

**ECOLOGICAL STATUS OF *Ulmus wallichiana*
(Planch.) IN HIMACHAL PRADESH**

Thesis

by

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(F-2020-35-M)**

submitted to



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CERTIFICATE - I

This is to certify that the thesis titled, “**Ecological status of *Ulmus wallichiana* (Planch.) in Himachal Pradesh**” submitted in partial fulfillment of the requirements for the award of the degree of **MASTER OF SCIENCE (FORESTRY)** in the discipline of **Forest Genetic Resources** of Dr. Yashwant Singh Parmar University of Horticulture and Forestry, (Nauni) Solan (HP) - 173230 India is a bonafide research work carried out by **Mr. Satyam SINGH** son of **Shri. Sohan Singh** under my supervision and that no part of this thesis has been submitted for any other degree or diploma.

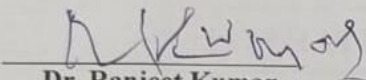
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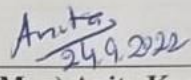
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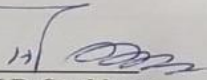
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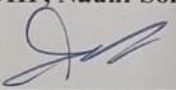
This is to certify that the thesis entitled, "Ecological Status of *Ulmus wallichiana* (Planch.) in Himachal Pradesh" submitted by Mr. Satyam (F-2020-35-M) son of Shri Sohan Singh to Dr. Yashwant Singh Parmar University of Horticulture & Forestry, (Nauni), Solan (H.P.) 173 230 India in partial fulfillment of the requirements for the award of degree of **MASTER OF SCIENCE (FORESTRY)** in the discipline of **Forest 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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LIST OF ABBREVIATIONS

%	:	Per cent
&	:	And
^o C	:	Degree Celsius
Alt	:	Altitude
Amsl	:	Above mean sea level
BA	:	Basal Area
C	:	Carbon
cm	:	Centimetre
dbh	:	Diameter at breast height
E/ha	:	Established/ha
<i>et al.</i>	:	Co-workers
<i>etc</i>	:	Et Cetera
Fig.	:	Figure
FRI	:	Forest Research Institute
FSI	:	Forest Survey of India
g	:	Grams
ha	:	Hectare
HP	:	Himachal Pradesh
i.e.	:	That is
IPCC	:	Intergovernmental Panel on Climate Change
IV%	:	Important value percentage
IVI	:	Importance value index
Kg	:	Kilogram
m	:	Meter
OC	:	Organic carbon
RBA	:	Relative basal area
RD	:	Relative density
RF	:	Relative Frequency
SI	:	Similarity index
SOC	:	Soil organic carbon
sp.	:	Species
TIGR	:	Tree Improvement and Genetic Resources

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Chapter-1

INTRODUCTION

Forests are one of nature's most significant natural resources, and they are both environmentally and economically vital to humanity. They are biodiversity hotspots that serve as home to a diverse range of flora and wildlife. Forests provide a variety of ecological services, including nitrogen replenishment, rainfall, landslide avoidance, soil erosion control, and watershed management. However, as the world's population and development activities grow, this vital resource is being depleted and degraded. As a result, many species are on the verge of extinction or have vanished entirely, demanding immediate conservation and management solutions. In a country like India, forests are critical to its socioeconomic growth. Not only do they supply abundant energy, shelter, fuel, lumber, and feed, but they also employ a huge portion of the rural people. Forestry accounts for 1.7% of all gross domestic output (Singh and Beniwal, 1995). However, as the country's economy grows, industrialisation occurs, and the human population grows, the demand for forest goods and services grows in lockstep.

The vascular flora of Himachal Pradesh's woods is abundant, forming a visible vegetative cover. The richness and diversity of the flora may be seen in the fact that the state has 3295 species (7.32 percent) of the total 45,000 species discovered in the country.

Elms are deciduous and semi-deciduous trees that belong to the genus *Ulmus*, which is part of the Ulmaceae plant family. *Ulmus* (elm) is a genus of tree with roughly 30 to 40 different species. *Ulmus wallichiana*, sometimes known as Himalayan elm, is a mountain tree that grows between 800 to 3000 metres above sea level. It is found in Afghanistan, Pakistan, Northern India, and Western Nepal (Batool et al., 2014). Jammu and Kashmir, Uttaranchal, and Himachal Pradesh are the states where this species is found in India.

The Himalayan elm may reach a height of 30 metres and has a wide ground with rising branches. The trunk's bark is greyish brown and wrinkled lengthwise. The leaves are elliptic-acuminate, with a length of less than 13 cm and a width of less than 6 cm (Batool et al., 2014). The blooms are known as samara and have a diameter of less than 13 mm (Melville and Heybrock, 1971). They are found in clusters of branches and blossom between March and April (Batool et al., 2014).

Elm leaves provide good feed, and the bark produces a strong fibre that may be used to make cordage and rope. The bark of *Ulmus wallichiana* is extensively employed in Himalayan folk medicine for the healing of shattered bones in both animals and humans. Trays, ploughs, construction materials, and fuel are all made from wood. The young shoots are prized by buffaloes as feed. Furniture, light construction, and planking are all possible applications (Gamble, 1922; Pearson and Brown, 1932). The tree has been widely exploited as a consequence of its many uses, and as a result, the species has become endangered. The species is now classified as vulnerable by the IUCN, 1998. Heavy lopping for fodder and fuel wood, as well as removal of fibrous bark for rope manufacture, annihilated the tree and rendered it incapable of reproducing naturally through seeds. Due to a high prevalence of empty seeds, natural regeneration of the species is weak. Seeds of the species are uncommon, but if those that are accessible are not viable due to their limited viability, artificial afforestation is difficult. Vegetative propagation is also difficult as cuttings are difficult to root (Wester *et al.*, 2019).

Community composition and structure are the important ecological attributes of forests which are influenced by the regional environmental, edaphic and anthropogenic factors (Saxena and Singh, 1984). Assessment of the forest community composition and structure is very useful in understanding the tree population dynamics, regeneration pattern and diversity (Mishra *et al.*, 2013; Dash *et al.*, 2021). In a forest community, trees are the fundamental component as they influence the resources and physical structure of habitats for almost all other forest organisms (Rawat *et al.*, 2018a). The subsistence of a tree species in forest community mainly depends on its regeneration potential under varied environmental conditions (Gairola *et al.*, 2012; Malik and Bhatt, 2016) The term "regeneration" refers to a variety of activities that include seed development, distribution, and germination, as well as seedling establishment. It is the most critical mechanism for maintaining a community's stable age structure of plant species, which is influenced directly or indirectly by numerous climatic and edaphic conditions (Singh and Singh, 1992). In forest management, a regeneration study illustrates not only the current state of the forest, but also hints to future forest composition changes (Malik and Bhatt, 2016; Sharma *et al.*, 2014). One of the key areas of research in modern ecology is the study of tree regeneration, which has significant implications for natural forest management (Murthy *et al.*, 2002; Sukumar *et al.*, 1997). It is, probably, the single most crucial step in ensuring forest long-term viability (Malik, 2014; Malik and Bhatt, 2016; Saikia and Khan, 2013).

Regeneration of any species is confined to particular range of habitat conditions and extent of those conditions is the primary determinant of its geographic distribution (Grubb, 1977). Regeneration study can depict the current status of forest composition as well as provide hints about forest composition in future (Henle *et al.*, 2004). It can be predicted by analysing the density of seedlings, sapling and mature trees within a particular forest (Austin, 1977). The regeneration status of a forest can also be assessed by studying the distribution of tree individuals of different diameter classes. High density of new recruits (seedling) and low diameter individuals in comparison to the mature, indicates good regeneration potentials. In a forest, older trees serve as seed banks which produce young ones and the process continues in time and space (Pokhriyal *et al.*, 2010). For a successful natural regeneration, survival and growth of seedlings/saplings and the pace at which the younger trees are replacing the older ones are the most determining factors (Good and Good, 1972). Poor regeneration due to habitat loss, land degradation, deforestation, forest fires, over grazing, lopping, etc. is the major problem of mountain forests (Parveen *et al.*, 2017; Pant and Samant, 2012).

Climate change and environmental disturbances are causing various changes in the structure, composition, and regeneration of natural forests in the Indian Himalayan Region (IHR). Because the Himalayan woods are often dominated by low-temperature conditions, they are vulnerable to significant climate change consequences (Wester *et al.*, 2019). By comparing current vegetation and climatic data to historical trends, continuing changes in every Himalayan Forest may be tracked. As a result, a quantitative research of Himalayan forests is required to quantify the impact of climate change on future species coexistence, as well as to provide baseline data for long-term monitoring and species shift processes (Sharma *et al.*, 2016; Dash *et al.*, 2021).

Forest soils also influence the composition of the forest stands and ground cover, as well as the rate of tree growth and the strength of natural reproduction (Bhatnagar, 1965) Forest soil physicochemical parameters of forest soil also changes through time and location due to terrain, climate, weathering processes, plant cover, microbial activity (Paudel and Sah, 2003), and a variety of other biotic and abiotic variables. Vegetation plays a significant role in soil formation, soil structure, infiltration rate, and aeration (Champan and Reiss, 1992). Plants are the primary source of soil organic matter, which affects physicochemical qualities such as texture, pH, water holding capacity, and nutrient availability (Johnston, 1986). The type of the soil profile, pH, and nutrient cycling between soils and plants are all key factors in determining the quality of a forest site.

Keeping in view the above-mentioned aspects the present investigation “Ecological status of *Ulmus wallichiana* Planch in Himachal Pradesh” was carried out with the following objectives:

- i) To study the ecological status of *Ulmus wallichiana* & other woody associated species.
- ii) To study regeneration potential of *Ulmus wallichiana*.

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:

2.1 PHYTOSOCIOLOGICAL STUDIES

2.2 NATURAL REGENERATION STUDIES

2.3 SOIL NUTRIENT 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 Whittaker, 1970). In geo-botany, phytosociology is also known as sociologic geo-botany, vegetation science, plant sociology or synecology (community ecology).

Fischer (2000) surveyed the vegetation and phytosociological relations on calcareous steep 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.

Ahmed *et al.* (2006) studied a quantitative phytosociological survey conducted in 184 sampling stands in various climatic zones of Himalayan forests of Pakistan. Based on floristic composition and importance value, 24 different communities and 4 monospecific forest vegetation's were recognized. Quantitative description and their population structure are presented. Many communities show similar floristic composition, however, differ in quantitative values.

Sanjeev *et al.* (2006), undertook phytosociological analysis of Amigad micro watershed in Mussoorie hills of Garhwal Himalayas and revealed that *Quercus leucotrichophora* was the dominant species with highest IVI value (114.4) followed by *Rhododendron arboreum* (42.6) and *Cedrus deodara*, (28.4). However, in shrubs, *Berberis aristata* was the dominant species with highest IVI of 134.9 followed by *Myrsine africana* (86.2). Among herbs, *Eupatorium* was the dominant one (106.2) followed by fern species (92.8). Similarly, density per hectare was highest for *Quercus leucotrichophora* (325 trees/ha), *Berberis aristata* (800 shrub/ha) and *Erigeron mucronatus* (10000 herbs/ha). 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.

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.

Hussain *et al.*, (2008) studied the Kumaon forest, Himalaya, India revealed a total of 19 tree communities and 17 ground vegetation communities. Maximum tree species diversity and species richness were recorded at an altitudinal range of 2020-2440m amsl. The distribution of tree species indicated influence of altitudinal gradient as well as of canopy cover and shrub diversity.

Bhatt and Khanal (2010) found that vegetation covering an area has a definite structure and composition developed as a result of long-term interaction with biotic and abiotic factor, and any change in the status of these factors disturbs the floristic composition of the environment. Total stand density and basal area were 638.55 trees/ha and 17.68 m² /ha in five plots, respectively. The highest IVI value was that of *Alnus nepalensis* (30.21) followed by *Castanopsis tribuloides* (21.22) and *Lyonia ovalifolia* (19.27) in plot 3, where the DBH of tree was ≤10cm. Based on IVI values, *Alnus nepalensis*, *Castanopsis tribuloides* and *Lyonia*

ovalifolia were found to be the most dominant species in the study area. The three values as 0.09333, 0.9066 and 10.71 of Simpsons Diversity (D) of 33 species represent different biodiversity.

Dass *et al.*, (2010), carried out phytosociological study of Rono hills of Arunachal Pradesh and concluded that importance value index of some ecologically significant trees, shrubs and herbs were found as *Callicarpa arborea* (24), *Lantana camara* (51) and *Ageratum conizoides* (19), respectively. The total basal area of trees was 17.84m²/ha. The highest Shannon-Wiener diversity index was recorded for trees (3.66) and minimum for herbs (3.60).

Rana *et al.*, (2010) studied the dynamics of plant bio-resources related to structure of vegetation and variation in dominant species in three watersheds located in different agro climatic regions in Himachal Pradesh (India) and reported that the tree density for individual tree species ranged from 0.001 to 2.23/100 m² across the watersheds. They reported that *P. roxburghii* along with *Quercus leucotrichophora* accounted for high abundance (58%) in one watershed. They also reported shrubs like *Myrsine africana*, *Berberis asiatica* and *Rubus ellipticus* in *P. roxburghii* stands and recorded shrub density for individual species ranging from 0.001 to 2.644/25 m².

Mir *et al.*, (2011) while doing ecological analysis of woody species of the Chopal forest division, Himachal Pradesh at five sites under different altitudes and aspects found that the total basal area covers of the forests varied between 0.093 m² ha⁻¹ (*Alnus nepalensis*) at site-IV and 46.682 m² ha⁻¹ at site-V (*Cedrus deodara*). The distribution pattern was found regular, random and contagious. Species diversity index was found maximum 1.597 at site IV and minimum 0.574 at site-1. Whereas, species richness was found highest (9) at site-V and lowest (2) at site-I and II, respectively.

Pala *et al.*, (2011) studied species composition and phytosociological status of Chanderbadni sacred forest in Garhwal Himalaya, Uttarakhand India. They recorded that *Quercus leucotrichophora* with IVI (116.63), *Berberis aristata* with IVI (30.23) and *Andropogon munrol* with IVI of (38.84) were dominant among trees, shrubs and herbs, respectively.

Sobuj and Rahman (2011) while studying phytodiversity in Khadimnagar National Park of Bangladesh. They Concluded that among the tree species, *Tectona grandis* showed

the highest density (3.03/100m²), frequency (76.67%), relative density (17.7%), relative frequency (11.3%) and relative dominance (37.3%). On the contrary, *Alstonia scholaris* represented the lowest density (0.07/100m²), frequency (6.67%), relative density (0.39%) and relative frequency (0.99%). The lowest relative dominance was found for *Sterculia villosa* (0.14%). However, species with the highest abundance was calculated for *Chukrasia tabularis* (4.58), whereas the lowest was recorded for *Alstonia scholaris*, *Cynometrapo lyandra*, *Sterculia villosa*. Moreover, highest importance value index was measured in *Tectona grandis* (66.3) while it was lowest in *Alstonia scholaris* (1.54). Among shrub species, *Clerodendrum viscosum* represented the highest density (1.03/4m²) and frequency (50%). In contrast, lowest density (0.08/4m²) and frequency (8.33%) were measured in *Antidesma ghaesembila*. Species with the highest abundance was found in *Urena lobata* (2.35) whereas lowest is in *Antidesma ghaesembila* (1.0).

Sinha and Sinha (2013) explored phytosociological behavior of species in terms of their Importance Value Index (IVI) and revealed that maximum IVI was exhibited by *Woodfordia fruticosa* (28.65), *Shorea robusta* (23.25). *Dodonaea viscosa*, *Albizia odoratissima* and *Lawsonia inermis* ranked second with the range of IVI (16.99 to 17.87) and *Butea monosperma*, *Corchorus trilocularis*, *Vanda roxburghii* and *Cymbopogon martini* were third ranking species, based on the IVI while other species showed very low IVI.

Woziwoda et al. (2014) presents the effects of the intentional introduction of the North-American *Quercus rubra* in European mixed Scots pine-Pedunculate oak forests (POFs): *Quercus robur*-*Pinetum*. Phytosociological data from field research combined with GIS data analysis of the current distribution of Northern Red oak in the studied habitat were used to determine the composition and structure of forest communities in plots with and without *Q. rubra* participation. The results showed that *Q. rubra* significantly reduces native species richness and abundance, both in old-growth and in secondary (post-agricultural) forests.

Bhatt et al., (2015) investigated the phytosociological measurements and comparative assessment of vegetation of Lolab valley, Kupawara along an altitudinal gradient in different sites. On the basis of Importance Value Index, *Cedrus deodara* was the most abundant species of the area followed by *Pinus excelsa* and the third associated species was *Abies pindrow* which was also reported the second associated tree species in the site at elevation

range of 2106 to 2938 m. The result clearly indicates that elevation gradient plays vital role in the distribution of conifer species as well.

Plant phytosociology patterns in seven temperate forest types, *Populus deltoides*, (PD) *Juglans regia*, (JR) *Cedrus deodara*, (CD) *Pinus wallichiana*, (PW) mixed coniferous, *Abies pindrow* and, (AP) *Betula utilis* (BU) were analysed in Kashmir Himalaya by (Dar and Sundarapandian 2016). The total number of stem and basal area of trees were: 35,794 stems (stand mean 330 stems/ha) and 481.1 m² (stand mean 40.2 m² /ha), respectively. The mean density and basal area ranged from 103 stems ha⁻¹ (BU) to 1,201 stems ha⁻¹ (PD), and from 19.4 m² ha⁻¹ (BU) to 51.9 m² ha⁻¹ (AP), respectively. Tree density decreased with increase in diameter class. A positive relationship was obtained between elevation and species richness and between elevation and evenness ($R^2 = 0.37$ and 0.19, respectively). Tree and shrub communities were homogenous in nature across the seven forest types, while herbs showed heterogeneous distribution pattern.

Khan *et al.*, (2016) studied the pine communities at Indus Kohistan valley in quantitative term and thirty stands of relatively undisturbed vegetation were selected for sampling. They reported that seven tree species were common in the Indus Kohistan valley. *Cedrus deodara* exhibited the highest mean Importance Value Index (IVI) followed by *Pinus wallichiana*, *Abies pindrow* and *Picea smithiana*. *Pinus gerardiana*, *Quercus baloot* and *Taxus fuana* were the rare species in this area. Six communities and four monospecific stands of *Cedrus deodara* were recognized. *Cedrus-Pinus* community was the most occurring community, which was recorded from 13 different stands. The second most occurring community in the study area was *Abies - Pinus wallichiana* which was recorded from six locations while *Cedrus -Picea* and *Abies- Picea* communities were observed at two locations each. *Pinus wallichiana - Picea* and *Cedrus-Pinus gerardiana* communities were restricted to one location.

Kumari *et al.* (2017) carried out a study in oak (*Quercus leucotrichophora*) dominated forest of Pauri Garhwal. Two permanent plots were selected of which one was BPS (burn protected site) and other was UBPS (unburn protected site). The vegetational data were analysed for both the sites i.e., floristic composition, density, basal cover, A/F, Shannon Wiener index and Simpson's index of dominance (cd). Results showed that a total of 6-8 trees species and 24-26 shrub species were found on both BPS and UBPS. BPS showed maximum density than UBPS. Contagious pattern of distribution was common. The

results also show a close association among man, fire and forest ecosystem.

Hailemariam and Temam (2018) conducted a study in Gole natural forest (Dodola) West Arsi Zone of Oromia Regional State, Ethiopia. The study was intended to investigate the vegetation composition, structure, and community types. A total of 114 plant species belonging to 57 families and 94 genera were identified. The most dominant families were Asteraceae, followed by Acanthaceae and Lamiaceae. Out of 114 species, 17 were endemic to Ethiopia. Five plant community types were identified. The rarefaction revealed that there is difference in species richness among communities. The Sorensen's similarity index showed that, there was a difference in the distribution of plant species composition among the five plant communities.

Kevey and Toth (2018) studied the phytosociological characteristics of the oak-ash-elm hardwood forests growing in the Mohács Island in Southern Hungary. These forests occur in habitats where soil moisture is highly dependent on groundwater. They harbour a relatively large number of sub-montane species including many Fagetalia elements: *Anemone ranunculoides*, *Arum maculatum*, *Asarum europaeum*, *Carpinus betulus*, *Corydalis cava*, *Dryopteris filix-mas*, *Epipactis helleborine*, *Epipactis microphylla*, *Euphorbia amygdaloides*, *Gagea lutea*, *Galium odoratum*, *Hedera helix*, *Lathraea squamaria*, *Milium effusum*, *Primula vulgaris*, *Pulmonaria officinalis*, *Sanicula europaea*, *Scilla vindobonensis*, *Senecio germanicus subsp. nemorensis*, *Stachys sylvatica*, *Stellaria holostea*, *Ulmus glabra*, *Veronica montana*, *Vinca minor*, *Viola reichenbachiana* etc. The occurrence of species characteristic of the Aremonio-Fagion alliance (*Helleborus odoratus*, *Lonicera caprifolium*, *Primula vulgaris*, *Scutellaria altissima*, *Tamus communis*, *Tilia tomentosa*) lends this community a weak sub-Mediterranean character.

Khan *et al.*, (2020) worked on evaluation of the conservation status of *Ulmus wallichiana* and *U. vilosa* in Pakistan, reported that these species grow at an elevation range of 2200-3000m. Most individuals of the taxon were found growing in areas with slopes, on limestone cliffs and at the rock's edges in dense as well as in fragmented form. These taxa are confined to Himalayan ranges mostly. During the study, *Ulmus wallichiana* was recorded in 52 localities, some individuals of the taxon were found within the dense forests of *Pinus wallichiana*, *Abies pindrow*, *Picea smithiana* and *Pinus roxburghii*. All these localities collectively encompassed an area of 1632 km² for *Ulmus wallichiana*.

2.2 NATURAL REGENERATION STUDIES

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 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 gamillinea* 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.

Gairola *et al.*, (2012) undertaken a study to understand the regeneration dynamics of the dominant tree species along an altitudinal gradient in naturally regenerating, restricted access forest of Mandal-Chopta area in the Garhwal region of Uttarakhand, India. The overall regeneration status was fairly high in the study area. Most of the native canopy and under canopy dominants had frequent reproduction and expanding populations, which suggests the stability of forest structure/composition and further expansion of dominant species. The overall regeneration of trees in the forest had a greater contribution of middle and understorey species. Because of infrequent reproduction and declining populations of some of the dominant native species viz., *Abies pindrow*, *Alnus nepalensis* and *Betula alnoides*, structural/compositional changes in the future are expected in respective forests dominated by them. *Abies pindrow* and *Taxus baccata* need immediate attention by forest managers for their survival in the area. Seedlings were found to be more prone to competition from herb and shrubs than saplings.

Pant and Samant (2012) reported diversity and regeneration in Khokhan Wildlife Sanctuary (KoWLS) located in the Kullu district. Sixty-five sites were sampled between 1640-2400 m amsl. Seventeen forest tree communities were recorded. *Cedrus deodara* community was the most widely distributed followed by *Quercus leucotrichophora*, *Abies*

pindrow and *Quercus semecarpifolia* communities. *Cedrus deodara* community had maximum density of trees (1468 ind ha⁻¹). while *Picea smithiana* community recorded the maximum total basal area (182.2 m² ha⁻¹). Out of the 17 forest tree communities identified, eight showed maximum regeneration of the dominant species, six showed maximum regeneration of the co-dominant species indicating the possibility of at least partial replacement of the dominant species by the co-dominant species in the future; and three communities showed poor or no regeneration of the dominant species indicating a total replacement of the dominants in the coming years.

Bargali *et al.* (2013) studied the regeneration status of tree species in two adjacent sites (site I – undisturbed open area and Site II – moderately disturbed area) in mixed oak forest zone at Nainital Catchment, Uttarakhand India. In both the sites, *Quercus leucotrichophora* and *Q. floribunda* have higher proportion of individuals in younger girth classes indicating expanding type of population structure. However, conversion into higher girth classes was more prominent at protected site as compared to disturbed site. Thus, it was concluded that oak species of Kumaun Himalayan region have ability to regenerate when anthropogenic pressures are negligible.

Bisht *et al.*, (2013) investigated the population status and regeneration of *Quercus semecarpifolia* and *Q. floribunda* in a sub-alpine forest of Uttarakhand in Western Himalaya. Saplings of *Q. semecarpifolia* with 51-100 cm size and those of *Q. floribunda* in 101-150 cm size class were well represented in these sub alpine forests. Seedling to tree ratio for *Q. semecarpifolia* was higher in the stand dominated by *Q. floribunda*, while comparable pattern was observed for *Q. floribunda* in the stand dominated by *Q. semecarpifolia*. Establishment of higher per cent seedlings of one species in the habitats dominated by another species of *Quercus* appeared to indicate an oligarchic nature of oaks in sub-alpine forests.

Vacek *et al.*, (2014) studied tree regeneration of forest stands in the Cerný dul Nature Reserve, which is situated in the Orlicke Hory Mountains, protected landscape area in the Czech Republic. Research was conducted in a spruce-beech stand with an admixture of silver fir, sycamore maple and rowan on two comparative permanent research plots (PRPs) (PRP 1-fenced enclosure and PRP 2-unfenced). Typological, soil, phytosociological and stand characteristics of the two PRPs were similar. The results showed that unregulated browsing is a limiting factor for successful development of natural regeneration of autochthonous tree species. The population of tree species of natural regeneration on the fenced plot (PRP 1) is

sufficient in relation to the site and stand conditions. However, natural regeneration on PRP 2 is considerably limited by browsing. Damage is greatest to fir, sycamore maple and rowan; less severe to beech; and the least to spruce.

A regeneration survey of *Pinus wallichiana* was conducted by Bhat *et al.* (2015) at four different altitudes viz., A1; 1600-2000, A2; 2000-2400, A3; 2400-2800 and A4; 2800-3200 amsl at different Forest Division of Kashmir valley. The assessment of status was done by laying four quadrates of 10×10-m² with regeneration units of 2×2 m within each quadrate at all altitudes. The maximum numbers of Kail trees 512-556/ha were recorded at lower altitudes (1,600-2,400 amsl) with their average height and DBH ranging from 26.15 to 27.38 meters and 43.19 to 7.86 cm respectively. The natural regeneration indicated that maximum number of recruits, seedlings and saplings of 1171.87, 937.50 and 730.25/ha was recorded at A1 altitude followed by 1015.62, 703.25 and 468.71/ha at A2 altitude on northern aspects at an elevation of 2,000-2,400 amsl. The frequency, density and abundance of recruits, seedlings, saplings (15.62, 15.62, 12.50), (0.47, 0.37, 0.28) and (3.16, 2.50, 2.25) were recorded maximum at lower altitude. The study thus concluded that the altitudinal range of 1600-2400 amsl is suitable for proper growth and natural regeneration of *Pinus wallichiana* under temperate conditions of north-western Himalayas.

Malik and Bhatt. (2016) studied the regeneration status of tree species and survival of naturally emerged seedlings along an altitudinal gradient in a protected area of Western Himalaya, India. In 900-1200 amsl, the highest density was recorded for seedlings (5330 ind ha⁻¹), followed by saplings (2685 ind ha⁻¹) and trees (280 ind ha⁻¹). As far as the regeneration status is concerned in this forest, most (50 %) tree species showed good regeneration and the other tree species showed fair (7.1 %), poor (28.6 %) or new (14.3%) regeneration. The highest density was recorded for seedlings (4535 ind ha⁻¹), followed by saplings (2950 ind ha⁻¹) and trees (410 ind/ ha). Most of the tree species in 1600-2250 amsl showed either good or poor regeneration (41% each), while the remaining ones (5.9% and 11.8%) showed fair and new regeneration respectively. In 2250-2600 amsl. the highest density was recorded for seedlings (4740 ind ha⁻¹), followed by saplings (3200 ind/ ha) and trees (465 ind ha⁻¹). Most species (56 %) showed good regeneration and the remaining ones showed fair (8 %), poor (24%) or new (12%) regeneration.

Hanief *et al.*, (2016) undertaken three different forest cover types which were dominated by *Quercus incana*, *Persea duthiei* and *Abies pindrow*, respectively. They

reported that the density of seedlings: saplings and trees increased with increase in elevation. All the three forest types have poor regeneration. The recruitment of *Q. incana* seedlings and the rate of conversion of *A. pindrow* seedlings to saplings and then saplings to young trees were very low, Proper care needed to prevent excessive exploitation of these forests and livestock grazing should be controlled in all these forest types to conserve these forests.

Parrey *et al.*, (2017) studied the regeneration status of Spruce (*Picea smithiana*) and assessed with the major focus on regeneration pertaining to the poor recruitment and seedling establishment in south Kashmir of western Himalayas. The study was concentrated along the three altitudinal gradients viz. 2,200 - 2,400 m (Anantnag), 2,400- 2,600 m (Lidder) and 2,600 - 2,800 m (Shopian), at each altitude two sites were randomly selected for the study. The regeneration at all the sites was poor to fair, but did not show any definite trend along the altitudinal gradient. The maximum density of recruits (1031.25 ind ha⁻¹), number of un-established regeneration (562.50 ind ha⁻¹) and number of established regeneration (273.44 ind ha⁻¹). maximum height of un-established regeneration (5.80 m), weighted average height (99.32 m). stocking index (0.16), establishment stocking per cent (5.64) and regeneration success (17.19%) was recorded at middle altitudinal gradient (2,400-2,600 m), whereas the minimum regeneration was recorded at upper altitudinal gradient (2,600- 2,800 m).

Lone *et al.*, (2018) conducted a study on natural regeneration status of *Picea smithiana* along the altitudinal gradient in North Kashmir J&K, India (Western Himalayas). The species was found mixed with Pine at lower altitude and with *Abies* at upper altitude. Significant variation in the regeneration was recorded along the altitudinal gradients with respect to various parameters of regeneration, viz. number of recruits, number of seedlings, number of saplings and number of trees. Maximum number of recruits (1.151.67 ind ha⁻¹), number of seedlings (1049.64 ind ha⁻¹) number of saplings (358.12 ind ha⁻¹) and trees (410.69 ind ha⁻¹) were present at lower altitude (2,200-2,600 amsl). In terms of individual sites, the maximum number of recruits, seedlings, saplings and trees 1220.75, 1117.53, 410.44 and 433.56 ha⁻¹, respectively was recorded at Wadder. Whereas, the minimum number of recruits (330.44), seedlings (310.50) saplings (165.66) and trees (185.75) ha⁻¹ were recorded at Puthshahi which represented the upper altitude (3,000-3,400) m. In general, the density of seedlings, saplings and trees increased with increase in elevation. All the three forest types have poor regeneration. The recruitment of *Q. incana* seedlings and the rate of conversion of *A. pindrow* seedlings to saplings and then to from saplings to young trees were very low.

2.3 SOIL NUTRIENT STUDIES

Singh *et al.* (1984) reported (37%) of total nitrogen in oak vegetation and 22 per cent in pine. In pine substantial quantities of nitrogen and phosphorous were reabsorbed from old leaves before abscission and re-used for growth. The high Dry Matter, C: N ratio of the litter and high C: N ratio of the soil in pine forest reduced the rate of litter decomposition and increased the forest floor fuel load, which suggested as the main reason that why the pine resists reinvasion by oaks requiring heavy demand for N and do not succeed in N poor soil. Recurring fires in the pine system also led to N loss.

Singh and Bhatnagar (1997) found differences in nutrient status of the forest soils receiving litter from chir pine, deodar and ban oak in a naturally growing stand. The amount of available nutrients in the soil was in the order of oak>deodar > pine forest.

Dhanai (2000) studied the phytosociological attributes, including associate species, quantitative and qualitative changes, successional trends, and physicochemical properties of the soil in *Quercus leucotrichophora* forests in the Garhwal Himalaya, Uttar Pradesh, India. The soil of the forest on the various aspects had a moderate pH. The maximum amount of potassium (800 kg/ha) and phosphorus (36.84 kg/ha) was observed on northeast and southwest aspects, respectively. Based on these findings, it is recommended that plantations of *Q. leucotrichophora* should be established on northeastern and southwestern aspects for optimum yield and sustainable development.

Sharma and Tripathi (2003) conducted field experiment in Himachal Pradesh, on sandy loam soils to study the effect of resource constraints, i.e. nutrient and moisture on the growth performance of *Pinus roxburghii*. The amount of available nutrients decreased with the increase in the soil depth. The study indicated that plant growth parameters were positively and significantly correlated with available N, P and Ca in surface and subsurface soil layers.

Raina and Gupta (2009) studied the soil characteristics in relation to forest vegetation and parent material in Kempty range of Mussoorie forest (Uttarakhand) and found that the organic matter and available nitrogen contents in the surface horizons increased with increase in altitude.

Singh *et al.* (2009) conducted a study in the oak and pine forest for community composition and soil characteristics along altitudinal gradients of Garhwal Himalaya. The

soil pH of oak forest was acidic while in pine forest it was slightly acidic. The soil organic carbon was higher in oak forest.

Mehraj *et al.* (2010) analysed the soils of two forest types i.e., oak (*Quercus leucotrichophora*) and pine (*Pinus roxburghii*) for physico-chemical properties and economic analysis. The collected soil samples from both the forests were analysed for texture, water holding capacity, pH, potassium, phosphorus and nitrogen. The results show that the higher percent of moisture and water holding capacity was in oak forest and lower in pine forest. The forest types indicate that the soil of oak forest was acidic and slightly acidic to pine forest. The average soil organic carbon in oak forest was 2.19% followed by 1.63% in pine. The nitrogen for oak and pine forests was 0.15 and 0.19% respectively. The available phosphorus in oak forest was higher (17.99 kg ha⁻¹) than in pine forest (16.88 kg ha⁻¹). The exchangeable potassium was 188.92 kg ha⁻¹ in oak forest and 166.43 kg ha⁻¹ in pine forest.

Aponte *et al.* (2011) sampled and chemically analysed five different ecosystem components: leaves, leaf fall, litter and superficial (0-25 cm) and sub-superficial (25-50 cm) soil beneath the canopies of evergreen *Quercus suber* and deciduous *Q. Canariensis* trees. Variability in the concentration of chemical elements was related to the nature of their biogeochemical cycles. In the studied Mediterranean forests, oak species distinctly modify soil fertility conditions through different nutrient return pathways.

Jina *et al.* (2011) studied the physicochemical properties of soil in two different forest sites (*P. roxburghii* and *Q. leucotrichophora*) which were degraded and non-degraded forests at Lamgarha block of Almora district of Kumaun Central Himalaya. Soil texture varied from loamy to sandy loam. Soil moisture ranged from (6.6-18.1%) and showed fixed seasonal pattern and maximum in rainy season (mid-September) followed by winter and summer. Water holding capacity was more or less similar in all the sites. Soil was acidic with pH ranging from 5.5-6.5 across the sites. Soil nutrient concentration also varied across the study sites.

Raina and Gupta (2013) estimated the soil fertility status of soil and sequestered organic carbon under different forest covers viz. *Cedrus deodara*, *Pinus roxburghii*, *Quercus leucotrichophora*, *Picea smithiana*, *Abies pindrow* and *Shorea robusta* and miscellaneous forest, available in Garhwal region of Uttarakhand. Soils were well enriched by primary 22 nutrients i.e., available nitrogen, phosphorous and potassium. Available nitrogen was higher

under *Picea smithiana* and *Abies pindrow* followed by *Cedrus deodara* and the least was found under miscellaneous forests. In general, nutrients were decreasing with increasing soil depth under all the forest stands.

Tiwari *et al* (2013) studied the physico-chemical properties of soils in temperate forests of the Nanda Devi Biosphere Reserve in Uttarakhand. Bulk density of the soil varied from 1.14 to 1.91 gm cm⁻³ under various soil depths ranging from 0 to 15, 15 to 30 and 30 to 45 cm. While, an average water holding capacity of soil ranged from 36.50 ± 0.52 to 67.39 ± 1.79% for 0 to 45 cm soil depth. The soil was found acidic in nature, which ranged from 5.09 ± 0.06 to 6.46 ± 0.05 for 0 to 45 cm depth. With increasing soil depths, the percentage of gravel particles (>4.75 mm) was found in ascending order under *Abies pindrow*, *Betula utilis* and *Quercus semecarpifolia* dominated forests. The least percentage of fine particles was found in *Quercus semecarpifolia* dominated forest under 30 to 45 cm soil depth. Organic carbon was observed highest (6.10 ± 0.39%) and lowest (0.52 ± 0.13%) under *Quercus semecarpifolia* and *Abies pindrow* dominated forests for 0 to 15 and 30 to 45 cm depths.

Chaturvedi and Melkania (2013) measured the soil organic carbon (SOC) stock and soil characteristics in mixed oak and mixed pine forest at different altitudes of Kumaon Himalaya. The study revealed that soil texture at selected sites varied from loam to sandy loam and soil pH ranged from slightly acidic to neutral. The SOC stock was found to be higher in mixed oak forests than mixed pine forests. The average SOC stock ranged from 110.37 to 125.03 ton/ ha at nondegraded mixed oak forest site and 43.81 to 53.47 ton/ ha at degraded mixed pine forest site, T: N and C:N ratio were also found to be higher in mixed oak forest than mixed pine forest.

Saleem and Kumar (2015) studied the species composition, distribution pattern and soil properties in the influenced zone of Srinagar hydroelectric project of Garhwal Himalayas and reported average moisture content, water holding capacity, and bulk density of zone reported 7.26 per cent, 30.26 per cent, and 1.47 g m⁻³ respectively. The average value of soil pH was 7.32 which was slightly basic, however, the average value of soil organic carbon was 0.24 per cent, which was found reducing with increasing soil depths in each site.

Schua *et al.* (2015) studied the soil chemical and microbial properties in a mixed stand of spruce and birch in the Ore Mountains, Germany. In spruce-dominated stands, single birch trees have major effects on chemical and microbial top soil properties, according to the

results of the case study. As a result, birch admixture in spruce stands can have a significant impact on nutrient cycling as well as soil carbon sequestration.

Zellweger *et al.* (2015) studied the effects of climate, topography, soil and vegetation on stand scale species richness in temperate forests. They found that, in addition to environment, site-specific habitat factors played significant role in the spatial variation of species richness at the local scale. The strength and the direction of determinants vary with taxa, therefore, indicating a functional relationship between site conditions and respective species community.

Chandra *et al.* (2016) studied the impact of forest vegetation on soil characteristics in temperate and dry deciduous forests of Nainital and Sonbhadra district of Uttarakhand and Uttar Pradesh states, respectively. They studied soil physico-chemical properties and microbial activity in five different sites located in two forest types. The results of the study revealed that bulk density, particle density and porosity were highest in dry deciduous forest, whereas the EC in these forest sites were lowest i.e., 31.33 dSm⁻³. The overall soil microbial biomass carbon (MBC), microbial biomass nitrogen (MBN), and microbial biomass phosphorous (MBP) were recorded higher in the temperate forest as compared to dry deciduous forest.

Mehta *et al.*, (2017) concluded that Ban oak forest generally had a greater moderating effect during both the season and are rich in nutrient availability as compared to chir pine and mixed forest and directly influenced the soil physico-chemical properties, nutrient cycling, microbial biomass and therefore, affects the natural regeneration process of native species. A comparison of below forest canopy and open sites was carried out for abiotic and biotic factors under five forest ecosystems (Chir Pine Forest, Mixed Forest, Ban Oak Forest, Agriculture Field and Bare Area) and analysed the physico-chemical properties of soil. The collected soil samples from the forest ecosystem were analysed for soil moisture, bulk density, pH, electrical conductivity, soil organic carbon and available NPK. The results showed that the higher percent of moisture was found in forest ecosystem as compared to open area and having difference of (8.0-15.2%) and found higher in oak forest. The forest ecosystem indicate that the soil of oak forest was slightly acidic to pine forest. The forest ecosystem wise soil organic carbon and available K status followed the order of ban oak forest > mixed forest > chir pine forest > agriculture field > bare area. However, the status of available N and P followed the order of agriculture field > ban oak forest > 3 mixed forests

>chir pine forest > bare area. Although the bulk density was observed highest in bare area (1.41 g cm) and lowest was reported 3 under ban oak forest (1.27g cm).

Pandey *et al.*, (2018) studied the physico-chemical properties of three forest types i.e., banj-oak (*Quercus leucotrichophora*) chir-pine (*Pinus roxburghii*) and sal (*Shorea robusta*) of Betalghat block, Nainital District, (Kumaun Himalaya). Banj-oak forest shows rich physical properties followed by sal and chir-pine forest while chir-pine forest shows rich chemical properties as compared to sal and banj-oak forest.

Verma and Garkoti (2019) studied the regeneration status, population structure, soil characteristics and carbon stock of regenerating banj oak (*Quercus leucotrichophora*) forests in the central Himalaya. Results revealed that soil nutrient (especially carbon and nitrogen) improved with increase in density and basal area of forests. Additionally, substantial amount of carbon stored by these trees makes them viable for the region. Thus, identification and conservation of such forests are recommended.

Nickmans (2019) concluded that litter fall and the associated nutrient return will affect available nutrients in the soil. This availability will influence the nutrient status at the local tree level. Using ion-exchange resins, they estimated resin available soil nutrients at two depths. With this method they measured the integrated nutrient availability originating from different sources. They used mixed model comparison, observing that available nutrients were only poorly related to foliar nutrient concentrations.

Marnal *et al.* (2020) conducted a study to determine how natural Banj oak, Chir pine, and mixed oak-pine forest differ in soil microbial biomass and soil nutrients. The result indicated that low microbial biomass N and P may be one of the reasons to create a nutrient poor site in Chir pine forest. The collection of pine litter by local people also impairs the return of nutrients to the soil and makes it difficult for Banj oak to re-invade areas occupied by Chir pine.

Chapter-3

MATERIALS AND METHODS

The present investigation entitled “**Ecological Status of *Ulmus wallichiana* (Planch.) in Himachal Pradesh.**” was conducted in Deptt of Tree Improvement and Genetic Resources during the year 2020-22. Field studies were conducted in *Ulmus wallichiana* bearing forests of Kullu Forest Division of Himachal Pradesh. Soil samples were analysed in the Department of Silviculture and Agroforestry, Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (HP). This chapter provides details of experimental sites, materials use, and methods adopted during the course of investigation. Sampling designs, data collection methods, and analysis methods that helped to draw necessary conclusions have been discussed as below:

3.1 Study Area

3.2 Experimental Methodology

3.3 Experimental layout and Statistical analysis

3.1 STUDY AREA

The present study was carried out in Kullu Forest Division of Himachal Pradesh situated between 76 – 59'E and 77 – 50'E longitudes and 31 -45'N and 32 – 26'N latitudes.

3.1.1 Climate

The climate is typical of the temperate zone at higher altitude, above 1000 meters and subtropical at lower elevations. Plant succession and distribution are affected by varying climatic conditions, especially temperature variations and patterns of rainfall. Generally, April to June and October to November are dry months.

3.1.2 Geology, Rock and Soil

3.1.2.1 Geology & Rock

The Kullu District forms a transitional zone between the Lesser and Greater Himalaya and is characterized by high NW-SE trending ridges and deep river valleys, a number of which in their upper reaches bear imprints of glacial activity in the near past.

The altitudes vary from 950 m to 6000 m. The area in general represents young, immature topography, controlled both by the structure and lithology of the underlying rocks. The weathering resistant rocks, like the dolomite of the Aut formation and Quartzite of the Manikaran formation, form cliffs and escarpments, while the slate, phyllite and schist of different formations form gentle to moderately steep slopes. The roughly N-S course of the Beas River between Kullu and Aut is controlled by a fault.

3.1.2.2 Soils

The Soils in the Himalaya change frequently, depending upon the underlying rocks and the effect of various agencies from time to time. The lateritic soils, rich in iron and alumina, can be found as cover over the gneissic rocks, whereas red soil forms on the granite and gneisses. The red soils are deficient, in phosphorus, lime and nitrogen. These also occur over the rocks of green Bed Formation (Basic rocks). The sandstone, siltstone, quartzite yields sandy soil, while the area underlain by limestone and shale yield loamy soil. In the valley portions, both transported as well as insitu, alluvial soils reworked by water, can be found.

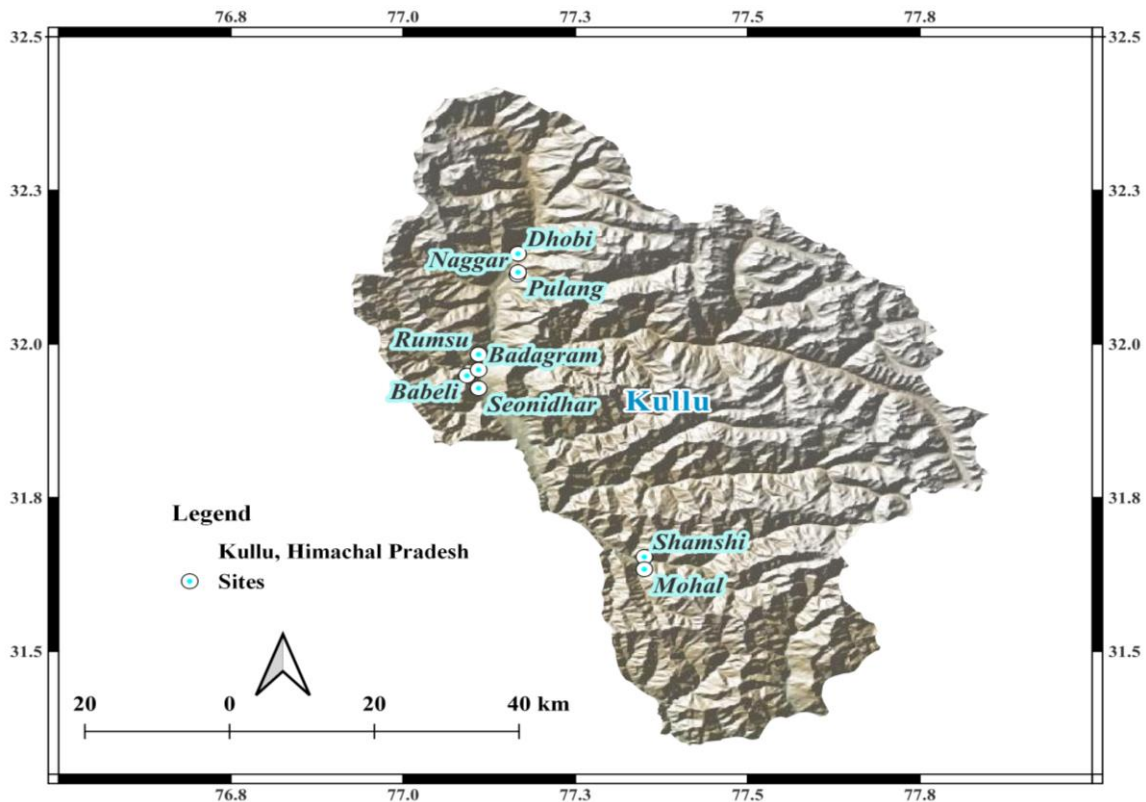


Fig 1: Map location of study area

Table 1. Selected sites in Kullu forest division of Kullu district (H.P.)

Ranges	Sites	Altitudes (m)
Kullu	Shamshi	1100-1250
	Mohal	1250-1350
	Babeli	1350-1500
Patlikuhl	Badagram	1500-1600
	Seonidhar	1600-1700
	Dhobi	1700-1800
Nagggar	Nagggar	1800-1900
	Pulang	1900-2000
	Rumsu	2000-2100

3.2 EXPERIMENTAL METHODOLOGY

The study was carried out in year 2020 to 2022 in upper Beas valley of district Kullu. Quadrats were laid out by using species area curve method. To fulfill the objectives of the study, three Ranges from Kullu Forest division were selected purposely i.e., Kullu, Patlikuhl and Nagggar. From each range three sites were selected further for carrying out survey (Table.1)

3.2.1 Sampling Procedure

The study on phytosociology of forests was carried out after laying out sample plots in each of the selected sites. The observations for tree and shrubs were recorded by laying Quadrats of size (30m × 10m). In each site having 5 quadrats were laid out in *Ulmus wallichiana* bearing area and 5 with non *Ulmus wallichiana* bearing areas.

Experiment 1: To study the ecological status of *Ulmus wallichiana* & other woody associated species.

Following observations were recorded.

1. Frequency
2. Density
3. Basal area
4. Importance value index (IVI)
5. Diversity indices
6. Similarity/ Dissimilarity Index

7. Simpson Index
8. Shannon Index
9. Equitability
10. Species Richness Index

Percent Frequency: It expresses the distribution of various species in a community. Percent frequency was calculated as follows:

$$\text{Percent frequency} = \frac{\text{Number of sampling units in which this species occurs}}{\text{Total number of units studied}} \times 100$$

Density: The term density represents the numerical strength of species in the community. It was calculated as follows:

$$\text{Density} = \frac{\text{Total no. of individual}}{\text{Total no. of quadrates studied}} \times 100$$

Mean basal area: Basal area is the area of ground penetrated by stems, and is seen when leaves and stems are clipped at ground surface (Hanson and Churchill, 1961).

$$\text{Basal area} = \pi r^2$$

For seedlings, saplings, herbs and climbers the diameter was taken with help of calipers.

Relative dominance, Relative density and Relative frequency was calculated from the basic data as given by Phillips (1959).

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

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

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

Importance value index (IVI) = It was calculated by summing up Relative dominance, Relative density and Relative frequency.

Diversity indices

a) Species Richness

The Species Richness was calculated by using the method 'Margalefs index of richness' (Dmg) (Magurran, 1988).

$$Dmg = S-1 / \ln N$$

Where, S = Total number of species

N = Total number of individuals.

Species diversity and Dominance will be evaluated by using the following methods:

Shannon's diversity index and Simpson's index of dominance was calculated by using Importance Value Index (IVI) of species.

b) Shannon-Wiener Index of diversity (\bar{H})

The index was calculated by using importance value index (IVI) of species by using formula given by Shannon-Wiener (1963).

$$H = -\sum p_i \ln p_i$$

Where,

H = Shannon Index of diversity

p_i = the proportion of important value of the i^{th} species ($p_i = n_i/N$, n_i is the importance value index of i^{th} species and N is the important value index of all the species)

c) Simpson (1949) Index of dominance

The equation used to calculate Simpson's index is

$$D = \sum (p_i)^2$$

$$p_i = n_i/N$$

Where,

D = Simpson index of dominance.

p_i = the proportion of important value of the i^{th} species ($p_i = n_i/N$, n_i is the important value index of i^{th} species and N is the important value index of all the species).

d) Equitability (e)

The Equitability was calculated by following method:

$$e = H/\ln S$$

where,

e is equitability

H is Shanon-Weiner Index and S is Total number of species

e) Similarity and dissimilarity indices

These indices were calculated using formulae as given by Mishra (1989) and Sorensen (1948).

Index of similarity (S) = $2C / A+B$

Where,

A = Number of species in community A

B = Number of species in community B

C = Number of species common in both the communities

Index of dissimilarity = $1-S$

3.2.2 Soil characteristics:

Soil characteristics of *Ulmus* growing population and non-*Ulmus* growing population were studied on the basis of samples collected from selected sites and analyzed in the laboratory. Soil sample were collected from each quadrat at two different depths (0-15 cm, 15-30 cm). These soil samples were packed in cloth bags, marked and brought to the main campus, air dried, made free from plant material and gravels, etc., passed through a sieve of 4 mm mesh and again stored in cloth bags separately. The following parameters were estimated:

1. Soil pH
2. Electrical conductivity
3. Organic carbon
4. Available nitrogen
5. Available phosphorus
6. Available potassium

3.2.2.1 Soil pH

The air-dried soil samples were dissolved in double distilled water (1:2), shaken on electric shaker for two hours, allowed to rest and pH estimated through digital pH meter (Jackson, 1973).

3.2.2.2 Electrical conductivity (EC)

EC was estimated from the supernatant liquid of the same samples used for pH estimation using conductivity bridge (Jackson, 1973).

3.2.2.3 Organic carbon (OC)

It was estimated by using Walkley and Black method.

Weighted out 2 g of soil in a 250 ml conical flask. Added to it, 10 ml of 1N $K_2Cr_2O_7$ solution and mixed. Then added 20 ml of concentrated H_2SO_4 , while swirling the flask during addition. Left the flask as such so as to cool the contents and make the reaction complete. Then added approximately 2 g of NaF powder or 10 ml of orthophosphoric acid, (both NaF and orthophosphoric acid are the flocculation agents) 100 ml of distilled water and shaken vigorously. Added 10 drops of diphenylamine indicator, which will give a violet colour to the suspension. Titrated the contents of the flask with 0.5 N ferrous ammonium sulphate solution. The end point in this titration was a change of the colour from blue violet to bright green. Noted the volume of the ferrous ammonium sulphate solution used and calculate the results. Run a blank titration also in the similar way (Walkley and Black, 1954),

3.2.2.4 Nitrogen (N)

Available nitrogen was determined through Macro Kjeldahl method (Subbiah and Asija, 1956). Air dried soil (1 g) was digested with sulphuric acid, ammonia evolved absorbed in boric acid and titrated against standard hydrochloric acid and amount of nitrogen calculated accordingly.

3.2.5.5 Phosphorus (P)

Available phosphorus was extracted by sodium bicarbonate method and determined through colorimetric method following Olsen et al. (1954) and the blue colour developed was read at 660 nm within 20 minutes on Spectronic-20 against a blank. The amount of available phosphorus was calculated from the standard curve prepared from KH_2PO_4 .

3.2.2.6 Potassium (K)

The quantitative estimations of potassium, was carried through ammonium acetate extract following Richards (1968). The leachates were diluted to desired amount and treated as stock solution. The estimations were carried out through Flame Photometer against their respective filters. Standards for K, Na and Ca were prepared from KCL, NaCl and CaCO₃, respectively.

Objective 2: Regeneration potential of *Ulmus wallichiana*

To study the regeneration status of major species, survey was carried out from rainy season onwards. Observations on regeneration were made in a recording unit (quadrat) size by species area curve method.

Recruits, un-established and established per cent regeneration:

i) The total number of recruits (r):

Which may be defined as current year seedlings.

ii) The number of un-established regeneration (μ):

Seedling other than recruits which had not established by not reaching established height of 2m. Four un-established plants were considered equivalent to one established plant.

iii) The number of established regeneration (e):

Seedlings above 2m height.

The recruits, un-established and established regeneration was computed using formulae given by Chacko (1965) as:

$$\text{Recruits (r) / ha} = \frac{2500 \times \text{total number of recruits}}{\text{Total number of recording units}}$$

$$\text{Unestablished (u)/ha} = \frac{2500 \times \text{total number of un established plants in sampling units}}{\text{Total number of recording units}}$$

$$\text{Established (e)/ ha} = \frac{2500 \times \text{total number of established plants in sampling units}}{\text{Total number of recording units}}$$

3.3. STATISTICAL ANALYSIS

Data obtained during the course of the investigation was subjected to statistical analysis as per the procedure suggested by Gomez and Gomez (1984). The least significant difference at 5 per cent level (<0.05) was used for testing the significant differences among treatments. ANOVA tables was used to detect statistically significant differences of functional attributes.

Chapter-4

RESULTS AND DISCUSSION

The results of the present investigation “**Ecological Status of *Ulmus wallichiana* Planch. in Kullu district of Himachal Pradesh**” are described in this chapter under the following heads to study the below mentioned objectives:

- 4.1 **Phytosociology of *Ulmus wallichiana* in different forest of Kullu district.**
- 4.2 **Physico-chemical properties of the soil.**
- 4.3 **Natural regeneration status of *Ulmus wallichiana* in different forest of Kullu division.**

4.1 PHYTOSOCIOLOGY

The phytosociological studies revealed the floristic composition of trees and shrubs in natural population of *Ulmus wallichiana* growing and non-*Ulmus wallichiana* growing.

The tree species observed in Shamshi, Mohal, Babeli, Badagram, Seonidhar, Dhobi, Naggar, Pulang and Rumsu in natural *Ulmus* growing population were as 8, 9, 9, 11, 10, 10, 8, 10, and 10 (Table 2), respectively. Maximum number of trees were noted in Badagram (11) followed, by Dhobi, Seonidhar, Pulang and Rumsu (10), Mohal and Babeli (9), Shamshi and Naggar (8). In non-*Ulmus* bearing natural population tree species were 7, 5, 11, 3, 4, 4, 7, 7, and 7, respectively. Among all the populations, the maximum number of trees were found in Babeli (11), followed by Shamshi, Naggar, Pulang and Rumsu (7), Mohal (5), Seonidhar and Dhobi (4) and minimum in Badagram (3).

The number of shrub species observed in Shamshi, Mohal, Babeli, Badagram, Seonidhar, Dhobi, Naggar, Pulang and Rumsu in natural *Ulmus* growing population were as 4, 4, 5, 9, 9, 11, 6, 6 and 6 (Table 3), respectively. Among all the populations, the maximum number of shrubs were found in Dhobi (11), followed by Badagram and Seonidhar (9), Naggar, Pulang and Rumsu (6), Babeli (5) and minimum in Shamshi and Mohal (4). In non-*Ulmus* growing population, shrubs species observed were 4, 4, 5, 5, 5, 5, 6, 6 and 6. Among all the population maximum number of species were observed in Naggar, Pulang and Rumsu (6), Babeli, Badagram, Seonidhar and Dhobi (5) and minimum in Shamshi and Mohal (4).

Table 2: Floristic composition of trees in natural population of *Ulmus wallichiana* and non- *Ulmus wallichiana* growing population

Sr.No.	Species	KULLU						PATLIKUHL						NAGGAR					
		Shamshi		Mohal		Babeli		Badagram		Seonidhar		Dhobi		Naggar		Pulang		Rumsu	
		UP	UA	UP	UA	UP	UA	UP	UA	UP	UA	UP	UA	UP	UA	UP	UA	UP	UA
2	<i>Abies pindrow</i>	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
1	<i>Aesculus indica</i>	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
8	<i>Ailanthus altissima</i>	-	+	-	+	-	-	-	-	-	-	+	-	-	+	-	+	-	+
4	<i>Alnus nepalensis</i>	-	-	-	-	-	-	+	-	+	-	+	-	-	-	+	-	+	-
3	<i>Betula alnoides</i>	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
5	<i>Cedrus deodara</i>	-	-	+	-	-	+	+	+	+	+	+	+	-	-	+	-	+	-
6	<i>Celtis australis</i>	+	+	+	+	+	+	-	-	-	-	-	-	+	-	-	-	-	-
9	<i>Eucalyptus globulus</i>	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
10	<i>Ficus palmata</i>	+	-	+	+	+	+	+	-	+	+	-	-	+	+	+	+	+	+
11	<i>Jacaranda mimosifolia</i>	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
12	<i>Juglans regia</i>	-	-	+	-	-	-	+	-	+	-	+	-	+	-	+	-	+	-
13	<i>Melia azedarach</i>	+	+	+	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-
14	<i>Melia composita</i>	-	-	-	-	-	-	+	-	+	-	+	-	-	+	+	+	+	+
7	<i>Morus alba</i>	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	<i>Morus serrata</i>	+	+	-	-	+	+	+	-	+	-	+	-	-	-	+	-	+	-
16	<i>Picea smithiana</i>	-	-	-	-	-	-	+	-	+	-	+	-	-	-	+	-	+	-
17	<i>Pinus wallichiana</i>	-	-	-	-	-	-	+	+	+	+	+	+	+	-	+	-	+	-
18	<i>Pistacia integerrima</i>	+	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-
19	<i>Platanus orientalis</i>	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
20	<i>Populus ciliate</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+	-	+
21	<i>Populus deltoides</i>	-	+	+	+	-	-	+	+	-	+	-	+	-	+	-	+	-	+
22	<i>Populus nigra</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+	-	+
23	<i>Pyrus pashia</i>	+	+	-	-	-	-	-	-	-	-	-	-	-	+	-	+	-	+
24	<i>Robinia pseudocacia</i>	-	-	+	+	+	+	-	-	-	-	-	-	+	-	-	-	-	-
25	<i>Sapindus mukorosii</i>	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
26	<i>Sterculia urens</i>	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-
27	<i>Toona serrata</i>	-	-	-	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-
28	<i>Ulmus wallichiana</i>	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-
	Total	8	7	9	5	9	11	11	3	10	4	10	4	8	7	10	7	10	7

Where - U P- *Ulmus wallichiana* present, U A- *Ulmus wallichiana* absent

Table 3: Floristic composition of shrubs in natural population of *Ulmus wallichiana* and non- *Ulmus wallichiana* growing population

Sr. No.	Species	KULLU						PATLIKUHL						NAGGAR					
		Shamshi		Badagram		Seonidhar		Badagram		Seonidhar		Dhobi		Naggar		Pulang		Rumsu	
		UP	UA	UP	UA	UP	UA	UP	UA	UP	UA	UP	UA	UP	UA	UP	UA	UP	UA
3	<i>Berberis lycium</i>	-	-	+	+	+	+	+	-	-	-	+	-	-	-	-	-	-	-
4	<i>Bochmeria mivea</i>	-	-	-	-	-	-	+	-	+	+	+	+	-	-	-	-	-	-
5	<i>Daphne cannabina</i>	-	-	-	-	-	-	+	-	-	-	+	-	+	-	+	-	+	-
6	<i>Debregeasia hypoleuca</i>	-	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
2	<i>Indigofera heterantha</i>	+	+	-	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+
8	<i>Prinsepia utilis</i>	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
9	<i>Rosa macrophylla</i>	-	-	-	-	-	+	-	-	-	-	-	-	-	+	-	+	-	+
10	<i>Rosa moschata</i>	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
11	<i>Rubus ellipticus</i>	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
1	<i>Rubus niveus</i>	-	-	-	-	-	-	-	-	+	-	+	-	-	-	-	-	-	-
7	<i>Sarcococca saligna</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+	-	+
12	<i>Skimmia laureola</i>	-	-	-	-	-	-	+	-	+	-	+	-	-	-	-	-	-	-
13	<i>Strobilanthes glutinosus</i>	-	-	-	-	-	-	+	-	+	-	+	-	-	-	-	-	-	-
14	<i>Zanthoxylum armatum</i>	-	-	-	-	-	-	-	+	-	-	-	-	+	-	+	-	+	-
15	<i>Zizyphus jujuba</i>	-	-	-	-	-	-	-	-	+	-	+	-	-	-	-	-	-	-
	Total	4	4	4	4	5	5	9	5	9	5	11	5	6	6	6	6	6	6

Where - U P- *Ulmus wallichiana* present, U A- *Ulmus wallichiana* absent

4.1.1 Phytosociology studies

4.1.1.1 Shamshi

Total 8 species of trees were observed in *Ulmus* growing population (Table 4). The dominating species in this area was *Ulmus wallichiana* (89.08), followed by *Morus alba* (61.43), and least dominating was *Morus serrata* with IVI of 10.95.

In non- *Ulmus* growing population 7 species of trees were recorded. *Ailanthus altissima* was the dominating species reported with IVI (125.61), followed by *Morus alba* (83.32) and *Celtis australis* (32.74). The least dominating species was *Melia azedarach* with IVI 8.37. There were 6 species of shrubs observed in *Ulmus* growing population (Table 5). The dominating species found was *Prinsepia utilis* (82.63). followed by *Rosa moschata* (75.84), *Rubus ellipticus* (57.79), associated species were *Zizyphus jujuba* and *Rosa macrophylla*, whereas the least dominating species was *Indigofera heterantha* (17.59). Four species of shrubs were recorded in non-*Ulmus* growing population. The dominating species was *Prinsepia utilis* (126.28), followed by *Debregeasia hypoleuca* (103.45). The least dominating species in this population was reported as *Rosa moschata* with IVI (27.93). Observations recorded in terms of total shrub density were in conformation with Rana et al. (2015) who reported that shrub density ranged from 4-46 in Central Himalayan Cypress Forest. Kumar and Sharma (2016) also reported the relative density and relative basal area. The structural characteristics like density and basal area showed a marked variation among different sites.

Table 4. Relative density, relative frequency, relative basal area and IVI of tree species in Shamshi (Kullu)

Tree species	Relative density		Relative frequency		Relative basal area		IVI	
	U P	U A	U P	U A	U P	U A	U P	U A
<i>Ailanthus altissima</i>	-	50	-	21.42	-	54.18	-	125.61
<i>Celtis Australis</i>	2	4.46	6.25	21.42	2.95	6.85	11.24	32.74
<i>Ficus palmata</i>	4	-	12.5	-	4.12	-	20.62	-
<i>Melia azedarach</i>	10	0.89	12.5	7.14	15.01	0.34	37.51	8.37
<i>Morus alba</i>	46	33.92	12.5	21.42	2.93	27.96	61.43	83.32
<i>Morus serrata</i>	2	0.89	6.25	7.14	2.74	0.65	10.95	8.68
<i>Pistacia integerrima</i>	4	-	6.25	-	8.57	-	18.82	-
<i>Populus deltoides</i>	-	1.78	-	7.18	-	2.38	-	11.36
<i>Pyrus pashia</i>	14	8.06	12.5	14.28	23.85	7.64	50.35	29.92
<i>Ulmus wallichiana</i>	18	-	31.25	-	39.83	-	89.08	-

Table 5. Relative density, relative frequency, relative basal area and IVI of shrub species in Shamshi (Kullu)

Shrubs species	Relative density		Relative frequency		Relative basal area		IVI	
	U P	U A	U P	U A	U P	U A	U P	U A
<i>Debregeasia hypoleuca</i>	-	44.11	-	16.66	-	42.67	-	103.45
<i>Indigofera heterantha</i>	1.68	14.72	15.38	16.66	0.53	10.96	17.59	42.34
<i>Prinsepia utilis</i>	20.16	32.35	30.79	50	31.69	43.93	82.63	126.28
<i>Rosa macrophylla</i>	12.62	-	7.69	-	9.11	-	29.4	-
<i>Rosa moschata</i>	28.57	8.82	23.07	16.68	24.15	2.44	75.84	27.93
<i>Rubus ellipticus</i>	26.89	-	7.69	-	23.24	-	57.79	-
<i>Zizyphus jujuba</i>	10.08	-	15.38	-	11.28	-	36.75	-

Where - U P – *Ulmus wallichiana* present, U A - *Ulmus wallichiana* absent

4.1.1.2 Mohal

There were 9 species of trees observed in *Ulmus* growing population (Table 6). The most dominating species found was *Robenia pseudocacia* (74.94), codominant species were *Ulmus wallichiana* (73.69) and *Populus deltoides* (70.24), associated species were *Celtis australis*, *Ficus palmata*, *Plantanus orientalis*, *Junglans regia*, and *Pyrus pashia*. The least dominating species was *Melia azedarach* (6.52). There were 5 species of trees recorded in non-*Ulmus* growing population. The dominating species was *Pyrus pashia* (119.72), codominating species was *Populus deltoides* (107.33), and least dominating species reported was *Melia azedarach* (9.54). Four species of shrubs were recorded in *Ulmus* growing population.

Table 6. Relative density, relative frequency, relative basal area and IVI of tree species in Mohal (Kullu)

Tree species	Relative density		Relative frequency		Relative basal area		IVI	
	U P	U A	U P	U A	U P	U A	U P	U A
<i>Ailanthus altissima</i>	-	13.59	-	13.33	-	15.25	-	42.17
<i>Cedrus deodara</i>	1.28	-	4.54	-	1.23	-	7.06	-
<i>Celtis australis</i>	10.25	4.86	9.09	13.33	7.51	3.05	26.86	21.24
<i>Ficus palmata</i>	7.69	-	9.09	-	5.64	-	22.43	-
<i>Junglans regia</i>	2.56	-	4.54	-	1.26	-	8.37	-
<i>Melia azedarach</i>	1.28	0.97	4.54	6.66	0.69	1.9	6.52	9.54
<i>Platanus orientalis</i>	2.56	-	4.54	-	2.78	-	9.89	-
<i>Populus deltoides</i>	25.64	34.95	22.72	33.35	21.87	39.05	70.24	107.33
<i>Pyrus pashia</i>	-	45.63	-	33.33	-	40.75	-	119.72
<i>Robenia pseudocacia</i>	32.05	-	18.18	-	24.66	-	74.94	-
<i>Ulmus wallichiana</i>	16.69	-	22.76	-	34.36	-	73.69	-

The dominating species observed was *Rosa moschata* (174.33), whereas least dominating species was *Berberis lycium* with IVI of (19.87). Four species of shrubs were observed in non-*Ulmus* growing population (Table 7). The maximum dominance was shown by *Prinsepia utilis* with IVI of (117.13), and the least dominance was depicted by *Berberis lycium* (22.73). The range of density values of shrubs were reported similar as reported by finding of Verma (2016).

Table 7. Relative density, relative frequency, relative basal area and IVI of shrub species in Mohal (Kullu)

Shrubs species	Relaive density		Relative frequency		Relative basal area		IVI	
	U P	U A	U P	U A	U P	U A	U P	U A
<i>Berberis lycium</i>	2.43	6.17	16.66	11.11	0.78	5.44	19.87	22.73
<i>Prinsepia utilis</i>	12.04	40.74	41.66	33.33	12.56	43.06	66.27	117.13
<i>Rosa morchata</i>	67.46	34.56	33.33	44.44	73.53	30.39	174.33	109.40
<i>Rubus ellipticus</i>	18.07	18.53	8.35	11.12	13.13	21.11	39.53	50.74

Where - U P – *Ulmus wallichiana* present, U A - *Ulmus wallichiana* absent

4.1.1.3 Babeli

There were 9 species of trees observed in *Ulmus* growing population (Table 8). The most dominating species was *Ulmus wallichiana* (145.74), codominant species were *Robenia pseudocacia* (33.62), *Celtis australis* (27.43), associated species were *Melia azedarach*, *Ficus palmata*, *Eucalyptus spp.*, *Pistacia integerrima* and *Toona serrata*. The least dominating species was *Morus serrata* (10.4). There were 11 species of trees recorded in non-*Ulmus* growing population. The dominating species was *Melia azedarach* (67.18), codominating species was *Robenia pseudocacia* (61.08), and least dominating species reported was *Betula alnoides* (8.33). There were 4 species of shrubs observed in *Ulmus* growing population (Table 9). The dominating species found was *Rosa moschata* (178.68), whereas the least dominating species was *Prinsepia utilis* (17.65). Five species of shrubs were recorded in non-*Ulmus* growing population (Table 9). The dominating species was *Rosa moschata* (110.59), followed by *Rosa macrophylla* (78.83). The least dominating species in this population was *Prinsepia utilis* (16.78).

Comparable values of tree relative density 1.88-50.3 in temperate forests of Himalaya have been reported by Sharma *et al.* (2001) in Pauri Garhwal Himalaya. Gairola *et al.* (2011a) in moist temperate forests of Garhwal Himalayas also reported 493 stems ha⁻¹.

Table 8. Relative density, relative frequency, relative basal area and IVI of tree species in Babeli (Kullu)

Tree species	Relative density		Relative frequency		Relative basal area		IVI	
	U P	U A	U P	U A	U P	U A	U P	U A
<i>Aesculus indica</i>	-	7.54	-	5	-	17.35	-	29.9
<i>Betula alnoides</i>	-	1.88	-	5	-	1.44	-	8.33
<i>Cedrus deodara</i>	-	11.38	-	5	-	11.67	-	27.99
<i>Celtis australis</i>	10	3.77	11.11	5	6.31	4.36	27.43	13.13
<i>Eucalyptus globulus</i>	6.66	-	5.55	-	5.83	-	18.05	-
<i>Ficus palmata</i>	6.66	9.43	11.11	10	3.23	7.75	21.01	27.19
<i>Jacaranda mimosifolia</i>	-	3.77	-	5	-	3.88	-	12.65
<i>Melia azedarach</i>	6.66	30.18	11.11	20	4.55	16.99	22.33	67.18
<i>Morus serrata</i>	3.33	1.88	5.55	5	1.57	2.01	10.4	8.96
<i>Pistacia integerrima</i>	3.33	7.54	5.55	15	2.03	6.78	10.96	29.32
<i>Robenia pseudocacia</i>	10	18.86	16.66	20	6.95	22.21	33.62	61.08
<i>Sapindus mukorosii</i>	-	3.77	-	5	-	5.56	-	14.27
<i>Toona serrata</i>	3.33	-	5.59	-	1.57	-	10.46	-
<i>Ulmus wallichiana</i>	50.03	-	27.77	-	67.96	-	145.74	-

Table 9. Relative density, relative frequency, relative basal area and IVI of shrub species in Babeli (Kullu)

Shrubs species	Relative density		Relative frequency		Relative basal area		IVI	
	U P	U A	U P	U A	U P	U A	U P	U A
<i>Berberis lycium</i>	3.86	7.83	28.59	7.14	1.55	6.88	33.97	21.84
<i>Debregeasia hypoleuca</i>	28.84	-	14.28	-	26.57	-	69.7	-
<i>Prinsepia utilis</i>	1.92	1.56	14.28	14.28	1.44	0.95	17.65	16.78
<i>Rosa macrophylla</i>	-	23.43	-	28.57	-	26.8	-	78.83
<i>Rosa moschata</i>	65.38	43.75	42.85	28.57	70.44	38.57	178.68	110.89
<i>Rubus ellipticus</i>	-	23.43	-	21.44	-	26.8	-	71.66

Where - U P – *Ulmus wallichiana* present, U A - *Ulmus wallichiana* absent

4.1.1.4 Badagram

There were 12 species of trees observed in *Ulmus* growing population (Table 10). The most dominating species observed was *Ulmus wallichiana* (55.92), codominant species were *Pinus wallichiana* (40.09), *Robenia pseudocacia* (29.76), associated species were *Morus serrata*, *Ficus palmata*, *Melia composita*, *Junglans regia* and *Alnus nepalensis*. The least dominating species was *Cedrus deodara* (15.36). There were 4 species of trees recorded in non-*Ulmus* growing population. The dominating species was *Pinus wallichiana* (145.96), codominating species was *Cedrus deodara* (108.43), and least dominating species reported was *Ficus palmata* (14.32). Nine species of shrubs were recorded in *Ulmus* growing population (Table 11). The most dominating species observed was *Prinsepia utilis* (73.63), whereas least dominating species was *Daphne cannabina* with IVI of 12.25. Five species of shrubs were observed in non-*Ulmus* growing population. The maximum dominance was shown by *Indigofera heterantha* with IVI of 95.69, and the least dominance was depicted by *Rubus ellipticus* (12.45).

Table 10. Relative density, relative frequency, relative basal area and IVI of tree species in Badagram

Tree species	Relative density		Relative frequency		Relative basal area		IVI	
	U P	U A	U P	U A	U P	U A	U P	U A
<i>Alnus nepalensis</i>	7.14	-	4.54	-	4.12	-	15.81	-
<i>Cedrus deodara</i>	7.14	21.92	9.09	55.55	7.42	30.93	23.66	108.43
<i>Ficus palmata</i>	5.71	0.87	13.63	11.11	7.56	2.33	26.91	14.32
<i>Junglans regia</i>	11.42	-	4.54	-	7.96	-	23.93	-
<i>Melia composita</i>	5.71	-	4.54	-	5.76	-	16.07	-
<i>Morus serrata</i>	8.57	-	4.54	-	7.96	-	21.08	-
<i>Picea smithiana</i>	5.77	-	4.54	-	2.74	-	13	-
<i>Pinus wallichiana</i>	11.42	68.44	13.69	22.22	15.02	55.33	40.09	145.96
<i>Populus ciliate</i>	5.71	-	4.54	-	5.17	-	15.36	-
<i>Populus deltoides</i>	-	8.77	-	11.12	-	11.41	-	31.29
<i>Robenia pseudocacia</i>	14.28	-	4.54	-	10.93	-	29.76	-
<i>Toona serrata</i>	5.71	-	9.09	-	3.6	-	18.41	-
<i>Ulmus wallichiana</i>	11.42	-	22.72	-	21.76	-	55.92	-

Table 11. Relative density, relative frequency, relative basal area and IVI of shrub species in Badagram

Shrubs species	Relative density		Relative frequency		Relative basal area		IVI	
	U P	U A	U P	U A	U P	U A	U P	U A
<i>Berberis lycium</i>	1.84	-	9.09	-	1.75	-	12.69	-
<i>Bochmeria nivea</i>	5.23	-	4.54	-	4.61	-	14.38	-
<i>Daphne cannabina</i>	2.15	-	9.09	-	1.0	-	12.25	-
<i>Indigofera heterantha</i>	4.92	32.65	13.63	40.0	1.25	23.04	19.81	95.69
<i>Prinsepia utilis</i>	25.53	26.53	22.72	30.0	25.37	27.59	73.63	84.12
<i>Rosa moschata</i>	17.84	36.73	22.72	10.0	8.71	48.17	49.29	94.91
<i>Rubus ellipticus</i>	21.84	2.04	9.09	10.0	35.79	0.41	66.73	12.45
<i>Skimmia laureola</i>	12.92	-	4.54	-	16.79	-	34.26	-
<i>Strobilanthes glutinosus</i>	7.69	-	4.54	-	4.68	-	16.92	-
<i>Zanthoxylum armatum</i>	-	2.04	-	10.0	-	0.76	-	12.8

Where - U P – *Ulmus wallichiana* present, U A - *Ulmus wallichiana* absent

4.1.1.5 Seonidhar

There were 11 species of trees observed in *Ulmus* growing population (Table 12). The most dominating species found was *Ulmus wallichiana* (54.67), codominant species were *Pinus wallichiana* (43.58), *Robenia pseudocacia* (30.21), associated species were *Morus serrata*, *Ficus palmata*, *Melia composita*, *Junglans regia* and *Cedrus deodara*. The least dominating species was *Alnus nepalensis* (15.69). There were 4 species of trees recorded in non-*Ulmus* growing population. The dominating species was *Cedrus deodara* (106.57), codominating species was *Pinus wallichiana* (75.19), and least dominating species reported

was *Ficus palmata* (46.47). Nine species of shrubs were recorded in *Ulmus* growing population (Table 13). The dominating species observed was *Prinsepia utilis* (62.97), whereas least dominating species was *Rubus niveus* with IVI of 5.82. Five species of shrubs were observed in non-*Ulmus* growing population. The maximum dominance was shown by *Indigofera heterantha* with IVI of 91.12 and the least dominance was depicted by *Rubus ellipticus* (23.24).

Table 12. Relative density, relative frequency, relative basal area and IVI of tree species in Seonidhar

Tree species	Relative density		Relative frequency		Relative basal area		IVI	
	UP	UA	UP	UA	UP	UA	UP	UA
<i>Alnus nepalensis</i>	7.35	-	4	-	4.34	-	15.69	-
<i>Cedrus deodara</i>	7.35	36.73	8	33.33	7.81	36.52	23.16	106.57
<i>Ficus palmata</i>	8.82	10.22	12	25	8.08	11.24	28.91	46.47
<i>Junglans regia</i>	11.76	-	4	-	8.38	-	24.14	-
<i>Melia composita</i>	5.88	-	8	-	6.06	-	19.94	-
<i>Morus serrata</i>	8.82	-	4	-	8.38	-	21.25	-
<i>Picea smithiana</i>	5.88	-	8	-	2.89	-	16.77	-
<i>Pinus wallichiana</i>	11.76	33.67	16	16.67	15.87	24.85	43.58	75.19
<i>Populus deltoides</i>	-	19.38	-	25	-	27.39	-	71.77
<i>Robenia pseudocacia</i>	14.74	-	4	-	11.5	-	30.21	-
<i>Toona serrata</i>	5.88	-	12	-	3.79	-	21.68	-
<i>Ulmus wallichiana</i>	11.76	-	20	-	22.9	-	54.67	-

Table 13. Relative density, relative frequency, relative basal area and IVI of shrub species in Seonidhar

Shrubs species	Relative density		Relative frequency		Relative basal area		IVI	
	UP	UA	UP	UA	UP	UA	UP	UA
<i>Bochmeria nivea</i>	7.29	17.85	11.53	15.38	7.54	14.96	26.37	48.2
<i>Indigofera heterantha</i>	14.23	35.71	19.23	23.07	19.54	32.33	53.01	91.12
<i>Prinsepia utilis</i>	22.91	21.42	19.23	23.07	20.82	25.73	62.97	70.23
<i>Rosa moschata</i>	21.52	21.42	19.23	23.07	14.38	22.68	55.14	67.18
<i>Rubus ellipticus</i>	20.83	3.57	7.69	15.38	25.2	4.28	53.73	23.24
<i>Rubus niveus</i>	1.38	-	3.84	-	0.58	-	5.82	-
<i>Skimmia laureola</i>	4.16	-	7.69	-	5.72	-	17.57	-
<i>Strobilanthes glutinosus</i>	3.47	-	3.84	-	3.32	-	10.64	-
<i>Zizyphus jujuba</i>	4.16	-	7.69	-	2.85	-	14.71	-

4.1.1.6 Dhobi

There were 11 species of trees observed in *Ulmus* growing population (Table 14). The most dominating species found was *Pinus wallichiana* (56.75), codominant species were *Ulmus wallichiana* (43.69), *Cedrus deodara* (42.01), associated species were *Morus serrata*, *Toona serrata*, *Melia composita*, *Junglans regia* and *Ailanthus altissima*. The least

dominating species was *Picea smithiana* (13.7). There were 4 species of trees recorded in non-*Ulmus* growing population. The dominating species was *Cedrus deodara* (107.04), codominating species was *Pinus wallichiana* (76.11), and least dominating species reported was *Populus deltoides* (57.91). Nine species of shrubs were recorded in *Ulmus* growing population (Table 15). The dominating species observed was *Prinsepia utilis* (91.76), whereas least dominating species was *Zizyphus jujuba* with IVI of 11.5. Four species of shrubs were observed in non-*Ulmus* growing population. The maximum dominance was shown by *Indigofera heterantha* with IVI of (97.99) and the least dominance was depicted by *Rosa moschata* (53.41).

Table 14. Relative density, relative frequency, relative basal area and IVI of tree species in Dhobi

Tree Species	Relative density		Relative frequency		Relative basal area		IVI	
	U P	U A	U P	U A	U P	U A	U P	U A
<i>Abies pindrow</i>	-	14.94	-	27.27	-	16.73	-	58.94
<i>Ailanthus altissima</i>	4.65	-	8.0	-	5.26	-	17.91	-
<i>Alnus nepalensis</i>	4.65	-	8.0	-	4.24	-	16.89	-
<i>Cedrus deodara</i>	16.27	35.64	8.0	27.27	17.73	44.13	42.01	107.04
<i>Junglans regia</i>	20.93	-	4.0	-	11.44	-	36.37	-
<i>Melia composita</i>	8.13	-	8.0	-	9.81	-	25.95	-
<i>Morus serrata</i>	1.16	-	4.0	-	0.64	-	5.87	-
<i>Picea smithiana</i>	3.48	-	8.0	-	2.27	-	13.7	-
<i>Pinus wallichiana</i>	16.27	29.88	20.0	18.19	20.47	28.05	56.75	76.11
<i>Populus deltoides</i>	-	19.54	-	27.27	-	11.09	-	57.91
<i>Robenia pseudocacia</i>	9.35	-	4.0	-	8.54	-	21.84	-
<i>Toona serrata</i>	5.81	-	8.0	-	5.21	-	19.02	-
<i>Ulmus wallichiana</i>	9.3	-	20.0	-	14.39	-	43.69	-

Table 15. Relative density, relative frequency, relative basal area and IVI of shrub species in Dhobi

Shrubs species	Relative density		Relative frequency		Relative basal area		IVI	
	U P	U A	U P	U A	U P	U A	U P	U A
<i>Berberis lycium</i>	3.38	-	6.89	-	1.96	-	12.24	-
<i>Bochmeria mivea</i>	6.76	18.46	6.89	14.28	6.98	27.83	20.64	60.58
<i>Daphne cannabina</i>	3.38	-	6.89	-	3.46	-	13.74	-
<i>Indigofera heterantha</i>	3.07	32.3	6.89	28.57	1.74	37.11	11.64	97.99
<i>Prinsepia utilis</i>	36.84	21.53	17.24	21.42	37.67	20.62	91.76	63.59
<i>Rosa moschata</i>	17.29	21.53	17.24	21.42	23.3	10.44	57.84	53.41
<i>Rubus ellipticus</i>	5.63	6.15	10.34	14.28	2.45	3.96	18.44	24.4
<i>Rubus niveus</i>	2.63	-	6.89	-	2.08	-	11.6	-
<i>Skimmia laureola</i>	9.77	-	6.89	-	8.4	-	25.07	-
<i>Strobilanthes glutinosus</i>	7.89	-	6.89	-	10.69	-	25.48	-
<i>Zizyphus jujuba</i>	3.38	-	6.89	-	1.22	-	11.5	-

Where - U P – *Ulmus wallichiana* present, U A - *Ulmus wallichiana* absent

4.1.1.7 Naggar

There were 8 species of trees observed in *Ulmus* growing population (Table 16). The most dominating species found was *Ulmus wallichiana* (89.14), codominant species were *Robinia pseudocacia* (66.95), *Juglans regia* (37.39), associated species were *Celtis australis*, *Toona serrata*, *Pinus wallichiana*, *Juglans regia* and *Sterculia urens*. The least dominating species was *Ficus palmata* (12.43). There were 7 species of trees recorded in non-*Ulmus* growing population. The dominating species was *Populus nigra* (67.87), codominant species was *Populus deltoides* (67.76), and least dominating species reported was *Melia composita* (15.11). Six species of shrubs were recorded in *Ulmus* growing population (Table 17).

Table 16. Relative density, relative frequency, relative basal area and IVI of tree species in Naggar

Tree species	Relative density		Relative frequency		Relative basal area		IVI	
	U P	U A	U P	U A	U P	U A	U P	U A
<i>Ailanthus altissima</i>	-	17.94	-	10.0	-	26.33	-	54.28
<i>Celtis australis</i>	4.87	-	6.66	-	3.65	-	15.2	-
<i>Ficus palmata</i>	2.43	5.12	6.66	10.0	3.32	6.65	12.43	21.78
<i>Juglans regia</i>	14.63	-	6.66	-	16.09	-	37.39	-
<i>Melia composita</i>	-	2.56	-	10.0	-	2.54	-	15.11
<i>Pinus wallichiana</i>	12.19	-	13.33	-	9.4	-	34.93	-
<i>Populus ciliata</i>	-	12.82	-	20.0	-	9.13	-	41.95
<i>Populus deltoides</i>	-	23.07	-	20.0	-	24.68	-	67.76
<i>Populus nigra</i>	-	25.64	-	20.0	-	22.23	-	67.87
<i>Pyrus pashia</i>	-	12.82	-	10.0	-	8.44	-	31.25
<i>Robinia pseudocacia</i>	31.75	-	13.37	-	21.96	-	66.95	-
<i>Sterculia urens</i>	4.87	-	6.66	-	5.09	-	16.64	-
<i>Toona serrata</i>	7.31	-	13.33	-	6.67	-	27.32	-
<i>Ulmus wallichiana</i>	21.95	-	33.33	-	33.82	-	89.14	-

Table 17. Relative density, relative frequency, relative basal area and IVI of shrub species in Naggar

Shrub species	Relative density		Relative frequency		Relative basal area		IVI	
	U P	U A	U P	U A	U P	U A	U P	U A
<i>Daphne cannabina</i>	12.82	-	7.69	-	18.94	-	39.45	-
<i>Indigofera heterantha</i>	36.75	27.65	30.76	18.18	19.23	28.9	86.75	74.74
<i>Prinsepia utilis</i>	41.02	31.91	30.76	18.18	46.87	43.95	118.66	94.05
<i>Rosa macrophylla</i>	-	6.38	-	9.09	-	3.78	-	19.25
<i>Rosa moschata</i>	5.12	21.27	7.69	27.27	7.57	17.19	20.39	65.74
<i>Rubus ellipticus</i>	0.85	10.63	7.69	18.18	0.71	3.93	9.26	32.75
<i>Sarcococca saligna</i>	-	2.12	-	9.09	-	2.22	-	13.44
<i>Zanthoxylum armatum</i>	3.41	-	15.38	-	6.65	-	25.45	-

Where - U P – *Ulmus wallichiana* present, U A - *Ulmus wallichiana* absent

The dominating species observed was *Prinsepia utilis* (118.66), whereas least dominating species was *Rubus ellipticus* with IVI of 20.39. Six species of shrubs were observed in non-*Ulmus* growing population. The maximum dominance was shown by *Prinsepia utilis* with IVI of (94.05) and the least dominance was depicted by *Sarcococca saligna* (13.44). Similar species were recorded by Sunil (2015) in Kerala and Sharma et al. (2014) in Sangla valley, Northwest Himalaya.

4.1.1.8 Pulang

There were 10 species of trees observed in *Ulmus* growing population (Table 18). The most dominating species found was *Cedrus deodara* (50.24), codominant species were *Ulmus wallichiana* (45.3), *Pinus wallichiana* (39.86), associated species were *Ailanthus altissima*, *Toona serrata*, *Ficus palmata*, *Juglans regia* and *Morus serrata*. The least dominating species was *Alnus nepalensis* (17.16). There were 7 species of trees recorded in non-*Ulmus* growing population. The dominating species was *Populus nigra* (58.85), codominating species was *Pyrus pashia* (54.45) and least dominating species reported was *Ailanthus altissima* (27.09). Six species of shrubs were recorded in *Ulmus* growing population (Table 19). The dominating species observed was *Prinsepia utilis* (117.17), whereas least dominating species was *Indigofera heterantha* with IVI of (68.92). Six species of shrubs were observed in non-*Ulmus* growing population. The maximum dominance was shown by *Rosa moschata* with IVI of (80.4) and the least dominance was depicted by *Rosa macrophylla* (31.21).

Table 18. Relative density, relative frequency, relative basal area and IVI of tree species in Pulang

Tree species	Relative density		Relative frequency		Relative basal area		IVI	
	U P	U A	U P	U A	U P	U A	U P	U A
<i>Ailanthus altissima</i>	-	8.64	-	5.26	-	13.18	-	27.09
<i>Alnus nepalensis</i>	5.68	-	8.57	-	2.9	-	17.16	-
<i>Cedrus deodara</i>	19.31	-	11.42	-	19.49	-	50.24	-
<i>Ficus palmata</i>	7.95	13.58	8.57	15.78	7.86	16.82	24.33	46.19
<i>Juglans regia</i>	13.63	-	8.57	-	10.82	-	33.03	-
<i>Melia composita</i>	6.81	9.87	5.71	10.56	8.38	6.71	20.91	27.11
<i>Morus serrata</i>	6.81	-	8.57	-	7.09	-	22.48	-
<i>Picea smithiana</i>	5.68	-	8.57	-	5.29	-	19.54	-
<i>Pinus wallichiana</i>	14.77	-	14.28	-	10.8	-	39.86	-
<i>Populus ciliate</i>	-	16.04	-	21.05	-	16.44	-	53.54
<i>Populus deltoides</i>	-	11.14	-	10.52	-	11.13	-	32.77
<i>Populus nigra</i>	-	19.75	-	21.05	-	18.05	-	58.85
<i>Pyrus pashia</i>	-	20.98	-	15.78	-	17.67	-	54.45
<i>Toona serrata</i>	9.09	-	11.46	-	6.58	-	27.15	-
<i>Ulmus wallichiana</i>	10.27	-	14.28	-	20.79	-	45.3	-

Singh et al. (2016) reported that the value of basal area ranges from 2.2-87.07 m² /ha. It was also observed that diversity and density of trees and shrubs decreased with the increase in basal area at the sites, which are dominated by conifers. Similar trend has been observed by Hara et al. (1997) in Taiwan, Chauhan et al. (2001) and Singh and Kaushal (2006) in India.

Table 19. Relative density, relative frequency, relative basal area and IVI of shrub species in Pulang

Shrub species	Relative density		Relative frequency		Relative basal area		IVI	
	U P	U A	U P	U A	U P	U A	U P	U A
<i>Daphne cannabina</i>	18.79	-	28.57	-	7.01	-	54.38	-
<i>Indigofera heterantha</i>	32.33	17.14	7.14	17.64	29.44	6.54	68.92	41.33
<i>Prinsepia utilis</i>	36.09	17.14	28.57	17.64	52.5	24.42	117.17	59.21
<i>Rosa macrophylla</i>	-	11.42	-	11.76	-	8.01	-	31.21
<i>Rosa moschata</i>	4.51	22.85	7.14	23.52	3.22	34.01	14.88	80.4
<i>Rubus ellipticus</i>	5.26	20.0	14.28	17.64	3.61	18.63	23.15	56.27
<i>Sarcococca saligna</i>	-	11.42	-	11.76	-	8.36	-	31.55
<i>Zanthoxylum armatum</i>	3.0	-	14.28	-	4.19	-	21.48	-

Where - U P – *Ulmus wallichiana* present, U A - *Ulmus wallichiana* absent

4.1.1.9 Rumsu

There were 10 species of trees observed in *Ulmus* growing population (Table 20). The most dominating species found was *Cedrus deodara* (50.9), codominant species were *Ulmus wallichiana* (47.79), *Juglans regia* (41.87), associated species were *Alnus nepalensis*, *Toona serrata*, *Pinus wallichiana*, *Ficus palmata* and *Melia composita*. The least dominating species was *Morus serrata* (18.28). There were 7 species of trees recorded in non-*Ulmus* growing population. The dominating species was *Cedrus deodara* (64.82), codominating species was *Ailanthus altissima* (55.2) and least dominating species reported was *Pyrus pashia* (21.38). Six species of shrubs were recorded in *Ulmus* growing population (Table 21). The dominating species observed was *Prinsepia utilis* (108.64), whereas least dominating species was *Rosa moschata* with IVI of 17.33. Six species of shrubs were observed in non-*Ulmus* growing population. The maximum dominance was shown by *Rosa moschata* with IVI (64.69) and the least dominance was depicted by *Rosa macrophylla* (34.04).

Observations recorded in terms of tree density, basal area, and altitudinal zone of *Cedrus deodara* and *Pinus wallichiana* were in conformation with Siddiqui et al. (2013) who reported the same range in terms of tree density, basal area and altitudinal zone in pine stands of Malam Jabba, Pakistan. *Pinus wallichiana* had the highest density at all the three elevations of study site.

Table 20. Relative density, relative frequency, relative basal area and IVI of tree species in Rumsu

Tree species	Relative density		Relative frequency		Relative basal area		IVI	
	U P	U A	U P	U A	U P	U A	U P	U A
<i>Ailanthus altissima</i>	-	17.86	-	17.39	-	21.37	-	55.2
<i>Alnus nepalensis</i>	5.71	-	8.82	-	7.35	-	21.84	-
<i>Cedrus deodara</i>	18.57	-	11.76	-	20.56	29.65	50.9	64.82
<i>Ficus palmata</i>	7.14	16.43	5.88	17.39	8.75	-	21.77	-
<i>Juglans regia</i>	17.14	-	8.82	-	15.9	-	41.87	-
<i>Melia composita</i>	7.14	9.58	5.88	17.39	6.51	7.26	19.53	34.24
<i>Morus serrata</i>	5.71	-	8.86	-	3.68	-	18.28	-
<i>Picea smithiana</i>	7.14	-	8.82	-	6.67	-	22.63	-
<i>Pinus wallichiana</i>	11.46	-	14.7	-	6.35	-	32.48	-
<i>Populus ciliate</i>	-	12.32	-	17.39	-	10.29	-	40.05
<i>Populus deltoides</i>	-	15.06	-	13.04	-	14.78	-	42.89
<i>Populus nigra</i>	-	17.8	-	13.04	-	10.57	-	41.42
<i>Pyrus pashia</i>	-	10.95	-	4.36	-	6.08	-	21.38
<i>Toona serrata</i>	7.14	-	11.76	-	4.01	-	22.91	-
<i>Ulmus wallichiana</i>	12.85	-	14.7	-	20.22	-	47.79	-

Table 21. Relative density, relative frequency, relative basal area and IVI of tree species in Rumsu

Shrub species	Relative density		Relative frequency		Relative basal area		IVI	
	U P	U A	U P	U A	U P	U A	U P	U A
<i>Daphne cannabina</i>	17.47	-	20.0	-	16.69	-	54.17	-
<i>Indigofera heterantha</i>	26.21	19.78	20.0	22.72	16.16	18.31	62.38	60.81
<i>Prinsepia utilis</i>	36.89	12.08	25.0	13.63	46.75	14.84	108.64	40.56
<i>Rosa macrophylla</i>	-	10.98	-	13.63	-	9.41	-	34.04
<i>Rosa moschata</i>	5.82	20.87	5.0	18.18	6.5	25.63	17.33	64.69
<i>Rubus ellipticus</i>	8.73	15.38	15.0	13.63	7.72	9.19	31.46	38.21
<i>Sarcococca saligna</i>	-	20.87	-	18.18	-	22.59	-	61.65
<i>Zanthoxylum armatum</i>	4.85	-	15.0	-	6.15	-	26	-

Where - U P – *Ulmus wallichiana* present, U A - *Ulmus wallichiana* absent.

4.1.2 Similarity and Disimilarity indices

The Similarity index in *Ulmus* growing population for tree species ranged from 0.09-0.95 (Table 22). It was recorded maximum in Pulang and Naggar (0.95), whereas it was recorded minimum for *Ulmus* growing population in Rumsu and Naggar (0.09). The dissimilarity index for trees varied from 0.05-0.89. It was recorded maximum for *Ulmus* growing population in Pulang and Mohal, Rumsu and Mohal (0.89) whereas minimum (0.05) was recorded in Pulang and Naggar. The species present in sites Pulang and Naggar depicted highest similarity because these two populations were under the same range. Rumsu and Naggar are at a distant from each other, hence there are less similarity of trees and shrubs.

The results are in line with those of Kumari and Thakur (2008) in mid-hills of Himachal Pradesh.

In non-*Ulmus* bearing population similarity index for the tree species ranged from 0 to 0.9 (Table 23), it was recorded maximum (0.90) in Babeli and Shamshi, and no similarity was shown by Badagram and Shamshi population 0. Dissimilarity index ranged from (0.09) to 1 (Table 23), it was recorded maximum (1) for Badagram and Shamshi population while minimum was recorded in Babeli and Shamshi (0.09). A similarity index is an index that reflects the similarity of species in two separate locations. A similarity of 1 was reported for trees, showing that vegetation of tree species is common or shared across forest sites at distinct altitudinal gradients, whereas 0 implies no similarity among the tree species.

Table 22. Similarity and dissimilarity index of trees in natural *Ulmus wallichiana* growing population

D \ S	Shamshi	Mohal	Babeli	Badagram	Seonidhar	Dhobi	Naggar	Pulang	Rumsu
Shamshi	1	0.44	0.70	0.42	0.33	0.31	0.37	0.33	0.33
Mohal	0.55	1	0.37	0.22	0.11	0.22	0.13	0.11	0.11
Babeli	0.30	0.62	1	0.47	0.40	0.28	0.55	0.4	0.30
Badagram	0.57	0.77	0.52	1	0.13	0.25	0.46	0.13	0.13
Seonidhar	0.66	0.88	0.60	0.86	1	0.4	0.55	0.42	0.42
Dhobi	0.68	0.77	0.71	0.75	0.60	1	0.31	0.28	0.28
Naggar	0.63	0.87	0.45	0.54	0.45	0.69	1	0.95	0.09
Pulang	0.67	0.89	0.60	0.87	0.58	0.72	0.05	1	0.28
Rumsu	0.67	0.89	0.70	0.87	0.58	0.72	0.91	0.72	1

Table 23. Index of similarity and dissimilarity of trees in natural non- *Ulmus wallichiana* growing population

D \ S	Shamshi	Mohal	Babeli	Badagram	Seonidhar	Dhobi	Naggar	Pulang	Rumsu
Shamshi	1	0.61	0.90	0	0.16	0.12	0.80	0.26	0.33
Mohal	0.38	1	0.35	0.18	0.18	0.18	0.42	0.42	0.11
Babeli	0.09	0.64	1	0.28	0.42	0.42	0.23	0.23	0.30
Badagram	1.00	0.81	0.71	1	0.44	0.44	0.50	0.5	0.13
Seonidhar	0.83	0.81	0.57	0.55	1	0.15	0.12	0.12	0.42
Dhobi	0.83	0.81	0.57	0.55	0.84	1	0.11	0.11	0.28
Naggar	0.20	0.58	0.77	0.5	0.88	0.89	1	0.33	0.09
Pulang	0.74	0.58	0.77	0.50	0.88	0.89	0.67	1	0.28
Rumsu	0.67	0.89	0.70	0.87	0.58	0.72	0.91	0.72	1

The Similarity index for the shrubs in *Ulmus* bearing populations ranged from 0.16-0.75 (Table 24). It was recorded maximum for *Ulmus* growing population in Seonidhar and Shamshi (0.75) population whereas it was recorded minimum for *Ulmus* growing population in Dhobi and Seonidhar (0.16). The dissimilarity index for shrubs varied from 0.25-0.84. It was recorded maximum for *Ulmus* growing population in Seonidhar and Dhobi (0.84) population, whereas minimum (0.25) was recorded for *Ulmus* growing population in Seonidhar and Shamshi. Less difference in the value of similarity index indicated that growth forms in the stands responded in a similar fashion. Whereas, minimum similarity observed between different forest types may be due to different climatic and topographic conditions, different habitat and soil type (Adhikari *et al.* 1991). Itow *et al.* (1980) reported that large area contained more varied habitat types than smaller ones, and each of the habitat type supports a specific set of its habitat, which is more or less different from that of other habitat types. Suyal *et al.* (2010) propounded the close proximity results in high similarity index of vegetation and the same could be related to grouping of forest based on similarity index.

Table 24. Similarity and dissimilarity index of shrubs in natural *Ulmus wallichiana* growing population

D \ S	Shamshi	Mohal	Babeli	Badagram	Seonidhar	Dhobi	Naggar	Pulang	Rumsu
Shamshi	1	0.50	0.28	0.50	0.75	0.62	0.66	0.33	0.33
Mohal	0.50	1	0.40	0.42	0.42	0.40	0.60	0.60	0.60
Babeli	0.72	0.60	1	0.33	0.33	0.30	0.50	0.50	0.50
Badagram	0.50	0.58	0.67	1	0.33	0.30	0.50	0.50	0.50
Seonidhar	0.25	0.58	0.67	0.67	1	0.16	0.28	0.28	0.28
Dhobi	0.38	0.60	0.70	0.70	0.84	1	0.28	0.28	0.28
Naggar	0.34	0.40	0.50	0.50	0.72	0.72	1	0.62	0.62
Pulang	0.67	0.40	0.50	0.50	0.72	0.72	0.38	1	0.45
Rumsu	0.67	0.40	0.50	0.50	0.72	0.72	0.38	0.55	1

Similarity index for the shrub species in non- *Ulmus* bearing population ranged from 0.25 to 0.72 (Table 25), it was recorded maximum for Badagram and Shamshi, Seonidhar and Shamshi, Dhobi and Shamshi, Pulang and Naggar, Rumsu and Naggar i.e., 0.72 and minimum recorded in Mohal and Shamshi 0.25. Dissimilarity index ranged from 0.28 to 0.75 (Table 25), it was recorded maximum (0.75) in Mohal and Shamshi and minimum (0.28) was recorded in Badagram and Shamshi, Seonidhar and Shamshi, Dhobi and Shamshi, Pulang and Naggar, Rumsu and Naggar. Species found in one location may also be found in the other locations. Further more, the dissimilarity index indicates that some species were found in one zone but not in the other locations (Chirchir *et al.* 2018). Dissimilarity in community composition is one of the most fundamental and obvious characteristics that distinguishes

distinct forest ecosystems. A smaller difference in the value of the similarity index showed that growth forms in the stands responded similarly. Whereas the least resemblance detected across various forest sites and elevations may be due to differences in climatic, topographic, habitat, and soil type (Adhikari *et al.* 1991).

Table 25. Similarity and dissimilarity index of shrubs in natural non-*Ulmus wallichiana* growing population

D \ S	Shamshi	Mohal	Babeli	Badagram	Seonidhar	Dhobi	Nagggar	Pulang	Rumsu
Shamshi	1	0.25	0.28	0.72	0.72	0.72	0.41	0.41	0.41
Mohal	0.75	1	0.40	0.66	0.66	0.66	0.30	0.30	0.30
Babeli	0.72	0.60	1	0.57	0.57	0.57	0.50	0.50	0.50
Badagram	0.28	0.34	0.43	1	0.57	0.57	0.50	0.50	0.50
Seonidhar	0.28	0.34	0.43	0.43	1	0.33	0.28	0.28	0.28
Dhobi	0.28	0.34	0.43	0.43	0.67	1	0.28	0.28	0.28
Nagggar	0.59	0.70	0.50	0.50	0.72	0.72	1	0.72	0.72
Pulang	0.59	0.70	0.50	0.50	0.72	0.72	0.28	1	0.62
Rumsu	0.59	0.70	0.50	0.50	0.72	0.72	0.28	0.38	1

4.1.3 Diversity indices of *Ulmus* growing and non-*Ulmus* growing population.

The following Diversity indices of natural population of *Ulmus* growing and non-*Ulmus* growing are presented in table (26).

4.1.3.1 Simpson index (D)

The Simpson index is a measure of importance of one species in relation to community. The Simpson index for tree species in *Ulmus* growing population was observed maximum (0.881) for Pulang, and minimum (0.667) in Mohal (Table 26). In case of non-*Ulmus* growing population, it was observed maximum for Rumsu (0.850) and minimum (0.528) was recorded for Badagram. In case of shrubs, it was recorded maximum for Seonidhar (0.827) and minimum was recorded for Nagggar (0.676) for *Ulmus* growing population (Table 27). whereas in case of non-*Ulmus* growing population it was recorded maximum for Dhobi (0.765) and minimum was recorded for Shamshi (0.671). Shafi et al. (2018) reported simpson index for tree and shrubs ranged from 0.93 to 0.95. Chauhan (2021) reported that Simpson index in shrubs species varied from 0.811 to 0.902 in *Elaeagnus* bearing population while in non- *Elaeagnus* bearing population it was observed from 0.850 to 0.885.

4.2.3.2 Shannon index (\bar{H})

The Shannon index is used to characterize species diversity in a community, Shannon index for trees in *Ulmus* growing population was observed maximum (2.427) for Badagram indicating that more than two tree species displayed codominance. The minimum (1.488) was recorded for Mohal depicting that (90%) of the dominance was contributed by single species. In non-*Ulmus* bearing population, it was recorded maximum for Babeli (2.056) and minimum (0.847) was observed for Badagram (Table 26). In case of shrubs, it was observed maximum (1.988) for Dhobi and minimum (0.342) was recorded for Babeli in *Ulmus* growing population. In non-*Ulmus* growing population, it was recorded maximum (1.91) for Pulang, minimum (0.853) was recorded for Babeli (Table 27). Shafi et al. (2018) reported that shanon index for tree and shrubs varied from 2.92 to 3.15. Sharma et al (2020) observed that the shannon index for shrubs ranged from 2.13 to 2.47, with highest recorded towards east direction reflecting highest species diversity in east side of Sargujja, Chattisgarh, India. Chauhan (2021) reported Shannon index in shrubs species varied from 1.80 to 2.35 in *Elaeagnus* bearing population while in non- *Elaeagnus* bearing population it was observed from 2.009 to 2.27.

4.1.3.3 Equitability (e)

Equitability is a measure of relative abundance of species within a community. Equitability for trees in *Ulmus* growing population was observed maximum (0.962) for Pulang (Table 26), whereas minimum was recorded for Mohal (0.646). In non-*Ulmus* growing population, it was recorded maximum (0.987) for Rumsu and minimum (0.622) was observed for Shamshi. In case of shrubs, it was observed maximum for Seonidhar (0.866), and minimum (0.728) was recorded for Naggar in *Ulmus* growing population (Table 27). In non-*Ulmus* growing population, it was recorded maximum (0.995) for Mohal and minimum (0.773) was recorded for Badagram. The higher value of equitability index indicates complete evenness. Khan et al (2020) reported that equitability index for shrubs was higher in the south direction (1.32) of Sargujja, Chattisgarh, India representing higher equal distribution of species in concerned site. Chauhan (2021) reported equitability index in shrubs species varied from 0.92 to 1.013 in *Elaeagnus* bearing population while in non-*Elaeagnus* bearing population it was observed from 0.96 to 1.006.

4.1.3.4 Species richness index (D_{mg})

Species richness is an effective measure of species density. Species richness for trees in *Ulmus* growing population was observed maximum (2.589) for Badagram (Table 26), whereas minimum (1.789) was recorded for Shamshi. In non-*Ulmus* growing population, it was recorded maximum for Babeli (2.519), and minimum (0.464) was recorded for Dhobi. In case of shrubs it was observed maximum (1.791) for Dhobi, whereas minimum (0.488) was recorded for Babeli in *Ulmus* growing population. In non-*Ulmus* growing population, it was recorded maximum (1.377) for Pulang and minimum (0.738) was recorded for Babeli (Table 27). Kumar et al. (2020) reported that species richness index for shrubs ranged from 0.66-1.54 in chirpine forest in Central Himalayas.

Table 26. Diversity indices of tree species in natural population of *Ulmus wallichiana* and non- *Ulmus wallichiana* growing population

Population	Diversity indices							
	Simpson		Shannon		Equitability		Species richness	
	U P	U A	U P	U A	U P	U A	U P	U A
Shamshi	0.722	0.626	1.585	1.211	0.762	0.622	1.789	1.272
Mohal	0.667	0.648	1.488	1.189	0.646	0.738	1.907	0.863
Babeli	0.713	0.829	1.689	2.056	0.768	0.845	2.352	2.519
Badagram	0.863	0.528	2.427	0.847	0.887	0.633	2.589	0.633
Seonidhar	0.874	0.703	2.349	1.285	0.940	0.927	2.37	0.654
Dhobi	0.872	0.723	2.184	1.07	0.915	0.960	2.245	0.464
Naggar	0.804	0.812	1.811	1.769	0.871	0.908	1.885	1.638
Pulang	0.881	0.843	2.216	1.897	0.962	0.975	2.01	1.36
Rumsu	0.870	0.850	2.208	1.922	0.941	0.987	2.118	1.398

Where - U P – *Ulmus wallichiana* present, U A - *Ulmus wallichiana* absent.

Table 27. Diversity indices of shrub species in natural population of *Ulmus wallichiana* and non- *Ulmus wallichiana* growing population

Population	Diversity indices							
	Simpson		Shannon		Equitability		Species richness	
	U P	U A	U P	U A	U P	U A	U P	U A
Shamshi	0.736	0.671	1.793	1.222	0.799	0.881	1.227	0.850
Mohal	0.742	0.696	1.793	1.222	0.812	0.995	1.227	0.85
Babeli	0.773	0.713	0.342	0.853	0.843	0.977	0.488	0.738
Badagram	0.826	0.687	1.909	1.244	0.868	0.773	1.383	1.028
Seonidhar	0.827	0.747	1.904	1.499	0.866	0.903	1.412	1.033
Dhobi	0.805	0.765	1.988	1.51	0.829	0.938	1.791	0.958
Naggar	0.676	0.700	1.305	1.545	0.728	0.927	1.05	1.299
Pulang	0.724	0.746	1.447	1.91	0.807	0.994	1.022	1.377
Rumsu	0.751	0.739	1.549	1.761	0.864	0.984	1.079	1.108

Where - U P – *Ulmus wallichiana* present, U A - *Ulmus wallichiana* absent

These studies also supported an earlier investigation that species richness increased from the higher elevation towards the lower elevation (Kumar and Thakur, 2008; Sharma et al., 2009; Raturi, 2012; Singh, 2013). Chauhan (2021) reported species richness index in shrubs species varied from 1.38 to 2.53 in *Elaeagnus* bearing population while in non-*Elaeagnus* bearing population it was observed from 0.66 to 1.54 (Plate 1).

4.2 PHYSICO-CHEMICAL PROPERTIES OF SOIL

The soil physico-chemical properties of natural population of *Ulmus* growing and non-*Ulmus* growing population was depicted in the Table 28.

The maximum pH was recorded for *Ulmus* growing population in Rumsu (8.05) at the depth of 0-15 cm and minimum was recorded in Pulang (6.34) at a depth of 15-30 cm. The maximum pH in non-*Ulmus* growing population was reported in Seonidhar (7.76) cm and minimum was recorded in Pulang (6.52) at a depth of 15-30. The maximum electrical conductivity (EC) was recorded for *Ulmus* growing population in Seonidhar (0.85 dSm⁻¹) at a depth of 0-15 cm and minimum EC was recorded in Shamshi (0.56 dSm⁻¹) at a depth 15-30. The maximum EC in non-*Ulmus* growing population was recorded in Badagram (1.54 dSm⁻¹) at a depth of 0-15 cm and minimum was recorded in Shamshi (0.23 dSm⁻¹) at a depth of 15-30 cm. The organic carbon (OC) was recorded maximum for *Ulmus* growing population in Naggar (1.82 %) at the depth of 0-15 cm and minimum was recorded in Shamshi (0.14 %) at a depth of 15-30 cm. The maximum OC for non-*Ulmus* growing population was recorded in Badagram (1.44 %) at a depth of (0-15 cm) and minimum was recorded in Pulang (0.27 %) at a depth of 15-30 cm.

The maximum available nitrogen for *Ulmus* growing population was recorded in Badagram (290 kg/ha) at a depth of 15-30 cm and minimum was recorded in Pulang and Rumsu (118 Kg/ha) at a depth of 15-30cm. In non-*Ulmus* growing population the available nitrogen was recorded maximum (274 kg/ha) in Rumsu at a depth of 0-15cm and minimum (131 kg/ha) was recorded in Seonidhar at a depth of 15-30cm. Goldstein (2010) reported that net nitrogen mineralization and nitrification rates were higher under the soil bearing *Elaeagnus umbellata*, compared to open filed soil. Devi (2011) reported that available nitrogen present in soils of Ban oak and chirpine forests in ranged from 448-633 kg/ha.

The available phosphorus was recorded maximum in Dhobi (21 kg/ha) at a depth of 0-15cm and minimum was recorded in Shamshi (9 kg/ha) at a depth of 15-30 cm in *Ulmus*



Plate 1: Layout of quadrats and phytosociological studies of *Ulmus wallichiana*

Table 28. Soil physico-chemical properties at different depth in natural population of *Ulmus wallichiana* and non- *Ulmus wallichiana* growing population

Ranges	Site	pH				EC (dS m ⁻¹)				OC (%)			
		0-15		15-30		0-15		15-30		0-15		15-30	
		U P	U A	U P	U A	U P	U A	U P	U A	U P	U A	U P	U A
Kullu	Shamshi	7.38	7.69	7.21	7.5	0.75	1.45	0.56	0.23	1.45	1.4	0.14	0.58
	Mohal	6.63	7.56	6.41	7.38	0.74	0.83	0.58	0.25	1.19	1.37	0.54	0.66
	Babeli	6.42	7.61	6.24	7.39	0.8	0.82	0.68	0.34	1.13	1.3	0.18	0.4
Patlikuhl	Badagram	7.73	7.19	7.45	7.93	0.78	1.54	0.66	1.25	1.3	1.44	0.17	0.82
	Seonidhar	7.54	7.34	7.42	7.76	0.85	1.39	0.67	1.13	1.2	1.42	0.33	0.74
	Dhobi	7.53	7.57	7.47	7.55	0.76	1.3	0.67	1.2	1.06	1.32	0.2	0.85
Naggar	Naggar	7.63	6.61	7.26	7.68	0.81	1.24	0.67	0.58	1.82	1.3	0.24	0.44
	Pulang	6.54	6.84	6.34	6.52	0.78	0.94	0.69	0.41	1.46	1.27	0.22	0.27
	Rumsu	8.05	7.55	7.61	7.23	1.18	0.86	0.83	0.67	1.28	0.83	0.21	0.33

Where-EC- Electrical conductivity, OC-Organic carbon

Ranges	Site	N (Kg/ha)				P (Kg/ha)				K (Kg/ha)			
		0-15		15-30		0-15		15-30		0-15		15-30	
		U P	U A	U P	U A	U P	U A	U P	U A	U P	U A	U P	U A
Kullu	Shamshi	247	248	242	204	10	10	9	9	606	101	482	98
	Mohal	271	265	234	188	14	13	12	11	322	118	224	91
	Babeli	172	237	143	168	15	16	13	12	218	117	138	102
Patlikuhl	Badagram	230	246	290	133	16	13	13	11	505	130	366	98
	Seonidhar	220	240	184	131	18	15	14	11	555	140	418	137
	Dhobi	259	175	207	144	21	16	18	13	464	135	373	118
Naggar	Naggar	151	149	137	141	16	13	14	10	763	172	566	142
	Pulang	176	255	118	175	18	16	14	15	695	142	519	162
	Rumsu	124	274	118	159	17	16	14	15	389	154	332	131

Where- N-Nitrogen, P-Phosphorous, K-Potassium.

growing population. In non- *Ulmus* growing population the maximum available Phosphorus was recorded in Babeli and Dhobi (16 kg/ha) at a depth of 0-15 cm and minimum was recorded in Shamshi (9 kg/ha) at a depth of 15-30cm.

In *Ulmus* growing population the available Potassium was recorded maximum in Naggar (763 kg/ha) at a depth of 0-15cm and minimum was also recorded in Babeli (138 kg/ha) at a depth of 15-30 cm. While in non-*Ulmus* growing population the available Potassium was recorded maximum in Naggar (172 kg/ha) at a depth of 0-15 cm and minimum was recorded in Mohal (91 kg/ha) at a depth of 15- 30cm. Thakur et al. (2019) reported that potassium levels in forest soils of Shimla district ranged from 310-365 kg/ha.

Devi *et al.* (2020) reported that *Ulmus wallichiana* is positive for nitrogen fixing ability as well as ammonia production in Kullu range thus it helps to increase the soil nutritions (Plate 2).

4.3 REGENERATION STUDIES

Regeneration is a key feature of the forest dynamics. The plants present in particular forest, grow maintain and expand their populations in time and space by the process of regeneration. Regeneration of any species is restricted to a peculiar range of habitat conditions and the extent of these conditions is a major determinant of its geographic distribution (Grubb, 1977). The natural regeneration of a tree species however depends largely on the production and germination of seeds and the establishment of seedlings and saplings. Less seedlings and saplings than mature trees in particular forest indicate declining trends of forest regeneration which can be rated as poor regenerating forest.

The regeneration studies were carried out for recruits (R), un-established (Un) and established (E) seedlings in different forest of Kullu, Patlikuhl and Naggar Ranges of Kullu Forest division of Himachal Pradesh (Table 29)

From the data (Table 29) it is revealed that the total no. of recruit/ha was recorded in Kullu, Patlikuhl and Naggar they were 1125,750 and 500 respectively. In Kullu range the maximum (750) number of recruits found in Babeli and minimum (125) recruits found in Mohal, In Patlikuhl range the maximum (375) number of recruits found in Badagram and minimum (125) in Seonidhar and in Naggar range maximum (250) number of recruits found in Naggar and minimum (125) in Pulang and Rumsu.



Plate 2: Study of physio-chemical properties of soil

The unestablished regeneration/ha of Kullu, Patlikuhl and Naggar ranges they were 750,500 and 375 respectively. In Kullu range the maximum (375) number of unestablished regeneration found in Babeli and minimum (125) in Mohal, In Patlikuhl range the maximum (250) number of unestablished regeneration found in Badagram and minimum (125) in Seonidhar and Dhobi and in Naggar range maximum (128) number of unestablished regeneration found in Naggar and minimum (122) in Rumsu.

The regeneration success of Kullu, Patlikuhl and Naggar ranges they were 7.5, 5 and 3.75 respectively. In Kullu range the maximum (3.75%) of regeneration success found in Babeli and minimum (1.25%) in Mohal, In Patlikuhl range maximum (2.5%) of regeneration success found in Badagram and minimum (1.25%) in Seonidhar and Dhobi and in Naggar range maximum (1.28%) of regeneration success found in Naggar and minimum (1.22%) in Rumsu. The established regeneration recorded Nil in all the populations.

Table 29. Regeneration status of *Ulmus wallichiana* in Kullu district of Himachal Pradesh

<u>Kullu</u>	Sites	Recruits/ha	Unestablished regeneration/ha	Establishment regeneration / ha	Regeneration Success %
Tree Species	Shams hi	250	250	0	2.5
<i>Ulmus wallichiana</i>	Mohal	125	125	0	1.25
	Babeli	750	375	0	3.75
	Total	1125	750	0	7.5
<u>Patlikuhl</u>	Sites	Recruits/ha	Unestablished regeneration/ha	Establishment regeneration / ha	Regeneration Success %
Tree Species	Badagram	375	250	0	2.5
<i>Ulmus wallichiana</i>	Seonidhar	125	125	0	1.25
	Dhobi	250	125	0	1.25
	Total	750	500	0	5
<u>Naggar</u>	Sites	Recruits/ha	Unestablished regeneration/ha	Establishment regeneration / ha	Regeneration Success %
Tree Species	Naggar	250	128	0	1.28
<i>Ulmus wallichiana</i>	Pulang	125	125	0	1.25
	Rumsu	125	122	0	1.22
	Total	500	375	0	3.75

It is clear that *Ulmus* forest showed decreasing trend of regeneration success with altitudinal ranges: Kullu > Patlikuhl > Naggar. Maximum regeneration success of *Ulmus wallichiana* (7.5) was observed in Kullu range (1100-1500) and the minimum regeneration success of *Ulmus wallichiana* (3.75) was observed in Naggar range (1800-2100). Maximum regeneration was recorded at lower altitude. The variation in seedling density among the forests and/or species along the altitudinal gradient may be attribute to change in climatic conditions which could restrict the distribution of particular species by the germination and establishment of seedlings (Vera 1997). Minimum regeneration was recorded at higher elevation. Lack of sufficient regeneration in mountain forests and the results draw support from the findings, reported by Krauchi *et al.* (2000) Plate 3.



Plate 3: Regeneration status of *Ulmus wallichiana* in Kullu Forest Division

Chapter-5

SUMMARY AND CONCLUSION

The present investigation entitled "**Ecological Status of *Ulmus wallichiana* (Planch.) in Himachal Pradesh**" was carried out in the Department of Tree Improvement and Genetic Resources, College of Forestry, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh during 2020-2022. Three ranges of Kullu forest division were selected *i.e.*, Kullu, Patlikuhl and Naggar. From each range three sites were selected randomly. In total nine sites were selected *i.e.*, Shamshi, Mohal, Babeli, Badagram, Seonidhar, Dhobi, Naggar, Pulang and Rumsu. The key features of this investigation included phytosociological studies, soil physico-chemical properties and regeneration status in *Ulmus* growing and non-*Ulmus* growing populations.

5.1 PHYTOSOCIOLOGICAL STUDIES OF *ULMUS WALLICHIANA* (PLANCH.)

The phytosociological studies revealed the floristic composition of trees and shrubs in natural population of *Ulmus wallichiana* and non-*Ulmus wallichiana* growing population.

The tree species observed in Shamshi, Mohal, Babeli, Badagram, Seonidhar, Dhobi, Naggar, Pulang and Rumsu in *Ulmus* growing population were 8, 9, 9, 11, 10, 10, 8, 10, and 10, respectively. Maximum number of trees were noted in Badagram (11) and minimum in Shamshi and Naggar (8). In non-*Ulmus* bearing population, tree species reported were 7, 5, 11, 3, 4, 4, 7, 7, and 7, respectively. The maximum (11) number of trees were found in Babeli and minimum in Badagram *i.e.*, three.

The number of shrub species observed in Shamshi, Mohal, Babeli, Badagram, Seonidhar, Dhobi, Naggar, Pulang and Rumsu in *Ulmus* growing population were 4, 4, 5, 9, 9, 11, 6, 6 and 6 respectively. Among all the populations, the maximum number of shrubs were found in Dhobi (11) and minimum (4) in Shamshi and Mohal. In non-*Ulmus* growing populations shrub species observed were 4, 4, 5, 5, 5, 5, 6, 6 and 6, respectively. Among all the populations, maximum (6) number of species were observed in Naggar, Pulang and Rumsu and minimum in Shamshi and Mohal *i.e.*, four.

In Ulmus bearing population of Shamshi, most dominating tree species recorded was *Ulmus wallichiana* (89.08) and shrub species was *Prinsepia utilis* (82.63) whereas least dominating tree species was *Morus serrata* (10.95) and shrub species was *Indigofera heterantha* (17.59). In non- Ulmus bearing population dominating tree species recorded was *Ailanthus altissima* (125.61) and shrub species was *Prinsepia utilis* (126.28) whereas least dominating tree species was *Melia azedarach* (8.37) and shrub species was *Rosa moschata* (27.93). In Ulmus bearing population of Mohal most dominating tree species was *Robenia pseudocacia* (74.94) and shrub species recorded was *Rosa moschata* (174.33). The least dominating tree species was *Melia azedarach* (6.52) and shrub species was *Berberis lycium* (19.87). In non- Ulmus bearing population dominating tree species was *Pyrus pashia* (119.72) and shrub species was *Prinsepia utilis* (117.13) whereas least dominating tree species was *Melia azedarach* (9.54) and shrub species was *Berberis lycium* (22.73). In Ulmus bearing population of Babeli, most dominating tree species recorded was *Ulmus wallichiana* (145.74) and shrub species was *Rosa moschata* (178.68). The least dominating tree species was *Morus serrata* (10.4) and shrub species was *Prinsepia utilis* (17.65). In non- Ulmus bearing population dominating tree species recorded was *Melia azedarach* (67.18) and shrub species recorded was *Rosa moschata* (110.89) whereas least dominating tree species was *Betula alnoides* (8.33) and shrub species was *Prinsepia utilis* (16.78).

In Ulmus bearing population of Badagram, most dominating tree species was *Ulmus wallichiana* (55.92) and shrub species recorded was *Prinsepia utilis* (73.63), whereas least dominating tree species recorded was *Picea smithiana* (13.0) and shrub species was *Daphne cannabina* (12.25). In non- Ulmus bearing population dominating tree species was *Pinus wallichiana* (145.96) and shrub species recorded was *Indigofera heterantha* (95.69) whereas least dominating tree species was *Ficus palmata* (14.32) and shrub species was *Rubus ellipticus* (12.45). In Ulmus bearing population of Seonidhar, most dominating tree species was *Ulmus wallichiana* (54.67) and shrub species recorded was *Prinsepia utilis* (62.97), whereas least dominating tree species was *Alnus nepalensis* (15.69) and shrub species was *Rubus niveus* (5.82). In non- Ulmus bearing population dominating tree species recorded was *Cedrus deodara* (106.57) and shrub species recorded was *Indigofera heterantha* (91.12) whereas least dominating tree species was *Ficus palmata* (46.47) and shrub species was *Rubus ellipticus* (23.24). In Ulmus bearing population of Dhobi, most dominating tree species was *Pinus wallichiana* (56.75) and shrub species was *Prinsepia utilis* (91.76), whereas least dominating tree species was *Morus serrata* (5.87) and shrub species was

Zizyphus jujuba (11.5). In non- *Ulmus* bearing population dominating tree species was *Cedrus deodara* (107.04) and shrub species was *Indigofera heterantha* (97.99) whereas least dominating tree species was *Populus deltoides* (57.91) and shrub species was *Rubus ellipticus* (24.4).

In *Ulmus* bearing population of Naggar, most dominating tree species recorded was *Ulmus wallichiana* (89.14) and shrub species was *Prinsepia utilis* (118.66), whereas least dominating tree species was *Ficus palmata* (12.43) and shrub species was *Rubus ellipticus* (9.26). In non- *Ulmus* bearing population dominating tree species was recorded *Populus nigra* (67.87) and shrub species was *Prinsepia utilis* (94.05), whereas least dominating tree species was *Melia composita* (15.11) and shrub species was *Sarcococca saligna* (13.44). In *Ulmus* bearing population of Pulang, most dominating tree species was *Cedrus deodara* (50.24) and shrub species was *Prinsepia utilis* (117.17), whereas least dominating tree species was *Alnus nepalensis* (17.16) and shrub species was *Rosa moschata* (14.88). In non- *Ulmus* bearing population dominating tree species was *Populus nigra* (58.85) and shrub species recorded was *Rosa moschata* (80.4), whereas least dominating tree species was *Ailanthus altissima* (27.09) and shrub species was *Rosa macrophylla* (31.21). In *Ulmus* bearing population of Rumsu, most dominating tree species was *Cedrus deodara* (50.9) and shrub species was *Prinsepia utilis* (108.64), whereas least dominating tree species was *Morus serrata* (18.28) and shrub species was *Rosa moschata* (17.33). In non- *Ulmus* bearing population dominating tree species was *Cedrus deodara* (64.82) and shrub species was *Rosa moschata* (64.69), whereas least dominating tree species was *Pyrus pashia* (21.38) and shrub species was *Rosa macrophylla* (34.04).

In *Ulmus* growing populations the similarity index for the trees ranged from (0.09 to 0.95). It was recorded maximum in Pulang and Naggar (0.95), whereas minimum was recorded in Rumsu and Naggar (0.09). The dissimilarity index for trees varied from (0.05 to 0.89). It was recorded maximum in Pulang and Mohal (0.89), Rumsu and Mohal (0.89) whereas minimum (0.05) was recorded in Pulang and Naggar. In non- *Ulmus* bearing populations similarity index ranged from (0 to 0.90) for the tree species it was recorded maximum in Babeli and shamshi (0.9) and minimum was in Badagram and Shamshi *i.e.*, zero. Dissimilarity index ranged from (0.09 to 1) it was maximum (1) in Badagram and Shamshi and minimum in Babeli and Shamshi (0.09). The similarity index for the shrubs ranged from (0.16 to 0.75) in *Ulmus* bearing population. It was recorded maximum for

Seonidhar and Shamshi (0.75), whereas minimum was in Dhobi and Seonidhar (0.16). The dissimilarity index varied from (0.25 to 0.84). It was recorded maximum for Seonidhar and Dhobi (0.84), whereas minimum *i.e.*, 0.25 recorded for Seonidhar and Shamshi. In non-Ulmus growing populations similarity index ranged from 0.25 to 0.72, it was recorded maximum for Seonidhar and shamshi (0.72), and minimum in Mohal and Shamshi *i.e.*, 0.25. Dissimilarity index ranged from (0.28 to 0.75). It was recorded maximum (0.75) in Mohal and Shamshi and minimum recorded in Pulang and Naggar *i.e.*, 0.28.

The Simpson index for tree species in Ulmus growing population was observed maximum (0.881) for Pulang, and minimum (0.667) in Mohal. In case of non-Ulmus growing population, it was observed maximum for Rumsu (0.850) and minimum for (0.528) Badagram. In case of shrubs, it was recorded maximum for Seonidhar (0.827) and minimum for Naggar (0.676). In case of non-Ulmus growing population, it was recorded maximum (0.765) for Dhobi and minimum for Shamshi *i.e.*, (0.671).

Shannon index for tree species in Ulmus growing populations was observed maximum (2.427) for Badagram and the minimum (1.488) was recorded for Mohal. In non-Ulmus bearing populations, it was recorded maximum for Babeli (2.056) and minimum (0.847) was observed for Badagram. In case of shrubs for Ulmus growing populations, it was observed maximum (1.988) for Dhobi and minimum (0.342) was recorded for Babeli. In non-Ulmus growing population, it was recorded maximum (1.91) for Pulang and minimum (0.853) for Babeli.

Equitability for trees in Ulmus growing populations was observed maximum (0.962) for Pulang, whereas minimum was recorded (0.646) for Mohal. In non-Ulmus growing populations, it was recorded maximum (0.987) for Rumsu and minimum (0.622) was observed for Shamshi. In case of shrubs in Ulmus growing populations, it was observed maximum for Seonidhar (0.866), and minimum (0.728) was recorded for Naggar. In non-Ulmus growing populations, it was recorded maximum (0.995) for Mohal and minimum (0.773) for Badagram.

Species richness for trees in Ulmus growing populations was observed maximum (2.589) for Badagram, whereas minimum (1.789) was recorded for Shamshi. In non-Ulmus growing populations, it was recorded maximum for Babeli (2.519) and minimum (0.464) was recorded for Dhobi. In case of shrubs in Ulmus growing populations, it was observed

maximum (1.791) for Dhobi, whereas minimum (0.488) was recorded for Babeli. In non-Ulmus growing populations, it was recorded maximum (1.377) for Pulang and minimum (0.738) for Babeli.

5.2 PHYSICO-CHEMICAL PROPERTIES OF SOIL

The maximum pH for Ulmus growing populations recorded in Rumsu (8.05) at the depth of 0-15 cm and minimum was recorded in Pulang (6.34) at a depth of 15-30 cm. The maximum pH for non-Ulmus growing populations was reported in Seonidhar (7.76) at a depth of 15-30 cm and minimum recorded in Pulang (6.52). The maximum electrical conductivity (EC) for Ulmus growing populations was recorded in Seonidhar (0.85 dSm^{-1}) at a depth of 0-15 cm and minimum recorded in Shamshi (0.56 dSm^{-1}) at a depth 15-30. The maximum EC in non-Ulmus growing populations recorded in Badagram (1.54 dSm^{-1}) at a depth of 0-15 cm and minimum recorded in Shamshi (0.23 dSm^{-1}) at a depth of 15-30 cm. The organic carbon (OC) for Ulmus growing populations recorded maximum in Naggar (1.82 %) at the depth of 0-15 cm and minimum recorded in Shamshi (0.14 %) at a depth of 15-30 cm. The maximum OC for non-Ulmus growing populations recorded in Badagram (1.44 %) at a depth of (0-15 cm) and minimum recorded in Pulang (0.27 %) at a depth of 15-30 cm. The maximum available nitrogen for Ulmus growing populations recorded in Badagram (290 kg/ha) at a depth of 15-30 cm and minimum recorded in Pulang and Rumsu (118 Kg/ha) at a depth of 15-30cm. The available nitrogen for non-Ulmus growing populations recorded maximum in Rumsu (274 kg/ha) at a depth of 0-15cm and minimum recorded in Seonidhar (131 kg/ha) at a depth of 15-30cm. The available phosphorus for Ulmus growing populations recorded maximum in Dhobi (21 kg/ha) at a depth of 0-15cm and minimum recorded in Shamshi (9 kg/ha) at a depth of 15-30 cm. The maximum available phosphorus for non- Ulmus growing populations recorded in Babeli and Dhobi (16 kg/ha) at a depth of 0-15 cm and minimum recorded in Shamshi (9 kg/ha) at a depth of 15-30cm. The available Potassium for Ulmus growing populations recorded maximum in Naggar (763 kg/ha) at a depth of 0-15cm and minimum recorded in Babeli (138 kg/ha) at a depth of 15-30 cm. The available Potassium for non- Ulmus growing populations recorded maximum in Naggar (172 kg/ha) at a depth of 0-15 cm and minimum recorded in Mohal (91 kg/ha) at a depth of 15- 30cm.

5.3 REGENERATION STUDIES

The regeneration studies were carried out for recruits (R), un-established (Un), established (E) seedlings and regeneration success (%) in different forest of Kullu, Patlikuhl

and Naggar ranges of Kullu forest division.

The total no. of recruits/ha in Kullu, Patlikuhl and Naggar ranges were 1125,750 and 500, respectively. In Kullu range the maximum no. of recruits found in Babeli (750) and minimum recruits found in Mohal *i.e.*, 125. In Patlikuhl range the maximum no. of recruits found in Badagram (375) and minimum in Seonidhar (125). In Naggar range maximum 250 number of recruits found in Naggar and minimum in Pulang and Rumsu *i.e.*, 125.

The unestablished seedlings/ha of Kullu, Patlikuhl and Naggar ranges were 750,500 and 375, respectively. In Kullu range the maximum no. of unestablished seedlings found in Babeli (375) and minimum (125) in Mohal. In Patlikuhl range the maximum no. of unestablished seedlings found in Badagram (250) and minimum in Seonidhar and Dhobi *i.e.*, 125. In Naggar range maximum no. of unestablished seedlings found in Naggar (128) and minimum (122) in Rumsu. The established regeneration was recorded nil in all the populations.

The regeneration success of Kullu, Patlikuhl and Naggar ranges were 7.5, 5 and 3.75 percent, respectively. In Kullu range the maximum no. of regeneration success (3.75%) was found in Babeli and minimum in Mohal *i.e.*, 1.25 percent. In Patlikuhl range maximum no. of regeneration success (2.5%) was found in Badagram while minimum in Seonidhar and Dhobi *i.e.*, 1.25 percent. In Naggar range maximum no. of regeneration success (1.28%) was found in Naggar and minimum in Rumsu *i.e.*, 1.22 percent.

It is clear that *Ulmus* forest showed decreasing trend of regeneration success with altitudinal ranges: Kullu > Patlikuhl > Naggar. Maximum regeneration success of *Ulmus wallichiana* (7.5%) was observed in Kullu range (1100-1500m) amsl and the minimum regeneration success of *Ulmus wallichiana* (3.75%) was observed in Naggar range (1800-2100m) amsl.

CONCLUSIONS

1. In Kullu range, most dominating tree species was *Ulmus wallichiana* and most dominating shrub species was *Rosa moschata* in *Ulmus* bearing population. While in non-*Ulmus* bearing population *Ailanthus altissima* was most dominating tree species and *Prinsepia utilis* was most dominating shrub species.
2. In Patlikuhl range, most dominating tree species was *Ulmus wallichiana* and most dominating shrub species was *Prinsepia utilis* in *Ulmus* bearing population. While in

non-Ulmus bearing population *Cedrus deodara* was most dominating tree species and *Indigofera heterantha* most dominating shrub species.

3. In Naggar range, most dominating tree species was *Cedrus deodara* and most dominating shrub species was *Prinsepia utilis* in Ulmus bearing population. While in non-Ulmus bearing population *Populus nigra* was most dominating tree species and *Rosa moschata* was most dominating shrub species.
4. In Ulmus bearing population maximum similarity indices for tree species was recorded in Pulang and Naggar (0.95) and minimum (0.09) in Rumsu and Naggar. While in shrub species maximum similarity indices was recorded (0.9) in Babeli and Shamshi and minimum (0) in Badagram and Shamshi. Dissimilarity index for trees was recorded maximum in Pulang and Mohal, Rumsu and Mohal (0.89) and minimum (0.05) was recorded in Pulang and Naggar. While in case of shrub species maximum dissimilarity index was recorded (1) in Badagram and Shamshi and minimum (0.09) in Babeli and Shamshi.
5. In Ulmus bearing population of tree species maximum Shannon index (H) was observed in Badagram (2.427) and minimum (1.488) in Mohal. Maximum species richness was recorded (2.589) in Badagram and minimum (1.789) in Shamshi. Whereas in case of shrub species maximum shannon index (0.827) was observed in Seonidhar and minimum (0.676) in Naggar and maximum species richness was recorded (1.791) in Dhobi and minimum (0.488) in Babeli.
6. In Ulmus bearing population, maximum pH (8.05) was recorded in Rumsu at a depth of (0-15) and minimum (6.34) recorded in Pulang at a depth of (15-30). Whereas maximum EC recorded in Rumsu (1.18) at a depth of (0-15) and minimum (0.56) in Shamshi at a depth of (15-30). Maximum OC (1.82 %) in Naggar at a depth of (0-15) and minimum (0.2%) in Dhobi at a depth of (15-30). While maximum nitrogen (271 kg/ha) was recorded in Mohal at a depth of (0-15) and minimum (118 kg/ha) was recorded in Pulang and Rumsu at a depth of (15-30). Maximum phosphorous (21 kg/ha) in Dhobi at a depth of (0-15) and minimum (9 kg/ha) in Shamshi at a depth of (15-30). Maximum potassium (763 kg/ha) was recorded in Naggar at depth of (0-15) and minimum (138 kg/ha) in Babeli at a depth of (15-30).
7. Maximum recruits/ha were recorded (1125/ha) in Kullu range and minimum (500/ha) in Naggar range. Maximum unestablished seedlings (750/ha) were recorded in Kullu range and minimum (375/ha) in Naggar range. Maximum regeneration success (7.5%) was recorded in Kullu range and minimum (3.75%) in Naggar range.

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Title of Thesis	:	“Ecological Status of <i>Ulmus wallichiana</i> (Planch.) in Himachal Pradesh”
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Admission Number	:	F-2020-35-M
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Major Field	:	Forestry
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ABSTRACT

The present investigation entitled “**Ecological Status of *Ulmus wallichiana* (Planch.) in Himachal Pradesh.**” was conducted during the year 2020-22. Field studies were conducted in *Ulmus wallichiana* and non *Ulmus wallichiana* bearing forests of Kullu district of Himachal Pradesh. Laboratory studies were conducted in the Department of Silviculture and Agroforestry, Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (HP). Three ranges of Kullu forest division were selected *i.e.*, Kullu, Patlikuhl and Naggar. From each range three sites were selected randomly. In total nine sites were selected *i.e.*, Shamshi, Mohal, Babeli, Badagram, Seonidhar, Dhobi, Naggar, Pulang and Rumsu systematically with random start to assess the phytosociology, and natural regeneration status of *Ulmus wallichiana*. Data collection, analysis and interpretation were conducted based on standard field, laboratory and Statistical procedures. Species composition, soil characteristics and status of natural regeneration varies significantly along altitudinal gradient. The results of the present study revealed that the overall highest (145.74) IVI of tree species was found for *Ulmus wallichiana* in Babeli in kullu range and overall highest (118.66) IVI of shrub species was found for *Prinsepia utilis* in Naggar. The natural regeneration of *Ulmus wallichiana* were recorded maximum (7.5%) at lower altitudinal range (1100-1500m) and minimum (3.75%) at higher altitudinal range (1800-2100m). The soils of study site were found slightly acidic (pH: 6.24- 8.05) in nature. Soil available nitrogen, available soil phosphorus and organic carbon content showed a decreasing trend with increase in the altitudinal range. An increasing trend was observed in the available soil potassium as the elevation increased.

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APPENDIX-I

Effect of Range, Depth and Altitudinal gradient on Soil pH on all the three different ranges of Kullu Division with Ulmus bearing population and non-Ulmus bearing population

	Kullu				Naggar				Patlikuhl							
Depth	S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3	Mean
15-20	7.38	6.638	6.426	6.815	7.738	7.544	7.53	7.604	7.63	6.546	8.052	7.409	7.583	6.909	7.336	7.276
25-30	7.212	6.41	6.24	6.621	7.45	7.424	7.472	7.449	7.262	6.34	7.612	7.071	7.308	6.725	7.108	7.047
	7.296	6.524	6.333	6.718	7.594	7.484	7.501	7.526	7.446	6.443	7.832	7.24	7.445	6.817	7.222	

	Kullu				Naggar				Patlikuhl							
Depth	S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3	Mean
15-20	7.696	7.56	7.616	7.624	7.192	7.344	7.57	7.369	6.618	6.848	7.55	7.005	7.169	7.251	7.579	7.333
25-30	7.5	7.386	7.396	7.427	7.934	7.766	7.552	7.751	7.688	6.526	7.238	7.151	7.707	7.226	7.395	7.443
	7.598	7.473	7.506	7.526	7.563	7.555	7.561	7.56	7.153	6.687	7.394	7.078	7.438	7.238	7.487	

APPENDIX-II

Effect of Range, Depth and Altitudinal gradient on Soil EC (dS m⁻¹) on all the three different ranges of Kullu Division with Ulmus bearing population and non-Ulmus bearing population.

	Kullu				Naggar				Patlikuhl							
Depth	S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3	Mean
0-20	0.755	0.748	0.802	0.768	0.785	0.854	0.767	0.802	0.813	0.783	1.189	0.928	0.784	0.795	0.919	0.833
20-30	0.569	0.588	0.683	0.614	0.666	0.678	0.677	0.674	0.674	0.693	0.835	0.734	0.637	0.653	0.732	0.674
	0.662	0.668	0.743	0.691	0.726	0.766	0.722	0.738	0.744	0.738	1.012	0.831	0.71	0.724	0.826	

	Kullu				Naggar				Patlikuhl							
Depth	S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3	Mean
15-20	1.451	0.831	0.823	1.035	1.54	1.399	1.302	1.414	1.247	0.941	0.861	1.016	1.413	1.057	0.995	1.155
25-30	0.235	0.251	0.341	0.275	1.252	1.138	1.205	1.198	0.584	0.416	0.676	0.558	0.69	0.602	0.74	0.677
	0.843	0.541	0.582	0.655	1.396	1.269	1.253	1.306	0.915	0.679	0.769	0.787	1.052	0.829	0.868	

APPENDIX- III

Effect of Range, Depth and Altitudinal gradient on Soil Organic Carbon (%) on all the three different ranges of Kullu Division with Ulmus bearing population and non-Ulmus bearing population.

	Kullu				Naggar				Patlikuhl							
Depth	S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3	Mean
15-20	1.454	1.191	1.131	1.259	1.3	1.206	1.067	1.191	1.824	1.463	1.28	1.522	1.526	1.286	1.159	1.324
25-30	0.142	0.54	0.189	0.29	0.171	0.339	0.203	0.237	0.244	0.22	0.214	0.226	0.186	0.366	0.202	0.251
	0.798	0.865	0.66	0.774	0.735	0.772	0.635	0.714	1.034	0.841	0.747	0.874	0.856	0.826	0.681	

	Kullu				Naggar				Patlikuhl							
Depth	S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3	Mean
15-20	1.407	1.373	1.303	1.361	1.445	1.423	1.322	1.397	1.309	1.279	0.833	1.141	1.387	1.358	1.153	1.299
25-30	0.581	0.667	0.409	0.553	1.248	1.193	0.853	1.098	1.149	1.093	0.713	0.985	0.993	0.984	0.659	0.879
	0.994	1.02	0.856	0.957	1.346	1.308	1.088	1.247	1.229	1.186	0.773	1.063	1.19	1.171	0.906	

APPENDIX-IV

Effect of Range, Depth and Altitudinal gradient on Soil Available Nitrogen (kg ha⁻¹) on all the three different ranges of Kullu Division with Ulmus bearing population and non-Ulmus bearing population

	Kullu				Naggar				Patlikuhl							
Depth	S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3	Mean
15-20	247.596	271.582	172.2	230.459	302	279.2	259.6	280.267	151.8	176	124	150.6	233.799	242.261	185.267	220.442
25-30	242.85	234.196	143.6	206.882	290.6	184.4	207	227.333	137.6	118	118	124.533	223.683	178.865	156.2	186.25
	245.223	252.889	157.9	218.671	296.3	231.8	233.3	253.8	144.7	147	121	137.567	228.741	210.563	170.733	

	Kullu				Naggar				Patlikuhl							
Depth	S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3	Mean
15-20	248.2	265.4	237.6	250.4	143.2	137.6	175.2	152	149.2	255.2	274.8	226.4	180.2	219.4	229.2	209.6
25-30	204.6	188.8	168	187.13	133.2	131.8	144.8	136.6	141.2	175.2	159.4	158.6	159.66	165.26	157.4	160.77
	226.4	227.1	202.8	218.76	138.2	134.7	160	144.3	145.2	215.2	217.1	192.5	169.93	192.33	193.3	

APPENDIX-V

Effect of Range, Depth and Altitudinal gradient on Soil Available Phosphorus (kg ha⁻¹) on all the three different ranges of Kullu Division with Ulmus bearing population and non-Ulmus bearing population

	Kullu				Naggar				Patlikuhl							
Depth	S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3	Mean
15-20	10.3	14.6	15.5	13.46	16.3	18.35	21.6	18.75	16	18.252	17.8	17.351	14.2	17.068	18.3	16.523
25-30	9.3	12.25	13.94	11.83	13.4	14.95	18.95	15.76	14.1	14	14.4	14.167	12.267	13.736	15.76	13.922
	9.8	13.42	14.72	12.64	14.8	16.65	20.27	17.26	15.05	16.126	16.1	15.759	13.233	15.402	17.03	

	Kullu				Naggar				Patlikuhl							
Depth	S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3	Mean
15-20	10.725	13.68	16.667	13.691	13.361	15.909	16.23	15.167	12.509	16.553	16.779	15.281	12.199	15.381	16.559	14.713
25-30	9.338	11.351	12.489	11.059	11.587	11.985	13.098	12.224	10.363	15.217	15.091	13.557	10.43	12.851	13.56	12.28
	10.032	12.516	14.578	12.375	12.474	13.947	14.664	13.695	11.436	15.885	15.935	14.419	11.314	14.116	15.059	

APPENDIX-VI

Effect of Range, Depth and Altitudinal gradient on Soil Available Potassium (kg ha⁻¹) on all the three different ranges of Kullu Division with Ulmus bearing population and non-Ulmus bearing population

	Kullu				Naggar				Patlikuhl							
Depth	S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3	Mean
15-20	606.2	322	218.2	382.13	505.4	555	464.2	508.2	763	695.2	389.8	616	624.86	524.06	357.4	502.11
25-30	482.2	224.2	138.2	281.53	366.2	418.8	373.6	386.2	566.6	519.2	332	472.6	471.66	387.4	281.26	380.11
	544.2	273.1	178.2	331.83	435.8	486.9	418.9	447.2	664.8	607.2	360.9	544.3	548.26	455.73	319.33	

	Kullu				Naggar				Patlikuhl							
Depth	S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3	Mean
15-20	101.66	118.61	117.52	112.60	130.22	140.90	135.36	135.49	148.12	172.59	142.47	154.39	126.67	144.03	131.79	134.16
25-30	98.64	91.05	102.09	97.26	98.66	137.09	118.42	118.06	142.37	162.10	131.68	145.38	113.22	130.08	117.40	120.23
	100.15	104.83	109.80	104.93	114.44	138.99	126.89	126.77	145.24	167.34	137.08	149.89	119.94	137.06	124.59	

BRIEF BIO-DATA

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12 th Class	March 2015	DALIMSS, Varanasi	Central Board of Secondary Education	59%	Second
B Sc	July 2020	SHUATS, Allahabad agriculture University	Sam Higginbottom University of Agriculture, Technology and Sciences	67.4%	First

Whether sponsored by some state/
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