ECOLOGICAL CHARACTERISTICS OF SOME IMPORTANT PLANT SPECIES IN LAHAUL VALLEY, HIMACHAL PRADESH.

THESIS

By

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(S-2009-30-23)

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of

MASTER OF SCIENCE IN BASIC SCIENCES
(DEPARTMENT OF BIOLOGY AND ENVIRONMENTAL SCIENCES)
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When you feel like breaking down or crashing in,
Who do you turn to, to forgive your sin?
When you cried your lonely tears,
Who will be there to fight your fears?
And when it feels like no one would understand,
Who was there to hold your hand?

There are people whom you can't replace,
They're the ones who gave you your face.
They'll love you through thick and thin,
They show you the light from deep within.
And if by chance, you happen to die,
They'll be the ones who will really cry.
You see, my friend, there's no one who can love you more,
Then your very own parents, that's for sure.
Always remember that this is true,
That wherever you go, your parents will be there

Thank u nanaji..... thank u paa n maa.....

Love u sooo much..... ☺

Dr. Virendra Singh

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Certificate-I

This is to certify that the thesis entitled **"Ecological Characteristics of some Important Plant Species in Lahaul valley, Himachal Pradesh."** submitted in partial fulfillment of the requirements for the award of the degree of **Master of Science (Basic Sciences)** in the discipline of **Environmental Sciences** of CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur is a bonafide research work carried out by **Ms. Natasha Sharma (Admission No. S-2009-30-23)** daughter of **Sh. Som Parkash Sharma,** and under my supervision and that no part of this thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been duly acknowledged.

(Dr. Virendra Singh)
Major Advisor

Place: Palampur
Dated: 5.7.2011

Certificate-II

This is to certify that the thesis entitled **"Ecological Characteristics of Some Important Plant Species in Lahaul valley, Himachal Pradesh"** submitted by **Ms. Natasha Sharma (Admission No. S-2009-30-23)** daughter of **Sh. Som Parkash Sharma** to the CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur in partial fulfillment of the requirements for the degree of **Master of Science (Basic Sciences)** in the discipline of **Environmental Sciences** has been approved by the Advisory Committee after an oral examination of the student in collaboration with an External Examiner.

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(NATASHA SHARMA)

Place: Palampur

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LIST OF ABBREVIATIONS USED

Sr. no.	Abbreviation	Meaning
1	*et al.*	et alii (and others)
2	*i.e.*	Id est (that is)
3	*viz.*	vi delicet (namely)
5	p.	Page
6	pp.	Pages
7	^{o}C	Degree Celsius
8	g	Gram
9	kg	Kilogram
10	/	Per
11	%	Per cent
12	Fig.	Figure
13	cm.	Centimeter
14	Ml	Milliliter
15	Tonnes/ha	Tonnes per Hectare
16	gm/l	Grams per litre

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ABSTRACT

The three species namely *Hippophae rhamnoides* ssp. *turkestanica, Artemisia maritima* and *Juniperous communis* growing in Lahaul, a semi-arid region of Himachal Pradesh were considered for the study. The architecture of the above ground parts and pattern of root distribution in the three species were studied. The plant height was maximum for *Hippophae rhamnoides* (68.3 cm) followed by *Juniperous communis* (42.5 cm) and *Artemisia maritima* (41.2 cm). The above ground parts of *Hippophae rhamnoides* were most compact i.e. 9.7 number of primary branches and 3219.9 cm^2 crown spread followed by *Artemisia maritima* (11 number of branches and 3008.4 cm^2) and *Juniperous communis* (4.1 number of branches and 1914.8cm^2), respectively. Below ground parts of *Hippophae rhamnoides* were most extensive with the mean horizontal root spread up to 151.2 cm followed by *Juniperous communis* (150.56 cm) and *Artemisia maritima* (71.86 cm). However, the root depth was maximum in *Artemisia maritima* (81.7 cm) followed by *Juniperous communis* (54.22 cm) and *Hippophae rhamnoides* (42.1 cm). In *Hippophae rhamnoides*, horizontal root system was most extensively developed in the early stage of plant development, holding soil particles on the fragile sites, followed by *Juniperous communis* and *Artemisia maritima*. However, all the three plant species could be considered as an important approach to ecosystem stability and the soil loss will also be reduced by the presence of these plant communities.

(Natasha Sharma) **Student** **Date:** 5.7.11	**Head of Department**	**(Dr. Virendra Singh)** **Major Advisor** **Date:** 5.7.11

INTRODUCTION

1. INTRODUCTION

Lahaul-Spiti is an integral part of Indian Cold Desert area of Himachal Pradesh in North Western Himalayas. 25 per cent of the total geographical area of cold desert (74,809 km^2) occurs in Lahaul-Spiti district. Scant rainfall, massive snowfall, high wind velocity, extreme temperature conditions from low to high, sparse vegetation, high UV radiation, intense solar radiation and extremely xeric conditions are the common features of the this region. The diverse climate and the varied environmental conditions prevailing in Lahaul support diverse habitat and ecosystems with equally diverse life forms. But this unique and the most beautiful corner of the Himalayas is under threat due to various environmental problems prevailing in the region these include the utilization of the slope land resources for agriculture, poor water management soil erosion, and degradation of soil fertility.

The degradation of the soil resources is accounted as one of the real problems. Steep slopes, present and past glaciations, and sparse vegetative cover has helped high soil erosion rates in these regions. Erosion results in the degradation of a soil's productivity in a number of ways. It reduces the efficiency of plant nutrient use, damages plant seedlings, decreases plants, rooting depth, reduces the soils water holding capacity, decreasing its permeability, increases runoff and reduces infiltration rate (Troeh 1991). Throughout the world, 18.4 tonnes/ha of topsoil is lost on average every year. At the same time, species diversity of plants, animals, and microbes is significantly reduced. One of the most effective measures for erosion control and regeneration the degraded former soil is the establishment of plant covers. Soil erosion can be controlled through a process of assessment at regional scales for the development and restoration of the plant cover, and the introduction of conservation measures in the areas at greatest risk (Subramani *et al.* 2006). To an estimate from May to September, every year the Chenab river of this district gets heavily loaded with

silt, which is recorded to be high as 34.27 gms per litre of water. The problem of soil erosion is widely prevalent in Lahaul leading to deposition of silt in Chandra-Bhaga and Spiti rivers. For this, the forest plants play a vital role in the conservation of soil in these areas. These plants include handful species like *Betula utilis*, *Artemisia maritima*, *Pinus wallichiana*, *Juniperous cummunis*, *Cedrus deodar* and *Hippophae rhamnoides*. Their plantation is of great appreciation, as these species have their own ecological as well as economical importance.

Seabuckthorn (*Hippophae)* is one of the unique medicinal and aromatic plant of the region and belongs to the family of Elaeagnaceae (Lu Rongsen 1992). Seabuckthorn is a dioecious multi-branched, medium sized or small deciduous tree or thorny shrub, reaching 2 to 4 m in height with stout branches forming a round often symmetrical head. The root system is characterized by nitrogen fixing nodules (Akkermans *et al.* 1983). In addition to being a nitrogen fixer, seabuckthorn has a strong and extensive root system, which can penetrate to 3 m and propagates by producing suckers from this root system. The distribution of seabuckthorn ranges from Himalayan regions including India, Nepal, Bhutan, Pakistan and Afghanistan, to China, Mongolia, Russia, Kazakhstan, Hungary, Romania, Switzerland, Germany, France and Britain, and northwards to Finland, Sweden and Norway (Rousi 1971; Singh 2003). All these attributes combine to make seabuckthorn an ideal plant for erosion control for which it is used extensively in China where they have upward of 30,00,000 hectares planted for this purpose.

Artemisia belongs to the family Asteraceae, which is the largest family of flowering plants in terms of the number of species. The genus *Artemisia* contains between 200 and 400 described species. They can be found from the Arctic alpine or mountainous areas to the dry deserts, and dominate the steppe communities of Asia, South Africa, and the New World. Artemisia is known for its medicinal values as well as for environmental conservation of fragile slopes (Mucciarelli and Maffei 2002). These are mostly perennial plants and are

frequently aromatic. *Artemisia maritima* L. stems rise about a foot or 18 inches in height. The leaves are twice pinnatifid, with narrow, linear segments and like the whole plant, are covered on both sides with a coat of white cottony fibers. The plant is the source of the alkaloid Santonin.

Junipers are the second most diverse genus of the conifers and consist of approximately 67 species and 28 varieties. The species belong to family Cupressaceae. It generally grows in poor, rocky and sandy soils. *Juniperus communis* has one of the widest global distributions of any gymnosperm, occurring throughout most of Europe, North Africa, and North Asia Southwards to the Himalaya, and North America from the mountains of North California to Pennsylvania. The root system is highly developed. The presence of antimycobacterial terpenoids in *Juniperus communis* aerial parts and roots justifies, to some extent, the ethnomedicinal use of this species as a traditional anti-TB remedy (Gordien *et al.* 2009).

Considering their uniqueness and high ecological values, the present study of the three important species will be a great source of information for their potential in environmetal conservation of mountain ecosystem in the coming years. The present study 'Ecological characteristics of some important plant species in Lahaul valley, Himachal Pradesh' was planned with the following major objectives:

1. To study the morphology and architecture of plant canopies of seabuckthorn *(Hippophae rhamnoides)*, Artemisia (*Artemisia maritima*) and Juniper *(Juniperous communis*) in Lahaul Valley.
2. To study the pattern of course roots distribution of seabuckthorn *(Hippophae rhamnoides*), Artemisia (*Artemisia maritima*) and Juniper (*Juniperous communis*).

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Naturally occurring plants in forest ecosystem evidently play an important role in ecosystem stability. Field studies on the ecological effects of native plants and their resistance to adverse climatic stress, and soil erosion is of great appreciation. The quantative assessment of soil erosion hazards requires full knowledge of many factors related to some soil properties, species growth parameters, the architecture and finally the root distribution of the desirable plants. The small-scale effects of plant morphology in improving soil quality and reducing runoff and soil loss have remained unclear, especially in some arid environments with sparse vegetation. Below ground (root) interactions in forest systems are widely recognized as one of the most important challenges. The species which are opted for the studies, *i.e. Hippophae rhamnoides*, *Artemisia mariitima* and *Juniperous communis* have not been studied well with concern to the environmental degradation in the past particularly in India. Though, they have been taxonomically characterized a long back.

In view of the facts that very limited information is available on architecture and pattern of root systems of three Indian species, which grow very widely in cold desert, available information on the subject is reviewed briefly under the following subheads:

2.1 Architectural and Morphological Characterization.

2.1.1 *Hippophae* ssp.

- **i) Studies in Abroad**
- **ii) Studies in India**

2.1.2 *Artemisia* ssp.

- **i) Studies in Abroad**
- **ii) Studies in India**

2.1.3 *Juniperous* ssp.

- **i) Studies in Abroad**
- **ii) Studies in India**

2.1.4 Other Species

2.2 Potential of species to control Soil Erosion

2.1 Architectural and Morphological Characterization

2.1.1 *Hippophae* ssp.

i) Studies in Abroad

Gatner and Gardener (1970) studied the morphology of seabuckthorn plant. Seabuckthorn is a dioecious species with male and female flowers on separate trees. Seabuckthorn is a pioneer species, and often is the first woody species colonizing open areas, such as abandoned farmland, wasteland, and rocky islands. According to the studies, the plant rapidly spreads by rhizomatous roots, and suckers develop at 2–3 years of planting, which quickly colonize adjacent areas. The presence of thorns, terminal and lateral, is a biological characteristic of the seabuckthorn. Observations showed a large variation in terms of thorn density, length, shape, and sharpness in natural populations. It has numerous stems and will form a colony, spread by rhizomes, if left to grow naturally. The root system of seabuckthorn consists of a light-colored, thick, rope-like primary root with horizontal rhizomatous side roots. On sandy meadow soil, the seabuckthorn forms a root system of the surface horizontal type which can be found in a layer 0.1–0.5 m deep. This characteristic is particularly important since seabuckthorn is used to control soil erosion with this rapidly spreading root system. Like other members of the Elaeagnaceae, 1–2 year old seabuckthorn plants have root nodules, which are small round, and yellowish, containing *Frankia*, a nitrogen-fixing microorganism.

Seabuckthorn (*Hippophae rhamnoides* L.) is a hardy, deciduous shrub belonging to the family Elaeagnaceae. Natural seabuckthorn stands are also widespread in Europe on river banks and coastal dunes along the Baltic Coasts of Finland, Poland, and Germany. The re-classified Hippophae, recognized three species based on morphological variations: *H. rhamnoides* L., *H. salicifolia* D. Don, and *H. tibetana* Schlecht. Growth habit of seabuckthorn varied from a tree (H. salicifolia) to a dwarf bush (*H.tibetana*) and a bush-like habit (*H. rhamnoides*). *Hippophae rhamnoides* was further divided into 9 subspecies: *carpatica,*

caucasica, fluviatilis, gyantsensis, mongolica, rhamnoides, sinensis, turkestanica, and *yunnanensis* (Rousi 1971).

Alternate and willow-like leaves emerge 7–10 days after the flower buds, ranging from 3 to 6 cm in length, narrow, and lanceolate with a silver-grey color on the upper side (Synge 1974). Seabuckthorn is a woody, fruit-bearing, deciduous, dioecious, spiny shrub or tree covered with silvery scales. It is usually spine scent and usually reaches 2–4 m in height, although some in China can reach up to 18 m, and others grow no higher than 50 cm. It has brown or black rough bark and a thick greyish-green crown. It bears yellow or orange fruits that have been used for centuries in both Europe and Asia for food, therapeutic, and pharmaceutical purposes (Bailey and Bailey 1978). Seabuckthorn tolerates low temperatures to –43°C, high soil pH up to 8.0, and salt from sea water around the coastal regions (Bond 1983). Akkermans *et al.* (1983) showed that seabuckthorn has an extensive root system which is capable of holding the soil on fragile slopes. It can be planted on marginal land due to its symbiotic association with nitrogen-fixing actinomycetes on its root system. Lian (1988) reported the most recent classification of Genus *Hippophae*. There are a total of 6 species and 12 subspecies. *Hippophae* is a hardy shrub or small tree, 2-5 m height. Epidermis of branches is silvery, with many and usually branched thorns. Leaves are alternate, narrow, 2-5 mm wide, both surfaces being silvery. Flower buds are spiral tower-shaped. The length of most fruits greater than width. Fruits are usually red, reddish orange in colour. Carpopodium is 3-7 mm long. Seabuckthorn occurs as a native plant distributed widely throughout temperate zones between 27 and 69EN latitude and 7EW and 122EE longitude (Pan *et al.* 1989) including China, Mongolia, Russia, United Kingdom, France, Denmark, Netherlands, Germany, Poland, Finland, Sweden, and Norway (Wahlberg and Jeppsson 1990).

Rongsen (1992) studied the distribution of seabuckthorn in Asia. The majority of *Hippophae* species are distributed around the northern region of China, throughout the Himalayan region, including India, Nepal, Bhutan, and in

the northern parts of Pakistan and Afghanistan. Seabuckthorn grows on hills and hillsides, in valleys and river beds, along coastal regions and on islands, in small isolated or large continuous pure stands, or in mixed stands with other species of shrubs or trees. Roots of seabuckthorn are also able to transform insoluble organic and mineral matter in the soil into more soluble forms.

Qinxiao (2003) studied that seabuckthorn plays an important role in soil erosion control, reclamation of degraded and wastelands, besides improving soil fertility through nitrogen fixation and helps in poverty alleviation through economic benefits to local people in China. Seabuckthorn plantation makes a 2-3 cm thick litter ground cover to the woodland, along with 4-10 m horizontally spread and 20-40 cm vertically deep, well developed root system network, which effectively helps in soil and water conservation. The properly developed canopy of 5-7 years old stand intercepts about 10-20 tons/square meters rainwater, thereby conserving soil moisture and reducing rain splash. Also seabuckthorn improves the fertility and physio- chemical properties of the soil.

ii) Studies in India

Singh *et al.* (1995) studied the distribution of seabuckthorn in Himachal Pradesh. Seabuckthorn grows mainly in the districts of Lahaul-Spiti, parts of Kinnaur and Chamba, which are surrounded by Tibet state of China and Ladakh region of Jammu and Kashmir state in the north on the southern side. Seabuckthorn grows at 2500-3300 m asl in Lahaul. In Lahaul, it grows throughout the length of the Chandra valley in the villages, i.e. Sissu, Khorpani, Raling, Khongsar, Gondhla and Dalang. Several good stands of *H. rhamnoides* sub species *turkestanica*, grows on both sides of Bhaga river (Tinu, Gemur, Jispa and Darcha). In Chandra-Bhaga (Chenab) valley, seabuckthorn is found as component of agroforestry systems in the villages Kirting, Sansa, Jhalma, Jhunda, Jasratha and Madhgaon. In Mayar valley, seabuckthorn is spread in Urgos and Chaling villages.

Singh and Dogra (1996) studied the above ground biomass in a stand of seabuckthorn, selected for genetic improvement studies, varied from 0.13 kg per

plant with a 4.6 cm girth and 78 cm height, to 6.6 kg in the plant with a 19 cm girth and 360 height. Fruit yield also varied from 10 g to 950 g per plant. Root turion seedlings were estimated on the horizontal roots of seabuckthorn plants growing on the river side. Number of sister plants of several generations varied from 9 in a 245 cm long root to 29 plants in 682 cm long root.

Singh [illegible] (1994) studied the distribution, characterization, regeneration, biomass of seabuckthorn in Lahaul valley located in high hill dry temperate Himalaya. Detailed studies were made on H. *rhamnoides* subsp. *turkestanica* growing in 3 protected stands near Udaipur. The plant has a high regenerative potential even in dry infertile soil. Horizontal roots extend up to 245-680 cm and the surficial roots produced 9-27 root turion seedlings per root. The fruit yield varied from 590 to 956 g per plant and the seed oil content varied from 8.2 to 11.7%, and protein content ranged from 25.8 to 35.9%. Basistha *et al.* 2001 studied seabuckthorn with special reference to agro-technique in the Sikkim Himalayas. According to him, seabuckthorn grows in dry temperate regions in north district of Sikkim at an altitude of 2280-3100 m asl and about 300 ha area is under seabuckthorn in Sikkim. Seabuckthorn flowering season was observed in February-March and fruiting season in November-February.

Singh and Singh (2001) studied the distribution of seabuckthorn in the cold deserts of Ladakh in the Jammu-Kashmir state, comprising Leh and Kargil districts of Jammu And Kashmir State. Seabuckthorn was reported growing in four of the five valleys of Ladakh, i.e. Indus, Nubra, Zanskar and Suru. It grows well on the riverbeds, riversides, and slopes. It was found growing upto 4100 m asl in the region. In Indus valley, seabuckthorn grows from Thiksey to Shey, Choglamsar, Spituk, Phyang, Nimmu, Bazgo and Saspol. It also grows well in villages like Turtuk, Thoise, Partapur, Hundar and Khalsar. The region possessed a very rich resources under seabuckthorn.

Singh [illegible] (2001) studied the pattern of root distribution in 1-2 years old nursery plants and 10-12 years old stand of seabuckthorn. The horizontal roots in 1-2 year old extended up to 65 cm, and vertical roots were 47 cm deep. 92 % of

root biomass was confined in top 10 cm of soil horizon. The root system of 10-12 year old plants was well developed and extended horizontally up to 537 cm and vertically up to 127 cm. Strong root system of seabuckthorn makes it a valuable soil binder on fragile mountainous land.

Singh (2003) studied the five exotic improved forms of seabuckthorn at Kukumseri in Lahaul. The first exotic form "H1-1" introduced in 1995, after 7 years of growth, had a diameter of 2.8 cm at base, 178 cm of height, a narrow canopy spread of 29 cm. This form had the fruit weight of 30.5 cm/100 fruits. The two other exotics HI-2 and HI-3, after 4 years of growth had the heights of 37 and 52 cm and canopy spread of 6.5 and 12 cm, respectively. The other two exotics HI-4 and HI-5 introduced in 2001, have also adapted to the local conditions. No decease has been recorded in any exotic form introduced at the center. All the forms were nearly thorn less, except HI-4. Dwivedi *et al.* (2004) studied the morphological and biochemical variations in naturally growing population of seabuckthorn in Ladakh. They showed that there was a considerable variation in plant morphology in fruit, leaf, root, stem, bark, thorn seed etc were observed in *Hippophae rhamnoides.* Plant is highly thorny with 4-24 ft height. It has tap root and runs horizontally up to 7 m.

Singh *et al.* (2004) studied the distribution, architectural, morphological and biochemical variations in 9 populations of *Hipophae rhamnoides* and 1 population of *H. salaicifolia,* growing in 4 valleys of Lahaul sub-division of district Lahaul-spiti, a dry temperate region of Himachal Pradesh. The plant size, canopy spread, weight of fruit, seed and color of seed were measured. The plant size varied from 101-271 cm in *H. rhamnoides* to 400-700 cm in *H. salicifolia*. The weight of 100 fruits varied from 11.6-19.5 g in *H. rhamnoides*, to 30.7 g in *H. salicifolia* and the weight of 100 seeds also varied from 0.64-1.26 g in *H. rhamnoides*, to 1.03 g in *H. salicifolia*, also the shape of the seeds in *H. rhamnoides* was oval to ovate, elongate, round elliptical, whereas it was ovate in *H. salicifolia.*

Sankhyan *et al.* (2005) studied the morphology of sea buckthorn (*Hippophae rhamnoides*) populations at various sites in Lahaul (Jhalma, Sansha and Gondhla), Spiti (Tabo, Lingthi and Shego) and Kinnaur (Meeru, Chitkul and Chango), Himachal Pradesh, India. According to his observation the plant height ranged from 220 cm (Shego) to 300 cm (Chango). The collar diameter varied from 2.80 cm (Meeru) to 6.40 cm (Jhalma). The canopy spread was lowest in Jhalma (42 cm) and greatest in Gondhla (107 cm). The number of thorns per 10 cm in a 3-year-old branch varied from 2.30 (Sansha) to 3.50 (Lingthi). Plant height was greatest (2.73 cm) in Kinnaur (dry temperate climate) and lowest (2.46 cm) in Spiti (harsh cold desert conditions). The collar diameter was greatest in Spiti (3.73 cm) and lowest in Lahaul (2.96 cm). Canopy spread was also greatest in Spiti (90.0 cm) and lowest in Kinnaur (58.0 cm). The study concluded with the fact that the plant height decreased with increasing altitude in moist environment and the plants in sloping habitat were slightly shorter than those in river sides. The collar diameter and canopy spread increased with increasing latitude in river sides.

Rana *et al.* (2007) also studied the morphological variations in natural populations of seabuckthorn in Lahaul valley. In general, fruit weight for *H. rhamnoides* ssp. *turkastanica* varies from 11.57-25.41 gm/100 fruits, fruit size 0.5x0.4-0.9x0.8 cm (length x width). The numbers of thorns were 3 – 12 per 10 cm shoot length, leaf size 2.1x0.6 – 9.5x0.9 cm. However, for *H. salicifolia* fruit weight varies from 24.93–29.69 gm/100 fruits, fruit size 0.5x0.4 – 0.9x0.8 cm (length x width), number of thorns were 2 – 10 per 10 cm shoot length, leaf size 4.0x0.4 – 8.5x1.1 cm.

2.1.2 *Artemisia* ssp.

i) Studies in Abroad

Nadkarni (1976) studied *Artemisia maritima* with respect to distribution, taxonomy and morphology in Pakistan. According to him the plant grows abundantly in high altitude of NWFP and Baluchistan provinces of Pakistan. *A.maritima* L. (Syn: *A. brevifolia* Wall., *A.herba alba* Asso., *A. kurramensis*

Qazalbash) belongs to family Asteraceae. The Asteraceae consist of more than 1100 genera and perhaps as many as 20000 species, being the second largest family in the flowering plants. The only other family of comparable size is the Orchidaceae with some estimates run as high as 30000 species (Cronquist 1981). Mingxuan *et al.* (1990) studied the root system of *Artemisia dalailamae. Artemisia dalailamae* is a major species of the semi-desert vegetation in Gansu province. The study showed that the plant had a relatively shallow but well laterally developed root system. The average root system of the plant had 118 g of dried weight, 211.25 cm^3 of volume and 997.56 m of total length, with 77.72% of the root weight and 75.74% of the volume distributed in the soil layer of 0-20cm. Within the soil layer of 0-30 cm the root system was dominated by roots larger than 2 mm in diameter. Barney *et al.* (2002) stated that *Artemisia vulgaris* L. exhibited extreme morphological and physiological variability in different ecological regions, including: branching habit (branched or non-branched), degree of branching, leaf morphology within an individual and within a population and diameter of rhizomes (hair-like to 1 cm) population.

Ghafoor (2002) studied the Artemisia genus. According to him, Artemisia is a taxonomically complex genus because some species have different morphological forms. Artemisia species are mostly herbs, and sometimes shrubs, usually with strong aroma. Plant bodies are often densely hairy. Leaves are pinnatifid to pinnatisect with variable dimensions. Capitulum inflorescence is generally in the form of a paniculate-raceme arrangement. Herbaceous involucral bracts are present. Receptacles are convex or flat and naked or covered by hairs. Ray florets are pistillate. Corolla color is yellow or green and rarely brown. Disk florets are bisexual. Cypselas are obovoid to oblong and mostly brown. Watson *et al.* (2002) studied the phylogeny of subtribe *Artemisiinae* (Asteraceae), including Artemisia and its allied and segregate genera.

Valles *et al.* (2003) stated that most of the species of Artemisia are perennial with only ten being annuals or biannual. Due to high number of species, ecological and economic importance, the genus Artemisia has been the

object of diversity focused studies. Fox (2004) studied the morphological characteristics in *Artemisia spinescens.* He found it to be summer-deciduous shrub and small, round and prickly with a height of 4 to 10 inches (10-25 cm) and a spread of 8 to 12 inches (20-30 cm) with leaves alternate, fan-shaped, with 3-5 linear spatulate lobes, which are again divided. Surfaces are hairy. The buds are large and hairy. Fox in 2004 studied the extensive root system in *Artemisia spinescens* which showed that it has a short, thick, vertical taproot up to 6 inches (15 cm). Peek *et al.* (2004) studied the fine root distribution and persistence under field conditions of three co-occurring Great Basin species of different life form including *Artemisia tridentate.* Zhang *et al.* in 2008 investigated the distribution and dynamics of roots in a revegetated stand of *Artemisia ordosica* Kracsh. in the Tengger Desert during the growing seasons of 2004 and 2005. The root systems of *Artemisia ordosica* are distributed vertically in the uppermost soil profile, especially for coarse roots, which were concentrated in the 0.2-m soil profile. The horizontal distribution of coarse roots was limited to a range of 0.6 m and 0.4 m away from the trunk for root length and weight, respectively. The total root biomass and fine root biomass were 0.42 and 0.26 kg m^{-2}, which accounted for about 80% and 50% of the total biomass, respectively. The growth and distribution of fine roots were mainly related to soil water content.

In 2011 Khan *et al.* studied important medicinal plants of Chitral gol national park at Pakistan. According to him *Artemisia maritima* is a wild shrub with the height upto 100 cm and also found the plant decoction is used as antiseptic and anti-inflammatory and antimalarial. The leaves which were linear and obtuse apexed were utilized for cooling purposes. Plant powder is used for intestinal worms. The plant is also used as broom.

ii) Studies in India

Dey (1980) studied a large number of medicinal plants including *Artemisia maritima* in India. According to him it is a bitter aromatic herb or low shrub with much divided leaves and inconspicuous flowers born on numerous small heads.

Kaul *et al.* (1984) studied the genus *Artemisia* L. in North-West Himalaya with particular reference to Kashmir. The study deals with 20 species of the genus *Artemisia* occurring in the North-West Himalaya. The chromosome counts were given for 18 species (for 3 species for the first time). Two new species, *A. banihalensis (A. roxburghiana* agg.) and *A. cashemirica (A. parviflora* agg.), were desciribed. Singh *et al.* (1990) studied the root characteristics and the biomass of *Artemisia maritima.* According to the study a brief data was presented on the growth characteristics of this deciduous shrub in Himachal Pradesh. The study showed that the plant was aromatic and a valuable drug, santonin, is extracted from its flower buds. The species was a good soil binder on open shaly slopes with many small horizontal side branches. The root system grows primarily in the top 6 to 21.7 inches (15-55 cm) of soil; but in gravel-free sandy soils, roots may extend up to 6 feet (1.8 m).

Hayat *et al.* (2009) studied the ethnobotany of the genus Artemisia L., the plant morphological descriptions were noted by means of observations and ethnobotanical details were documented through questionnaires and meetings, with herbalists and local inhabitants. Twelve *Artemisia* species were popularly found *Artemisia absinthium* L., *Artemisia annua* L., *Artemisia brevifolia*Wall. ex DC., *Artemisia dracunculus* L., *Artemisia dubia* Wall.ex Besser, *Artemisia herba-alba* Asso., *Artemisia japonica* Thunb., *Artemisia maritima* L. ex Hook.f., *Artemisia roxburghiana* Wall. Ex Besser, *Artemisia santolinifolia* Turcz. ex Krasch., *Artemisia scoparia* Waldst. & Kit. and *Artemisia vulgaris* L and was used commercially by the inhabitants. In his studies he characterized *Artemisia maritima* L. Ex Hook.f as a plant with a strongly aromatic shrub numerous erect, up to 100 cm tall branches. Basal and middle leaves were whitish cottony appearance, 2-2.5 X 3.5-4 cm, 2-pinnatisect, with numerous small segments, linear with obtuse apex. Upper most leaves were simple and linear in shape. Oblong to ovoid capitula, present in the axil of upper leaves forming a raceme and 10 mm in diameter. It contains 3-10 florets. Minute cypselas are oblong to obvoid in shape.and the flowering period is from August to September.

Artemisia maritima of the family Compositae is a perennial temperate species with localized distribution. The species were reported from some areas in northwestern India, including Kashmir, Kurram, Kishtwar and Gurez. In Kishtwar District, Jammu and Kashmir (the area of the study), the species forms extensive natural populations. The plant perennates in winter via horizontal rhizome sprouting in the month of March. It remains in vegetative state for 5–7 months, and subsequently flowers in October/November, when the day temperature fluctuates between 25°C and 30°C. Seed set is initiated during December and averages 83.4% on open pollination. Individual plant attains an average height of 70.34 cm. Each plant is branched from the base and bears white, green to grey pinnatisect leaves. The flowers arise in axillary spikes terminating into heads. The small, oblong flower heads, each containing 6–13 tubular florets, are yellowish to brownish-red in colour (Parihar *et al.* 2009).

2.1.3 *Juniperous* ssp.

i) Studies in Abroad

McGowan *et al.* (1998) studied the status of *Juniperus communis* ssp. *nana* (dwarf juniper) communities at six sites in north and north-west Scotland. Sites ranged in area from 0.15-2.0 km^2 and showed few signs of management. *Juniperus communis* is a component of the montane scrub vegetation community. The physiognomy of individual plants and plant density varied within and between sites. The communities appear to be at risk because of a lack of seedling recruitment and from possible impacts of grazing or burning. Environmental change and nitrogen deposition may also affect the dynamics of dwarf juniper populations. Houle *et al.* (1999) studied the spatial pattern of a *Juniperus communis* var. *depressa* population on a continental dune in subarctic Québec, Canada. Sullivian (2001) studied the leaf morphology of *Juniperus communis*. According to him the leaves were mostly 8–20 × 1–1.5 mm, loosely set, patent, spreading at almost right angles to the stem, gradually tapering to a sharp point so that branchlets are prickly to the touch. Mature female cone globose usually with one seed. Adams (2004) studied the genus

Juniperus communis. According to him, the shrub is erect and dense up to 1.5 m or prostrate. Leaves spreading, needle like, 6-15 mm, with a broad bluish white band above, in whorls of 3, stems swollen below leaf insertion. Male cones are tiny ovoid. Fruit a fleshy blue-black berry, ovoid, 6-8 mm, 3 seeded.

Sweeney (2004) studied the growth of trunk in *Juniperous communis* species. According to his observation, the growth of the trunk is frequently one-sided with many incomplete rings, commonly due to browsing damage. He also mentioned that the shoots were either erect or spreading and very shiny, initially they are greenish-yellow, turning reddish-brown with age. Ward (2007) studied that female branches tend to be smaller and more multi- stemmed although in young stands at Porton Down females have been seen to be taller than the males. According to him Juniper is usually a multi-stemmed shrub, or sometimes a small tree. The canopy form varies from a prostrate, mat-forming shrub to upright.

Verheyen *et al.* (2005) studied the *Juniperus osteosperma* root and correlated it with the soil water potential. In the study Juniper exhibited a flexible root depth distribution throughout the 20 months of the study, indicating the potential to respond to shifting soil water resources despite long fine root life spans.

ii) Studies in India

Kirtikar and Basu (1935) described the genus *Juniperus communis* L., a gymnosperm, belonging to the family Cupressaceae (common name-Juniper). It is a high altitude shrub which occurs at 2000 to 2400 m in Kumaun Himalaya. The species vernacular names are Jhora, Betar, Pama, etc. It is well documented for its medicinal value for diarrhea, abdominal pain, tumors, piles, bronchitis and indigestion in traditional system of medicine. Santosh (1983) studied the morphology and embryology of *Juniperous communis* spp.

Kramer and Kozlowski (1979) studied the root systems of 55 *Juniperus occidentalis* Hook. ssp. *occidentalis*. The plants excavated were 4–65 cm tall, 3–28 years old at two sites in central Oregon. Above and below ground tree components were

measured, and root system morphology was studied. According to the study the prominence of tap root length and biomass declined as trees grew. In the tallest trees total root length for was 152 m, lateral roots extended 5.7 m from the trunk, occupied 102 m^2 of soil, and were concentrated in the upper 25 cm of the profile. Tree height was a good predictor of root parameters of biomass, length, tap root penetration and lateral root extension with r^2 values of 0.82–0.96.

Bhattarai *et al* (2006) studied the Ethnobotany of Junipers (*Juniperous indica* Bertol., *Juniperous squamata* Buch.-Ham. ex D. Don and *Juniperous communis* L.) in Manang district, Trans-Himalayan region of Nepal. Fruits, leaves, stems and barks are used in traditional medicinal practice for curing of cough and cold, tonsillitis, headache, malarial fever, neck pain, to reduce blood pressure, chest pains, lung diseases, bronchitis and respiratory diseases, for animals affected by different kinds of insects, scabies and wounds. Also the Juniperous species develop anchoring root system binding firmly the soil. Juniperous species grow along riverbanks, canals, and sloppy fields preventing soil erosion due to stormy winds that commonly prevail in Manang district.

2.1.4 Other species

Dhyani *et al.* (1990) studied the growth performance, rooting behaviour and distribution of roots of five species (*Bauhinia purpurea, Grewia optiva, Eucalyptus tereticornis, Leucaena leucocephala* and *Ougeinia oojeinensis*). Total root weight and root volume were highest in *E. tereticornis* and lowest in *B. purpurea.* There was significant soil nutrient enrichment under the tree canopies, particularly under *B. purpurea, O. oojeinensis* and *L. leucocephala.* Bisht *et al.* (1993) showed that there is a wide variation in growth pattern and shoot architecture in nine important multipurpose trees in an arid region of India. In his study he took six-year-old trees growing in plantation monocultures. The results showed that annual shoot extension and radial growth varied from 20.6 to 111.2 cm and from 2.2 to 9.3 mm, respectively. Significant differences were found ($P < 0.05$) among species and among positions within the crown of each species. *Dalbergia sissoo, Melia azedarach,* and *Morus alba* completed most of their growth in 120 days

during the initial dry part of the growing season these species apparently are able to utilize food reserves of the preceding year for growth. The remaining species showed a more exploitive growth strategy, having a longer period of growth which began in the dry season, but most shoot extension was completed during the rainy season that followed. Branch angle also differed significantly ($P < 0.05$) among crown positions of each species, except *Acacia nilotica* and *Dalbergia sissoo.* Hua *et al.* (1998) described and discussed the root morphological characteristics and biomass distribution for the 8 main species of shelterbelt trees used on river embankments in Jiangsu, China. The results showed that all the root systems extended along sloping surfaces of river banks in a 'hen's claw' pattern, but there were differences in root morphology: *Robinia pseudoacacia* and *Sabina chinensis* [*Juniperus chinensis*] cv. Kaizuca roots were drooping, *Metasequoia glyptostroboides, Cunninghamia lanceolata* and Cinnamomum camphora roots were oblique, and *Salix chaenomeloides*, *Cupressus lusitanica* cv. Zhong-shan and *Prunus persica* had flat roots. Except for *Robinia pseudoacacia*, over 90% of root biomass was distributed in the top 0-50 cm soil layer, and the average root depth was about 1.0 m. Thus planting trees on the river bank increases the stability.

Keer *et al.* (2001) explored the canopy architecture (plant cover, height, and layering) in three contexts: a reference marsh, a field experiment, and a greenhouse experiment. Liangjun *et al* (2003) studied the biomass, soil characteristics and root distribution of a 26-year-old poplar (*Populus simonii*) stand and poplar-seabuckthorn (*Hippophae rhamnoides*) mixed stand in Ansai, Shaanxi, China. Results showed that the mean height, diameter at breast height and stand biomass was 44.8, 32.7 and 139.76% higher in the mixed stand than in the pure stand, respectively. The biomass allocation patterns of the two forest stands were significantly different. The total biomass, as well as each of the parts in the mixed stand, was higher than that of the pure stand.

Morgan *et al.* (2004) described the effect of plant architecture on soil particle detachment by rainfall. Plant architecture significantly affected the

distance from the plant stem at which detachment was concentrated even though the canopy diameters of the plants were similar. No significant relationships were obtained between detachment and any of the plant parameters. Parameters such as plant height and plant canopy area are sufficient descriptors for modeling plant effects. Plant architecture is an important concept that describes the topological and geometrical development over time at the whole-plant level (Barthelemy *et al.* 2007).

2.2 Potential of species to control Erosion

Chen *et al.* (2004) studied the species diversified plant cover role in enhancing the orchard ecosystem resistance to climatic stress and soil erosion in subtropical hillside. The study was on the ecological effects of native plants conserved in orchard and their resistance to adverse climatic stress, and soil erosion. According to the observation, the plant cover significantly increased the soil moisture in seasonal mega thermal drought period and when the plant species numbers in cover plant communities increased the better moisture maintenance and soil erosion reduction was found. Also the higher root density in plant communities with higher species richness increased significantly the antiscourability of the soil. From the study it was suggested that conserving plant communities with diversified native species could produce the best positive ecological effects on ecosystem stability. Baets *et al.* (2007) studied the root characteristics of representative Mediterranean plant species and their erosion-reducing potential during concentrated runoff. In the study typical Mediterranean grass, herb, reed, shrub and tree root systems of plants growing in habitats that are prone to concentrated flow erosion were examined and their erosion-reducing potential was evaluated. Root density, root length density and root diameters are measured for 26 typical Mediterranean plant species. The results showed that grasses suchas *Helictotrichon filifolium* ((Lag.)Henrard), *Juncus acutus* (L.), *Avenula bromoides* ((Gouan) H. Scholz), *Lygeum spartum* (L.) and *Brachypodium retusum* ((Pers.) Beauv.) have the highest potential to reduce soil erosion rates by concentrated flow in the 0–0.1 m topsoil and the shrubs such

as *Anthyllis cytisoides* (L.) and *Tamarix canariensis* (Willd.) also have the high root densities in the topsoil, can reduce erosion rates drastically. These findings have been implicated for ecological restoration and management of erosion-prone slopes.

Chaturvedi and Das *l.* (2008) studied the on root phytomass recovery by sieves of different mesh sizes (2.0, 1.0, 0.5 and 0.25 mm) and root distribution for five, four-year-old agroforestry tree species, namely, *Acacia auriculiformis*, *Azadirachta indica*, *Bauhinia variegata*, *Bombax ceiba* and *Wendalendia exserta*. This study inferred that although all trees have potential to conserve water and improve fertility status of the soil, *A. auriculiformis* is the most effective for promoting soil fertility. The deep rooted *W. exserta* and *A. auriculiformis* will be preferred for cultivation under agroforestry systems and could reduce competition for nutrients and water by pumping from deeper layers of soil. The studied the ability of seabuckthorn *(Hippophae rhamnoides* L.) species to form great number of root –shoots has a great importance for protecting the soil against erosion. The number of roots was much more in soil erosion prone sites without grasses than in those covered with grass.

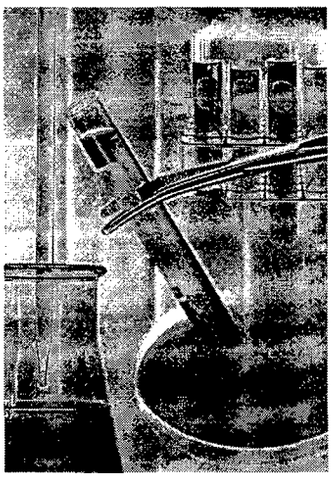
A study was conducted on measures for erosion control and regeneration of the degraded soil by establishing plant cover. In the Mediterranean region the intensities and amounts of soil loss and runoff on sloping land are governed by rainfall pattern and vegetation cover was studied. The study includes the impact of erosion of soil productivity with particular focus on climate and soil erosion; soil seal and crust development and C losses from soils; and land use and soil erosion with particular focus on soil loss in agricultural lands; shrub and forest lands; and the impact of erosion in the Mediterranean terraced lands (Zuazo and Pleguezuelo 2008).

Xu *et al.* (2008) studied the effect of plant morphology on soil quality, runoff, and soil loss in the dry-warm river valley of the upper reach of Minjiang River, South West China. In his studies he took three species (*Artemisia gmelinii*, *Ajania potaninii*, *Pulicaria chrysantha*) to examine the effect. The two herbs, *A.*

gmelinii and *P. chrysantha*, had greater improvements on soil quality yielding high soil nutrient content and low soil compactness, while the effectiveness of the small shrub, *A. potaninii*, was minimal. Thus all the three species can improve soil quality and reduce runoff and soil loss, but their effects vary, which implies that plant morphology has to be considered while selecting species for ecosystem restoration.

Baets *et al.* (2009) gave the methodological framework to select plant species for controlling rill and gully erosion with application to a Mediterranean ecosystem.In the analysis determination of suitable plants for controlling concentrated flow erosion was based on a multi-criteria analysis. First, four main criteria were determined, i.e. (1) the potential of plants to prevent incision by concentrated flow erosion, (2) the potential of plants to improve slope stability, (3) the resistance of plants to bending by water flow and (4) the ability of plants to trap sediments and organic debris. Both above- and below-ground plant traits were taken into account and measured to assess the scores for the five indicators, i.e. stem density, sediment and organic debris obstruction potential, modulus of elasticity of the stems, moment of inertia of the stems, root density, root diameter distribution, root area ratio and root tensile strength. The grasses *Stipa tenacissima* L. and *Lygeum spartum*L. and the shrub *Salsola genistoides* Juss. Ex Poir. amongst others, were selected as very suitable plant species for rill and gully erosion control. The methodology developed in this study was applied to other plant species in areas suffering from rill and gully erosion.

Rahim et al (2011) studied the indigenous fodder species for the increasing the accessibility for landless and mobile pastoralists in Pakistan. This study proposes an alternative strategy of planting indigenous fodder shrubs including *Artemisia maritima* that are well-suited to the local socio-ecological characteristics and also benefit all social segments. The choice of fodder tree species, their nutritional value and distribution within the complex socio-ecological system was studied.



MATERIALS AND METHODS

3. MATERIALS AND METHODS

An appropriate selection and application of scientific methodology is a prerequisite for conducting any investigation as it adds to precision, reliability and validity of the findings/ facts relating to the research problem and the present study is no exception. Therefore, this chapter is devoted to explain the methodology used in the present study. This includes the description of the study area, selection of plants, morphological studies, collection of samples, and analytical framework employed to draw inferences.

3.1 General description of the study area

The present study on the ecological characterization of important species was carried out in the Lahaul valley, the cold desert of Himachal Pradesh. This region is characterized by extreme climatic conditions, high rates of soil erosion and landslides, low productivity of agricultural land and sparse vegetation. There is a pronounced latitudinal succession of vegetation types with the tropical forest at the base, leading to the eternal snow on the peaks in Lahaul. Due to prevalence of cold and dry climatic conditions, just a handful of tree and shrub species like *Betula utilis*, *Artemisia marittima*, *Pinus wallichiana*, *Juniperous cummunis*, *Cedrus deodar* and *Hippophae rhamnoides* can grow in this region.

3.1.1 Location

Lahaul valley of Himachal Pradesh is located at extreme North end of Himachal Pradesh with the international boundaries in the eastern side with Tibet. Lahaul and Spiti district, which lies between the North latitude 31° 44' and 33° 42' and East longitude 76° 56' and 78° 41'.

3.1.2 Experimental site

The three species namely *Hippophae rhamnoides* growing at the river side, *Artemisia maritima* and *Juniperous cummunis* on the southern slope near Kukumeseri (Elevation-2630 m asl, N 32° 40.00', E 76° 39.092'), Lahaul were selected for the study.

3.1.3 Orography

Lahaul lies between the crest of very high mountains, ranging from 2700 m to 6400 m in altitude above sea level. Topographically is composed of rugged and difficult mountainous terrains which are the part of The Great Himalayas. Numerous lateral spurs shoot off from the main mountains filling all the valleys with glaciers. It is this feature which made Andrew Wilson (1873), a European traveler, call Lahaul "a valley of glaciers".

3.1.4 Geology

The soil of the region is sandy loam and varies from few centimeters to about one metre in depth.

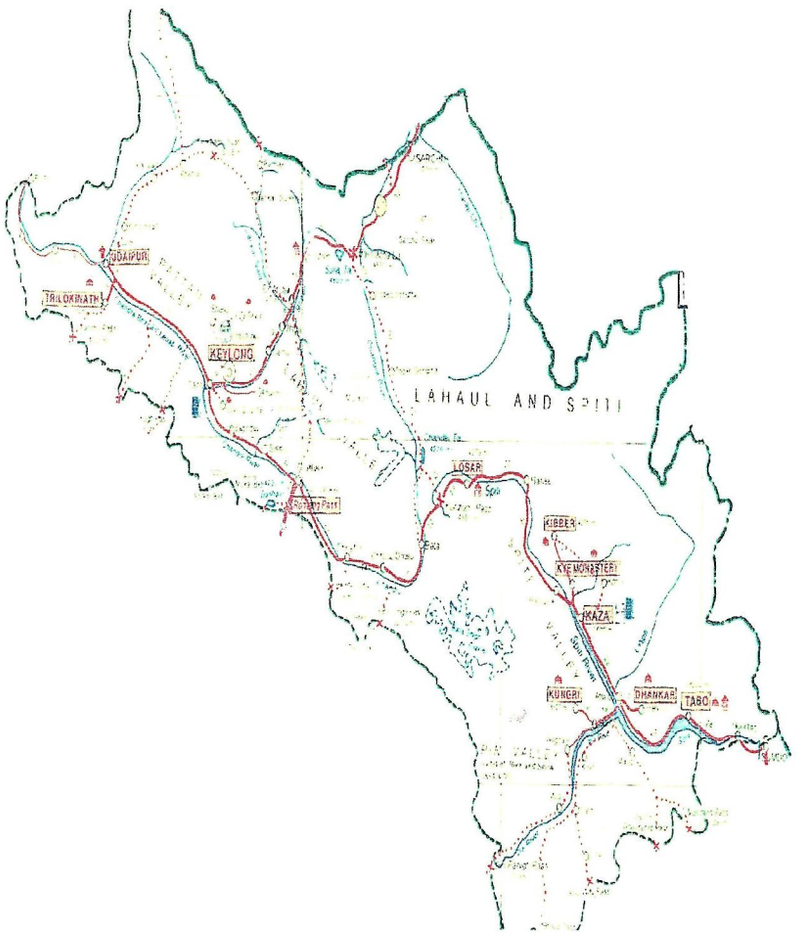


Fig. 3.1 Geographical Map of Lahaul and Spiti.

3.1.5 Climate

Climatically, the Lahaul valley is cold and arid with low rainfall, high snowfall and severe winters. Broadly, the valley has two seasons, short lived summers and prolonged severe winter. Meteorological data of the study area pertaining to the periods of study were procedure from the observatory maintained at HAREC Kukumseri, Lahaul. The region experiences extreme climatic conditions (minimum temperature as low as -16° C in winters and maximum of 27° C in July). Rainfall fluctuates from 50 to700 mm per year. During winters this region is affected by the series of western disturbances which causes heavy snowfall i.e. 200-400 cm/yr. The months of February and March received more than 50% of the snowfall. However, smaller snowfall is common from December to April. Rainfall is scarce although showers occasionally occur May to September. The annual average rainfall is 267 mm.

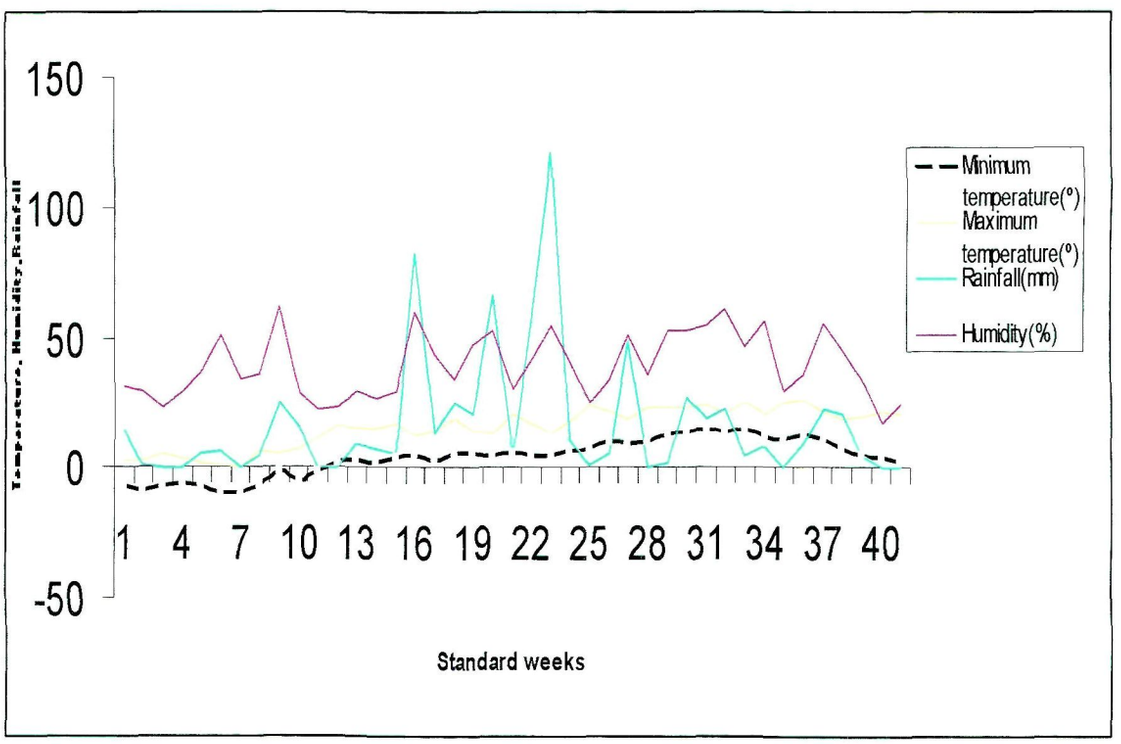


Fig. 3.1.1 Weekly Variation in the temperature, rainfall and humidity at Kukumseri w.e.f. January - September 2010.

3.2 Field study

The field study was done in three species growing in the same locality, at Kukumseri in Lahaul.

3.2.1 Selection of plant

The site was observed firstly and then the plants of each species were measured for the collar diameter above ground and grouped into three diameter classes according to their habit.

3.2.2. Morphological characterization

Each plant was characterized on the basis of the various parameters using scientific techniques and standard methods. The various parameters recorded were as follows:

i) Collar diameter

For each plant, the collar diameter was measured at the base with the help of digital caliper without disturbing the plant parts and then the observations were classified under different collar diameter classes which were initially made. The average collar diameter of the 3 plants was calculated and expressed as the mean collar diameter.

ii) Plant height

The height of the plants under the respective class from the groundto the top of the tallest part of plant was measured. The average height of the 3 plants was calculated and expressed as the mean plant height.

iii) Crown cover

The measurement of the crown was done with the help of method given by Bisht (1993). In this method the spread was recorded in two directions. And then the mean canopy diameter (D) was calculated. Further the crown cover was calculated mathematically.

$$\text{The crown cover (CC)} = \pi (D / 2)^2$$

$$D = \text{canopy diameter}$$

iv) Primary branches

The primary branches of the plant were counted and with respect of the main stem their branch angle was measured. The branch angle was measured considering the main axis as the base and further determined by trigonometric ratios.

v) Leaf

The leaves were randomly selected and the length and width were measured with the help of digital calliper. Also the leaf color was recorded on the visual observation basis.

vi) Thorns

In some species modifications in form of thorns were observed. The numbers of thorns per 10 cm were counted on two year old branches. And the mean was calculated.

vii) Root Spread

To study the below ground parts, the method of Baldwin and Stewart (1987) was followed. As the excavation of root system is labour expensive and extensive, the number of replicates were decreased to 3 in each class, totally to 9 per species. The area of about 1 m radius around the plant was excavated. For the horizontal extension of the root system to be excavated the surface layer was removed carefully. The tools used were spade and shovel for digging. After the excavation the clearing of soil particles and then the careful measurements and drawings of the root system were made. The vertical distance from the soil surface to the tip of the furthest root was measured in order to determine the maximum rooting depth and after excavation, the entire root system was rearranged as far as possible into its original position.

viii) Primary Roots

The roots that originated from the main or tap root, irrespective of their size were designated as primary roots or the first order roots. The primary roots of the plant were counted. The diameter of each primary root was measured. The roots originated from these primary roots were the secondary roots or the second order root was counted.

ix) Root Angle or Orientation

The angle of the primary roots was measured. The root angles were calculated by using the trigonometric ratios. The root angles were measured using 2 scales, one kept horizontal (i.e. perpendicular to the stem) and a perpendicular was dropped by using another scale onto the root. The perpendicular was dropped on the root up to the point it was straight. Further bending of the root was not taken into consideration. The horizontal scale was designated as the base and its distance from the trunk was measured. The length of perpendicular was also measured. Tan θ was calculated by dividing perpendicular by base and taking its inverse tan value. Root angle was expressed in degrees. Also the distribution of the roots along the four directions was noted depending upon their direction of penetration.

3.2.3 Soil properties

a) Collection of soil samples

Three samples were taken at random from the each site. The soil collected at different depths up to 30 cm while taking a sample. Soil samples were collected directly into clean plastic bags. These samples collected from different sites were brought to laboratory for further studies.

b) Soil texture

The mechanical and particle size analysis of soil before the initiation of experiment was done by the International Pipette Method (Piper 1950). The texture of soil was determined by relative distribution of sand, silt and clay in the sample and the textural classification was made using the textural triangle given by The International Society of Soil Science.

c) Clay ratio (CR)

Clay ratio as suggested by Bouyoucos (1935) was calculated by dividing total sand and silt % in soil by the % clay it contains.

$$CR = \frac{\% \text{ Sand} + \% \text{ Silt}}{\% \text{ Clay}} \qquad (3.2)$$

d) Silt : clay ratio (SCR)

Silt: Clay ratio was determined by dividing total % of silt with total % of clay.

$$SCR = \frac{\% \text{ Silt}}{\% \text{Clay}} \quad - (3.3)$$

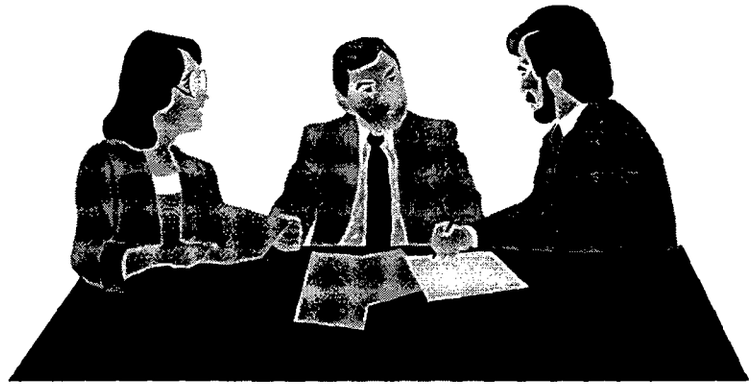
e) Soil pH

The soil pH was determined using glass electrode pH meter using soil water suspension in the ratio of 1:2.5 (Jakson 1973).

3.2.4 Statistical analysis

The entire data generated from the present investigation was put to statistical analysis.

Data was presented as arithmetic means and standard deviation. The statistical comparison of values within and between the species was conducted by analysis of variance procedure by calculating the critical difference (CD). The different parameters were tested at 5 per cent level of significance(Panse and Sukhatme 1985)



RESULTS AND DISCUSSION

4. RESULTS AND DISCUSSION

The results obtained from the present study entitled, "Ecological characteristics of some important plant species in Lahaul valley, Himachal Pradesh" have been presented in this chapter. The various parameters consisting of morphological, ecological and soil physical properties have been discussed in detail with the help of tables.

4.1 Soil properties

The soil and plant relationship is quite dynamic and, therefore, different forest types will impart differences in soil properties.

4.1.1 Soil texture

A perusal of Table 4.1 showed that soil under *Artemisia maritima* contained the silt content up to 36.4 per cent, whereas the clay content was 6.9 per cent. The sand percentage was highest about 56.4 per cent. Textural class of soil was silty loam. For *Hippophae rhamnoides* growing on the river side, the sand content in the soil was the maximum (94.7%), where as silt and clay showed almost equal proportions, i.e. 2.1 per cent and 1.4 per cent respectively. Sandy loam was the textural class for *Hippophae rhamnoides*. About 7.6 per cent clay content along with 52.9 per cent of sand and 37.9 per cent silt content were recorded for *Juniperous communis* soil. The textural class of the soil was silty loam.

4.1.2. Clay Ratio (CR)

The clay ratio is considered as a suitable erodibility index. For *Artemisia maritima* the ratio was 14.7 and for *Juniperous communis* the ratio was 12.5. The maximum was measured for *Hippophae rhamnoides* and that was approximately 70.1 (Table 4.1).

4.1.3 Silt Clay Ratio (SCR)

The maximum silt clay ratio was measured in *Juniperous communis* soil (5.33) and for *Hippophae rhamnoides and Artemisia maritima* soil the ratio were 4.1 and 1.4 respectively (Table 4.1).

4.1.4 Soil pH

The soil pH for *Artemisia maritima* and *Juniperous communis* ranged from 7.1 to 7.3 which was neutral to mild alkaline in reaction. *Hippophae rhamnoides* soil pH was recorded to be 7.4 near the river side stand at Kukumseri (Table 4.1).

Table 4.1 The physical properties and pH of soil in the study sites, Lahaul.

Species		Clay (%)	Silt (%)	Sand (%)	Clay Ratio	Silt: Clay Ratio	pH	Textural Class
Artemisia maritima	Mean	6.9	36.4	56.4	14.7	4.1	7.1	Silty loam
	± SE	1.4	6.8	3.2	1.1	0.3	0.1	
Hippophae rhamnoides	Mean	1.4	2.1	94.7	70.1	1.4	7.4	Sandy loam
	± SE	0.2	0.2	0.9	11.1	0.1	0.1	
Juniperous communis	Mean	7.6	37.9	52.9	12.5	5.3	7.1	Silty loam
	± SE	1.0	3.6	2.6	2.0	1.3	0.1	

4.2 Plant Observations

The three species were studied for their morphological characterization, architecture of plant canopy and the distribution of coarse root system. The observations are as follows:

4.2.1 *Hippophae rhamnoides*

The morphological study of *Hippophae rhamnoides* was done for various parameters, i.e. collar diameter, plant height, crown cover, number of primary branches, branch angle, root spread and depth, number of primary and secondary roots, root angle and leaf length and width. Data analyzed was categorized into two groups, above ground and below ground parts to know architecture of the species.

i) Above ground parts

Firstly, the different collar diameter classes made were 0-15 mm, 15-30 mm and 30-45 mm, respectively. The mean collar diameter for the first class was calculated to be 8.2 mm. Mean collar diameter for 15-30 mm and 30-45 mm class was 22.0 mm and 37.4 mm, respectively (Table 4.2). The 0-15 mm class showed the mean height up to 30.6 cm. The maximum mean height was recorded to 99.3 cm for the 30-45 mm class (Table 4.2). As the collar diameter increased, the height also increased.

The canopy architecture is one of the important parameters in the study. The canopy architecture was very pronounced as it showed a great variation according to height. The biggest plant had the largest canopy spread and their mean crown cover was 5549 cm^2. The smaller plants showed the lesser cover, i.e. 493.8 cm^2. For the medium-sized plants, mean crown cover was calculated to be 3616.6 cm^2 (Table 4.2). The primary branch varied from 4 to 6 in number. The colour of stem was visualized to be greyish green and the leaves were silvery green in colour. The length of leaves varied from 42.6 mm to 51.8 mm and the width ranged from 4.7 mm to 5.3 mm, respectively. The leaves were alternate. The orientation of the primary branches was towards the north west direction with the angle varying from 25° to 35° (Table 4.2).

The presence of thorns was observed on the stems of seabuckthorn. These are the modifications, which help to overcome the xeric conditions. Number of thorns per 10 cm was observed to be varying from 4 to 6 per 10 cm of 2 year old branches (Sankhyan *et al.* 2005). The following table shows the architecture and morphology of above ground parts of seabuckthorn(Table 4.2)

ii) Below ground parts

Seabuckthorn showed a well developed tap root system. The maximum vertical root penetration in the soil was shown by the plants under the class 30-45 mm to 72.6 cm. For the class 15–30 mm the mean root depth was 49.6 cm and 24.0 cm for the class 0-15 mm (Table 4.3). The root horizontally spread were 86.1 cm, 179.1 cm and 202.3 cm with the collar diameter class of 0-15 mm , 15-

30 mm and 30-45 mm, respectively. The root system became more horizontally spread with increasing diameter and height of plants (Singh *et al.* 2001).

Table 4.2 Architecture and morphology of the above ground parts of *Hippophae rhamnoides* growing at river side, Kukumesri, Lahaul.

Collar diameter class (mm)		Collar diameter (mm)	Height (cm)	Crown cover $(cm)^2$	Leaf		Number of primary branches	Degree of primary branches (°)	No. of thorns per 10 cm
					Length (mm)	Width (mm)			
0 – 15	Mean	8.2	30.6	493.8	42.6	4.7	4.0	28.3	5.6
	±SE	0.6	3.4	56.6	2.5	0.5	0.8	1.6	0.3
15 – 30	Mean	22.0	75.0	3616.6	42.2	4.8	5.0	36.6	4.0
	±SE	2.8	2.8	408.8	0.6	0.1	0.5	1.6	0.5
30 – 45	Mean	37.4	99.3	5549.2	51.8	5.3	6.6	35.0	6.0
	±SE	2.8	3.4	583.8	1.1	0.1	0.8	2.8	1.1

Plate1. Above ground parts of *H. rhamnoides*

The primary roots varied from 3.3 to 9.6 in numbers (Table 4.3). The roots also became thick more up to 6.8 mm diameter. The secondary roots on each primary roots were found to be 1.9 to 5.2 in number. The root orientation was maximum towards the north-west direction and the angles measured were 55° to 75°. The presences of nitrogen fixing root nodules were also found in the vertical roots. The following table shows the pattern of course root distribution in seabuckthorn:

Table 4.3 Pattern of coarse root distribution in *Hippophae rhamnoides* growing at river side, Kukumseri, Lahaul.

Collar diameter class (mm)		Root Depth (cm)	Root Spread (cm)	Number of primary root	Diameter (mm)	Number of secondary root per primary root	Primary root angle (°)
0 – 15	Mean	24.0	86.1	3.3	3.8	1.9	81.5
	±SE	0.5	6.0	0.3	0.5	0.2	3.1
15 – 30	Mean	49.6	179.1	6.3	4.5	4.6	63.4
	±SE	3.7	1.0	0.8	0.2	0.6	3.7
30 – 45	Mean	72.6	202.3	9.6	6.8	5.2	69.2
	±SE	6.3	4.0	0.8	0.8	0.8	1.9

4.2.2 *Artemisia maritima*

The morphological study of *Artemisia maritima* was done for various parameters, i.e. collar diameter, plant height, crown cover, number of primary branches, branch angle, root spread and depth, number of primary and secondary roots, root angle and leaf length and width. Data analyzed was categorized into two groups, above ground and below ground parts to know architecture of the species.

Plate 2. Root system of first diameter class of *H. rhamnoides*

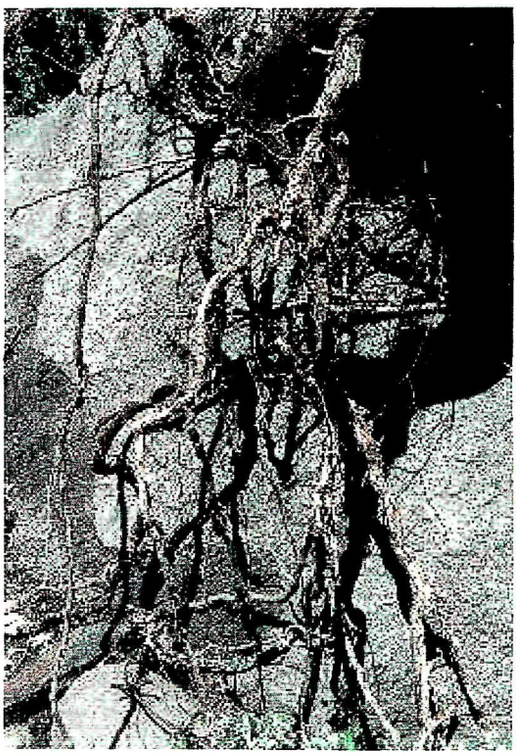


Plate 3. Root system of second diameter class of *H. rhamnoides*

Plate 4. Root system of third diameter class of *H. rhamnoides*

i) Above ground parts

A. maritima plants were categorized into three classes on the basis of the collar diameter i.e. 15-30 mm, 30-45 mm and 45-60 mm. The mean collar diameter for each class was 22.4 mm, 37.0 mm and 53.6 mm respectively. The plant height was for the class 45-60 was maximum to 54 cm from the ground level and minimum (30.33 cm) was for the class 15-30 mm (Fox 2004). The crown cover was maximum 3763 cm^2 for the plants with the collar diameter class 45–60 mm. The class 15-30 mm had the crown cover 2040 cm^2 and 2546.6 cm^2 for 30-45 mm class. As the collar diameter increased, the number of primary branches also increased resulting in the increase in plant canopy architecture (Table 4.4).

The stem of *Artemisia maritima* was covered by white cottony fibers which is a prominent feature of the family Asteraceae . The leaves were twice pinnatified with narrow, linear segments. The leaf length ranged from 25.4 mm to 38.5 mm and the width of leaf ranged from 11.9 mm to 23.5 mm, respectively. The colour of leaves was ashy green.

The number of primary branches was maximum up to 12.3 for the class 45-60 mm and minimum was recorded to be 8.6 for the class 15- 30 mm. The primary branch angle which indicates the architecture of the above ground parts was maximum observed to be 73.33°. The following table highlights the architecture and morphology of above ground parts of *Artemisia maritima*:

Table 4.4 Architecture and morphology of the above ground parts of *A. maritima* growing at Kukumesri, Lahaul.

Collar diameter class(mm)		Collar diameter (mm)	Height (cm)	Crown cover $(cm)^2$	Leaf		Number of primary branches	Degree of primary branches (°)
					Length (mm)	Width (mm)		
15-30	Mean	22.4	30.3	2040.0	25.4	11.9	8.6	73.3
	±SE	3.2	3.2	62.4	3.5	2.1	0.8	4.4
30-45	Mean	37.0	39.3	3222.1	30.4	17.5	12.0	66.6
	±SE	3.1	3.1	206.9	1.0	1.3	0.5	4.4
45-60	Mean	53.6	54.0	3763.0	38.5	23.5	12.3	73.3
	±SE	2.9	0.8	237.3	0.8	0.3	1.4	1.6

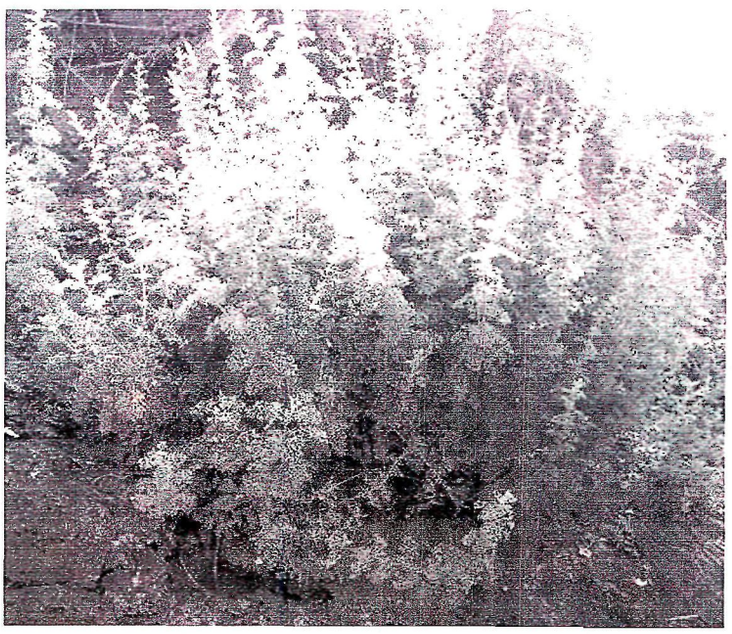


Plate5. Above ground parts of *A. maritima*

ii) Below ground parts

After excavation the root system was measured which included the observation on root depth, root spread, number of primary roots and their root orientation.

The mean root depth for the plants under the class 15-30 mm was 78.3 cm. For the class 30-45 mm, the mean root depth recorded was 80.6 cm and 86.6 cm of root depth for the highest class i.e. 45-60 mm. With the increase in collar diameter, the root depth also increased indicating the plant growth with the age. The mean root horizontally spread was maximum of 83.8 cm for the class 45-60 mm and minimum was 61.6 cm for the 15- 30 mm class. The mean root horizontally spread for the class 30-45 mm was 70.0 cm. (Table 4.5). As this clearly depicts that the root system of *Artemisia maritima* was vertical and had a deep root system instead of the shallow root system. Similar observation was given by Zang *et al.* (2008).

The range of primary roots was from 8.3 to 11 in number. The thickness of roots was measured up to 4.6 mm. The primary roots constituted of various secondary roots and a number of fine roots. The amount of secondary roots varied from 2 to 2.4 in number for each primary root. The root system was more spread at the uppermost soil layer. The root angle or orientation of the primary roots ranged from measured 40.1° to 47° and the direction of the roots was mainly towards north west. The following table displays the pattern of coarse root distribution in *Artemisia maritima*:

Table 4.5 Pattern of coarse root distribution in *Artemisia maritima* growing at Kukumseri, Lahaul

Collar diameter class(mm)		Root Depth (cm)	Root Spread (cm)	Number of primary root	Diameter (mm)	Number of secondary root	Primary root angle (°)
15-30	Mean	78.3	61.6	8.6	3.1	2.0	40.1
	±SE	7.2	2.2	1.2	0.2	0.2	3.0
30-45	Mean	80.1	70.0	11.0	3.3	2.4	47.0
	±SE	10.5	10.9	1.5	0.2	0.3	3.8
45-60	Mean	86.6	83.8	8.3	4.6	2.4	47.0
	±SE	1.7	1.8	0.8	0.6	0.3	4.0

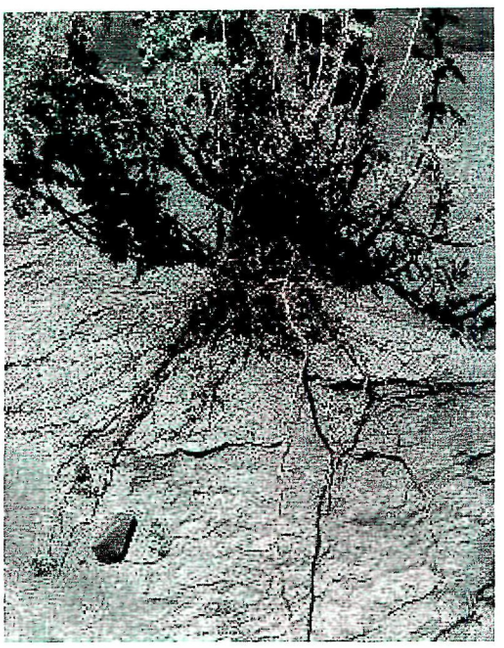


Plate 6. Root system of first diameter class of *Artemisia maritima.*

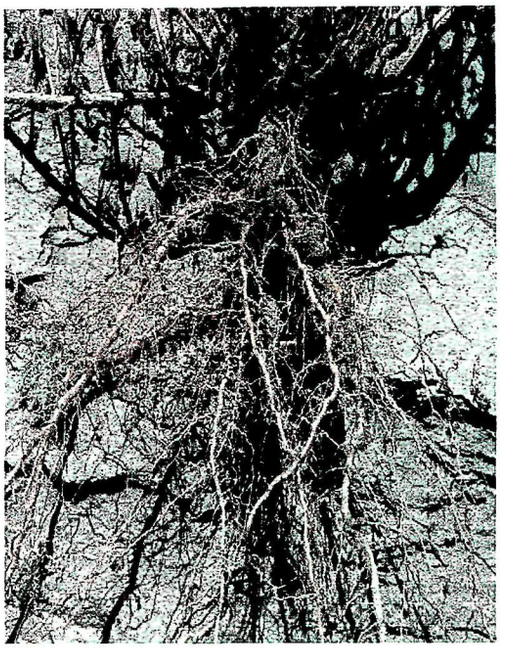


Plate7. Root system of second diameter class of *Artemisia maritima.*

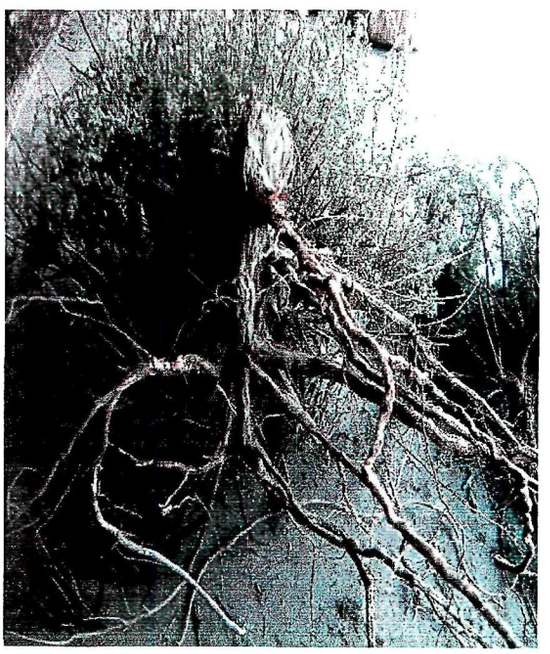


Plate 8. Root system of third diameter class of *Artemisia maritima.*

4.2.3 *Juniperous communis*

The architecture and morphology of above ground parts were studied along with the pattern of course root distribution in *Juniperous communis* plants.

i) Above ground parts

J. communis plants were categorized mainly into three collar diameter classes 0-10 mm, 10-20 mm and 20-30 mm and were frequently found with *A. maritima*. The maximum mean collar diameter was up to 25.9 mm and the minimum was observed to 5.5 mm (Table 4.6). As the collar diameter increased, the height also increased with the growth and age of the plant. The mean height was maximum for the class 20-30 mm (58 cm) and for 10-20 mm class the mean height observed was 45 cm. The minimum mean height for *J. communis* plants was observed 24.6 cm. The prostrate system was found in some of the plants and the height for the prostrate stem was up to 63.6 cm.

The mean crown cover extended from 337.3 cm^2 to 3051.2 cm^2 which showed a great variation (Table 4.6). The primary branches which indicated the plant architecture as well as plant size ranged 3–6 in number. The primary branches were reddish brown in colour with the leaves which were needle-like and had an acute apex. The length of leaves ranged between 9.9 mm to 10.1 mm and the width of leaf was observed up to 1.4 mm (Sullivian 2001). The main stem was reddish brown in colour. The colour of leaves was pure green. The branch angle which is important for the runoff was observed to be ranging from 31.6 ^{o} to 35 ^{o}. This is shown in the following table:

Table 4.6 Architecture and morphology of the above ground parts of *Juniperous communis* growing at Kukumesri, Lahaul

Collar diameter class(mm)		Collar diameter (mm)	Height (cm)	Prostrate stem height (cm)	Crown cover (cm)²	Leaf		Number of primary branches	Degree of primary branches (°)
						Length (mm)	Width (mm)		
0 – 10	Mean	5.5	24.6	3.3	337.3	10.2	1.4	6.0	31.6
	±SE	1.4	2.9	3.3	71.4	0.1	0.1	0.5	1.6
20-30	Mean	16.9	45.0	0	2355.6	9.9	1.4	3.3	33.3
	±SE	1.5	2.8	0	211.3	0.2	0.1	0.3	3.3
20 – 30	Mean	25.9	58.0	63.6	3051.2	9.9	1.4	3.0	35.0
	±SE	1.2	2.0	2.0	86.6	0.2	0.1	0.5	2.8

Plate 9. Above ground parts of *J. communis*

ii) Below ground parts

The root system of *J. communis* was also well developed. The maximum mean root penetration was up to 72.6 cm for the class 20–30 mm. The root vertical depth for the class 10–20 mm was 60.0 cm and for 0–10 mm class the mean root depth was 35.0 cm (Table 4.7). The mean root horizontally spread was maximum to 196.6 cm for the class 20–30 mm and minimum up to 90.8 cm for the class 0-10 mm. The primary roots observed were maximum to 11 in number for the plants with collar diameter class 10-20 mm and minimum 5 for the 0-10 mm class.

The roots were reddish brown in colour and the thickness of the roots was up to 4.91 mm diameter. The secondary roots on each primary root were 2.5 to 3.3 in number. The root angle ranged between 61.6° to 73.8° for the different classes. The root orientation was in the north west direction and the roots were spread on the surface widely resulting in the binding of maximum soil particles in the area. The following table highlights this observation:

Table 4.7 Pattern of coarse root distribution in *Juniperous communis* growing at Kukumseri, Lahaul.

Collar diameter class		Root Depth (cm)	Root Spread (cm)	Number of primary root	Diameter (mm)	Number of secondary root per primary root	Primary root angle (°)
0 – 10	Mean	35.0	90.8	5.6	2.1	2.5	61.6
	±SE	2.8	8.7	0.5	0.3	0.3	1.5
10 – 20	Mean	60.0	180.0	11.0	3.3	2.5	73.8
	±SE	2.8	8.7	0.5	0.3	0.4	1.4
20 – 30	Mean	72.6	196.6	10.6	4.4	3.3	71.3
	±SE	1.4	2.6	0.8	0.5	0.5	1.9

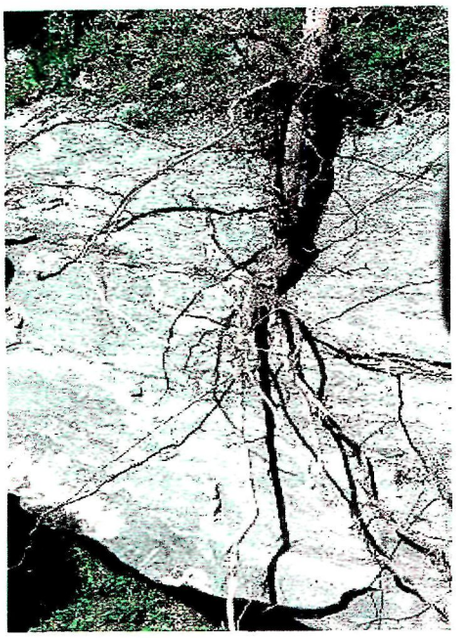


Plate 10. Root system of first diameter class of *Juniperous communis.*

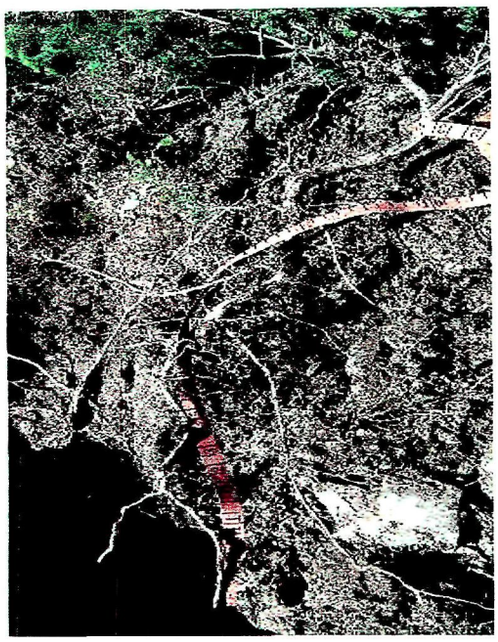


Plate 11. Root system of second diameter class of *Juniperous communis.*

Plate 12. Root system of third diameter class of *Juniperous communis.*

4.3 Correlation between different parameters

4.3.1 *Hippophae rhamnoides*

The correlation between collar diameter, plant height, canopy diameter, crown cover, number of primary branches, root depth, root spread and number of primary roots was tested, only some parameters showed significant correlation. The collar diameter of the plant and the plant height were significantly positive correlated (r= 0.96, P≤ 0.05, n= 9). The height of the plant and its vertical root spread showed a significant positive correlation (r= 0.87, P≤ 0.05, n= 9). The significant positive correlation was seen in the crown cover of the plant and its horizontal root spread (r= 0.93, P≤0.05, n= 9). This information reveals that with the age of the plant the various growth parameters also increase. The following table amply clarifies it.

Table 4.8 Correlation between collar diameter, plant height, canopy diameter, crown cover, number of primary branches, root depth, root spread and number of primary roots with each other in *Hippophae rhamnoides.*

Parameters	Collar diameter (mm)	Height (cm)	Canopy diameter (cm)	Crown cover $(cm)^2$	Number of primary branches	Root depth (cm)	Root spread (cm)	Number of primary root
Collar diameter (mm)	1							
Height (cm)	0.969493	1						
Canopy diameter (cm)	0.934859	0.979971	1					
Crown cover $(cm)^2$	0.951458	0.967044	0.989513	1				
Number of primary branches	0.164741	-0.03968	-0.14287	-0.04748	1			
Root depth (cm)	0.804478	0.873857	0.946804	0.938092	-0.26335	1		
Root spread (cm)	0.862258	0.946308	0.971042	0.938423	-0.24217	0.949813	1	
Number of primary root	0.441683	0.580896	0.669068	0.598516	-0.56916	0.799006	0.778997	1

(r = 0.666, P≤ 0.05)

4.3.2 *Artemisia maritima*

The correlation between collar diameter, plant height, canopy diameter, crown cover, number of primary branches, root depth, root spread and number of primary roots of *Artemisia maritima* was tested , only some parameters showed significant correlation. The significant positive correlation was shown between the crown cover and the horizontal root spread of the plant ($r = 0.74$, $P \leq 0.05$, $n = 9$), collar diameter and canopy diameter also showed a significant positive correlation ($r = 0.74$, $P \leq 0.05$, $n = 9$) resulting in the increase in crown cover with the age of plant. A significant negative correlation was shown between the height of plant and horizontal root spread of the plant ($r = -0.72$, $P \leq 0.05$, $n = 9$). The following table amply clarifies it.

Table 4.9 Correlation between collar diameter, plant height, canopy diameter, crown cover, number of primary branches, root depth, root spread and number of primary roots with each other in *Artemisia maritima*.

Parameters	Collar diameter (mm	Height (cm)	Canopy diameter (cm)	Crown cover $(cm)^2$	Number of primary branches	Root depth (cm)	Root spread (cm)	Number of primary root
Collar diameter (mm)	1							
Height (cm)	-0.97757	1						
Canopy diameter (cm)	0.945718	-0.9526	1					
Crown cover $(cm)^2$	0.951829	-0.95058	0.998893	1				
Number of primary branches	0.690753	-0.76912	0.710227	0.69315	1			
Root depth (cm)	0.354833	-0.34124	0.369187	0.385695	0.171519	1		
Root spread (cm)	0.747417	-0.72885	0.738411	0.748958	0.513965	0.837526	1	
Number of primary root	-0.02653	-0.08907	0.146672	0.121665	0.500568	0.025248	0.174955	1

($r = 0.666$, $P \leq 0.05$)

4.3.3 *Juniperous communis*

In *Juniperous communis* various growth parameters were correlated with each other where some of the parameters showed significant positive and negative correlation. The collar diameter and height of plant were significantly positive correlated ($r = 0.99$, $P \leq 0.05$, $n = 9$) showing a prominent growth with the age of the plant. Also the height of plant and the vertical spread were significantly positive correlated ($r = 0.99$, $P \leq 0.05$, $n = 9$). The crown cover and the horizontal root spread showed a significant positive correlation amplifying the vegetative growth of the plant with the age ($r = 0.99$, $P \leq 0.05$, $n = 9$). The following table highlights the correlation between various growth parameters.

Table 4.10 Correlation between collar diameter, plant height, canopy diameter, crown cover, number of primary branches, root depth, root spread and number of primary roots with each other in *Juniperous communis.*

Parameters	Collar diameter (mm)	Height (cm)	Canopy diameter (cm)	Crown cover $(cm)^2$	Number of primary branches	Root depth (cm)	Root spread (cm)	Number of primary root
Collar diameter (mm)	1							
Height (cm)	0.997479	1						
Canopy diameter (cm)	0.956862	0.968357	1					
Crown cover $(cm)^2$	0.973534	0.980376	0.995132	1				
Number of primary branches	-0.83876	-0.84903	-0.89522	-0.88332	1			
Root depth (cm)	0.99757	0.994089	0.9493	0.967135	-0.82788	1		
Root spread (cm)	0.985181	0.992205	0.987742	0.991646	-0.88364	0.983403	1	
Number of primary root	0.758797	0.795199	0.845389	0.827954	-0.78298	0.737784	0.821695	1

($r = 0.666$, $P \leq 0.05$)

4.4 Comparisons among the species

The three species, i.e. *Hippophae rhamnoides, Artemisia maritima* and *Juniperous communis* were compared with respect to different above ground and below ground parameters. The significant difference was determined for the mean of distinct parameters of the three species.

i) Collar Diameter

The mean collar diameter calculated for the three species i.e. *A. maritima, H. rhamnoides* and *J. communis* was 37.7 mm, 22.5 mm and 16.1 mm, respectively. *A. maritima* collar diameter was significantly higher than the other two species as very young plants of *H. rhamnoides* were selected for the study, as illustrated in the Table 4.11.

ii) Height

Height of the plant is one of the important parameters indicating the vegetative growth of plant. The increase in plant height continued during most of the entire life span of the plant. As per the results, the mean height observed was a maximum of 68.3 cm for *H. rhamnoides*, 42.55 cm for *J. communis* and minimum height was observed for *A. maritima* i.e. 41.22 cm. Height in *H. rhamnoides* was significantly higher ($P \leq 0.05$) than *A. maritima* and *J. communis* (Table 4.11).

iii) Canopy Diameter

Canopy architecture is one of an important ecological parameters, which helps in controlling the runoff. As per the results, the mean canopy spread for the three species, i.e. *A. maritima, H. rhamnoides* and *J. communis* was 61.3 cm, 58.8 cm and 45.8 cm, respectively (Table 4.11).

iv) Crown Cover

The crown of a plant is distinctively crucial for the soil environment. A complete cover of the soil surface fully protects the soil from raindrop impact as the plant canopy intercepts raindrops before they hit the soil which results in the less runoff from the area under the canopy spread (Chapman 1948). The mean crown cover was maximum for *Hippophae rhamnoides* (3219.9 cm^2).

v) Number of primary branches

The number of primary branches indicates the growth of plant and is important for the plant architecture. The branches are held intact with the stem which gives the plant a better architecture. The orientation of the branches also gives a plant a better shape. The maximum primary branches were found in *A. maritima* (11), which was significantly higher ($P \leq 0.05$) than the other two species i.e. *H. rhamnoides* and *J. communis* (Table 4.11).

Table 4.11 Comparison of the three species with respect to above ground parameters.

Species	Collar diameter (mm)	Height (cm)	Canopy diameter (cm)	Crown cover $(cm)^2$	Number of primary branches
H. rhamnoides	22.5^b	68.3^a	58.8^a	3219.9^a	9.7^b
A. maritima	37.7^a	41.2^b	61.3^a	3008.4^a	11.0^a
J. communis	16.1^b	42.5^b	45.8^a	1914.8^a	4.1^b
Total Mean	25.4	50.7	55.3	2714.3	6.6
CD (5%)	12.0	20.1	19.2	1533.9	1.8

Mean values with the same superscript within a column are not significantly different ($P \geq 0.05$).

vi) Root depth / penetration

All the species exhibited a well developed tap roots. The root depth indicates the growth of the plant with the age. The penetration was maximum for *A. maritima* i.e. 81.7 cm which showed a deep root system. *J. communis* mean root depth was 54.2 cm which was significantly different ($P \leq 0.05$) from *A. maritima*. *H. rhamnoides* had 42.1 cm of the mean root depth, which indicated the shallow root system (Table 4.10). The root penetration was maximum near the stump, however the penetration decreased steeply. *H. rhamnoides* mean root

depth was not significantly different from *J. communis*. Density of rootlets, root biomass and root characteristics can reduce soil erosion (Gyssels and Poesen 2003).

vii) Root spread

H. rhamnoides showed a maximum root spread up to 151.2 cm, followed by *J. communis* (150.5 cm) and minimum of 71.8 cm in *A. maritima*. The first two showed no significant difference but *H. rhamnoides* mean root spread was significantly larger ($P \leq 0.05$). Most of the roots extended well beyond the crowns in all the species. Also the pattern of root system was influenced by both the genetic characters of the species and the soil conditions (Huck 1983). As the deep root system is generally found in the plants growing in the xeric conditions (Kazlowski 1979; Philips 1963), here both the vertical and horizontal spread was quite extensive, which indicated their potential to bind the soil particles and control the runoff.

viii) Number of primary roots

It is true that not only does the upward flow of resources from the soil depend on the root networking, constituted by the formation of primary roots but also confirms the firmness of plant in soil. The maximum number of primary roots were found (9.3) in *A. maritima* which was significantly higher ($P \leq 0.05$) from the other two species i.e. *H. rhamnoides* and *J. communis*. These roots of *A. maritima* were thicker and further branched into several thin and long or small roots which function to provide anchorage to the plant in the soil. The development of this portion of a plant is a complex process in which development at any point in time is influenced by the pervious development of root systems (Berta *et al.* 1990; Atkinson 1983).

ix) Root orientation

Root angles, which indicate the horizontal and vertical distributions of the primary roots, varied considerably among the three species. Root branch angle is the key component of the root architecture. The maximum root angle was measured to be 65° for *J. communis* which was significantly different ($P \leq 0.05$)

from the root angle of *A. maritima* which was minimum, i.e. 45.9 ° (Table 4.12). The distribution of primary roots in *A. maritima* was more vertically oriented than that of *H. rhamnoides*. Lesser the root angle, more roots the networking will be present in tap root layers of soils. As *A. maritima* showed the minimum root angle, indicating comparatively a more vertical root system than other two species which showed a horizontal root system to be more prominent.

Table 4.12 Pattern of root distribution in the three species.

Species	Root depth (cm)	Root spread (cm)	Number of primary root	Primary root angle (°)
Hippophae rhamnoides	42.1^{b}	151.2^{a}	6.4^{b}	62.0^{a}
Artemisia maritima	81.7^{a}	71.8^{b}	9.3^{a}	45.9^{b}
Juniperous communis	54.2^{b}	150.5^{a}	4.8^{b}	65.0^{a}
Total Mean	59.3	124.5	6.8	57.7
CD (5%)	14.2	39.8	2.3	9.5

Mean values with the same superscript within a column are not significantly different ($P \geq 0.05$).

Plate 13. Pattern of root distribution in *Hippophae rhamnoides*.

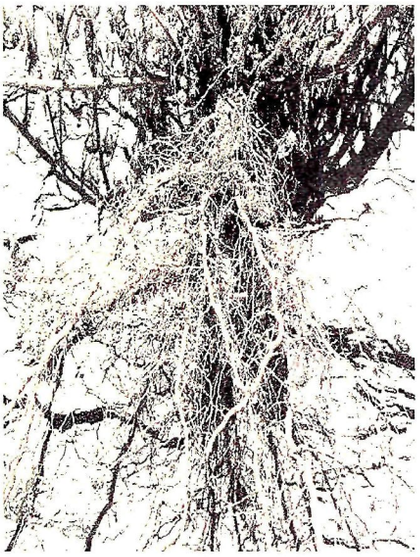


Plate 14. Pattern of root distribution in Artemisia maritima.

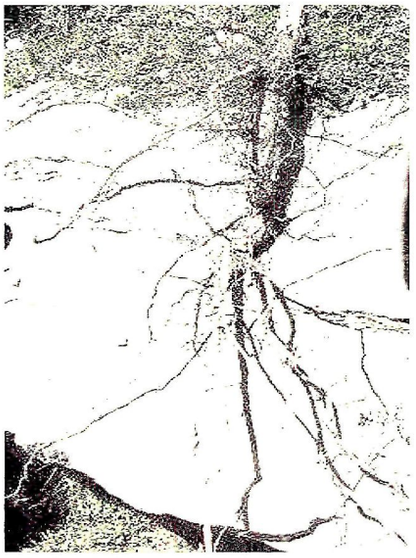


Plate 15. Pattern of root distribution in Juniperous communis.

SUMMARY AND CONCLUSIONS

5. SUMMARY AND CONCLUSIONS

In the present study, investigations were carried out on the architecture of the above ground parts and pattern of root distribution in three important species of ecological importance, i.e. seabuckthorn (*Hippophae rhamnoides* ssp. *turkestanica*), Artemisia (*Artemisia maritima*) and Juniper (*Juniperous communis*) growing in Lahaul, district Lahaul –Spiti, a cold desert region of Himachal Pradesh.

Regarding the architecture of *Hippophae rhamnoides,* the plant height varied from 30.6 cm to 99.3 cm, the crown cover of the plants ranging from 493.8 cm^2 to 5549 cm^2, and collar diameter varied from 37.4 to 8.2 mm. The mean root depth recorded was maximum up to 72.6 cm and the root spread was up to 202 cm. The number of primary roots varied from 3 to 12 on the tap root.

In *Artemisia maritima*, the height varied from 30.3 cm to 54 cm. The collar diameter ranged from 22.4 mm to 53.6 mm. The crown cover was up to a maximum of 3763.0 cm^2. The primary branches were 8 to 12 in number. Distribution of the root was almost vertical in nature. The root penetration was up to 86.6 cm and the spread ranged from 61.6 cm to 83.8 cm. The primary roots were found to be 8 to 11 in number. Similarly in *Juniperous communis*, the above ground shoot was a prostrate system with the maximum height of 63.6 cm and the collar diameter ranging from 5.54 mm to 25.97 mm. The canopy spread was up to maximum of 3051.2 cm^2. The plants had a compact architecture with the number of primary branches being maximum to 6. The root system was also well developed with the mean root spread up to 196.6 cm and the root depth was up to 72.66 cm respectively. The primary roots ranged from 3 to 9 in number with the secondary roots being 2 to 4 in number on each primary root.

The comparison of all the species was done with respect to different parameters and it was observed that *Hippophae rhamnoides* has the most shallow root system, which was highly extensive particularly horizontally developed, holding the soil particles on the fragile sites. Similarly *Artemisia*

maritima also has quite high ecological potential. The good adaptive features of seabuckthorn, its wide ecological amplitude and potential of its use for the control of erosion in these conditions are revealed. The results obtained are very important for predicting the potential of plants for controlling the menace of soil erosion. Thus, the experiment suggested that the three plant species could be considered as an important approach to ecosystem stability and the soil loss will also reduce by the presence of these plant communities.

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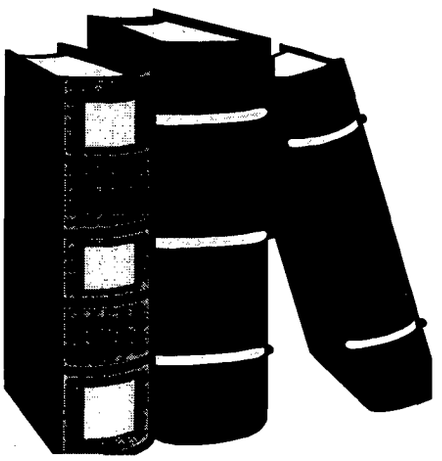

APPENDICES

APPENDIX - I
Weather Report for the season Jan 2010 to Sept 2010.

Standard week	Minimum Temperature(°)	Maximum temperature(°)	Rainfall (mm)	Sun duration (hrs)	Humidity (%)
1	-7.05	3.28	14.5	5.92	31.714
2	-9.05	2.5	1	6.90	29.714
3	-6.94	5.4	0.5	7.29	23.42
4	-5.8	4.17	0	6.91	29.71
5	-7.12	1.94	6	6.10	36.71
6	-9.3	0.95	6.16	6.16	51.75
7	-9.3	0.4	0	7.74	34.14
8	-6.52	6.25	5	8.00	36.42
9	-1.28	5.6	25	6.36	61.71
10	-5.32	7.68	15.5	7.96	29
11	-1.88	11.67	0	8.27	22.42
12	1.68	16.32	0	8.77	23.14
13	2.48	15.55	9	7.91	29.71
14	1.81	15.22	7	8.96	27
15	3.68	17.32	5.5	8.44	29.42
16	4.65	12.58	82.5	6.27	60
17	2.87	14.7	13.5	8.31	44.14
18	5.41	18.64	25.5	8.68	34.42
19	5.37	14.5	21	7.45	47.57
20	4.35	13.51	67	5.9	53
21	5.37	20.6	5	8.79	31
22	4.57	16.87	56.5	8.41	41.57
23	4.88	13.37	121.5	7.97	54.85
24	6.08	18.04	11	9.56	41.28
25	7.75	24.1	1.5	9.83	25.28
26	9.7	21.61	6	9.4	34
27	8.85	19.04	48.5	7.42	51.42
28	10.05	23.4	0	9.05	36
29	12.95	23.27	2	8.61	53.28
30	13.45	23.41	27	9.41	53.57
31	14.15	24.14	19.5	9.37	55.14
32	14.1	21.12	23	9.18	61.28
33	14.28	25.47	5	9.49	46.85
34	11.44	20.72	8	8.39	56.28
35	11.18	24.94	0	8.06	29.42
36	12.37	26.24	9.2	8.46	36.42

Brief Biodata of the Student

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Academic Qualifications:

Class	Year	School/ College	Board/ University	Marks (%)	Division
10	2004	B.D.D.A.V. Public School, Dharmshala	C.B.S.E	84.6	1st
12	2006	K.S.A, Shaheed Bhagat Singh Nagar, Punjab	C.B.S.E	80.2	1st
B.Sc (Hons.)	2009	Miranda House, Delhi	Delhi University	68.1	1st
M.Sc Environmental Sciences	2011	College of Basic Sciences	CSK HPKV, Palampur	[illegible]	1st