ALTITUDINAL VARIATIONS IN THE VEGETATION OF HUNZA VALLEY

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A thesis is submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy

in

PLANT PHYSIOLOGY

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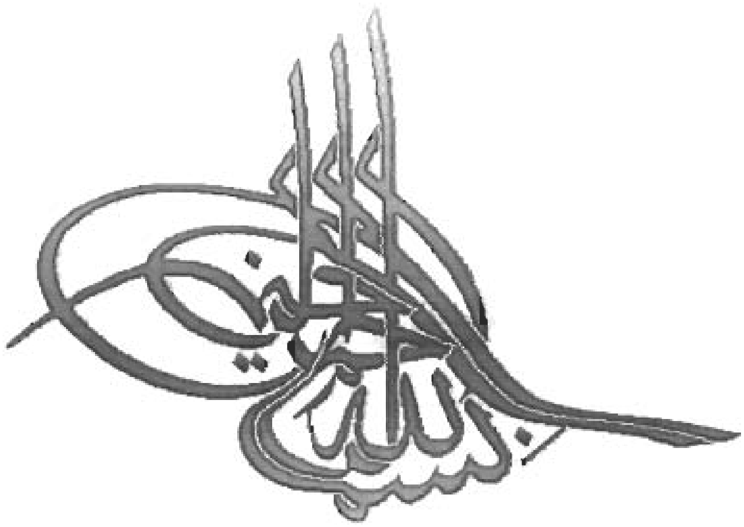

In the name of Allah, the Compassionate and

Merciful Lord do not cause our hearts to go astray

after

You have guided us and grant us

Your own mercy;

You are the

Munificent

Giver

(Al, Quran 3-8)

DECLARATION

I hereby declare that the work presented in the following thesis is my own effort, except where otherwise acknowledged, and that the thesis is my own composition. No part of this thesis has been previously presented for any other degree.

Abdul Rehman

April, 2008

CERTIFICATE

This thesis entitled "Altitudinal variations in the vegetation of Hunza valley" submitted by ***Mr. Abdul Rehman*** is accepted in its present form by the Department of Plant Sciences, Faculty of Biological Sciences, Quaid-i-Azam University, Islamabad as satisfying the thesis requirements for the degree of Doctor of Philosophy (Ph.D.) in Plant Physiology.

SUPERVISOR: ____________________
(Prof. Dr. Asghari Bano)

EXTERNAL EXAMINER: ____________________
(Dr. Sajjad M. Mirza)

EXTERNAL EXAMINER: ____________________
(Dr. Muhammad Aslam)

CHAIRMAN: ____________________
(Prof. Dr. Mir Ajab Khan)

Dated: 12-04-2008

DEDICATED

TO

MY PARENTS

AND FAMILY MEMBERS

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ABBREVIATIONS

ABA	Abscisic acid
a.s.l.	Above sea level
BHT	Butylated hydroxy Toluene
BSA	Bovine Serum Albumen
dbh	Diameter at breast height
DTPA	Diethylene triamine pentaacetic acid
DW	Dry weight
FAO	Food & Agriculture Organization
HPLC	High Performance Liquid Chromatography
ICIMOD	International Centre for Integrated Mountain Development
IUCN	International Union for Conservation of Nature
KKH	Karakoram Highway
µg	Microgram
mL	Millilitre
ng	Nanogram
NO_3	Nitrate
^{o}C	Degree centigrade
OD	Optical density
OUMNH	Oxford University Museum of Natural History
PMNH	Pakistan Museum of Natural History
RFE	Rotary Film Evaporator
rpm	Revolution per minute
UNDP	United Nations Development Programme
UNESCO	United Nations Educational, Scientific and Cultural Organisation

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ABSTRACT

Mountains have a diverse array of microclimates arising from their varied topography. Due to the diversity of altitudes, climates and landscapes. they support a high diversity of plants, including many endemic and rare species. The objective of the project was to investigate the impact of climate, altitude and edaphic factors on the floral diversity in Hunza valley (Northern Areas, Pakistan), and further to investigate the changes in endogenous stress hormone (abscisic acid), sugar and proline (as osmoregulant) in plants with respect to variation in altitude.

Five field areas viz. Ultar, Sheshpar, Updegar, Batura and Chupursan were selected for vegetation surveys, measurement of air temperature and humidity during summer, determination of chemical characteristics of the soils and ethnobotanical studies of selected flora. To record the important plants used as curatives by Brusho tribes of Hunza valley an ethnobotanical survey was conducted. Thermo- hygrograph with hair element and bimetal were installed for the measurement of temperature and humidity. Soil moisture determination was made by jet filled tensiometers. High Performance Liquid Chromatography was used for determination of a plant stress hormone abscisic acid whereas, sugars, protein and proline were determined spectrophotometerically. The Ultar pasture was chosen as the area for detailed study, because of its easy access and high plant species diversity. Chemical characteristics of soil were determined using Atomic Absorption Spectrophotometer, as and where applied.

The total number of identified species from the field areas of Sheshpar, Ultar, Batura, Updeger, and Chupursan was 218. belonging to 47 families. The important families were Asteraceae (37 species), Papilionaceae (20 species). Poaceae (14 species), Lamiaceae (11 species) and Rosaceae (10 species). The observed species richness pattern in the field areas showed that Sheshpar with 116 species had the highest species richness while Chupursan with 82 species inhabit minimum number of species.

The number of observed species at one to five sites and the number of commonly occurring species differed significantly whereas, the number of rare species showed no significant difference in the five field areas.

Species like *Anaphalis nepalensis, Thymus serpyllum* and *Aristida* showed a greater range of altitudinal limits as compared to other plant species observed in the areas of Ultar and Updegar. There was a significant difference in the number of species growing in the range of 0-300 m in the field areas of Ultar and Updegar.

The yearly average maximum and minimum temperatures and humidity recorded from April to September at Ultar and Chupursan showed that 2002 was a relatively warm year than 2001. A decreasing trend of humidity patterns was observed from south (Ultar) to north (Chupursan), showing adequate moisture availability at Ultar as compared to Chupursan.

The observed species richness was higher at Ultar as compared to Chupursan. Data showed that the soils of Ultar and Sheshpar are more acidic as compared to the other field areas. Values for K, Mn, P and $NO_3 - N$ were observed to be highest at Ultar as compared with other field areas. Chupursan soil showed significantly higher Fe content, lower EC values and lower value of $NO_3 - N$ content as compared to other areas.

Endogenous sugar, protein, proline and abscisic acid content of leaves were higher in all the species collected at 3,500 m a.s.l. as compared to 3,000 m a.s.l. Higher average soil moisture values were recorded on north facing slope than south facing slope at Ultar.

Over-gazing reduced the diversity of flora, and changed species composition, by depleting species at Ultar pastures. Stocking densities at Ultar pastures for three consecutive years (2000, 2001 and 2002) showed a general trend of increasing number of animal units. The increase in abscisic acid, protein, sugar and proline contents appeared to be correlated with the increase in altitude in all the plant species.

INTRODUCTION

1.1 MOUNTAIN ECOSYSTEMS

From the scientific viewpoint, mountains are large, interesting laboratories of knowledge where species and communities, which have adapted in various ways to their environment, are to be found; they are places where one can observe and understand the evolution of species and the efficient distribution of organisms between similar environments from one mountain "island" to another, separated from each other by thousands of kilometers.

Mountains represent an enormous compression of life zones. The wide diversity of climates combined with local differences owing to geomorphological, edaphic and plant cover features have given rise to a range of microclimates which have become habitats for different species which adapt to them, making them their specific niches.

About 3% of the terrestrial surface of the Earth is covered by high mountain ecosystems, where about 4% of the Earth's flora is found (Heywood, 1995). In most areas of the world, high mountains do not form a continuous landscape and alpine habitats occur as sporadic and isolated islands (Coe, 1967).

Estimates as to how many people live in mountains vary. According to (Baatzing *et al.* 1996) about 10% of the world's population lives in high mountains and middle mountain regions. According to estimates published by FAO (2001), in the tropics, 3.4% of the Earth's area falls in the montane and alpine (including nival) zones. A fundamental characteristic of mountain ecosystems is the drastic change in vegetation as well as in climate from the base to the summit of mountain. Elevation gradients create varied climates, along with resultant soil differentiation; promote the diversification of plant species (Brown and Lomolino, 1998).

High mountains often harbour a specialized flora and fauna with many endemic species, which have developed because of historic isolation or other forms of speciation (Churchill *et al.* 1995). Alpine environments are characterized by a short growing season and low temperatures (Billings and Mooney, 1968; Billings, 1974; Pickering, 1997; Korner 1999; Costin *et al.* 2000).

The alpine zone of the high mountains harbour specialized life forms at high elevations. These high mountains form a break to natural species distributions and control the spread of species which are usually associated with human activities. Introduced species therefore are rare in the high mountain zone. Differences in topography and surface properties (e.g. long smooth ridge type slopes vs. scree slopes) of high mountains are important for determining the rate of colonization and lead to differential degrees of establishment of plants upslope (Grabherr *et al.* 1994; Pauli *et al.* 2003).

Although alpine terrain makes up only 3% of Earth's continents, it houses 10,000 species of higher plants, or 4% of the global total (Gough *et al.* 1994). It is estimated that there are about 250000 flowering plants species in the world.

There are different current trends in agricultural land use in the world's high mountains (Hamilton *et al.* 1997). Modern agricultural production is fundamentally based on cultivation of large fields and, as a result of globalization, the monopolistic imposition of cultivation technologies on producers. The technologies require intensive practices such as fertilizer, heavy machinery and pesticide application for producing marketable commodities. The application of such agricultural production in high mountain environments is much restricted by the prevalent natural and socio-economic conditions, i.e. limited accessibility, fragility of the ecosystem, marginal productivity of land, and topography and related diversity (Jodha, 1997).

The ancient civilizations of the New World have modified the tropical highland landscape through agriculture in a localized manner, particularly around the ancient indigenous centers and their associated villages. There are still large areas under low intensity cultivation or in pasture, where agricultural techniques differ little from those employed 100–200 years ago, particularly in steep mountainous regions, where smaller towns and villages still rely on local plants for various uses (Churchill *et al.* 1995).

In mountain areas, agroforestry systems are of importance for soil, water and nutrient conservation for sustainable agricultural production (Sharma *et al.* 2001).

1.2 MOUNTAIN RANGES OF PAKISTAN

Pakistan is the proud custodian of a variety of mountains found nowhere else in the world. A great part of Pakistan's renewable clean water resources are formed and stored in these mountain areas. The fabled Sulaiman Range that runs for a distance of 480 kilometers in the south-north direction starting from the heart of Balochistan and continues up to the North West Frontier Province. Sulaiman range is known for its historic passes such as Bolan, Gomal, Tochi, and Khyber.

The other four ranges of the Hindukush, Pamir, Karakoram and the Great Himalaya form one of the most dense concentrations of high peaks in the world. Five of the fourteen highest mountains in the world are found here, which are above 26,000 feet including The K2 (8,611 m a.s.l.), Nanga Parbat (8,125 m a.s.l.), Gasherbrum-I (8,068 m a.s.l.), Broad Peak (8,407 m a.s.l.), and Gasherbrum-II (8,035 m a.s.l.). There are forty-two others, which are higher than all the highest peaks of the other continents (UNIC, 2002).

1.3 KARAKORAM MOUNTAINS

Karakoram mountains (71° – 79° E, 35° – 36° N) petrographically and orographically form one component of the young folded mountain belt of Central Asia (Hewitt, 1989; Schneider, 1956; Searle, 1991). The Toponym *Karakoram* derives from the Turkic expression for black gravel or black rock. The Karakoram Mountains are part of an alpine orogenic belt, which includes the South and Central Pamirs, the Aghil Range, The Kashmir Himalaya and the eastern Hindukush (Desio, 1974). In the Karakoram Mountains high-lying valley floors stretch over a long distances and the mountain ridges also rest comparatively high (Iturrizaga, 1998).

Located in the northwestern part of the Tibetan Plateu, the Karakoram Mountains consist of parallel ranges that stretch from Pamir and the Hindukush in the northwest to the

Qiangtang Plateau in the southeast. The Karakoram, with elevations of 6,000-7,000 m. a.s.l. and higher is the highest mountain range in the northwestern part of Tibetan Plateau. The western Karakoram, situated in the west of the Karakoram Pass, consists of the Saltoro Karakoram, Hunza Karakoram, and the High Karakoram. The large part of the Karakoram, with great relative elevation and steep slopes, is characterized by high relief energy and immense geomorphological processes (Zheng, 1998).

The Karakoram Mountains are considered as a winter precipitation area influenced by westerlies (Paffen, 1956) with precipitation amounts hardly exceeding 130 mm per year at the valley floors (Goudie *et al.* 1984). The extreme dissection of the Karakoram, with a vertical relief usually exceeding 3000 m causes a very steep, non-linear vertical gradient of moisture, with eu-or-per-arid conditions in the sub-alpine/alpine belts (Miehe *et al.* 1996). Steep slopes and uneven topography divide the area into small patches. Villages are situated on a series of fans. These fans have been terraced for several hundred years (Butz, 1998).

Human life in these barren Karakoram valleys is a continuous struggle for existence: a struggle not only to force the sterile soil to yield enough to keep them from starvation, but also a struggle against the terrible menace of Nature (Visser-Hooft, 1926).

On the southern flanks of the Karkorum, conspicuous arid valley landscapes occur in the upper reaches of the Indus River, in particular in the middle and lower Hunza region (Zheng, 1998).

The discharge pattern in the Karakoram is strongly linked with the seasonal temperature peaks causing glacier melting. About 60 % of the annual runoff appears in the months of July and August (Ferguson, 1984). Climatically the Karakoram mountains form a barrier between the monsoon-dominated lowlands of the Indian subcontinent and the arid belt of Central Asia (Kreutzmann, 2000).

1.4 NORTHERN AREAS

The Northern Area is situated in the extreme north of Pakistan. Its position is of strategic importance as it is the only part of Pakistan surrounded by three foreign countries: India to the east, China to the north, and Afghanistan to the west (Fig.1.1).

Northern Pakistan, including the Himalayas, the Karakorams and the Hindukush, presents a formidable arrangement of mountains and mountain eco-systems which is very unique and rare throughout the world. Northern area is one of the most rugged in the world where four mountain ranges, The Himalayan, Karakoram, Hindu Kush and Pamir meet.

The Northern Areas enclose an area of 72, 496 sq. km. The geographical position of the Northern Areas (35– 37° North; 73 – 78° East) represents one section of the Asian high-mountain system of Hindukush-Karakoram-Westhimalaya. The region was divided into three districts namely Gilgit, Diamir and Baltistan in 1967. In 1989 the region was further decentralized into five districts (Dittrich, 1998). Presently, the Northern Areas are divided into six administrative districts of Gilgit, Skardu, Diamir, Ghizar and Ghanche and Astore.

The first jeep had reached Gilgit via the Kaghan-Babusar-Route in 1949.Later the completeion of the Karakoram Highway (1978) and the Skardu road (1981) gave decisive impetus to the reinforced improvement of the road network (Schickoff, 1998). Three-forths of the area is permanently covered by snow and ice. It possesses some of the world's largest glaciers outside Poplar regions (Kamal and Nasir, 1998).

Land use is dominated by mountains (34% of area), rangelands (52%) with a small area of natural forest (4%). Less than 1% of the land is cultivated, about one percent of land is cultivable waste and 8% uncultivated waste (Table 1.1).

These areas are populated by about one million people with population density as 14 person/square kilometers. The average household size is 7.2 persons. People with an average of 0.12 million hectare of agricultural land are living in about 650 villages, which

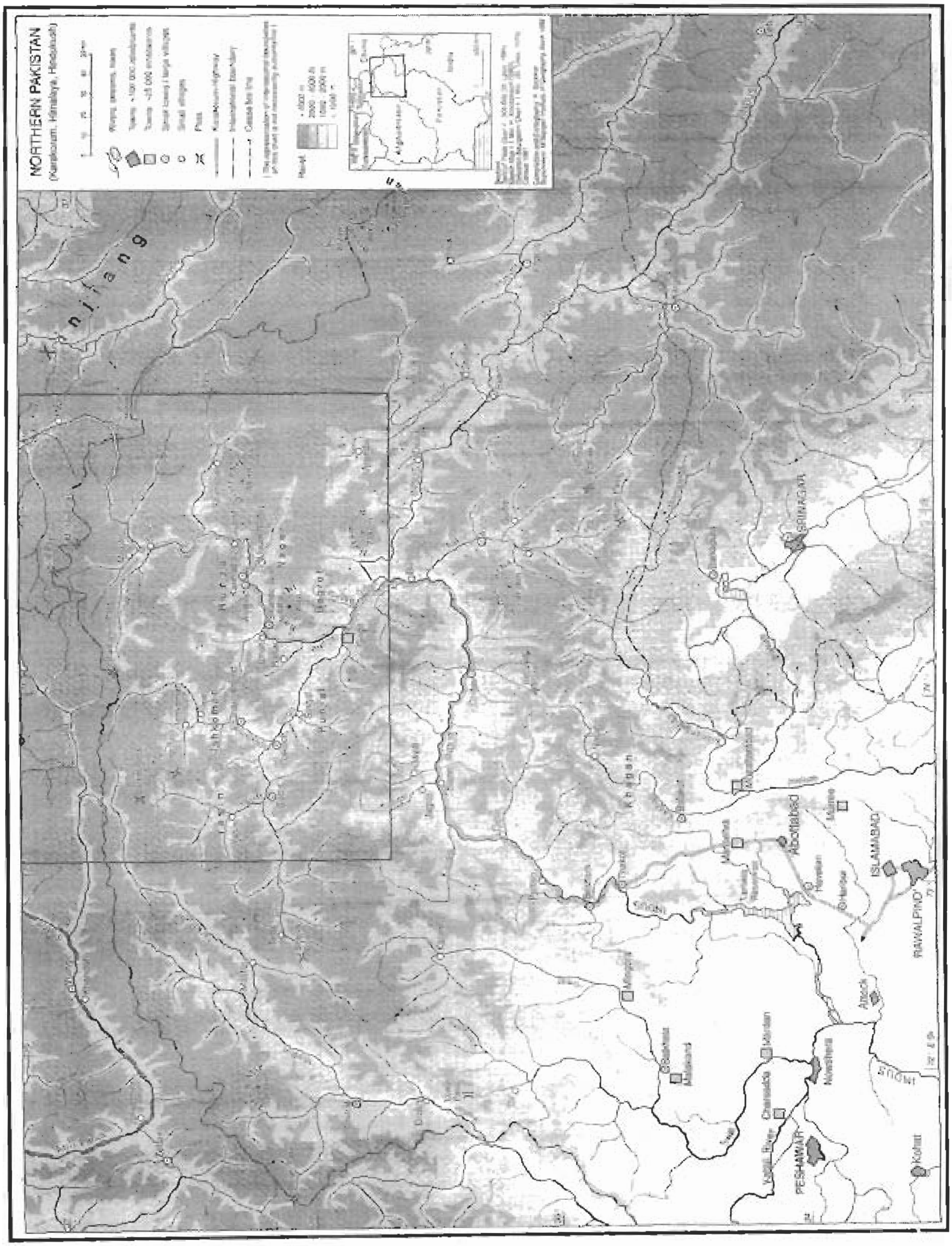


Fig. 1.1 Map of Northern Pakistan

are very widely scattered (NAS, 1996). The major inhabited land lies between 1100-2200 m (Whiteman, 1985).

Table 1.1: Land use Area (million ha) Percentage in Northern Areas

Land Use	Area (million ha)	Percentage
Mountains	2.440	34
Forests	0.313	4
Rangelands	3.760	52
Cultivated area	0.054	1
Cultivable waste	0.060	1
Uncultivated waste	0.618	8
Total	7.245	100

Source: Census of Agriculture, Northern Areas, 1990

In the northern part of the Northern Areas, the permanent settlements and the agricultural land are mainly located on terraced alluvial fans and slopes. In the northern part of Northern Areas, the altitudinal limit of the irrigation agriculture is between 3,000 m – 3,200 m (Dittrich, 1998).

The area as a whole is mostly mountainous and rugged. The occupation is agriculture, and mainly pastoralism in the areas located at higher altitudes (Rasool, 1998).The Northern areas of Pakistan is well known for its biodiversity. About 3000 species of plants have been reported to exist in the area, out of which approximately 124 species have medicinal properties (UNDP/IUCN, 1999).

1.5 HUNZA VALLEY

Hunza valley (36.38° N, 73.34° E) is the northern part of a region known as the Northern Areas of Pakistan. It comprises an area of 10,101 km². Karakoram Highway connects

Pakistan to China through the Khunjerab Pass (Fig. 1.2). The population comprises of three ethnic groups.The upper part of Hunza valley is populated by Wakhi speakers called Gojal; Central, with Brushaski speaking people and the Shina speaking people live in the lower part of Hunza. The people of Hunza are called 'Hunzukuts', while Brushaski speaking people are called "Brusho". Apart from Burushaski is the other Languages spoken are Wakhi, Shina, and Domaski. Brushaski is spoken by some fifty thousand people in northern Pakistan (Blair and McCarry, 1994).

Hunza was a princely state until 1947 and Karimabad (Baltit) was its capital. After the dismissal of the ruler in 1974, Hunza was fully integrated into the Islamic Republic of Pakistan (Schmid, 2000). It is now ruled directly from Islamabad through the administration based in Gilgit, the regional capital of Gilgit-Baltistan. In agro-climatological approaches Hunza is characterized as a transition zone from double cropping to single cropping (Conway *et al.* 1987).

Cultivated lands on the southern sides of the Karakoram are distributed on fluvial-proluvial terraces and fans. In the Hunza region, the Hunza people have dug channels to direct melt water for irrigation and have built terraced fields on unstable landforms such as proluvial fans and talus cones. The Hunza region, with its long history of cultivation and intense utilization, is an important agricultural area in northern Pakistan. Maize, wheat and barley are important cereal crops.

Double cropping is practiced up to 2,300 m while above that altitude only single, short-duration crops can be raised. Orchards of apricot, apple and mulberry are important components of the farming system. Due to low precipitation, crop cultivation is possible only in irrigated areas. Cultivation is practiced on river terraces, alluvial fans and scree slopes.

Many crops are grown as part of agroforestry systems in the montane zone. The upper montane zone and the treeline ecotone are mostly used for pasturing. In upper Hunza, with elevations of more than 2,300-2,400 m a.s.l., the main crops are spring potatoes,

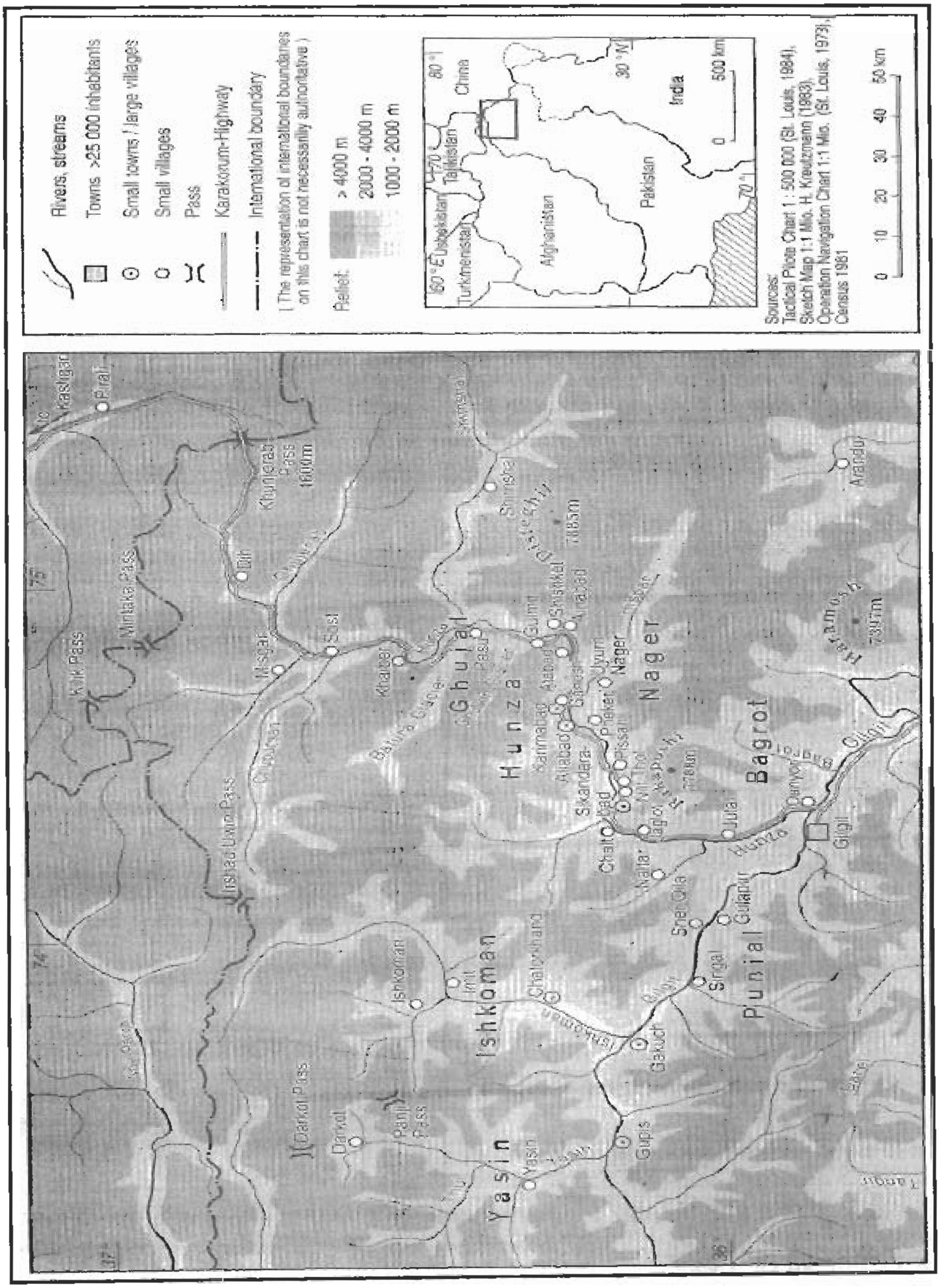


Fig. 1.2 Map of Gilgit and adjoining valleys

with one harvest per year, while in the middle and lower Hunza areas, the main crops are winter wheat and maize, with two harvests a year. The cultivation of temperate zone fruit such as apples, pears, grapes, and apricots has been widespread for a long time (Zheng, 1998).

In the Hunza valley people reside amidst some of Pakistan's most spectacular and rugged mountain scenery. They usually depend upon animal husbandry and tourism for their livelihood. Cattle are grazed on the alpine and sub-alpine pastures. Himalayan brown bear (*Ursos arctos*), snow-leopard (*Panthera uncia*) and wild ungulates such as blue sheep (*Pseudois nayaur*), and Siberian ibex (*Capra ibex siberica*) and Marco Polo sheep (*Ovis ammon polii*) are native to the area (Knudsen, 1999).

1.5.1 Physical Environment

The Hunza valley in Northern Pakistan shows greater relative relief than any other place on Earth. The climate of the area, transitional between that of Central Asia and monsoonal lands of South Asia, varies considerably with latitude, altitude, aspect and localized relief (Goudie *et al.* 1984).

The Hunza valley has some of the steepest slopes on earth that leaves only limited space for cultivation. Between the Hunza river at Altit (2,100 m) and the Ultar I peak (7,390m) the average inclination of the slope ranges around 60 per cent (Kreutzmann, 2000). Due to Hunza's position at the cross-section of the Central-Asian arid zone and the sub-tropical zone, agriculture production is only possible through irrigation and the construction of channel networks allows the cultivation of agricultural lands (Schmid, 2000).

1.5.2 Vegetation

Champion *et al.* (1965) gave a comprehensive description of the forest types of Pakistan. Stewart published Catalogue of Flora of Pakistan (1972). Nasir and Ali worked on Flora of Pakistan National Herbarium Islamabad, during 1970-2002.

Dickore (1995) surveyed and studied the flora of Karakoram and adjacent tare (Monocotyledons).The flora of the Northern Areas has yet to be fully described, and it is very likely that new species of plants remain to be discovered.

Sheikh and Khan (1982) described the forest and range vegetation of the Northern Areas. According to them, the areas are subject to heavy pressure by livestock as well as a shortage of fuel wood. Beg and Bakhsh (1979) distinguished eight plant communities in scree slopes in Chitral.

The vicinity of the Indus along the Karakoram Highway through upper Hunza (Gojal) to Sost, includes wide stretches of arid mountain slopes, with vegetation most obvious along the edges of glacier-fed streams, and in the irrigated orchards and fields surrounding villages (Hussain, 2003).

Hussain (1968) gave the description of vegetation types in the alpine pastures in the northern mountains of Pakistan. The habitat is characterized by the presence of scree sand bits of rocks. *Saxifraga imbricata*, which is adapted to high winds, strong radiation and snow, is dominant. Vegetation consists of perennial forbs, and grasses belonging to the genera *Poa, Festuca, Stipa* and *Agropyron*. Above 3200 m elevation, the forest is replaced by scrub consisting of *Juniperus* and *Artemisia* which occupy exposed slopes in the interior valleys. *Ephedera gerardiana* occurs on gravel deposits in the bottom.

Braun (1992, 1995) successfully tried to reconstruct the potential extent of "economically important" forests. According to him in small test areas of Hunza Karakoram, relicts of the natural forests are still present. The open forest of *Juniperus excelsa* is commonly found in middle and upper Hunza. Its upper limit may reach to 3,600-3,800 m a.s.l. *Juniperus excelsa* may grow at an upper elevation of 4,000-4,100 m a.s.l. in the areas near Batura Glacier, forming an upper tree line (Zheng, 1998).

In the transition from the new Himalayas to the adjacent Karakoram in the north, the *Abies-Pinus* forests of the sunny slope are replaced by junipers (Schickhoff, 1993; Troll, 1939). Only at the boarder between humid and arid altitudinal sequence types in the slopes: on the arid side, the juniper stands remain open (closing at most in the semi-arid type within the sub-alpine zone near the tree line), and closed coniferous forests are restricted to the shady slopes.

Einar (2004) presents the floristic results of his studies in an annotated checklist of vascular plants of Batura valley, Hunza Karakuram. In the interior of Karakoram, such as Hunza, a montane coniferous forest of *Juniperus semiglobosa* can be observed (Zheng, 1998). Suffrutescent desert vegetation, occurring at the valley bottom of the Hunza River, consists chiefly of *Krascheninnikovia ceratoides* and *Salsola* spp. (Zheng, 1998).

In arid high mountains usually there are two treelines, a lower and an upper one. Tree growth below the lower treeline is limited by water shortage, while the upper treeline may be a combination of water shortage and low temperatures. Tree growth occurs in a belt which coincides with cloud belts (e.g. 3400-3900 m in the Hunza Karakoram (Troll 1973).

In fact, however, the upper montane/sub-alpine forest belt on that slope is very narrow and lacks *Pinus* trees; the forests are entirely constituted of junipers, succeed by a broad willow zone in the lower alpine belt. Three diagrams originate from stations situated in the lowest zone of the montane *Artemisia* dwarf-scrub belt where it is assumably still too dry for the growth of juniper trees: Karimabad/Baltit (137 mm) in the semi-humid sequence type and Misgar (104 mm) in the eu-arid sequence type of upper Hunza.

According to Paffen (1956) the basal belt in the Hunza area is a montane desert steppe belt, composed of *Artemisia brevifolia*, but Miehe and Miehe (1998) found a montane desert belt in Hunza consisting mainly of *Salsola* spp. and *Krascheninnikovia ceratoides*.

1.5.3 Species Richness

Several studies have found a decreasing trend in species richness with altitude (Yoda 1967; Alexander and Hilliard 1969; Kikkawa and Williams 1971; Hamilton 1975). The flora of Karakoram is poor in species, but essentially transitional and dominated by taxonomically complex and widely distributed groups (Dickore, 1995). Northern Areas harbour some of the richest plant communities in the region. The total number of plant species occurring in Northern Areas is not yet fully elucidated. However, some studies suggest high richness in plant communities. The richness in flora is due to the great variation in light, elevation, climate, water, terrain and soil, which create a variety of micro-climate that support a tremendous diversity of flora (Virk, 2003).

In fact, biodiversity richness in Northern areas has never been evaluated systematically. However, some studies have documented floral diversity of some areas, which provides partial picture of biodiversity in Northern Areas. About 342 species of plants belonging to 36 families and 142 genera have been recorded from the Deosai plateau.

Patterns of species richness show a general trend of increased richness in plant species from north to south and from west to east. For example, 134 species belonging to 35 families and about 90 genera of plants have been recorded from Khunjerab National Park (IUCN, 2003 a). Almost at the same elevations of Deosai National Park in the western Himalayas 342 species of plants belonging to 36 families and 142 genera have been listed (Woods *et al.* 1997). In total 153 plant species belonging to 38 families and 113 genera have been recorded after extensive field research in the area (Sheikh, 2002). Ali and Qaiser (1986) recognize four phytogeographic regions in Pakistan, which help in explaining richness and diversity of the flora.

The latitudinal decrease in species richness has been known for over a century (Wallace 1878; Pianka 1966; Brown and Lomolino 1998). Altitudinal trends in species richness are generally thought to mimic latitudinal trends in species richness, and the same factors are often used to explain this altitudinal pattern (MacArthur 1969, 1972; Begon *et. al.* 1990; Rohde 1992; Rahbek 1997; Brown and Lomolino 1998; Givnish 1999).

The relationship between species richness and ecosystem functioning has been the subject of many debates (Schulze and Mooney, 1993; Lawton, 2000). The regional patterns of species richness are a consequence of many interacting factors, such as plant productivity, competition, geographical area, historical or evolutional development, regional species dynamics, regional species pool, environmental variables, and human activity (Woodward, 1988; Palmer, 1991; Eriksson, 1996; Zobel, 1997; Criddle *et al.* 2003).

The richness of the Northern Areas flora is the result of the great variations in light, elevation, temperature, water availability, terrain and soil type, which create a variety of micro-climates and growing environments.

Rahbek (1995) presented a critical literature review on species richness patterns in relation to altitude and showed that approximately half of the studies detected a mid altitude peak in species richness. Other authors also reported humped relationship between species richness and altitude (Whittaker, 1960; Rahbek, 1997).

The range of a species along an altitudinal gradient is geometrically constrained by sea level or the bottom of a valley as a lower boundary and the top of a mountain or an ecophysiological constraint as an upper boundary (Colwell and Lees 2000).

1.5.4 Distribution Patterns

Traditional viewpoints state that lowlands in the tropical and sub-tropical zones have the highest biodiversity (MacArthur, 1972) that is, plant species diversity declines with higher altitude. However, this hypothesis lacks support (Colwell and Hurtt, 1994). Nevertheless, plant species diversity increasing with altitude has been observed in humid climates, owing to the additional precipitation at higher altitudes or to the heterogeneity of habitats, such as soil, snow, or wind (Peet, 1978; Itow, 1991).

Distribution patterns of plants are controlled by water and temperature conditions (Holdridge, 1947). Altitudinal patterns are the results of interactions between the altitudinal gradient and the water gradient (Minchin, 1989). In addition, the soil base of the mountain and precipitation also have a considerable effect on the altitudinal pattern of plant species diversity (Wilson *et al.* 1990).

Variation in microclimate with topography and elevation is a major factor of species distribution within a forest landscape. Mark *et al* (2000) found topographic features (elevation, exposure and slope) to be responsible for the macroscale patterns of alpine vegetation distribution on Mount Armstrong in New Zealand.

Altitudinal differences in the mountains have also made for very varied climates, promoting the diversification of groups of species, adaptable to different environments. The distribution of species richness along elevation gradients is governed by a series of interacting biological and climatic factors (Colwell and Lees, 2000). Further, elevation represents a complex gradient along which many environmental variables change simultaneously (Austin *et al.* 1996).

The different mountain ranges are differently exposed to summer temperatures and amount of snow falls. The permanent snow line and the timber line also vary in various ranges and even on the different exposures of the same range. Southern ranges are more exposed to summer monsoons than the central and northern slopes. These variations have greatly affected the distribution of flora on mountain slopes (Mirza, 2003).

According to Sultana *et al.* (2003) majority of the species were found in altitudinal ranges 3501-4000 m and 4001-4500 m. Only 13 samples were obtained from the altitudinal ranges 3,000-3,500 m. The highest range 4501-4,800, due to extreme cold climate, showed only 4 species. Occurrence of few species on the lowest zone may be due to more dry conditions in this zone.

The Himalayan elevation gradient is the longest bioclimatic gradient in the world, and vascular plants in Nepal are found from 60 to 6,400 m above sea level (a.s.l.). The highest limit of the overlying sub-alpine zone, which is between 4,000 and 4,500 m, defines the tree limit in Nepal. In the alpine zone, there are some shrubs, but grassland is predominant. In the high-alpine zone, the vegetation is more discontinuous (Dobremez 1976).

The distribution of a species is the result of physiological adaptation to biotic and environmental conditions (Clayton 1981, Ricardi *et al.* 1997, Sklenar and Jorgensen 1999, Sklenar and Ramsay 2001). Gates (1980) considers temperature and humidity as the main determinants of distribution patterns in grasslands.

Forsyth (1970) correlated Gordon's vegetation types to edaphic factors such as the availability of moisture, parent geologic material, topography, and direction of slope. He found that the distribution of these vegetation types, or plant communities, is predictable on the basis of climate, geology, and topography.

Because of periodic natural disturbances, vegetation seldom maintains a constant species composition for more than a few centuries (Noss, 1985). The distribution of the forest resources in Northern Areas is not only horizontally limited, it is also vertically restricted.

Vegetation and other land cover classes in the Karakoram Mountains depend on the topographical variables of slope inclination, slope aspect, shading and altitude. By means of digital satellite image processing and GIS modeling, Braun (1995) developed methods to quantify the decline of near natural forest stands in Hunza Karakoram and to compute the potential short-wave irradiation on a digital elevation model of this area.

In Hunza Valley, the transition from arid Chenopodiaceae dwarf-shrublands to *Artemisia* dwarf-scrub with scattered small trees takes place around 2000 m (Braun, 1996). The valleys represent a typical subtropical steppic high mountain area with altitudinal zonation of vegetation cover. The classification of vegetational belts begins at the valley bottom with desert conditions. Next comes the Artemisia steppe where most permanent settlements are located. If one follows the slope gradient upwards, humid-temperated stretches where coniferous woods occur locally at northern exposures. Above this is found the zone of high pastures; an important economic resource is composed of valuable meadows reaching upwards to the zone of perennial snow and ice (Paffen *et al.* 1956).

The vertical distribution of plant communities is shown to be affected by altitude. Paffen *et al.* (1956) and Schweinfurth (1957) observed in the Hunza valley that the valley floor at 2000 m is semi desert which is followed at higher altitudes by, *Artemisia* steppe, *Juniperus* scrub, *Picea-Pinus* forest, *Betula* and *Salix-Betula* scrub and finally there is moist alpine meadow reaching up to 5000-6000 m a.s.l.

1.5.5 Climate

High mountain sites are stress - dominated habitats characterized by low air and soil temperatures, night frost during growing season. strong winds, high evaporation and intensive day time radiation (Larcher, 1983). These are unique environments favouring selection and adaptive radiation among regional floras in response to steep temperature gradients (Billings, 1973, 1974; Larcher, 1980).

These areas are very often characterized as marginal ecosystems which have become seriously endangered by human activities and, therefore, play a major role in the discussions on global environmental change.

Geographically, Pakistan has a diverse climate ranging from subtropical to temperate and alpine forests. Climatically, it is arid and semi-arid. The altitudinal variations are wide ranging from sea level to 8,000 meters. Annual rainfall varies from 50 mm in arid and semi-arid areas to 2.000 mm in moist forests. The temperature influenced by altitude varies from below freezing in northern mountains during winter to 35-50 °C during summer in southern plains (Ahmed and Ghafoor, 2003).

Arid mountain environments have desert-like habitats and their plant and animal life usually has a different evolutionary history from that in humid alpine environments (Varga, 2003). The major part of Pakistan lies in the arid and semi-arid zone, characterized by low precipitation, extreme temperatures and low humidity (Said, 1961).

About 70 percent area of the country is arid to semi-arid. Summers are extremely hot while winters are cold. Northern snow-covered mountains of the Himalayas, Hindukush and Karakoram ranges are the main source of runoff for the mighty Indus river and its tributaries (Mohammad, 1989).

Mian and Syal (1986) classified mountains as one of the ten geomorphic units of Pakistan. Rafiq (1976) delineated crop ecological zones on the basis of physiography and climate. Khan (1971) divided northern Pakistan into alpine, sub-alpine, dry temperate, sub-tropical humid and sub humid zones.

The areas lying above an altitude of about 3000 m and below the zone of perpetual snow constitute alpine pastures. Mohammad (1987) described in detail the alpine ecosystems. Alpine pastures are characterized by short, cool growing seasons and long, cold winters. The vegetation is mostly dominated by slow growing perennial, herbaceous and shrubby vascular plants and extensive mats of cryptogams (mosses, lichens, etc.). Much of the landscape of alpine pastures is rugged and broken with rocky snow-caped peaks, spectacular cliffs and slopes. However, there are also many large areas, gently rolling to almost flat topography.

The amount of precipitation increases considerably with altitude: At a height about 5,000 m, close to the snow line, precipitation can reach more than 2,000 mm per year (Iturrizaga, 1998). Generally, a decreasing humidity and an increasing significance of continental climate elements can be observed from south to north. The amount of precipitation increases with altitude, an essential precondition for the expanded glaciation of the mountain peaks. Down in the valley, aridity prevails with an annual precipitation of less than 300 mm (Dittrich, 1998).

Apart from the potential of climate changes for direct impact on the hydrological cycle (Loaiciga *et al.* 2000), they will very probably also change vegetation properties.
The physical geography branch of the CAK Project tried in a multidisciplinary approach to understand and to quantify the climate of western Karakoram (Kandel, 1995). For the

assessment of the humidity patterns, Weirs (1995) evaluated all available precipitation and runoff data. At the same time, the first series of climatic stations at various heights above the valley floor were installed in Bagrot Valley (Cramer, 1993) and in Yasin catchment area (Jacobson, 1993).

When complicated topographic pattern in the Karakoram is kept in mind, it is well imaginable that each valley has its individual radiation regime and rainward/rainshadow position concerning summer and winter precipitation, resulting in valley-specific horizontal and vertical gradients of climatic patterns (Miehe and Miehe, 1998).

Climatic data are available for longer periods only from weather stations in valleys thus showing the limitations for agriculture in the permanent settlements (Kreutzmann, 2000). Since the autumn of 1990, a climatic measurement network with high altitude stations has been established within the context of the Culture Area Karakoram Project. Thus for the first time a series of measurements at high altitudes over several years has become available, providing a significantly better data base for future climatological studies in these high mountain areas (Jacobsen, 1998).

1.5.6 Ethnobotany

Since times immemorial, medicinal plants have been used in virtually all cultures as a source of medicine. The use of traditional medicine and medicinal plants in most developing countries, as a normative basis for the maintenance of good health, has been widely observed (UNESCO, 1996).

One of the objective of ethnobotanical study is to record the indigenous knowledge about plants. A number of efforts have been done in this regard. The first written record of the use of herbal medicines dates back as early as 101 B.C.(Sun, 1996; Huang, 1998). The anonymous Shen Nong Ben Cao Jing (Sheng Nong's Classic of the Materia Medica) summarized the experience of the use of herbal medicine and stories on tasting trials of hundreds of herbals since 2,800 B.C. Almost at the same time, Huang Di Nei Jing (The

Yellow Emperor's Classic of Internal Medicine) recorded 13 herbal decoction formulas and detailed information on their manufacture, usage, and dosage (Liu and Liu, 2001).

Motely (1994) presented a comprehensive survey of past, present and future uses of Sweet flag *Acorus calamus* (Araceae). According to him the plant has a rich ethnobotanical history dating back possibly to the time of Moses [The Prophet Musa (peace be upon him)] in the old testament of Bible and in early Greek and Roman medicines.

Bhuyan (1994) studied indigenous medicinal therapies of the Lohit district of Arunachal Pradesh, India. He described 15 drugs of plant origin commonly used in abortion and easy delivery after proper identification with their scientific, local name, part used and method of administration.

Medicinal plants continue to be extensively used as a major source of drugs for the treatment of many health disorders all over the world. In Pakistan, the field of ethnobotany is quite virgin. Only a few papers have been published. Rafiq (1995) documented ethnobotanical use of 96 plant species along with notes on their altitudinal distribution, origin and their conservation status.

It is estimated that there are about 6000 species of higher plants in Pakistan (Stewart, 1972). Most of the floristic surveys conducted in Pakistan indicated that at least 1000 species of medicinal plants occur in northern parts of Pakistan (Ikram and Fazal, 1978), of these species approximately 500 are known for their active constituents from research conducted in Pakistan or elsewhere (Williams and Ahmed, 1999).

Shinwari (1996) discussed the present status of ethnobotany in Pakistan. He described the need of investigation, documentation, explanation and application of traditional knowledge in the use of natural resources. According to Rasool (1998) some 60 plant species of medicinal value are found in Norhern Areas. Shinwari *et al.* (2002) studied the

Fig. 1.3 Photograph showing dominant species of *Onobrachis dealbata* at Gusesum (3,700 m a.s.l.), Batura glacier.

current status of medicinal plants of Bar and Shinaki Valleys, District Gilgit, Northern Areas. Ahmed (1986) studied the vegetation of some foothills of Himalayan range in Pakistan along the great silk route from Gilgit to Passu.

Hussain and Mustafa (1995) reported ecological studies of plants in relation to animal use found in Nasirabad valley, Hunza, Pakistan. Ali (2001) studied the ethnobotany and conservation status of Nagar velley, Northern Pakistan. Zaidi (1998) described *in situ* cultivation and propagation of medicinal plants in the northern regions and classified temperate medicinal and aromatic plants occurring at higher elevations. A list of 136 species of medicinal plants, together with information on their local names, distribution and current uses was published by the researchers of the Culture Area Karakoram Scientific Project.

Over collection and exploitation of medicinal plants both for sale and for local use has threatened some rare plants to get extinct. Rasool (1998) reported that *Saussuria lappa* known locally as *kuth and Picrorhiza kurroa* (know as *karu*), have been heavily exploited in the past and is at the verge of extinction from many of its natural habitats.

Khan (1994) described the past and present status of natural tropical thorn forest in Punjab, which were the main sources of firewood supplies for urban and rural populations. Leporatti and Lattanzi (1994) studied 27 medicinal plants ethnobotanically in Makran (Southern Pakistan). They reported and discussed their traditional medicinal uses. Goodman and Ghafoor (1992) conducted ethnobotanical study in Baluchistan province of southwestern Pakistan. Hocking (1958, 1962) wrote a series of papers on medicinal plants of Pakistan and included some information on Baluchistan.

Shinwari and Malik (1989) concluded a field study of plant utilization of northeastern Baluchistan. Malik *et al.* (1990) gathered some preliminary ethnobotanical information about Kharan district of Baluchistan. Yong (1998) reported some of the famous traditional Chinese medicines, for example: *Glycyrrhiza uralensis, G. inflate, Codonopsis clematidea, Lepyroidiclis, Polygonum aviculara, Oxyria digyna, Chenopodium album,* *Kockia scoparia, Tribulus terrestris* and *Ephedra* spp. *Lathariella cashmerianai* has a bright orange colour visible from a distance. Besides, this species is highly valued as a medicinal plant and widely known by the local population (Brushaski: *gulgul*) (Miehe and Miehe, 1998).

1.5.7 Land Use

In the Northern Areas, nearly every household has a piece of cultivated land. Until recently, land was cultivated jointly by the family. With the opening of off-farm job opportunities, land is now being leased (Kamal and Nasir, 1998).

A number of vegetables have been introduced by the IRDP and FAO in 1982. These include the following: peas, radishes, asparagus, broccoli, Brussels sprouts, red and yellow onions, and capsicum sweet peppers (Kamal and Nasir, 1998). A numbers of fruit varieties have been introduced by the IRBD. This includes the following: Red Delicious and Golden Delicious varieties of apples, introduced in 1982 and 1983. Recently, Stark Delicious has also been introduced. Two varieties of cherries were introduced in 1983; they have now almost replaced the local varieties. These include Napolean (red) and Early River (black). Recently two new varieties, Being and Talarium, have been introduced (Kamal and Nasir, 1998).

The vast majority of households keep livestock for a range of purposes: milk, meat, wool, hair, dung production, as gifts for religious purposes, for traction and as capital investment. For many households, livestock products remain mostly within the household although some households use livestock as a source of cash income (ICIMOD, 2001).

According to Mohammad (1989), rangelands in Pakistan occupy 45.2 million ha, which is about 51.4% of the total land surface of country. Rangelands of Northern Areas occupy 2.1 million ha, which constitute about 29.8% of the total rangelands of the Northern Areas.

According to FAO (1987) the critical stocking rate should be of 16 ha/animal unit for low potential range. IUCN (2003 b) reported that the total animal unit present in Northern Areas are 0.72 million where the rangelands are 3.76 million. Therefore, the stocking rate is 5.2 ha/animal unit. The above calculation leads to the conclusion that the current stocking rate is about 3 times more than reported by FAO and the rangelands are burdened and over grazed.

According to Shiekh and Khan (1982), these areas are subjected to heavy pressure by livestock as well as shortage of fuel wood.

According to the livestock census of Northern Area (Pakistan), 1996, the population of sheep and goats has increased substantially from 0.88 million in 1976 to 1.56 million in 1996, with an annual growth rate of 3.56%. This increase has resulted pressure on rangelands.

In Pakistan, the local term for rangeland is "Chiragah", which is erroneously considered as wasteland and synonymous with desert or arid land. However, in 1973, the National Committee on Range Management defined rangelands as "Uncultivated areas (although sometimes disturbed by unthoughtful cultivation) that support natural or seeded herbaceous or shrubby vegetation with or without trees."

In Pakistan's agricultural system, rangelands are considered as an important component. Due to the arid and semiarid environment and limited irrigation facilities, these areas can not be converted into croplands. In the past, the rangelands in Pakistan have primarily been managed for livestock production. However, the multiple use concepts of rangelands also includes the production of watersheds which drain into a number of big dams like Tarbela and Mangla, and providing of wildlife with a vast complex of natural habitats (Mohammad, 1989).

In most cases, the separate areas defined by grazing rights are confined by physical boundaries like ridges or drainage lines (Nusser, 1998). In Hunza Karakoram, sectors of the village land are distinguished as belonging to certain kinship groups. The quarters of the four clans of the Diraming, Buroung, Barataling and Khurukutz enjoys the traditional grazing rights (Kreutzmann, 2000).

The scarcity of fodder during wintertime presents the main limiting factor of animal husbandry in the entire mountainous region of northern Pakistan. Traditional rules forbid the grazing of animals near settlements with cultivation during the vegetation period of the crops. While the upward movement of the flocks depends upon snow conditions in the high pastures and the extent of fodder shortage in the lower settlements, the downward movement from the pasture settlements can only be carried out after the last harvests in autumn (Nusser, 1998).

Except for rock faces, debris cones and very steep slopes most of the study area has been historically influenced by livestock grazing. In some cases personal communication with land owners provided additional information. Nevertheless, exact dates of abandonment were not available for a considerable part of summer farms.

In the mountain areas the short growing season and the difficulty of the terrain limit the potential for intensive agriculture. By and large, the rangelands are common tribal or village property not conducive to the regulation of proper grazing. Except the forests in Chilas and Darel/Tangir-Subdivisions, which are privately owned and exploited on commercial lines, all the other forest stands of the Northern Areas are classified as "Government Protected Forests" (Sheikh and Aleem, 1975).

In Northern Areas local communities are aware of the flora and fauna in their valleys and adjacent areas (Virk, 1999). However, there is lack of awareness about the conservation aspect of these valuable resources and effects on biodiversity.

Some times the traditional live stock management involves a large amount of human intervention and the grazing behavior of the animals on the pastures is guided by shepherds. Additionally, in many places the flocks and herds are moved long distances to seasonally available pastures-a practice known as transhumance.

In some parts of Northern Areas, Gujars practice transhumance. For example in Danyore and Sultanabad villages they, along with their herds of cattle, goat, and sheep, move to Naltar, where they own land and pastures.

Grazing at low intensities has no appreciable negative impacts on ecosystems and is the essential food source for ungulate wildlife and domestic livestock. It has been reported that low-moderate grazing resulted in the varied plant life of the alpine meadows in the European Alps (e.g.), and the abandonment of grazing resulted in decrease species richness (Tontini *et al.* 2003).

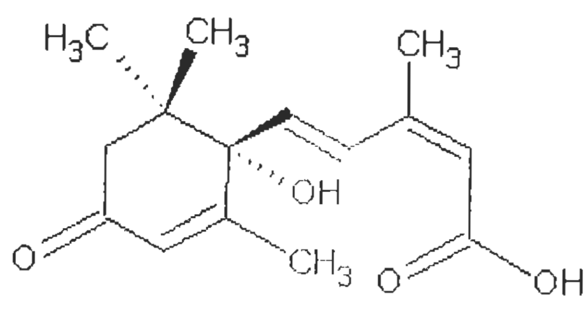
1.6 ALTITUDINAL VARIATIONS IN BIOCHEMICAL CONTENTS

Induction of osmoprotectants biosynthesis is part of the plant response to both drought and low temperature. Elevated levels of proline and sugars are found in plants of high altitude and they are normally associated with cold acclimation (Gilmour *et al.* 2000).Plants are constantly exposed to, and need to survive, a changing and often unfavorable environment.

1.6.1 Abscisic Acid (ABA)

Abscisic acid (ABA) was first identified and characterized by Frederick Addicott and his associates in 1963. They were studying compounds responsible for the abscission of fruits (cotton). ABA is a naturally occurring compound in plants.

It is a sesquiterpenoid (15-carbon) which is partially produced via the mevalonic acid pathway in chloroplasts and other plastids. The production of ABA is accentuated by stresses such as water loss and freezing temperatures.



Abscisic acid (ABA)

1.6.1.1 ABA and Cold Acclimation

In mountain areas, the drop in temperature associated with rising altitudes brings with it an increase in frequency and degree of frost to which the plants are exposed (Sakai and Larcher, 1987). Several lines of evidence indicate the role of *abscisic acid*-controlled processes in cold acclimation: There is a transient increase in endogenous ABA at the onset of acclimation. Perception of the low temperature stimulus leads to a transient increase in ABA (Lang *et al.* 1994).

The exposure of chilling sensitive plants to low temperatures raises the endogenous level of ABA (Rikin *et al.* 1976; Daie and Campbell, 1981; Eamus and Wilson, 1983).Both genetic and biochemical studies established that ABA plays an essential role in stress responses (Leung and Giraudat, 1998). Studies indicate that ABA may serve as a signal, which triggers processes leading to increased frost tolerance (Abromeit *et al.* 1992; Sarnighausen, 1994; Abromeit, 1996). Doerffling *et al.* (1998) showed that under growth chamber conditions, low temperature (2 °C) caused transient increases in the level of ABA in leaves.

Johson - Flanagen and Singh (1986) reported that microspore derived suspension cultures of winter rape (*Brassica napus*) developed freezing tolerance within 8 days in presence of ABA. Chilling - sensitive species including maize have been shown to exhibit increased levels of ABA when exposed to low temperature (Daie *et al.* 1981; Capell and Doerffling, 1989, 1993; Janowiak and Doerffling, 1996).

Cowan *et al.* (1997) observed an increase in ABA levels as an early response to cold hardening temperatures. Zhang *et al.* (1986) also concluded that the ABA content under chilling conditions is probably directly affected by the temperature.

It has also been extensively reported by research workers that many plant species exhibit an increase in endogenous ABA concentrations when exposed to low temperature (Irving, 1969; Chen and Gusta (1983) and that exogenous ABA can increase cold tolerance by 6 to 23 °C (Chen *et al.* 1983; Keith and Mckersie, 1986; Xin and Li, 1992). ABA has also been reported to induce the hardy plant species to become freezing tolerant (Gareth, 1998).

1.6.2 Proteins and Cold Acclimation

Cold acclimation has been reported to be associated with marked changes in protein composition and can affect both the amount and the type of polypeptides produced by the plant. Mohapatra *et al.* (1987) showed that two days of cold acclimation at 4 °C increased protein content by 200% and total RNA content by 100% in *Medicago sativa* L. cv. Saranac. Danyluk *et al.* (1991) and Ryu and Li, (1994) demonstrated that a specific subset of proteins are synthesized during cold acclimation of plants.

Deharden proteins are induced in plants by dehydration related environmental stresses such as low temperature, drought or high salinity (Close, 1996). Cold acclimation also induces their accumulation in the mitochondria of several plant species (Borovskii *et al.* 2000). In annual blue grass, higher levels of amino acid and greater differences among ecotypes were observed after acclimation at subzero temperatures (Dionne *et al.*, 2001). According to Gusta *et al.* (1996), cold acclimation-induced proteins may act in combination with soluble carbohydrates and other compounds in the acquisition of freezing tolerance.

1.6.3 Sugars and Cold Acclimation

Sugar has been considered as one of the most important factors in freezing tolerance (Sasaki *et al.* 1996).The study of localization of sugar in cells of hardy plants is of great importance in order to explain their role at low temperature and to understand the mechanism of their protective effect (Heber, 1959).

In some herbaceous plants, including wheat (Perras and Sarhan, 1984) changes in sugar content are correlated with freezing tolerance. Sucrose and fructose content have also been reported to increase during cold stress in rye (Antikainen and Pihakaski, 1994).

Levels of proline and sugars have also been observed to be associated with cold acclimation (Gilmour *et al.* 2000).

1.6.4 Proline and Cold Acclimation

Proline has been found to accumulate during cold acclimation and freezing tolerance has been found in several plants (Koster and Lynch, 1992; Doerffling *et al.*, 1998).

Cold acclimation process involves changes in gene expression profiles and increase in the sugar, and proline content (Ait Baraka and Audran, 1996, 1997; Wanner and Junttila, 1999). Paquin and Pelletier (1981) showed that cold acclimation of alfalfa is characterized by significant biochemical changes including modifications in proline.

Hare *et al.* (1999) also reported that accumulation of free proline in plants is the result of exposure to low temperature.

1.7 RATIONALE OF THE STUDY

The hierarchical plan of parameters studied in the field areas is shown in Figure 3.1.

The objective of the project was to investigate the impact of climate, altitude and edaphic factors on the floral diversity in Hunza valley, and further to investigate the changes in endogenous hormone abscisic acid, sugar and proline (as osmoregulant) in plants with respect to variation in altitude.

The first objective was to get an inventory of plant species growing in the alpine region of Hunza valley. This study was conducted with the aim to investigate the patterns of distribution and richness of plant species and chemical characteristics of soil along elevation gradient in Hunza valley. To compare the altitudinal limits of selected flora, two field areas Updegar and Ultar were selected as field areas. The areas are easily accessible and are rather in closer vicinity and had many species in common.
For the first time climatic stations were installed in the three selected test areas (Chupursan 3,200 m a.s.l. and Ultar 3,120 m a.s.l.) of Hunza valley to record air temperature and humidity.

Patterns of species richness have been shown to have a general trend of increased richness in plant species from north to south and from west to east in Northern Areas. Given the reported values of decreasing species richness from south to north, data was also collected to study such relationships with climate, soil factor and altitude.

Vegetation interacts with topography and soils, modifying micro sites and creating ecological niches for various plants. Altitudinal variations in the level of abscisic acid, protein, sugar and proline (as osmoregulent) were analyzed with the perspective of their role as biochemical markers for frost tolerance in selected plant species of Ultar pasture. The Ultar pasture was chosen as the study region because of its easy access and high plant species diversity.

In Northern Areas, livestock are reared mainly on rangeland pasture/natural pasture. Alpine pastures are subjected to heavy grazing during summer. The population of sheep and goats has increased substantially with an annual growth rate of 3.56% (Livestock Census of Northern Areas, Pakistan (1996). Keeping in view the present scenario, stocking density at Ultar was recorded for three consecutive years. A variety of medicinal plants grow in the region and inhabitants of Hunza valley had been using the resources for centuries. To record the important plants used as curatives by Brusho tribes of Hunza valley an ethnobotanical survey was conducted.

MATERIALS

&

METHODS

2.1 INTRODUCTION TO THE AREA

The research was conducted in Hunza valley. The area is localized (36.38° N, 73.34° E) in the northern part of Pakistan (Figure 1.2) which comprises an area of 10,101 km². The selected field areas for the present investigation were Batura, Sheshpar, Ultar, Updegar and Chupursan.

2.1.1 Batura

The 59 km long Batura Glacier (36°42' N/74°52' E) ends at 2,540 m a.s.l. The moraine crest increases in height by 50-80 m. Young popular trees were growing on the alluvial ground (Meiners, 1998).This is the traditional pasture area of Hussaini and Passu villages of Gojal, Hunza.

2.1.2 Sheshpar

On the south side of the Batura Mustagh, the 11 Km long and southerly exposed Sheshpar Glacier (36° 20' - 29' N/74°36' E) reaches down to the upper Hassanabad Valley. The highest peak of the catchment area is the Sheshpar Peak (7,611 m a.s.l.) This avalanche-fed glacier ends after the confluence with the neighboring Mchinal Glacier at 2,440 m a.s.l. (Meiners, 1998).

2.1.3 Ultar

This pasture area is located north of Karimabad. Hunza. Ultar is a multispecies grazing area, where the inhabitants of Karimabad and adjoining villages take their cattle for grazing by mid of May till mid of September. There is practically only one slope where vascular plants grow, that is the eastern slope. The other slopes are very steep and rocky.

2.1.4 Updegar

This pasture area is located on the east of Passu village across the Hunza river. A locally assembled suspension bridge is the only access to the pasture by inhabitants. Only yaks graze this area during winter by crossing the shallow waters of river Hunza.

2.1.5 Chupursan Valley

The valley is at about 3,200 m a.s.l. with surrounding peaks up to 4,000 m a.s.l.. The climate is dry. It lies outside the monsoon zone, in the rain shadow of the mountains. Mean annual rainfall is between 100 and 200 mm. The active growth period extends from May till October due to the prevailing frost during the rest of the year.

2.2 PARAMETERS STUDIED

2.2.1 Chemical Characteristics of Soil

At each elevation, a soil sample (20 cm depth) were taken with a stainless steel auger. The samples were collected randomly from 8 sites pooled together, stored in plastic bags, sealed and labeled. Soil samples were dried in an air-forced oven at 40° C.

The dried samples were sieved out to remove stones and plant residues and were ground in a stainless steel mill and passed through a 2-mm sieve. The sieved soils were collected, sub sampled (~ 500 g), and stored. The soil samples were analyzed for the content of available nitrogen and phosphorous, calcium, magnesium, sodium, potassium, iron and manganese and the pH and electric conductivity.

2.2.1.1 pH and Electrical Conductivity

The soil pH was determined following the method of McKeague (1978) and Mclean, (1982). The method of 1:1 (soil:water) suspension was used for the determination of Soil EC (Richards, 1954).

2.2.1.2 Estimation of Ca, Na, Mg and K

The Ca, Na, Mg and K content of soil were determined by atomic absorption following the method of Mehlich (1984).

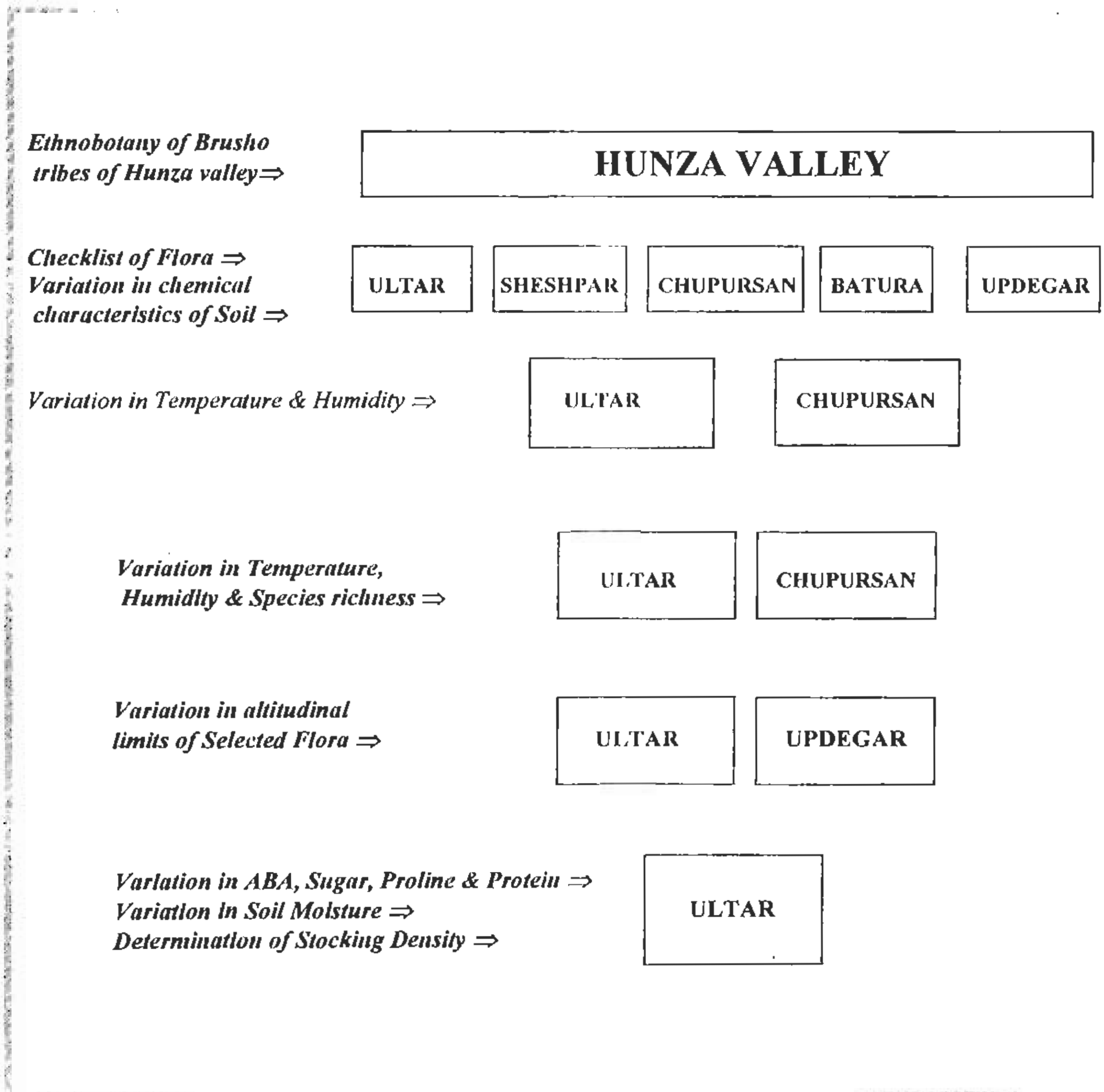


Fig. 2.1 Hierarchical Plan of Parameters Studied in the Selected Field Areas

Procedure

Extracting solution (Appendix A) 20 mL was added to the extraction flask containing 2 g of sieved soil. The solution was shaken for 5 minutes on the shaker at 200 rpm. The suspensions were filtered through Whatman No. 2 filter paper. A stock solution 1,000 ppm of Ca, Na, Mg and K were prepared. The standard curve was obtained using the standards (Sigma Chemical Co. Ltd. UK) and the concentrations of Ca, Na, Mg and K were determined in the extract using Atomic Absorption Spectrophotometer (Model AA-6300, Shimadzu).

2.2.1.3 Estimation of Mn and Fe

The diethylene triamine pentaacetic acid (DTPA) test of Lindsay and Norvell (1978) was used for the determination of Mn and Fe.

Procedure

Air dried soil (10 g) was added into a 125 mL flask. 20 mL of extraction solution (Appendix B) was added and the solution was shaken for 2 hrs on a reciprocal shaker. The suspension was filtered through a Whatman No. 42 filter paper. Concentrations of Fe and Mn were directly measured by Atomic Absorption Spectrophotometer.

2.2.1.4 Estimation of Phosphorus and Nitrate-Nitogen

P and NO_3^- - N were analyzed by the AB-DTPA method developed by Soltanpour and Schwab (1977), as modified by Soltanpour and Workman (1979).

Procedure

10 g air dried soil was added into a 125 mL conical flask. Extracting solution (Appendix C) 20 mL was added and shaken on a reciprocal shaker for 15 minutes. The extracts were then filtered through Whatman No. 42 filter paper.

Nitrate-N

Soil extract (1 mL) was transferred to 25 mL test tube, to which was added 3 mL copper sulphate, 2 mL hydrazine sulphate and 3 mL sodium hydroxide. The solution was mixed and placed in a water bath (38 °C) for 20 minutes. After removing from the water bath, 3 mL colour developing reagent (Appendix C) was added, mixed and left for 20 minutes at room temperature. The absorbance was recorded at 540 nm wavelength on spectrophotometer, model UV-160, Shimadzu (Kamphake *et al.* 1967). The calibration curve was prepared using standards.

Phosphorus

1 mL aliquot of the soil extract was diluted to 10 mL with deionized water. 2.5 mL colour developing reagent (Appendix C) was added carefully to prevent loss of sample du% to excessive foaming. The sample was stirred and left for 30 minutes. The colour intensity was measured at 880 nm wavelength using a spectrophotometer. The calibration curve was prepared using 3tandards.

2.2.2 Determination of Soil moisture

Jet filled Tensiometers, model 2725 (Santa Barbara, California, USA) were installed at 3,300 m on north and south facing slopes at 10 Cm depth from soil surface. The data was recorded at each 24h. Soil moisture was measured in centibars (cb).

2.2.3 Air Temperature and Humidity

In the two selected test areas (Chupursan 3,200 m a.s.l. and Ultar 3,120 m a.s.l.) thermo-hygrograph (Model 3.015, Wittich & Visser) with hair element and bimetal were installed. Standard parameters such as air temperature and air humidity were recorded. The analogous graph produced by the thermohygrographs was interpreted into daily averages from the minimum and maximum values and monthly means were calculated.

2.2.4 Vegetation and Species Richness

A floristic checklist (alphabetical order) was compiled for five field areas (Table 3.1). These data were compiled form extensive field collections. Local names, place of collection, date of collection, were noted on the spot. Blotting papers and a presser was used for the preservation of specimens and the blotting papers were changed from time to time. The fully dried specimens were mounted on herbarium sheet. The specimens were identified with the help of the herbarium of Quaid-i-Azam University, Islamabad and National Herbarium, National Agriculture Research Centre, Islamabad. Total of 218 species were included on the checklist. Species richness was defined as the total number of species present in particular area (Whittaker, 1972).

2.2.5 Altitudinal Limits

Altitudinal limits of the selected flora were recorded from the field areas of Ultar and Updegar on east-facing slopes. The plant species were recorded both on the way up and down (Kilander, 1955). An altimeter was used to keep track of the changing altitude.

2.2.6 Collection of Plant Samples for Biochemical Analysis

The mature green leaves of each plant species at flowering stage were collected randomly from 3-5 plants. The leaves were collected during summer, 2002 from the Ultar pastures, Hunza valley from two different altitudes viz. 3, 000 m to 3,500 m for the analyses of endogenous level of abscisic acid, sugar and protein content of leaves.

2.2.6.1 Extraction of leaf tissue for ABA

The leaves were extracted and purified for endogenous ABA following the method of Kettner and Dorffling (1995).

The freeze-dried plant leaves (500mg) were homogenized in 80% Methanol in presence of butylated hydroxytoluene (10 mg L^{-1}), used as an antioxidant. The hormone was extracted for 72 h at 4° C in 80 % methanol with concomitant change in the solvent at each 24 h. The extract was centrifuged at 3,000 g for 10 min and the supernatant was evaporated to dryness on Rotary Film Evaporator at 35° C.The extract was reduced to aqueous phase and adjusted to pH 2.5 with 1N HCl, and extracted with ethyl acetate (3 times using 1/3rd volume). The aqueous phase was discarded, and the ethyl acetate phase were pooled and evaporated to dryness on Rotary Film Evaporator at 35° C. The residue was re-dissolved in HPLC - grade methanol. The samples were passed through a 0.45-μm polytetrafluoroethylene disposable filter. The purified sample was injected onto a C_{18} column and eluted with a linear gradient of methanol (10–70%), containing 0.01% acetic acid, at a flow rate of 4 mL/min. The retention time of Abscisic Acid was determined by using authentic standards (Sigma Chemical Company), at 210 nm.

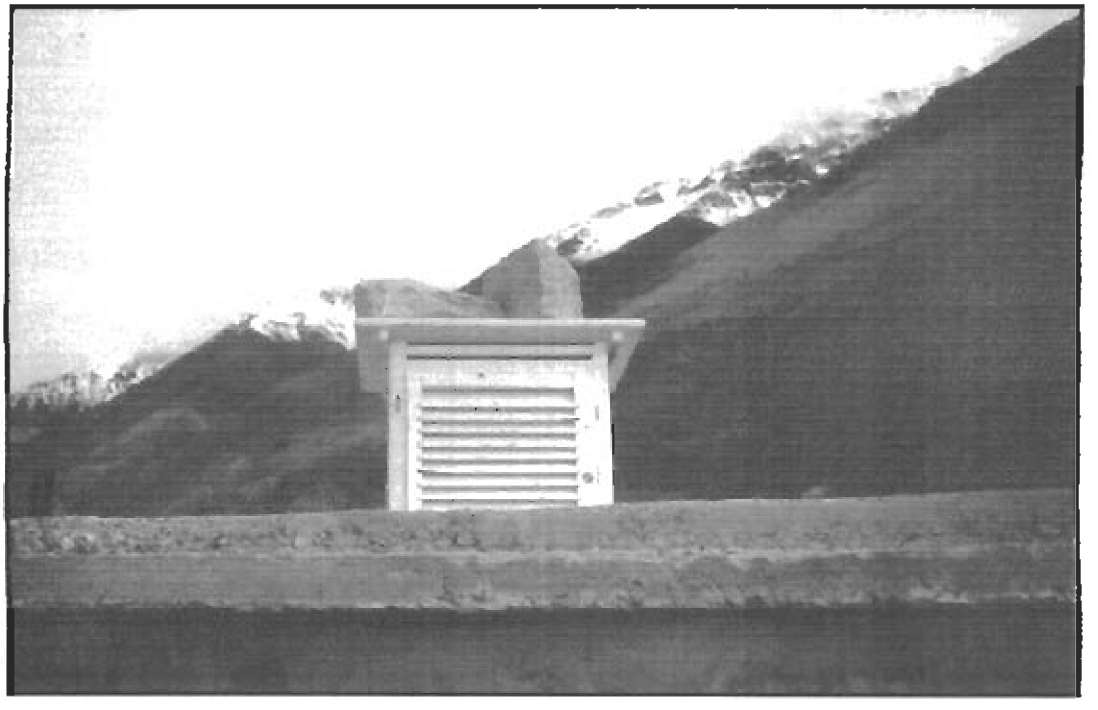


Fig. 2.2 Photograph of the thermohygrograph installed at village Shetimerg, Chupursan valley.

Fig. 2.3 Photograph of the Tensiometer installed on north facing slope of Ultar pastures.

2.2.6.2 Analysis of leaf tissue for protein

The leaves were analyzed for protein content following the method of Lowry *et al.* (1951) using BSA as standard.
The reagents and stock solution were shown in Appendix D.

Procedure:

Fresh leaves 0.1 g were ground in 1 ml of phosphate buffer pH 7.5 with the help of mortar and pestle and was centrifuged at 3000 rpm for 10 min. The supernatant (0.1 ml) of the given sample containing unknown amount of protein was poured in the test tube. Distilled water was added to make the total volume of 1 ml. 1 ml of Reagent C was added. After shaking for 10 minutes, 0.1 ml of Reagent D was added. The absorbance of each sample was recorded at 650 nm after 30 min incubation.

The concentration of unknown sample was calculated for the protein content with reference to standard curve made by using standard BSA. The BSA of different concentrations viz 40, 80, 120, 160, 200 mg were prepared. The reagents were added in the sequence as described above. Finally the absorbance of BSA was recorded at 650 nm.

2.2.6.3 Extraction of leaf tissue for sugar

The leaves were analyzed for sugar content following the method of Dubo *et al.* (1956) as modified by Johnson *et al.* (1966), using glucose as standard.

Fresh plant material (0.5 g) were homogenized with 10 ml of distilled water in a mortar and pestle and volume was made up to 20 ml with distilled water. The extract was centrifuged at 3,000 rpm for 5 min. To 0.1 ml of supernatant, 1 ml of 80 % (w/v) phenol was added. After 1 h incubation at room temperature, 5 ml of concentrated H_2SO_4 were added. After 1 h incubation, the absorbance of each sample was recorded at 420 nm.
The concentration of unknown sample was calculated with reference to standard curve of glucose.

2.2.6.4 Extraction of leaf tissue for Proline

Proline content was measured according to the method of Bates *et al.* (1973). Fresh leaves (0.5 g) was homogenized in 10 ml of 3% aqueous sulfosalicylic acid and filtered through Whatman # 2 paper. Then, 2 ml of filtrate was mixed with 2 ml of acidic-ninhydrin and 2 ml of glacial acetic acid and heated at 100°C for 1 h. The reaction was terminated in an ice bath; then 4 ml of toluene was added to the mixture and contents of tubes were stirred for 15 to 20 s. The absorbance of the samples was read at 520 nm.

2.2.7 Stocking Density and Grazing Status of Ultar Pastures

The plant species were classified as palatable or unpalatable based on interviews with the herders and the secondary sources. The interviews were conducted during the field visits of summer 2001 and 2002.

2.2.8 Ethnobotany

To collect an ethnobotanical data of Hunza valley, a field survey was conducted in December, 2000.Throughout the field visit medicinally important plants were collected and data were recorded. Local names, place of collection, date of collection, part used, purpose of use, and method of preparation were noted on the spot. The data were gathered from elders and key informants of the area. A sample questionnaire was given in Figure 2.4.

ETHNOBOTANICAL SURVEY QUESTIONNAIRE

Date: ....

Name of the informant:...

Father's name: ....

Village: ....

Tribe: ....

Plant used for: ....

Local name: ....

Scientific name: ....

Flowering period: ....

Part of the plant used: ....

Method: ....

..

Fig. 2.4 Sample of ethnobotanical survey questionnaire

RESULTS

3.1 VEGETATION AND SPECIES RICHNESS

The vegetation survey presented here is based on the fieldwork undertaken during 2000/2001 in the selected field areas of Hunza valley (Table 3.1). The total number of identified species from the field areas of Sheshpar, Ultar, Batura, Updeger, and Chupursan is 218, belonging to 47 families (Figure 3.9).

The important families were Asteraceae (37 species), Papilionaceae (20 species), Poaceae (14 species), Lamiaceae (11 species) and Rosaceae (10 species). The observed species richness pattern in the field areas showed that Sheshpar with 116 species showed the maximum number of species while minimum species richness was recorded at Chupursan with 82 species (Figure 3.10).

Colour figures 3.1 to 3.8 represent the general floral biodiversity of Hunza valley. The figures of *Onobrychis dealbata* and *Oxyria digyna* are representing palatable species, and *Acantholimon lycopodioides* and *Polygonum alpinum* the unpalatable ones. *Allium carolinianum* showed a very narrow range of altitudinal limit, while *Epilobium angustifolium* showed a wide range distribution limits. *Thymus serpyllum* and *Gentiana tianshanica* are widely known for their medicinal properties.

The variation in the number of species (Table 3.2) differed significantly (χ^2 =48.26, df = 4, p < 0.0001) and the variation in the number of commonly occurring species (Table 3.4) was also evident (χ^2 = 28.43, df = 4, p < 0.0001). The number of rare species (Table 3.3) in the filed areas did not show a significant difference (χ^2 = 5.16, df = 4, p < 0.0001).

3.2 ALTITUDINAL AND ZONAL DISTRIBUTION PATTERNS

3.2.1 Ultar

The valley floor of Karimabad lies at 2,400 m a.s.l. Species of *Sophora mollis* and *Capparis spinosa* along with *Ephedra* sp. dominate the vegetation type particularly on scree slopes at 2,500 m a.s.l.

From 2,500 - 3,000 m a.s.l. species of *Artemisia rutifolia, A. laciniata, Cichorium intybus, Astragalus psilocentros, Allium jacquemontii, Potentilla bifurcta,*and *Swertia cordata* are more commonly found. Shrubs like *Rosa webbiana* and *Berberis* sp. are found on dry slopes, however, on moist slopes species like *Epilobium chitralense, Oxyria digyna* and *Echinops* sp. can be observed.

Along the streams at 2,600 m a.s.l. *Mentha longifolia, Mentha royleana, Erysimum hieraciifolium* are found. *Ranunculus aquatilis* is usually grown on hygromorphic soils. Above 3,000 m a.s.l. species of *Geranium wallichianum, Polygonum alpinum, Polygonum tortuosum, Saxifraga flagellaris, Sedum ewersii, Stellaria graminea,* and *Sibbaldia cuneata* dominate the alpine vegetation.

3.2.2 Sheshpar

At altitudes ranging from 2,500 m to 2,800 m a.s.l. species like *Capparis spinosa, Melilotis albus, Melilotis indicus, Haloxylon thomsonii, Tribulus terrestris* and *Krascheninnikovia ceratoides* were found. *Myricaria* is also found on damp soils.The *Oxyria digyna* were found particularly on moist debris of the glacier.

From 2,800 m a.s.l. onwards *Artemisia rutifolia A. laciniata Acantholimon lycopodioides* and *Sophora mollis* and *Juniperus* trees dominate the area on slopes up to 3,000 m a.s.l. *Polygonum corrigioloides* was usually found on plain areas from 2,500 m to 3, 500 m a.s.l.

Above 3,000 m a.s.l. *Artemisia roxburghiana, Onobrychis dealbata, Solidago virgaurea, Codonopis clematidea* and were found. *Rosa webbiana* and *Spiraea cantoniensis* occasionally occur in this belt. From 3,000 to 3,500 m a.s.l. alpine vegetation is usually dominated by *Geranium wallichianum, Stellaria graminea, Saxifraga flagellaris, Thymus serpyllum, Gentiana tianshanica, G. stracheyi, Polygonum alpinum P. tortuosum* and species of Poaceae family.

3.2.3 Chupursan

At valley floor of Chupursan valley, *Capparis spinosa, Ephedra gerardiana, E. intermedia Krascheninnikovia ceratoides* and *Corispermum* sp. were found almost on all exposures. Above 3,200 m a.s.l. species of *Artemisia laciniata A. macrocephalai, Gentiana stracheyi G. tianshanica, Lepidium* sp.with cushions of *Acantholimon lycopodioides* were found on dry slopes. Shrubs like

Spiraea cantoniensis Berberis lycium Myricaria sp. and *Rosa webbiana* are usually found up to 3, 400 m a.s.l.

Juniperus trees are also found up to 4,000 m a.s.l. on the north facing slopes, but their density is not much as they are at the comparable altitudes of other study areas. Above 3,700 m a.s.l., *Allium carolinianum, Aquiligia moorcroftiana, Artemisia laciniata, Astragalus candolleanus, Berginia ciliata, Sedum ewersii, S. roseum* and *Androsace rotundifolia* dominate the vegetation on dry slopes, and species of *Bupleurum linearifolium, Astragalus candolleanus, Erysimum hieracifolium* and *Epilobium angustifolium* are found on moist slopes.

3.2.4 Updegar

The vegetation at low altitudes up to 3,000 m a.s.l. comprises of *Anaphalis nepalensis, Artemisia roxburghiana A. scoparia, Astragalus concretus, Capparis spinosa, Lepyrodiclis holosteoides, Haloxylon thomsonii* and *Sophora mollis* .

Above this altitude *Juniperus* sp. starts appearing and their density increases with the increase in altitude up to 3,800 m a.s.l. The other species growing in this belt were *Artemisia laciniata, Allium jacquemontii, A.barsczewskii, Galium asperifolium, Gentiana stracheyi, Polygonum alpinum, Geranium wallichianum* and shrubs like *Spiraea cantoniensis* and *Rosa webbiana* are also found at fewer places.

3.2.5 Batura

North of the Batura glacier is the pasture area of the inhabitants of Passu village, while the southern side of the Batura glacier is the traditional pasture area of village Hussaini. Both the areas showed characteristic vegetation types. The south facing slopes exhibited dense vegetation cover than the adjacent north facing side of the glacier.

Around 2,800 m a.s.l. the vegetation comprised of the same species like *Sophora mollis, Capparis spinosa Ephedra gerardiana, E. intermedia* on scree slopes. Species of *Artemisia roxburghiana, Arundo donax* and *Echinops* sp. were found at moist slopes.

Juniperus trees were growing on both sides up to 4,000 m a.s.l. but their density increased on the northern slopes. Few trees of *Betula utilis* were also found above the *Juniperus* line. Trees like *Salix acmophylla* and *S. tetrasperma* were also found up to 3000 m a.s.l. along with the shrubs like *Rosa webbiana* and *Spiraea cantoniensis*. Alpine vegetation was dominated by the species of *Anaphalis neplensis, Lloydia serotina, Paraquilegia anemonoides,Thymus serpyllum, Pleurospermum stylosum* and *polygonum alpinum*.

Table 3.1 Species list (+ indicates presence) for the individual sites. Site acronyms are as follows. CH = Chupursan; SH = Sheshpar; UL= Ultar; BA = Batura and UP = Updeger.

S.No.	FAMILY/PLANT SPECIES	CH	SH	UL	BA	UP
	ALLIACEAE					
1	*Allium barszcewskii*	-	-	-	-	+
2	*Allium carolinianum* DC.	-	+	-	+	-
3	*Allium jacquemontii* Kunth.	-	+	+	-	+
4	*Gagea* sp.	+	-	-	-	-
5	*Lloydia serotina* (L.) Reichenb.	-	-	-	+	-
	APIACEAE					
6	*Bupleurum hoffmeisteri* Kl.	-	-	+	-	-
7	*Bupleurum linearifolium* DC.	+	+	+	-	+
8	*Platytaenia lasiocarpa* ssp. Radiata Rech. f. & Riedl.	+	-	-	-	-
9	*Platytaenia* sp.	+	-	-	-	-
10	*Pleurospermum stylosum* Clarke.	-	-	-	+	-
11	*Sesili libanotis* (L.) Koch.	-	-	-	+	+
	ASCLEPIADACEAE					
12	*Cynanchum acutum* L.	-	-	-	-	+
13	*Ipomoea* sp.	-	+	+	+	+
	ASTERACEAE					
14	*Achillea* sp.	-	+	-	+	+
15	*Ajania* sp	-	+	-	-	-
16	*Anaphalis neplensis* (Spreng.) Hand. Mazz	-	+	+	+	+
17	*Anthemis cotula* L.	-	-	-	-	+
18	*Artemisia laciniata* Willd.	+	+	+	-	+
19	*Artemisia macrocephala* Jacq. ex Bess.	+	-	-	-	-
20	*Artemisia roxburghiana* Wall. ex Besser.	-	+	-	-	+
21	*Artemisia rutifolia* Steph. ex Spreng.	+	+	+	+	+
22	*Artemisia scoparia* Waldst. & Kit.	-	-	-	+	+
23	*Artemisia sieversiana* Ehrh. ex willd.	-	+	-	-	-

24	*Bidens* sp.	-	-	+	-	+
25	*Centaurea* sp.	-	+	+	-	+
26	*Chrysanthemum* sp.	-	-	+	-	-
27	*Cichorium intybus* L.	-	-	+	-	-
28	*Cirsium* sp.	+	-	-	-	-
29	*Conyza* sp.	-	+	+	-	+
30	*Crepis* sp	-	-	+	-	-
31	*Cynoglossum lanceolatum* Forssk.	+	+	-	+	-
32	*Echinops* sp.	+	+	+	-	+
33	*Erigeron bellidioides* (D.Don) Bth & Hk.f.	-	+	+	+	-
34	*Filago pyramidata* L.	+	+	-	+	-
35	*Gnaphalium luteo-album* (DC.) Hk. F.	-	+	+	+	+
36	*Lactuca dissecta* D.Don.	-	+	+	-	+
37	*Lactuca* sp.	+	-	+	+	-
38	*Psychrogeton andryaloides* (DC.) Novopokr. ex Krasch.	+	-	-	-	-
39	*Psychrogeton* sp.	+	-	-	-	-
40	*Saussurea atkinsonii* Clarke.	-	-	-	-	+
41	*Saussurea lappa* (Denc.) sch. Bip.	-	+	+	-	-
42	*Saussurea* sp.	-	-	+	-	-
43	*Senecio* sp.	+	-	+	-	-
44	*Seriphidium* sp.	-	-	+	-	-
45	*Serratula procumbens* Regel.	+	-	-	-	-
46	*Solidago virgaurea* L.	-	+	+	-	-
47	*Tanacetum aretemisioides* Sch. Bip. ex Hk. f.	-	+	-	-	-
48	*Tanacetum falconeri* Hk. f.	-	+	-	-	-
49	*Taraxacum officinale* Weber.	+	+	+	+	+
50	*Tragopogon gracilis* D. Don.	-	-	-	-	+
	BERBERIDACEAE					
51	*Berberis lycium* Royle.	-	+	+	-	-
52	*Berberis pseudumbellata* Parker.	-	-	-	+	-

	BETULACEAE					
53	*Betula utilis* D. Don.	-	-	-	+	+
	BORAGINACEAE					
54	*Arnebia hispidissima* (Lehm.) DC.	+	+	-	+	+
55	*Heliotropium strigosum* Willd.	-	-	-	-	+
56	*Myosotis* sp.	-	-	-	+	-
	BRASSICACEAE					
57	*Arabis* sp.	-	-	-	+	-
58	*Capsella bursa-pastoris* (L.) Medic.	-	+	+	+	+
59	*Christolea crassifolia* Camb.	-	+	-	-	-
60	*Chroispora* sp.	+	-	-	-	-
61	*Didymophysa fedtschenkoana* Regel.	-	+	-	-	-
62	*Erysimum hieraciifolium* L.	+	+	+	-	-
63	*Farsetia* sp.	-	-	-	+	-
64	*Lepidium* sp.	+	+	-	-	-
65	*Malcolmia Africana* (L.) R.Br.	-	+	-	-	-
	CAMPANULACEAE					
66	*Campanula* sp.	-	+	-	+	-
67	*Codonopis clematidea* (Schrenk) Clarke.	-	+	-	-	+
	CANNABACEAE					
68	*Cannabis sativa* L.	-	-	+	+	+
	CAPPARIDACEAE					
69	*Capparis spinosa* L.	+	+	+	+	+
	CAPRIFOLIACEAE					
70	*Lonicera semenovii* Regel.	-	-	-	+	-
	CARYOPHYLLACEAE					
71	*Arenaria leptoclados* (Reichb.) Guss.	-	-	+	-	-
72	*Dianthus angulatus* Royle.	-	+	-	-	+
73	*Lepyrodiclis holosteoides* (C.A. Mev.)Fenzl ex F. & M.	+	-	-	-	+
74	*Minuartia kashmirica* (Edgew.)RRS.	-	-	-	-	+

75	*Spergularia marina* (L.) Griseb.	-	-	+	-	-
76	*Stellaria graminea* L.	+	+	+	+	+
	CHENOPODIACEAE					
77	*Atriplex* sp.	-	+	-	-	-
78	*Chenopodium* sp.	+	-	-	-	-
79	*Corispermum* sp.	+	-	-	-	-
80	*Haloxylon thomsonii* Bunge. ex Boiss.	-	+	-	-	+
81	*Kochia* sp.	-	-	-	-	+
82	*Krascheninnikovia ceratoides* L.	+	-	-	+	+
	CRASSULACEAE					
83	*Rosularia* sp.	-	-	+	-	+
84	*Sedum ewersii* Ledeb.	+	+	+	+	+
85	*Sedum roseum* (L.) scop.	+	-	-	+	-
86	*Semipervivum* sp.	-	-	-	+	-
87	*Semipervivum tectorum*	-	-	-	-	+
	CUPRESSACEAE					
88	*Juniperus communis* L.	+	+	+	+	+
89	*Juniperus marcopoda* HK.f.	+	+	+	+	+
	ELAEGNACEAE					
90	*Hippophae rhamnoides* L.	+	+	+	+	+
	EPHEDERACEAE					
91	*Ephedra gerardiana* Wall. ex Stapf.	+	+	+	+	+
92	*Ephedra intermedia* Schrenk.	+	+	+	+	+
	FUMARIACEAE					
93	*Corydalis flabellate* Edgew.	+	-	-	+	-
94	*Corydalis* sp.	+	+	-	-	+
	GENTIANACEAE					
95	*Comastoma* sp.	-	+	-	-	-
96	*Gentiana clarkei* Kusnezow	+	-	-	-	-
97	*Gentiana stracheyi* (C.B.Cl.)Kita.	+	-	+	-	+

98	*Gentiana tianshanica* Rupr. ex Kusn.	+	+	+	+	+
99	*Swertia cordata* (G. Don) Clarke.	-	-	+	-	-
100	*Swertia* sp.	-	+	-	-	-
	GERANIACEAE					
101	*Geranium* sp.	+	+	-	-	-
102	*Geranium wallichianum* D.Don ex Sweet.	-	-	+	-	+
	JUNCACEAE					
103	*Juncus concinnus* D. Don.	+	-	-	-	-
	JUNCAGINACEAE					
104	*Triglochin palustris* L.	+	-	-	-	-
	LAMIACEAE					
105	*Dracocephalum bipinnatum* Rupr.	-	+	-	-	-
106	*Mentha longifolia* (L.) Huds.	-	+	+	+	+
107	*Mentha royleana* Wall. ex Bth.	-	+	+	+	-
108	*Nepeta eriostacha* Bth.	-	-	+	-	+
109	*Nepeta* sp.	+	+	+	+	+
110	*Perovskia abrotanoides* Karel.	-	-	-	+	-
111	*Perovskia atriplicifolia* Bth	-	+	-	-	-
112	*Salvia* sp.	-	-	+	-	-
113	*Scutellaria* sp.	-	+	-	+	-
114	*Stachys* sp.	-	-	+	-	+
115	*Thymus serpyllum* L.	+	+	+	+	+
	MORACEAE					
116	*Morus alba* L.	-	-	+	+	+
117	*Morus nigra* L.	-	-	+	+	+
	OLEACEAE					
118	*Jasminum* sp.	-	-	-	+	-
	ONAGRACEAE					
119	*Epilobium angustifolium* L.	-	+	+	+	+
120	*Epilobium chitralense* Raven.	+	+	+	-	-

121	*Epilobium* sp.	+	-	-	+	+
	OROBANCHACEAE					
122	*Cistanche tubulosa* (Schenk)R. Wight.	-	+	+	-	+
	PAPAVERACEAE					
123	*Papaver* sp.	+	-	-	-	-
	PAPILIONACEAE					
124	*Astragalus afghanus* Boiss.	-	-	+	-	-
125	*Astragalus amherstianus* Bth. ex Royle.	-	-	+	+	-
126	*Astragalus candolleenus* Royle. ex Bth.	+	-	-	-	-
127	*Astragalus concretus* Bth.	-	-	-	-	+
128	*Astragalus gahiratensis* Ali.	-	-	-	-	+
129	*Astragalus leucocephalus* Grah. ex Bth.	-	-	-	+	-
130	*Astragalus psilocentros* Fisch.	-	+	+	+	-
131	*Colutea* sp.	-	-	-	+	-
132	*Hedysarum falconeri* Baker.	-	-	-	+	-
133	*Lathyrus sativus* L.	-	-	-	+	+
134	*Medicago sativa* L.	-	+	+	-	-
135	*Melilotis albus* Desr.	-	+	+	-	-
136	*Melilotis indicus* (L.) All.	+	+	+	-	+
137	*Onobrychis dealbata* Stocks.	-	+	+	+	+
138	*Onobrychis laxiflora* Baker.	-	-	-	+	-
139	*Oxytropis tatarica* Camb.	-	+	+	-	-
140	*Sophora mollis* (Royal) Backer	-	+	+	+	+
141	*Taverniera cuneifolia* (Roth.) Arnott.	-	-	-	+	+
142	*Trifolium pratense* L.	-	+	+	+	-
143	*Trigonella* sp.	-	+	+	-	-
	PARNASSIACEAE					
144	*Parnassia nubicola* Wall. ex Royle.	-	-	+	+	-
	PLANTAGINACEAE					
145	*Plantago lanceolata* L.	+	+	+	+	+

146	*Plantago major* L.	-	+	+	+	+
	PLUMBAGINACEAE					
147	*Acantholimon lycopodioides* (Girard)Boiss.	+	+	+	+	+
148	*Limonium gilesii* (Hemsl. Aitch.) Rech. f.	-	+	+	-	-
	POACEAE					
149	*Agropyron* sp.	-	-	-	+	+
150	*Aristida* sp.	-	+	+	+	+
151	*Arundo donax* L.	-	+	+	+	+
152	*Brachypodium sylvaticum* (Huds.)P. Beauv	-	+	-	+	+
153	*Bromus pinnatus* L.	+	-	-	+	-
154	*Bromus* sp.	+	-	-	-	-
155	*Cenchrus pennisetiformis* Hochst. & Steud.	-	+	+	-	-
156	*Chrysopogon* sp.	-	-	-	+	+
157	*Clamatogrostis* sp.	+	+	-	-	-
158	*Cymbopogon parkeri* Stapf.	-	-	-	+	+
159	*Cymbopogon* sp.	-	-	-	+	+
160	*Festuca nutans* Biehler	-	+	+	-	-
161	*Festuca* sp.	+	-	-	-	-
162	*Stipagrostis plumosa* (L.) Munro ex T. Anders.	-	-	-	+	+
	POLYGALACEAE					
163	*Polygala* sp.	+	-	-	+	-
	POLYGONACEAE					
164	*Fagopyrum esculentum* Moench.	-	-	-	+	+
165	*Oxyria digyna* (L.) Hill.	-	+	+	+	-
166	*Polygonum alpinum* All.	+	+	+	+	+
167	*Polygonum aviculare* L.	-	+	+	-	-
168	*Polygonum corrigioloides* J.& S.	+	+	+	+	+
169	*Polygonum plebejum* R. Br.	-	+	+	+	-
170	*Polygonum tortuosum* D. Don.	-	+	+	-	-
171	*Rheum emodi* Wall	+	-	-	+	+

	PRIMULACEAE					
172	*Androsace rotundifolia* Hardw.	+	-	-	+	+
173	*Primula* sp.	+	-	-	+	-
	RANUNCULACEAE					
174	*Aconitum violaceum* Stapf.	-	+	+	-	-
175	*Aquilegia fragrans* Bth.	-	-	-	+	+
176	*Aquiligia moorcroftiana* Wall. ex Royle	+	+	-	+	+
177	*Clematis montana* Buch. Ham.	-	+	+	-	-
178	*Clematis orientalis* L.	-	-	-	+	+
179	*Delphinium brunonianum* Royle.	+	+	-	+	-
180	*Paraquilegia anemonoides* (Willd.) Ulbr.	+	-	-	+	-
181	*Pulsatilla wallichiana* (Royle) Ulbr.	-	-	-	+	+
182	*Thalictrum minus* L.	+	+	-	-	-
	ROSACEAE					
183	*Potentilla argyrophylla* Wall. ex Lehm.	-	+	-	+	-
184	*Potentilla bifurcta* L.	+	+	+	+	+
185	*Potentilla gelida* C.A. Mey.	-	+	+	-	-
186	*Potentilla salesoviana* Steph.	-	-	-	+	+
187	*Potentilla supine* L.	+	-	-	-	+
188	*Ranunculus aquatilis* L.	-	-	+	-	-
189	*Ranunculus hirtellus* Royle.	+	-	-	+	-
190	*Rosa webbiana* Wall.	+	+	+	+	+
191	*Sibbaldia cuneata* Kunze.	-	+	+	-	-
192	*Spiraea cantoniensis* Lour.	+	+	+	+	+
	RUBIACEAE					
193	*Asperula oppositifolia* Reg. & Schmalh.	-	+	+	-	+
194	*Galium aparine* L.	+	+	+	+	+
195	*Galium asperifolium* Wall.	-	-	+	-	+
196	*Rubia cordifolia* L.	-	+	+	-	-
	SALICACEAE					

197	*Populus alba* L.	+	+	+	+	+
198	*Populus nigra* L.	+	+	+	+	+
199	Salix acmophylla *Boiss.*	-	-	-	+	+
200	*Salix babylonica* L.	+	+	+	-	+
201	*Salix tetrasperma* Roxb.	-	-	-	+	+
	SAXIFRAGACEAE					
202	*Berginia ciliata* (Haw.) Sternb.	+	+	-	+	+
203	*Saxifraga flagellaris* Willd.	-	+	+	+	+
	SCROPHULARIACEAE					
204	*Antirrhinum* sp.	+	-	-	+	-
205	*Bacopa* sp.	+	+	-	+	-
206	*Euphrasia aristulata* Penn.	+	+	+	+	-
207	*Linaria vulgaris* Mill.	+	+	-	+	-
208	*Matthiola flavida* Boiss.	-	+	+	+	-
209	*Pedicularis pectinata* Wall. ex Bth.	-	+	+	+	+
210	*Scrophularia* sp.	+	-	-	+	-
	SOLANACEAE					
211	*Datura stramonium* L.	-	+	+	+	+
	TAMARICACEAE					
212	*Myricaria* sp.	-	+	-	+	-
213	*Tamarix dioica* Roxb. ex Roth.	+	+	+	+	+
214	*Tamarix gallica* L.	-	+	+	+	+
	THYMELEACEAE					
215	*Daphne mucronata* Royle.	-	+	+	-	-
216	*Daphne oleoides* Schreb.	-	-	-	+	-
	ZYGOPHYLLACEAE					
217	*Peganum harmala* L.	+	+	+	+	+
218	*Tribulus terrestris* L.	-	+	+	-	-

Fig. 3.1 Photograph of *Polygonum alpinum* All.
Family: Polygonaceae Species No. 166

Fig. 3.2 Photograph of *Oxyria digyna* (L.) Hill.
Family: Polygonaceae Species No. 165

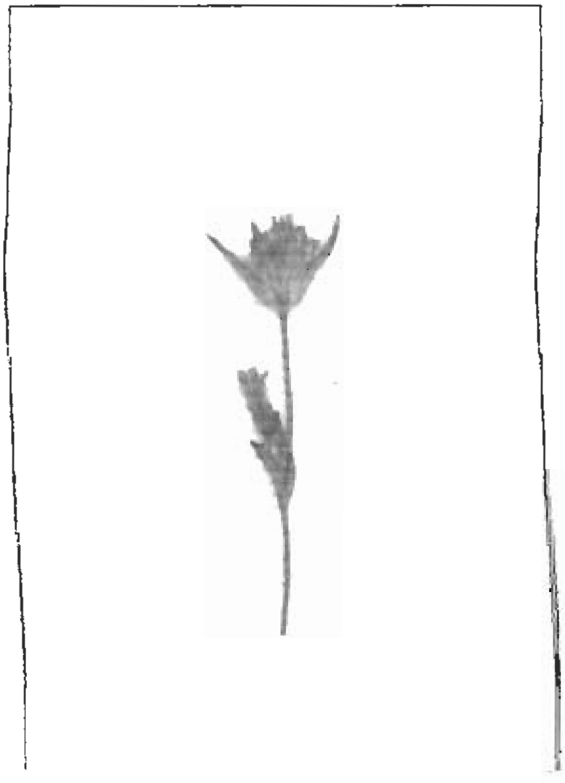


Fig. 3.3 Photograph of *Gentiana tianshanica* Rupr. ex Kusn.
Family: Gentianaceae Species No. 98

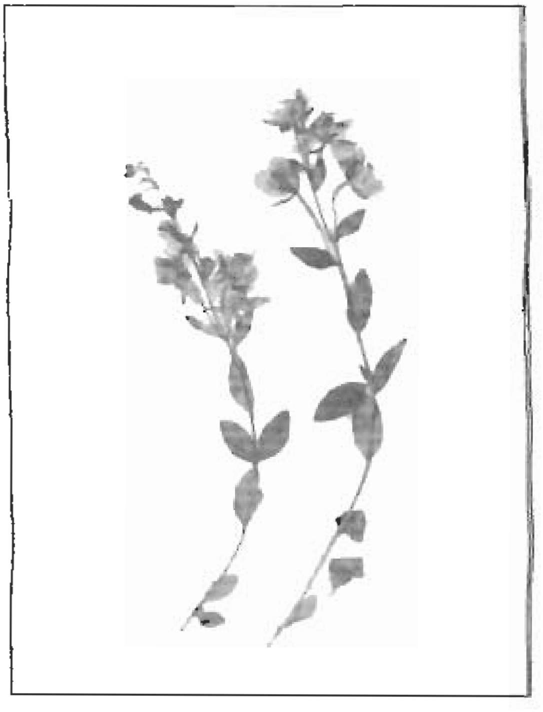


Fig. 3.4 Photograph of *Epilobium angustifolium* L.
Family: Onagraceae Species No. 119

Fig. 3.5 Photograph of *Acantholimon lycopodioides* (Girard) Boiss.
Family: Plumbaginaceae Species No. 147

Fig. 3.6 Photograph of *Thymus serpyllum* L.
Family: Lamiaceae Species No. 115

Fig. 3.7 Photograph of *Geranium wallichianum* D.Don ex Sweet.
Family: Geraniaceae Species No. 102

Fig. 3.8 Photograph of *Onobrychis dealbata* Stocks.
Family: Papilionaceae Species No. 137

Table 3.2 Number of species occurring at one to five sites in the selected field areas of Hunza valley.

Species occurring at one to five sites					
Number of species occurring at one site only	Number of species occurring at two of the sites	Number of species occurring at three of the sites	Number of species occurring at four of the sites	Number of species occurring at all five sites	Total number of species
68	69	32	24	25	218
χ^2 = 48.26 df = 4 p = < 0.0001					

Table 3.3 Number of rare species occurring at only one site, for each of the five sites in the selected field areas of Hunza valley.

Number of rare species occurring at only one site, for each of the five sites				
CH	**SH**	**UL**	**BA**	**UP**
18	12	08	13	09
χ^2 = 5.16 df = 4 p = 0.2712				

Table 3.4 Number of commonly occurring species at four of the five sites in the selected field areas of Hunza valley.

Common species occurring at four of the five sites. Numbers of these common species not occurring at each site.				
CH	**SH**	**UL**	**BA**	**UP**
14	0	03	04	01
χ^2 = 28.43 df = 4 p = <0.0001				

Table 3.5 List of commonly occurring species at all five sites in the selected field areas of Hunza valley.

S. #	Plant Species	Family
1.	*Acantholimon lycopodioides* (Girard)Boiss.	Plumbaginaceae
2.	*Ephedra gerardiana* Wall. ex Stapf.	Ephederaceae
3.	*Galium aparine* L.	Rubiaceae
4.	*Gentiana tianshanica* Rupr. ex Kusn.	Gentianaeae
5.	*Hippophae rhamnoides* L.	Elaeagnaceae
6.	*Juniperus communis* L.	Cupressaceae
7.	*Juniperus marcopoda* HK.f.	Cupressaceae
8.	*Nepeta* sp.	Lamiaceae
9.	*Peganum harmala* L.	Zygophyllaceae
10.	*Plantago lanceolata* L.	Plantaginaceae
11.	*Polygonum alpinum* All.	Polygonaceae
12.	*Polygonum corrigioloides* J.& S.	Polygonaceae
13.	*Populus alba* L.	Salicaceac
14.	*Populus nigra* L.	Salicaceae
15.	*Potentilla bifurcta* L.	Rosaceae
16.	*Spiraea cantoniensis* Lour.	Rosaceae
17.	*Tamarix dioica Roxb.* ex Roth.	Tamaricaceae
18.	*Thymus serpyllum* L.	Lamiaceae

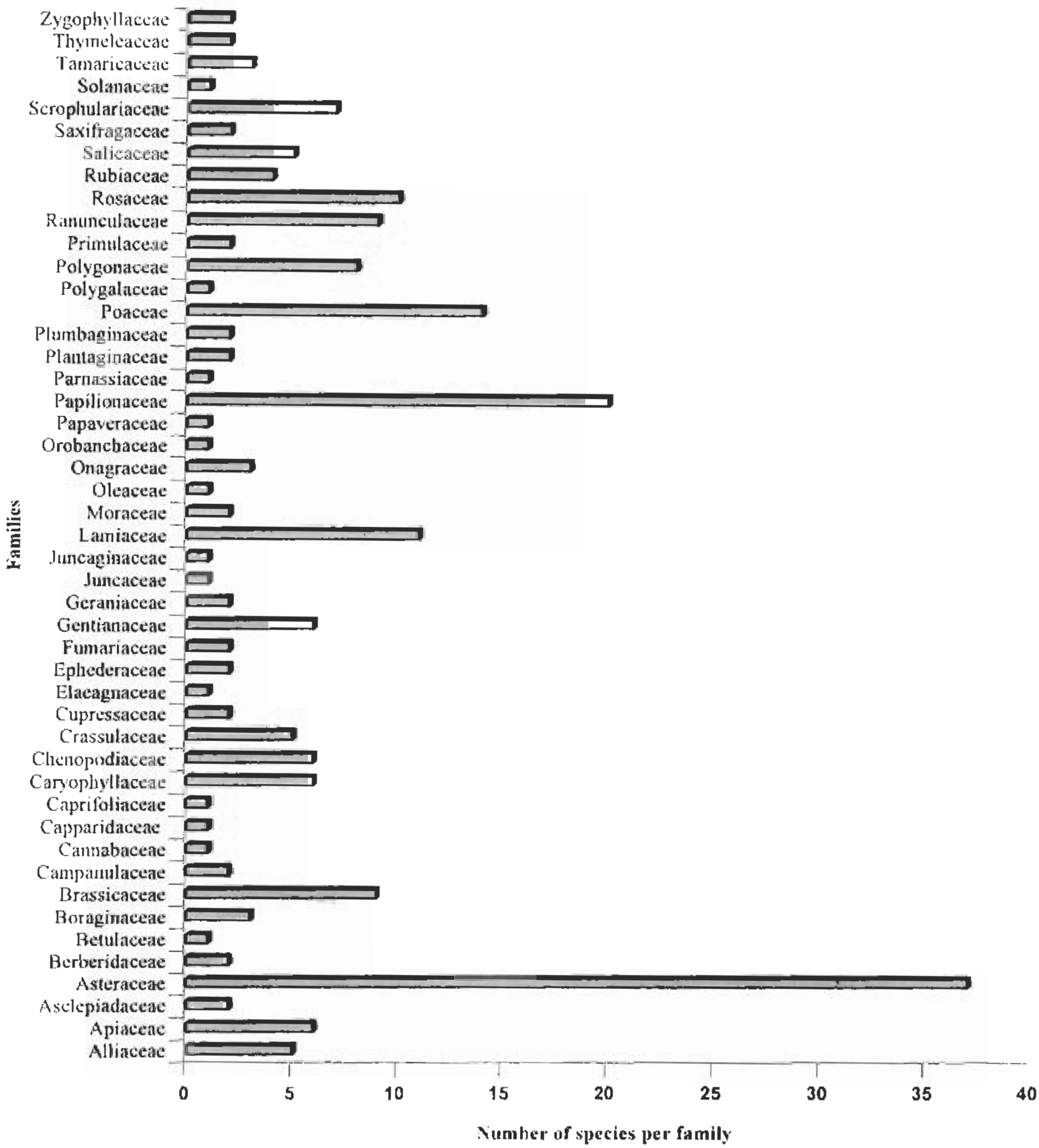


Fig. 3.9 Family-wise distribution of species (e.g. number of species in each family) in the field areas of Hunza valley.

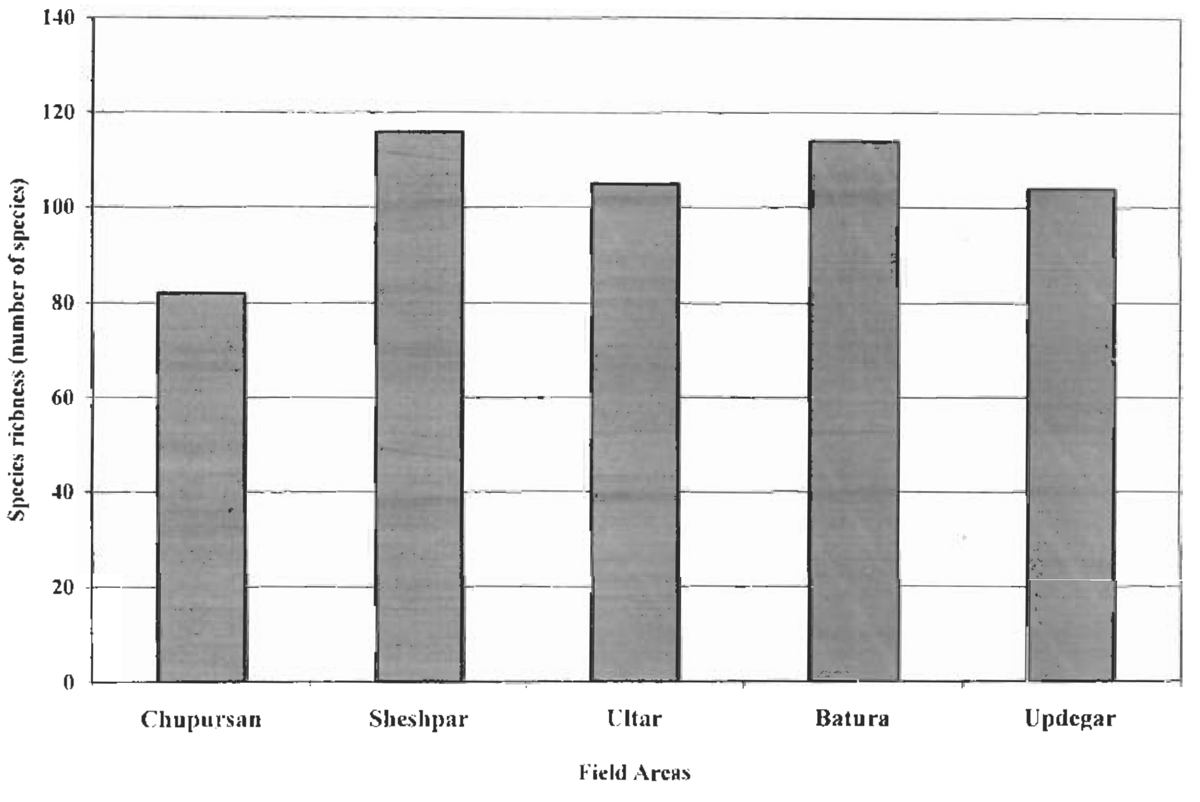


Fig. 3.10 The observed species richness pattern (number of species) in the field areas of Hunza valley.

3.3 CHEMICAL CHARACTERISTICS OF SOIL

Soil samples were collected from different altitudes to study the chemical characteristics of soil viz. micro and macronutrients, pH, and Electrical Conductivity of the soils of field areas. Table 3.6 showed the variation in the study areas. Data showed that the soils of Ultar and Sheshpar are more acidic as compared to the other field areas. Electrical Conductivity (µS/cm) and Na were observed to be highest at Updegar and lowest at Chupursan. Ultar showed the highest NO^{-}_{3} - N and lowest values were observed at Chupursan. Values for K were observed to be highest at Ultar whereas, Updegar showed the lowest values.

Again the highest values for P and Mn were observed at Ultar whereas, lowest values for P and Mn were observed at Batura and Chupursan respectively. Fe was highest at Chupursan and lowest at Batura.

Table 3.6 Chemical characteristics of soils of Hunza valley collected during summer 2001 – 2002.

Field Areas	Altitude (m) a.s.l	pH	EC µS/cm	ppm							
				Na	NO_3^--N	P	K	Ca	Mg	Mn	Fe
ULTAR	2500 ↓ 3500	6.27	179.3	3.931	1.27	7.07	129.0	273.8	81.16	0.006	0.106
SHESHPAR	2600 ↓ 3700	6.40	128.3	4.081	0.63	7.03	93.5	282.4	85.14	0.004	0.217
BATURA	2800 ↓ 3730	7.0	139.7	1.763	0.63	2.65	83.5	344.3	94.20	0.005	0.022
UPDEGAR	2700 ↓ 3800	7.06	208.2	4.251	0.70	4.67	35.0	464.7	116.2	0.002	0.106
CHUPURSAN	3200 ↓ 4100	6.77	96.6	1.633	0.52	2.67	127.0	412.1	92.98	0.001	1.563

3.4 ALTITUDINAL LIMITS OF SELECTED FLORA

Variations in the altitudinal limits of 13 commonly occurring plant species in the field areas of Ultar and Updegar are shown in Figure 3.11. Species located at one altitude were commonly observed at the other area. Species like *Achillea. Aconitum violaceum, Brumus, Aquiligia moorcroftiana, Gentiana tianshanica, Strellaria graminae,* and *Tribulus terrestris* showed a narrow range of distribution limits. The opposite is true for *Anaphalis nepalensis, Thymus serpyllum, Filago pyranidata, Scropularia decomposita* and *Aristida* sp. Table 3.9 shows a summary of altitudinal limits of selected flora. With the exception of the species observed in the altitudinal limits of 0 to 300 m, most of the genera showed almost the similar trend for the lower and higher altitudinal ranges.

3.4.1 Updegar

Variation in the altitudinal limits of selected flora of Updegar are shown in Table 3.7. Species like *Androsace rotundifolia, Cenchrus pennisetiformis, Clematis orientalis, Ephedra gerardiana, Krascheninnikovia ceratoides, Polygonum corrigioloides, Potentilla bifurcta,* and *Spiraea cantoniensis* showed a wide range of limits exceeding 1,000 m. Other species like *Allium carolinianum, Dianthus angulatus, Pedicularis pectinata,* and *Sedum ewersii,* showed a narrow range of altitudinal limits growing within 300 m.

3.4.2 Ultar

Table 3.8 showed the variation in altitudinal limits of selected flora at Ultar. Among the species growing in a range of 9,00 m a.s.l. are *Chrysopogon. Dianthus angulatus, Galium aparine. Oxyria digyna. Polygonum alpinum. Onobrychis dealbata,* and *Sibbaldia cuneata. Saxifraga flagellaris* grow in a narrow range of 250 m a.s.l.

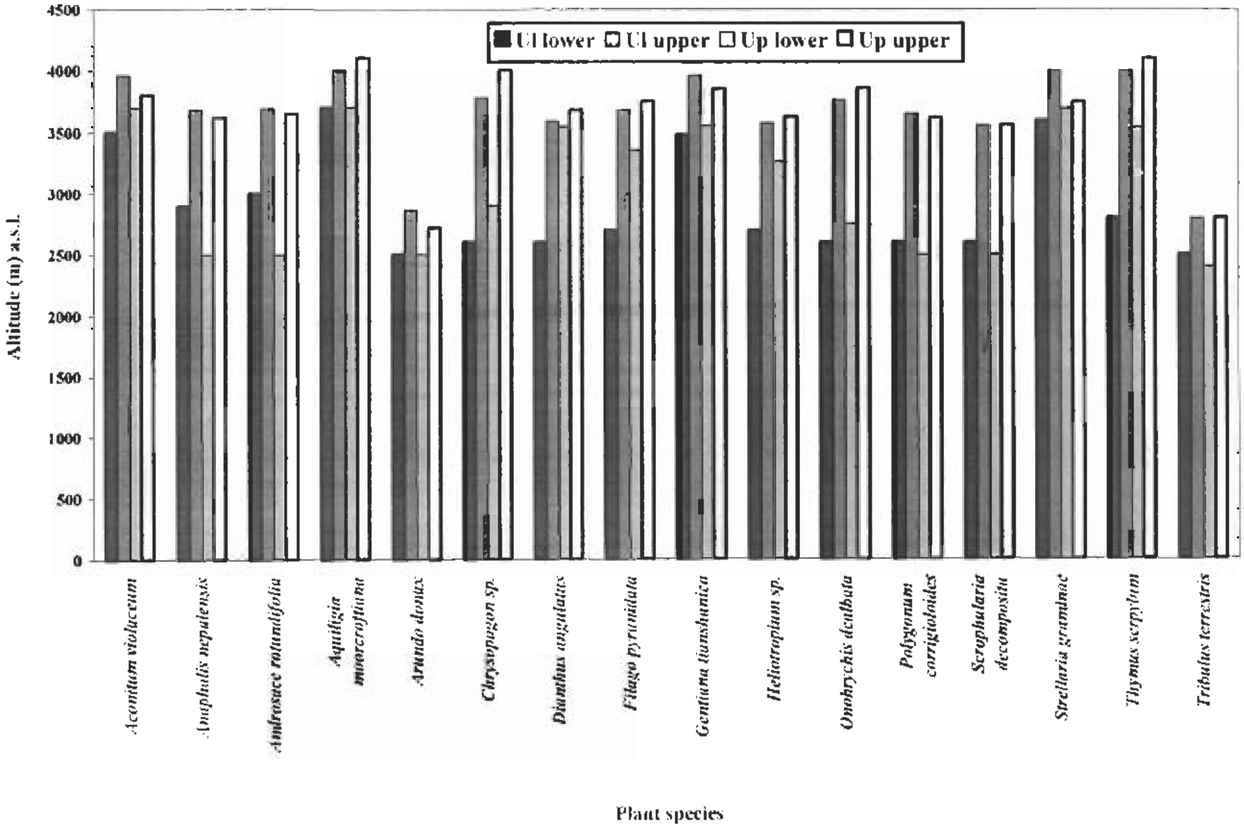


Fig. 3.11 Variation in altitudinal limits of commonly occurring species of Ultar (North of Karimabad) and Updegar (East of Passu) Hunza. Site acronyms are as UL= Ultar and UP= Updegar.

Table 3.7 Altitudinal limits of selected flora of Updegar (East of Passu) Hunza.

S #	Name of species	Family	Lower limit (m) a.s.l.	Upper limit (m) a.s.l.
1	*Allium carolinianum*DC.	Alliaceae	3,700	3,900
2	*Androsace rotundifolia* Hardw.	Primulaceae	2,500	3,650
3	*Artemisia laciniata* Willd.	Asteraceae	3,420	3,800
4	*Artemisia rutifolia* Steph. ex Spreng.	Asteraceae	2,960	3,950
5	*Artemisia scoparia* Waldst. & Kit.	Asteraceae	2,450	2,780
6	*Arundo donax* L.	Poaceae	2500	2,720
7	*Capparis spinosa* L.	Capparidaceae	2,400	2,700
8	*Cenchrus pennisetiformis* Hochst. & Steud.	Poaceae	2,400	3,850
9	*Clematis montana* Buch. Ham.	Ranunculaceae	2,500	2,700
10	*Clematis orientalis* L.	Ranunculaceae	2,450	3,660
11	*Codonopis clematidea* (Schrenk) Clarke.	Companulaceae	3,650	3,950
12	*Dianthus angulatus* Royle.	Caryophyllaceae	3,550	3,680
13	*Ephedra gerardiana* Wall. ex Stapf.	Ephederaceae	2,400	3,750
14	*Epilobium angustifolium* L.	Onagraceae	2,930	3,500
15	*Krascheninnikovia ceratoides* L.	Chenopodiaceae	2,400	3,400
16	*Pedicularis pectinata* Wall. ex Bth.	Scrophulariaceae	3,550	3,750
17	*Polygonum corrigioloides* J.& S.	Polygonaceae	2,500	3,620
18	*Potentilla bifurcta* L.	Rosaceae	2,800	3,800
19	*Sedum ewersii* Ledeb.	Crassulaceae	3,680	3,860
20	*Spiraea cantoniensis* Lour.	Rosaceae	2,700	3,800

Table 3.8 Altitudinal limits of selected flora of Ultar (North of Karimabad) Hunza.

S #	Name of species	Family	Lower limit (m) a.s.l.	Upper limit (m) a.s.l.
1	*Acantholimon lycopodioides* (Girard)Boiss.	Plumbaginaceae	3,250	3,960
2	*Anaphalis neplensis* (Spreng.) Hand. Mazz	Asteraceae	2,800	3,280
3	*Androsace* sp.	Primulaceae	3,000	3,690
4	*Artemisia* sp.	Asteraceae	2,600	2,960
5	*Astragalus* sp.	Papilionaceae	2,600	3,280
6	*Chrysopogon* sp.	Poaceae	2,600	3,780
7	*Companula* sp.	Campanulaceae	2,500	3,320
8	*Dianthus angulatus* Royle.	Caryophyllaceae	2,600	3,590
9	*Epilobium chitralense* Raven.	Onagraceae	2,500	3,100
10	*Galium aparine* L.	Rubiaceae	2,800	3,780
11	*Geranium* sp.	Geraniaceae	3,400	4,000
12	*Heliotropium strigosum* Willd.	Boraginaceae	2,700	3,580
13	*Oxyria digyna* (L.) Hill.	Polygonaceae	2,600	3,520
14	*Polygonum alpinum* All.	Polygonaceae	3,100	4,000
15	*Polygonum plebejum* R. Br.	Polygonaceae	2,600	3,260
16	*Onobrychis dealbata* Stocks.	Papilionaceae	2,600	3,760
17	*Saxifraga flagellaris* Willd.	Saxifragaceae	3,700	3,950
18	*Sibbaldia cuneata* Kunze.	Rosaceae	2,600	3,820

Table 3.9 Summary of altitudinal limits of selected flora at Updegar and Ultar.

Summary of altitudinal limits of selected flora at Updegar and Ultar. Number of species in different altitudinal limits.			
Site	**0 to 300 m**	**Greater than 300 m to 700 m**	**Greater than 700 m**
Updegar	8	5	9
Ultar	2	7	7

3.5 ETHNOBOTANY OF BRUSHO TRIBES OF HUNZA VALLEY

The Hunza valley presents exceptional ethnic, geographic, and linguistic diversity, where high mountains and intervening deep river gorges often mark the boundary lines of ethnic and linguistic features. Hunza has three parts divided ethnically: Gojal, mainly populated with Wakhi speakers; Central, with Brushaski speaking people and Shinaki, the Shina speaking people.

The people of Hunza are called 'Hunzukuts', while Burusho is the term used for only Brushaski speaking people. Brusho people seem to have developed a strong relation to the native flora and there is a rich culture to utilize the flora in one way or the other, for their personal requirements. They frequently utilized the plants for fuel, fodder, timber, food, medicine, and many other ways. The brief details of plants, their local use with their local names are presented in Table 3.10. A summary showing habit and parts of the plants used is shown in Table 3.11. Table 3.12 shows a summary of number of plants used for different ailments. Mostly the people used herbs and aerial parts for different kinds of ailments.

Table 3.10 Plants used for different ailments by the inhabitants of Hunza valley.

1:	**Botanical name**	*Berberis lycium* Royle
	Family	Berberidaceae
	Local name	Ishkeen
	Habit	Shrub
	Part used	Root
	Folk use	Used for the bruises and pain of joints, backache etc.
2:	**Botanical name**	*Capparis spinosa* L.
	Family	Capparidaceae
	Local name	Chopri
	Habit	Shrub
	Part used	Seeds
	Folk use	Oil is extracted and used for the relief of body pain.
3:	**Botanical name**	*Thymus serpyllum* L.
	Family	Labiatae
	Local name	Tumuro
	Habit	Herb
	Part used	Aerial parts
	Folk use	For relief of cold and flu symptoms, also used for the relief of cough and sore throat.
4:	**Botanical name**	*Gnaphalium luteo-album* L.
	Family	Asteraceae
	Local name	Sumbul
	Habit	Herb
	Part used	Aerial parts
	Folk use	Given to diabetic patients to control sugar level.
5:	**Botanical name**	*Artemisia* sp.
	Family	Asteraceae
	Local name	Moing
	Habit	Herb
	Part used	Aerial parts
	Folk use	Capable of destroying intestinal worms.
6:	**Botanical name**	*Artemisia scoparia* Waldst. & Kit.
	Family	Asteraceae
	Local name	Moing
	Habit	Herb

	Part used	Aerial parts
	Folk use	Plant leaves are used for ear ache.
7:	**Botanical name**	*Juniperus* sp.
	Family	Cupressaceae
	Local name	Gal
	Habit	Shrub
	Part used	Berries
	Folk use	Mainly aromatic in nature, also used to cure high blood pressure & asthma.
8:	**Botanical name**	*Mentha royleana* Benth.
	Family	Labiatae
	Local name	Filaling
	Habit	Herb
	Part used	Aerial parts
	Folk use	Used as an anti diarrhoeal agent.
9:	**Botanical name**	*Nepeta eriostachya* Bth.
	Family	Labiatae
	Local name	Jangali filaling
	Habit	Herb
	Part used	Aerial parts
	Folk use	For the relief of dysentery.
10:	**Botanical name**	*Trigonella foenum-graecum* L.
	Family	Papilionaceae
	Local name	Shikarkutz
	Habit	Herb
	Part used	Aerial parts
	Folk use	For the relief of stomach trouble.
11:	**Botanical name**	*Saussurea lappa* (Dcne.) Sch.Bip.
	Family	Asteraceae
	Local name	Menal
	Habit	Herb
	Part used	Roots
	Folk use	For the relief of asthma.
12:	**Botanical name**	*Canabis sativa* L.
	Family	Cannabinaceae
	Local name	Thoonch
	Habit	Herb

	Part used	Seeds
	Folk use	The seeds are used as a narcotic drug.
13:	**Botanical name**	*Peganum harmala* L.
	Family	Zygophyllaceae
	Local name	Supandur
	Habit	Herb
	Part used	Aerial parts
	Folk use	Seeds of the plant are well known for fragrance and Smoke has insect killing properties.
14:	**Botanical name**	*Hippophae rhamnoides* L.
	Family	Elaeagnaceae
	Local name	Chang
	Habit	Shrub
	Part used	Berries
	Folk use	Berries are used for high blood pressure and heart disease.
15:	**Botanical name**	*Populus nigra* L.
	Family	Salicaceae
	Local name	Jarpa
	Habit	Tree
	Part used	Leaves
	Folk use	Used for high blood pressure symptoms.
16:	**Botanical name**	*Allium cepa* L.
	Family	Alliaceae
	Local name	Ghashu
	Habit	Herb
	Part used	Bulb
	Folk use	Decoction of roasted Onion bulb is used for the cough remedy.
17:	**Botanical name**	*Allium sativum* L.
	Family	Alliaceae
	Local name	Buqpa
	Habit	Herb
	Part used	Bulbs
	Folk use	Bulbs are used for the relief of high blood pressure, heart diseases and also in cooking for flavour.
18:	**Botanical name**	*Coriandum sativum* L.
	Family	Apiaceae

	Local name	Thon
	Habit	Herb
	Part used	Aerial parts
	Folk use	Aerial parts are edible and used as a flavoring agent and used as a blood purifier.
19:	**Botanical name**	*Elaeagnus angustifolia* L.
	Family	Elaeagnaceae
	Local name	Gindawar
	Habit	Tree
	Part used	Fruit
	Folk use	Used for cough remedy.
20:	**Botanical name**	*Morus nigra* L.
	Family	Moraceae
	Local name	Biranch
	Habit	Tree
	Part used	Fruit
	Folk use	Fruit is edible and dried fruit is commonly used for the preparation of local alcoholic beverages.
21:	**Botanical name**	*Prunus armeniaca* L.
	Family	Rosaceae
	Local name	Jhoo
	Habit	Tree
	Part used	Fruit/Gum
	Folk use	Fruit is edible and also eaten in dried form. Apricot oil is used as a substitute for oil of Almonds for its softening action on the skin. Gum is very effective in heart burning and acidity.
22:	**Botanical name**	*Prunus persica* (L.) Batsch.
	Family	Rosaceae
	Local name	Chugudar
	Habit	Tree
	Part used	Fruit/Kernel
	Folk use	Fruit is edible, bitter taste kernels are very effective for the relief of amoebic dysentery.
23:	**Botanical name**	*Plantago lanceolata* L.
	Family	Plantaginaceae
	Local name	Ispaghol
	Habit	Herb

	Part used	Seeds
	Folk use	The husk of the tiny seeds is used for Diarrrhoea and Constipation.
24:	**Botanical name**	*Betula utilis* D.Don.
	Family	Betulaceae
	Local name	Halli
	Habit	Tree
	Part used	Bark
	Folk use	Butter is wrapped in the bark paper and stored. Also used as a substitute for writing paper.
25:	**Botanical name**	*Juglans regia* L.
	Family	Juglandaceae
	Local name	Tilli
	Habit	Tree
	Part used	Bark, Leaves, Fruit
	Folk use	The bark and the leaves are used for teeth cleaning purposes. Fruit is edible. Wood is used for furniture.
26:	**Botanical name**	*Pyrus malus* L.
	Family	Rosaceae
	Local name	Balt
	Habit	Tree
	Part used	Fruit
	Folk use	Fruit is edible. Dried fruit powder is mixed with water and the juice is used as a cooling agent.
27:	**Botanical name**	*Amygdalus communis* L.
	Family	Rosaceae
	Local name	Badam
	Habit	Tree
	Part used	Kernels/Oil
	Folk use	For its softening action on the skin. It forms a good remedy for chapped hands.
28:	**Botanical name**	*Vitis* sp.
	Family	Vitaceae
	Local name	Ghaing
	Habit	Vine
	Part used	Fruit
	Folk use	The fruit is edible and used for making local alcoholic beverages.
29:	**Botanical name**	*Punica granatum* L.

	Family	Punicaceae
	Local name	Bichil
	Habit	Tree
	Part used	Fruit
	Folk use	Seeds are dried and condiments and used as spices. Bark of stem used to cure fever.
30:	**Botanical name**	*Ephedra gerardiana* Wall ex satpf.
	Family	Ephedraceae
	Local name	Sopat
	Habit	Shrub
	Part used	Aerial parts
	Folk use	Used for the healing of wounds and for the Asthma.
31:	**Botanical name**	*Gentiana tianschanica* Rupr.ex Kusn
	Family	Gentianaceae
	Local name	Palamating
	Habit	Herb
	Part used	Aerial parts
	Folk use	Given to diabetic patients to control sugar level.

Table 3.11 Summary showing habit and parts of the plant used for different ailments.

Plant type				Part of the plant used					
Herb	**Shrub**	**Tree**	**Vine**	**Aerial**	**Roots**	**Seeds**	**Berries**	**Kernels**	**Fruit**
15	5	10	1	11	2	6	2	2	8

Table 3.12 Summary showing number of species used for different ailments and for preparing different products.

Body pains	Skin problems	Diabetes	Stomach troubles	Blood Pressure	Asthma	Cough	Alcoholic beverages
3	2	2	7	4	3	3	2

3.6 CLIMATE STUDIES

Thermohygrograph with hair element and bimetal were installed to record the air temperature and relative humidity at Chupursan 3,200 m a.s.l. and Ultar 3, 120 m a.s.l.

3.6.1 Ultar

Figure 3.12 showed the records of daily temperatures at Ultar during summer 2001-2002. The yearly average maximum and minimum temperatures (°C) recorded from April to September at Ultar were 14.96/5.7 and 17.8/8.2 during 2001 and 2002 respectively. The data reveal that 2002 was a relatively warm year than 2001.

Monthly averages in temperature (Figure 3.13) revealed that in August the average temperature was 4 °C higher during 2002 as compared to 2001. A general tendency of higher monthly averages was observed during the year 2002.

Figure 3.14 showed the daily records of the air humidity (%) during summer 2001-2002. The yearly average maximum and minimum humidity (%) recorded from April to September at Ultar were 40.3/19.1 and 37.7/19.5 during 2001 and 2002 respectively. Similar to temperature in August the relative humidity was 6 (%) lower during 2002 as compared to 2001 (Figure 3.15).

3.6.2 Chupursan

Figure 3.16 showed the record of daily temperatures at Chupursan. The yearly average maximum and minimum temperatures (°C) recorded from April to September at Chupursan were 16.8/6.8 and 20.4/8.5 during 2001 and 2002 respectively. Higher monthly averages were observed for all the recorded months during 2002, showing an increase of 6 °C in the month of August as compared to 2001 (Figure 3.17).

Figure 3.18 showed record of yearly maximum and minimum humidity (%) for the same period. The recorded values were 37.2/16.0 and 39.3/12.0 for the year 2001 and 2002 respectively. With the exception of August and September, the other months showed a relatively higher humidity levels during 2001 (Figure 3.19).

3.6.3 Climate and Species Richness

Figure 3.20 showed the comparative records of monthly averages for daily temperatures at Ultar and Chupursan during 2001 and 2002. Higher monthly averages for air temperature(°C) were observed for all the recorded months at Chupursan during summer 2001 and 2002 as compared to Ultar.

Similar to temperatures, Figure 3.21 showed the records of monthly averages for the relative humidity (%) during summer 2001-2002. The yearly average maximum and minimum humidity (%) recorded showed a general tendency of higher monthly averages at Ultar during the first four months of the year 2001.During summer 2002, the relative humidity was 3 % lower at Ultar, but the average minimum humidity was 7 % higher as compared to Chupursan during 2002. This showed adequate moisture availability at Ultar as compared to Chupursan. This may account for the higher species richness (number of species) (Figure 3.22).

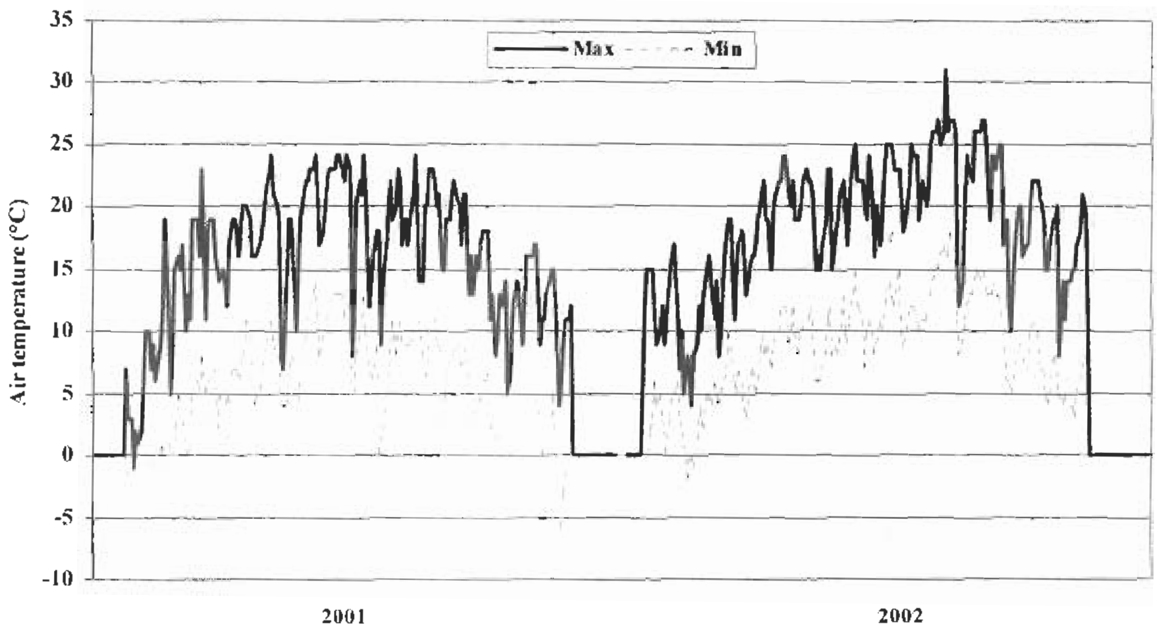


Fig. 3.12 Variation in Air temperature (°C) at Ultar during 2001- 2002. The data was recorded from April – September. Upper lines represent maximum values. Lower lines represent minimum values.

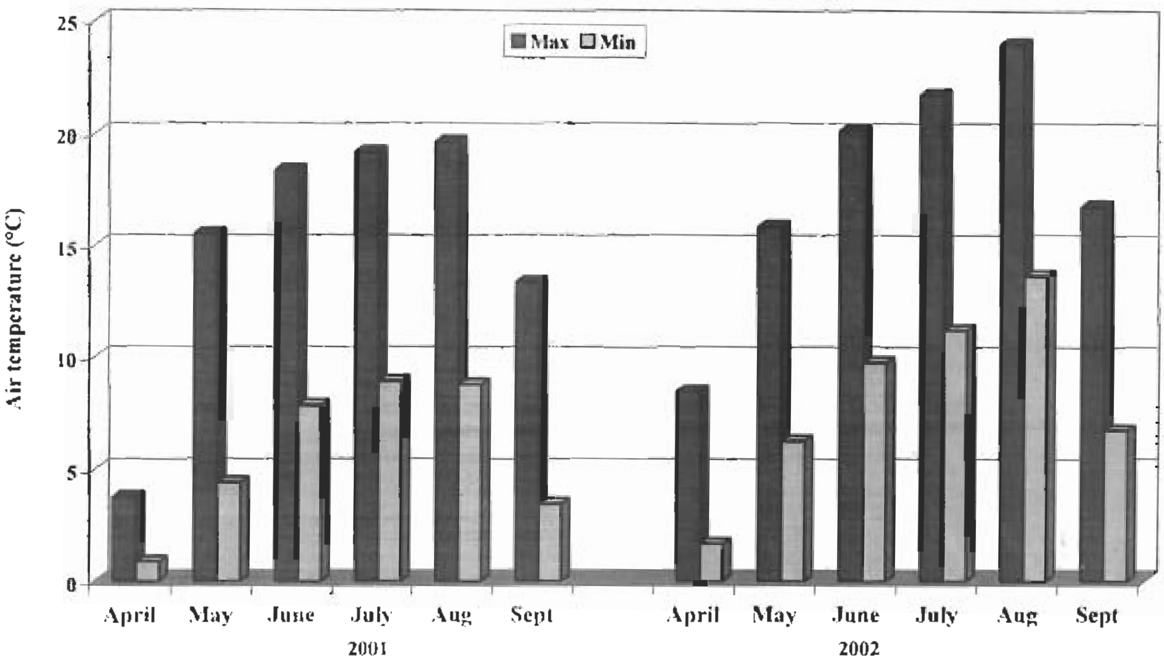


Fig. 3.13 Monthly averages in Air temperature (°C) at Ultar during 2001- 2002. The data was recorded from April – September. Each data represent 30 measurements for the months of April, June and September and 31 measurements for the months of May, July and August. In the pairs of bars, left hand bars represent maximum values, and right hand bars represent minimum values.

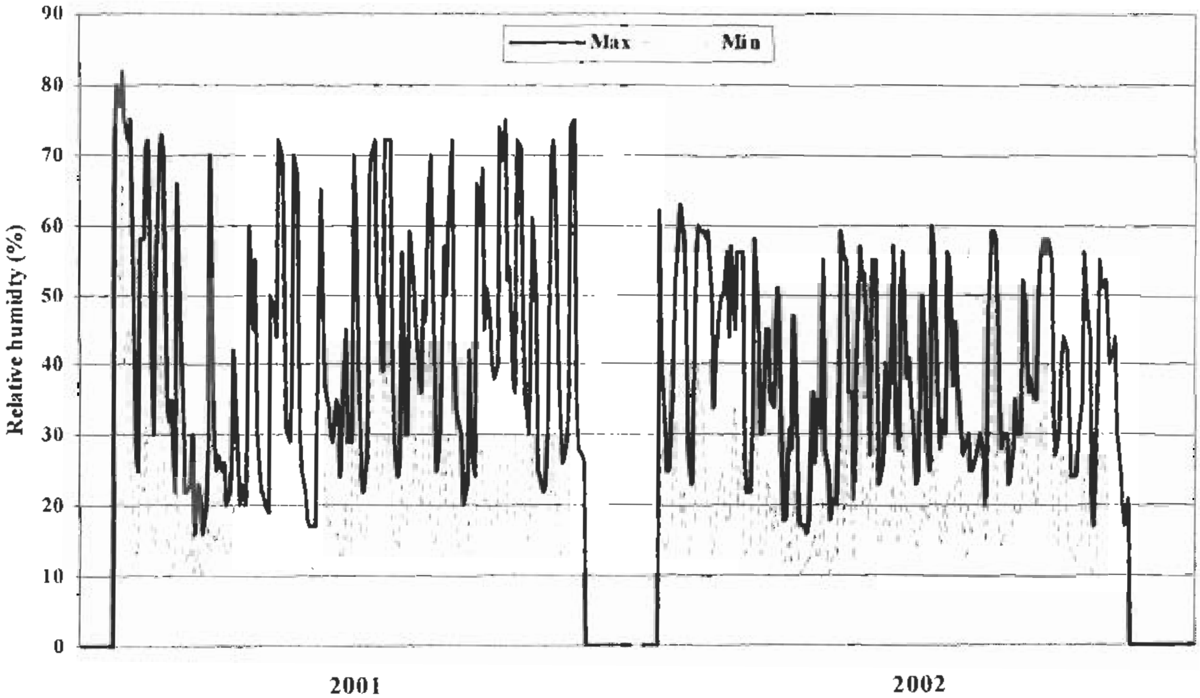


Fig. 3.14 Data showing the variation in Relative humidity (%) at Ultar during 2001-2002. The data was recorded from April – September. Lower lines represent minimum values.

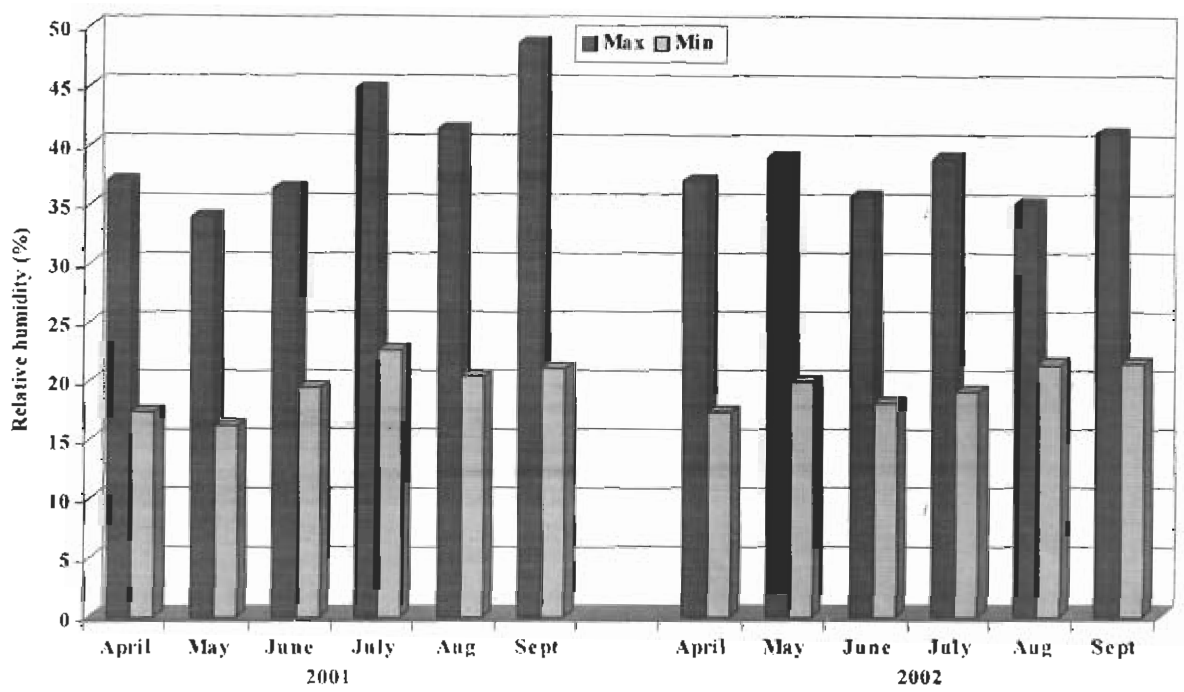


Fig. 3.15 Data showing the monthly averages of Relative humidity (%) at Ultar during 2001- 2002. The data was recorded from April – September. Each data represent 30 measurements for the months of April, June and September and 31 measurements for the months of May, July and August. In the pairs of bars, left hand bars represent maximum values, and right hand bars represent minimum values.

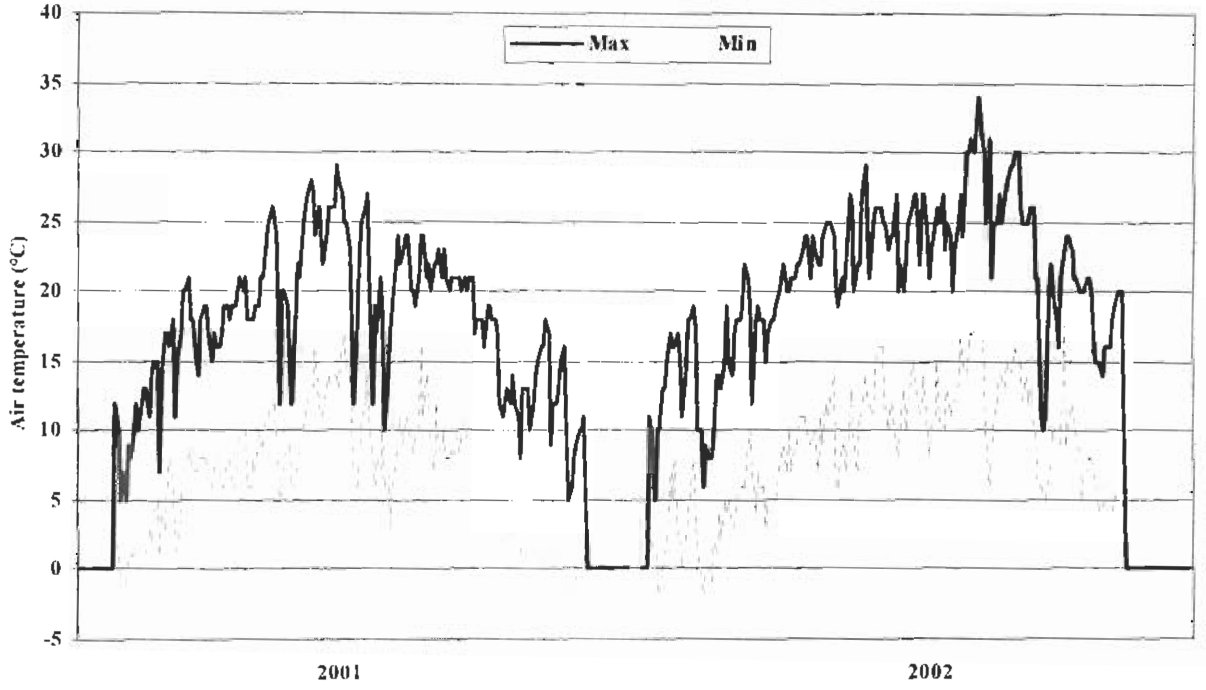


Fig. 3.16 Data showing the variation in Air temperature (°C) at Chupursan during 2001-2002. The data was recorded from April – September. Lower lines represent minimum values.

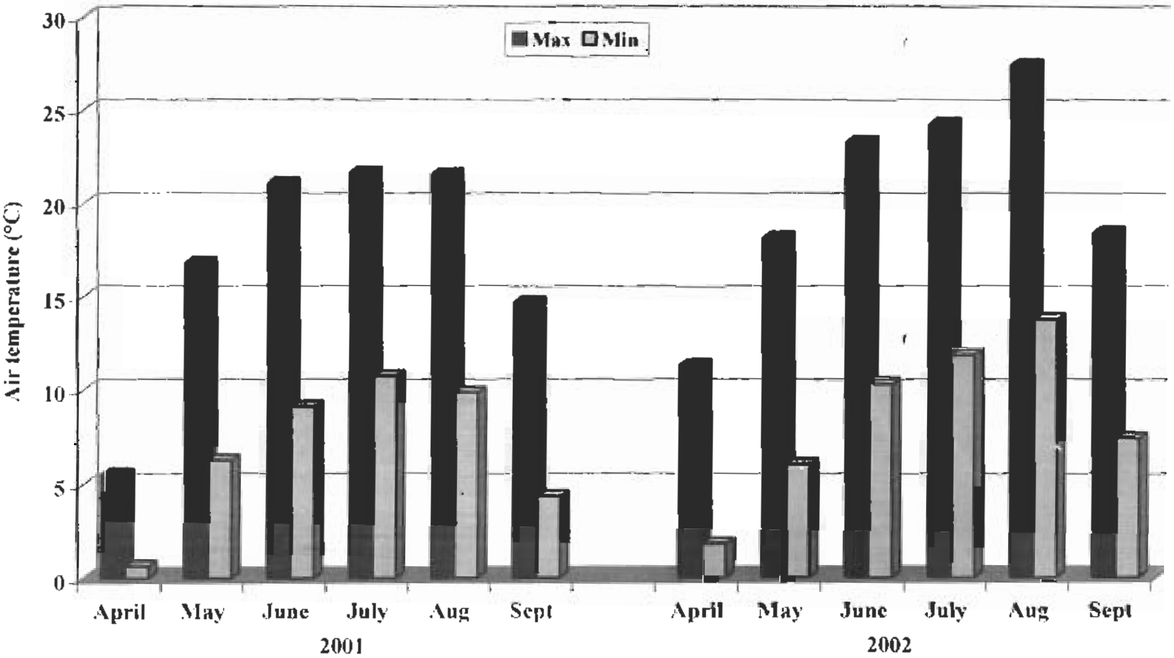


Fig. 3.17 Data showing the monthly averages in Air temperature (°C) at Chupursan during 2001- 2002.The data was recorded from April – September. Each data represent 30 measurements for the months of April, June and September and 31 measurements for the months of May, July and August. In the pairs of bars, left hand bars represent maximum values, and right hand bars represent minimum values.

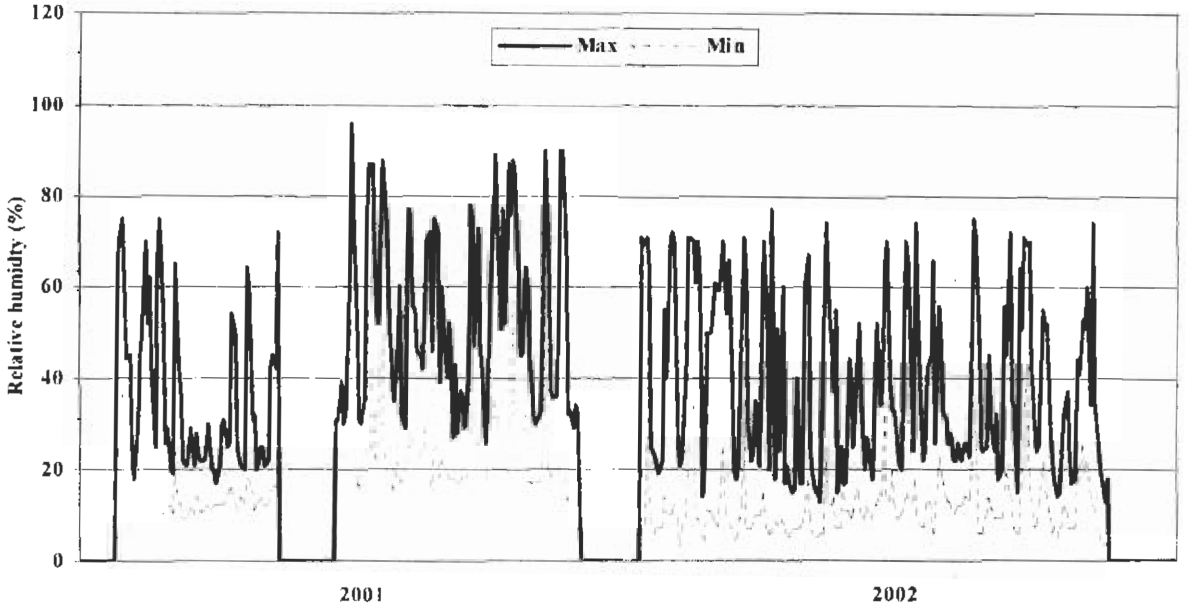


Fig. 3.18 Data showing the variation in Relative humidity (%) at Chupursan during 2001-2002. The data was recorded from April – September. Lower lines represent minimum values.

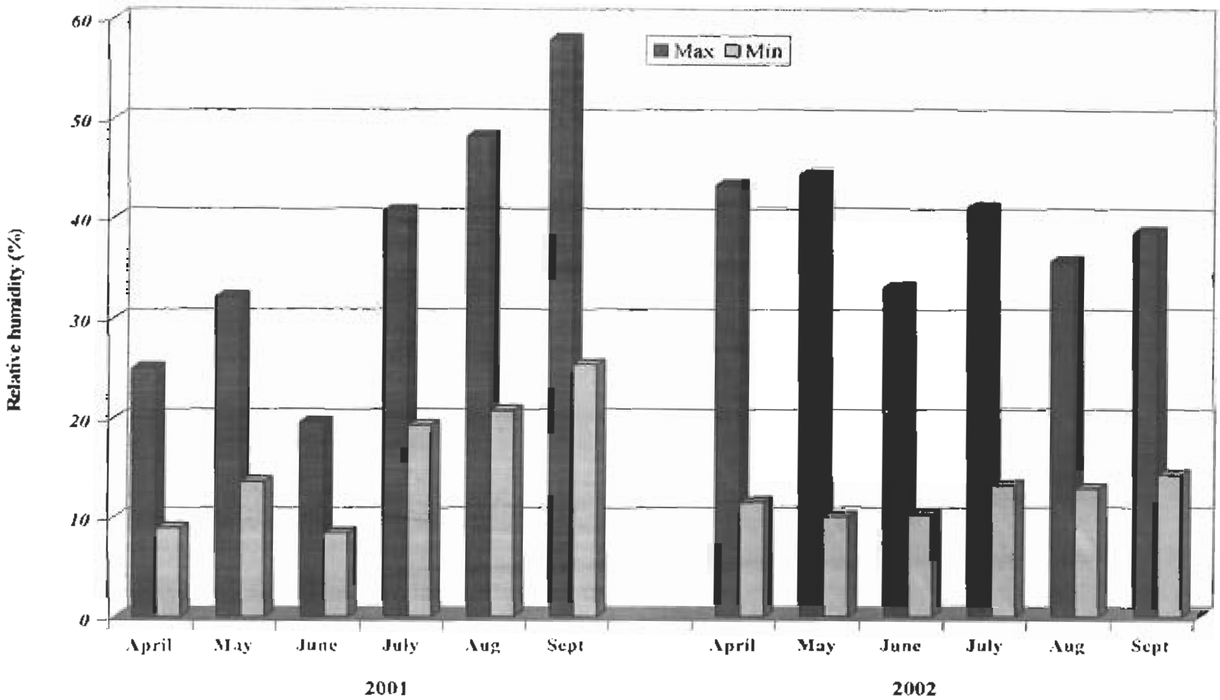


Fig. 3.19 Data showing the monthly averages Relative humidity (%) at Chupursan during 2001- 2002. The data was recorded from April – September. Each data represent 30 measurements for the months of April, June and September and 31 measurements for the months of May, July and August. In the pairs of bars, left hand bars represent maximum values, and right hand bars represent minimum values.

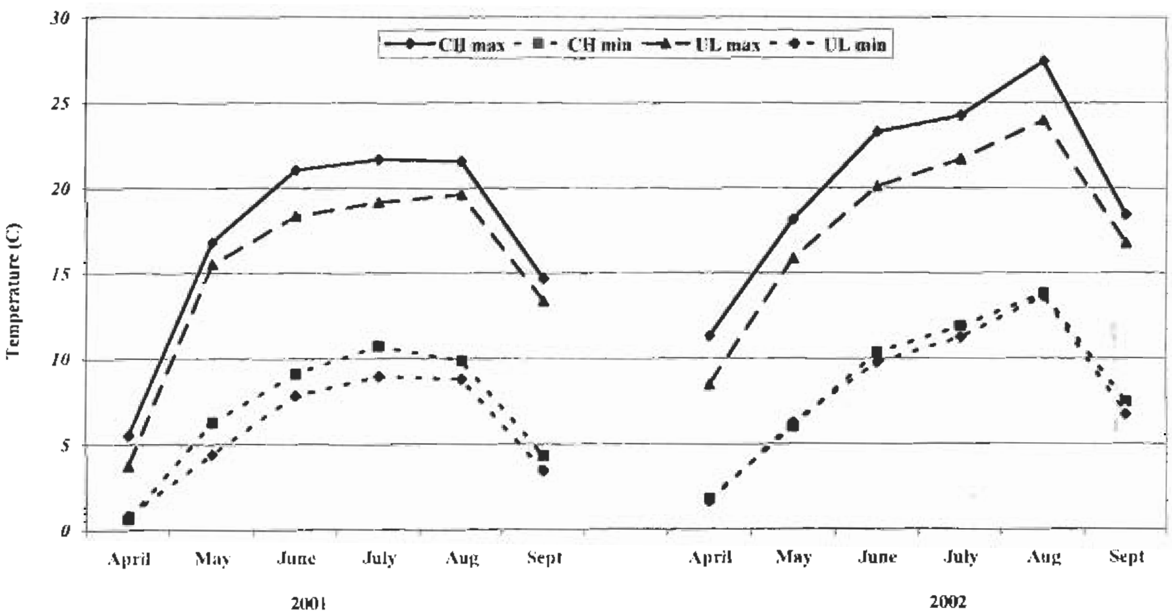


Fig. 3.20 Data showing the comparative monthly averages of Air temperature (°C) at Ultar and Chupursan during 2001- 2002. The data was recorded from April – September.

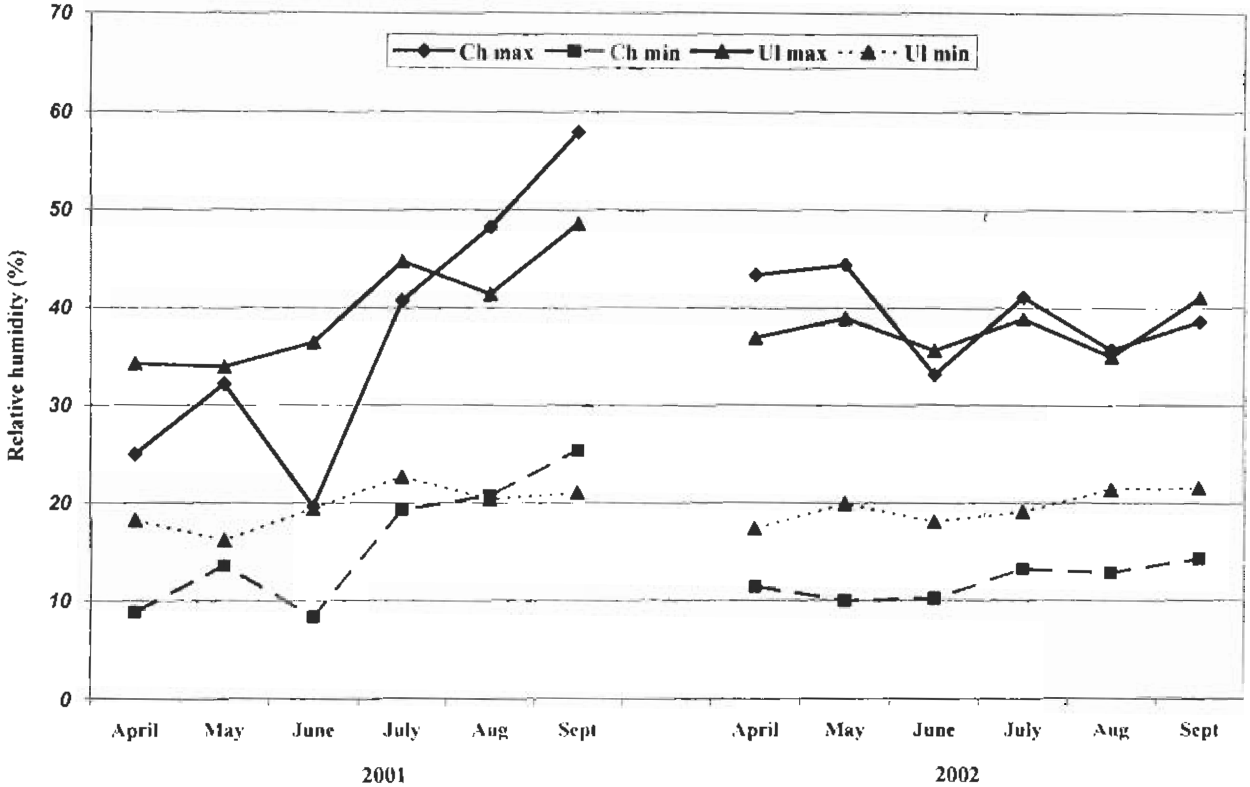


Fig. 3.21 Data showing the comparative monthly averages of Relative Humidity (%) at Ultar and Chupursan during 2001- 2002. The data was recorded from April – September.

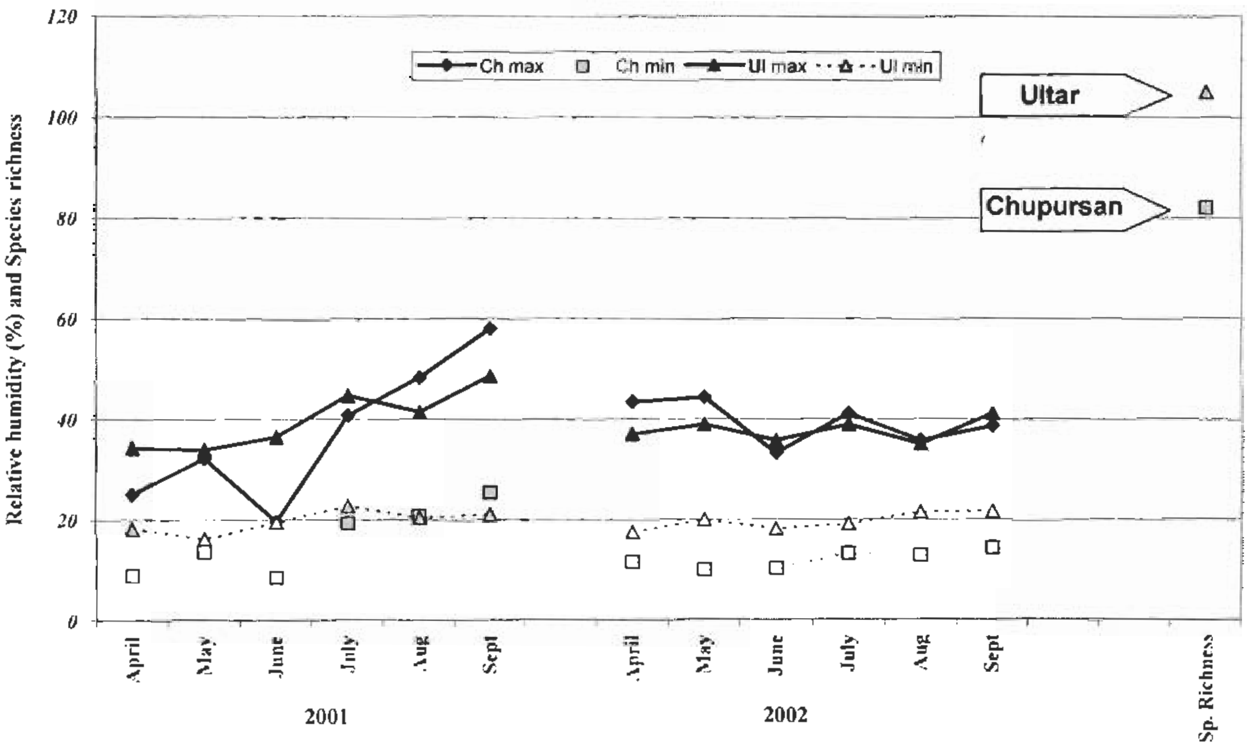


Fig. 3.22 Data showing the comparative monthly averages of Relative Humidity (%) and Species richness at Ultar and Chupursan. The data was recorded from April – September 2001- 2002.

3.7 SOIL MOISTURE

Soil Tensiometers were installed at 3,300 m a.s.l. at two different slopes. Tensiometer-1 was installed on the south facing slope while, Tensiometer-2 was installed at north facing slope. Figure 3.23 clearly showed that dryer conditions prevail throughout the study period at south facing slope, and that the north facing slope retained much moisture at the comparable altitude.

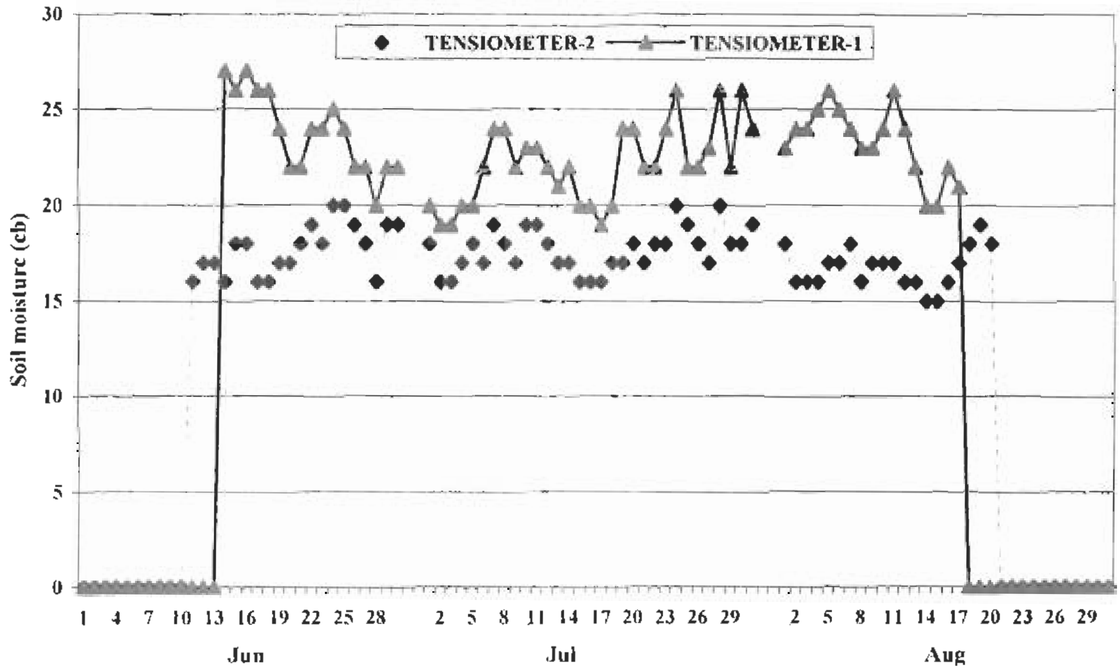


Fig. 3.23 Soil moisture variation (cb = centibars) at Ultar pastures, Hunza valley. Tensiometer-(upper line) was installed at 3,300m on South facing slope, while Tensiometer-2 (lowe line) was installed at 3,300m on North facing slope.

3.8 BIOCHEMICAL CONTENTS

Leaves of four herbaceous plant species were collected during summer from two different altitudes viz 3,000 m a.s.l. and 3,500 m a.s.l. at Ultar pastures to determine the variation in the levels of abscisic acid (ABA), sugar, protein and proline content of leaves. The selected plant species were *Onobrychis dealbata* (Onagraceae), *Galium aparine* (Rubiaceae), *Polygonum alpinum* (Polygonaceae) and *Thymus serpyllum* (Labiatae).

3.8.1 ABA Content

Figure 3.24 showed the variation in the endogenous level of ABA. Endogenous ABA content of all the species were found to be higher in plant species collected at altitude of 3,500 m a.s.l. as compared to that of collected at the altitude of 3,000 m a.s.l. *Galium aparine* showing the highest endogenous level of ABA was at altitude of 3,500 m a.s.l., whereas *Onobrychis dealbata* had lowest level of endogenous ABA at the altitude of 3,000 m a.s.l.

3.8.2 Sugar Content

Figure 3.25 showed the variation in the endogenous level of sugar in the plant species. Endogenous sugar content was also found to be higher in plant species collected at altitude of 3,500 m a.s.l. as compared to that of collected at the altitude of 3,000 m a.s.l. The sugar content was higher in *Onobrychis dealbata*, which was at the altitude of 3,500 m a.s.l., while *Galium aparine* showed minimum sugar content at altitude of 3,000 m a.s.l.

3.8.3 Protein Content

Figure 3.26 showed the variation in the endogenous level of protein in the leaves of plant species. Protein content of leaves was observed to be higher in all the plant species collected at 3,500 m a.s.l. The protein content was found to be maximum in *Onobrychis dealbata*, which was at altitude of 3,500 m, while *Thymus serpyllum* showed the minimum protein content, which was at altitude of 3,000 m.

3.8.4 Proline Content

Figure 3.27 showed the variation in the endogenous proline content. Proline content of leaves showed similar trend and was observed to be higher in all the plant species collected at 3,500 m a.s.l. The proline content was found to be maximum in *Polygonum alpinum* , which was at altitude of 3,500 m a.s.l., while *Galium aparine* showed the minimum protein content, which was at altitude of 3,000 m a.s.l.

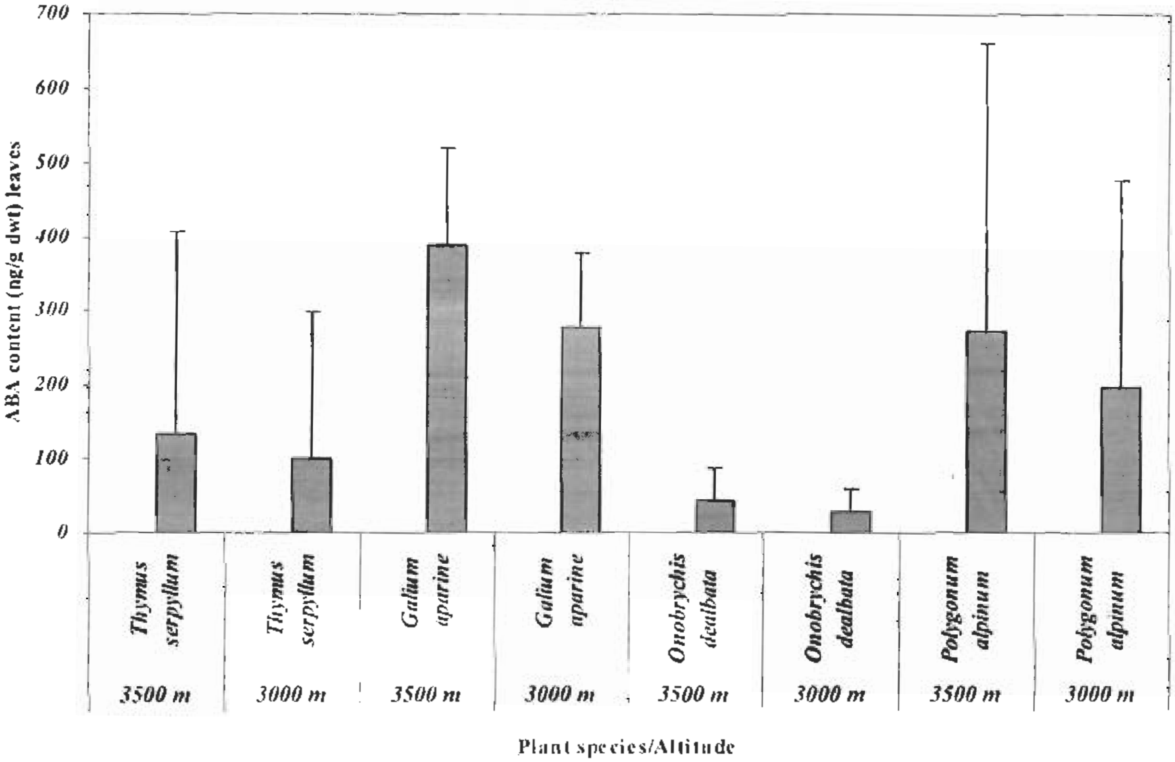


Fig. 3.24 Endogenous ABA content (ng/g dwt) in leaves of plant species collected from two different altitudes of Ultar pastures. The plant samples were collected at flowering stage at altitudes ranging from 3,000 m to 3,500 m during summer season. Each value is the mean of three observations ± s.e.

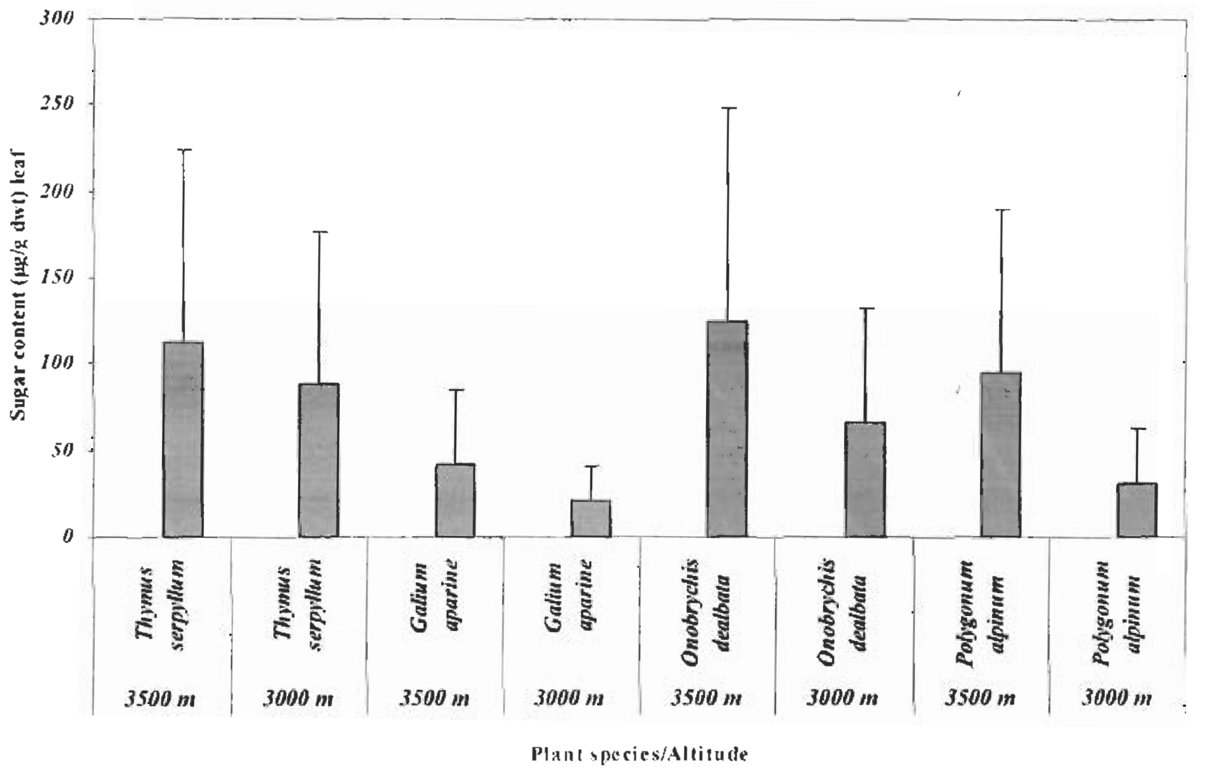


Fig. 3.25 Endogenous sugar content (µg/g dwt) in leaves of plant species collected from two different altitudes of Ultar pastures. The plant samples were collected at flowering stage at altitudes ranging from 3,000 m to 3,500 m during summer season. Each value is the mean of three observations ± s.e.

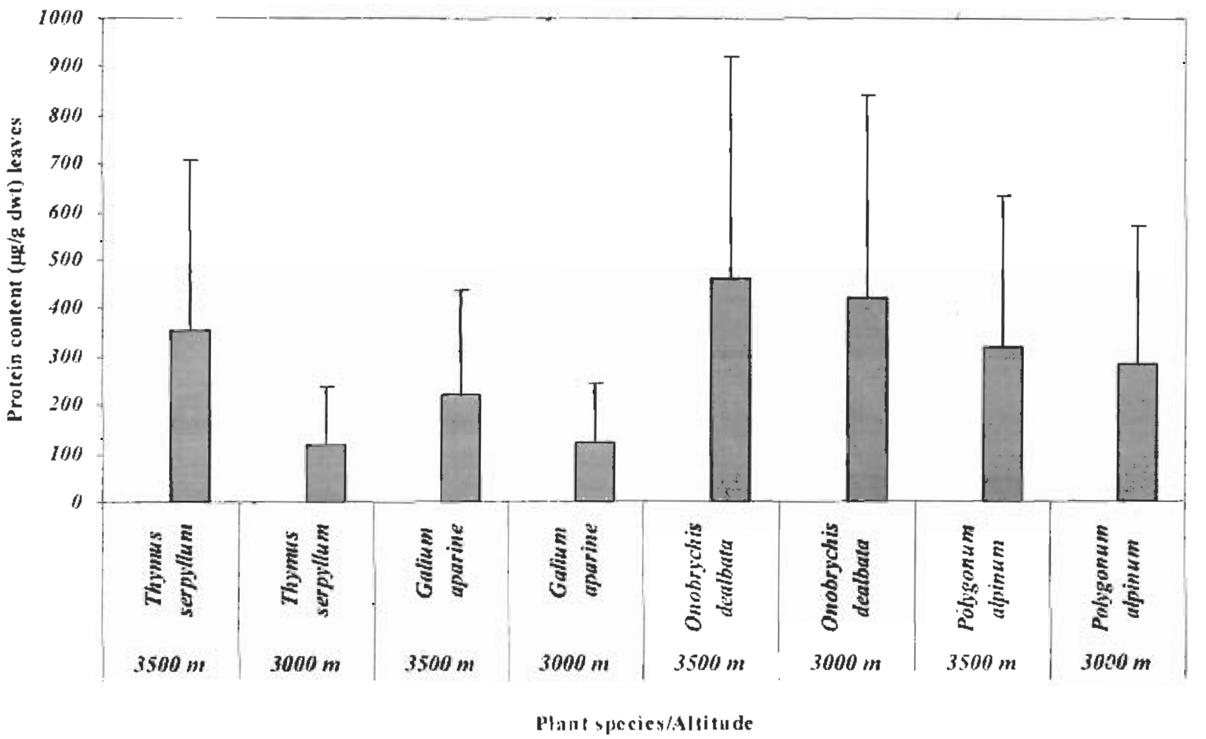


Fig. 3.26 Endogenous protein content (µg/g dwt) in leaves of plant species collected from two different altitudes of Ultar pastures. The plant samples were collected at flowering stage at altitudes ranging from 3,000 m to 3,500 m during summer season. Each value is the mean of three observations ± s.e.

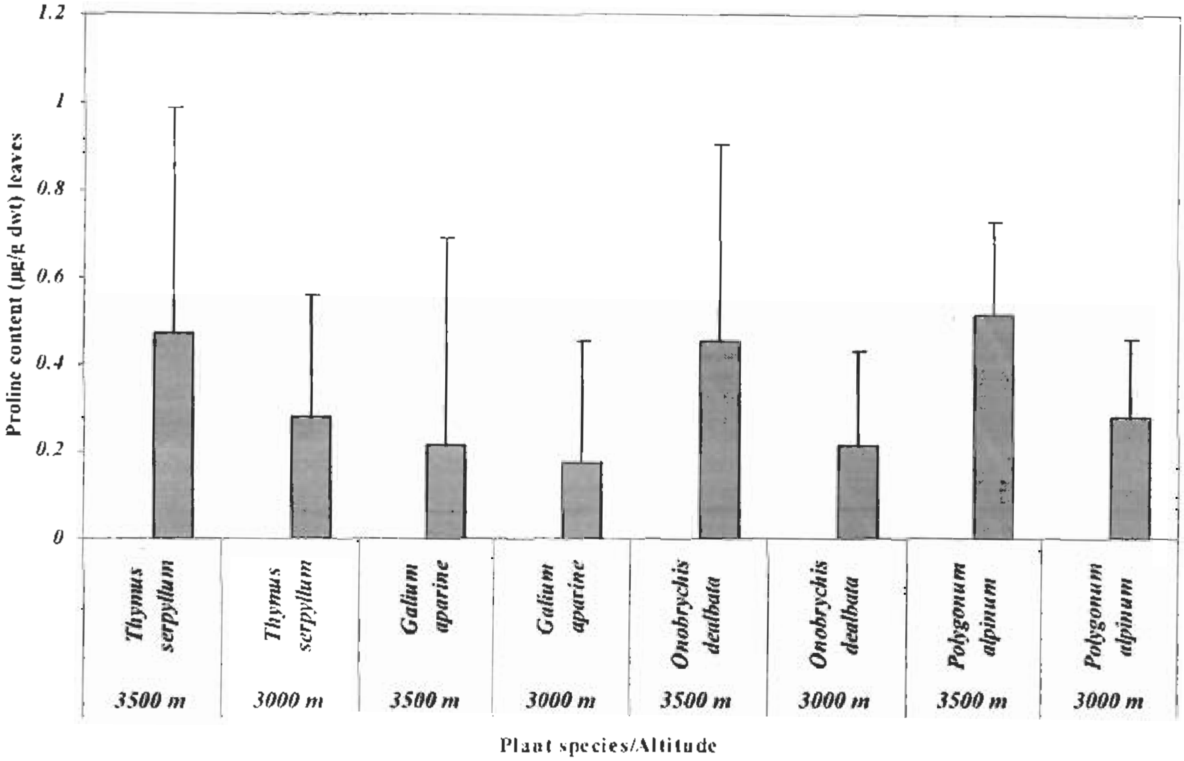


Fig. 3.27 Endogenous proline content (µg/g dwt) in leaves of plant species collected from two different altitudes of Ultar pastures. The plant samples were collected at flowering stage at altitudes ranging from 3,000 m to 3,500 m during summer season. Each value is the mean of three observations ± s.e.

3.9 STOCKING DENSITY AND GRAZING STATUS OF ULTAR PASTURES

Ultar (North of Karimabad) is an important summer pastures of the inhabitants of central Hunza valley. The pasture is generally rich in plant biomass due to an adequate moisture regime and is therefore an important food habitat for both domestic and wild herbivores. Sedges and grasses dominate, but other genera such as *Potentilla*, *Saxifraga*, *Artemisia*, *Primula*, *Sedum*, and *Polygonum* are also common. The four kinship groups Diramiting, Barataling, Khurukutz, and Buroung enjoy traditional grazing rights. The locals use the pasture for nearly four months to graze their livestock which comprises of sheep, goat, yak and cows.

A list of palatable and unpalatable species of Ultar is presented in tables 3.15 and 3.16. The palatable pasture species include species like *Gentiana tianshanica, Trifolium pratense, Potentilla sp., Polygonum sp., Sibaldia cuneata, Anaphalis nepalesis, Dianthus angulatus, Astragalus sp., Filago pyranidata, Scrophuilaria decomposita, Oxyria digyna* (Table 3.15) and *Thymus serpyllum* where as, *Echnops* sp., *Polygonum* , *Acantholimon lycopodiodes, Aristida* sp., *Scutellaria* sp., are among the species which are less preferable by all kinds of grazing cattle (Table 3.16). Goats prefer shrubs like *Rosa nanothamnus* and *Berberis lycium.*

Table 3.13 shows the commonly used animal equivalents. Animal unit is expressed as one mature non-lactating bovine weighing 500 kg and fed at a maintenance level, or the equivalent, expressed as (weight) 0.75, in other kinds or classes of animals. Table 3.14 showed the stocking densities at Ultar pastures for the year 2000, 2001 and 2002. The number of Animal Units/year for different live stock classes at Ultar meadows were 202.1, 219.5 and 328.6 during 2000, 2001 and 2002 respectively. This showed a general trend of increasing number of animal units year by year, but the year 2002 showed a drastic increase in the number of animal units as compared to 2001 , despite the fact that year 2001 had better humidity conditions as compared to year 2002 (Figure 3.14) for the growth of plant species.

Table 3.13 Commonly used Animal Unit Equivalents

Class of Animal	Animal Unit Equivalent
Cow, 1000 lb, dry	0.92
Cow, 1000 lb, with calf	1.00
Bull, mature	1.35
Cattle, 1 year old	0.60
Cattle, 2 years old	0.80
Horse, mature	1.25
Sheep, mature	0.20
Lamb, 1 year old	0.15
goat, mature	0.15
Kid, 1 year old	0.10
Deer, white tailed, mature	0.15
Deer, mule, mature	0.20
Elk, mature	0.60
Antelope, mature	0.20
Bison, mature	1.00
Sheep, bighorn, mature	0.20

(from National Range and Pasture Handbook, USDA NRCS (1997)

Table 3.14 Data showing the Number of Animal Units/year for different livestock classes at Ultar meadows during 2000, 2001 and 2002.

Live stock class	No. of Animal Units/year		
	2000	**2001**	**2002**
Cow (non lactating)	57.0	16.0	45.0
Cow/Calf pair	3.9	5.2	6.5
Calf under 12 months	0.0	0.6	0.0
Mature bull	84.0	45.0	61.5
Yalk	12.0	16.5	19.5
Sheep (non lactating)	10.0	31.2	41.6
Goat (non lactating)	19.6	56.4	78.0
Ewe (with young)	6.0	13.2	27.6
Goat (with young)	9.6	35.4	48.9
Total:	202.1	219.5	328.6

Source: Personal communication (Mr Ibrahim, Local shephard)

Table 3.15 Data showing the list of palatable species at Ultar pastures Hunza.

Palatable species	Family
Anaphalis neplensis (Spreng.) Hand. Mazz	Asteraceae
Dianthus angulatus Royle.	Caryophyllaceae
Astragalus sp.	Papilionaceae
Onobrychis dealbata Stocks.	Papilionaceae
Filago pyramidata L.	Asteraceae
Gentiana tianshanica Rupr. ex Kusn.	Gentianaceae
Berberis lycium Royle.	Berberidaceae
Polygonum sp.	Polygonaceae
Oxyria digyna (L.) Hill.	Polygonaceae
Rosa webbiana Wall.	Rosaceae
Scrophularia sp.	Scrophulariaceae
Sibbaldia cuneata Kunze.	Rosaceae
Thymus serpyllum L.	Lamiaceae
Trifolium pratense L.	Papilionaceae

Table 3.16 Data showing the list of un-palatable species at Ultar pastures Hunza.

Un palatable species	Family
Acantholimon lycopodioides (Girard)Boiss.	*Plumbaginaceae*
Aconitum violaceum Stapf.	Ranunculaceae
Aristida sp.	Poaceae
Capparis spinosa L.	Capparidaceae
Echinops sp.	Asteraceae
Polygonum alpinum All.	Polygonaceae
Polygonum tortuosum D. Don.	Polygonaceae
Scutellaria sp.	Lamiaceae
Sophora mollis (Royal) Backer	Papilionaceae

DISCUSSION

The biogeography of mountains is unique. The diverse nature of its life zones possesses high level of species diversity (Jenik, 1997; Korner, 2002). The factors that create high levels of biodiversity at the regional scale are: the combination of steep altitudinal gradient and topographic variation and range of aspects are the factors contributing to the biodiversity of microhabitats.

Climate change, including temperatures and precipitation patterns, has caused a vast number of documented ecological responses on ecosystems from the tropics to polar regions. The responses are expressed in a range of ways, from changes in phenology and physiology to altered distribution limits, community interactions and ecosystem dynamics (Holten and Carrey. 1992; McCarty, 2001; Walther *et al.* 2002).

Physical environment is one of the attributes to the variations in plant community's structure and composition (Tivy, 1993). According to (Gaston and Spicer, 1998; Huston, 1994) environmental gradients determine the levels of biodiversity and altitude is an indirect gradient which is correlated with resources and regulators of plant growth (Austin, 1980; Austin and Smith, 1989).

4.1 FLORAL BIODIVERSITY, SPECIES RICHNESS AND ALTITUDINAL LIMITS

Mountains because of the steep climatic gradients provide an ideal setting to study changes in the biodiversity over short distances, as most of the species in mountain environments have unique microhabitats which are set by environmental parameters (Grabherr *et al.* 1995; Theurillat *et al.* 2003).

A large number of areas of high species diversity coincide with high mountain areas (Davis *et al.* 1994; Barthlott *et al.* 1997). Mountains may not have a range of latitudinal climate zones arranged along altitude, and have a diverse array of microclimates arising from their varied topography, but they can locally modify climate (which is largely determined by latitude, altitude and oceanity-continentality). In arid mountains, clouds may form around a mountain core and cause the girdle forests. In addition, mountains can give rise to local wind systems (Barry, 1992).

Several attempts have been made to describe the vegetation of the Karakoram phsiognomically (Paffen *et al.* 1956; Schweinfurth, 1957; Troll, 1939; Zheng, 1994), but there are no precise statistics on the flora of the Karakoram as yet.

Troll collected some 1000 species of vascular plants in the area of Nanga Parbat in the western Himalayas. The flora amounts to 291 genera and 763 species in the southern and western parts of Karakoram (Wu, 1990).

A joint expedition carried out by the Oxford University Museum of Natural History (OUMNH) and the Pakistan Museum of Natural History (PMNH) during the summer of 2000 recorded some 100 species of shrubs, trees and herbaceous plants from upper Hunza; approximately 20 per cent of these were new records to PMNH's collection (Preliminary Expedition Report, 2001). Sheikh (2002) recorded 153 plant species belonging to 38 families and 113 genera after extensive field research in the area.

The present investigation showed that out of 218 species identified, family Asteraceae consisting of 37 species predominates among other families. Family Asteraceae has also been reported to be the largest family in terms of number of species by many authors in other alpine regions of the world (Taye, 1995).

Biodiversity richness in Northern Areas has never been evaluated systematically. However, some studies have documented floral diversity of some areas, which provides partial picture of biodiversity in Northern Areas exists. About 342 species of plants belonging to 36 families and 142 genera have been recorded from the Deosai plateau. Based on statistical analysis of the floristic composition, the total number of plant species amount to 315, 296 and 275 respectively. in the northern flanks of western, central and eastern sections of the Karakoram (Zheng, 1998).

The decreasing trend of species richness is also evident during the present investigation. Figure 3.10 clearly showed that Sheshpar has the highest number of species as compared to Chupursan which showed lowest number of species, lying extreme north of Hunza valley.

The soil base of the mountain and precipitation also has a considerable effect on the altitudinal pattern of plant species diversity (Wilson *et al.* 1990).

Species richness has had the longest history of study (Gaston, 1996). Many studies have investigated species richness along elevation gradient across habits and taxa (Rahbek, 1995, 1997; Austrheim, 2002; Vetaas and Gerytnes, 2002; Sanders *et al.*, 2003), as part of efforts to understand ecosystem effects on biodiversity and conservation of biodiversity (Tilman and Downing, 1994; Vetaas and Gerytnes, 2002).

Apart from other factors, lowest levels of Nitrate-Nitrogen and highest levels of Iron in soil of at Chupursan might have an effect on low species richness as compared to Ultar (Table 3.6).

The interdependency of vegetation type and soil chemical properties leads to a variety of species, vegetation types, and plant communities existing on a rangeland with the same parent material and single climate regime. In addition, soil chemical properties and in turn plant growth are significantly controlled by variation in landscape attributes including slope, aspect, and elevation which influence the distribution of energy, plant nutrients, and vegetation (Buol *et al.*1989).

4.2 ALTITUDINAL AND ZONAL DISTRIBUTION PATTERNS AND THE ROLE OF CLIMATE

The present investigation showed that species of *Sophora mollis* and *Capparis spinosa* along with *Ephedra gerardiana* at altitudes ranging from 2,500 m to 3,000 m a.s.l., dominate the vegetation type in all field areas particularly on scree slopes. However, at valley floor of Chupursan *Krascheninnikovia ceratoides* and *Corispermum* sp. were also found almost on all exposures. Above 3,000 m a.s.l. species of *Geranium wallichianum, Polygonum alpinum, Artemisia laciniata,* and *Thymus serpyllum* dominate the alpine vegetation.

The altitudinal limits of 13 commonly occurring plant species in the field areas of Ultar and Updegar (Figure 3.11) showed variation in the limits of some species.

The comparative records of monthly averages for daily temperatures (Figure 3.20) and relative humidity (%) (Figure 3.21) at Ultar and Chupursan during 2001 and 2002 showed adequate moisture availability at Ultar as compared to Chupursan. Therefore, observed species richness was higher at Ultar as compared to Chupursan (Figure 3.22).

On an altitudinal gradient, vegetation changes are often gradual, though at certain elevations those variations are sufficiently conspicuous to allow the recognition of discrete units usually called altitudinal vegetation belts (Moravec, 1989; Kitayama, 1992).

According to Ahmed and Qadir (1976) a phytosociological study along Gilgit to Gupis revealed that *Juniperus marcopoda, Pinus gerardiana, P. wallichiana, Cedrus deodara, Artemis maritime, A. Sacrorum, Daphne oleoides, Sophra spp, Ephedera spp, and Salix spp* as trees/shrubs and *Chrysopogon spp, Dichanthium annulatum, Aristida spp, Poa spp, Bromus spp, Agropyron spp,* as grasses and *Polygonum spp, Astragalus spp, Medicago spp, Plantago lanceolata, Lathyrus spp, Thymus serpyllum, Nepeta spp, and Taraxacum officinale* as forbs dominate the vegetation type.

Hussain (1968) gave the description of vegetation types in the alpine pastures in the northern mountains of Pakistan. According to him native flora of alpine pastures is dominated by *Juniperus, Rosa webbiana, Berberis lycium* as shrubs/trees and species like *Agrostis gigantea, Poa* spp. *Agropyron* sp. *Festuca* sp. *Clematogrostis* and *Carex* as grasses and *Plantago ovata*, *Plantago major*, *P. Lanceolata*, *Trifolium pretense*, *T. rapens*, *Medicago spp*, *Potentilla spp*, *Polygonum alpinum*, *Anaphalis sp.*, *Thymus serpyllum*, *Astragalus spp*, *Taraxacum officinale*, *Nepeta spp*, and *Saxifraga spp.* as forbs are present.

Altitudinal patterns of plant species diversity have long been the focus of attention of ecologists (Whittaker, 1960; MacArthur, 1972; Walter, 1979; Fang, 2004). These patterns are the results of interactions between the altitudinal gradient and the water gradient (Minchin, 1989).

Climate plays an important role in determining geographic range for many species (Saetersdal and Birks, 1997; McCarty, 2001) and temperature and precipitation undoubtedly influence vegetation distribution (Saetersdal *et al.* 1998; Austrheim and Eriksson 2001). For example, many studies in different alpine zones have established that temperature and some characteristic of the substrate are the main determinants of the vegetation belt limits (Chabot and Billings, 1972; Squeo *et al.* 1993; Velazquez, 1994; Fernandez-Palacios and de Nicolas, 1995; Ferreyra *et al.* 1998).

Composition and diversity of alpine plant communities is strongly determined by specific disturbance regimes (Chambers, 1995; Bohmer, 1999). In addition to macroclimate, other environmental variables such as slope aspect, slope inclination and substrate may affect plant distribution in high mountains.

Natural distribution patterns of vegetation are also controlled by temperature and precipitation conditions and all factors that can alter temperature and precipitation could affect these patterns. Changes in altitude, accompanied by changes in temperature, precipitation, and light conditions (Johnson *et al.* 1986), alter the distribution of vegetation.

Precipitation data of the climatic stations in Northern Areas show a SW-NE directed gradient of decreasing humidity. The seasonally alternating circulation systems, westerlies and monsoon enable the transport of maritime air masses into the high mountain regions by their synoptic interaction (Weirs, 1995), are the prerequisite for the development of the humidity gradient. However the specific differentiation of the gradient depends on the topography of the high mountain chains, acting as barriers against moist monsoonal air masses from the south. Mean annual precipitation decreases from south to north. Karimabad 137 mm; and Misgar 109 mm (Zheng, 1998). The Batura Glacier Investigation Group (1979) showed that rainfall amounts probably decreases in north-eastwards direction along the Hunza Valley as compared with Gilgit.

According to a study by WWF (2000) in Northern Areas, the patterns of species richness show a general trend of increased richness in plant species from North to South and from West to East. For example, 134 species belonging to 35 families and about 90 genera of plants have been recorded from Khunjerab National Park. Almost at the same elevations of Deosai National Park in the western Himalayas 342 species of plants belonging to 36 families and 142 genera have been listed (Woods *et al.* 1997).

Similar results were shown by Wu (1990). According to them, the number of species decreases rapidly northwards and the total number of vascular plants may be less than 800 in Hunza area. The flora amounts to 291 genera and 763 species in the southern and western parts of Karakoram. The distribution of natural vegetation is closely linked to climatic and topographic conditions. The decreasing diversity of natural vegetation to the north is due to increasing aridity (Dittrich, 1998).

4.3 ETHNOBOTANY OF BRUSHO TRIBES OF HUNZA VALLEY

A total of 31 plant species were identified to have medicinal properties collected during the field survey of Hunza valley, Northern Pakistan (Table 3.10).

One of the objective of ethnobotanical study is to record the indigenous knowledge about plants. A number of efforts have been done in this regard. The first written record of the use of herbal medicines dates back as early as 101 B.C. (Sun, 1996; Huang, 1998).

Developed countries, in recent times, are turning to the use of traditional medicinal systems that involve the use of herbal drugs and remedies. About 1400 herbal preparations are used widely, according to a recent survey in Member States of the European Union (Edgar and Lucy Hoareau, 1999).

One aspect of ethnomedicinal survey among the rural societies is to record hitherto less known or un known folk herbal remedies from tribal groups, before it is lost forever in the race of modern civilization (Amminuddin *et al.* 1994).

Pakistan has about 6,000 species of wild plants of which about 400 to 600 are considered to be medicinally important (Hamayun *et al.* 2003). A significant proportion of species are confined to the Northern Mountains of Pakistan, Kashmir and east Afghanistan. (Rafiq 1995, 1996). Karakoram, Himalaya, and Hidukush region of Asia contains about 25, 000 plant species i.e. about 10% of the world plants, of which 10,000 are economically or medicinally important (Pei, 1992).

Most of the floristic surveys conducted in Pakistan indicated that at least 1000 species of medicinal plants occur in northern parts of Pakistan (Ikram and Fazal, 1978), of these species approximately 500 are known for their active constituents from research conducted in Pakistan or elsewhere (Williams and Ahmed, 1999).

Shinwari (2003) documented the local use methodology of more than 150 plant species from two villages (Bar Ghabair and Shuki Sair) of Palas Valley, Kohistan. Shinwari and Gillani (2003) surveyed the Astore area, Gilgit to provide information on the conservation of plant biodiversity, potential income to local people, and to determine and monitor harvest levels of medicinal plants.

Rasool (1998) has provided a detailed account of the NA's economically important plants. He described some 60 plants of medicinal and economic value. Shinwari *et al.* (2002) studied the current status of medicinal plants of Bar and Shinaki Valleys, District Gilgit, Northern Areas. Ahmed (1986) studied the vegetation of some foothills of

Himalayan range in Pakistan along the great silk route from Gilgit to Passu. Ali (2001) studied the ethnobotany and conservation status of Nagar valley, Northern Pakistan.

4.4 CLIMATE STUDIES OF ULTAR AND CHUPURSAN

Figure 3.12 showed the records of daily temperatures at Ultar during summer 2001-2002. The data revealed that 2002 was a relatively warm year than 2001. Higher monthly averages were observed for all the recorded months at Chupursan during 2002 (Figure 3.17).

High mountain ecosystems are considered particularly vulnerable to climate change (Beniston, 1994; Grabherr *et al.* 1995; Beniston *et al.* 1996; Theurillat and Guisan, 2001). They are of special interest for climatological research because of their importance as key areas of the global ecosystem and because of their function as resource areas for lowlands (Winiger, 1992).

Climate plays an important role in determining geographic range for many species (Saetersdal and Birks 1997, McCarty 2001).As a result of increasing concern about the effects of climate change, there has been an increase of international initiatives on mountains and climate change(Becker and Bugmann, 2001; Grabherr *et al.* 2001; Huber *et al.* 2005). The distribution pattern of individual plant species, as well as of plant communities, at the transition between the alpine and the nival environment (alpine-nival ecotone), is likely to be drastically affected by climate change (Gottfried, *et al.* 1998).

Reimers (1992) defines various precipitation regions in the high mountains of Northern Pakistan and adjacent areas. The Northern Areas are located in the "transitional zone' between the arid Central Asia and the semi-humid subtropics of the northern South Asia (Schneider, 1969).

The high mountain walls prevent the monsoon rains from reaching to the north from the south, making much of the inner valleys a "vertical desert" and a partial rain shadow area. Below 3000 m, precipitation is minimal, rarely exceeding 200 mm annually, but at an altitude of 6000 m and above, it could be as high as 2000 mm a year, mostly in the form of snow (Khan and Hunzai, 2000). Due to the effects of high mountain barriers with relatively high elevations, the central Karakoram is far from the moisture transport pathways coming respectively from the Bay of Bengal and from the Arabian Sea.

The physical geography branch of the CAK Project tried in a multidisciplinary approach to understand and to quantify the climate of western Karakoram (Kandel, 1995). For the assessment of the humidity patterns, Weirs (1995) evaluated all available precipitation and runoff data. At the same time, the first series of climatic stations at various heights above the valley floor were installed in Bagrot Valley (Cramer, 1993) and in Yasin catchment area (Jacobson, 1993).

Since the autumn of 1990, the first series of measurements at high altitudes over several years had become available, providing a significantly better data base for future climatological studies in these high mountain areas (Jacobsen, 1998).

Micro-climates significantly affect regeneration, species distribution and richness (Moir *et al.* 1999; Grytnes, 2000; Carrer and Carlo, 2001; Erschbamer *et al.* 2001) and have been shown to differently influence plant community response to regional climate change (Gavin and Brubaker, 1999).

4.5 SOIL MOISTURE OF ULTAR

Soil moisture and increase nutrient availability may be altered with the change in climatic conditions and, in combination with the direct warming effect, they may impact the growth, reproduction and resource allocation of the plants (Klanderud, 2005).

Results obtained revealed that the north facing slope of Ultar pastures retained much moisture at the comparable altitude. The average soil moisture recorded was 13.4 cb and 16.17 cb on north facing and south facing slopes respectively (Figure 3.23).

Greater soil moisture on north- than on south-facing slopes has often been cited as partial explanation for the greater diversity and cover on north facing slopes. Causal factors implicated have been lower insulation (Shanks and Norris, 1950; Cantlon, 1953; Ayyad and Dix, 1964). lower air and soil temperatures (Weaver, 1917; Gail, 1921; Miller, 1947; Parker, 1952 and Cooper, 1961), and higher air humidity and lower wind speeds (Weaver, 1917; Gail, 1921; Cottle, 1932; and Parker, 1952) on north than on south-facing slopes.

As in other subtropical high mountain regions, pronounced effects of radiation exposure are to be observed within the forest belt, leading to striking contrasts between north and south-facing slopes. Moist temperate coniferous forests are mostly confined to north-facing slopes (Schickoff, 1998). Mark *et al.* (2000) found topographic features (elevation, exposure and slope) to be responsible for the macro scale patterns of alpine vegetation distribution on Mount Armstrong in New Zealand.

4.6 BIOCHEMICAL CONTENTS AND ALTITUDINAL VARIATIONS

The alpine environment is also associated with changes in plant functioning. This concerns many species, including the most common and often abundant species, as shown by the morphological changes observed in several ubiquitous species growing in high-altitudes (Fleury, 1994).

In mountain areas, the drop in temperature associated with rising altitudes brings with it an increase in frequency and degree of frost to which the plants are exposed (Sakai and Larcher, 1987).

Cold acclimation is associated with several physiological and biochemical alterations in the plants. The best-characterized changes include alterations in gene expression, changes in hormone levels, increases in soluble sugars, amino acids and organic acids, accumulation of osmoprotectants and protective proteins as well as modification of

Doerffling *et al.* (1998) showed that under growth chamber conditions, low temperature (2/0 °C) caused transient increases in the level of ABA in leaves. Chilling - sensitive species including maize have been shown to exhibit increased levels of ABA when exposed to low temperature (Daie *et al.*, 1981; Capell and Doerffling, 1989, 1993; Janowiak and Doerffling, 1996). It has also been extensively reported by research workers that many plant species exhibit an increase in endogenous ABA concentrations when exposed to low temperature (Irving, 1969; Chen and Gusta, 1983).

The protective role of endogenous ABA against chilling injury is confirmed in rice (Lee *et al.* 1993) and maize (Capell and Doerffling, 1993). Increase in the endogenous free ABA content increases in some plants during cold hardening has also been reported (Chen *et al.* 1983; Guy and Haskell,1988; Doerffling *et al.* 1990; Ryu *et al.* 1993).

Studies indicate that ABA may serve as a signal, which triggers processes leading to, increased frost tolerance (Abromeit *et al.* 1992; Sarnighausen, 1994; Nordin *et al.* 1993; Abromeit, 1996).

4.6.2 Sugar Content

Figure 3.25 showed the variation in the level of sugar in the plant species. Sugar content was also found to be higher in plant species collected at altitude of 3,500 m a.s.l. as compared to that of collected at the altitude of 3,000 m a.s.l.

In several plant species, the adaptation of plants to low temperature stress involves changes in several metabolic pathways, including carbohydrate synthesis (Guy *et al.* 1992; Hommo, 1994 a; Koster and Lynch, 1992; Tronsmo *et al.* 1993).

Sugars are thought to play an important role in the stress tolerance of plants. Sucrose is accumulated in many plants during cold acclimation (Kandler and Hopf, 1982).An accumulation of glucose during cold acclimation has been associated with increased cold resistance (Larsson *et al.* 1992; Levitt, 1980). The sucrose content increased in shoots and roots of winter wheat cultivars during the 5-week cold acclimation (Hommo, 1994 b).

Measurements made in herbaceous and woody plants over the years clearly showed that soluble carbohydrates increase from fall to winter and decrease in spring as they deharden (Levit, 1956, 1980; Biebl, 1962; Sakai, 1962; Parker, 1963; Jeremias, 1964; Alden and Hermann, 1971; Tumanov, 1979; Siminovitch, 1981).Elevated levels of sugars are normally associated with cold acclimation (Gilmour *et al.*, 2000).

4.6.3 Protein Content

Figure 3.26 showed the variation in the level of protein in the leaves of plant species. Protein content of leaves was observed to be higher in all the plant species collected at 3,500 m a.s.l.

Ingram and Bartels (1996) demonstrated that extra cellular freezing can induce the development of tolerance to cellular dehydration during cold acclimation and sugars and certain proteins are thought to protect cell structures during dehydration by binding water molecules.

It has been well documented that during cold acclimation, most freezing tolerant plant species synthesize new sets of proteins that are correlated with the increase of cold hardiness (Guy, 1990; Howarth and Ougham, 1993; Chen *et al.* 1983).

Protein quantity and quality with respect to seasonal variation has been studied in many plant species. Pine needles have been reported to show increase in soluble protein concentrations during cold acclimation (Pomeroy and Siminovitch 1970, Nasholm and Ericsson 1990, Nozzalillo *et al.* 1990; Sulitinen 1992).

Alteration in gene expression and synthesis of novel proteins are associated with increase in freezing tolerance (Guy, 1990; Lee and Chen, 1993; Ciamporova *et al.* 1994).New protein form on the effect of low temperature which help to adapt the plant to the altered environment (Kenward *et al.* 1993; Chauvin *et al.* 1993; Hahn and Walbot, 1989).

4.6.4 Proline Content

Figure 3.27 showed the variation in the endogenous proline content. Proline content of leaves showed similar trend and was observed to be higher in all the plant species collected at 3,500 m a.s.l.

Several investigations have shown that, besides other solutes, the level of free amino acids, especially proline, increases during cold hardening (Galiba *et al.* 1994).

The proline content in the shoots and roots of two wheat cultivars increased during the cold acclimation (Hommo, 1994 b). Significant positive correlations between proline level and frost tolerance have been found in a broad spectrum of genotypes reviewed by Galiba (1994).

Doerffling *et al.* (1990) found also a peak in proline content of a winter wheat after 3-week hardening period. In winter wheat the hydroxyproline-resistant lines are significantly more frost tolerant than wild-type (Doerffling *et al*, 1993).

The increase in all the biochemical contents appears to be correlated with the increase in altitude in all the plant species. The altitudinal differences in the mountain areas greatly influence the climate of that region. Diurnal as well as seasonal temperature variations and inadequate precipitation can be observed at valley bottoms and hill slopes in the mountain regions. Snow fall is a common feature of the areas at high. Areas above 3,300 m show a limited growing season because of intense cold. Winter and early spring are the seasons of annual rainfall in these areas, which is between 100 and 300 mm (Mohammad, 1989).

4.7 STOCKING DENSITY AND GRAZING STATUS OF ULTAR PASTURES

A list of palatable (Table 3.15) and unpalatable (Table 3.16) species of Ultar pastures was presented. Table 3.14 showed the stocking densities at Ultar pastures for the year 2000, 2001 and 2002.

Grazing is an important factor influencing the composition of many plant communities (Moen and Oksanen, 1998; Suominen and Olofsson, 2000; Grellman, 2002).Livestock rearing with seasonal utilization of high pastures forms an integral part of the agro-pastoral economy called "mixed mountain agriculture" according to Rhodes and Thompson (1975) and Kreutzmann (1989).

Ultar (North of Karimabad) is an important summer pastures of the inhabitants of central Hunza valley. The pasture is generally rich in plant biomass due to an adequate moisture regime and is therefore important food habitats for both domestic and wild herbivores. The four kinship groups Diramiting, Barataling, Khurukutz, and Buroung enjoy traditional grazing rights.

In Northern Areas, livestock are reared mainly on rangeland pasture/natural pasture and January through April there is a critical shortage of feed for livestock. Rangelands constitute an important component of the agricultural system in Pakistan. This vast natural resource covering over 60 percent area of the country provides great potential for livestock grazing (Mohammad, 1989). 52 % of the land is dominated by rangelands in Northern Areas (Table 1.1).

According to the livestock census of Northern Area , Pakistan (1996), the population of sheep and goats has increased substantially from 0.88 million in 1976 to 1.56 million in 1996, with an annual growth rate of 3.56%. This increase has resulted pressure on rangelands.

Alpine deserts have little value as grazing lands due to the absence of forage and difficult topography. Alpine pastures are subjected to heavy grazing during summer. No planned grazing system is followed (Hussain, 1968).

Fodder situation in Northern Areas indicate a fodder deficiency from November to March, when the season for the main summer fodder crop (maize) is over and the traditional winter fodders such as shaftal (*Trifolium resupinaturn*) and Lucerne (*Medicago sativa*) are still dormant. To varying degrees, every valley experiences fodder shortages during winter season. Debord (1989) generally estimates for the whole Northern Areas that animals receive only 60 % of their maintenance nutrient requirements. Hussain and Mustafa (1995) reported ecological studies of plants in relation to animal use found in Nasirabad valley, Hunza, Pakistan.

As the hay production does not allow the stall-feeding of all animals, the large goat herds are pastured by paid shepherds. Stall-feeding during the cold season is necessary for all animals. Therefore, crop residues, wild hay, and dried leaves form the major winter fodder sources in the more elevated side valleys. Sheep and goats have always been the dominant village animals in the whole study area (Nusser, 1998).

CONCLUSION

The mountainous area of Hunza valley represents highly diverse landscapes, with variations in geological substrate, terrain, climate, and soil. These landscapes support a great variety of habitats. which support distinctive flora.

This is inferred from the present investigation that Family Asteraceae is the dominant family among other family's surveyed. The observed species richness showed a decreasing trend from South to North.

The endogenous of ABA and proline content can be used as biochemical marker for determining frost tolerance of plants growing at high altitudes of Hunza valley. It is possible that proline and ABA have more intimate association with survival adaptability of plants at high altitude. Whereas, sugar and protein content have species specific variation, determined by the plasticity of individual, the critical basal level of sugar and protein at low altitude and the sensitivity of a plant to respond to cold stress. From the results it appears that there was a certain critical level of sugar and protein to be attained at high altitude.

Hunza valley is rich in medicinal plants. There has been a considerable trend in use of plants as a source of medicine. Search for active ingredient analysis for ethnobotanical plants and protection of ethnobotanical culture is needed.

Another important aspect is to investigate the microbial biodiversity in the context of diverse climates and varied topography of the area.

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APPENDIX A

Extracting Solution (Mehlich-3) for the Estimation of Ca, Na, Mg and K

The ammonium nitrate 100 g was dissolved in 2 L distilled water to which were added 20 mL NH_4F-EDTA stock solution, 6.0 mL acetic acid and 4.1 mL of nitric acid. Finally distilled water was added to bring volume to 5 L. The reagents were mixed thoroughly.

APPENDIX B

Extracting Solution for the Estimation of Mn and Fe

The diethylene triamine pentaacetic acid (DTPA) 1.97 g and calcium chloride ($CaCl_2$) 1.1 g were added in a beaker, dissolved in deionized water and then transferred to a 1 L volumetric flask. In another beaker, 13.38 mL Triethanolamine (TEA) was added to 1 L beaker containing deionized water and the volume was made up to 900 mL with deionized water. The pH was adjusted to 7.3 with 6 N HCl, and the volume was made up to 1 L with deionized water. The final extractant solution contained 0.005 M DTPA, 0.1 M TEA and 0.1 M $CaCl_2$.

APPENDIX C

a. Extraction Solution for the Estimation of Phosphorus and Nitrate-Nitogen

The DTPA solution (0.005 M) was prepared by adding 1.97 g DTPA to 800 mL deionized water. Approximately 2 mL ammonium hydroxide (NH_4OH) was added to facilitate dissolution and to prevent effervescence when bicarbonate was added. When the most of DTPA was dissolved, 79.06 g ammonium bicarbonate (NH_4HCO_3) was added and stirred gently until dissolved. The pH was adjusted to 7.6 with ammonium hydroxide. The solution was diluted to 1 L volume with deionized water.

b. Mixed Reagent for Phosphorus

12 g of ammonium hexamolybdate was dissolved in 250 mL of deionized water. 0.2908 g antimony potassium tartarate was dissolved in a separate flask with 1L 5 N sulphuric acid and the two solutions were mixed together thoroughly, and the volume was made up to 2 L with deionized water. The solution was stored in a dark bottle placed in refrigerator.

c. Colour Developing Solution for Phosphorous

0.739 g of L-ascorbic acid was added to 140 mL of mixed reagent for P.

d. Colour Developing Solution for Nitrate-Nitrogen

5 g sulfanilamide and 0.25 g N-(1-naphthyl)-ethylenediamine dihydrochloride was added to 300 mL deionized water. 50 mL 85% orthophosphoric acid was added slowly with stirring and the volume was made to up to 500 mL.

e. Hydrazine Sulphate Stock Solution ($H_2N_2H_2.H_2SO_4$)

27 g hydrazine sulphate was dissolved in 750 mL deionized water and the volume was made to 1 L. The solution was shaken well. Hydrazine sulphate working solution was prepared by diluting 6.25 mL of the stock solution to 1 L volume with deionized water.

f. Copper Sulphate Stock Solution ($CuSO_4.5H_2O$)

3.9 g copper sulphate pentahydrate was dissolved in 800 mL deionized water and the volume was made up to 1 L. The solution was shaken well.

g. Sodium Hydroxide Stock solution (NaOH), 1.5 N

60 g sodium hydroxide was dissolved in 500 mL deionized water. The solution was cooled and brought the volume up to 1 L with deionized water.

APPENDIX D

Phosphate Buffer (Stock Solution)

Monobasic Sodium Phosphate: 27.6 g was dissolved in 1000 ml distilled water.
Dibasic sodium phosphate: 53.5 g was dissolved in 1000 ml distilled water.
16 ml of monobasic sodium phosphate solution and 84 ml of dibasic sodium phosphate were mixed together to obtain the desired pH 7.5 of phosphate buffer.

Reagent A:

2 g Sodium Carbonate (Na_2CO_3), 0.4 g NaOH (0.1 N), and 1 g Na – K tartarate were dissolved in 100 ml distilled water.

Reagent B:

The $CuSO_4.5\ H_2O$ (0.5 g) was dissolved in 100 ml distilled water.

Reagent C:

50 ml of solution A and 1 ml of solution B were mixed together.

Reagent D:

Folin phenol was diluted with distilled water in the ratio 1:1.

Alluvial Fan	Large fan shaped terrestrial deposit of alluvial sediment on which a braided stream flows over. Form as stream load is deposited because of a reduction in the velocity of stream flow.
Aspect	The direction a slope faces.
Boreal	Of or relating to the forest areas of the northern temperate zone, dominated by coniferous trees.
Ecotone	A transition area between two adjacent ecological communities.
Forb	Any herbaceous (herb-like) plant other than grass and grass-like plants.
Krumholz	A dense clump (or clumps) of stunted trees growing near or at timberline. Shintangle is a popular name for Krumholz.
Lateral Moraine	Moraine forming and embankment between the ice of an alpine glacier and the adjacent valley wall.
Lower Montane	Of, growing in, or inhabiting the lower elevational mountain areas.
Montane	Of, growing in, or inhabiting mountain areas.
Moraine	Accumulation of rock debris carried by an alpine glacier.
Orography	The average height of land, measured in geopotential meters, over a certain domain.
Petrography	Branch of petrology which focuses on detailed descriptions of rocks.
Scree	A slope covered with a tumbled mass of angular rock fragments, generally unstable, resulting essentially from frost action.

Sediment Solid material, both mineral and organic, that is in suspension, being transported, or has been moved from its site of origin by air, water, gravity or ice.

Shintangle A popular name for Krumholz (a dense clump of stunted trees growing near or at a timberline).

Stand A community of trees or other vegetative growth occupying a specified area and sufficiently uniform in composition (species), age, spatial arrangement, and conditions as to be distinguishable from the other growth on adjoining lands, so forming a silvicultural or management entity.

Talus Accumulation of loose rock fragments derived by fall of rock from a cliff.

Terminal Moraine Moraine deposited as an embankment at the glacier terminus of an alpine glacier.