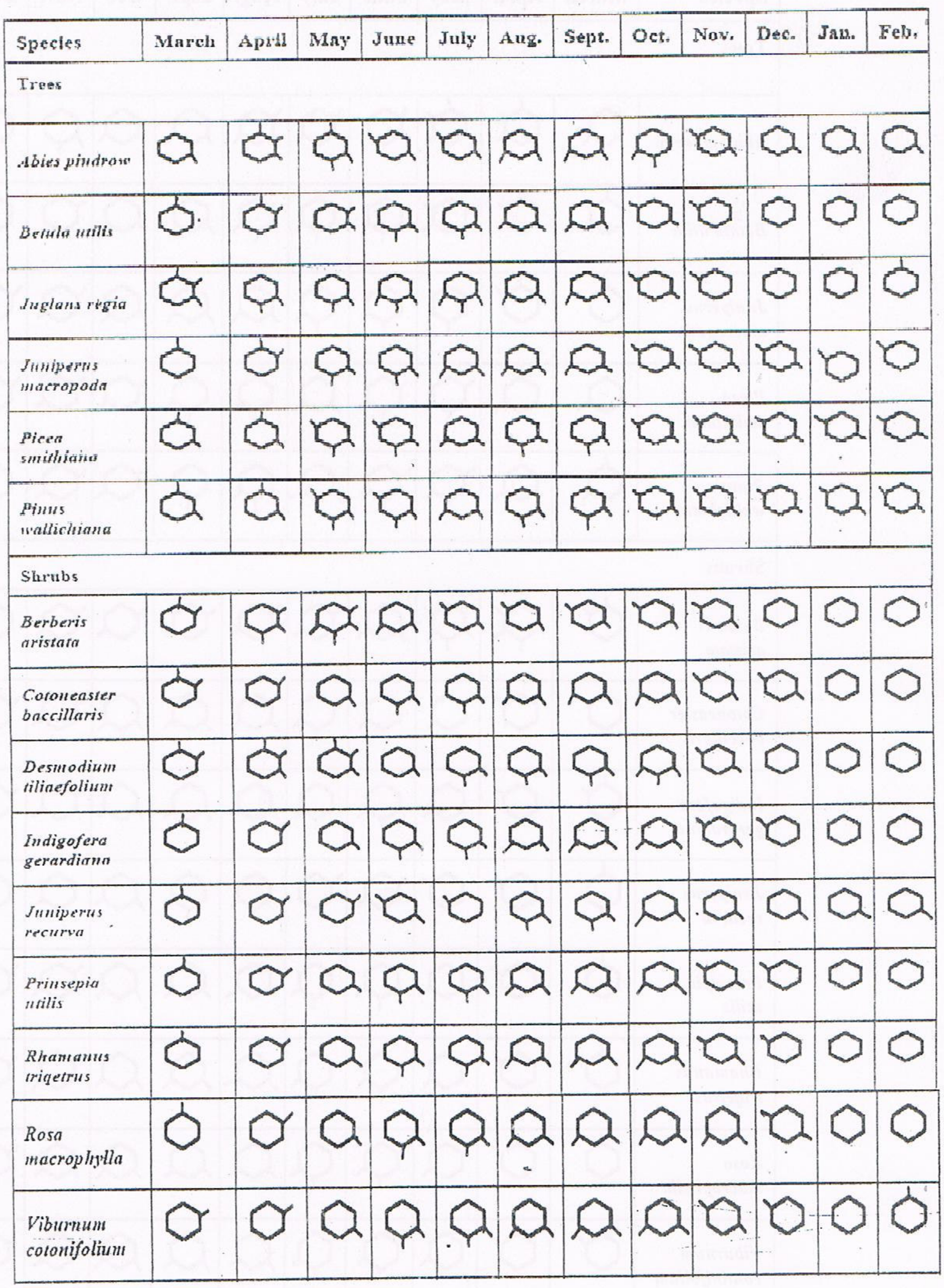


Table 2: Phenophases observed for different woody elements in lower elevation (3000-3300m) in the study area.



Species	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Trees												
Abies pindrow												
Betula utilis												
Juglans regia												
Juniperus macropoda												
Picea smithiana												
Pinus wallichiana												
Shrubs												
Berberis aristata												
Cotoneaster baccillaris												
Desmodium tiliaefolium												
Indigofera gerardiana												
Juniperus recurva												
Prinsepia utilis												
Rhamanus triqetrus												
Rosa macrophylla												
Viburnum cotonifolium												

Table 4: Phenophases observed for different woody elements in upper elevation (3600-3900m) in the study area.

Species	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Trees												
Abies pindrow												
Betula utilis												
Picea smithiana												
Pinus wallichiana												
Shrubs												
Berberis aristata												
Cotoneaster baccillaris												
Juniperus recurva												
Prinsepia utilis												
Rosa macrophylla												
Viburnum continifolium												

phenology. In the present study different phenophases of all the species in various elevations of betula forests in Sangla valley is reported and presented in Tables 2-4.

At lower elevation, six tree and nine shrub species were present and it was observed that with the advent of spring during March, bud sprout was observed in almost all tree species. Flowering was observed during April to May in *Abies pindrow, Picea smithiana, Pinus wallichiana, Juglans regia* and *Juniperus macropoda*, whereas in case of *Betula utilis*, flowering started in June and continued till July. Needle fall for *Abies pindrow, Picea smithiana* and *Pinus wallichiana* continued from May to June. However the leaf fall for board leaved species, i.e., *B. utilis* and *J. regia* started from September onwards and continued till November, there after both the species remained leafless for nearly three months. In *J. regia* seed fall took place just before leaf fall. In shrubs namely *Berberis aristata, Rosa macrophylla, Desmodium tiliaefolium, Prisepia utilis, Rhaminus triqetrus, Viburnum contonifolium.* Seed as well as leaf fall was observed between November and December. Fresh leaves appered only after the winter season i.e., during March and April (Table 2).

At middle elevation five tree and eight shrub species were observed and almost similar trend was observed for the different phenophases to appear at different stages for the species. However *Betula utilis* depicted emergence of bud sprout and leaf initiation from April and completed leaf fall was observed before November (Table 3).

However, at upper elevation only four tree and six shrub species were found of which the *Betula utilis* was only nonconifer species present and showed leaf initiation from may and complete leaf fall in November (Table 4).

4.3 Phytosociological Studies

The phytosociological parameters such as density, basal area, percentage frequency, relative density (RD), relatively basal area (RBA), relative frequency (RF), important value index (IVI), similarity and dissimilarity index, Shannon's diversity index in Betula forests of Sangla valley were calculated and are depicted in Tables 5 to 31.

4.3.1 Lower Elevation

Quadrate 1

The data presented in the quadrate 1 revealed the presence of six tree species and eight shrub species (Table 5). Among tree species *Pinus wallichiana* was having the maximum dominance followed by *Picea smithiana* and *Betula utilis* with IVI values of 49.98, 35.94 and 23.66, respectively. *Juniper macropoda* recorded minimum IVI value of 9.41. In case of shrubs, *Berberis aristata* was the dominant species followed by *Rosa macrophylla* and *Indigofera macrophylla* with IVI values of 33.85, 25.70 and 21.41, respectively. *Juniper recurva* had the lowest IVI value of 8.96. Similarly, the maximum share for basal area was contributed by *Pinus wallichiana* (34.51%) followed by *Picea smithiana* (24.35%). However, the maximum share for density (12.77%) was contributed by *Betula utilis* and followed by *Pinus wallichiana* (8.33%).

Quadrate 2

The data presented in Table 6 revealed that out of four tree species present in the quadrate 2, *Pinus wallichiana* was the most dominating with maximum IVI value of 46.15. This was, however, followed by *Picea smithiana* and *Abies pindrow* with IVI values 43.52 and 35.95, respectively, whereas, *Betula utilis* exhibited the lowest IVI value of 23.62 among the trees. Similarly, out of eight shrub species present in the forest, *Berberis aristata* had highest value for all phytosociological parameters with an IVI value of 28.51, which was followed by *Rosa*

Table 5 : Phytosociological data of quadrate 1 in study area at lower elevation (3000-3300m).

S.No	Species	RBA	RD	RF	IVI
		Trees			
1	*Abies pindrow*	13.07	2.77	7.14	22.99
2	*Betula utilis*	3.75	12.77	7.14	23.66
3	*Juglans regia*	1.64	1.67	7.14	10.45
4	*Juniperus macropoda*	0.60	1.67	7.14	9.41
5	*Picea smithiana*	24.35	4.44	7.14	35.94
6	*Pinus wallichiana*	34.51	8.33	7.14	49.98
		Shrubs			
1	*Berberis aristata*	5.60	21.11	7.14	33.85
2	*Cotoneaster baccillaris*	1.37	5.55	7.14	14.06
3	*Desmodium tiliaefolium*	0.53	5.55	7.14	13.22
4	*Indigofera gerardiana*	3.80	4.44	7.14	15.38
5	*Juniperus recurva*	0.15	1.67	7.14	8.96
6	*Prinsepia utilis*	3.15	11.11	7.14	21.41
7	*Rosa macrophylla*	4.12	14.44	7.14	25.70
8	*Viburnum continifolium*	3.35	4.44	7.14	14.94
	Total	**99.99**	**99.96**	**99.96**	**299.91**

Where: RBA = Relative basal area, RD = Relative density, RF = Relative frequency, IVI = Important value index

Table 6 : Phytosociological data of quadrate 2 in study area at lower elevation (3000-3300m).

S.No	Species	RBA	RD	RF	IVI
		Trees			
1	*Abies pindrow*	20.63	6.99	8.33	35.95
2	*Betula utilis*	3.46	11.83	8.33	23.62
3	*Picea smithiana*	28.20	6.99	8.33	43.52
4	*Pinus wallichiana*	28.68	9.14	8.33	46.15
		Shrubs			
1	*Berberis aristata*	4.05	16.13	8.33	28.51
2	*Cotoneaster baccillaris*	1.61	6.99	8.33	16.94
3	*Indigofera gerardiana*	2.90	5.38	8.33	16.61
4	*Juniperus recurva*	0.19	2.69	8.33	11.21
5	*Prinsepia utilis*	2.55	9.68	8.33	20.56
6	*Rhamnus triqetrus*	0.98	4.30	8.33	13.61
7	*Rosa macrophylla*	3.29	12.90	8.33	24.53
8	*Viburnum continifolium*	3.47	6.99	8.33	18.78
	Total	**100.01**	**99.99**	**99.96**	**299.96**

Where: RBA = Relative basal area, RD = Relative density, RF = Relative frequency, IVI = Important value index

macrophylla in all the phytosociological parameters with an IVI value of 24.53. The minimum value for all phytosociological parameters was recorded for *Junipers recurva* with an IVI value of 11.21. The maximum share for basal area (28.68%) was observed for *Pinus wallichiana*, however, the maximum share for density (11.83%) was observed for *Betula utilis* for tree species (Table 6).

Quadrate 3

In quadrate 3, four tree and eight shrub species were present. Among trees, maximum dominance was observed for *Pinus wallichiana* with an IVI value of 54.27, followed by *Abies pindrow* and *Betula utilis* with an IVI value of 44.90 and 26.91, respectively. However, the lowest IVI value of 15.88 was recorded for *Picea smithiana*. Whereas, for basal area the maximum contribution was observed for *P. wallichiana* (37.77%) followed by *Abies pindrow* (30.96%), in case of density, maximum contribution is by *Betula utilis* (13.78%) followed by *P. wallichiana* (8.16%). Among shrubs the maximum dominance was observed for *Berberis aristata* with an IVI value of 26.47, followed by *Rosa macrophylla* and *Viburnum continifolium* with an IVI value of 22.94 and 22.85, respectively. However, the lowest contribution was recorded for *Juniper recurva* within IVI value of 10.05 (Table 7).

Quadrate 4

The data collected from the quadrate 4 is presented in Table 8 and it revealed the presence of five tree and seven shrubs species. Among tree species, *Pinus wallichiana* was the prominent one having IVI value of 53.88, the co-dominating species was *Picea smithiana* and associated species was *Betula utilis* with IVI values of 24.78 and 22.85, respectively. Whereas, the least IVI value of 11.00 was observed for *Juglans regia*. Similarly, the maximum contribution of basal area (34.17%) was recorded for *P. wallichiana* and followed by *Picea smithiana* (12.85%). However, the maximum share for density of 11.97 per cent was recorded by

Table 7 : Phytosociological data of quadrate 3 in study area at lower elevation (3000-3300m).

S.No	Species	RBA	RD	RF	IVI
Trees					
1	*Abies pindrow*	30.96	5.61	8.33	44.90
2	*Betula utilis*	4.80	13.78	8.33	26.91
3	*Picea smithiana*	2.44	5.10	8.33	15.88
4	*Pinus wallichiana*	37.77	8.16	8.33	54.27
Shrubs					
1	*Berberis aristata*	4.36	13.77	8.33	26.47
2	*Cotoneaster baccillaris*	2.48	7.65	8.33	18.46
3	*Indigofera gerardiana*	3.11	8.16	8.33	19.61
4	*Juniperus recurva*	0.19	1.53	8.33	10.05
5	*Prinsepia utilis*	2.89	7.65	8.33	18.88
6	*Rhamnus triqetrus*	1.72	8.67	8.33	18.73
7	*Rosa macrophylla*	4.40	10.20	8.33	22.94
8	*Viburnum continifolium*	4.82	9.69	8.33	22.85
	Total	**99.94**	**99.97**	**99.96**	**299.94**

Where: RBA = Relative basal area, RD = Relative density, RF = Relative frequency, IVI = Important value index

Table 8 : Phytosociological data of quadrate 4 in study area at lower elevation (3000-3300m).

S.No	Species	RBA	RD	RF	IVI
Trees					
1	*Abies pindrow*	8.64	2.99	8.33	19.96
2	*Betula utilis*	2.55	11.97	8.33	22.85
3	*Juglans regia*	1.47	1.20	8.33	11.00
4	*Picea smithiana*	12.85	3.59	8.33	24.78
5	*Pinus wallichiana*	34.17	11.38	8.33	53.88
Shrubs					
1	*Berberis aristata*	3.99	19.16	8.33	31.48
2	*Cotoneaster baccillaris*	1.59	6.59	8.33	16.51
3	*Desmodium tiliaefolium*	0.47	7.19	8.33	15.98
4	*Indigofera gerardiana*	2.61	5.39	8.33	16.34
5	*Prinsepia utilis*	26.73	13.77	8.33	48.83
6	*Rosa macrophylla*	2.80	11.98	8.33	23.10
7	*Viburnum continifolium*	2.10	4.79	8.33	15.22
	Total	**99.99**	**100.01**	**99.96**	**299.96**

Where: RBA = Relative basal area, RD = Relative density, RF = Relative frequency, IVI = Important value index

Betula utilis and followed by *Pinus wallichiana* (11.38%). Among shrubs, *Prinsepia utilis* was the dominant species co-dominant was *Berberis aristata* with IVI values of 48.83 and 31.48, respectively. Among shrubs *Viburnum continifolium* had the least IVI value of 15.22 (Table 8).

Quadrate 5

The data for quadrate 5 depicted that among four tree species present *Pinus wallichiana* dominated both IVI value (59.03) and share of basal area (40.59%) followed by *Picea smithiana* with value at 31.01 and 19.72 per cent, respectively. However, the maximum share for density (14.28%) was contributed by *Betula utilis* followed by *P. wallichiana* (9.34%) and the minimum IVI value (24.63) was recorded for *Abies pindrow*. The highest share for basal area (4.96%) and density (2.20%) was recorded for *B. utilis and P. smithiana,* respectively. Among shrubs, the maximum IVI value (29.33) was observed for *Berberis aristata* followed by *Rhamnus triqetris* (23.52) and *Prinsepia utilis* (23.24) while the lowest IVI value (15.12) was observed for *Desmodium tiliaefolium* (Table 9).

Table 9 : Phytosociological data of quadrate 5 in study area at lower elevation (3000-3300m).

S.No	Species	RBA	RD	RF	IVI
Trees					
1	*Abies pindrow*	12.25	3.29	9.09	24.63
2	*Betula utilis*	4.96	14.28	9.09	28.33
3	*Picea smithiana*	19.72	2.20	9.09	31.01
4	*Pinus wallichiana*	40.59	9.34	9.09	59.03
Shrubs					
1	*Berberis aristata*	4.85	15.38	9.09	29.33
2	*Cotoneaster baccillaris*	3.03	10.44	9.09	22.56
3	*Desmodium tiliaefolium*	0.53	5.49	9.09	15.12
4	*Prinsepia utilis*	3.71	10.44	9.09	23.24
5	*Rhamnus triqetrus*	2.90	11.53	9.09	23.52
6	*Rosa macrophylla*	3.86	9.89	9.09	22.83
7	*Viburnum continifolium*	3.57	7.69	9.09	20.35
	Total	**99.97**	**99.97**	**99.99**	**299.93**

Where: RBA = Relative basal area, RD = Relative density, RF = Relative frequency, IVI = Important value index

4.3.2 Middle Elevation

Quadrate 6

The phytosociological data presented in Table 10 for quadrate 6 of middle elevation of Sangla valley indicated the presence of five tree and seven shrub species. The IVI values obtained showed that in case of trees, the maximum value (45.38) was observed for *Pinus wallichiana*, followed by *Picea smithiana* (36.19), *Abies pindrow* (28.87) and *Betula utilis* (24.25). The minimum value (10.19) was observed in case of *Juniper macropoda*. The maximum contribution for basal area (30.55%) was recorded for *P. wallichiana*, followed by *P. smithiana* (22.66%), whereas the maximum contribution for density was observed in case of *B. utilis* (12.33%) followed by *P. wallichiana* (6.49%). Among the shrubs species, the maximum IVI value was recorded in case of *Berberis aristata* (32.37), followed by *Rosa macrophylla* (27.09), with minimum IVI value of 13.16 for *Juniper recurva* (Table 10).

Table 10 : Phytosociological data of quadrate 6 in study area at middle elevation (3300-3600m).

S.No	Species	RBA	RD	RF	IVI
	Trees				
1	*Abies pindrow*	17.94	2.59	8.33	28.87
2	*Betula utilis*	3.58	12.33	8.33	24.25
3	*Juniperus macropoda*	0.56	1.29	8.33	10.19
4	*Picea smithiana*	22.66	5.19	8.33	36.19
5	*Pinus wallichiana*	30.55	6.49	8.33	45.38
	Shrubs				
1	*Berberis aristata*	5.20	18.83	8.33	32.37
2	*Cotoneaster baccillaris*	3.42	8.44	8.33	20.19
3	*Indigofera gerardiana*	2.67	4.54	8.33	15.55
4	*Juniperus recurva*	0.28	4.54	8.33	13.16
5	*Prinsepia utilis*	3.54	14.28	8.33	26.16
6	*Rosa macrophylla*	5.77	12.99	8.33	27.09
7	*Viburnum continifolium*	3.79	8.44	8.33	20.56
	Total	**99.96**	**100.01**	**99.96**	**299.93**

Where: RBA = Relative basal area, RD = Relative density, RF = Relative frequency, IVI = Important value index

Quadrate 7

The floristic composition of quadrate 7 located in middle elevation of Betula bearing forest revealed that among tree species *Pinus wallichiana* was dominating with maximum IVI value of 46.71 followed by *Picea smithiana, Abies pindrow* and *Betula utilis* with IVI values of 30.65, 26.97 and 24.82, respectively (Table 11). Whereas, the minimum IVI value of 9.39 was observed in case of *Juniper macropoda*. The highest share of basal area (31.83%) was observed for *P. wallichiana*. The maximum contribution to density was recorded in case of *Betula utilis* with a share of 13.17 per cent. Among shrub species, the maximum IVI value of 27.51 was observed in case of *Rosa macrophylla,* closely followed by *Berberis aristata* with an IVI value of 26.87, whereas, the minimum IVI value was recorded for *Junipers recurva* (9.81).

Table 11 : Phytosociological data of quadrate 7 in study area at middle elevation (3300-3600m).

S.No	Species	RBA	RD	RF	IVI
	Trees				
1	*Abies pindrow*	16.88	2.40	7.69	26.97
2	*Betula utilis*	3.95	13.17	7.69	24.82
3	*Juniperus macropoda*	0.50	1.20	7.69	9.39
4	*Picea smithiana*	19.37	3.59	7.69	30.65
5	*Pinus wallichiana*	31.83	7.19	7.69	46.71
	Shrubs				
1	*Berberis aristata*	4.81	14.37	7.69	26.87
2	*Cotoneaster baccillaris*	2.96	5.99	7.69	16.64
3	*Indigofera gerardiana*	2.96	5.99	7.69	16.64
4	*Juniperus recurva*	0.33	1.80	7.69	9.81
5	*Prinsepia utilis*	3.35	11.98	7.69	23.02
6	*Rhamnus triqetrus*	3.34	10.78	7.69	21.81
7	*Rosa macrophylla*	6.05	13.77	7.69	27.51
8	*Viburnum continifolium*	3.68	7.78	7.69	19.16
	Total	**100.01**	**99.93**	**100.01**	**299.95**

Where: RBA = Relative basal area, RD = Relative density, RF = Relative frequency, IVI = Important value index

Quadrate 8

From the perusal of data given in Table 12, it is evident that four tree and six shrub species were present in quadrate 8 at middle elevation. Among trees, the maximum dominance was observed for *Pinus wallichiana* with an IVI value of 47.23, which was followed by *Picea smithiana* and *Abies pindrow* with IVI values of 37.20 and 27.29, respectively. However, minimum IVI value of 25.16 was observed for *Betula utilis*. Similarly, the maximum contribution to basal area of 30.98 per cent was recorded in case of *P. wallichiana.* The maximum share for density was contributed by *B. utilis* (10.80%), whereas, in case of shrub species, the maximum dominance was recorded for *Berberis aristata* with an IVI value of 35.55 followed *by Rosa macrophylla* and *Prinsepia utilis* with an IVI values of 32.93 and 31.72, respectively. The minimum IVI value was observed for *Juniper recurva* with an IVI value of 12.14 (Table 12).

Table 12 : Phytosociological data of quadrate 8 in study area at middle elevation (3300-3600m)

S.No	Species	RBA	RD	RF	IVI
	Trees				
1	*Abies pindrow*	15.02	2.27	10.00	27.29
2	*Betula utilis*	4.37	10.80	10.00	25.16
3	*Picea smithiana*	23.22	3.98	10.00	37.20
4	*Pinus wallichiana*	30.98	6.25	10.00	47.23
	Shrubs				
1	*Berberis aristata*	6.80	18.75	10.00	35.55
2	*Cotoneaster baccillaris*	4.48	11.93	10.00	26.41
3	*Juniperus recurva*	0.43	1.70	10.00	12.14
4	*Prinsepia utilis*	4.11	17.61	10.00	31.72
5	*Rosa macrophylla*	7.02	15.91	10.00	32.93
6	*Viburnum continifolium*	3.58	10.80	10.00	24.38
	Total	**100.00**	**100.00**	**100.00**	**300.00**

Where: RBA = Relative basal area, RD = Relative density, RF = Relative frequency, IVI = Important value index

Quadrate 9

The maximum dominance in quadrate 9 in middle elevation for tree species was observed for *Pinus wallichiana* with an IVI value of 49.22, which was followed by *Picea smithiana* and *Abies pindrow* with an IVI values of 28.51 and 27.67, respectively. However, the minimum IVI value (23.56) for tree species was observed for *Betula utilis*, while the maximum contribution for basal area was observed for *P. wallichiana* with the share of 33.18 per cent and the maximum contribution for density was recorded for *B. utilis* with a share of 10.70 per cent. Among the shrub species recorded the maximum IVI value (31.26) with recorded for *Berberis aristata* which was closely followed by *Prinsepia utilis* and *Rosa macrophylla* with IVI value of 29.38 and 28.07, respectively. However, the minimum IVI value was (10.62) recorded in case of *Juniper recurva* (Table 13).

Table 13 : Phytosociological data of quadrate 9 in study area at middle elevation (3300-3600m)

S.No	Species	RBA	RD	RF	IVI
	Trees				
1	*Abies pindrow*	15.37	3.21	9.09	27.67
2	*Betula utilis*	3.77	10.70	9.09	23.56
3	*Picea smithiana*	17.28	2.14	9.09	28.51
4	*Pinus wallichiana*	33.18	6.95	9.09	49.22
	Shrubs				
1	*Berberis aristata*	6.13	16.04	9.09	31.26
2	*Cotoneaster baccillaris*	4.27	10.70	9.09	24.06
3	*Juniperus recurva*	0.46	1.07	9.09	10.62
4	*Prinsepia utilis*	5.32	14.97	9.09	29.38
5	*Rhamnus triqetrus*	2.81	9.63	9.09	21.52
6	*Rosa macrophylla*	6.14	12.83	9.09	28.07
7	*Viburnum continifolium*	5.27	11.76	9.09	26.13
	Total	**99.97**	**99.98**	**99.99**	**299.94**

Where: RBA = Relative basal area, RD = Relative density, RF = Relative frequency, IVI = Important value index

Quadrate 10

The tabulated data for the quadrate 10 showed that the maximum IVI value was found for *Pinus wallichiana* among trees (46.84) followed by *Picea smithiana (*36.10) and *Betula utilis* (25.42), respectively (Table 14). *Abies pindrow* with a minimum IVI value of 13.65 was the least in dominance. Also the maximum contribution of basal area was recorded for *P. wallichiana* with the share of 30.69 per cent, while the maximum contribution towards density was recorded for *Betula utilis* with the share of 12.35 per cent. Among shrubs the species category which dominated the habitat was *Berberis aristata* with an IVI value of 31.58 followed by *Prinsepia utilis* (29.42) and *Rosa macrophylla* (28.05), respectively. Whereas, the minimum IVI value (10.70) was found for *Juniper recurva* (Table 14).

Table 14 : Phytosociological data of quadrate 10 in study area at middle elevation (3300-3600m)

S.No	Species	RBA	RD	RF	IVI
Trees					
1	*Abies pindrow*	13.68	1.76	9.09	24.53
2	*Betula utilis*	3.98	12.35	9.09	25.42
3	*Picea smithiana*	22.31	4.71	9.09	36.10
4	*Pinus wallichiana*	30.69	7.06	9.09	46.84
Shrubs					
1	*Berberis aristata*	6.02	16.47	9.09	31.58
2	*Cotoneaster baccillaris*	3.15	7.06	9.09	19.30
3	*Juniperus recurva*	0.43	1.18	9.09	10.70
4	*Prinsepia utilis*	5.03	15.29	9.09	29.42
5	*Rhamnus triqetrus*	2.37	8.82	9.09	20.29
6	*Rosa macrophylla*	6.02	12.94	9.09	28.05
7	*Viburnum continifolium*	6.32	12.35	9.09	27.77
	Total	**99.99**	**99.98**	**99.99**	**299.96**

Where: RBA = Relative basal area, RD = Relative density, RF = Relative frequency, IVI = Important value index

4.3.3 Upper Elevation

Quadrate 11

The phytosociological data presented in Table 15 recorded from quadrate 11 at upper elevation in Betula forests of Sangla valley indicated the presence of four trees and six shrub species. The IVI values obtained showed that in case of trees, this habitat was dominated by *Pinus wallichiana* with an IVI value of 62.95 followed by *Betula utilis* (26.87) and *Abies pindrow* (25.70). However, the lowest IVI value was obtained in case of *Picea smithiana* (24.58). The maximum contribution for basal area was recorded for *Pinus wallichiana* with a share of 44.75 per cent and the maximum contribution for density was recorded for *Betula utilis* with a share of 13.93 per cent (Table 15). Among shrubs maximum IVI (31.74) was obtained for *Prinsepia utilis* which was closely followed by *Berberis aristata* (31.71), while the minimum IVI value was recorded for *Juniper recurva* (12.87).

Table 15 : Phytosociological data of quadrate 11 in study area at upper elevation (3600-3900m)

S.No	Species	RBA	RD	RF	IVI
	Trees				
1	*Abies pindrow*	13.23	2.46	10.00	25.69
2	*Betula utilis*	2.93	13.93	10.00	26.87
3	*Picea smithiana*	12.13	2.46	10.00	24.58
4	*Pinus wallichiana*	44.75	8.20	10.00	62.95
	Shrubs				
1	*Berberis aristata*	6.13	15.57	10.00	31.71
2	*Cotoneaster baccillaris*	3.39	11.48	10.00	24.86
3	*Juniperus recurva*	0.41	2.46	10.00	12.87
4	*Prinsepia utilis*	5.35	16.39	10.00	31.74
5	*Rosa macrophylla*	4.40	13.93	10.00	28.34
6	*Viburnum continifolium*	7.28	13.11	10.00	30.40
	Total	**100.01**	**99.98**	**100.00**	**299.99**

Where: RBA = Relative basal area, RD = Relative density, RF = Relative frequency, IVI = Important value index

Quadrate 12

The data in Table 16 pertaining to upper elevation of Betula bearing forest area revealed the presence of four tree and four shrubs species. Among trees, the maximum dominance was observed for *Pinus wallichiana* with an IVI value of 68.14 followed by *Betula utilis* and *Abies pindrow* with an IVI value of 41.87 and 33.33, respectively. However, the minimum IVI value was observed for *Picea smithiana* (30.85). The maximum contribution to basal area was also observed in case of *P. wallichiana* with the share of 47.22 per cent and the maximum contribution to density was observed in case of *Betula utilis* with a share of 24.21 per cent. Among shrub species, the maximum dominance was recorded for *Berberis aristata* with an IVI value of 37.74 closely followed by *Rosa macrophylla* and *Prinsepia utilize* with an IVI value of 35.88 and 34.84, respectively, however, the minimum at 17.35 IVI value was reported for *Juniper recurva* (Table 16).

Table 16 : Phytosociological data of quadrate 12 in study area at upper elevation (3600-3900m)

S.No	Species	RBA	RD	RF	IVI
	Trees				
1	*Abies pindrow*	15.57	5.26	12.50	33.33
2	*Betula utilis*	5.16	24.21	12.50	41.87
3	*Picea smithiana*	14.14	4.21	12.50	30.85
4	*Pinus wallichiana*	47.22	8.42	12.50	68.14
	Shrubs				
1	*Berberis aristata*	6.29	18.95	12.50	37.74
2	*Juniperus recurva*	0.64	4.21	12.50	17.35
3	*Prinsepia utilis*	5.50	16.84	12.50	34.84
4	*Rosa macrophylla*	5.49	17.89	12.50	35.88
	Total	**99.97**	**99.99**	**99.99**	**299.95**

Where: RBA = Relative basal area, RD = Relative density, RF = Relative frequency, IVI = Important value index

Quadrate 13

The data for quadrate 13 at upper elevation reveals that among tree species *Pinus wallichiana* dominated with a maximum IVI value of 58.25 followed by *Betula utilis* (38.66), while, minimum IVI value (25.51) was obtained for *Abies pindrow* (Table 18). The maximum contribution towards basal area was observed for *P. wallichiana* (41.26%) and maximum contribution to density was observed for *Betula utilis* (21.85%). Among shrubs, the maximum IVI value of 34.29 was recorded for *Berberis aristata,* followed by *Rosa macrophylla* (32.42) and *Prinsepia utilis* (32.18). However, the minimum IVI value was at 22.58 observed for *Cotoneaster baccillaris* (Table 17).

Table 17 : Phytosociological data of quadrate 13 in study area at upper elevation (3600-3900m).

S.No	Species	RBA	RD	RF	IVI
	Trees				
1	*Abies pindrow*	11.88	2.52	11.11	25.51
2	*Betula utilis*	5.70	21.85	11.11	38.66
3	*Picea smithiana*	12.57	2.52	11.11	26.20
4	*Pinus wallichiana*	41.26	5.88	11.11	58.25
	Shrubs				
1	*Berberis aristata*	6.37	16.81	11.11	34.29
2	*Cotoneaster baccillaris*	3.06	8.40	11.11	22.58
3	*Prinsepia utilis*	5.94	15.13	11.11	32.18
4	*Rosa macrophylla*	6.18	15.13	11.11	32.42
5	*Viburnum continifolium*	7.04	11.76	11.11	29.92
	Total	**99.99**	**99.99**	**99.99**	**299.97**

Where: RBA = Relative basal area, RD = Relative density, RF = Relative frequency, IVI = Important value index

Quadrate 14

The tabulated data for the quadrate 14 for upper elevation (Table 18) showed that the maximum IVI value was found for *Pinus wallichiana* (55.78) among trees followed by *Betula utilis* (35.72) and *Picea smithiana* (31.04) respectively, while the least IVI value (21.95) was recorded for *Abies pindrow*. Among shrub species the habitat was dominated by *Berberis aristata* with an IVI value of 34.73 and minimum IVI value of 25.80 was found for *Cotoneaster baccillaris* (Table18).

Quadrate 15

From the data presented in Table 19 pertaining to upper elevation, it is clear that this plot contained four tree and five shrub species. Among trees, *Pinus wallichiana* was recorded for maximum dominance with an IVI value 43.82 which was followed by all three species with IVI value of almost 34.02 for each species. The maximum contribution of 27.15 per cent for basal area was reported by *P. wallichiana* and maximum contribution for density (18.52%) was reported for *Betula utilis*. Out of five shrub species present the maximum IVI value was recorded for *Berberis aristata* (37.22) followed by *Prinsepia utilis* (33.89) and *Rosa macrophylla* (32.57), however, the minimum IVI value (23.41) was reported in case of *Cotoneaster beccillaris* (Table 19).

Table 18 : Phytosociological data of quadrate 14 in study area at upper elevation (3600-3900m)

S.No	Species	RBA	RD	RF	IVI
Trees					
1	*Abies pindrow*	8.95	1.89	11.11	21.95
2	*Betula utilis*	5.74	18.87	11.11	35.72
3	*Picea smithiana*	17.10	2.83	11.11	31.04
4	*Pinus wallichiana*	37.12	7.55	11.11	55.78
Shrubs					
1	*Berberis aristata*	6.64	16.98	11.11	34.73
2	*Cotoneaster baccillaris*	4.31	10.38	11.11	25.80
3	*Prinsepia utilis*	6.30	15.09	11.11	32.51
4	*Rosa macrophylla*	6.65	14.15	11.11	31.92
5	*Viburnum continifolium*	7.19	12.26	11.11	30.56
	Total	**99.99**	**99.99**	**99.99**	**299.97**

Where: RBA = Relative basal area, RD = Relative density, RF = Relative frequency, IVI = Important value index

Table 19 : Phytosociological data of quadrate 15 in study area at upper elevation (3600-3900m)

S.No	Species	RBA	RD	RF	IVI
Trees					
1	*Abies pindrow*	19.31	3.70	11.11	34.12
2	*Betula utilis*	4.39	18.52	11.11	34.02
3	*Picea smithiana*	20.03	3.70	11.11	34.84
4	*Pinus wallichiana*	27.15	5.56	11.11	43.82
Shrubs					
1	*Berberis aristata*	6.66	19.44	11.11	37.22
2	*Cotoneaster baccillaris*	3.97	8.33	11.11	23.41
3	*Prinsepia utilis*	6.11	16.67	11.11	33.89
4	*Rosa macrophylla*	6.64	14.81	11.11	32.57
5	*Viburnum continifolium*	5.73	9.26	11.11	26.10
	Total	**99.99**	**99.98**	**99.99**	**299.96**

Where: RBA = Relative basal area, RD = Relative density, RF = Relative frequency, IVI = Important value index

4.3.4 Phytosociology of Lower Elevation (per hectare basis)

The mean phytosociology data on per hectare basis for this elevation of Sangla valley Betula bearing forest (Table 20) showed that there existed six tree and nine shrub species in the forest. The maximum IVI value was observed for *Pinus wallichiana* (52.67) among trees, being followed by *Picea smithiana* (30.23) whereas, *Juniper macropoda* exhibited a minimum IVI value of 1.88 The maximum contribution to basal area was recorded for *P. wallichiana* (35.15%) and maximum contribution to density was recorded for *Betula utilis* (12.93%). Among shrubs, the species which dominated that habitat was found to be *Berberis aristata* with an IVI value of 29.93 being followed by *Prinsepia utilis* (26.59). The minimum IVI value (6.04) was, however, found in case of *Juniper recurva* and maximum contribution to basal area and density was contributed by *B. aristata* at 4.57 and 17.11, respectively.

Table 20 : Mean phytosociological data in study area at lower horizontal elevation (3000-3300m) on per hectare basis.

S.No	Species	RBA	RD	RF	IVI
	Trees				
1	*Abies pindrow*	17.11	4.33	8.24	29.69
2	*Betula utilis*	3.90	12.93	8.24	25.08
3	*Juglans regia*	0.62	0.57	3.09	4.29
4	*Juniperus macropoda*	0.12	0.33	1.42	1.88
5	*Picea smithiana*	17.52	4.64	8.24	30.23
6	*Pinus wallichiana*	35.15	9.27	8.24	52.67
	Shrubs				
1	*Berberis aristata*	4.57	17.11	8.24	29.93
2	*Cotoneaster baccillaris*	2.02	7.44	8.24	17.71
3	*Desmodium tiliaefolium*	0.88	4.72	6.57	12.19
4	*Indigofera gerardiana*	1.91	3.59	4.76	10.27
5	*Juniperus recurva*	0.10	1.17	4.76	6.04
6	*Prinsepia utilis*	7.81	10.53	8.24	26.59
7	*Rhamnus triqetrus*	1.12	4.90	5.15	11.18
8	*Rosa macrophylla*	3.69	11.88	8.24	23.83
9	*Viburnum continifolium*	3.46	6.72	8.24	18.43
	$CD_{0.05}$	**6.10**	**3.11**	**3.50**	**9.43**

Where: RBA = Relative basal area, RD = Relative density, RF = Relative frequency, IVI = Important value index

4.3.5 Phytosociology of Middle Elevation (per hectare basis)

The data present in Table 21 indicated five tree and eight shrub species in this elevation class. Among trees, *Pinus wallichiana* had the maximum IVI value (47.08) followed by *Picea smithiana* (33.73) and *Abies pindrow* (27.07). Similarly, the maximum contribution to basal area and density was depicted for *Pinus wallichiana* (31.45 %) and *Betula utilis* (11.48%), respectively. However, the minimum IVI value (3.91) was observed for *Juniper macropoda*. Among eight shrub species, *Berberis aristata* showed maximum value for IVI value (31.53) and density (16.89%) and for basal area maximum contribution was recorded for *Rosa macrophylla* (6.20%). Highest IVI was found for *Berberis aristata* which was followed by *R. macrophylla* (28.73) and *Prinsepia utilis* (27.94), respectively, and minimum IVI value (6.43) was observed for *Indigofera gerardiana* (Table 21).

Table 21 : Mean phytosociological data in study area at middle horizontal elevation (3300-3600m) on per hectare basis.

S.No	Species	RBA	RD	RF	IVI
Trees					
1	*Abies pindrow*	15.78	2.45	8.84	27.07
2	*Betula utilis*	3.93	11.48	8.84	24.64
3	*Juniperus macropoda*	0.21	0.49	3.20	3.91
4	*Picea smithiana*	20.97	3.92	8.84	33.73
5	*Pinus wallichiana*	31.45	6.78	8.84	47.08
Shrubs					
1	*Berberis aristata*	5.79	16.89	8.84	31.53
2	*Cotoneaster baccillaris*	3.65	8.82	8.84	21.32
3	*Indigofera gerardiana*	1.12	2.10	3.20	6.43
4	*Juniperus recurva*	0.38	2.05	8.84	11.29
5	*Prinsepia utilis*	4.27	14.83	8.84	27.94
6	*Rhamnus triqetrus*	1.70	5.84	5.17	12.72
7	*Rosa macrophylla*	6.20	13.69	8.84	28.73
8	*Viburnum continifolium*	4.53	10.23	8.84	23.60
	$CD_{0.05}$	**1.60**	**2.90**	**3.04**	**6.55**

Where: RBA = Relative basal area, RD = Relative density, RF = Relative frequency, IVI = Important value index

4.3.6 Phytosociology of Upper Elevation (per hectare basis)

The phytosociological data for upper elevation (per ha) in Betula forests of Sangla valley indicated the presence of four tree and six shrub species. In case of trees maximum IVI (57.79) and maximum contribution to basal area (39.50%) was observed for *Pinus wallichiana*. The maximum IVI for *Pinus wallichiana* was followed by *Betula utilis* (35.43) and *Picea smithiana* (29.50). Whereas, the maximum contribution for density (19.48%) was recorded for *B. utilis.* However, the minimum IVI value was recorded for *Abies pindrow* (28.12). In case of shrubs, the maximum IVI value (35.14) was observed for *Berberis aristata,* being followed by *Prinsepia utilis* (33.03) and *Rosa macrophylla* (32.22), respectively and minimum IVI value (6.04) was observed for *Juniper recurva* (Table 22).

Table 22 : Mean phytosociological data in study area at upper horizontal elevation (3600-3900m) on per hectare basis.

S.No	Species	RBA	RD	RF	IVI
	Trees				
1	*Abies pindrow*	13.79	3.16	11.17	28.12
2	*Betula utilis*	4.78	19.48	11.17	35.43
3	*Picea smithiana*	15.19	3.14	11.17	29.50
4	*Pinus wallichiana*	39.50	7.12	11.17	57.79
	Shrubs				
1	*Berberis aristata*	6.42	17.55	11.17	35.14
2	*Cotoneaster baccillaris*	2.94	7.72	8.67	19.33
3	*Juniperus recurva*	0.21	1.33	4.50	6.04
4	*Prinsepia utilis*	5.84	16.02	11.17	33.03
5	*Rosa macrophylla*	5.87	15.18	11.17	32.22
6	*Viburnum continifolium*	5.45	9.28	8.67	23.40
	$CD_{0.05}$	**4.35**	**3.77**	**4.09**	**9.92**

Where: RBA = Relative basal area, RD = Relative density, RF = Relative frequency, IVI = Important value index

4.3.7 Combined Data for Phytosociology of Sangla valley

The Data presented in Table 23 represents the overall dominance of tree and shrub species in the Betula forests of Sangla valley. The table revealed the presence of six tree and nine shrub species in the forest. Among tree species *Pinus wallichiana* was having maximum dominance with IVI value of 52.51, followed by *Picea smithiana* and *Betula utilis* with IVI values of 31.15 and 28.38, respectively. Whereas, the minimum IVI value (1.43) was observed for *Juglans regia*. Similarly, in case of shrubs, the maximum dominance with IVI value of 32.20 was recorded for *Berberis aristata*, followed by *Prinsepia utilis* and *Rosa macrophylla* with IVI of 29.18 and 28.26 (Table 23).

Table 23 : Cummulative and mean phytosociological data in study area.

S.No	Species	Lower	Middle	Upper	Mean
	Trees				
1	*Abies pindrow*	29.69	27.07	28.12	28.29
2	*Betula utilis*	25.08	24.64	35.43	28.38
3	*Juglans regia*	4.29	0.00	0.00	1.43
4	*Juniperus macropoda*	1.88	3.91	0.00	1.93
5	*Picea smithiana*	30.23	33.73	29.5	31.15
6	*Pinus wallichiana*	52.67	47.08	57.79	52.51
	Shrubs				
1	*Berberis aristata*	29.93	31.53	35.14	32.20
2	*Cotoneaster baccillaris*	17.71	21.32	19.33	19.45
3	*Desmodium tiliaefolium*	12.19	0.00	0.00	4.063
4	*Indigofera gerardiana*	10.27	6.43	0.00	5.567
5	*Juniperus recurva*	6.04	11.29	6.04	7.79
6	*Prinsepia utilis*	26.59	27.94	33.03	29.18
7	*Rhamnus triqetrus*	11.18	12.72	0.00	7.967
8	*Rosa macrophylla*	23.83	28.73	32.22	28.26
9	*Viburnum continifolium*	18.43	23.6	23.40	21.81

Where: RBA = Relative basal area, RD = Relative density, RF = Relative frequency, IVI = Important value index

4.3.8 Phytosociology of Vertical Quadrates (per hectare basis)

Phytosociology of V1

The phytosociology data for vertical (per ha) in Betula forests of Sangla valley is presented in Table 24. The table revealed the presence of six tree and eight shrub species. Among trees, *Pinus wallichiana* had the maximum IVI value (52.05) followed by *Picea smithiana* (33.56) and *Abies pindrow* (25.83). Among shrubs, the maximum (33.04) IVI value recorded for *Berberis aristata*, followed by *Rosa macrophylla* (27.09) and *Prinsepia utilis* (25.98).

Table 24 : Mean phytosociological data in study site at vertical 1 (3000-3900) on per hectare basis.

S.No	Species	RBA	RD	RF	IVI
	Trees				
1	*Abies pindrow*	14.62	2.63	8.57	25.83
2	*Betula utilis*	3.50	12.94	8.57	25.01
3	*Juglans regia*	0.73	0.66	2.86	4.24
4	*Juniperus macropoda*	0.44	1.10	2.86	4.39
5	*Picea smithiana*	20.82	4.17	8.57	33.56
6	*Pinus wallichiana*	35.80	7.68	8.57	52.05
	Shrubs				
1	*Berberis aristata*	5.61	18.86	8.57	33.04
2	*Cotoneaster baccillaris*	2.50	8.11	8.57	19.19
3	*Desmodium tiliaefolium*	0.23	2.19	2.86	5.28
4	*Indigofera gerardiana*	2.51	3.29	5.71	11.52
5	*Juniperus recurva*	0.26	2.85	8.57	11.68
6	*Prinsepia utilis*	3.81	13.60	8.57	25.98
7	*Rosa macrophylla*	4.70	13.82	8.57	27.09
8	*Viburnum continifolium*	4.45	8.11	8.57	21.14
	Total	**100.00**	**100.00**	**100.00**	**300.00**

Where: RBA = Relative basal area, RD = Relative density, RF = Relative frequency, IVI = Important value index

Table 25 : Mean phytosociological data in study site at vertical 2 (3000-3900) on per hectare basis.

S.No	Species	RBA	RD	RF	IVI
	Trees				
1	*Abies pindrow*	18.46	4.91	8.82	32.19
2	*Betula utilis*	3.96	14.96	8.82	27.74
3	*Juniperus macropoda*	0.15	0.45	2.94	3.54
4	*Picea smithiana*	22.64	5.13	8.82	36.60
5	*Pinus wallichiana*	33.45	8.26	8.82	50.53
	Shrubs				
1	*Berberis aristata*	4.74	16.07	8.82	29.63
2	*Cotoneaster baccillaris*	1.69	5.13	8.82	15.64
3	*Indigofera gerardiana*	2.32	4.46	5.88	12.67
4	*Juniperus recurva*	0.32	2.68	8.82	11.83
5	*Prinsepia utilis*	3.40	12.05	8.82	24.27
6	*Rhamnus triqetrus*	1.49	5.80	5.88	13.17
7	*Rosa macrophylla*	4.57	14.29	8.82	27.68
8	*Viburnum continifolium*	2.81	5.80	5.88	14.50
	Total	**100.00**	**100.00**	**100.00**	**300.00**

Where: RBA = Relative basal area, RD = Relative density, RF = Relative frequency, IVI = Important value index

Phytosociology of V2

Table 25, represents the phytosociological data for Vertical 2 (per ha) of Betula forests in Sangla valley. It indicated five tree and eight shrub species were present. Among trees, the maximum dominance was for *P. wallichiana* with IVI value of 50.53, followed by *P. smithiana* and *A. pindrow* with IVI value of 36.60 and 32.19, respectively. The minimum IVI value (3.54) was observed for *Juniperus macropoda*. Among shrubs, the maximum dominance was shown by *B. aristata* with IVI value of 29.63, followed by *R. macrophylla* and *P. utilis* with IVI value of 27.68 and 24.27, respectively (Table 25).

Phytosociology of V3

In vertical 3, four tree and eight shrub species were present. Among trees, the maximum IVI value (53.15) was recorded for *P. wallichiana*, followed by *A. pindrow* (34.63) and *Betula utilis* (29.23), respectively. Whereas, the minimum IVI (25.12) was observed for *P. smithiana*. Among shrubs, the maximum IVI (31.59) was recorded for *B. aristata*, followed by *R. macrophylla* (28.77) and *P. utilis* (26.74), respectively (Table 26).

Table 26 : Mean phytosociological data in study site at vertical 3 (3000-3900) on per hectare basis.

S.No	Species	RBA	RD	RF	IVI
	Trees				
1	*Abies pindrow*	21.29	3.67	9.68	34.63
2	*Betula utilis*	4.89	14.66	9.68	29.23
3	*Picea smithiana*	11.37	4.07	9.68	25.12
4	*Pinus wallichiana*	36.55	6.92	9.68	53.15
	Shrubs				
1	*Berberis aristata*	5.62	16.29	9.68	31.59
2	*Cotoneaster baccillaris*	3.24	9.37	9.68	22.29
3	*Indigofera gerardiana*	1.38	3.26	3.23	7.86
4	*Juniperus recurva*	0.22	1.22	6.45	7.89
5	*Prinsepia utilis*	4.03	13.03	9.68	26.74
6	*Rhamnus triqetrus*	0.76	3.46	3.23	7.45
7	*Rosa macrophylla*	5.66	13.44	9.68	28.77
8	*Viburnum continifolium*	4.99	10.59	9.68	25.26
	Total	**100.00**	**100.00**	**100.00**	**300.00**

Where: RBA = Relative basal area, RD = Relative density, RF = Relative frequency, IVI = Important value index

Table 27 : Mean phytosociological data in study site at vertical 4 (3000-3900) on per hectare basis.

S.No	Species	RBA	RD	RF	IVI
	Trees				
1	*Abies pindrow*	10.65	2.83	9.38	22.85
2	*Betula utilis*	3.46	13.04	9.38	25.88
3	*Juglans regia*	0.79	0.43	3.12	4.35
4	*Picea smithiana*	14.88	2.83	9.38	27.08
5	*Pinus wallichiana*	34.40	8.70	9.38	52.47
	Shrubs				
1	*Berberis aristata*	5.07	17.39	9.38	31.84
2	*Cotoneaster baccillaris*	2.84	9.13	9.38	21.35
3	*Desmodium tiliaefolium*	0.25	2.61	3.12	5.98
4	*Indigofera gerardiana*	1.40	1.96	3.12	6.49
5	*Juniperus recurva*	0.13	0.43	3.12	3.69
6	*Prinsepia utilis*	16.97	14.57	9.38	40.91
7	*Rhamnus triqetrus*	0.81	3.91	3.12	7.85
8	*Rosa macrophylla*	4.44	12.83	9.38	26.64
9	*Viburnum continifolium*	3.91	9.35	9.38	22.63
	Total	**100.00**	**100.00**	**100.00**	**300.00**

Where: RBA = Relative basal area, RD = Relative density, RF = Relative frequency, IVI = Important value index

Table 28 : Mean phytosociological data in study site at vertical 5 (3000-3900) on per hectare basis.

S.No	Species	RBA	RD	RF	IVI
	Trees				
1	*Abies pindrow*	14.31	2.83	9.68	26.81
2	*Betula utilis*	4.50	14.57	9.68	28.75
3	*Picea smithiana*	20.66	3.48	9.68	33.82
4	*Pinus wallichiana*	34.26	7.61	9.68	51.55
	Shrubs				
1	*Berberis aristata*	5.65	16.74	9.68	32.07
2	*Cotoneaster baccillaris*	3.28	8.70	9.68	21.65
3	*Desmodium tiliaefolium*	0.24	2.17	3.23	5.64
4	*Juniperus recurva*	0.15	0.43	3.23	3.81
5	*Prinsepia utilis*	4.69	13.70	9.68	28.06
6	*Rhamnus triqetrus*	2.07	7.83	6.45	16.35
7	*Rosa macrophylla*	5.21	12.17	9.68	27.06
8	*Viburnum continifolium*	4.98	9.78	9.68	24.44
	Total	**100.00**	**100.00**	**100.00**	**300.00**

Where: RBA = Relative basal area, RD = Relative density, RF = Relative frequency, IVI = Important value index

Phytosociology of V4

The data presented in Table 27 indicated five tree and nine shrubs species. In case of trees, the maximum dominance was exhibited by *P. wallichiana* with IVI value 52.47, followed by *P. smithiana* and *B. utilis* with IVI value of 27.08 and 25.88, respectively. While as, in case of shrubs the maximum dominance was observed for *P. utilis* with IVI value of 40.91, which was followed by *B. aristata* and *R. macrophylla* with IVI value of 31.84 and 26.64, respectively (Table 27).

Phytosociology of V5

Table 28, represents the phytosociology of vertical 5 (per ha) four tree and eight shrub species were present in the forest. Among trees, the maximum IVI value (51.55) was recorded for *P. wallichiana*, followed by *P. smithiana* (33.82) and *B. utilis* (28.75) in case of shrubs, maximum IVI value (32.07) was observed for *B. aristata*, followed by *P. utilis* (28.06) and *R. macrophylla* (27.06), respectively.

4.3.9 Similarity Index

The data pertaining to number of species present in different elevations was used to calculate the similarity and dissimilarity index among different elevations between different species (Table 29). The similarity index in vegetation calculated in per cent for trees and shrubs was found maximum of 90.90 per cent among the lower and middle elevations and was found minimum of 80.00 per cent in case of lower and upper elevations.

Table 29: Similarity index (%) for woody elements between different elevations in study area.

Similarity / Dissimilarity	Lower Elevation (3000-3300 m)	Middle Elevation (3300-3600 m)	Upper Elevation (3600-3900 m)
Lower Elevation	-	90.90	80.00
Middle Elevation	9.10	-	80.80
Upper Elevation	20.00	19.20	-

4.3.10 Diversity Index

To know the species richness, the diversity indexes were calculated from different phytosociological parameters on the basis of elevation class for trees and shrubs (Table 30). The data indicated that the Shanon index of general diversity was found maximum (0.65) for trees at lower elevation and was recorded minimum (0.48) at upper elevation while for shrubs the maximum value for Shannon of general diversity was maximum (0.72) at lower elevation and was found minimum of 0.56 in upper elevation. The maximum value for index of dominance of the community was for both trees and shrubs at lower elevation with values of 0.40 and 0.29, respectively. However, the minimum values for both trees and shrubs were recorded at upper elevation with values 0.26 and 0.20, respectively. But, species richness (Margalef index) was found maximum for both trees and shrubs at lower elevation with values 5.63 and 5.67, respectively. Whereas, the minimum for both trees and shrubs was recorded at upper elevation with values 3.60 and 3.64, respectively. Similarly, the evenness index of community was recorded maximum of 0.83 and 0.93 for trees and shrubs at lower elevation, while minimum value were 0.80 for trees at upper and middle elevation and 0.92 for shrubs in middle elevation (Table 30).

Table 30 : Diversity index, dominance, species richness and evenness values for woody elements at different elevations in study area

Parameters	Shannon index of general diversity	Index of dominance (C) of the community	Species richness (Margalef index)	Evenness index of the community
Lower Elevation (3000- 3300 m)				
Tree	0.64716	0.264731	5.637139	0.831664
Shrubs	0.72534	0.206076	5.675238	0.932132
Middle Elevation (3300 – 3600 m)				
Tree	0.56058	0.318843	4.619785	0.802009
Shrubs	0.64582	0.245319	4.660891	0.92396
Upper Elevation (3600 – 3900 m)				
Tree	0.48202	0.400608	3.603627	0.800618
Shrubs	0.56426	0.290316	3.646556	0.937216

4.4 Regeneration Studies

The present investigations for regeneration studies were carried out on recruits, unestablished, established and regeneration success in Betula forests of Sangla valley in Himachal Pradesh. The data on various regeneration parameters is described as under.

Lowever elevation:

Quadrate 1

The data in Table 31 represent the regeneration status of *Betula utilis* and its associated species at lower elevation in Betula bearing forests of Sangla valley. The results revealed that in quadrate 1 the maximum number of recruits was obtained for *Betula utilis* (102.00) followed by *Pinus wallichiana* (83.00) and *Picea smithiana* (52.00), respectively. Similarly, the maximum number of unestablished seedlings was recorded for *B. utilis* (35.00), whereas, the number for *P. wallichiana* and *Picea smithiana* was recorded 25.00 and 16.00, respectively. The established regeneration on the other hand was found 13.00 tree of *B. utilis*, 11.00 tree of *P. wallichiana*, 3.00 trees of *P. smithiana* and 2.00 trees of *Abies pindrow*. However, no established tree was recorded for *Juniper macropoda* in the quadrat (Table 31).

Quadrate 2

The perusal of data in Table 31 reveals that maximum number of recruits with value of 93.00 (34.19%) was recorded in case of *Betula utilis* followed by *Pinus wallichiana, Picea smithiana* and *Abies pindrow* with numbers 72.00 (26.47%), 55.00 (20.22%) and 52.00 (19.12%), respectively. Similarly, the maximum number of unestablished plants was found for *B. utilis* with 32.00 (36.78%) plants in the quadrate, being followed by *P. wallichiana* and *Picea smithiana* with values of 23.00 (26.44%)and 18.00 (16.09%), respectively.However, the minimum number

Table 31 : Regeneration status of different tree species in study area at lower elevation (3000-3300 m).

S.No	Species	Recruits No. (%)	Unestablished No. (%)	Established No. (%)
Quadrate 1				
1	*Abies pindrow*	33.00 (11.19)	12.00 (13.04)	2.00 (6.90)
2	*Betula utilis*	102.00 (34.58)	35.00 (38.04)	13.00 (44.83)
3	*Juniperus macropoda*	25.00 (8.47)	4.00 (4.35)	0.00 (0.00)
4	*Picea smithiana*	52.00 (17.63)	16.00 (17.39)	3.00 (10.34)
5	*Pinus wallichiana*	83.00 (28.14)	25.00 (27.17)	11.00 (37.93)
	Total	295.00	92.00	29.00
Quadrate 2				
1	*Abies pindrow*	52.00 (19.12)	14.00 (16.09)	4.00 (12.90)
2	*Betula utilis*	93.00 (34.19)	32.00 (36.78)	12.00 (38.71)
3	*Picea smithiana*	55.00 (20.22)	18.00 (20.69)	5.00 (16.13)
4	*Pinus wallichiana*	72.00 (26.47)	23.00 (26.44)	10.00 (32.26)
	Total	272.00	87.00	31.00
Quadrate 3				
1	*Abies pindrow*	43.00 (14.83)	14.00 (15.22)	3.00 (8.57)
2	*Betula utilis*	108.00 (37.24)	38.00 (41.30)	15.00 (42.86)
3	*Picea smithiana*	47.00 (16.21)	13.00 (14.13)	3.00 (8.57)
4	*Pinus wallichiana*	92.00 (31.72)	27.00 (29.35)	14.00 (40.00)
	Total	290.00	92.00	35.00
Quadrate 4				
1	*Abies pindrow*	51.00 (10.89)	20.00 (17.24)	3.00 (7.32)
2	*Betula utilis*	111.00 (36.75)	40.00 (34.48)	19.00 (46.34)
3	*Picea smithiana*	47.00 (15.56)	18.00 (15.52)	4.00 (9.76)
4	*Pinus wallichiana*	93.00 (37.81)	38.00 (32.76)	15.00 (36.58)
	Total	302.00	116.00	41.00
Quadrate 5				
1	*Abies pindrow*	42.00 (14.79)	12.00 (12.76)	2.00 (5.88)
2	*Betula utilis*	108.00 (38.03)	32.00 (34.04)	16.00 (47.06)
3	*Picea smithiana*	43.00 (15.14)	17.00 (18.09)	3.00 (8.82)
4	*Pinus wallichiana*	91.00 (32.04)	33.00 (35.87)	13.00 (38.24)
	Total	284.00	94.00	34.00

Where figures in parenthesis are percentage values

of unestablished plants was recorded for *Abies pindrow* with 14.00 (16.09%) plants. The maximum number of established plants were also recorded for *Betula utilis* with 12.00 (38.71%) plants in the quadrate followed by *P. wallichiana and P. smithiana* with 10.00 (32.26%) and 5.00 (16.13%) plants, respectively. Whereas, the minimum number of established plants were recorded for *Abies pindrow* with 4.00 (12.90%) plants in the quadrate (Table 31).

Quadrate 3

The data also revealed that in quadrate 3, the maximum recruits, unestablished and established plants were found for *Betula utilis* with values of 108.00 (37.24%), 38.00 (41.30%) and 15.00 (42.86%), respectively, followed by *Pinus wallichiana* with values of 92.00 (31.72%), 27.00 (29.35%) and 14.00 (40.00%), respectively. The minimum number were recorded for *A. pindrow* with values of 43.00 (14.83%), 14.00 (15.22%) and 3.00 (8.57%), respectively (Table 31).

Quadrate 4

It was evident from the data that the maximum recruits, unestablished and established plants were recorded for *Betula utilis* with values of 111.00 (36.75%), 40.00 (34.48%) and 19.00 (46.86%), respectively which was followed by *Pinus wallichiana* with values of 93.00 (37.81%), 38.00 (32.76%) and 15.00 (36.58%), respectively (Table 31). Whereas, the minimum numbers for recruits and unestablished was recorded for *Picea smithiana* with values of 47.00 (15.56%) and 18.00 (15.52%) respectively, and for established plants it was recorded for *Abies pindrow* with 3.00 (7.32%) plants in the quadrate (Table 31).

Quadrate 5

The maximum number of recruits in quadrate 5 was of *Betula utilis* (108.00, 38.08%) followed by *Pinus wallichiana* and *Picea smithiana* with values of 91.00 (32.04%) and 43.00 (15.14%), respectively, while the minimum recruits were recorded for *Abies pindrow* with a value of 42.00

(14.79%). The highest number of unestablished plants 33.00 (35.87%) were recorded for *P. wallichiana* closely followed by *B. utilis* with number of 32.00 (34.04%) and minimum number of 12.00 (12.76%) was recorded for *A. pindrow*. Similarly, for established plants the maximum *B. utilis* with 16.00 (47.06%) plants was followed *by P. wallichiana* with 13.00 (38.24%) plants and minimum number of established plants 2.00 (5.88%) was recorded for *A. pindrow* (Table 31).

Middle Elevation

Quadrate 6

The data presented in Table 32 revealed that maximum number of recruits, unestablished and established plants were observed for *Betula utilis* with values of 84.00 (35.17%), 36.00 (43.37%) and 12.00 (46.15%), respectively. However, the minimum values were recorded for *Abies pindrow* with 28.00 (11.72%), 8.00 (9.64%) and 1.00 (3.85%) plants, respectively (Table 32).

Quadrate 7

The perusal of data presented in Table 32 depicts that maximum number of recruits, unestablished and established plants were recorded for *Betula utilis* with number 97.00 (38.80%), 33.00 (41.25%) and 10.00 (45.46%), respectively, being followed by *Pinus wallichiana* with values of 76.00 (30.40%), 30.00 (37.50%) and 8.00 (36.36%). However, the minimum recruits and unestablished were observed for *Picea smithiana* with numbers 37.00 (14.80%) and 8.00 (10.00%), respectively. Whereas, the minimum for established plants were recorded for both *P. smithiana* and *A. pindrow* (2.00 each).

Table 32 : Regeneration status of different tree species in study area at middle elevation (3300-3600 m).

S.No	Species	Recruits No. (%)	Unestablished No. (%)	Established No. (%)
Quadrate 6				
1	*Abies pindrow*	28.00 (11.72)	8.00 (9.64)	1.00 (3.85)
2	*Betula utilis*	84.00 (35.17)	36.00 (43.37)	12.00 (46.15)
3	*Picea smithiana*	46.00 (19.25)	12.00 (14.46)	3.00 (11.54)
4	*Pinus wallichiana*	81.00 (33.89)	27.00 (32.53)	10.00 (38.46)
	Total	239.00	83.00	26.00
Quadrate 7				
1	*Abies pindrow*	40.00 (16.00)	9.00 (11.25)	2.00 (9.09)
2	*Betula utilis*	97.00 (38.80)	33.00 (41.25)	10.00 (45.46)
3	*Picea smithiana*	37.00 (14.80)	8.00 (10.00)	2.00 (9.09)
4	*Pinus wallichiana*	76.00 (30.40)	30.00 (37.50)	8.00 (36.36)
	Total	250.00	80.00	22.00
Quadrate 8				
1	*Abies pindrow*	37.00 (15.42)	10.00 (12.05)	2.00 (8.33)
2	*Betula utilis*	91.00 (37.92)	33.00 (39.76)	12.00 (50.00)
3	*Picea smithiana*	38.00 (15.83)	11.00 (13.25)	2.00 (8.33)
4	*Pinus wallichiana*	74.00 (30.83)	29.00 (39.94)	8.00 (33.33)
	Total	240.00	83.00	24.00
Quadrate 9				
1	*Abies pindrow*	35.00 (14.17)	6.00 (7.69)	2.00 (9.09)
2	*Betula utilis*	91.00 (36.84)	34.00 (43.59)	11.00 (50.00)
3	*Picea smithiana*	49.00 (19.84)	7.00 (8.97)	2.00 (9.09)
4	*Pinus wallichiana*	72.00 (29.15)	31.00 (39.74)	7.00 (31.82)
	Total	247.00	78.00	22.00
Quadrate 10				
1	*Abies pindrow*	38.00 (15.57)	8.00 (10.67)	2.00 (9.52)
2	*Betula utilis*	88.00 (36.07)	31.00 (41.33)	11.00 (52.38)
3	*Picea smithiana*	39.00 (15.98)	7.00 (9.33)	1.00 (4.76)
4	*Pinus wallichiana*	79.00 (32.38)	29.00 (38.67)	7.00 (33.33)
	Total	244.00	75.00	21.00

Where figures in parenthesis are percentage values

Quadrate 8

It is evident from the data that the maximum number of recruits, unestablished and established plants were recorded for *Betula utilis* with numbers 91.00 (37.92%), 33.00 (41.25%) and 12.00 (50.00%), respectively. Which was found to be followed by *Pinus wallichiana* with values of 74.00 (30.40%), 29.00 937.50%) and 8.00 (36.36%), respectively. However, the minimum for recurits and unestablished plants were recorded for *Abies pindrow* with numbers 37.00 (14.42%) and 10.00 (12.05%), respectively, while as minimum for established plants were recorded 2.00 (8.33%) each for *A. pindrow* and *Picea smithiana* (Table 32).

Quadrate 9

The maximum number of recruits were recorded for *Betula utilis* with the number of 91.00 (36.84%) plants followed by *Pinus wallichiana* and *Picea smithiana* with numbers 72.00 (29.15%) and 49.00 (19.84%), respectively, whereas, the minimum number 35.00 (14.17%) was recorded for *Abies pindrow*. Similarly, the maximum number of unestablished plants were recorded for *B. utilis* with number of 34.00 (43.59%) plants in the quadrate, being followed by *P. wallichiana* and *P. smithiana* with numbers 31.00 (39.74%) and 7.00 (8.97%), respectively, while the minimum number of unestablished plants were recorded for *A. pindrow* with 6.00 (7.69%) plants. Also, for established plants the maximum number of 11.00 (50.00%) was recorded with account of 7.00 (31.82%) plants in the quadrate. A minimum value of 2.00 (9.09%) was recorded *Abies pindrow* and *P. smithiana*, each (Table 32).

Quadrate 10

The perusal of data in Table 32 reveals that maximum number of recruits, unestablished and established plants were recorded for *Betula utilis* with numbers of 88.00 (36.07%), 31.00 (41.33%) and 11.00 (52.38%), respectively. The maximum in each parameters were followed by *Pinus wallichiana* with numbers 79.00 (32.38%), 29.00 (38.67%) and 7.00 (33.33%), respectively. However, the parameters were found minimum for recruits in case of *Abies pindrow* with number of 38.00 (15.57%). For established and established plants, the minimum was recorded for *Picea smithiana* with numbers of 7.00 (9.33%) and 1.00 (4.76%), respectively (Table 32).

Upper Elevation

Quadrate 11

The data in Table 33 represent the regeneration status of *Betula utilis* and its associated species in upper elevation of Sangla valley forests. The results revealed that maximum number of recruits, unestablished and established plants were found of *Betula utilis* with numbers 54.00 (33.96%), 19.00 (43.18%) and 8.00 (47.06%) being followed by *Pinus wallichiana* with numbers 44.00 (27.67%), 12.00 (27.27%) and 5.00 (29.41%), respectively. Minimum for recruits and unestablished plants were recorded for *Abies pindrow* with numbers 31.00 (19.50%) and 6.00 (13.94%), respectively, for established plants the minimum of 2.00 (11.76%) plants each was observed for *A. pindrow* and *Picea smithiana* (Table 33).

Quadrate 12

It was evident from the data, that maximum recruits 61.00 (38.12%) were recorded for *Betula utilis*, followed by *Pinus wallichiana* and *Abies pindrow* with numbers 46.00 (28.75%) and 29.00 (18.00%), respectively. The minimum number of recruits were recorded for *Picea smithiana* with number of 24.00 (15.00%) plants. However, the maximum number of unestablished plants were also found for *B. utilis* with number of 15.00 (39.17%), followed by *P. wallichiana* and *Abies pindrow* with numbers 10.00 (26.32%) and 7.00 (18.42%), respectively. However, minimum number of unestablished plants was recorded for *P. smithiana* with 6.00

Table 33 : Regeneration status of different tree species in study area at upper elevation (3600-3900 m

S.No	Species	Recruits No. (%)	Unestablished No. (%)	Established No. (%)
Quadrate 11				
1	*Abies pindrow*	31.00 (19.50)	6.00 (13.46)	2.00 (11.76)
2	*Betula utilis*	54.00 (33.96)	19.00 (43.18)	8.00 (47.06)
3	*Picea smithiana*	30.00 (18.87)	7.00 (15.91)	2.00 (11.76)
4	*Pinus wallichiana*	44.00 (37.67)	12.00 (27.27)	5.00 (29.41)
	Total	159.00	44.00	17.00
Quadrate 12				
1	*Abies pindrow*	29.00 (18.12)	7.00 (18.42)	1.00 (7.69)
2	*Betula utilis*	61.00 (38.12)	15.00 (39.47)	6.00 (46.17)
3	*Picea smithiana*	24.00 (15.00)	6.00 (15.79)	2.00 (15.38)
4	*Pinus wallichiana*	46.00 (28.75)	10.00 (26.32)	4.00 (30.77)
	Total	160.00	38.00	13.00
Quadrate 13				
1	*Abies pindrow*	36.00 (19.89)	9.00 (20.45)	2.00 (11.76)
2	*Betula utilis*	63.00 (34.81)	15.00 (34.09)	7.00 (41.18)
3	*Picea smithiana*	30.00 (16.57)	8.00 (18.18)	2.00 (11.76)
4	*Pinus wallichiana*	52.00 (28.73)	12.00 (27.27)	6.00 (35.20)
	Total	181.00	44.00	17.00
Quadrate 14				
1	*Abies pindrow*	36.00 (19.46)	7.00 (16.28)	1.00 (7.46)
2	*Betula utilis*	64.00 (35.59)	17.00 (39.53)	6.00 (46.15)
3	*Picea smithiana*	29.00 (15.68)	6.00 (13.95)	2.00 (15.38)
4	*Pinus wallichiana*	56.00 (30.27)	13.00 (30.23)	4.00 (30.77)
	Total	185.00	43.00	13.00
Quadrate 15				
1	*Abies pindrow*	31.00 (18.13)	6.00 (13.95)	1.00 (9.09)
2	*Betula utilis*	62.00 (36.26)	18.00 (41.86)	5.00 (45.45)
3	*Picea smithiana*	26.00 (15.20)	6.00 (13.95)	1.00 (9.09)
4	*Pinus wallichiana*	52.00 (30.41)	13.00 (30.23)	4.00 (36.36)
	Total	171.00	43.00	11.00

Where figures in parenthesis are percentage values

(15.79%) plants. Similarly, the maximum number of established plants were recorded for *B. utilis* with 6.00 (46.15%) plants, followed by *P. wallichiana* with number of 4.00 (30.77%) plants, whileas, minimum number i.e. 1.00 (7.69%) plants was recorded for *A. pindrow* (Table 33).

Quadrate 13

The perusal of data in Table 33 reveal that maximum number of recruits, unestablished and established plants were observed for *Betula utilis* with numbers 63.00 (34.81%), 15.00 (34.09%) and 7.00 (41.86%), followed by *Pinus wallichiana* with numbers 46.00 (28.75%), 10.00 (26.32%) and 4.00 (30.77%), respectively. However, the minimum number of recruits and unestablished plants were recorded for *Picea smithiana* with numbers 29.00 (15.68%) and 6.00 (13.95%), while the minimum number of established plants 2.00 (11.76%) each were recorded for *P. smithiana* and *Abies pindrow* (Table 33).

Quadrate 14

The perusal of data for quadrate 14 depicts that maximum number of recruits, unestablished and established plants were recorded for *Betula utilis* with numbers 64.00 (35.59%), 17.00 (41.86%) and 6.00 (46.15%), being followed by *Pinus wallichiana* with numbers 56.00 (30.27%), 13.00 (30.23%) and 4.00 (30.77%), respectively. Whereas, the minimum number of recruits and unestablished plants were recorded for *Picea smithiana* with numbers 29.00 (15.68%) and 6.00 (13.95%), respectively. However, for established plants the minimum was recorded in case of *Abies pindrow* (Table 33).

Quadrate 15

The regeneration status of Beutla forests in quadrate 15 depicts that the maximum number of recruits, unestablished and established plants were recorded for *Betula utilis* with numbers 62.00 (36.26%), 18.00 (41.86%) and 5.00 (45.45%), which was followed by *Pinus wallichiana* with numbers 53.00 (30.41%), 13.00 (30.23%) and 4.00 (36.36%), respectively. However, the minimum number of recruits were recorded for

Abies pindrow with number 31.00 (18.13%) whereas, the minimum of unestablished and established plants with numbers 6.00 (13.95%) and 1.00 (9.09), respectively, where recorded for both *A. pindrow* and *Picea smithiana*, each (Table 33).

Regeneration Status at Different Elevations

Lower Elevation

The pooled data for different elevations (lower, middle and upper) depicted that the regeneration status of *Betula utilis* and its associated species in Sangla valley of H.P. and the results reveale that maximum number of recruits 1044.00/ha (36.17%) were recorded for *Betula utilis* followed by *Pinus wallichiana* and *Picea smithiana* with numbers 862.00/ha (29.89%) and 488.00/ha (16.91%), respectively. Whereas, the minimum number was reported for *Juniper macropoda* with number of 50.00 /ha (1.73%). Similarly, the maximum number of unestablished plants were found maximum 354.00/ha (36.80%) in case of *B. utilis*, followed by *P. wallichiana* and *P. smithiana* with numbers 292.00 (30.35%) and 164.00 (17.05%), respectively. However minimum number of unestablished plants were found minimum 8.00 /ha (0.83%) for *Juniper macropoda*. Also the maximum established plants of 150.00/ha (44.12%) were recorded for *B. utilis* followed by *P. wallichiana* with 126.00/ha (37.06%) plants while, not a single established plant was observed for *Juniper macropoda* (Table 34).

Middle Elevation

The maximum number of recruits, unestablished and established plants were observed in case of *Betula utilis* with numbers 902.00/ha (36.70%), 334.00/ha (41.85%) and 112.00/ha (48.69%), followed by *Pinus wallichiana* with numbers 764.00/ha (31.31%), 292.00/ha (36.59%) and 80.00/ha (34.78%), respectively. The minimum numbers were recorded in case of *Abies pindrow* with numbers 356.00/ha (14.59%), 82.00/ha (10.28%) and 18.00/ha (7.83%) plants, respectively (Table 34).

Table 34 : Regeneration status of different tree species in study area at different elevations

S.No	Species	Recruits No. (%)	Unestablished No. (%)	Established No. (%)
Lower				
1	*Abies pindrow*	442.00 (15.32)	144.00 (14.97)	28.00 (8.24)
2	*Betula utilis*	1044.00 (36.17)	354.00 (36.80)	150.00 (44.12)
3	*Juniperus macropoda*	50.00 (1.73)	8.00 (0.83)	0.00 (0.00)
4	*Pinus wallichiana*	862.00 (29.89)	292.00 (30.35)	126.00 (37.06)
5	*Picea smithiana*	488.00 (16.91)	164.00 (17.05)	36.00 (10.59)
	Total	2886.00	962.00	340.00
Middle				
1	*Abies pindrow*	356.00 (14.59)	82.00 (10.28)	18.00 (7.83)
2	*Betula utilis*	902.00 (36.70)	334.00 (41.85)	112.00 (48.69)
3	*Picea smithiana*	418.00 (17.13)	90.00 (11.28)	20.00 (8.69)
4	*Pinus wallichiana*	764.00 (31.31)	292.00 (36.59)	80.00 (34.78)
	Total	2440.00	798.00	230.00
Upper				
1	*Abies pindrow*	326.00 (19.04)	70.00 (16.50)	14.00 (9.86)
2	*Betula utilis*	608.00 (35.51)	168.00 (39.62)	64.00 (45.07)
3	*Picea smithiana*	278.00 (16.24)	66.00 (15.56)	18.00 (12.68)
4	*Pinus wallichiana*	500.00 (29.21)	120.00 (28.30)	46.00 (32.39)
	Total	1721.00	424.00	142.00
	$CD_{0.05}$	**163.49**	**90.72**	**38.24**

Where figures in parenthesis are percentage values

Upper elevation

The data in Table 34 revealed that in upper elevation, the maximum number of recruits, unestablished and established plants was found for *Betula utilis* with values of 608.00/ha (35.51%), 168.00/ha (39.62%) and 64.00/ha (45.07%), which were followed by *Pinus wallichiana* with values of 500.00/ha (29.21%), 120.00/ha (28.30%) and 46.00/ha (32.39%), respectively. However, the minimum numbers for recruits and unestablished plants were recorded for *Picea smithiana* with values of 278.00/ha (16.24%) and 66.00/ha (15.36%), respectively and for established plants minimum of 14.00/ha (9.86%) was recorded for *Abies pindrow* (Table 34).

Regeneration Establishment and Stocking

Lower Elevation

Persual of data in Table 36 represents the regeneration establishment and stocking data for different tree species in Betula forest of Sangla valley. The data reveals that the maximum weighted average height for *Picea smithiana* (96.85 cm), followed by *Beutla utilis* (79.99 cm) and *Pinus wallichiana* (76.95 cm), respectively. While minimum was reported for *Juniper macropoda* (15.00 cm). The establishment index was found maximum (0.48) for *P. smithiana*, followed by *B. utilis* (0.40) and *P. wallichiana* (0.39), respectively, whereas minimum establishment index was reported for *Juniper macropoda* (0.07). The maximum stocking index was reported for *B. utilis* (0.095), followed by *P. smithiana* (0.079) and *P. wallichiana* (0.030), respectively, while the minimum was recorded for *B. utilis* (0.0008). The maximum establishment stocking per cent was observed in case of *Picea smithiana* (3.85), closely followed by *Betula utilis* (3.81) and *Abies pindrow* (0.98), respectively, whereas, minimum

Table 35 : Establishment and stocking data for different tree species in Betula forests at different elevations

S.No	Species	ht of unestablished regeneration	Weighted average height	Establishment index	Stocking index	Establishment stocking Per cent	Regeneration Success (%)
Lower Elevation							
1	*Abies pindrow*	53.03	76.95	0.38	0.0256	0.98	2.56
2	*Betula utilis*	29.14	79.99	0.39	0.0954	3.81	9.54
3	*Juniperus macropoda*	15.00	15.00	0.07	0.0008	0.006	0.08
4	*Picea smithiana*	52.34	96.85	0.48	0.0796	3.85	7.96
5	*Pinus wallichiana*	51.88	78.54	0.39	0.0308	1.20	3.08
	Total		347.34	1.73	0.2322	9.87	
Middle Elevation							
1	*Abies pindrow*	53.48	79.85	0.39	0.0154	0.61	1.54
2	*Betula utilis*	30.88	73.35	0.36	0.0782	2.86	7.82
3	*Picea smithiana*	44.00	72.37	0.36	0.0170	0.61	1.70
4	*Pinus wallichiana*	50.91	82.97	0.41	0.0612	2.53	6.12
	Total		308.55	1.54	0.1718	6.63	
Upper Elevation							
1	*Abies pindrow*	53.68	78.07	0.39	0.0126	0.49	1.26
2	*Betula utilis*	30.59	77.32	0.38	0.0424	1.64	4.24
3	*Picea smithiana*	49.45	81.71	0.40	0.0138	0.56	1.38
4	*Pinus wallichiana*	43.35	86.76	0.433	0.0304	1.31	3.04
	Total		323.86	1.62	0.0992	4.01	

establishment stocking per cent was recorded for *Juniper macropoda* (0.006) as depicted in Table 35.

Middle Elevation

The regeneration establishment and stocking data for different tree species at middle elevation presented in Table 35 reveals that the maximum weighted average height was recorded for *Pinus wallichiana* (82.97 cm) followed by *Abies pindrow* (79.85 cm) and *Betula utilis* (73.35 cm). Whereas, the minimum weighted average height was observed for *Picea smithiana* (72.37 cm). The maximum establishment index (0.41) was observed for *P. wallichiana* followed by *A. pindrow* (0.39) and least for *B. utilis* (0.36) and *P. smithiana*. The stocking index was found maximum in case of *B. utilis* (0.07) followed by *P. wallichiana* (0.06) and the minimum stocking index (0.015) was recorded for *A. pindrow*. The maximum establishment stocking per cent (2.86) was recorded for *B. utilis* followed by *P. wallichiana* (2.53) and *Abies pindrow* (0.61), whereas, the minimum establishment stocking per cent (0.61) for *P. smithiana* (Table 35).

Upper Elevation

The perusal of data reveals that maximum weighted average height (86.76 cm) was observed for *Pinus wallichiana* followed by *Picea smithiana* (81.71 cm) and *Abies pindrow* (78.07 cm), respectively. Whereas, minimum weight average height (77.32 cm) was recorded for *Betula utilis.* Similarly, maximum establishment index (0.43) was observed for *P. wallichiana* followed by *P. smithiana* (0.40). The minimum establishment index (0.38) was recorded for *B. utilis*. However, the maximum stocking index (0.042) was observed for *B. utilis*, followed by *P. wallichiana* (0.030) and *P. smithiana* (0.013) and the minimum stocking index is observed for *A. pindrow* (0.012). The maximum establishment stocking per cent (1.64) was observed for *B. utilis*, followed by *P. wallichiana* (1.31) and *P. smithiana* (0.56) while *A. pindrow* (0.49) depicted the minimum value (Table 35).

4.5 Soil Characteristics

The effect of different site factors like soil nutrient (N, P, K), soil pH, soil moisture, organic carbon, depth of organic matter, bulk density and porosity (%) of Betula forests in Sangla valley was studied during different seasons i.e., summer, winter and rainy seasons. The findings are described here as under:

Soil Moisture

The per cent soil moisture was found more at upper elevation than other elevations studied during all the three seasons studied. The overall highest value for per cent soil moisture was recorded during rainy season, followed by summer and winter season, respectively. In rainy season at depth 0-15 cm the maximum (33.50%) was recorded at upper elevation followed by middle (31.40%) and lower (30.44%) elevations, respectively. However at 15-30 cm depth, the maximum (31.45%) was recorded at upper elevation, followed by middle (29.66%) and lower (29.22%) elevations, respectively. Similarly, in summer season the maximum per cent soil moisture at depth 0-15 cm was recorded at upper elevation (30.24%) and minimum (28.00%) at lower elevation, whereas, at depth 15-30 cm maximum was recorded at upper (28.50%) elevation and minimum (24.55%) was recorded at lower elevation. Also, in winter season at depth 0-15 cm, the maximum per cent soil moisture (29.22%) at lower elevation, whereas, at depth 15-30 cm, the maximum per cent soil moisture (27.56%) was observed at upper elevation and minimum (23.44%) at lower elevation (Table 36).

Soil pH

The soil pH value was recorded highest at upper elevation irrespective of season studied and among seasons studied the maximum

Table 36 :Soil physico-chemical properties and site characteristics at different elevations in the study area

Parameters	Elevation	Summer		Rainy		Winter	
		Depths		Depths		Depths	
		0 – 15 cm	15 – 30 cm	0 – 15 cm	15 – 30 cm	0 – 15 cm	15 – 30 cm
Percent Soil moisture (%)	Upper	30.24± 1.42	28.50 ± 2.50	29.22 ± 1.65	27.56 ± 2.54	33.50 ± 3.54	31.45 ± 3.54
	Middle	28.15 ± 2.54	25.64 ± 2.84	27.45 ± 1.54	24.68 ± 2.66	31.40 ± 4.23	29.66 ± 4.20
	Lower	28.00 ± 2.65	23.44 ± 2.44	26.33 ± 1.23	24.55 ± 2.55	30.44 ± 2.56	29.22 ± 3.26
pH value	Upper	6.68 ± 0.04	6.72 ± 0.08	6.54 ± 0.04	6.64 ± 0.04	6.62 0.04	6.68 ± 0.06
	Middle	6.64 ± 0.04	6.69 ± 0.07	6.42 ± 0.03	6.61 ± 0.03	6.49 ± 0.04	6.67 ± 0.04
	Lower	6.60 ± 0.04	6.68 ± 0.08	5.99 ± 0.06	6.40 ± 0.04	6.43 ±0.06	6.64 0.04
Bulk Density (g/cm^3)	Upper	1.35 ± 0.10	1.48 ± 0.14	1.45 ± 0.05	1.52 ± 0.08	1.39 ± 0.12	1.42 ± 0.80
	Middle	1.42 ± 0.14	1.46 ± 0.14	1.47 ± 0.12	1.56 ± 0.08	1.44 ± 0.08	1.45 ± 0.90
	Lower	1.43 ± 0.14	1.45 ± 0.6	1.48 ± 0.08	1.60 ± 0.06	1.46 ± 0.10	1.48 ± 0.14
Porosity (%)	Upper	42.23 ± 4.20	40.25 ± 5.23	45.23 ± 2.32	42.30 ± 3.52	38.45 ± 3.54	34.12 ± 3.84
	Middle	39.65 ± 3.56	38.62 ± 4.23	42.35 ± 2.42	39.65 ± 2.80	36.56 ± 5.42	32.36 ± 3.54
	Lower	38.95 ± 4.56	37.55 ± 4.85	41.56 ± 3.26	37.45 ± 3.54	33.22 ± 3.42	29.12 ± 3.65
Percent organic carbon	Upper	4.20 ± 0.18	2.75 ± 0.12	3.82 ± 0.20	2.10 ± 0.14	4.00 ± 0.22	2.19 ± 0.14
	Middle	4.15 ± 0.20	2.64 ± 0.10	3.45 ± 0.16	2.08 ± 0.15	3.70 ± 0.20	2.18 ± 0.16
	Lower	3.85 ± 0.22	2.40 ± 0.14	3.38 ± 0.12	2.06 ± 0.16	3.65 ± 0.24	2.13 ± 0.14
Available Nitrogen (kg/h)	Upper	412.54 ± 30	342.23 ± 22	368.00 ± 26	315.00 ± 25	402.00 ± 35	335.67 ± 24
	Middle	418.35 ± 28	346.32 ± 20	375.00 ± 25	318.00 ± 20	407.33 ± 32	337.00 ± 23
	Lower	420.50 ± 24	352.12 ± 18	380.00 ± 22	320.00 ± 22	414.67 ± 33	348.00 ± 27
Available Phosphorus (kg/h)	Upper	32.15 ± 3.80	25.22 ± 2.16	28.24 ± 2.23	22.58 ± 2.12	29.40 ± 3.12	23.60 ± 2.12
	Middle	33.35 ± 3.40	28.52 ± 2.10	29.05 ± 2.46	24.65 ± 2.40	30.49 ± 3.10	27.43 ± 2.20
	Lower	36.45 ± 3.60	29.36 ± 2.14	32.20 ± 2.54	26.54 ± 2.20	34.06 ± 3.12	28.13 ± 2.14
Available Potassium (kg/h)	Upper	326.00 ± 36	305.25 ± 20	302.36 ± 25	285.65 ± 18	312.25 ± 28	295.47 ± 19
	Middle	332.00 ± 33	312.00 ± 22	312.00 ± 35	290.85 ± 19	318.23 ± 25	296.55 ± 18
	Lower	338.00 ± 32	321.00 ± 20	316.56 ± 34	296.65 ± 18	322.22 ± 20	301.25 ± 19
$CD_{0.05}$	Percent soil moisture =		0.55	pH value =		0.17	
	Bulk density =		0.02	Porosity =		0.88	
	Percent organic carbon =		0.13	Nitrogen =		2.61	
	Phosphorus =		0.94	Potassium =		2.52	
	Organic matter layer =		1.20				

soil pH was observed in summer season followed by rainy and winter season, respectively. In summer season at depth 0-15 cm, the maximum soil pH (6.68) was recorded at upper elevation and minimum (6.60) at lower elevation, similarly at depth 15-30 cm, the maximum soil pH (6.72) was recorded at upper elevation and minimum (6.68) was observed at lower elevation. Whereas, in rainy reason at depth 0-15 cm the highest soil pH (6.62) was recorded at upper elevation and lowest (6.43) was recorded at lower elevation, at depth 15-30 cm, the maximum soil pH (6.68) was recorded at upper elevation and minimum (6.64) was observed at lower elevation. However, in winter reason at depth 0-15 cm the highest soil pH (6.54) was recorded at upper elevation and lowest (6.40) was recorded at lower elevation, at depth 15-30 cm, the maximum soil pH (6.64) was recorded at upper elevation and minimum (5.99) was observed at lower elevation (Table 36).

Bulk Density

It is evident from Table 36 that the bulk density was recorded more in winter season and followed a decreasing trend with increase in elevation. Also the bulk density increased with increase in depth of soil. At depth 0-15 cm the maximum bulk density was recorded 1.48 g/cm^3, 1.43 g/cm^3 and 1.46 g/cm^3 at lower elevation for winter, rainy and summer season, respectively. Similarly at depth 15-30 cm the maximum bulk density was recorded 1.60 g/cm^3, 1.48 g/cm^3 and 1.45 g/cm^3 at lower elevation for winter, rainy and summer season, respectively. However, the lowest bulk density at depth 0-15 cm was recorded 1.45 g/cm^3, 1.39 g/cm^3 and 1.35 g/cm^3 for winter, rainy and summer season, respectively. Also for depth 15-30 cm the maximum bulk density was recorded 1.52 g/cm^3, 1.42 g/cm^3 and 1.52 g/cm^3 at upper elevation for winter, rainy and summer season, respectively (Table 36).

Soil Porosity

The porosity per cent was having an increasing trend with increase in elevation. Among season winter season was having maximum porosity followed with summer and rainy season, respectively. At depth 0-15 cm the maximum porosity 45.23 per cent, 42.23 per cent and 38.45 per cent was observed for winter, summer and rainy season, respectively and for depth 15-30 cm the maximum porosity 42.30 per cent, 40.25 per cent and 34.12 per cent was observed for winter, summer and rainy season, respectively at upper elevation. Similarly, the minimum values at depth 0-15 cm were 41.56 per cent, 38.95 per cent and 33.22 per cent was observed for winter, summer and rainy season, respectively and for depth 15-30 cm the minimum porosity 37.55 per cent, 37.45 per cent and 29.12 per cent was observed for summer, winter and rainy season, respectively at lower elevation (Table 36).

Soil Organic Carbon

For per cent organic carbon the maximum was recoded at upper elevation irrespective of season. However, summer season was having the maximum organic carbon among all the seasons. For summer at 0-15 cm and 15-30 cm soil depths the maximum was 4.20 per cent and 2.75 per cent at upper elevation and minimum was 3.85 per cent and 2.40 per cent, respectively at lower elevation. For rainy season, at 0-15 cm and 15-30 cm soil depths the maximum was 4.00 per cent and 2.19 per cent, at upper elevation and minimum was 3.65 per cent and 2.13 per cent at lower elevation. In winter season, at 0-15 cm and 15-30 cm soil depths the maximum was 3.82 per cent and 2.10 per cent respectively, at upper elevation and minimum 3.38 per cent and 2.06 per cent, respectively was observed at lower elevation (Table 36).

Soil Available Nitrogen Content

The perusal of data in Table 36 depicts that the available nitrogen was found maximum at lower elevation irrespective of seasons. Among seasons the summer season exhibited maximum value followed by rainy season and winter season, respectively. In summer season the maximum for depth 0-15 cm and 15-30 cm was 420.50 kg/ha and 352.12 kg/ha, at lower elevation, for the same depths the minimum was 412.54 kg/ha and 342.23 kg/ha, respectively at upper elevation. In rainy season the maximum values at depths 0-15 cm and 15-30 cm were found to be 414.67 kg/ha and 348.00 kg/ha, at lower elevation, for the same depths the minimum values were 402.00 kg/ha and 335.67 kg/ha, respectively at upper elevation. In winter season, the maximum values for depth 0-15 cm and 15-30 cm were 380.00 kg/ha and 320.00 kg/ha, at lower elevation, for the same depths the minimum values were 368.00 kg/ha and 315.00 kg/ha, respectively at upper elevation (Table 36).

Soil Available Phosphorus Content

The phosphorus content in the soil was observed to decrease with increase in elevation. Further it also decrease with increase in soil depth. The maximum phosphorus content in the soil was recorded during the summer season and followed by rainy season and least was recorded in winter season. However, in summer season at depths 0-15 cm and 15-30 cm the maximum values of 36.45 kg/ha and 29.36 kg/ha, were observed at lower elevation and minimum of 32.15 kg/ha and 25.22 kg/ha, were recorded at upper elevation. In rainy season at depths 0-15 cm and 15-30 cm the maximum values (34.06 kg/ha and 28.13 kg/ha, respectively) was observed at lower elevation and minimum (29.40 kg/ha and 23.60 kg/ha, respectively) was recorded at upper elevation. Similarly, in winter season at depths 0-15 cm and 15-30 cm the maximum values of 32.20 kg/ha and 26.54 kg/ha, were found at lower elevation and minimum of 28.24 kg/ha and 22.58 kg/ha, respectively were recorded at upper elevation (Table 36).

Soil Available Potassium Content

It is evident from Table 36 that the potassium content in soil was found highest at lower elevation irrespective of seasons. Among seasons the potassium content in soil was found highest in summer followed by rainy and minimum during winter season. In summer season for depths 0-

15 cm and 15-30 cm the maximum values of 338.00 kg/ha and 321.00 kg/ha, were observed at lower elevation and minimum of 326.00 kg/ha and 305.25 kg/ha, respectively were observed at upper elevation. In rainy season for depths 0-15 cm and 15-30 cm the maximum (322.22 kg/ha and 301.25 kg/ha, respectively) was observed at lower elevation and minimum (312.25 kg/ha and 295.47 kg/ha, respectively) was observed at upper elevation. Similarly, in winter season for depth 0-15 cm and 15-30 cm the maximum (316.56 kg/ha and 296.65 kg/ha, respectively) was observed at lower elevation and minimum (302.36 kg/ha and 286.65 kg/ha, respectively) was observed at upper elevation (Table 36).

4.6 Plant Nutrient Status

The nutrient status of bark, wood, leaves and litter was carried out during peak growing period (August) and for this Betula trees were selected with three replications. The mean values along with standard deviation is presented in Table 37. The nutrient status of *Betula utilis* tree at different elevations is presented in Table 37, though the results were not found significantly different. For Bark the nitrogen content was maximum (0.96%) at lower elevation and the minimum (0.78%) at upper elevation, the phosphorus content in bark of Betula was found maximum (0.10%) at lower elevation and found minimum (0.06%) at lower elevation. Similarly, the potassium content in bark of Betula was found maximum (1.23%) at lower elevation and found minimum (1.18%) at upper elevation.

For wood the maximum content of nitrogen, phosphorus and potassium were found (2.01%, 0.22% and 2.23%, respectively) at lower elevation and minimum contents were found (1.75%, 0.19% and 2.18%, respectively) at upper elevation. Similarly, for leaf the maximum content of nitrogen, phosphorus and potassium were found to be 2.85 per cent, 0.41 per cent and 3.12 per cent, respectively at lower elevation and minimum content was found to be 2.62 per cent, 0.29 per cent and 3.04 per cent, respectively at upper elevation (Table 37).

Table 37 : Nutrient status of Betula tree in study site during August, 2009

	Bark (%)	Wood (%)	Leaf (%)	Litter (%)
Lower Elevation				
Nitrogen	0.96 ± 0.20	2.01 ± 0.08	2.85 ± 0.14	4.65 ± 0.40
Phosphorus	0.10 ± 0.06	0.22 ± 0.04	0.41 ± 0.05	1.15 ± 0.04
Potassium	1.23 ± 0.08	2.23 ± 0.18	3.12 ± 0.86	3.89 ± 0.60
Middle Elevation				
Nitrogen	0.85 ± 0.15	1.89 ± 0.04	2.74 ± 0.09	4.24 ± 0.46
Phosphorus	0.08 ± 0.05	0.20 ± 0.02	0.35 ± 0.04	1.12 ± 0.04
Potassium	1.20 ± 0.06	2.19 ± 0.06	3.09 ± 0.08	3.75 ± 0.68
Upper Elevation				
Nitrogen	0.78 ± 0.08	1.75 ± 0.06	2.62 ± 0.08	4.12 ± 0.42
Phosphorus	0.06 ± 0.04	0.19 ± 0.02	0.29 ± 0.05	1.10 ± 0.02
Potassium	1.18 ± 0.06	2.18 ± 0.08	3.04 ± 0.23	3.65 ± 0.72
$CD_{0.05}$	**NS**	**NS**	**NS**	**NS**

Photosynthesis Studies

The perusal of data in Table 38 revealed that the solar influx, photosynthesis, transpiration and water use efficiency decreased with increase in elevation. The solar influx was found maximum of 19.71 per cent at lower elevation and found to decrease to 16.33 per cent at upper elevation. The photosynthetic rate was found maximum (8.56 µ mol m^{-2} s^{-1}) at lower elevation and minimum (7.37 µ mol m^{-2} s^{-1}) at upper elevation. The transpiration rate was found maximum (1.25 µ mol m^{-2} s^{-1}) at lower elevation and minimum (0.91 µ mol m^{-2} s^{-1}) at upper elevation. The water use efficiency was found maximum (0.00037) at lower elevation and minimum (0.0023) at upper elevation (Table 38).

Table 38: Photosynthetic studies of *Betula utilis* at leaf maturation stage in study area during August 2009

Elevation	Solar influx (lux)		Solar influx (%)	Photosynthesis µ mol $m^{-2}s^{-1}$	Transpiration (m mol $m^{-2}s^{-1}$)	Water use efficiency
	Outside canopy	Inside canopy				
Upper	6025	984	16.33	7.37 ± 0.65	0.91 ± 0.67	0.0023
Middle	6081	1116	18.35	7.98 ± 0.47	1.08 ± 0.89	0.0028
Lower	6119	1206	19.71	8.56 ± 0.88	1.25 ± 0.93	0.0037

Simple correlation coefficient (Table 39) reveal that regeneration of *Betula utilis* has a positive and significant correlation with soil organic carbon (0.8652), solar influx (0.9452), soil moisture (0.7456), nitrogen (0.6741), phosphorus (0.8455) and potassium (0.7626). However the correlation was highly significant but negative with organic matter depth (-0.9235) and soil pH (-0.8765)

Table 39 : Simple correlation table between regeneration success of *Betula utilis* and different site characteristics in Sangla valley.

Parameters	Regeneration of *Betula utilis*
Regeneration of *Betula utilis*	1
Percent Soil moisture (%)	0.7456*
Percent organic carbon	0.8652**
Nitrogen (kg/h)	0.6741*
Phosphorus (kg/h)	0.8455*
Potassium (kg/h)	0.7626*
pH value	-0.8765**
Bulk Density	0.5428
Porosity (%)	0.5874
Organic matter depth (cm)	-0.9235**
Solar infux (%)	0.9452**

*** Significant at 5% level ** Significant at 1% level**

Chapter–5

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 information in the light of available literature in the following headings:

5.1 Floristic Composition
5.2 Phenological Studies
5.3 Phytosociological Studies
5.4 Regeneration Studies
5.5 Nutrient Status
5.6 Photosynthesis Studies

5.1 Floristic Composition

In the study area, it was observed that a total of 6 tree species and 9 shrub species dominated the scene of woody elements (Table 1). The floristic composition revealed that the occurrence of a species at different elevations as well as different species at single elevation depicted quite a bit of variation at the elevations under study. The main reason behind such varied associations/floristic composition is that all the species in a natural community are not isolated. They may exhibit either a positive or a negative relationship among themselves because of the interactions between the species or of the similar responses of the species to the same environment. These floristic compositions also indicate the spatial distribution pattern of the one species to another in a community (Misra and Misra, 1981).

The word association is deliberately used to indicate that we are referring to the plant community of a habitat and not the total community of all organisms. Since an association may be defined as an assemblage of plants living in close interdependence with similar growth and habitat requirements and with one or more dominant species, while a community may be defined as any natural occurring group of different organisms sharing a particular habitat and interacting with each other (Lal, 1992). Thus species and association both are important. Every species possesses an intrinsic value and is important, though it may play a big or small role in ecosystem functioning.

However, species diversity can be easily measured, while association diversity may not be and there are two main reasons for the same. Firstly, the associations are not discrete units, which can be easily defined on the ground. On the contrary, they are part of continuum (Groombridge 1992 and Lal 1989). It could be defined at many levels, viz., genes, species association, guilds, communities, ecosystem and landscapes, or at any spatial, or temporal scales. We shall however, restrict our discussions to species and association diversity.

Thus taking the case of different locations and degree of abiotic interferences in the study area we can depict that abiotic disturbances even at micro levels will ultimately be responsible for loss of biodiversity in this area at large.

5.2 Phenological studies

Phenology being the quantitative measure of the life or specific phenophases and their values with regard to ecosystem analysis, lies particularly in the understanding they provide of plant responses to climate. There was no single phenological stage which was not being overlapped by proceeding or the next stage. Thus, there was no major and abrupt change from one phenophase to another. The quantitative differences arise due to the different types of areas supporting different types of species and association, due to variation in supporting system like soil characteristics, altitude, slope, aspect, atmospheric temperature, etc.

On the other hand, the similarities present within the species in different elevations are mainly due to the initiation of active vegetative growth during the start of growing season during February and March. The flowering phase sets in from March onwards and lasts till June and July. However, late flowering was observed in conifers. The flowering stage was overlapped by seed maturity stage confined from June to January in different species. Similarly leaf fall stage starts from may onwards in conifers and the peak overall leaf fall is observed during November and December especially in broad leaf species. The leaf less stage in broad leaves remains till the initiation of active growth period during next March as depicted in synthetic phenogram (Fig. 2).

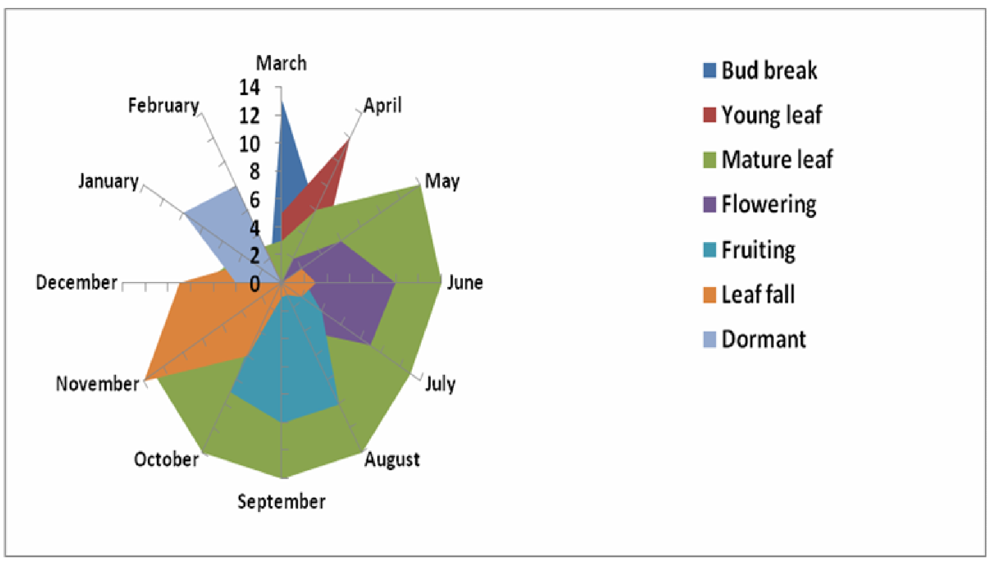


Fig.2: Synthetic phenological diagram of different elevations in study area during March 2009 to February 2010.

Blaisdell (1958) and Sauer (1971) have shown that temperature influences plant development and presumably through its effect on metabolic rate because of the alternating diurnal temperatures. Similar was the case in present investigation, where bud sprout was initiated during March and April, when the atmospheric temperature started to rise. Furthermore the overall phonological differences between the different elevations in present study might be because of temperature integral at each site, which did not reach the corresponding requirement of the species as also reported by Flower and Tiedemann (1980). Thus variation in flowering behavior can also be attributed to the different altitudinal ranges. Heslop-Harrison (1961) and Evans and Knox (1969) found that day length controls the expression of flowering behavior. Jackson (1966) gave the concept that phenological progression followed cumulative heat sums. Wang (1972) presented a historical account of development of phenological observation and the thermal heat index.

Mehar Homji (1964) is of the opinion that to judge the characteristics of aridity or humidity of a region, five criteria can be proposed, viz., climate, ephemonic, floristic, vegetational and agronomic. Frankie *et al.* (1974) and Medway (1972) described several types of variation in the timing and duration of leaf, flower and fruit production. According to them the northern collection started growth first, they were gradually followed by more southerly sources and plants from the most southern sources of the range started growth last in sugar maple (*Acer saccharum*). Phenological events are also influenced by the biotic influence of associations, species as well as by the climatic factors, stand density and site quality influences the flowering and fruiting of teak e.g., shallow soils induce early flowering (Hedegrat *et al.*, 1975).

5.3 Phytosociological Studies

The results of phytosociological studies revealed that the total number of tree species decreased with the increase in elevation. In case of lower elevation six tree species were recorded, whereas at upper elevation four tree species were observed. The decrease in number from lower elevation to higher elevation might probably be due to variation in edaphic and climatic conditions of lower temperature and short growing period at upper elevation. The results are also in accordance with the findings of number of researchers like Joshi *et al* (1986), Chandra *et al*. (1999), Sharma (2006) and Lanker (2007) who worked on different forest species/tree stands.

The IVI value of *Pinus wallichiana* was recorded highest at all the three elevations studied. This discrepancy might be attributed to higher relative basal area of the species in the area/forests. On the other hand, the IVI value of *Betula utilis* was found less than other associated species in spite of higher relative density which can be attributed to the presence of small sized trees in the area/stands. These results find support from the findings of Rikhari *et al*. (2000) while working on *Taxus baccata* and Sharma (2006) while working on fir and spruce forests in western Himalayas (Fig.3).

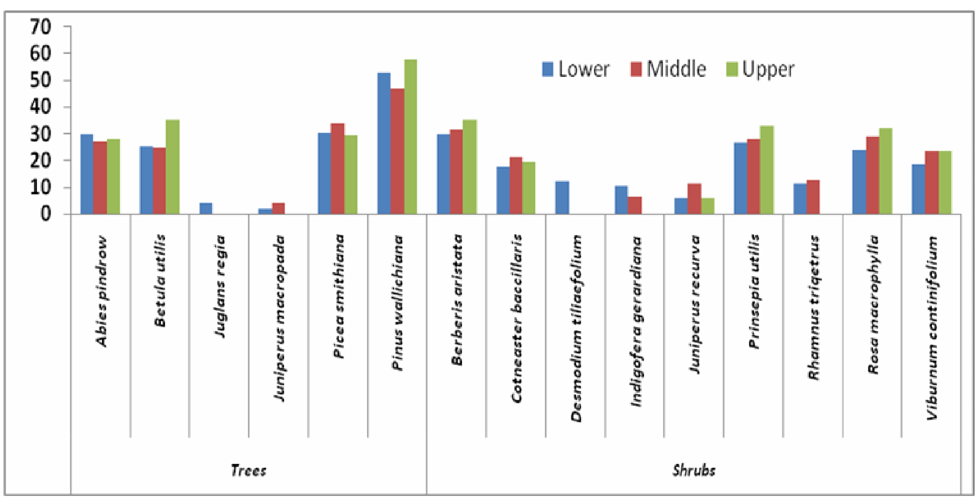


Fig. 3 : Mean IVI values of different woody elements at different elevations in the study area.

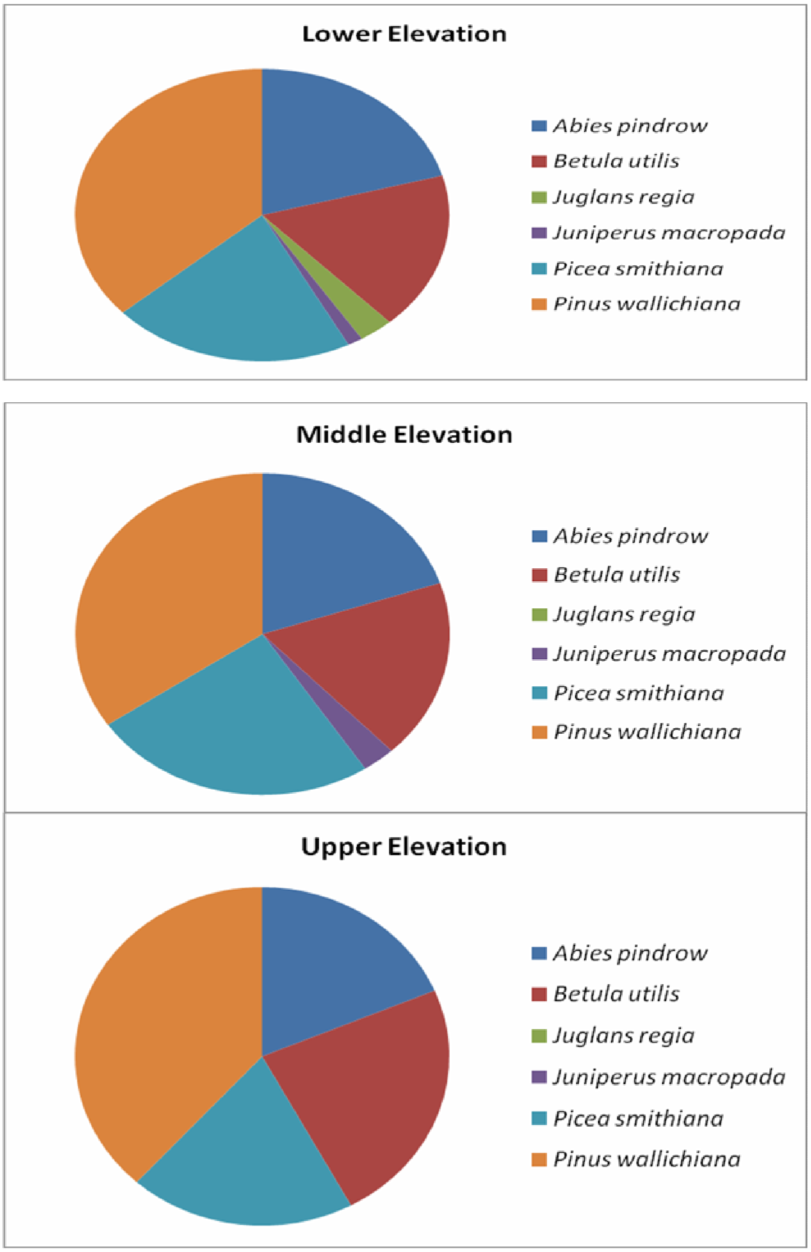


Fig. 4: Estimated distribution of trees (per ha) in different elevations in the study area.

The total number of trees per hectare was found to decrease with increase in elevation class, i.e., at 582/ha for lower elevation to 434/ha for middle elevation and 358/ha for upper elevation. The number of trees were more at lower elevation since the microclimate as conditioned by climate, edaphic and topographic conditions is more favorable for growth and development at lower elevation (Spurr and Barnes, 1980). The results are also in conformity with that of Rawat *et al*. (1989) while he was working on *Cedrus deodara* in western Himalayas (Fig.4).

The sequence of dominance as per the IVI values at lower elevation followed a trend of *Pinus wallichiana > Picea smithiania > Abies pindrow > Betula utilis > Juglans regia > Juniperus macropoda.* The dominance trend at middle elevation was of *Pinus wallichiana > Picea smithiania > Abies pindrow > Betula utilis > Juniperius macropoda.* The sequence of IVI at upper elevation showed a trend of *Pinus wallichiana > Betula utilis > Picea smithiania > Abies pindrow.* Thus depicting that the system is progressing towards climax stage, where broad leaved *Betula utilis* would form the most dominating species. The other reason for less IVI value for *Betula utilis* can be attributed to the reason that the mature trees are lopped and even cut by the local people for fuelwood.

As far as shrubs were concerned, they showed varying number and dominance in different Betula forests. Shrubs were found to be maximum (nine) at lower elevation and minimum (six) at upper elevation. The IVI value was found to be highest for *Berberis aristata* in almost all the elevations studied. The dominance on the basis of IVI values at different elevations was as fallowed a different trend. At lower elevation it was *Berberis aristata > Prinsepia utilis > Rosa macrophylla > Cotneaster baccillaris > Viburnum continifolium > Indigofera > Rhamnus triqetrus > Desmodium > Juniperus recurva*. At middle elevation it was *Berberis aristata > Rosa macrophylla > Prinsepia utilis > Viburnum continifolium > Cotneaster baccillaris > Rhamnus triqetrus > Indigofera gerardiana* and at upper elevation it was *Berberis aristata > Prinsepia utilis > Rosa macrophylla > Viburnum continifolium > Cotneaster baccillaris > Juniperus recurva*. The reason for dominance of *Berberis aristata* in all the three elevations can be attributed to its strong invading root system, which makes the species capable of growing even on rocky areas with less of top soil as in case of *Pinus gerardiana.*

Similarity Index

The maximum similarity among the woody elements (90.90%) for different elevations was found between lower and upper elevation (Table 29). It was 80.80 per cent between middle elevation and upper elevation and similarity between lower elevation and upper elevation was 80.00 per cent. The overall similarity was high between elevations, indicative of uniform distribution of vegetation. The high similarity index generally more than 50.00 per cent exhibit fairly uniform composition of the forests (Rikhari *et al.,* 1991).

5.4 Regeneration Studies

The results on regeneration studies depicted that recruits, unestablished and established plants of *Betula utilis* and associated species decreased with the increase in elevation (Fig. 5). This can be attributed to better edaphic and atmospheric parameters. More over, when the snow melts the seeds (which are very small in size) are slowly washed and they reach the lower elevation, higher values of available nitrogen, phosphorus and potassium (Table 36), photosynthetic rate, transpiration, water use efficiency (Table 38) at lower elevation. The results are thus in accordance with Rikhari *et al.* (2000) where they had reported similar results in *Taxus* species. Similarly, the regeneration success of *B. utilis* and associated species decreased with increase in elevation (Table 35). It could be attributed to lower incidence of solar influx at higher elevation (Table 38), as supported by the findings of Niemann (1992) and Seilding and Constein (1998) who investigated the importance of light for plant survival.

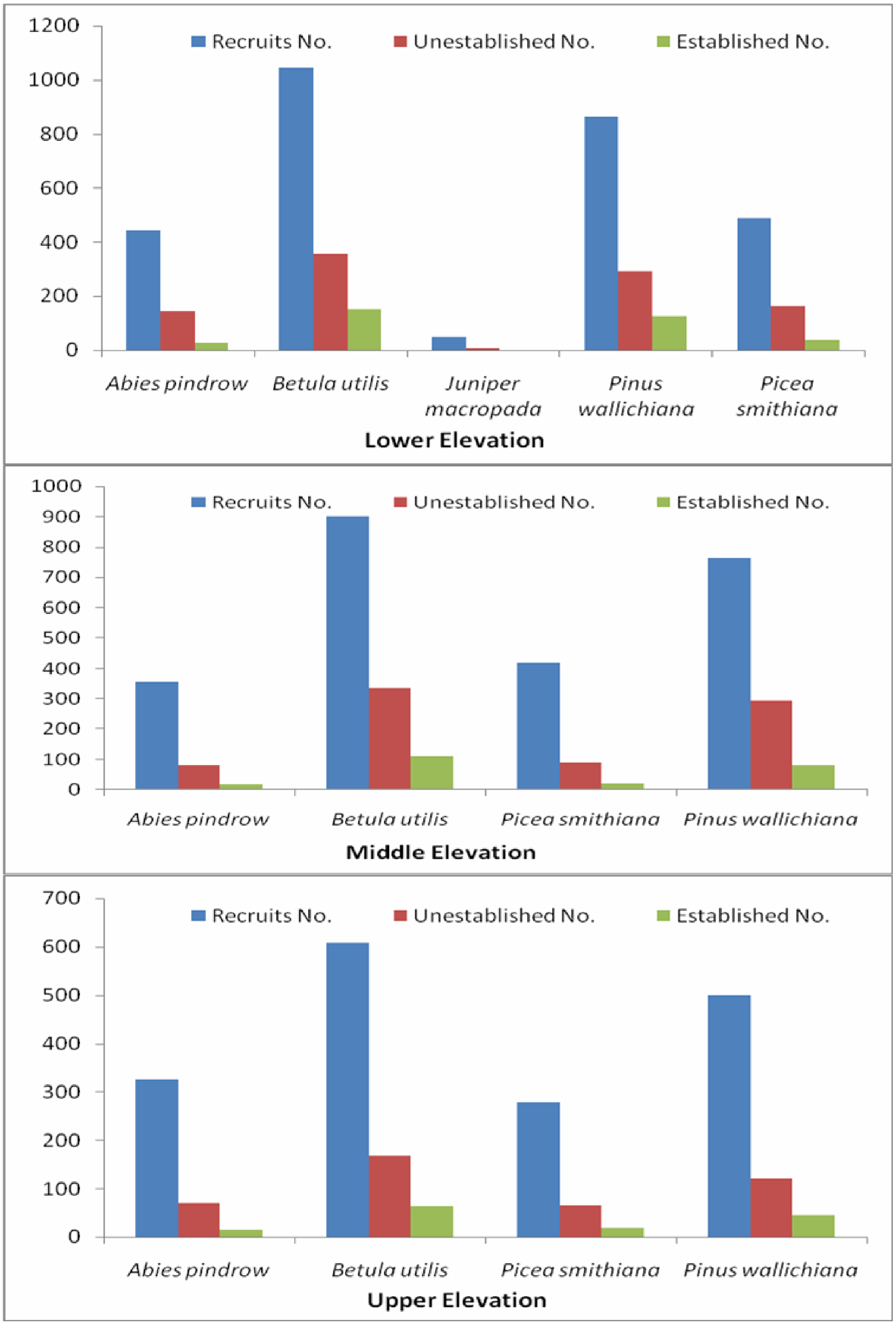


Fig. 5: Distribution of recruits, unestablished and established tree species at different elevations in the study area.

The maximum total weighted average height (347.34 cm), total established index (1.74); total stocking index (0.2322) and total establishment stocking per cent (9.87) were recorded at lower elevation (Fig. 6). This might be due to combined effect of various site factors like soil physico-chemical properties (Table 36) and other physiological parameters (Table 38) associated with warmer temperatures at lower elevation. The presents results are also in conformity with the earlier works of Jha *et al*. (1984), Singh *et al.* (1987), Kopp (1991), Feller (1998) and Lanker (2007) working on various tree species.

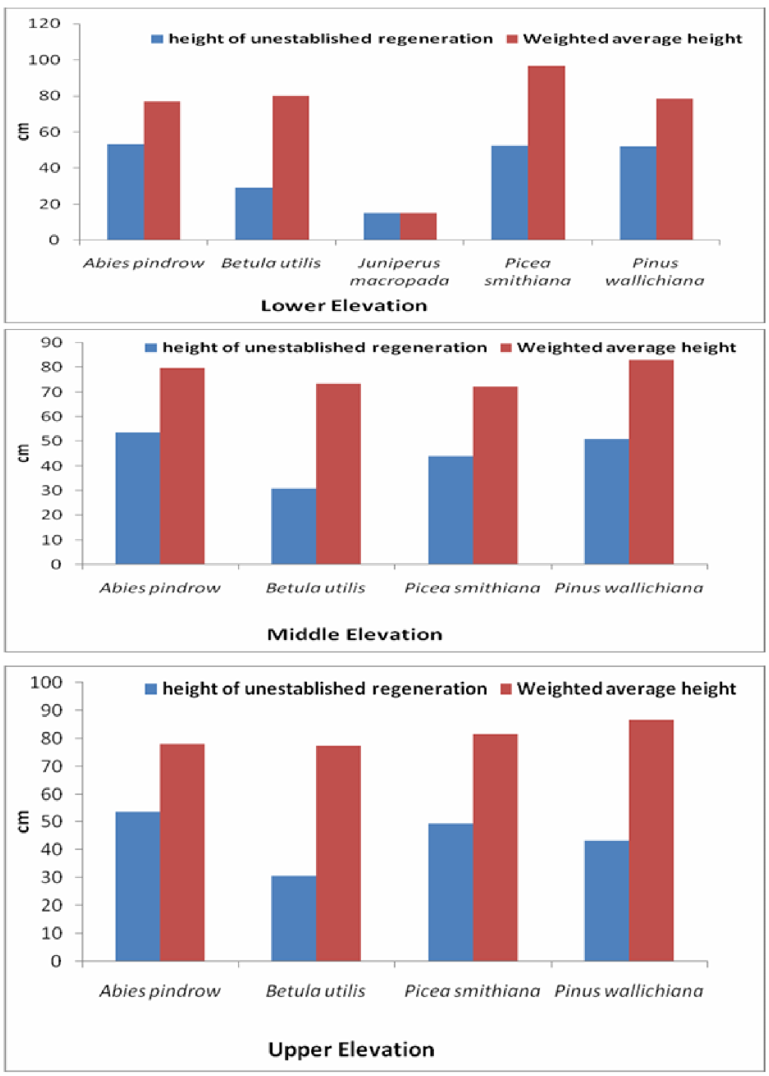


Fig. 6: Depicting height of unestablished regeneration and weighted average height in the study area.

In the present study, it was observed that the regeneration success of *B. utilis* decreased from lower (9.54 %) to upper (4.24 %) elevation (Table 35). Agarwal and Patil (1956) and Sharma (2006) also reported similar results while working on fir and spruce forests. Similar trend was also observed for their associated species. This trend of better regeneration in lower elevation can be attributed to better soil depth, higher moisture contents, higher soil temperature, more of soil nutrients and longer growing period. The present results from *Betula utilis* also draw support from work of Colaona and Giannini (1971), Singh (1983) and Pengshalin *et al.* (2006), where they have reported that depth of organic matter has indirect relationship with regeneration success. Similar finding also have been reported by Gorden (1970) in *Abies pindrow*, Ram Prakesh (1991) in *Cedrus deodara* and Zu Yuan Gang *et al.* (2006) in *Taxus baccata* (Fig. 7).

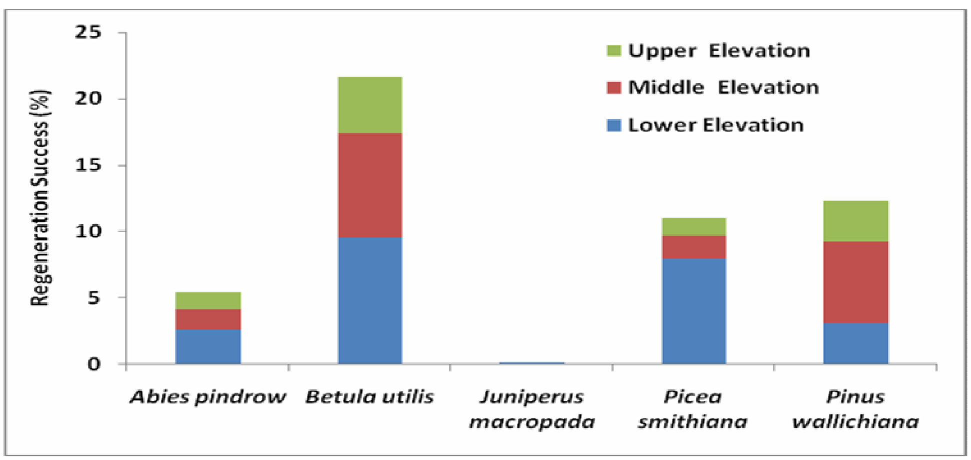


Fig. 7: Depicting the regeneration success of tree species at different elevations in the study area.

Simple correlation coefficient (Table 39) reveal that regeneration of *B. utilis* has a positive and significant correlation with soil organic carbon, pH, organic matter layer and solar influx, soil moisture, nitrogen, phosphorus and potassium. The results are thus in conformity with the finding of Filipiak and Komisaraek (2005) who reported potassium content and organic carbon in soil has positive effect on the regeneration of Silver fir.

5.5 Soil Physical and Nutrient Status

The physical and nutrient properties during different seasons (summer, rainy and winter) at two different depths (0-15 cm and 15-30 cm) and at different elevations (lower, middle and upper) showed that the soil moisture ranged between 23.44 ± 2.44 per cent at 15-30 cm depth at lower elevation in summer season to 33.54 ± 3.54 per cent at 0-15 cm depth and in the upper elevation during winter season. The soil pH value ranged between 5.99 ± 0.06 at 0-15 cm depth and at lower elevation in rainy season to 6.72 ± 0.08 at 15-30 cm depth and at upper elevation in summer season. The bulk density values ranged between 1.35 ± 0.10 g/cm^{-3} at 0-15 cm depth and at upper elevation in summer season to 1.60 ± 0.06 g/cm^{-3} at 15-30 cm depth and at lower elevation in rainy season. The porosity values were found to vary between 29.12 ± 3.65 per cent at 15-30 cm depth and at lower elevation in winter season to 45.23 ± 2.32 per cent at 0-15 cm depth and at upper elevation in summer season. The organic carbon value ranged from 2.06 ± 0.16 per cent at lower elevation in rainy season to 4.20 ± 0.18 per cent at 0-15 cm depth and at upper elevation in summer season. The available nitrogen contents were found to vary from 315.00 ± 25 kg/ha at 15-30 cm depth and at upper elevation in rainy season to 420.50 ± 24 kg/ha at 0-15 cm depth and at lower elevation in summer season. The available phosphorus value ranged from 23.60 ± 2.12 kg/ha at 15-30 cm depth and at upper elevation in winter season to 36.45 ± 3.60 kg/ha at 0-15 cm depth and at lower elevation in summer season. The available potassium value ranged from 285.65 ± 18 kg/ha at 15-30 cm depth and at upper elevation in rainy season to 338.00 ± 32 kg/ha at 0-15 cm depth and at lower elevation in summer season (Table 35). The variations in different the values for soil moisture contents, pH, porosity, organic carbon, organic layer and nutrient contents (N, P, K) were found to be significantly different owing to the reason of variation in altitude, slope, decomposition rates, top soil run off, leaching of nutrients from upper elevation to lower areas, etc. (Table 36)

5.6 Plant Nutrient Status

The nutrient status of *Betula utilis* tree during the peak growing season at different elevations showed that the nitrogen content ranged between 0.78 ± 0.08 per cent in bark at upper elevation to 4.65 ± 0.40 per cent in litter at lower elevation. The phosphorus content ranged between 0.06 ± 0.04 per cent in bark at upper elevation to 1.15 ± 0.04 per cent in litter at lower elevation. Similarly, the potassium content ranged between 1.18 ± 0.06 per cent in bark at upper elevation to 3.65 ± 0.72 per cent in litter at lower elevation. The critical difference studies depicted non significant differences between the different nutrients (N, P, K) at different elevations in the betuls bark, wood, leaf and litter contents, thus depicting that all the entire study area between 3,000 to 3,900 m amsl supports congenial edaphic and atmospheric characteristics for the growth of Betula tree (Table37).

5.6 Photosynthesis Studies

It was observed that the solar influx under the canopy was reduced by nearly 83.67 per cent in upper elevation, 81.65 per cent in middle elevation and by 80.20 per cent in lower elevation in the study sites; thus depicting the presence of thick top canopy cover. During peak growing season (August), when the leaves had matured and other atmospheric variables like atmospheric temperature, relative humidity, available soil moisture content etc., were not acting as limiting factors, the photosynthetic rate during noon (1100-1300 hrs) at different elevations range between 7.23 ± 0.65 μ mol m^{-2} s^{-1} at upper elevation to 8.56 ± 0.88 μ mol m^{-2} s^{-1} at lower elevation. The data depicting a decrease in rate from lower to upper elevation, which might be due to the decrease in leaf temperature. A similar trend was also observed for transpiration rate, where it ranged from1.25 ±

0.93 m mol m^{-2} s^{-1} from lower most elevation to 0.91 ± 0.67 m mol m^{-2} s^{-1} in upper elevation. This can also be due to the fact that at higher elevation, the atmospheric temperature was less (being near to the snowline) and the leaf area was not that much heated as at lower elevations, hence reduction in transpiration rate at higher elevations. Thus we can also draw the conclusion that the photosynthetic and transpiration rates are directly proportioned to each other. The water use efficiency of *Betula utilis* was also found to be normal during this period as it varied between 0.0023 at upper elevation to 0.0037 at lower elevation. This positive water use efficiency depicts the carbon assimilation through photosynthesis than loss due to respiration, which makes the species to survive and grow even in such harsh conditions (Bawa *et al.* 2011).

Chapter-6

SUMMARY AND CONCLUSION

The present investigation entitled, "Structural and Functional Studies of Woody Elements of Betula Forests in Sangla Valley of Himachal Pradesh", was conducted in Sangla valley of Himachal Pradesh during 2009-2010. The results of the investigation are summarized and conclusions arrived at are mentioned here in

6.1 Floristic Composition

In the study area, it was observed that a total of 6 tree species and 9 shrub species dominated the scene of woody elements (Table 1). The floristic composition revealed that the occurrence of a species at different elevations depicted quite a bit of variation at the elevations under study.

6.2 Phenological Studies

There was no single phenological stage which was not being overlapped by previous or the next stage. Thus, there was no major and abrupt change from one phenophase to another. The initiation of active growing vegetative phase was during the start of growing season, i.e., February and March. The flowering phase sets in from March onwards and lasted till June and July. However, late flowering was observed in conifers. The flowering stage was overlapped by seed maturity stage confined from June to January in different species. Similarly leaf fall stage starts from May onwards in conifers and the peak overall leaf fall was observed during November and December, especially in broad leaf species. The leaf less stage in broad leaves remained till the initiation of active growth period during the next year i.e., in March (Table 2-4).

6.3 Phytosociological Studies

The results on phytosociological studies reveal that the total number of tree species decreased with the increase in elevation from 3,000 to 3,900m amsl. In case of lower elevation six tree species were recorded, whereas at middle and upper elevations five and four tree species were observed, respectively (Table 23).

The IVI value of *Pinus wallichiana* was recorded highest at all the three elevations. Whereas, the IVI value of *Betula utilis* was found lesser than other associated species in spite of higher relative density.

The total number of trees per hectare were found to decrease with the increase in elevation class, i.e., 582/ha in lower, 434/ha in middle and 358/ha in upper elevations.

The sequence of IVI values at lower elevation showed a trend of *Pinus wallichiana* > *Picea smithiania* > *Abies pindrow* > *Betula utilis* > *Juglans regia* > *Juniperus macropoda;* and the sequence at middle elevation was of the order of *Pinus wallichiana* > *Picea smithiania* > *Abies pindrow* > *Betula utilis* > *Juniperius macropoda;* while the sequence of IVI values at upper elevation showed a trend of *Pinus wallichiana* > *Betula utilis* > *Picea smithiania* > *Abies pindrow* (Table 23).

As far as shrubs were concerned, they showed varying number and dominance in different Betula forests. Shrubs were found to be maximum (9) at lower elevation and minimum (6) at upper elevation. The IVI value were found to be highest for *Berberis aristata* in almost all the elevations studied. The dominance on the basis of IVI values at lower elevation showed a trend of *Berberis aristata* > *Prinsepia utilis* > *Rosa macrophylla* > *Cotoneaster baccillaris* > *Viburnum continifolium* > *Indigofera* > *Rhamnus triqetrus* > *Desmodium* > *Juniperus recurva*; at middle elevation it followed a trend of *Berberis aristata* > *Rosa macrophylla* > *Prinsepia utilis* > *Viburnum continifolium* > *Cotoneaster baccillaris* > *Rhamnus triqetrus* > *Indigofera gerardiana;* while at upper elevation it was *Berberis aristata* > *Prinsepia utilis* > *Rosa macrophylla* > *Viburnum continifolium* > *Cotoneaster baccillaris* > *Juniperus recurva* (Table 23)

The maximum similarity among the woody elements (90.90%) for different elevations was between lower elevation and upper elevation (Table 29).

6.4 Regeneration Studies

The recruits, unestablished and established plants of *Betula utilis* and associated species decreased with the increase in elevation at Sangla valley. Similarly, the regeneration success of *B. utilis* and associated species decreased with increase in elevation (Table 34). The maximum total weighted average height (347.34 cm), total established index (1.74), total stocking index (0.2322) and total establishment stocking per cent (9.87) were recorded at lower elevation.

The regeneration success of *B. utilis* was also observed to decrease from lower (9.54 %) to upper (4.24 %) elevation (Table 35).

Simple correlation coefficient reveal that regeneration of *B. utilis* had a positive and significant correlation with soil organic carbon, pH, organic matter layer and solar influx, soil moisture and soil nutrients, viz., nitrogen, phosphorus and potassium availability (Table 39).

6.5 Soil and Plant Nutrient Studies

There was a decrease in availability of moisture, organic carbon, available nitrogen, available potassium and available phosphorus with increase in soil depth. However, soil pH increased with increase in soil depth in all the elevations. The nutrient status of *Betula utilis* tree during the peak growing season at different elevations showed that the nutrients content decreased with the increase in elevation.

6.6 Photosynthesis Studies

The solar influx (%) remained almost same in different sites, however, it was slightly higher at lower elevations. The solar influx, photosynthesis, transpiration and water use efficiency decreased with increase in elevation. The nutrient status of Betula at different elevations was found maximum at lower elevation and found minimum at upper elevation (Table 36-38).

CONCLUSIONS

- Overall *Pinus wallichiana* was found to be the most dominant tree species, while *Betula utilis* was the co-dominant. Amongst shrubs, *Berberis aristata* and *Prinsepia utilis* were the dominant species in almost the study sites, depicting that the climax stage has not yet reached by the community, reason can be biotic interference.
- Total number of species decreased with the increase in elevation.
- The recruits, unestablished and established plants of *Betula utilis* and associated species decreased with increase in elevation.
- There was a decrease in availability of soil moisture, organic carbon, available nitrogen, available potassium and available phosphorus, with increase in soil depth. However, soil pH and BD increased with increase in soil depth in all the sites.
- The diversity index value for trees and shrubs was found to be maximum at lower elevation and the values decreased with the increase in elevation.
- There was decrease in soil available nitrogen, phosphorus and potassium and soil pH with the increase in elevation.
- Similar trend was also observed for solar infux (%), photosynthesis (µ mol $m^{-2}s^{-1}$), transpiration (m mol $m^{-2}s^{-1}$), and water use efficiency.
- Organic carbon, soil moisture, bulk density and organic matter thickness showed a reverse trend with increase in elevation.
- The similarity for vegetation was very high between different elevations (80.00%) in all cases.
- Soil physical properties like soil moisture, organic matter layer, soil pH and solar influx was having highly significant correlation with regeneration of Betula.

Chapter-7

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ABSTRACT

The present investigation entitled, "Structural and Functional Studies of Woody Elements of Betula Forests in Sangla Valley of Himachal Pradesh". The study area was divided into three horizontal (lower, middle and upper) elevations and vertically five zones. To carry out this study five quadrates of 10 x 100m were laid down for the study of trees and shrubs, whereas, twenty quadrates of 2 x 2m were layed per main plot to study the regeneration parameters. The IVI value of *Pinus wallichiana* was recorded highest at all the three elevations, whereas, the IVI value of *Betula utilis* was found lesser than other associated species in spite of higher relative density. The similarity index value was, in general, more than 50 per cent for both trees and shrubs indicating vegetational uniformity in the study area. The maximum diversity for woody elements was observed at lower elevations. There was no single phenological stage which was not being overlapped by previous or the next phenological stage. Thus, there was no major and abrupt change from one phenophase to another. The results on phytosociological studies reveal that the total number of tree species decreased with the increase in elevation from 3,000 to 3,900m amsl. The recruits, unestablished and established plants of *Betula utilis* and associated species decreased with the increase in elevation. Similarly, the regeneration success decreased with increase in elevation. The maximum total weighted average height, total established index, total stocking index and total establishment stocking per cent were recorded at lower elevation. There was a decrease in availability of soil moisture, organic carbon, available nitrogen, available potassium and available phosphorus with increase in soil depth. However, soil pH increased with increase in soil depth in all the elevations. The solar influx, photosynthesis, transpiration and water use efficiency decreased with increase in elevation. The nutrient status of Betula at different elevations was found maximum at lower elevation and found minimum at upper elevation. Simple correlation reveal that regeneration of *B. utilis* had a positive and significant correlation with soil organic carbon, pH, organic matter layer and solar influx, soil moisture and soil nutrients, viz., nitrogen, phosphorus and potassium availability.

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Appendix-I

Phytosociological data of study area at different elevation

S.No	Species	Average Basal Area cm^2	Average Density	Frequency	Abundance
Lower Elevation					
1	*Abies pindrow*	79753.22	80	100	21.33
2	*Betula utilis*	18052.76	236	100	7.67
3	*Juglans regia*	3203.64	10	40	2.50
4	*Juniper*	544.66	6	20	3.50
5	*Picea smithiana*	84678.38	82	100	7.00
6	*Pinus wallichiana*	165807.84	168	100	17.00
Middle Elevation					
1	*Abies pindrow*	49098.38	42	100	19.67
2	*Betula utilis*	12187.16	202	100	3.67
3	*Juniper*	675.82	8	40	2.00
4	*Picea smithiana*	64991.38	66	100	7.67
5	*Pinus wallichiana*	97699.14	116	100	11.00
Upper Elevation					
1	*Abies pindrow*	30403.56	34	100	19.00
2	*Betula utilis*	10422.46	212	100	3.00
3	*Picea smithiana*	32905.24	34	100	3.33
4	*Pinus wallichiana*	88108.82	78	100	8.00

Appendix-II

Organic matter depth study area at different elevation

Organic matter depth (cm)	
Upper Elevation	6.20 ± 0.40
Middle Elevation	5.40 ± 0.35
Lower Elevation	4.80 ± 0.55

Appendix-III

Analysis of variance for RBA of lower elevation

Source	DF	SS	MS	F
Treatment	14	6507.30	464.81	20.04
Replication	4	8.0000E-06	2.0000E-06	
Error	56	1299.10	23.199	
Total	74	7806.40		

Appendix-IV

Analysis of variance for RD of lower elevation

Source	DF	SS	MS	F
Treatment	14	1659.10	118.51	19.67
Replication	4	4.0000E-05	1.0000E-05	
Error	56	337.36	6.0242	
Total	74	1996.40		

Appendix-V

Analysis of variance for RF of lower elevation

Source	DF	SS	MS	F
Treatment	14	360.89	25.778	3.37
Replication	4	4.8000E-05	1.2000E-05	
Error	56	428.67	7.6547	
Total	74	789.56		

Appendix-VI

Analysis of variance for IVI of lower elevation

Source	DF	SS	MS	F
Treatment	14	1.2296E+04	878.29	15.85
Replication	4	4.8000E-05	1.2000E-05	
Error	56	3102.70	55.406	
Total	74	1.5399E+04		

Appendix-VII

Analysis of variance for RBA of middle elevation

Source	DF	SS	MS	F
Treatment	12	5260.9	438.41	275.55
Replication	4	5.6048E-18	1.4012E-18	
Error	48	76.371	1.5911	
Total	64	5337.30		

Appendix-VIII

Analysis of variance for RD of middle elevation

Source	DF	SS	MS	F
Treatment	12	1786.70	148.89	28.52
Replication	4	1.7756E-17	4.4389E-18	
Error	48	250.55	5.2198	
Total	64	2037.20		

Appendix-IX

Analysis of variance for RF of middle elevation

Source	DF	SS	MS	F
Treatment	12	299.07	24.922	4.34
Replication	4	2.3759E-18	5.9398E-19	
Error	48	275.52	5.7401	
Total	64	574.59		

Appendix-X

Analysis of variance for IVI of middle elevation

Source	DF	SS	MS	F
Treatment	12	8642.10	720.18	27.08
Replication	4	4.7139E-17	1.1785E-17	
Error	48	1276.50	26.594	
Total	64	9918.6		

Appendix-XI

Analysis of variance for RBA of upper elevation

Source	DF	SS	MS	F
Treatment	9	5761.30	640.14	55.60
Replication	4	9.1700E-18	2.2925E-18	
Error	36	414.52	11.514	
Total	49	6175.80		

Appendix-XII

Analysis of variance for RD of upper elevation

Source	DF	SS	MS	F
Treatment	9	1963.90	218.21	25.14
Replication	4	3.1179E-18	7.7948E-19	
Error	36	312.42	8.6783	
Total	49	2276.3		

Appendix-XIII

Analysis of variance for RF of upper elevation

Source	DF	SS	MS	F
Treatment	9	216.67	24.074	2.36
Replication	4	1.2809E-17	3.2022E-18	
Error	36	366.67	10.185	
Total	49	583.33		

Appendix-XIV

Analysis of variance for IVI of upper elevation

Source	DF	SS	MS	F
Treatment	9	7886.10	876.23	14.63
Replication	4	7.5488E-18	1.8872E-18	
Error	36	2156.30	59.898	
Total	49	1.0042E+04		

Appendix-XV

Analysis of variance for recruits number

Source	DF	SS	MS	F
Treatment	4	1.2679E+06	3.1699E+05	42.04
Replication	2	1.4048E+05	7.0239E+04	9.32
Error	8	6.0319E+04	7539.90	
Total	14			

Appendix-XIV

Analysis of variance for unestablished number

Source	DF	SS	MS	F
Treatment	4	1.5482E+05	3.8705E+04	16.67
Replication	2	3.0414E+04	1.5207E+04	6.55
Error	8	1.8575E+04	2321.90	
Total	14	2.0381E+05		

Appendix-XIV

Analysis of variance for established number

Source	DF	SS	MS	F
Treatment	4	2.5822E+04	6455.60	15.65
Replication	2	3936.50	1968.30	4.77
Error	8	3300.80	412.60	
Total	14			

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