FLORISTIC AND PRODUCTIVITY VARIATIONS AMONG DIFFERENT TREE BASED PASTURE SYSTEMS VIS-A-VIS GRASSLANDS IN TEMPERATE REGION

Thesis

by

ANIL KUMAR

Submitted in partial fulfilment of the requirements for the degree of

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in

AGROFORESTRY

COLLEGE OF FORESTRY
Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni,
Solan - 173 230 (H.P.) INDIA

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Dedicated

to my

Grandmother

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CERTIFICATE-I

This is to certify that the thesis entitled **"Floristic and productivity variations among different tree based pasture systems vis-à-vis grasslands in temperate region"**, submitted in partial fulfilment of the requirements for the award of degree of **MASTER OF SCIENCE** in **AGROFORESTRY** to Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Solan (H.P.) is a bonafide research work carried out by **Mr. Anil Kumar (F-99-1-M)** under my guidance and supervision. No part of this thesis has been submitted for any other degree or diploma.

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

Place : Nauni, Solan
Dated : 31 July, 2001

(B. Gupta)
Chairman
Advisory Committee

CERTIFICATE-II

This is to certify that the thesis entitled **"Floristic and productivity variations among different tree based pasture systems vis-à-vis grasslands in temperate region"**, submitted by **Mr. Anil Kumar (F-99-1-M)** to Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Solan (H.P.), in partial fulfilment of the requirements for the award of degree of **MASTER OF SCIENCE** in **AGROFORESTRY** has been approved by the Student's Advisory Committee after an oral examination of the same in collaboration with the external examiner.

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Date: July 31, 2001
Place: Nauni, Solan

(*Anil Kumar*)

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INTRODUCTION

Chapter-1

INTRODUCTION

India is an agriculturally dominant country and cattle are important part of it. Indian farmers depend wholly or partially upon domestic cattle for agricultural practices and other valuable products. Eighty per cent of cattle population depend upon grassland to meet their fodder requirement and this percentage is more in hilly regions of Himachal Pradesh, though grassland management is most neglected part of forest management here.

Grassland vegetation in India especially in H.P., owe its origin to interference of forest by man. The favourable climate for the development of a typical grassland does not prevail in this country and grasslands are destined to change from one to another forest type under natural succession. In Himachal Pradesh, there are 34.9 percent pasture land out of a total legally defined forest area of 66.48 per cent as per the records in statistical outline of H.P. 1998. Nearly entire north facing slopes of Himalayas are more heavily forested than those with Southern aspect supporting mostly mixed type of grassland communities (Gaston *et al.*, 1981). Himachal Pradesh supports more than 52 lakh of livestock population on 55673 km^2 area. Out of the total land area 26.8 per cent is under agriculture, 32.6 per cent under forest cover and 23.1 per cent under pastures and grazing lands (Anonymous, 1998).

Livestock economy plays an important role in hilly state like Himachal and in this context, the vast grassland resources of the state assume special significance and offers a great potential for cattle rearing. Climatic, topographic, physiographic factors, altitude and related aspects influence distribution of the various grass species which affect grassland production both quantitatively and qualitatively (Whyte, 1968). Natural

grasslands in Himachal Pradesh are spread over from 600-4800 m altitude. Their improvement recalls for the immediate attention.

Grassland improvement involves variety of techniques and methodologies, silvipasture is one of them. Silvipasture system is a land use system in which trees or shrubs are combined with livestock and pasture production on the same land management unit. Within this broad category, several types of sub-systems and practices can be identified depending on the role of trees / shrub component viz. protein bank fodder production, live fence of fodder trees and hedges, trees and shrubs on pasture (Nair, 1993). Silvipastoral system involving a large number of trees and shrubs species and various management intensities ranging from extensive nomadic silvipastoralism to very high intensity cut and carry fodder systems, have been practised in various countries. Silvipastoral system of farming has been recognised as a input technology for increasing forage and fuelwood production from the vast wastelands and degraded grassland of the country. The productivity from improved grasslands through silvipastoral system of forage production at Jhansi, registered a three fold increase (Hazra, 1989), while Menkania (1983) in western Himalayas reported that forage production under trees decreases.

All the species in a natural community are not isolated they may exhibit either a positive or negative relationship among themselves which ultimately determine the resultant species over the area. Floristic composition of a region is closely related to the vegetational diversity of that region. The general appearance of a community is caused more by the life forms of the dominant plant species than by any other characteristics of the vegetation. The information on floristic composition remains a basic requirement for any such study.

Study of phytomass in production ecology helps to have deep insight into the structural composition of the vegetation at a given time under the prevailing environmental conditions. The phytomass of vegetation decides about the fixation of energy by the living organisms from abiotic resources and helps to make the living

system efficient. The aboveground biomass especially of grasses are of paramount importance as these are fed to animals during drought period when no other feed is available. Belowground biomass helps to decide about the functioning of the ecosystem. The belowground composition and nutrient status of any grassland decides about its nutritional quality to meet the fodder requirements of cattle.

Keeping in view that grasslands are one of the important biomes and play significant role in the economy of the people in this region. An effort has been envisaged to analyse some of the grassland improvement practices which are in vogue. With this aim the present study was undertaken to study the "floristic and productivity variations among different tree based pasture systems vis-a-vis grasslands in temperate region" during growing season i.e. July 2000 to October 2000 at the university area of Regional Horticultural Research Station, Mashobra, Shimla, H.P. with the following objectives:

i) Temporal variations in floristic composition and phyto-sociology.
ii) Biomass productivity of herbage.
iii) Nutrient changes in grass during growing season.
iv) Soil nutrient status of different systems.

REVIEW OF LITERATURE

Chapter-2

REVIEW OF LITERATURE

Silvipastoral system integrates woody species with grasses or legumes-grass mixtures, simultaneously or sequentially on the same piece of land. These systems involve woody species that can be grown at different canopy heights and managed in a manner to obtain maximum benefits through efficient utilization of solar energy and other resources.

Appropriate literature pertaining to the various aspects of present investigation has been reviewed under the following headings:

2.1 Floristic composition and phytosociology of herbage.
2.2 Productivity of herbage.
2.3 Nutrient content of herbage.
2.4 Physico-chemical properties of soil.

2.1 FLORISTIC COMPOSITION AND PHYTOSOCILOGY TO HERBAGE

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

George and Vergease (1985) reported that rainfall of an area is the major factor which governs the dominance, growth, structure and floristic composition. The study carried out by Chopra (1956) on grasses of Kashmir reported that *Stipa sibirica* being the principle grass species in pine forest possessing poisonous properties, he also noted that dominant grass species which only from under growth in chir pine forests was *Themeda anathera*. From another study on phytosociology and ecology of natural grassland communities in Hawaii, Kartawinata and Dombois (1972) reported nine types of grass associations on the basis of dominant grass species.

Sajwan (1975) studied the ground flora in *Dalbergia sissoo, Prosopies juliflora, Dendrocalamus strictus* and mixed plantations etc. and reported *Apluda aristata* being the dominant herbage species possessing maximum frequency and density in *D. sissoo, Acacia catechu* and mixed plantations in Jamuna ravine in Agra region. Rao and Kharkongar (1978) reported 28 per cent of perennial grass have been reported in Shillong.

Several agrostologists (Gill, 1975; Singh and Joshi, 1979) observed variations in floristic composition and herbaceous vegetation with the varying climatic and biotic stresses. Singh *et al.* (1975) contended that the floristic composition of grasses varies greatly with the altitude. They reported in their study on grasslands at different altitude in Himachal Pradesh, that at and below 2360 m altitude the dominant grass were *Herteropogon contortus* Beauv., *Arundinella nepalensis* Trin., *Chrysopogon gryllus* Trin., *Bothriochloa pertusa* and *Arundinella camus*. Whereas, those at 2915m consisted of *Agrostis cania* L.; *A. stolonifera* L.; *Festuca gigantea* L.; *Dactylis glomerata* L. and *Bromus inermis* Leyss. They also found the dominance of grasses and few legumes below 3515m. Sundriyal *et al.* (1987) studied different grasslands of western Himalaya and reported that the composition of grasslands changed with altitude and various other attributes such as grazing, cutting and burning which were found to have considerable impact on the grassland vegetation functioning.

Sajwan *et. al.* (1980) in his study on forage yield on different habitats in low Ambala Shiwaliks reported that maximum Importance Value Index (IVI) of *Chrysopogon fulvus* was under *Eucalyptus* spp. and *Acacia catechu*. Reduction of forage under trees and increased percentage of perennial grasses have been reported by Ahuja *et al.* (1985) and they ascribed it to uneven rainfall. Chaturvedi and Mishra (1985) recorded 20 percent less grass under trees than the open, at Dudhwa National Park at Uttar Pradesh.

Singh *et al.* (1985) observed floristic composition of local grass under two age groups of chir pine (15 years and 30 years) and open grassland and observed *Chrysopogon sirrulatus* as a dominant grass species under and outside chir pine plantations by attaining highest IVI of 90.03 and 62.81 under two age groups of chir pine plantations, respectively. They further concluded that grasses were affected by the density and crown density of chir pine trees.

Chaturvedi *et al.* (1988) studied the floral ecology of central Himalayan chir pine forests and reported *Anthraxon lancifolius* as the dominant grass species in chir pine forests. Noor Mohammed (1989) in Pakistan noticed that ground flora varies with degree of canopy opening. Gupta and Bhardwaj (1993) in their study on biomass and productivity of forests in Shivalik hills concluded that composition of herbaceous layer was significantly affected by forest type, basal cover of tree and site conditions. Trivedi (1994) reported effect of soil water availability on species diversity and found maximum species in September and minimum in May. Grass species of perennial herbs under *Pinus kesiya* of Shillong in Meghalaya and also mentioned that most of the indigenous ground vegetation is killed by winter frost (Rao and Kharkongar, 1978).

Somaribba (1988) reported that natural and improved pastures growing in open as well as under the canopy of guava trees were similar in floristic composition. Dass (1995) evinced that total population strength of grasses (density) under tree stand of chir pine ranged between 1825.17 m^{-2} to 2093.67 m^{-2}. Among individual grass species, *Themeda anathera* attained the highest density in July, whereas, lowest density was contributed by *Imperata cylindrica* in the month of September. He further found that species diversity of

herbage vegetation under chirpine trees and in open grasslands varied from 0.679 to 0.984 and 0-929 to 0.966, respectively at Solan in H.P.

McIntosh (1967) considered diversity as the number of species in a community including distribution of individuals among the species. He further reported that community stability is controlled by species diversity while dominance controls community productivity. Species diversity refers to the richness of species as well as balanced species distribution (Odum, 1969). He further argued that species diversity correlated with stability of the community. Species diversity has been considered as a measure of successional stage by some workers (Holland, 1971 and Whittaker, 1972). They believed that diversity increases during succession and reaches to its maximum at climax stage. In grassland ecosystems species diversity decreases dominance and generates community stability (Sahai and Asthana, 1976).

2.2 PRODUCTIVITY OF HERBAGE

The assessment of productivity of herbage is of utmost importance to bring about any improvement in the ground flora production. The work done by various workers has been reviewed as below:

Singh *et. al.*(1975) reported the dry matter yield of grasslands of H.P. varied from 250-518g/m^2. They also observed lower dry matter yield with increasing altitude upto 2915 m beyond which dry matter yield registered a phenomenal increase. In general, grasslands located between altitudes 2360-2915m showed low productivity. Pearson (1975) contended the grass yield under southern pine increased with frequent burning of leaf litter. Shankar (1980) recorded the highest biomass (2.3 t/ha) of range grasses under the canopy of *Tecomella undulata, Albizzia lebbek* and *prosopis juliflora* in arid region.

The study carried out by Aggarwal *et al.* (1978) at CAZRI, Jodhpur revealed that among two grasses viz., *Cenchrus ciliaris* and *C. setigerus* the minimum value of aboveground biomass was obtained in the month of June for *C setigerus* (28 g/m^2) and in

May for *C.ciliaris* (63.5g/m²). Whereas, maximum aboveground biomass was recorded in October 150 g/m² and 210 g/m² for both the species, respectively.

Ahuja *et al.* (1978) investigated the biomass production of herbage under 15 years old stands of *Albizzia lebbek, Prosopis cineraria* and *Acacia senegal* and reported 1.4 to 1.5 t/ha air dry herbaceous biomass under first three species, the herbage production under *Acacia senegal* was reported significantly less (0-7 t/ha) than the other two species due to higher tree density. Pandey (1978) studied the seasonal variations in biomass productivity in protected grassland ecosystems and recorded maximum biomass in the beginning of winter whereas, seasonal net community production was found more in rainy season. Seasonal variations in biomass productivity of grasses and their associates in grassland ecosystem has been reported by various scientists (Das and Sahai, 1975; Bawa, 1986; Gupta, 1988; Das, 1995; Guleria, 1996).

Sajwan *et al.* (1980) studied the productivity of herbaceous vegetation under different tree species and registered maximum green forage yields under *Eucalyptus* plantation. Melkania *et al.* (1983) pointed out that grass productivity increased markedly under protection from grazing. However, they maintained that *Pinus roxburghii* had some deleterious effect on the herbaceous vegetation and production of herbaceous vegetation was not upto the mark even under heavy protection.

Ahuja *et al.* (1985) evaluated the forage production in forest plantations and indicated that the forage production was influenced during the year by quantity and distribution of rainfall, the percentage of perennial grasses was reported highest during the years of scarce rainfall but the total grass production of forage species was highest under *Prosopis cineraria* followed by *Techomella undulata, Albizzia lebbek* and *Acaica senegal* even though the density of trees under *Prosopis cineraria* was doubled than *Albizzia lebbek.*

Rajvanshi *et al.* (1987) in the study on herbaceous undegrowth in some forest habitats in Nilgiries reported that total biomass production of grasses varies with the tree

species. Chaturvedi *et al.* (1988) reported 241g/m² of total dry matter production of herbaceous vegetations under chir pine and out of which 175g/m² was contributed by aboveground biomass. Uresk and Severson (1989) reported that productivity of understorey vegetation increased with decreased in basal area per hectare of tree components. Annual understorey pasture production from the plantations relative to open pastures ranges as low as 7 per cent depending on the effects of the tree canopy was observed by Percival and Knowels (1988).

The study carried out by Saha and Saxena (1990) revealed that the contribution of grasses and sedges under *Quercus leucotrichophora* was around 90 percent. They further observed that *Themeda anathera* alone contributed 50 per cent under *Pinus roxburghii.* Melkania (1991) observed that grasses contributed about 93.5 percent of the aboveground biomass in *Pinus roxburghii* plantations with *Heteropogon contortus* being the dominant grass.

Gupta *et al.* (1994) registered maximum aboveground biomass of herbage during rainy seaosn and minimum in summer, while belowground biomass was maximum in winter season and minimum in summer. Bhatt *et al.* (1994) observed reduction in rate of transpiration, leaf temperature, and stomatal conductance of grasses under tree canopy which ultimately led to low biomass production. They further noticed that *Cenchrus ciliaris* grew successfully under tree canopy.

Dass (1995) observed reduction in herbage quantity in pine stands as compared to that in open grassland. Similar trend was also observed by Guleria (1996) in Chirpine stands grazing is another factor affecting structure and function of grassland ecosytem. The study conducted by Seth (1996) in a free grazing alpine psature lands of Kashmir revealed that aboveground biomass in grazed site was more (118.23 g/m²) than in fenced site (113.65 g/m²) thereby indicating that seasonal grazing significantly affect the structural and functional attributes of alpine pasture land.

The study conducted by Saxena *et al.* (1996) on seasonal changes in biomass, net primary productivity and turnover of dry matter of paragrass (*Brachiaria mutica*) under a

mixed tree stand and an adjacent open stand indicated that paragrass under mixed stand registered higher values than that of open stand for all the three parameters measured. Dalai (1997) registered maximum aboveground and belowground biomass of herbage in August month under chirpine forests, Rao (1998) reported Maximum biomass in September month under chirpine stand in Solan (H.P.). Dutt (1999) also reported that biomass production of understorey vegetation was higher in open grassland as compared to chirpine inhabitaed sites.

2.3 NUTRIENT CONTENT OF HERBAGE

The available literature consulted for the study of nutrient status of the grassland vegetation has been presented as below:

Hughes (1970) reported 10-12 per cent crude protein content in *Aristida stricta,* 'a three awned grass' in fresh herbage growth, grown under slash pine in United States. He further observed decrease in protein content to 8 per cent with on set of maturity.

Aggarwal *et al.* (1978) observed that total nitrogen content in grasses varied with the species and season. They further noticed that amount of rainfall had significant and positive effect on the aboveground/belowground biomass N concentration in some species. However, they recorded higher uptake of nitrogen in belowground biomass. At maturity, decrease in per cent nitrogen and phosphorus and increase in calcium content was recorded by Pal and Negi (1978) in high altitude Himalayan pasture.

Significant decrease in crude protein content after September was also noticed by Dogra *et al.*(1979) in grassland vegetation of H.P. They observed highest crude protein content in local grasses during first growth which decreased gradually as growing stage progressed.

Khatta and Katoch (1981) reported fairly high value of phosphorus in submontaneous grasses of Himachal Pradesh. Joshi and Gupta (1984) noticed decrease in

calcium and increase in magnesium with advancement of growth, while phosphorus was found maximum at pre-bloom stage of grasses in Thar desert.

Saha *et al.* (1985) reported that phosphorus ranged from 0.01 to 0.025 per cent and calcium from 0.21 to 1.48 per cent in different grasses at Sikkim. Seo *et al.* (1985) inferred that nutrient contents of grasses varied significantly with fertilizer application and found that fertilizer application under chirpine trees increased N and K contents of grasses but did not effect P, Ca, Mg and Na.

Bawa (1986) noticed variation in N, P, Ca, and Na per cent of grasses in different seasons and reported maximum nitrogen in grasses in September near Shimla, Himachal Pradesh. In another study, Seo *et al.* (1989) observed that in grasses nitrate content increased on account of high grazing intensity. Nitrate content was higher in summer and autumn than in spring. Gupta (1988) reported that N, P, K, Ca and Mg in above ground biomass of grasses at peak biomass stage (September) varied from 0.63 to 1.68, 0.05 to 0.16, 0.26 to 0.58, 0.28 to 0.94 and 0.47 to 0.72 per cent, respectively in monsoonal grasslands around Shimla, H.P.

Verma (1989) recorded maximum concentration of nitrogen, phosphorus and potassium at bloom stage in grasses under chirpine forest in Shimla, Himachal Pradesh. Sharma (1991) found maximum N. P and K content in grasses growing under chirpine at half bloom stage. Belsky *et al.* (1993) recorded increased N, P and K in understorey of *Acacia tortilis* and *A. digitata* in comparison to open grassland.

Guleria (1996) opined that there was not much different in nutrients of grasses under chirpine and in open grassland. He further noticed that different grasses ranged from 0.93 to 1.40, 0.12 to 0.30, 0.50 to 0.92, 0.28 to 0.76 and 0.25 to 0.86 per cent, respectively at the time of peak biomass stage in August/September and declined thereafter. Almost similar range of nutrient contents in herbage layer under chirpine at the time of peak biomass (August) was reported by Dalai (1997) Rao (1998), Dutt (1999) for grasslands at Solan, H.P.

Hazra (1990) reported that the result of a 7-year old study with *Leucaena leucocaephala, Acacia nilotica, Albizzia lebbek* and *Albizzia procera* tested against open grassland without trees. *Leucaena Lecucocaephala* lowered the soil pH and raised the nutrient status of soil remarkably as compared with open grassland. Callway (1991) in his study on nutrient cycling of grass species in California found that grass productivity was likely to be facilitated under ban oak by nutrient input through litterfall.

Park *et al.* (1988) in a study using artificial shading 10, 25, 50 and 75 per cent shades on *Dactylis glomerata, Phleum pratense, Lolium perenne* and *Trifolium repens* found that for all species crude protein content increased with shading.

2.4 PHYSICO CHEMICAL PROPERTIES OF SOIL

The related literature consulted for the study of physico-chemical properties of soil has been given below:

Zinke (1962) measured radial variation in soil properties surrounding *Pinus contorta* trees in southern california and reported decreased soil organic carbon, N and base cations with increased distance from tree trunk. Yadav and Pathak (1963) made a study of forest soil of India and recorded 2.07 per cent organic carbon in Punjab. Singh and Raman (1982) found that organic carbon content of forest soils of Darjeeling hills varied from 2.18 to 3.88 per cent for the surface. Soni (1991) while studying forest soils of wet temperate zone of Chamba district found that organic carbon ranged from 1.31 to 5.34 per cent. Organic carbon in soil was recorded to increase with increase in altitude and it decreased with increase in depth (Kaushal, 1992).

The study carried out by Sharma (1991) revealed that available nitrogen varied from 94.0 to 233.0 ppm under different association of chirpine in Solan district. The results obtained were similar to those of Malik (1992) for the same area. Kaushal (1992)

however, observed positive and significant correlation of organic carbon with altitude and available nitrogen in deodar forests of Himachal Pradesh.

Yadav and Pathak (1963) made a study of soil profiles in chakrata forest division of Uttar Pradesh and found that available P was low in all the soils and was not uniformly distributed throughout the depth of soil profile. Kaushal (1992) found decreasing value of available P with depth of soil under deodar stands in Kinnaur district of Himachal Pradesh. Sharma (1991) found that available phosphorus varied from 10.0 to 2.50 ppm under chirpine associations in Solan Forest Division.

The available potassium ranged from 0.017 to 0.170 per cent in the soils of Chakrata Forest Division of U.P. (Yadav and Singh, 1963). Singh and Raman (1982) recorded decreased potassium content with increase in depth in north-east Himalayan forest soils. Kaushal (1992) reported more available potassium in surface that sub-surface soils of deodar stand in H.P. The available potassium was noted to vary from 87.0 to 112.0 from in chirpine association (Sharma, 1991)

The bulk density of forest soils varied from 0.2 and 1.9g/cc in organic layer and coarse sands, respectively (Pritchett, 1979). Hazara *et al.* (1973) reported that soil bulk density decreases with increase in organic matter content of soil. Similar observation have been reported by Pritchett (1979); Bhagat and Acharya (1989). The surface soils were found to have lower values of bulk density, which increased with increase in depth of the soil profile. This view has further been supported by Malik (1992) for the same forests of Himachal Pradesh.

MATERIALS & METHODS

Chapter-3

MATERIALS AND METHODS

The present study, "Floristic and productivity variations among different tree based pasture systems vis-a-vis grasslands in temperate region" was conducted in district Shimla at Regional Horticulture Research Station, Mashobra under Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni-Solan (HP) during the year 2000. The materials and methods employed during the course of investigation have been detailed as under:

3.1 DESCRIPTION OF THE STUDY AREA

Location

The area of study was selected in Regional Horticulture Research Station, Mashobra in district, Shimla. The study area was located 16 Km towards north eastern direction from Shimla town on Shimla-Naldehra Road at 31.1°N latitude and 77.1°E longitude. The sample plots were selected in the area under research station at Sadhora, 2286 m above mean sea level.

Climate

The climate of the Shimla district is transitional between sub-temperate and temperate. The study site fall between agroclimatic zone II and III i.e. Temperate Wet zone. This region is subjected to high rainfall during monsoon and is covered with snow during winter. The temperature of this region ranges between 5-25°C. The fortnightly changes in temperature, rainfall and humidity during the study period are shown in Fig. 1.

Topography and Soil

The study sites were characterized with steep slopes having undulating terrain facing southern aspect. The soils were silty clay loam, acidic in nature having medium organic matter content, available nitrogen, phosphorus and potassium. The colour of soil in the sites was light to dark brown.

Demarcation of Research Plots

In the study area, different types of systems required for the present study were already existing and were well established like silvipastoral system and hortipastoral systems. In silvipastoral system the exotic grasses were planted alongwith the natural indigenous grasses under different fodder trees like *Morus serrata, Robinia pseudoacacia* and *Acacia mollisima* and in hortipasture systems there were many horticultural trees like pear, walnut, almond and apple and exotic grasses were introduced in natural grassland alongwith fruit trees in 1992. A thorough survey of whole area was conducted in the month of April-May. To meet out the objectives of our study five different systems were finally selected:

i) Natural grassland

The system represented natural grassland of temperate region without any interference of human or any other biotic factors. Trees were absent in this study site. This system was covering an area about 0.1ha.In this grassland no exotic grass was introduced.

ii) Pine based silvipastoral system

The system represented typical *Pinus wallichiana* forest. The understorey vegetation in such forests supports good forage for grazing of animals thus can be considered a natural pine based silvipastoral system. Though, the grazing was not allowed during the study period. The various silvological characters of trees in this site are given in Table 1.

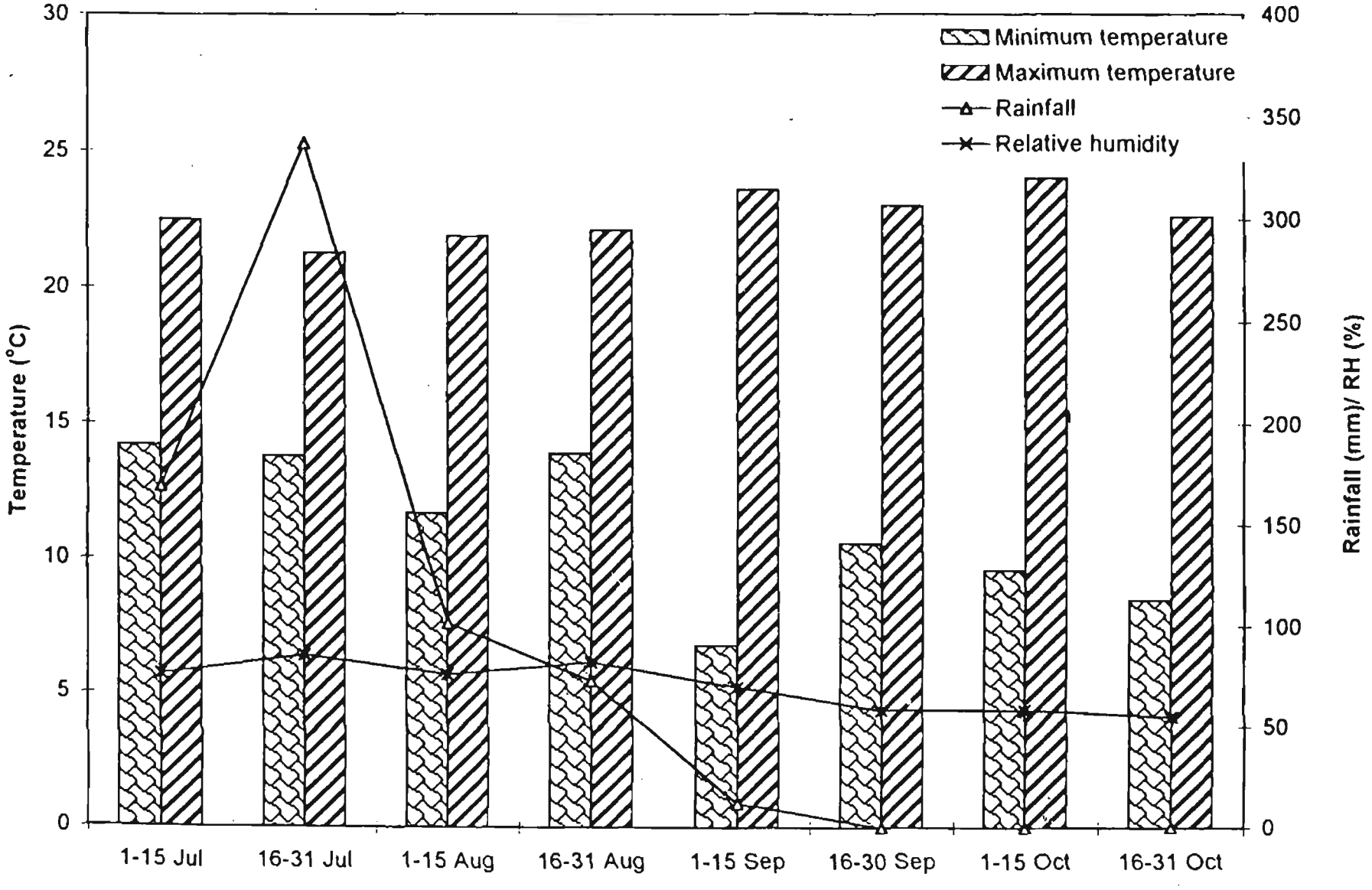

Fig. 1. Meteorological data of RHRS, Mashobra during 2000

iii) Hortipastoral system

Originally this site represented a natural temperate grassland and the improved grasses like *Dactylis glomerata* was introduced during 1992 along with apple trees. The various silvological characters of trees in site are given in Table 1.

iv) Improved grassland

Originally this site also represented a natural temperate grassland. Some tillage practices had been done to the soil and an improved grass *Dactylis glomerata* (orchard grass) was introduced along with existing local grasses in the year 1992.

v) Fodder trees based silvipastoral system

In this system natural grasses and an improved grass *Dactylis glomerata* were growing along with fodder trees like *Robinia pseudocasia* and *Acacia mollissima* planted in 1992 on a sloppy site to check the soil erosion. The various silvological characters of trees in this site are given in Table 1.

Table 1. Silvological characteristics of tree components in system I (natural grassland), II (pine based silvipastoral sustem), III (hortipastoral system), IV (improved grassland), V (fodder trees based silvipastoral system)

System	Density (number of trees/ha)	Tree height (m)	Crown height (m)	Crown diameter (m)
I	-	-	-	-
II	1600	39.2	8.4	10.6
III	500	2.89	0.43	4.08
IV	-	-	-	-
V	1500	10.2	1.68	5.1

In each system sampling plots of 0.1 ha were marked. The understorey vegetation data was recorded at fortnight interval from each sampling plot in each system.

Observations

The observations were recorded for tree components, herbage vegetation and nutrients in plants and soil from July, 2000 to October, 2000.

i) Tree Components

Height

The height of trees in different silvipastoral systems (pine based silvipastoral system and fodder trees based silvipastoral system) were measured using Spiegel Relaskope while in Horticultural system it was measured with wooden rod with the help of measuring tape.

Crown Height

The crown height of trees were determined from base of the tree upto mid point of lowest green branch and the dead branch adjacent to it by using Spiegel Relaskope and in Hortipastoral system it was determined with the help of measuring tape.

Density

Stand density is defined as the number of stems per unit area. Stand density was calculated by counting the number of trees in 0.1 ha area of sample plot.

ii) Herbaceous Vegetation Analysis

In each sample plot, herbaceous vegetation from five quadrates of size 50x50 cm was harvested at ground level at fortnightly interval following Milner and Hughes (1968). The sampling was done from July, 2000 to October, 2000 and the samples were utilized for herbage analysis.

iii) Phytosociological Analysis of grasses

Phytosociological attributes of grasses in five different systems were evaluated from harvested samples. The samples were collected from five quadrates in each system

at fortnight interval. The samples so collected were brought to the laboratory and washed properly with running water and then segregated species wise. The individuals of each species from different quadrates were counted separately and their basal area were calculated following Phillip (1959). The Importance Value Index (IVI) for each site was worked out by following the formula given by Misra (1969).

$$IVI = RF + RD + RB$$

where,

$$RF \text{ (Relative Frequency)} = \frac{\text{Frequency of individual species}}{\text{Frequency of all species}} \times 100$$

$$RD \text{ (Relative Density)} = \frac{\text{Density of individual species}}{\text{Density of all species}} \times 100$$

$$RB \text{ (Relative Basal area)} = \frac{\text{Basal area of individual species}}{\text{Basal area of all species}} \times 100$$

Species Diversity

The species diversity was determined by using Shannon index of general diversity following Margalef (1968).

$$\bar{H} = -\Sigma \left[\frac{ni}{N}\right] \log \left[\frac{ni}{N}\right]$$

Where,

$\bar{H}$ = Shannon index of general diversity

ni = Importance value index of individual species

N = Importance value index of all the species

Similarity index

The similarity index of grasses between two systems was calculated by using the following formula given by Margalef (1968).

$$S = \frac{2C}{A+B}$$

where,

S = Similarity index

A = Number of species in system I

B = Number of species in system II

C = Number of species common to both system I and II

iv) Biomass estimation of herbage

The herbage samples brought to the laboratory for phytosociological study were sorted out species wise and stored in different paper bags, dried in oven to a constant weight at 80°C for 48 hours. After attaining a constant weight, each sample was weighed for biomass estimation on top pan balance.

For estimation of belowground biomass, the roots from each quadrate a monoliths of size 25x25x25 cm was excavated with soil and was brought to the laboratory. The roots were segregated species wise and washed in running water. The roots of different grasses were kept in separate paper bags and dried in oven till a constant weight is attained at 80°C for 48 hours and weighed.

v) Nutrient analysis of herbage

The N, P, K, Ca and Mg concentration of different herbage species present in different systems sampled out at fortnightly intervals were determined by grinding oven

dried samples used for biomass estimation from July, 2000 to October, 2000. The common species in different quadrates in each system were mixed to make a composite sample.

For estimation of P, K, Ca and Mg content in plant, 0.5 g of sample was digested in 4:1 Nitro-perchloric acid (HNO_3:$HClO_4$) mixture. In order to have a complete transfer of digested material, three washings of digestion flask were given with distilled water and final volume was made to 100 ml. P was determined by Vanado-molybdate yellow colour method using Spectronic-20D. The K, Ca and Mg in the extract was determined by atomic absorption spectrophotometer. For estimation of Nitrogen, 0.2 gram of plant sample was digested in concentrated H_2SO_4 using standard digestion mixture K_2SO_4:$CuSO_4$ (3.5:0.4). After digestion, nitrogen was estimated in Kjeltec Auto 1030 Analyzer.

vi) Chemical Analysis of Soil

Collection of soil samples

The composite samples of soil from all the five systems were made by collecting soil from top 25 cm depth during September. Approximately 1 kg of soil sample was brought to the laboratory in polyethylene bags. These samples were air dried, brushed, passed through 2 mm sieve and stored in cloth bags for chemical analysis.

Soil Analysis

Soil analysis was done to estimate organic carbon (%), bulk density, available nitrogen, phosphorus and potassium (Kg/ha). The various methods used to determine these parameters/nutrients are given in Table 2.

Table 2. Method for analysis of different soil parameters

Sr. No.	Parameter	Method employed
1.	Organic carbon (%)	Walkley and Black method (1934)
2.	Bulk density	Chopra and Kanwar (1976)
3.	*Available nitrogen (Kg/ha)*	*Alkaline potassium permanganate* method (Subbiah and Asija, 1956)
4.	Available phosphorus (Kg/ha)	Olsen *et al.* (1954)
5.	Available potassium (Kg/ha)	Merwin and Peech (1951) and extract determined on flame photometer

EXPERIMENTAL RESULTS

Chapter-4

EXPERIMENTAL RESULTS

The present investigation "Floristic and productivity variations among different tree based pasture system vis-a-vis grasslands in temperate region" was carried out at Mashobra in district Shimla, H.P. during July 2000 to October 2000. The results thus obtained are presented in this Chapter under the following headings:

4.1 Floristic composition and phytosociology of herbage

4.2 Productivity of herbage

4.3 Nutrient content of herbage

4.4 Physico-chemical properties of soil

4.1 FLORISTIC COMPOSITION AND PHYTOSOCIOLOGY OF HERBAGE

4.1.1 Floristic composition

A perusal of results on floristic composition (Table 3) of different tree based pasture systems revealed that, in all, nine grasses viz., *Heteropogon contortus, Themeda triandra, Festuca rubra, Panicum maximum, Bromus inermis Oplismenus compositus, Chrysopogon montanus, Hemarthria protensa, Dactylis glomerata* were recorded during the study period. One fern : *Adiantum* sp. and two non-legumes : *Artemisia vestita* and *Thalictrum neurocarpum* were also recorded and grouped under miscellaneous species. The presence or absence of a herbage species under different systems on different sampling dates is shown in Table 3. It was evident from it that *Dactylis glomerata* was recorded in system III, IV and V while 'miscellaneous species' were recorded mainly in system II. *Festuca rubra* and *Chrysopogon montanus* were the most consistent in occurrence at different sampling intervals in all the systems. However, maximum number of species were recorded in July in all the systems.

4.1.2 Phytosociology of herbage

a) Density (tillers/m²)

Population strength of different grass species in five different systems is presented in Table 4.

Natural grassland

The total population of vegetation in natural grassland revealed that it ranged from 636.8 to 875.2 tillers/m² in different sampling dates. The scrutiny of data depicted that total population strength decreased gradually from 1st fortnight of July to 2nd fortnight of October. Maximum population was recorded in 1st fortnight of July. The contribution of *Chrysopogon montanus, Festuca rubra* and *Panicum maximum* to the total density of vegetation was higher as compared to other species. In natural grassland *Festuca rubra* exhibited highest density (500.0 tillers/m²) in 1st fortnight of August while lowest density (28.0 tillers/m²) was recorded for *Heteropogon contortus* in 2nd fortnight of October.

Pine based silvipastoral system

The total density of various grass species in pine based silvipastoral system ranged from 505.2 to 732.8 tillers/m² at different sampling times. A perusal of data depicted that total population strength decreased gradually from 1st fortnight of July to 2nd fortnight of October. Maximum population of vegetation was recorded in 1st fortnight of July, similar to natural grassland. *Festuca rubra, Chrysopogon montanus* and 'miscellaneous species' contributed maximum to the total density of vegetation. In this system *Festuca rubra* exhibited highest density (374.0 tillers/m²) in 2nd fortnight of August while lowest density (40.0 tillers/m²) was recorded for *Hemarthria protensa* in 1st fortnight of July. In general, the density of vegetation in this system was lower as compared to other four systems.

Table 3. ***Floristic composition of different grass species in systems I (natural grassland), II (pine based silvipastoral system), III (horti-pastoral system), IV (improved grassland), V (fodder trees based silvipastoral system) during the study period at different sampling intervals***

Species	JULY										AUGUST									
	1st Fortnight					2nd Fortnight					1st Fortnight					2nd Fortnight				
	System					System					System					System				
	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V
Heteropogon contortus	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Themeda triandra	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+	-	-	+	-
Festuca rubra	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Panicum maximum	+	+	+	+	-	+	+	+	-	-	+	+	+	-	+	+	+	+	+	+
Bromus inermis	+	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-
Oplismenus compositus	+	-	-	-	+	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-
Chrysopogon montanus	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Hemarthria protensa	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dactylis glomerata	-	-	+	+	+	-	-	+	+	+	-	-	+	+	+	-	-	+	+	+
Adiantum sp.	-	+	-	-	-	+	+	+	-	-	-	+	-	+	-	-	+	+	+	-
Artemisia vestita	-	+	-	-	-	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-
Thalictrum neurocarpum	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	+	-	-	-
Total	7	7	6	6	5	7	4	6	4	4	4	5	4	5	4	4	5	5	6	4

Species	SEPTEMBER										OCTOBER									
	1st Fortnight					2nd Fortnight					1st Fortnight					2nd Fortnight				
	System					System					System					System				
	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V
Heteropogon contortus	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Themeda triandra	+	+	-	+	-	+	-	-	+	-	+	-	-	-	-	+	-	-	-	-
Festuca rubra	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Panicum maximum	+	+	+	-	-	+	+	-	-	-	+	-	-	-	-	-	-	-	-	-
Bromus inermis	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Oplismenus compositus	-	-	-	+	+	-	-	+	+	+	-	-	-	-	+	-	-	-	-	+
Chrysopogon montanus	-	-	-	-	-	+	+	-	-	-	+	-	+	-	-	+	+	+	+	+
Hemarthria protensa	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Dactylis glomerata	-	-	+	+	+	-	-	+	+	+	-	-	+	+	+	-	-	+	+	+
Adiantum sp.	-	+	-	-	-	-	+	-	-	-	-	+	-	-	-	-	+	-	-	-
Artemisia vestita	-	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
Thalictrum neurocarpum	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	+	-	-	-
Total	4	5	3	5	3	4	4	4	4	3	4	4	3	3	3	4	4	3	3	4

Table 4. ***Density of different grass species in systems I (natural grassland), II (pine based silvipastoral system), III (horti-pastoral system), IV (improved grassland), V (fodder trees based silvipastoral system) during the study period at different sampling intervals***

Species	JULY										AUGUST									
	1st Fortnight					2nd Fortnight					1st Fortnight					2nd Fortnight				
	System					System					System					System				
	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V
Heteropogon contortus	138.40	208.8	32.0	279.20	216.8	140.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Themeda triandra	-	-	-	-	-	-	-	-	-	-	-	-	-	51.2	-	68.0	-	-	30.4	-
Festuca rubra	214.40	260.8	132.8	182.0	100.0	204.6	238.6	229.6	359.2	229.6	500.0	341.6	202.4	317.6	213.8	373.2	374.0	290.6	355.2	238.8
Panicum maximum	146.4	51.2	45.6	107.6	-	246.0	148.6	30.0	-	-	116.0	88.2	98.6	-	66.2	73.6	97.6	140.0	140.0	248.0
Bromus inermis	64.00	-	-	-	-	-	-	131.2	188.8	-	-	-	-	-	-	-	-	-	-	-
Oplismenus compositus	84.00	-	-	-	153.6	20.6	-	-	-	103.6	-	-	-	-	-	-	-	-	-	-
Chrysopogon montanus	129.6	172.0	108.0	82.4	52.0	170.4	183.6	120.0	117.2	260.8	166.2	249.4	128.4	148.4	225.6	274.8	201.2	178.2	193.6	190.6
Hemarthria protensa	98.4	40.0	123.2	44.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dactylis glomerata	-	-	199.2	70.0	82.4	-	-	126.4	106.2	120.2	-	-	259.2	225.2	212.0	-	-	154.4	123.2	135.2
Miscellaneous	-	19.2	-	-	-	13.6	19.6	13.6	-	-	14.6	17.6	-	5.60	-	-	14.4	19.2	36.8	-
Total	875.2	752.0	640.8	796.0	604.8	795.4	590.4	650.8	771.4	714.2	796.8	696.8	688.6	748.0	717.6	789.6	687.2	782.4	879.2	812.6

Species	SEPTEMBER										OCTOBER									
	1st Fortnight					2nd Fortnight					1st Fortnight					2nd Fortnight				
	System					System					System					System				
	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V
Heteropogon contortus	108.8	-	-	88.0	-	-	-	-	-	-	-	-	-	-	-	28.0	-	-	-	-
Themeda triandra	166.8	145.2	-	88.6	-	45.6	-	-	47.2	-	141.6	-	-	-	-	184.0	-	-	-	-
Festuca rubra	275.6	283.6	263.2	369.6	310.8	307.2	359.0	342.8	496.8	297.6	310.4	311.2	312.8	336.8	97.6	224.8	240.0	100.8	148.8	160.0
Panicum maximum	157.2	52.4	36.8	-	-	312.8	54.2	-	-	-	99.2	-	-	-	-	-	-	-	-	-
Bromus inermis	-	-	-	-	-	-	-	32.0	-	-	-	-	-	-	-	-	-	-	-	-
Oplismenus compositus	-	-	-	77.2	217.6	-	-	49.6	49.6	156.8	-	-	-	-	100.0	-	-	-	-	124.0
Chrysopogon montanus	-	-	-	-	-	78.4	56.0	-	-	-	105.0	-	122.4	-	-	200.0	241.2	174.0	206.4	124.8
Hemarthria protensa	-	-	-	-	-	-	-	-	-	-	-	-	-	81.6	-	-	-	-	-	-
Dactylis glomerata	-	-	268.0	164.8	212.4	-	-	142.4	142.4	158.4	-	-	117.6	243.6	340.8	-	-	256.0	300.4	105.6
Miscellaneous	-	41.6	-	-	-	-	38.0	-	-	-	-	44.8	-	-	-	-	24.0	-	-	-
Total	708.4	522.8	568.0	788.2	740 8	744.0	507.2	566.8	736.0	612..8	656.2	356.0	552.8	662.0	538.4	636.8	505.2	530.8	655.6	514.4

Hortipastoral system

During the study period, total density of different grass species in hortipastoral system ranged from 530.8 to 788.6 tillers/m² on different sampling dates. It was clear from the data that total density of vegetation first increased from 1st fortnight of July to 1st fortnight of August unlike natural grassland and pine based silvipastoral system, thereafter, it decreased to lowest density in 2nd fortnight of October. *Festuca rubra, Chrysopogon montanus and Dactylis glomerata* contributed maximum to the total density of vegetation. In hortipastoral system, *Festuca rubra* exhibited the highest density (342.8 tillers/m²) in 2nd fortnight of September. While, lowest density (30.0 tillers/m²) was recorded for *Panicum maximum* in 2nd fortnight of July. In general, the density of vegetation in this system attained lower values than system I, IV and V but more than system II during different sampling dates.

Improved grassland

The total density of different grass species in improved grassland ranged from 655.6 to 879.2 tillers/m² on different sampling dates. It was evident from the data that total density of community vegetation increased gradually from 1st fortnight of July to 2nd fortnight of August thereafter, it decreased similar to the case as in hortipastoral system which was different from natural grassland and pine based silvipastoral systems. Maximum population was recorded in 2nd fortnight of August. Among the individual grass species *Festuca rubra, Chrysopogon montanus* and *Dactylis glomerata* contributed maximum to the total density. *Festuca rubra* exhibited highest density (496.8 tilers/m²) in 2nd fortnight of September while the lowest density (44.8 tillers/m²) was recorded for *Hemarthria protensa* in 1st fortnight of July. In general, population strength of vegetation in this system was higher than systems II, III and V during different sampling dates.

Fodder trees based silvipastoral system

During the study period total density of different grass species in this system ranged from 514.4 to 812.0 tillers/m². It was recorded that total density increased

gradually from 1st fortnight of July to 2nd fortnight of August then it decreased similar to hortipastoral system and improved grassland but different from natural grassland and pine based silvipastoral systems. The maximum total density was recorded in 2nd fortnight of August. Among the individual species, *Festuca rubra, Oplismenus compositus* and *Dactylis glomerata* contributed maximum to the total density of vegetation. *Festuca rubra* exhibited the highest density as 310.8 tillers/m² in 1st fortnight of September. Lowest density (52.0 tillers/m²) of individual grass was exhibited by *Chrysopogon montanus* in 1st fortnight of July. In general, population strength of vegetation in this system was higher than systems II and III but lower than systems I and IV.

b) Basal area (cm²/m²)

The variation in basal area of different grass species in different systems is presented in Table 5.

Natural grassland

The total area of different grass species in natural grassland ranged from 82.72 to 111.96 cm/²/m² on different sampling dates. The data explicated that total basal area of community vegetation increased gradually from 2nd fortnight of July to 2nd fortnight of August thereafter it decreased gradually. Three species viz. *Festuca rubra, Panicum maximum* and *Chrysopogon montanus* were major contributors to the total basal area of vegetation. Among the individual grass species, *Festuca rubra* exhibited highest basal area (50.43 cm²/m²) in 1st fortnight of August while lowest (14.33 cm²/m²) basal area was recorded for *Oplismenus compositus* in 2nd fortnight of July. In general the total basal area of the vegetation in this system was higher than systems II and III, but lower than IV and V.

Pine based silvipastoral system

The total basal area of different species in this system fluctuated between 52.33 to 104.14 cm²/m² on different sampling dates. It was recorded that the total basal area of

Table 5. *Basal area of different grass species in systems I (natural grassland), II (pine based silvipastoral system), III (horti-pastoral system), IV (improved grassland), V (fodder trees based silvipastoral system) during the study period at different sampling intervals*

Species	JULY										AUGUST									
	1st Fortnight					2nd Fortnight					1st Fortnight					2nd Fortnight				
	System					System					System					System				
	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V
Heteropogon contortus	17.84	25.80	7.37	29.89	98.92	18.06	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Themeda triandra	-	-	-	-	-	-	-	-	-	-	-	-	-	20.34	-	22.17	-	-	12.47	-
Festuca rubra	23.71	29.43	17.87	20.89	15.14	23.07	26.48	25.78	32.95	25.33	50.43	38.83	28.19	34.99	29.78	39.83	41.07	31.08	37.84	30.38
Panicum maximum	19.19	17.43	8.86	15.02	-	25.14	21.34	8.65	-	-	15.29	13.18	19.12	-	14.47	16.87	19.63	20.94	21.15	33.67
Bromus inermis	12.17	-	-	-	-	-	-	18.88	21.36	-	-	-	-	-	-	-	-	-	-	-
Oplismenus compositus	10.93	-	-	-	19.78	3.84	-	-	-	14.33	-	-	-	-	-	-	-	-	-	-
Chrysopogon montanus	16.85	21.69	14.29	10.64	17.39	25.62	18.98	15.24	14.86	26.38	23.87	24.23	18.83	21.48	23.45	29.15	20.73	26.33	29.68	28.87
Hemarthria protensa	11.27	8.39	16.18	8.98	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dactylis glomerata	-	-	23.13	12.94	15.24	-	-	17.43	14.38	16.93	-	-	27.33	24.13	22.18	-	-	20.19	17.48	19.65
Miscellaneous	-	1.40	-	-	-	1.28	1.38	1.23	-	-	1.49	2.10	-	1.15	-	-	1.45	2.15	3.24	-
Total	111.96	104.14	87.7	98.36	89.47	97.01	68.18	87.21	83.55	82.97	89.59	76.24	93.47	102.09	89.88	108.02	82.88	100.69	121.86	112.57

Species	SEPTEMBER										OCTOBER									
	1st Fortnight					2nd Fortnight					1st Fortnight					2nd Fortnight				
	System					System					System					System				
	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V
Heteropogon contortus	15.87	-	-	12.13	-	-	-	-	-	-	-	-	-	-	-	9.15	-	-	-	-
Themeda triandra	19.95	17.53	-	12.48	-	16.18	-	-	16.97	-	16.15	-	-	-	-	19.87	-	-	-	-
Festuca rubra	34.52	36.67	35.18	47.93	39.16	39.32	45.64	42.13	48.87	36.84	39.62	41.15	42.65	44.15	15.32	25.75	27.67	15.25	19.47	21.65
Panicum maximum	24.17	15.13	8.95	-	-	34.16	15.83	-	-	-	18.35	-	-	-	-	-	-	-	-	-
Bromus inermis	-	-	-	-	-	-	-	8.09	-	-	-	-	-	-	-	-	-	-	-	-
Oplismenus compositus	-	-	-	10.97	22.95	-	-	8.11	8.17	18.14	-	-	-	-	14.18	-	-	-	-	17.18
Chrysopogon montanus	-	-	-	-	-	9.98	7.14	-	-	-	14.29	-	16.87	-	-	27.95	25.89	25.78	29.25	16.95
Hemarthria protensa	-	-	-	-	-	-	-	-	-	-	-	-	-	13.95	-	-	-	-	-	-
Dactylis glomerata	-	-	28.83	24.17	22.62	-	-	19.94	20.15	22.15	-	-	16.67	28.54	42.27	-	-	27.95	31.85	14.95
Miscellaneous	-	9.18	-	-	-	-	6.97	-	-	-	-	11.18	-	-	-	-	7.93	-	-	-
Total	94.51	78.51	72.96	107.68	84.73	99.64	75.58	78.27	94.16	77.13	88.81	52.33	76.19	86.64	71.77	82.72	60.95	68.98	80.57	70.73

community increased gradually from 2nd fortnight of july to 2nd fortnight of August, similar to the changes recorded for basal area of vegetation in natural grassland the individual grass species *Festuca rubra, Panicum maximum* and *Chrysopogon gryllus* were the major contributors to the total basal area of community. *Festuca rubra* exhibited the highest basal area (45.64 cm^2/m^2) in 2nd fortnight of September, while lowest (7.14 cm^2/m^2) was recorded_for *Chrysopogon montanus* in 2nd fortnight of September. In general the basal area of vegetation in this system was lower than all other systems.

Hortipastoral system

During the study period the total basal area of different species varied from 68.98 to 100.69 cm^2/m^2 on different sampling dates. It was evident from the data that total basal area increased gradually from 2nd fortnight of July to 2nd fortnight of August, thereafter, it decreased gradually. Similar to natural grassland and pine based silvipastoral system. Maximum total basal area of community vegetation was recorded in 2nd fortnight of August. The contribution of *Festuca rubra, Chrysopogon montanus* and *Dactylis glomerata* to the total basal area of vegetation was higher as compared to other species. In this system *Festuca rubra* exhibited the highest basal area 42.65 cm^2/m^2) in 1st fortnight of October while *Heteropogon controtus* attained the lowest (7.37 cm^2/m^2) basal area in 2nd fortnight of September. In general, the basal area of vegetation in this system in lower than system I, IV and V, but more than system II.

Improved grassland

The total basal area of different species in this system fluctuated between 80.57 to 121.86 cm^2/m^2 on different sampling dates. It was evident from Table 5 that total basal area of vegetation increased gradually from first fortnight of July to 2nd fortnight of August, thereafter, it decreased similar to the case of natural grassland and pine based silvipastoral and hortipastoral systems. Maximum total basal area of vegetation was recorded in 2nd fortnight of August. *Festuca rubra, Chrysopogon montanus* and *Dactylis glomerata* were major contributor to the total basal area of vegetation. Among individual

grass species, *Festuca rubra* exhibited the highest basal area (48.87 cm^2/m^2) in 2nd fortnight of September while lowest basal area (8.17 cm^2/m^2) was recorded for *Oplismenus compositus* in 2nd fortnight of September. In general, the basal area of vegetation was highest in this system than all other systems.

Fodder tree based silvipastoral system

The total basal area of different grass species in this system ranged from 79.73 to 112.57 cm^2/m^2 on different sampling dates. It was recorded that total basal area of vegetation increased gradually from 2nd fortnight of July to 2nd fortnight of August, thereafter, it decreased similar to all other systems. *Festuca rubra, Oplismenus compositus* and *Dactylis glomerata* were the major contributors to the total basal area of vegetation. Among individual grass species, *Dactylis glomerata* attained the highest basal area (42.27 cm^2/m^2) in 1st fortnight of October while the lowest basal area (14.18 cm^2/m^2) was recorded for *Oplismenus compositus* in 1st fortnight of October. In general, the basal area of vegetation in this system was higher than systems I, II and III on different sampling intervals.

c) Frequency

The total frequency of different grass species in different systems is presented in Table 6.

Natural grassland

The total frequency of different grass species in natural grassland on different sampling dates ranged from 2.20 to 3.00. It was clear from the data that maximum total frequency was recorded in 1st fortnight of September. Irregular increase and decrease in total frequency of vegetation in subsequent sampling intervals was observed during the study period. *Festuca rubra* was universally present on each sampling date while 'miscellaneous species' were rarely present. In general, system I showed the higher total frequency of vegetation than system II, III and IV but, lower than system V.

Table 6. ***Frequency of different grass species in systems I (natural grassland), II (pine based silvipastoral system), III (horti-pastoral system), IV (improved grassland), V (fodder trees based silvipastoral system) during the study period at different sampling intervals***

Species	JULY										AUGUST									
	1st Fortnight					2nd Fortnight					1st Fortnight					2nd Fortnight				
	System					System					System					System				
	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V
Heteropogon contortus	0.6	0.8	0.4	0.8	0.6	0.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Themeda triandra	-	-	-	-	-	-	-	-	-	-	-	-	-	0.4	-	0.4	-	-	0.4	-
Festuca rubra	0.8	0.6	0.6	0.6	0.4	0.8	0.8	0.4	0.8	1.0	1.0	0.8	0.6	1.0	1.0	0.8	0.6	0.6	1.0	1.0
Panicum maximum	0.4	0.6	0.2	0.6	-	0.6	0.6	0.4	-	-	0.4	0.4	0.2	-	0.4	0.4	0.8	0.2	0.6	0.6
Bromus inermis	0.2	-	-	-	-	-	-	0.4	0.6	-	-	-	-	-	-	-	-	-	-	-
Oplismenus compositus	0.4	-	-	-	0.6	0.2	-	-	-	0.6	-	-	-	-	-	-	-	-	-	-
Chrysopogon montanus	0.2	0.4	0.4	0.2	0.6	0.4	0.6	0.6	0.8	1.0	0.6	0.2	0.4	0.4	0.8	0.6	0.4	0.4	0.4	0.6
Hemarthria protensa	0.2	0.4	0.6	0.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dactylis glomerata	-	-	0.6	0.2	0.6	-	0.6	0.6	0.6	0.8	-	-	0.6	0.8	0.6	-	-	0.8	0.4	0.6
Adianthus sp.	-	0.2	-	-	-	0.2	-	0.2	-	-	0.4	0.2	-	0.2	-	-	0.2	0.2	0.4	-
Artemisia vestita	-	0.4	-	-	-	0.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Thalictrum neurocarpum	-	-	-	-	-	-	-	-	-	-	-	0.2	-	-	-	-	0.2	-	-	-
Total	2.80	3.40	2.80	2.80	2.80	2.80	2.40	2.60	2.80	3.40	2.40	1.80	1.80	2.80	2.80	2.20	2.20	2.20	3.20	2.80

Species	SEPTEMBER										OCTOBER									
	1st Fortnight					2nd Fortnight					1st Fortnight					2nd Fortnight				
	System					System					System					System				
	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V
Heteropogon contortus	0.6	-	-	0.2	-	-	-	-	-	-	-	-	-	-	-	0.2	-	-	-	-
Themeda triandra	0.8	0.6	-	0.4	-	0.4	-	-	0.4	-	0.8	-	-	-	-	0.8	-	-	-	-
Festuca rubra	0.6	0.8	1.0	0.8	1.0	1.0	1.0	1.0	1.0	1.0	0.8	1.0	1.0	0.2	0.2	0.8	0.4	1.0	0.4	0.6
Panicum maximum	1.0	0.2	0.4	-	-	1.0	0.4	-	-	-	0.4	-	-	-	-	-	-	-	-	-
Bromus inermis	-	-	-	-	-	-	-	0.4	-	-	-	-	-	-	-	-	-	-	-	-
Oplismenus compositus	-	-	-	0.4	0.8	-	-	0.2	0.2	1.0	-	-	-		0.8	-	-	-	-	0.8
Chrysopogon montanus	-	-	-	-	-	0.4	0.4	-	-	-	0.4	-	0.2	-	-	0.6	0.8	0.2	0.6	0.8
Hemarthria protensa	-	-	-	-	-	-	-	-	-	-	-	-	-	0.4	-	-	-	-	-	-
Dactylis glomerata	-	-	1.0	0.8	1.0	-	-	1.0	0.8	1.0	-	-	1.0	1.0	1.0	-	-	1.0	1.0	0.8
Adianthus sp.	-	0.4	-	-	-	-	0.2	-	-	-	-	0.2	-	-	-	-	0.2	-	-	-
Artemisia vestita	-	0.4	-	-	-	-	-	-	-	-	-	0.4	-	-	-	-	-	-	-	-
Thalictrum neurocarpum	-	-	-	-	-	-	-	-	-	-	-	0.4	-	-	-	-	0.2	-	-	-
Total	3.00	2.40	2.40	2.60	2.80	2.80	2.00	2.60	2.40	3.00	2.40	2.00	2.20	1.60	2.00	2.40	1.60	2.20	2.00	3.00

Pine based silvipastoral system

The total frequency of different species in this system on different sampling dates fluctuated between 1.60 to 3.40. It was evident from the data given in Table 6 that total frequency of vegetation was maximum in 1st fortnight of July similar to the case of natural grassland. *Festuca rubra* and 'miscellaneous species' were universally present in the system, while *Heteropogon contortus* was rarely present in system. In general this system showed the lowest total frequency of vegetation.

Improved grassland

It was evident from the data given in Table 6 that the total frequency of grass species in this system on different sampling dates ranged from 1.60 to 3.20. A perusal of data revealed that total frequency did not vary much throughout the study period. Among the individual grass species, *Festuca rubra* and *Dactylis glomerata* were recorded consistently. In general, the frequency of vegetation in this system was lower than systems I and V but higher than systems II and III.

Hortipastoral system

The total frequency of different species in hortipastoral system on different sampling dates ranged from 1.80 to 2.80. A scrutiny of data given in Table 6 revealed that total frequency was maximum in 1st fortnight of July similar to natural grassland and pine based silvipastoral system. Among individual grasses, *Dactylis glomerata* was universally present in all sampling dates while *Oplismensus compositus* was rarely present. In general, the total frequency of vegetation was lower than systems I, IV and V but higher than system II.

Fodder trees based silvipastoral system

The data given in Table 6 showed that the total frequency of grasses in this system varied from 2.00 to 3.40. It also revealed that the maximum total frequency was recorded in 2nd fortnight of July; while in natural grassland, pine based silvipastoral

system and horticultural system, it was recorded in 1st fortnight of July. In improved grassland it was recorded in 2nd fortnight of August. Irregular increase and decrease in total frequency was noticed in this system during the study period. Among individual grass species, *Oplismenus compositus* and *Dactylis glomerata* were universally present. In general, the total frequency of vegetation in this system was highest than all other systems.

d) Importance value index

Number values of importance value index (IVI) attained by different species and their dominance in different systems have been presented in Table 7.

Natural grassland

The fortnightly variations in IVI values of different species in natural grassland did not show particular trend. A scrutiny of data given in Table 7 revealed that *Festuca rubra* attained highest IVI as 157.79 in 1st fortnight of August. Among the grasses, *Festuca rubra, Panicum maximum* and *Chrysopogon montanus* registered higher IVI values than other species showing their dominance over other species.

Pine based silvipastoral system

The perusal of data on IVI values of different species revealed that in pine based silvipastoral system *Festuca rubra, Chrysopogon montanus* and miscellaneous species registered higher IVI values than other species showing their dominance in the system.

Hortipastoral system

The fortnightly variations in IVI values of different species in this system given in Table 7 revealed that highest IVI values was attained by *Festuca rubra* (158.01) in 2nd fortnight of October. *Festuca rubra* and *Dactylis glomerata* were dominant and

Table 7. IVI of different grass species in systems I (natural grassland), II (pine based silvipastoral system), III (horti-pastoral system), IV (improved grassland), V (fodder trees based silvipastoral system) during the study period at different sampling intervals

Species	JULY										AUGUST									
	1st Fortnight					2nd Fortnight					1st Fortnight					2nd Fortnight				
	System					System					System					System				
	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V
Heteropogon contortus	53.17	76.79	27.68	94.03	81.78	50.54	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Themeda triandra	-	-	-	-	-	-	-	-	-	-	-	-	-	41.05	-	47.31	-	-	26.19	-
Festuca rubra	74.25	81.50	48.24	69.27	47.73	78.08	112.55	85.92	117.22	92.09	157.79	143.02	89.15	112.44	98.63	120.80	131.21	113.46	102.70	92.11
Panicum maximum	48.46	41.38	24.36	50.22	-	92.55	80.47	22.23	-	-	48.02	51.68	34.06	-	39.61	43.12	74.24	47.77	52.02	81.90
Bromus inermis	25.14	-	-	-	-	-	-	50.50	70.36	-	-	-	-	-	-	-	-	-	-	-
Oplismenus compositus	33.64	-	-	-	67.08	13.68	-	-	-	49.35	-	-	-	-	-	-	-	-	-	-
Chrysopogon montanus	36.99	56.06	40.28	28.32	49.46	62.12	83.96	56.98	54.99	97.72	80.07	77.83	58.65	55.17	86.12	89.07	72.39	67.10	58.87	70.54
Hemarthria protensa	28.47	25.28	59.10	29.05	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dactylis glomerata	-	-	78.91	29.08	52.09	-	-	60.48	51.43	60.74	-	-	95.44	82.32	84.57	-	-	76.15	66.86	55.55
Miscellaneous	-	21.59	-	-	-	17.33	22.02	11.21	-	-	20.12	27.44	-	9.02	-	-	21.96	13.70	19.36	-

Species	SEPTEMBER										OCTOBER									
	1st Fortnight					2nd Fortnight					1st Fortnight					2nd Fortnight				
	System					System					System					System				
	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V
Heteropogon contortus	52.15	-	-	30.11	-	-	-	-	-	-	-	-	-	-	-	23.78	-	-	-	-
Themeda triandra	71.33	75.10	-	38.21	-	36.66	-	-	41.10	-	73.09	-	-	-	-	86.24	-	-	-	-
Festuca rubra	74.25	134.28	112.04	122.17	123.88	124.40	181.30	152.77	166.36	129.65	125.24	216.05	158.01	112.13	49.47	99.77	117.90	86.55	66.85	81.71
Panicum maximum	113.16	31.59	29.30	-	-	112.03	51.65	-	-	-	52.90	-	-	-	-	-	-	-	-	-
Bromus inermis	-	-	-	-	-	-	-	31.36	-	-	-	-	-	-	-	-	-	-	-	-
Oplismenus compositus	-	-	-	35.35	85.03	-	-	26.80	23.74	82.44	-	-	-	-	78.33	-	-	-	-	75.06
Chrysopogon montanus	-	-	-	-	-	34.80	40.51	-	-	-	48.77	-	53.38	-	-	90.21	140.22	79.25	97.78	74.88
Hemarthria protensa	-	-	-	-	-	-	-	-	-	-	-	-	-	52.89	-	-	-	-	-	-
Dactylis glomerata	-	-	134.36	74.16	91.09	-	-	88.07	74.09	87.91	-	-	88.61	134.98	172.20	-	-	134.20	135.37	68.35
Miscellaneous	-	52.99	-	-	-	-	26.74	-	-	-	-	83.95	-	-	-	-	42.88	-	-	-

codominant grasses which registered higher IVI values than other species encountered in this system.

Improved grassland

The fortnightly variation in IVI values of different species in improved grassland in Table 7 revealed that the highest IVI value was attained by *Festuca rubra* as 166.36 in 2nd fortnight of September and was the dominant species in this system, while second highest IVI value as 142.34 was recorded for *Dactylis glomerata* in 1st fortnight of October and was the codominant species in the system.

Fodder trees based silvipastoral system

The fortnightly variation in IVI values of different grass species in this system is presented in Table 7 which revealed that highest IVI value as 172.20 was attained by *Dactylis glomerata* in 1st fortnight of October and was the dominant species, while the second highest value of IVI was recorded as 129.65 for *Festuca rubra* in 2nd fortnight of September.

e) Shannon's index of species diversity

The fortnightly variation in species diversity of five different systems is shown in Table 8. The Shannon's index of species diversity ranged from 0.5058 to 0.8163 in natural grassland, 0.2573 to 0.6771 in pine based silvipastoral system, 0.4254 to 0.7199 in hortipastoral system, 0.4485 to 0.7277 in improved grassland and 0.4195 to 0.6872 in fodder tree based silvipastoral system. The highest value for species diversity in all the systems was recorded in 1st fortnight of July, thereafter, it decreased till October. The average values of Shannon's diversity index of different systems were, 0.6068, 0.5022, 0.5314, 0.5870 and 0.5514 for natural grassland, pine based silvipastoral system, hortipastoral system, improved grassland and fodder trees based silvipastoral system, respectively. Among different systems highest average Shannon's index of species

diversity (0.6068) was recorded for natural grassland, while lowest (0.5022) was recorded for pine based silvipastoral system.

f) Similarity index of different species

The fortnightly variations in similarity index of species in different systems is shown in Table 9a. The values for similarity index for different combinations at different fortnights has shown an increasing trend upto 2nd fortnight of August, thereafter, it decreased in subsequent sampling dates. Similarity index among different systems during study period is shown in Table 9b and highest value 0.93 was recorded for improved grassland and hortipastoral system.

4.2 BIOMASS PRODUCTION OF DIFFERENT SYSTEMS

4.2.1 Aboveground biomass

Total aboveground biomass (q/ha) of different systems during the study period is presented in Table 10.

Natural grassland

The total aboveground biomass of different species in natural grassland on different sampling dates varied from 20.07 to 32.23 q/ha. It was recorded that total aboveground biomass during the study period increased gradually from 1st fortnight of July to 1st fortnight of September, thereafter, it decreased. The highest total aboveground biomass (32.23 q/ha) was recorded for 1st fortnight of September, while the lowest total aboveground biomass (20.07 q/ha) of community was recorded for 2nd fortnight of July. *Festuca rubra, Panicum maximum* and *Chrysopogon montanus* were the major contributors to the total aboveground biomass of community. Performances of individual species revealed that *Festuca rubra* attained the highest (13.83 q/ha) aboveground biomass in 1st fortnight of September while *Heteropogon contortus* exhibited minimum (0.66 q/ha) above ground biomass in 2nd fortnight of October. In general, the total aboveground biomass in this system was lower than systems III, IV and V but, higher than system II.

Table 8. **Shannon's index of species diversity in system I (natural grassland), II (pine based silvipastoral system), III (horti-pastoral system), IV (improved grassland), V (fodder trees based silvipastoral system) during the study period at different sampling intervals**

System	JULY		AUGUST		SEPTEMBER		OCTOBER		
	1st fortnight	2nd fortnight	1st fortnight	2nd fortnight	1st fortnight	2nd fortnight	1st fortnight	2nd fortnight	Mean
I	0.8163	0.7141	0.5058	0.5630	0.5896	0.5382	0.5687	0.5587	0.6068
II	0.6771	0.5508	0.5318	0.5390	0.5526	0.4745	0.2573	0.4344	0.5022
III	0.7199	0.6466	0.5605	0.4990	0.4254	0.5016	0.4364	0.4646	0.5314
IV	0.7277	0.5734	0.6128	0.7443	0.6223	0.4972	0.4485	0.4597	0.5870
V	0.6872	0.5853	0.5853	0.5947	0.4708	0.4677	0.4195	0.6010	0.5514

Table 9a. Similarity index between system I (natural grassland), II (pine based silvipastoral system), III (horti-pastoral system), IV (improved grassland), V (fodder trees based silvipastoral system) during the study period at different sampling intervals

System	JULY										AUGUST									
	1st Fortnight					2nd Fortnight					1st Fortnight					2nd Fortnight				
	System																			
	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V
I		0.71	0.77	0.77	0.50		0.73	0.61	0.36	0.55		0.67	0.75	0.44	0.75		0.67	0.67	0.80	0.75
II			0.77	0.77	0.50			0.80	0.50	0.50			0.67	0.60	0.67			0.80	0.73	0.67
III				1.00	0.70				0.80	0.60				0.67	1.00				0.91	0.88
IV					0.55					0.75					0.67					0.80
V																				

System	SEPTEMBER										OCTOBER									
	1st Fortnight					2nd Fortnight					1st Fortnight					2nd Fortnight				
	System																			
	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V
I		0.67	0.57	0.67	0.29		0.75	0.25	0.50	0.29		0.25	0.57	0.29	0.29		0.50	0.29	0.29	0.50
II			0.50	0.40	0.25			0.25	0.25	0.29			0.29	0.29	0.29			0.57	0.57	0.50
III				0.50	0.67				0.75	0.86				0.33	0.33				1.00	0.85
IV					0.75					0.86					0.33					0.85
V																				

Table 9b. Similarity index in different system during the study period

System	I	II	III	IV	V
I		0.74	0.71	0.78	0.63
II			0.75	0.71	0.53
III				0.93	0.77
IV					0.71
V					

Table 10. The variation in above ground biomass (q/ha) of different grass species in systems I (natural grassland), II (pine based silvipastoral system), III (horti-pastoral system), IV (improved grassland), V (fodder trees based silvipastoral system) during the study period at different sampling intervals

Species	JULY										AUGUST									
	1st Fortnight					2nd Fortnight					1st Fortnight					2nd Fortnight				
	System					System					System					System				
	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V
Heteropogon contortus	3.77	6.28	2.30	10.46	8.93	4.56	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Themeda triandra	-	-	-	-	-	-	-	-	-	-	-	-	-	1.46	-	3.50	-	-	2.78	-
Festuca rubra	4.08	4.91	3.38	6.37	5.63	6.19	7.54	7.51	10.71	7.91	8.92	6.46	5.39	8.77	8.91	10.08	11.22	13.84	13.84	13.98
Panicum maximum	2.18	1.30	1.43	2.08	-	4.12	2.68	1.37	-	-	7.52	4.12	5.38	-	7.06	7.52	5.59	5.93	6.77	8.98
Bromus inermis	1.59	-	-	-	-	-	-	4.40	7.50	-	-	-	-	-	-	-	-	-	-	-
Oplismenus compositus	2.28	-	-	-	5.16	1.73	-	-	-	6.18	-	-	-	-	-	-	-	-	-	-
Chrysopogon montanus	4.90	4.48	4.01	1.96	1.36	3.15	3.86	2.81	4.30	7.89	4.63	6.01	3.63	4.57	7.18	9.13	6.34	6.58	6.43	5.54
Hemarthria protensa	1.65	1.15	5.63	2.68	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dactylis glomerata	-	-	5.34	2.02	3.73	-	-	6.57	4.57	6.62	-	-	12.67	10.29	10.78	-	-	8.27	7.19	8.37
Miscellaneous	-	0.53	-	-	-	0.32	0.34	0.37	-	-	3.68	1.95	-	1.93	-	-	2.09	1.49	1.78	-
Total	20.45	18.65	22.09	25.57	24.81	20.07	14.42	23.03	27.08	28.60	24.75	18.54	27.07	27.02	33.93	30.23	25.24	36.11	38.79	36.87

Species	SEPTEMBER										OCTOBER									
	1st Fortnight					2nd Fortnight					1st Fortnight					2nd Fortnight				
	System					System					System					System				
	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V
Heteropogon contortus	2.70	-	-	3.84	-	-	-	-	-	-	-	-	-	-	-	0.66	-	-	-	-
Themeda triandra	4.92	3.69	-	2.09	-	1.38	-	-	1.75	-	8.97	-	-	-	-	4.53	-	-	-	-
Festuca rubra	13.83	11.13	12.20	14.56	14.36	14.86	14.93	21.42	19.49	12.98	14.28	16.85	17.57	13.28	4.58	11.01	8.54	7.31	6.54	6.16
Panicum maximum	10.78	7.68	2.04	-	-	14.71	4.15	-	-	-	2.54	-	-	-	-	-	-	-	-	-
Bromus inermis	-	-	-	-	-	-	-	3.05	-	-	-	-	-	-	-	-	-	-	-	-
Oplismenus compositus	-	-	-	3.44	7.39	-	-	4.95	2.15	8.76	-	-	-	-	4.49	-	-	-	-	6.18
Chrysopogon montanus	-	-	-	-	-	3.95	2.60	-	-	-	2.53	-	3.79	-	-	8.66	8.55	6.46	6.93	3.83
Hemarthria protensa	-	-	-	-	-	-	-	-	-	-	-	-	-	9.73	-	-	-	-	-	-
Dactylis glomerata	-	-	23.07	17.06	16.43	-	-	10.86	18.69	13.84	-	-	9.12	14.53	20.48	-	-	12.74	14.81	8.19
Miscellaneous	-	2.23	-	-	-	-	1.76	-	-	-	-	3.67	-	-	-	-	1.61	-	-	-
Total	32.23	24.73	37.31	40.49	38.18	34.90	23.44	40.28	42.08	35.58	28.30	19.52	30.48	37.54	29.55	24.86	18.70	26.51	28.28	24.36

Pine based silvipastoral system

The total aboveground biomass of different species in pine based silvipastoral system on different sampling dates fluctuated between 14.42 to 25.24 q/ha. A scrutiny of data given in Table 10 revealed that the total aboveground biomass increased upto 2nd fortnight of August, thereafter, it decreased gradually similar to natural grassland. The maximum total aboveground biomass (25.24 q/ha) was recorded in 2nd fortnight of August. *Festuca rubra, Chrysopogon montanus* and 'miscellaneous species' contributed maximum to the total aboveground biomass of community. Among grasses, *Festuca rubra* exhibited the maximum aboveground biomass (14.93 q/ha) in 2nd fortnight of September while, the lowest (1.15 q/ha) aboveground biomass was recorded for *Hemarthria protensa* in 1st fortnight of July. In general, the total aboveground biomass was more than systems I and II but, lower than systems IV and V.

Improved grassland

The total aboveground biomass of different species in this system fluctuated between 27.02 to 42.08 q/ha on different sampling dates. It was evident from the data that total aboveground biomass increased from 1st fortnight of July to 2nd fortnight of September, thereafter, it decreased, similar to natural grassland, pine based silvipastoral and hortipastoral systems. *Festuca rubra, Chrysopogon montanus* and *Dactylis glomerata* were the major contributors to the total aboveground biomass on different sampling dates. Among grasses, *Festuca rubra* attained highest aboveground biomass (19.49 q/ha) in 2nd fortnight of September, while *Thumeda triandra* attained lowest (1.46 q/ha) aboveground biomass in 1st fortnight of August. In general, the total aboveground biomass in this system was higher than systems I, II and III but, lower than system V.

Fodder trees based silvipastoral system

The total aboveground biomass of different species under this system on different sampling dates varied from 24.36 to 36.87 q/ha. It was clear from the Table 10 that the

total aboveground biomass increased gradually from 1st fortnight of July to 2nd fortnight of August, thereafter, it decreased similar to all other systems. The highest total aboveground biomass (36.87 q/ha) was recorded in 2nd fortnight of August. *Festuca rubra, Oplismemus compositus, Chrysopogon montanus* and *Dactylis glomerata* were the major contributors to the total aboveground biomass. Among grasses, *Dactylis glomerata* attained the highest (20.48 q/ha) aboveground biomass in 1st fortnight October, while, lowest (1.25 q/ha) aboveground biomass was recorded for *Chrysopogon montanus* in 1st fortnight of July. In general, the total aboveground biomass in this system was highest than all other systems.

4.2.2 Belowground biomass

The total belowground biomass in different systems on different sampling dates have been presented in Table 11.

Natural grassland

The total belowground biomass different species in natural grassland sampling dates revealed that the total belowground biomass increased gradually from 1st fortnight of July to 2nd fortnight of August, thereafter, it decreased. *Festuca rubra, Panicum maximum* and *Chrysopogon montanus* were the major contributors to the total belowground biomass. Among grasses, *Festuca rubra* attained the highest (4.68 q/ha) belowground biomass in 1st fortnight of September, while lowest (0.21 q/ha) belowground biomass was recorded for *Hemarthria protensa* in 1st fortnight of July. In general, the total belowground biomass in this system was lower than systems III, IV and V, but higher than system II.

Pine based silvipastoral system

The total belowground biomass of different species in this system varied from 5.43 to 11.55 q/ha on different sampling dates. It was imperative from the data that the total belowground biomass increased from 2nd fortnight of July to 2nd fortnight of

Table 11. The variation in below ground biomass (q/ha) of different grass species in systems I (natural grassland), II (pine based silvipastoral system), III (horti-pastoral system), IV (improved grassland), V (fodder trees based silvipastoral system) during the study period at different sampling intervals

Species	JULY										AUGUST									
	1st Fortnight					2nd Fortnight					1st Fortnight					2nd Fortnight				
	System					System					System					System				
	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V
Heteropogon contortus	0.90	1.94	0.59	3.56	2.84	1.39	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Themeda triandra	-	-	-	-	-	-	-	-	-	-	-	-	-	0.46	-	1.28	-	-	1.12	-
Festuca rubra	2.40	2.34	1.67	2.83	2.23	3.24	3.12	3.03	3.79	2.92	3.96	3.62	2.54	3.35	3.49	4.09	4.87	4.99	4.91	4.97
Panicum maximum	0.63	0.59	0.66	0.60	-	1.22	0.97	0.65	-	-	3.48	1.38	2.12	-	3.32	3.32	2.04	2.29	2.85	3.13
Bromus inermis	0.57	-	-	-	-	-	-	1.74	2.94	-	-	-	-	-	-	-	-	-	-	-
Oplismenus compositus	0.70	-	-	-	2.20	-	-	-	-	2.50	-	-	-	-	-	-	-	-	-	-
Chrysopogon montanus	1.98	1.69	1.42	0.72	0.57	0.98	1.29	0.97	2.03	4.29	1.80	3.59	1.36	4.48	3.02	4.56	3.83	2.12	2.08	1.93
Hemarthria protensa	0.21	0.43	2.67	0.84	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dactylis glomerata	-	-	1.85	0.74	1.27	-	-	2.07	2.42	2.13	-	-	4.43	4.73	2.52	-	-	3.30	3.16	3.36
Miscellaneous	-	0.06	-	-	-	-	0.05	0.09	-	-	1.27	0.65	-	0.61	-	-	0.81	0.71	0.59	-
Total	7.39	7.05	8.86	9.29	9.11	6.83	5.43	8.55	1018	11.84	10.51	9.24	10.45	13.63	12.35	13.25	11.55	12.91	14.68	13.39

Species	SEPTEMBER										OCTOBER									
	1st Fortnight					2nd Fortnight					1st Fortnight					2nd Fortnight				
	System					System					System					System				
	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V
Heteropogon contortus	0.69	-	-	1.19	-	-	-	-	-	-	-	-	-	-	-	0.26	-	-	-	-
Themeda triandra	2.49	1.81	-	0.56	-	0.61	-	-	0.92	-	4.26	-	-	-	-	1.32	-	-	-	-
Festuca rubra	4.68	3.14	3.89	4.22	4.36	4.52	4.65	5.63	5.34	4.06	3.94	4.35	6.24	3.90	2.19	4.23	3.32	2.96	3.78	2.48
Panicum maximum	4.29	2.26	0.93	-	-	4.31	1.84	-	-	-	1.53	-	-	-	-	-	-	-	-	-
Bromus inermis	-	-	-	-	-	-	-	1.21	-	-	-	-	-	-	-	-	-	-	-	-
Oplismenus compositus	-	-	-	1.41	2.26	-	-	1.66	1.47	2.81	-	-	-	-	2.11	-	-	-	-	0.96
Chrysopogon montanus	-	-	-	-	-	1.72	1.12	-	-	-	1.11	-	1.77	-	-	3.95	3.31	2.87	3.16	1.89
Hemarthria protensa	-	-	-	-	-	-	-	-	-	-	-	-	-	3.95	-	-	-	-	-	-
Dactylis glomerata	-	-	7.36	5.38	4.87	-	-	3.81	5.41	4.57	-	-	3.30	4.51	6.39	-	-	4.23	5.06	2.84
Miscellaneous	-	0.51	-	-	-	-	0.70	-	-	-	-	1.41	-	-	-	-	0.47	-	-	-
Total	12.15	7.72	12.18	12.76	11.49	11.16	8.31	12.31	13.14	11.44	10.84	5.76	11.31	12.36	10.69	9.76	7.10	10.06	12.00	8.17

August, thereafter, it decreased similar to natural grassland. *Festuca rubra, Panicum maximum* and 'miscellaneous species' were major contributors to the total belowground biomass of community. Among grasses, *Festuca rubra* exhibited the highest (4.87 q/ha) belowground biomass in 2nd fortnight of August while lowest (0.43 q/ha) belowground biomass was recorded for *Hemarthria protensa* in 1st fortnight of September. In general, the total belowground biomass in this system was lowest than all other system.

Hortipastoral system

The total belowground biomass of different species in hortipastoral system on different sampling dates varied from 8.55 to 12.91 q/ha. It was recorded that there was a gradual increase in belowground biomass from 1nd fortnight of July to 2nd fortnight of August, thereafter,it decreased similar to natural grassland and pine based silvipastoral system. *Festuca rubra, Chrysopogon moutanus* and *Dactylis glomerata* contributed maximum to the total belowground biomass of community. Among grasses, *Festuca rubra* exhibited the highest (6.24 q/ha) belowground biomass in 1st fortnight of October while lowest (0.59 q/ha) belowground biomass was recorded for *Heteropogon contortus* in 2nd fortnight of July. In general, the total belowground biomass of this system was lower than systems IV and V, but higher than systems I and II.

Improved grassland

The total belowground biomass of different species in improved grassland ranged from 9.29 to 14.68 q/ha on different sampling dates. It was recorded that the maximum total belowground biomass was found in 2nd fortnight of August. There was an increasing trend in total belowground biomass from 1st fortnight of July to 2nd fortnight of August similar to natural grassland, pine based silvipastoral and hortipastoral systems. Among grasses, *Festuca rubra, Chrysopogon montanus* and *Dactylis glomerata* contributed maximum to the total belowground biomass of community. The highest belowground biomass among individual grasses was recorded as 5.41 q/ha for *Dactylis glomerata* in 2nd fortnight of September, while lowest (0.46 q/ha) belowground biomass

was recorded for *Themeda triandra* in 1st fortnight of August. In general, the total belowground biomass in this system was highest than all other systems.

Fodder trees based silvipastoral system

The total belowground biomass of different species in this system an different sampling dates varied from 4.94 to 12.01 q/ha. The total belowground biomass increased gradually from 1st fortnight of July to 2nd fortnight of August, thereafter, it decreased as in other systems. *Festuca rubra, Oplismenus compositus, Chrysopogon montanus* and *Dactylis glomerata* contributed maximum to the total belowground biomass of community. Among grasses *Dactylis glomerata* attained the highest belowground biomass (6.39 q/ha) in 1st fortnight of October while, lowest (0.57 q/ha) belowground biomass was recorded for *Chrysopogon montanus* in 1st fortnight of july. In general, the total belowground biomass in this system was higher than systems I, II and III, but lower than system IV.

4.3 NUTRIENT CONTENT OF HERBAGE

4.3.1 Nitrogen content of herbage

Nitrogen content of above ground and below ground biomass of herbage in different systems during the study period is presented in Table 12.

i) Natural grassland

a) Above ground biomass

The average nitrogen content (%) of above ground biomass of grasses in natural grassland varied from 0.74 to 0.97 per cent. Maximum average nitrogen content of aboveground biomass of grasses was recorded (0.97%) in 1st fortnight of September, thereafter it decreased gradually. Among the individual species, *Festuca rubra, Panicum maximum* showed gradual increase in nitrogen (%) till 1st fortnight of September, thereafter nitrogen (%) decreased. Other species attained peak nitrogen (%) in August

Table 12. **Variation in nitrogen (%) of different grass species in systems I (natural grassland), II (pine based silvipastoral system), III (horti-pastoral system), IV (improved grassland), V (fodder trees based silvipastoral system) during the study period at different sampling intervals. (Values in parentheses represent nitrogen per cent in belowground biomass)**

Species	JULY										AUGUST									
	1st Fortnight					2nd Fortnight					1st Fortnight					2nd Fortnight				
	System					System					System					System				
	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V
Heteropogon contortus	0.82 (0.57)	0.75 (0.70)	0.83 (0.68)	0.77 (0.58)	0.77 (0.69)	0.96 (0.66)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Themeda triandra	-	-	-	-	-	-	-	-	-	-	-	-	-	0.90 (0.72)	-	0.73 (0.62)	-	-	0.91 (0.71)	-
Festuca rubra	0.85 (0.62)	0.75 (0.48)	0.85 (0.71)	0.84 (0.66)	0.85 (0.74)	0.79 (0.53)	1.07 (0.61)	1.00 (0.86)	0.90 (0.73)	0.90 (0.76)	0.90 (0.62)	1.23 (0.84)	1.08 (0.92)	0.94 (0.77)	0.94 (0.84)	0.97 (0.63)	1.09 (0.81)	1.27 (0.93)	1.09 (0.89)	0.95 (0.93)
Panicum maximum	0.84 (0.54)	0.92 (0.45)	0.71 (0.55)	0.84 (0.70)	-	0.84 (0.54)	1.21 (0.75)	1.04 (0.83)	-	-	0.92 (0.64)	1.33 (0.87)	1.15 (0.97)	-	1.05 (0.90)	0.90 (0.56)	1.27 (1.01)	1.01 (0.85)	0.90 (0.80)	1.08 (0.91)
Bromus inermis	0.95 (0.52)	-	-	-	-	-	-	0.80 (0.71)	0.97 (0.84)	-	-	-	-	-	-	-	-	-	-	-
Oplismenus compositus	0.84 (0.79)	-	-	-	0.85 (0.75)	0.98 (0.72)	-	-	-	0.97 (0.81)	-	-	-	-	-	-	-	-	-	-
Chrysopogon montanus	0.85 (0.69)	0.91 (0.58)	0.85 (0.71)	0.77 (0.64)	0.85 (0.73)	0.93 (0.73)	1.07 (0.73)	0.94 (0.77)	0.77 (0.67)	1.19 (0.90)	1.09 (0.76)	1.23 (0.85)	1.23 (1.07)	0.87 (0.73)	0.99 (0.82)	0.87 (0.60)	1.29 (0.92)	1.28 (0.96)	0.98 (0.84)	1.04 (0.83)
Hemarthria protensa	0.82 (0.60)	0.85 (0.57)	0.83 (0.75)	0.88 (0.52)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dactylis glomerata	-	-	1.01 (0.86)	0.86 (0.80)	0.93 (0.80)	-	-	1.09 (0.87)	0.88 (0.75)	1.16 (0.80)	-	-	1.13 (0.93)	1.00 (0.85)	0.99 (0.85)	-	-	1.26 (0.97)	1.27 (0.87)	1.25 (0.97)
Miscellaneous	-	1.44 0.83	-	-	-	1.35 (0.95)	1.50 (0.92)	1.35 (0.96)	-	-	0.97 (0.67)	1.54 (0.93)	-	1.80 (1.09)	-	-	1.50 (0.94)	1.58 (1.09)	1.05 (0.89_	-
Average	**0.82 (0.61)**	**0.94 (0.60)**	**0.85 (0.71)**	**0.83 (0.65)**	**0.85 (0.74)**	**0.97 (0.69)**	**1.21 (0.75)**	**1.04 (0.83)**	**0.88 (0.75)**	**1.06 (0.82)**	**0.97 (0.67)**	**1.33 (0.87)**	**1.15 (0.97)**	**1.10 (0.83)**	**0.99 (0.85)**	**0.87 (0.60)**	**1.29 (0.92)**	**1.28 (0.96)**	**0.94 (0.83)**	**1.08 (0.91)**

Species	SEPTEMBER										OCTOBER									
	1st Fortnight					2nd Fortnight					1st Fortnight					2nd Fortnight				
	System					System					System					System				
	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V
Heteropogon contortus	0.96 (0.71)	-	-	1.07 (0.85)	-	-	-	-	-	-	-	-	-	-	-	0.85 (0.59)	-	-	-	-
Themeda triandra	0.84 (0.64)	1.29 (0.96)	-	1.10 (0.91)	-	0.82 (0.61)	-	-	1.07 (0.87)	-	0.73 (0.57)	-	-	-	-	0.71 (0.56)	-	-	-	-
Festuca rubra	1.09 (0.68)	1.35 (0.85)	1.43 (1.01)	1.27 (1.04)	1.01 (0.99)	0.95 (0.67)	1.78 (0.95)	1.36 (0.95)	1.13 (1.05)	1.27 (1.03)	0.81 (0.59)	1.43 (1.09)	1.08 (0.82)	0.84 (0.78)	1.00 (0.83)	0.73 (0.52)	1.13 (0.82)	1.13 (0.72)	0.94 (0.80)	0.84 (0.52)
Panicum maximum	0.98 (0.66)	1.45 (0.93)	1.12 (1.04)	-	-	0.81 (0.59)	1.50 (0.92)	-	-	-	0.71 (0.56)	-	-	-	-	-	-	-	-	-
Bromus inermis	-	-	-	-	-	-	-	1.01 (0.83)	-	-	-	-	-	-	-	-	-	-	-	0.84 (0.52)
Oplismenus compositus	-	-	-	1.17 (0.90)	1.19 (0.91)	-	-	1.01 (0.81)	1.15 (0.95)	1.27 (0.99)	-	-	-	-	1.03 (0.89)	-	-	-	-	0.97 (0.79)
Chrysopogon montanus	-	-	-	-	-	0.85 (0.66)	1.14 (0.84)	-	-	-	0.80 (0.58)	-	0.87 (0.73)	-	-	0.67 (0.57)	0.98 (0.70)	1.13 (0.84)	0.97 (0.88)	0.94 (0.82)
Hemarthria protensa	-	-	-	-	-	-	-	-	-	-	-	-	-	0.95 (0.79)	-	-	-	-	-	-
Dactylis glomerata	-	-	1.40 (0.99)	1.45 (1.01)	1.50 (1.08)	-	-	1.50 (0.99)	1.58 (1.03)	1.78 (1.04)	-	-	0.91 (0.85)	1.01 (0.81)	1.07 (0.94)	-	-	0.85 (0.74)	0.90 (0.71)	1.13 (0.83)
Miscellaneous	-	1.70 (0.99)	-	-	-	-	1.60 (0.96)	-	-	-	-	1.25 (0.90)	-	-	-	-	1.27 (0.94)	-	-	-
Average	**0.97 (0.67)**	**1.45 (0.93)**	**1.32 (1.01)**	**1.21 (0.96)**	**1.23 (0.99)**	**0.86 (0.63)**	**1.50 (0.92)**	**1.22 (0.90)**	**1.23 (0.98)**	**1.44 (1.02)**	**0.76 (0.57)**	**1.34 (1.00)**	**0.95 (0.80)**	**0.93 (0.79)**	**1.03 (0.89)**	**0.74 (0.56)**	**1.13 (0.82)**	**1.04 (0.77)**	**0.94 (0.80)**	**0.97 (0.74)**

and/or September. However, 'miscellaneous species' exhibited highest nitrogen (1.35%), which was recorded in 2nd fortnight of July.

b) Belowground biomass

The average nitrogen content (%) of below ground biomass of herbage in natural grassland ranged from 0.56 to 0.69%. During the study period average nitrogen content of below ground biomass was maximum (0.69%) in 2nd fortnight of July, thereafter, it decreased upto October. In general, on each sampling date average nitrogen content of belowground biomass was less as compared to their aboveground biomass counterparts. Among individual species, a continuous increase in nitrogen (%) of belowground biomass was observed upto 1st fortnight of September in *Festuca rubra* and *Panicum maximum*, while other species showed highest nitrogen(%) at different times. However, the highest nitrogen (%) in belowground biomass i.e. 0.95%, was observed for 'miscellaneous species' in 2nd fortnight of July.

ii) Pine based silvipastoral system

a) Aboveground biomass

The average nitrogen content (%) of aboveground biomass of herbage under pine based silvipastoral system fluctuated from 0.94 to 1.50 per cent. The data depicted that the average nitrogen content of different species increased gradually from 1st fortnight of July to 2nd fortnight of September, thereafter it decreased. The maximum average nitrogen content 1.50 per cent in aboveground biomass of community was recorded in 2nd fortnight of September. Thus, it differed from natural grassland where highest average nitrogen content of herbage was observed in 2nd fortnight of July. Among individual grasses, *Festuca rubra* showed a gradual increase in nitrogen(%) content of aboveground biomass till 2nd fortnight of September, whereas, other species showed higher nitrogen per cent in 2nd fortnight of August and/or in 1st fortnight of September. In this system too, 'miscellaneous species' exhibited highest nitrogen (%) i.e. 1.70 per cent in 1st fortnight of September.

b) **Belowground biomass**

The average nitrogen content(%) of belowground biomass of herbage under pine based silvipastoral system varied from 0.60 to 1.00% during the study period. It was evident from the data that average nitrogen content of belowground biomass gradually increased from 1st fortnight of July to 1st fortnight of October. The highest average nitrogen content for belowground biomass (1.00%) was recorded in 1st fortnight of October which differed from natural grassland in which the highest average nitrogen content for belowground biomass was recorded in 2nd fortnight of July. Among individual grass species, *Panicum maximum* exhibited the lowest nitrogen(%) i.e. 0.45 per cent in 1st fortnight of July. In this system too, 'miscellaneous species' attained the highest nitrogen (%) i.e. 0.99 per cent in 1st fortnight of September.

iii) Hortipastoral system

a) Aboveground biomass

The average nitrogen content (%) of aboveground biomass of herbage under hortipastoral system ranged from 0.85 to 1.32 per cent during the study period. It revealed from the data that average nitrogen content of aboveground biomass gradually increased from 1st fortnight of July to 1st fortnight of September, thereafter it decreased. The highest average nitrogen content for above ground biomass was recorded in 1st fortnight of September, whereas, in natural grassland and pine based silvipastoral system the highest average nitrogen content was observed in 2nd fortnight of July and 2nd fortnight of September. Among individual grass species, *Dactylis glomerata* attained highest nitrogen content in aboveground biomass i.e. 1.50 per cent in 2nd fortnight of September while *Panicum maximum* had the lowest nitrogen content (0.71%) in 1st fortnight of July.

b) **Belowground biomass**

The average nitrogen content (%) of belowground biomass of herbage in hortipastoral system fluctuated from 0.71 to 1.01%. During the study period, it was clear from the data that the average nitrogen content of belowground biomass increased gradually from 1st fortnight of July to 1st fortnight of September, thereafter it decreased till October. The highest average nitrogen content for belowground biomass was recorded in 1st fortnight of September whereas in natural grassland and pine based silvipastoral system the highest average nitrogen content was recorded in 2nd fortnight of July and 1st fortnight of October respectively. Among individual grass species, *Panicum maximum* attained highest nitrogen content in belowground biomass i.e. 1.04% N in 1st fortnight of September, whereas, the same species had lowest nitrogen content (0.55%) in 1st fortnight of July.

iv) Improved grassland

a) Aboveground biomass

The average nitrogen content (%) of aboveground biomass of herbage in improved grassland varied from 0.83 to 1.23 per cent during the study period. It was recorded that the average nitrogen content of aboveground biomass of herbage increased gradually from 1st fortnight of July to 2nd fortnight of September, thereafter it decreased. However, in natural grassland, pine based silvipastoral and hortipastoral systems the maximum average nitrogen content was recorded in 2nd fortnight of July, 2nd fortnight of September and 1st fortnight of September, respectively. Among the individual grasses, *Festuca rubra, Panicum maximum* and *Dactylis glomerata* contributed most to the average nitrogen content of the community at different fortnightly samplings. *Dactylis glomerata* exhibited the highest nitrogen content (1.58%) in 2nd fortnight of September while *Heteropogon contortus* showed the lowest nitrogen content (0.77%) in aboveground biomass in 1st fortnight of July.

b) **Belowground biomass**

The average nitrogen content (%) of belowground biomass of herbage in improved grassland varied from 0.65 to 0.98 per cent. It was evident from the data that average nitrogen content of belowground biomass gradually increased from 1st fortnight of July to 2nd fortnight of September, thereafter it decreased. The highest average nitrogen content of belowground biomass was recorded in 2nd fortnight of September whereas in natural grassland, pine based silvipastoral and hortipastoral system highest values for N per cent were recorded in 2nd fortnight of July, 1st fortnight of October and 1st fortnight of September respectively. Among the individual grasses, *Festuca rubra* attained the highest nitrogen content (1.05%) in 2nd fortnight of September while *Hemarthria protensa* showed the lowest nitrogen (0.52%) in 1st fortnight of July.

v) **Fodder trees based silvipastoral system**

a) **Aboveground biomass**

The average nitrogen content (%) of aboveground biomass of herbage in fodder trees based silvipastoral system ranged from 0.85 to 1.44 per cent. During the study period it explicated from data that the average nitrogen content of aboveground biomass increased steadily from 1st fortnight of July to 2nd fortnight of September, thereafter it decreased. The maximum average nitrogen content for aboveground biomass of herbage was recorded in 2nd fortnight of September similar to improved grassland but different from natural grassland, pine based silvipastoral and hortipastoral systems where the highest nitrogen content was recorded in 2nd fortnight of July, 2nd fortnight of September and 1st fortnight of September respectively. The average nitrogen content of aboveground biomass of herbage in different systems showed that in general, the highest average nitrogen content was observed in 1st and/or 2nd fortnight of September. Among the individual grasses, *Dactylis glomerata* exhibited the highest nitrogen content (1.78%) for aboveground biomass in 2nd fortnight of September while *Heteropogon contortus* showed the lowest nitrogen content (0.77%) in 1st fortnight of July.

b) **Belowground biomass**

The average nitrogen content (%) of belowground biomass in fodder trees based silvipastoral system varied from 0.73 to 1.02 per cent. It was clear from the data that average nitrogen content (%) of belowground biomass increased gradually from 1st fortnight of July to 2nd fortnight of September, then it decreased as in case of aboveground biomass. The maximum average nitrogen content of belowground biomass (1.02% N) was recorded in 2nd fortnight of September similar to improved grassland. But in case of natural grassland, pine based silvipastoral and hortipastoral systems, the maximum average nitrogen content was recorded in 1st fortnight of July, 1st fortnight of October and 1st fortnight of September, respectively. Among the individual grasses, *Dactylis glomerata* had the highest nitrogen content in belowground biomass (1.08%) in 1st fortnight of September whereas *Heteropogon contortus* showed the lowest nitrogen (0.69%) in 1st fortnight of July. It was evident from the data that the nitrogen content of belowground biomass was lower as compared to their aboveground counterparts at different samplings.

4.3.2 Phosphorus content of herbage

Phosphorus content of above ground and below ground biomass of herbage in different systems during the study period is presented in Table 13.

1. **Natural grassland**

a) **Aboveground biomass**

It evinced from the table that the average phosphorus content (%) of aboveground biomass of herbage in natural grassland varied from 0.07 to 0.14%. It was clear from the data that there was a constant increase in average phosphorus content from 1st fortnight of July to 2nd fortnight of September, thereafter it decreased. The highest average phosphorus content (0.14% P) of community aboveground biomass was recorded in 2nd fortnight of September, whereas, the lowest (0.07%) phosphorus content was recorded in 2nd fortnight of October. Among the individual grasses, *Panicum maximum* attained the

highest phosphorus content (0.17%) in 2nd fortnight of September while same species had the lowest phosphorus (0.06%) in 1st fortnight of July. The peak values of phosphorus content in different species were observed in 1st and/or 2nd fortnight of September.

b) Belowground biomass

The average phosphorus content (%) of belowground biomass of herbage in natural grassland fluctuated from 0.05 to 0.09 per cent during the study period. It evinced from the data that average phosphorus content of belowground biomass steadily increased from 1st fortnight of July to 2nd fortnight of September, thereafter it decreased. The highest average phosphorus content (0.09%) of belowground biomass was recorded in 2nd fortnight of September, while lowest average phosphorus content (0.05%) was recorded in 1st fortnight of October. Among the individual grasses, *Panicum maximum* attained the highest phosphorus content (0.11%) in 2nd fortnight of September while the lowest phosphorus content (0.02%) was recorded for same species in 1st fortnight of July.

ii) Pine based silvipastoral system

a) Aboveground biomass

It was clear from the Table 13 that the average phosphorus content (%) of aboveground biomass of herbage in pine based silvipastoral system varied from 0.098 to 0.13%. The data given in Table 13 depicted that there was constant increase in average phosphorus content of herbage from 1st fortnight of July to the 1st fortnight of September, thereafter, it decreased. The highest average phosphorus content of community above ground biomass (0.13%) was recorded in 1st fortnight of September. The lowest average phosphorus content of aboveground biomass (0.09%) was recorded in 1st fortnight of July, while in natural grassland it was recorded in 2nd fortnight of October. Among grasses, *Festuca rubra* attained the highest phosphorus content (0.15%) in 1st fortnight of September while the lowest phosphorus content (0.06%) was recorded for *Heteropogon contortus* in 1st fortnight of July.

Table 13. Variation in phosphorus (%) of different grass species in systems I (natural grassland), II (pine based silvipastoral system), III (horti-pastoral system), IV (improved grassland), V (fodder trees based silvipastoral system) during the study period at different sampling intervals. (Values in parentheses represent phosphorus per cent in belowground biomass)

Species	JULY										AUGUST									
	1st Fortnight					2nd Fortnight					1st Fortnight					2nd Fortnight				
	System					System					System					System				
	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V
Heteropogon contortus	0.06 (0.04)	0.06 (0.04)	0.08 (0.06)	0.06 (0.05)	0.07 (0.05)	0.09 (0.05)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Themeda triandra	-	-	-	-	-	-	-	-	-	-	-	-	-	0.09 (0.07)	-	0.08 (0.06)	-	-	0.08 (0.06)	-
Festuca rubra	0.06 (0.02)	0.08 (0.04)	0.07 (0.05)	0.08 (0.06)	0.08 (0.06)	0.07 (0.04)	0.09 (0.05)	0.09 (0.06)	0.08 (0.06)	0.08 (0.06)	0.08 (0.06)	0.11 (0.06)	0.10 (0.07)	0.10 (0.08)	0.10 (0.07)	0.11 (0.06)	0.09 (0.06)	0.10 (0.07)	0.11 (0.08)	0.11 (0.08)
Panicum maximum	0.10 (0.06)	0.10 (0.06)	0.06 (0.04)	0.07 (0.06)	-	0.06 (0.02)	0.10 (0.07)	0.09 (0.06)	-	-	0.08 (0.04)	0.12 (0.08)	0.10 (0.06)	-	0.09 (0.06)	0.15 (0.08)	0.12 (0.09)	0.09 (0.06)	0.10 (0.08)	0.10 (0.08)
Bromus inermis	0.12 (0.08)	-	-	-	-	-	-	0.09 (0.06)	0.09 (0.06)	-	-	-	-	-	-	-	-	-	-	-
Oplismenus compositus	0.13 (0.08)	-	-	-	0.08 (0.06)	0.13 (0.07)	-	-	-	0.08 (0.06)	-	-	-	-	-	-	-	-	-	-
Chrysopogon montanus	0.07 (0.04)	0.08 (0.06)	0.08 (0.05)	0.07 (0.04)	0.07 (0.06)	0.09 (0.05)	0.10 (0.07)	0.10 (0.06)	0.09 (0.06)	0.10 (0.07)	0.12 (0.05)	0.11 (0.08)	0.12 (0.06)	0.10 (0.07)	0.10 (0.08)	0.11 (0.07)	0.11 (0.08)	0.10 (0.07)	0.11 (0.07)	0.10 (0.08)
Hemarthria protensa	0.08 (0.04)	0.08 (0.06)	0.08 (0.06)	0.08 (0.05)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dactylis glomerata	-	-	0.07 (0.06)	0.08 (0.04)	0.08 (0.06)	-	-	0.08 (0.06)	0.09 (0.06)	0.10 (0.07)	-	-	0.09 (0.06)	0.11 (0.08)	0.10 (0.07)	-	-	0.10 (0.07)	0.12 (0.09)	0.12 (0.09)
Miscellaneous	-	0.11 (0.64)	-	-	-	0.18 (0.13)	0.12 (0.08)	0.10 (0.06)	-	-	0.09 (0.05)	0.13 (0.09)	-	0.10 (0.06)	-	-	0.13 (0.09)	0.11 (0.08)	0.10 (0.08)	-
Average	**0.09 (0.05)**	**0.09 (0.05)**	**0.07 (0.05)**	**0.07 (0.05)**	**0.08 (0.06)**	**0.11 (0.06)**	**0.10 (0.07)**	**0.09 (0.06)**	**0.09 (0.06)**	**0.09 (0.06)**	**0.09 (0.05)**	**0.12 (0.08)**	**0.10 (0.06)**	**0.10 (0.07)**	**0.10 (0.07)**	**0.11 (0.07)**	**0.11 (0.08)**	**0.10 (0.07)**	**0.10 (0.08)**	**0.10 (0.08)**

Species	SEPTEMBER										OCTOBER									
	1st Fortnight					2nd Fortnight					1st Fortnight					2nd Fortnight				
	System					System					System					System				
	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V
Heteropogon contortus	0.12 (0.06)	-	-	0.10 (0.07)	-	-	-	-	-	-	-	-	-	-	-	0.07 (0.05)	-	-	-	-
Themeda triandra	0.09 (0.07)	0.10 (0.07)	-	0.10 (0.08)	-	0.10 (0.07)	-	-	0.12 (0.08)	-	0.08 (0.06)	-	-	-	-	0.07 (0.04)	-	-	-	-
Festuca rubra	0.12 (0.08)	0.15 (0.08)	0.11 (0.08)	0.12 (0.10)	0.13 (0.10)	0.14 (0.09)	0.10 (0.07)	0.09 (0.06)	0.13 (0.10)	0.12 (0.10)	0.09 (0.06)	0.11 (0.07)	0.08 (0.06)	0.10 (0.09)	0.10 (0.09)	0.08 (0.05)	0.10 (0.07)	0.08 (0.06)	0.09 (0.06)	0.08 (0.06)
Panicum maximum	0.16 (0.10)	0.13 (0.10)	0.11 (0.07)	-	-	0.17 (0.11)	0.11 (0.07)	-	-	-	0.13 (0.05)	-	-	-	-	-	-	-	-	-
Bromus inermis	-	-	-	-	-	-	-	0.09 (0.07)	-	-	-	-	-	-	-	-	-	-	-	-
Oplismenus compositus	-	-	-	0.12 (0.08)	0.14 (0.12)	-	-	0.10 (0.08)	0.12 (0.10)	0.14 (0.12)	-	-	-	-	0.12 (0.10)	-	-	-	-	0.09 (0.08)
Chrysopogon montanus	-	-	-	-	-	0.14 (0.10)	0.09 (0.05)	-	-	-	0.10 (0.06)	-	0.09 (0.07)	-	-	0.07 (0.06)	0.08 (0.06)	0.08 (0.06)	0.09 (0.06)	0.10 (0.07)
Hemarthria protensa	-	-	-	-	-	-	-	-	-	-	-	-	-	0.09 (0.06)	-	-	-	-	-	-
Dactylis glomerata	-	-	0.11 (0.07)	0.13 (0.10)	0.12 (0.09)	-	-	0.11 (0.08)	0.12 (0.09)	0.11 (0.08)	-	-	0.11 (0.07)	0.11 (0.08)	0.10 (0.08)	-	-	0.10 (0.06)	0.09 (0.06)	0.10 (0.07)
Miscellaneous	-	0.15 (0.10)	-	-	-	-	0.13 (0.09)	-	-	-	-	0.13 (0.09)	-	-	-	-	0.12 (0.08)	-	-	-
Average	**0.12 (0.08)**	**0.13 (0.08)**	**0.11 (0.07)**	**0.11 (0.09)**	**0.13 (0.10)**	**0.14 (0.09)**	**0.11 (0.07)**	**0.10 (0.07)**	**0.12 (0.09)**	**0.12 (0.10)**	**0.10 (0.06)**	**0.12 (0.08)**	**0.09 (0.07)**	**0.10 (0.08)**	**0.11 (0.09)**	**0.07 (0.05)**	**0.10 (0.07)**	**0.09 (0.06)**	**0.09 (0.06)**	**0.09 (0.07)**

b) **Below ground biomass**

The average phosphorus content (%) of below ground biomass in pine based silvipastoral system varied from 0.05 to 0.08 per cent. The data showed that during the study period, in general, the average phosphorus content (0.08%) in below ground biomass of community remained constant. In natural grassland, phosphorus (%) increased steadily from 1st fortnight of July to 2nd fortnight of September. Among the individual grasses, *Paniccum maximum* attained the highest phosphorus content (0.09%) in 2nd fortnight of August and lowest phosphorus content (0.04%) was recorded for *Heteropogon contortus* in 1st fortnight of July. It was clear that the phosphorus content of below ground biomass remained less as compared to their respective above ground biomass counterparts.

iii) **Hortipastoral system**

a) **Above ground biomass**

It was evident from the Table 13 that the average phosphorus content (%) of above ground biomass of herbage in hortipastoral system ranged between 0.07 to 0.11 during the study period. A perusal of data depicted that there was steady increase in average phosphorus content of above ground biomass from 1st fortnight of July to 1st fortnight of September as in case of natural grassland and pine based silvipastoral system. The highest average phosphorus content (0.11%) of community above ground biomass was recorded in 1st fortnight of September as in case of pine based silvipastoral system. Among the individual grasses, *Festuca rubra, Panicum maximum* and *Dactylis glomerata* attained their highest phosphorus content in 1st fortnight of September. The highest phosphorus content (0.11%) was recorded for *Festuca rubra* in 1st fortnight of September while *Panicum maximum* exhibited the lowest phosphorus content (0.06%) in 1st fortnight of July.

b) Below ground biomass

The average phosphorus content of below ground biomass of herbage in hortipastoral system fluctuated between 0.05 to 0.07 per cent during the study period. It was recorded that the average phosphorus content of community below ground biomass remained constant as in case of pine based silvipastoral system contrary to natural grassland where a steady increase from 1st fortnight of July to 2nd fortnight of September was recorded. Among grasses, *Festuca rubra* exhibited the highest phosphorus content (0.08%) in 1st fortnight of September while the lowest (0.04%) was recorded for *Panicum maximum* in 1st fortnight of July.

iv) Improved grassland

a) Above ground biomass

The data given in Table 13 showed that average phosphorus content (%) in community above ground biomass of herbage in improved grassland ranged from 0.07 to 0.12 per cent. During the study period, the average phosphorus content of above ground biomass increased steadily from 1st fortnight of July to 2nd fortnight of September similar to natural grassland but in pine based silvipastoral and hortipastoral systems it increased upto 1st fortnight of September. The highest average phosphorus content (0.12% P) of above ground biomass was recorded in 2nd fortnight of September, thereafter it decreased similar to natural grassland, pine based silvipastoral and hortipastoral systems. Among individual grasses, *Dactylis glomerata* attained the highest phosphorus content (0.13%) in 1st fortnight of September while *Heteropogon contortus* attained the lowest phosphorus content (0.06%) in 1st fortnight of July.

b) Below ground biomass

The average phosphorus content (%) of below ground biomass of improved grassland varied from 0.05 to 0.09 per cent. During the study period, the average phosphorus content of below ground biomass increased steadily from 1st fortnight of July

to 2nd fortnight of September similar to the case of natural grassland while, in pine based silvipastoral and hortipastoral systems, it remained constant during the study period. The highest average phosphorus content (0.09%) in below ground biomass was recorded in 2nd fortnight of September as in case of natural grassland. Among individual grasses, most of the grasses attained their highest phosphorus content in 2nd fortnight of September. Further, it was noticed that phosphorus content of all species in below ground biomass was less as compared to their respective above ground counterparts.

v) Fodder trees based silvipastoral system

a) Above ground biomass

The average phosphorus content of above ground biomass of herbage in fodder trees based silvipastoral system ranged from 0.08 to 0.13 per cent. During the study period, there was a steady increase in average phosphorus content of community above ground biomass from 1st fortnight of July to 1st fortnight of September similar to pine based silvipastoral system and unlike other systems where it increased upto 2nd fortnight of September. The highest average phosphorus content of herbage was observed in 1st fortnight of September while the lowest was noticed in 1st fortnight of July. Among grasses, *Oplismenus compositus* attained the highest phosphorus content (0.14%) in 1st and 2nd fortnight of September, while, the lowest phosphorus content (0.07%) was recorded in *Heteropogen contortus* in 1st fortnight of July.

b) Below ground biomass

The data given in Table 13 revealed that average phosphorus content of community below ground biomass in fodder trees based silvipastoral system varied from 0.06 to 0.10 per cent. During the study period, it was found that there was a steady increase in average phosphorus content of below ground biomass from 1st fortnight of July to 2nd fortnight of September similar to the natural grassland while in other systems the average phosphorus content was nearly constant till 2nd fortnight of September, thereafter it decreased. The highest average phosphorus content in community below

ground biomass was recorded in September, while the lowest average phosphorus content was recorded in 1st fortnight of July. Among individual species, roots of *Dactylis glomerata* attained the highest phosphorus content (0.12%) in 2nd fortnight of August,while the lowest phosphorus content was recorded (0.05%) in *Heteropogan contorus* in 1st fortnight of July. It was evident from results that the phosphorus content of below ground biomass was less as compared to their above ground counterparts in all species during different sampling times.

4.3.3 Potassium content of herbage

The data relating to fortnightly variation in potassium content in aboveground and belowground biomass in different systems is presented in Table 14.

i) Natural grassland

a) Above ground biomass

It was evident from data, the average potassium content (%) in different grass species in natural grassland in above ground biomass varied from 0.64 to 1.11 per cent. Average potassium content of aboveground biomass increased steadily from 1st fortnight of July to 2nd fortnight of September, thereafter it decreased. The highest average potassium (1.11%) was recorded in 2nd fortnight of September. While the lowest average potassium content (0.64%) was recorded in 2nd fortnight of October. The performances of individual grass species showed that *Chrysopogon montanus* had the highest potassium content (1.26%) in 2nd fortnight of September and *Festuca rubra* had the lowest (0.52%) potassium content in 2nd fortnight of October. The peak values of potassium content was observed in 1st and/or 2nd fortnight of September.

b) Below ground biomass

The data in Table 14 revealed that the average potassium content in the roots of herbage vegetation in natural grassland ranged from 0.26 to 0.80 per cent. A scrutiny of data showed that average potassium content of belowground biomass increased gradually

Table 14. Variation in potassium (%) of different grass species in systems I (natural grassland), II (pine based silvipastoral system), III (horti-pastoral system), IV (improved grassland), V (fodder trees based silvipastoral system) during the study period at different sampling intervals. (Values in parentheses represent potassium per cent in belowground biomass)

Species	JULY										AUGUST									
	1st Fortnight					2nd Fortnight					1st Fortnight					2nd Fortnight				
	System					System					System					System				
	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V
Heteropogon contortus	0.60 (0.48)	0.58 (0.46)	0.72 (0.54)	0.4 (0.42)	0.68 (0.42)	0.74 (0.54)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Themeda triandra	-	-	-	-	-	-	-	-	-	-	-	-	-	0.88 (0.64)	-	0.98 (0.54)	-	-	0.84 (0.74)	-
Festuca rubra	0.56 (0.42)	0.68 (0.58)	0.70 (0.51)	0.86 (0.56)	0.84 (0.51)	0.54 (0.46)	0.82 (0.70)	0.78 (0.56)	0.76 (0.54)	0.96 (0.56)	0.62 (0.56)	0.90 (0.68)	0.84 (0.70)	0.96 (0.66)	1.08 (0.62)	0.84 (0.64)	0.90 (0.56)	0.84 (0.72)	1.10 (0.70)	1.12 (0.70)
Panicum maximum	0.74 (0.27)	0.70 (0.48)	0.68 (0.44)	0.76 (0.54)	-	0.66 (0.50)	0.96 (0.73)	0.88 (0.65)	-	-	0.78 (0.68)	1.26 (0.86)	0.95 (0.73)	-	0.96 (0.58)	1.08 (0.72)	1.18 (0.96)	0.88 (0.78)	1.04 (0.76)	1.18 (0.76)
Bromus inermis	0.84 (0.20)	-	-	-	-	-	-	0.86 (0.56)	0.74 (0.62)	-	-	-	-	-	-	-	-	-	-	-
Oplismenus compositus	0.76 (0.22)	-	-	-	0.78 (0.46)	0.72 (0.52)	-	-	-	1.00 (0.68)	-	-	-	-	-	-	-	-	-	-
Chrysopogon montanus	0.86 (0.22)	0.60 (0.44)	0.64 (0.50)	0.76 (0.54)	0.94 (0.68)	0.70 (0.46)	0.96 (0.64)	0.78 (0.60)	0.96 (0.70)	1.12 (0.78)	0.86 (0.72)	1.14 (0.84)	0.90 (0.62)	0.96 (0.68)	1.08 (0.70)	0.97 (0.63)	1.32 (0.90)	1.16 (0.86)	1.22 (0.78)	1.11 (0.74)
Hemarthria protensa	0.70 (0.25)	0.64 (0.42)	0.68 (0.42)	0.62 (0.44)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dactylis glomerata	-	-	0.78 (0.64)	0.72 (0.50)	0.96 (0.48)	-	-	1.02 (0.76)	0.82 (0.62)	1.02 (0.78)	-	-	1.04 (0.86)	0.94 (0.62)	1.04 (0.63)	-	-	1.46 (0.90)	1.12 (0.74)	1.04 (0.76)
Miscellaneous	-	0.92 (0.76)	-	-	-	1.04 (0.70)	1.10 (0.84)	0.98 (0.76)	-	-	0.75 (0.65)	1.74 (1.06)	-	1.18 (0.84)	-	-	1.88 (1.18)	1.46 (1.02)	1.08 (0.72)	-
Average	**0.72 (0.26)**	**0.69 (0.52)**	**0.70 (0.51)**	**0.73 (0.50)**	**0.84 (0.51)**	**0.73 (0.53)**	**0.96 (0.73)**	**0.88 (0.65)**	**0.82 (0.62)**	**1.03 (0.65)**	**0.75 (0.65)**	**1.26 (0.86)**	**0.95 (0.73)**	**0.98 (0.69)**	**1.04 (0.63)**	**0.97 (0.63)**	**1.32 (0.90)**	**1.16 (0.86)**	**1.07 (0.74)**	**1.11 (0.74)**

Species	SEPTEMBER										OCTOBER									
	1st Fortnight					2nd Fortnight					1st Fortnight					2nd Fortnight				
	System					System					System					System				
	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V
Heteropogon contortus	0.96 (0.70)	-	-	1.00 (0.76)	-	-	-	-	-	-	-	-	-	-	-	0.70 (0.54)	-	-	-	-
Themeda triandra	1.02 (0.62)	1.10 (0.62)	-	1.12 (0.78)	-	1.14 (0.76)	-	-	1.02 (0.70)	-	0.68 (0.50)	-	-	-	-	0.58 (0.42)	-	-	-	-
Festuca rubra	1.00 (0.70)	1.16 (0.80)	0.96 (0.82)	1.14 (0.76)	1.24 (0.78)	1.04 (0.72)	1.02 (0.66)	0.84 (0.70)	1.12 (0.68)	1.18 (0.82)	0.60 (0.42)	0.90 (0.64)	0.76 (0.58)	0.78 (0.56)	1.00 (0.70)	0.52 (0.34)	0.90 (0.65)	0.62 (0.48)	0.82 (0.60)	0.60 (0.46)
Panicum maximum	1.10 (0.78)	1.42 (0.91)	1.26 (0.84)	-	-	0.98 (0.70)	1.24 (0.81)	-	-	-	0.82 (0.52)	-	-	-	-	-	-	-	-	-
Bromus inermis	-	-	-	-	-	-	-	1.10 (0.88)	-	-	-	-	-	-	-	-	-	-	-	-
Oplismenus compositus	-	-	-	1.02 (0.64)	1.30 (0.90)	-	-	1.16 (0.84)	1.04 (0.76)	1.18 (0.84)	-	-	-	-	1.02 (0.76)	-	-	-	-	0.72 (0.50)
Chrysopogon montanus	-	-	-	-	-	1.26 (1.02)	0.96 (0.72)	-	-	-	1.12 (0.88)	-	0.86 (0.70)	-	-	0.76 (0.42)	0.76 (0.44)	0.98 (0.42)	0.86 (0.58)	0.74 (0.48)
Hemarthria protensa	-	-	-	-	-	-	-	-	-	-	-	-	-	0.62 (0.52)	-	-	-	-	-	-
Dactylis glomerata	-	-	1.68 (1.06)	1.24 (0.96)	1.10 (0.90)	-	-	1.38 (0.96)	1.06 (0.82)	1.14 (0.86)	-	-	1.04 (0.74)	1.08 (0.74)	0.96 (0.64)	-	-	0.88 (0.56)	0.78 (0.62)	0.88 (0.50)
Miscellaneous	-	2.00 (1.30)	-	-	-	-	1.46 (1.04)	-	-	-	-	1.22 (0.90)	-	-	-	-	1.04 (0.86)	-	-	-
Average	**1.02 (0.70)**	**1.42 (0.91)**	**1.30 (0.91)**	**1.10 (0.78)**	**1.21 (0.86)**	**1.11 (0.80)**	**1.24 (0.81)**	**1.12 (0.85)**	**1.06 (0.74)**	**1.17 (0.84)**	**0.70 (0.58)**	**1.06 (0.77)**	**0.89 (0.67)**	**0.83 (0.61)**	**0.99 (0.70)**	**0.64 (0.42)**	**0.90 (0.65)**	**0.83 (0.49)**	**0.82 (0.60)**	**0.74 (0.48)**

from 1st fortnight of July to 2nd fortnight of September, thereafter, it decreased. The individual performances of different species showed that *Chrysopogon montanus* attained the highest potassium content (1.02%) in 2nd fortnight of September while the *Bromus inermis* had the lowest potassium content (0.20%) in 1st fortnight of July. The peak values of potassium (%) in different species were recorded in 1st and/or 2nd fortnight of September. The values for potassium content in belowground biomass were less as compared to their respective above ground counterparts at different sampling times.

ii) Pine based silvipastoral system

a) Above ground biomass

The average potassium content (%) of different grass species in above ground biomass in pine based silvipastoral system ranged from 0.69 to 1.42 per cent. A perusal of data revealed that there was a continuous increase in average potassium content of above ground biomass from 1st fortnight of July to 1st fortnight of September. The highest average potassium content was observed in 1st fortnight of September, while the lowest was recorded in 1st fortnight of July similar to the results recorded for natural grassland. Among the individual species, *Panicum maximum* attained the highest potassium content (1.18%) in 2nd fortnight of August while *Heteropogan contortus* exhibited lowest (0.58%) value in 1st fortnight of July.

b) Below ground biomass

The data in Table 14 revealed that the average potassium content (%) in community below ground biomass of herbage in pine based silvipastoral system varied from 0.52 to 0.91%. It was also evident that there was gradual increase in average potassium content of below ground biomass from 1st fortnight of July to 1st fortnight of September, thereafter it decreased. Contrary to it in natural grassland potassium content increased upto 2nd fortnight of September. The highest average potassium content (0.91%) was recorded in 1st fortnight of September. Among the individual grasses, *Panicum maximum* attained the highest potassium content (0.96%) in 2nd fortnight of August while *Hemarthria protensa* exhibited the lowest potassium content (0.42%) in 1st fortnight of July.

iii) Hortipastoral system

a) Above ground biomass

A review of data in Table 14. showed that the average potassium content of different grass species in hortipastoral system in community above ground biomass varied from 0.70 to 1.30 per cent. A scrutiny of data showed that the average potassium content of above ground biomass increased steadily from 1st fortnight of July to 1st fortnight of September similar to pine based silvipastoral system but in natural grassland it contained upto 2nd fortnight of September, thereafter, it decreased. The highest average potassium content (1.30%) was recorded in 1st fortnight of September, while, the lowest (0.70%) was recorded in 1st fortnight of July. Among grasses highest potassium content (1.68%) was recorded for *Dactylis glomerata* in 1st fortnight of September while the lowest (0.64%) was observed for *Hemarthria protensa* in 1st fortnight of July. The peak values for different species were recorded in 2nd fortnight of August and/or 1st fortnight of September similar to the pine based silvipastoral system.

b) Below ground biomass

The average potassium content of different species in below ground biomass in hortipastoral system fluctuated from 0.49 to 0.91 per cent. A perusal of data revealed that the average potassium content of below ground biomass increased steadily from 1st fortnight of July to 1st fortnight of September similar to the case of pine based silvipastoral system, thereafter it decreased. The highest average potassium content was (0.91%) recorded in 1st fortnight of September. The performance of individual species showed that *Dactylis glomerata* attained the highest potassium content (1.06%) in 1st fortnight of September, while, the lowest was recorded (0.42%) for *Hemarthria protensa* in 1st fortnight of July. The values for potassium content in below ground biomass were less as compared to their respective above ground counterparts.

iv) **Improved grassland**

a) **Above ground biomass**

The data in Table 14 revealed that the average potassium content in community aboveground biomass of herbage in improved grassland fluctuated between 0.73 and 1.10 per cent. It evinced from the data that there was gradual increase in average potassium content of above ground biomass from 1st fortnight of July to 1st fortnight of September similar to the case of pine based silvipastoral and hortipastoral systems, thereafter, it decreased. Among individual grass species the highest potassium content (1.24%) was recorded for *Dactylis glomerata* in 1st fortnight of September, while, the lowest was recorded (0.40%) for *Heteropogon contortus* in 1st fortnight of July. The peak values for individual species were recorded in 2nd fortnight of August and/or 1st fortnight of September.

b) **Below ground biomass**

The average potassium content of different grass species in below ground biomass of herbage under improved grassland varied from 0.50 to 0.78 per cent. It was evident from the data that there was a gradual increase in the average potassium content of below ground biomass from 1st fortnight of July to 1st fortnight of September similar to the findings in pine based silvipastoral and hortipastoral systems, thereafter, it decreased. The highest average potassium content (0.78%) was observed in 1st fortnight of September while the lowest (0.50%) was observed in 1st fortnight of July. The performances of individual grass species showed that *Dactylis glomerata* attained highest (0.96%) potassium content in 1st fortnight of September while the lowest (0.42%) was recorded for *Heteropogon contortus* in 1st fortnight of July. The potassium content of below ground biomass was less as compared to their respective above ground counterparts in different species at different sampling dates.

v) **Fodder trees based silvipastoral system**

a) **Above ground biomass**

It evinced from the data in Table 14 that the average potassium content of different grass species in fodder trees based silvipastoral system in above ground biomass fluctuated between 0.80 and 1.21 per cent. It further revealed that the average potassium content of above ground biomass increased gradually from 1st fortnight of July to 1st fortnight of September similar to pine based silvipastoral hortipastoral systems, and improved grassland, thereafter, it decreased. Among individual grass species, *Oplismenus compositus* attained the highest (1.30%) potassium in 1st fortnight of September while the lowest was recorded as (0.60%) for *Themeda triandra* in 2nd fortnight of October. The peak values for different grass species were recorded in 1st and/or 2nd fortnight of September.

b) **Below ground biomass**

The average potassium content in belowground biomass of different grass species in fodder trees based silvipastoral system varied from 0.48 to 0.86 per cent. A scrutiny of data revealed that the average potassium content of below ground biomass increased steadily from 1st fortnight of July to 1st fortnight of September similar to the case pine based silvipastoral, hortipastoral systems and improved grassland, thereafter, it decreased. The highest average potassium content in below ground biomass was recorded (0.86%) in 1st fortnight of September, while, the lowest was recorded (0.48%) in 2nd fortnight of September. Among individual grass species *Oplismenus compositus* attained highest (0.90%) potassium content in 1st fortnight of September, while, lowest (0.42%) was recorded for *Heteropogon contortus* in 1st fortnight of July. The highest values for potassium content in below ground biomass for individual species were recorded in 1st and/or 2nd fortnight of September.

4.3.4 Calcium content of herbage

The data relating to fortnightly changes in calcium content in community above ground and below ground biomass in different systems is presented in Table 15.

Table 15. Variation in calcium (%) of different grass species in systems I (natural grassland), II (pine based silvipastoral system), III (horti-pastoral system), IV (improved grassland), V (fodder trees based silvipastoral system) during the study period at different sampling intervals. (Values in parentheses represent calcium per cent in belowground biomass)

Species	JULY										AUGUST									
	1st Fortnight					2nd Fortnight					1st Fortnight					2nd Fortnight				
	System					System					System					System				
	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V
Heteropogon contortus	1.60 (0.96)	1.68 (0.98)	1.68 (1.42)	2.30 (1.94)	2.24 (1.70)	1.69 (1.30)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Themeda triandra	-	-	-	-	-	-	-	-	-	-	-	-	-	2.66 (2.20)	-	1.12 (0.86)	-	-	2.08 (1.70)	-
Festuca rubra	1.64 (1.20)	1.56 (1.46)	2.00 (1.66)	2.36 (1.76)	2.59 (1.92)	1.50 (1.16)	1.50 (1.42)	2.34 (1.90)	1.90 (1.50)	2.96 (2.62)	1.36 (1.04)	1.48 (1.40)	2.28 (1.84)	1.82 (1.40)	2.84 (2.52)	1.16 (0.94)	2.36 (1.84)	1.96 (1.68)	1.74 (1.38)	2.76 (2.28)
Panicum maximum	1.61 (1.22)	1.42 (1.18)	2.24 (1.90)	2.62 (1.88)	-	1.36 (1.06)	2.07 (1.72)	2.58 (2.09)	-	-	1.78 (1.42)	1.83 (1.50)	1.99 (1.62)	-	2.40 (1.80)	1.12 (0.88)	1.18 (0.98)	1.94 (1.64)	1.58 (1.26)	2.02 (1.76)
Bromus inermis	1.62 (1.36)	-	-	-	-	-	-	1.74 (1.38)	1.94 (1.68)	-	-	-	-	-	-	-	-	-	-	-
Oplismenus compositus	1.62 (1.24)	-	-	-	2.86 (2.14)	-	-	-	-	2.64 (1.96)	-	-	-	-	-	-	-	-	-	-
Chrysopogon montanus	1.60 (1.40)	1.66 (1.46)	2.10 (1.56)	3.04 (2.52)	2.36 (1.96)	1.46 (1.36)	1.62 (1.38)	2.08 (1.50)	2.76 (2.26)	2.28 (1.64)	1.40 (1.20)	1.56 91.22)	1.96 (1.46)	1.90 (1.52)	2.40 (1.88)	1.13 (0.89)	1.83 (1.53)	2.10 (1.80)	1.64 (1.32)	2.40 (1.94)
Hemarthria protensa	1.63 (1.24)	1.64 (1.46)	1.70 (1.36)	1.64 (1.30)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dactylis glomerata	-		2.30 (2.08)	2.22 (1.98)	2.88 (1.88)	-	-	2.26 (1.84)	2.20 (1.84)	2.18 (1.81)	-	-	1.74 (1.56)	1.94 (1.70)	2.54 (2.06)	-	-	1.50 (1.40)	1.88 (1.64)	2.42 (1.78)
Miscellaneous	-	4.38 (2.64)	-	-	-	2.40 (1.58)	3.08 (2.36)	4.48 (1.84)	-	-	1.51 (1.22)	2.44 (1.88)	-	3.06 (2.28)	-	-	1.96 (1.76)	3.00 (2.46)	1.68 (1.54)	-
Average	**1.62 (1.23)**	**2.06 (1.53)**	**2.00 (1.66)**	**2.36 (1.90)**	**2.59 (1.92)**	**1.68 (1.29)**	**2.07 (1.72)**	**2.58 (2.04)**	**2.20 (1.81)**	**2.52 (1.96)**	**1.51 (1.22)**	**1.83 (1.50)**	**1.99 (1.62)**	**2.28 (1.82)**	**2.54 (2.06)**	**1.13 (0.89)**	**1.83 (1.53)**	**2.10 (1.80)**	**1.77 (1.48)**	**2.40 (1.94)**

Species	SEPTEMBER										OCTOBER									
	1st Fortnight					2nd Fortnight					1st Fortnight					2nd Fortnight				
	System					System					System					System				
	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V
Heteropogon contortus	1.16 (0.82)	-	-	1.78 (1.46)	-	-	-	-	-	-	-	-	-	-	-	0.96 (0.72)	-	-	-	-
Themeda triandra	1.08 (0.72	2.16 (1.70)	-	2.40 (1.96)	-	1.02 (0.64)	-	-	1.88 (1.70)	-	0.96 (0.62)	-	-	-	-	0.90 (0.60)	-	-	-	-
Festuca rubra	0.96 (0.86)	1.48 (1.38)	1.78 (1.50)	1.82 (1.40)	2.58 (2.10)	0.92 (0.80)	1.06 (1.00)	1.64 (1.36)	1.62 (1.48)	1.92 (1.62)	0.88 (0.76)	1.46 (1.30)	1.46 (1.30)	1.54 (1.36)	1.74 (1.56)	0.82 (0.68)	1.06 (0.93)	1.46 (1.28)	1.59 (1.39)	2.04 (1.68)
Panicum maximum	0.92 (0.78)	1.77 (1.49)	1.70 (1.16)	-	-	0.90 (0.78)	1.28 (1.08)	-	-	-	0.80 (0.72)	-	-	-	-	-	-	-	-	-
Bromus inermis	-	-	-	-	-	-	-	1.28 (1.12)	-	-	-	-	-	-	-	-	-	-	-	1.74 (1.44)
Oplismenus compositus	-	-	-	1.52 (1.08)	2.14 (1.88)	-	-	1.56 (1.30)	2.26 (1.82)	1.88 (1.72)	-	-	-	-	1.78 (1.52)	-	-	-	-	1.56 (1.38)
Chrysopogon montanus	-	-	-	-	-	1.20 (1.08)	1.36 (1.08)	-	-	-	1.02 (0.82)	-	1.68 (1.24)	-	-	0.78 (0.64)	1.00 (0.90)	1.54 (1.30)	1.56 (1.36)	2.02 (1.76)
Hemarthria protensa	-	-	-	-	-	-	-	-	-	-	-	-	-	1.58 (1.261	-	-	-	-	-	-
Dactylis glomerata	-	-	1.76 (1.36)	1.78 (1.56)	2.08 (1.74)	-	-	1.60 (1.16)	1.68 (1.50)	1.96 (1.70)	-	-	1.62 (1.04)	1.66 (1.48)	2.18 (1.58)	-	-	1.50 (1.10)	1.62 (1.42)	1.72 (1.44)
Miscellaneous	-	1.66 (1.38)	-	-	-	-	1.42 (1.16)	-	-	-	-	1.22 (1.10)	-	-	-	-	1.12 (0.96)	-	-	-
Average	**1.03 (0.80)**	**1.77 (1.49)**	**1.75 (1.34)**	**1.86 (1.49)**	**2.27 (1.91)**	**1.01 (0.83)**	**1.2824 (1.08)**	**1.52 (1.24)**	**1.86 (1.63)**	**1.92 (1.68)**	**0.92 (0.73)**	**1.38 (1.20)**	**1.59 (1.19)**	**1.59 (1.37)**	**1.90 (1.55)**	**0.86 (0.66)**	**1.06 (0.93)**	**1.50 (1.22)**	**1.59 (1.39)**	**1.74 (1.56)**

i) Natural grassland

a) Above ground biomass

It was evident from the data that the average calcium content in different grass species in natural grassland fluctuated between 0.86 to 1.68 per cent. During the study period, it was observed that average calcium content of community above ground biomass decreased from 2nd fortnight of July to 2nd fortnight of October. The highest value for average calcium content (1.68%) was recorded in 2nd fortnight of July while the lower calcium content (0.86%) was recorded in 2nd fortnight of October. Among the individual species, *Festuca rubra* attained the highest (1.64%) calcium content in 1st fortnight of July, while, the lowest (0.78%) was recorded for *Chrysopogon montanus* in 2nd fortnight of October. The peak values of calcium content in all the species were recorded in 1st and/or 2nd fortnight of July.

b) Below ground biomass

The average calcium content of below ground biomass of herbage in natural grassland ranged from 0.66 to 1.29 per cent. It was evident from data that the average calcium content of below ground biomass decreased from 2nd fortnight of July to 2nd fortnight of October as in case of above ground biomass. The highest average calcium content (1.29%) of below ground biomass was recorded in 2nd fortnight of July. While the lowest average calcium content (0.66%) was recorded in 2nd fortnight of October. The calcium content of individual species showed that *Festuca rubra* attained the highest calcium content (1.64%) in 1st fortnight of July while lowest (0.78%) was recorded from *Chrysopogon montanus* in 2nd fortnight of October.

ii) Pine based silvipastoral system

a) Above ground biomass

The average calcium content of above ground biomass of vegetation in pine based silvipastoral system varied from 1.06 to 2.07 per cent. It was evinced from data that average calcium content of above ground biomass decreased continuously from 2nd

fortnight of July to 2nd fortnight of October as in case of natural grassland. The highest average calcium content was recorded (2.07%) in 2nd fortnight of July, while, the lowest was (1.06%) recorded in 2nd fortnight of October. Among individual species *Chrysopogon montanus* attained the highest calcium (1.66%) in Ist fortnight of July, while, the same species had lowest (1.00%) calcium content in 2nd fortnight of October. The peak values of calcium per cent was recorded in Ist fortnight of July for all the species.

b) **Below ground biomass**

It was evident from the data that the average calcium content of below ground biomass in pine based silvipastoral system varied from 0.93 to 1.72 per cent. It was further noticed that the average calcium content of community below ground biomass decreased from 2nd fortnight of July to 2nd fortnight of October as in case of natural grassland. The highest calcium content (1.72%) in below ground biomass was recorded in 2nd fortnight of July, while, the lowest (0.93%) was recorded in 2nd fortnight of October. Among individual grass species, *Festuca rubra* attained highest (1.46%) calcium content in 1st fortnight of July and lowest (0.90%) was recorded for *Chrysopogon montanus* in 2nd fortnight of October.

iii) **Hortipastoral system**

a) **Above ground biomass**

The average calcium content of above ground biomass in hortipastoral system varied from 1.50 to 2.58 per cent. A scrutiny of data revealed that the average calcium content of above ground biomass decreased gradually from 2nd fortnight of July to 2nd fortnight of October as in case of natural grassland and pine based silvipastoral system. The highest average calcium content was recorded (2.58%) in 2nd fortnight of July, while, lowest was recorded (1.50%) in 2nd fortnight of October similar to natural grassland and pine based silvipastoral system. Among the individual species *Panicum maximum* attained the highest (2.24%) calcium content in 1st fortnight of July while lowest (1.46%) was recorded for *Festuca rubra* in 1st fortnight of October.

b) Below ground biomass

It was evident from data that the average calcium content of community below ground biomass in hortipastoral system ranged from 1.19 to 2.04 per cent. It was further noticed that the highest average calcium content was recorded (2.04%) in 2nd fortnight of July similar to natural grassland and pine based silvipastoral system. The lowest (1.19%) average calcium content was recorded in 1st fortnight of October, while, it was recorded for 2nd fortnight of October in natural grassland and pine based silvipastoral system. Among the performances of individual species *Dactylis glomerata* attained highest (2.08%) calcium per cent in 1st fortnight of July, while, the lowest (1.28%) was recorded for *Themeda triandra* in 2nd fortnight of October.

iv) Improved grassland

a) Above ground biomass

The average calcium content of community above ground biomass of herbage in improved grassland varied from 1.59 to 2.36 per cent. During the study period average calcium content of above ground biomass decreased continuously from 1st fortnight of July to 2nd fortnight of October. The highest average calcium content (2.36%) was recorded in 1st fortnight of July contrary to the natural grassland, pine based silvipastoral and hortipastoral systems where, highest values were recorded in 2nd fortnight of July. The lowest average calcium content (1.59%) was recorded in 2nd fortnight of October similar to natural grassland, pine based silvipastoral and hortipatoral systems. Among the performances of individual grasses *Chrysopogon montanus* attained the highest (3.04%) calcium content in 1st fortnight of July, while, the lowest (1.56%) calcium content was recorded for some species in 2nd fortnight of October.

b) Below ground biomass

It was clear from the data in Table 15 that the average calcium content of community below ground biomass in improved grassland varied from 1.39 to 1.90 per cent. It was further noticed that the average calcium content decreased from 1st fortnight of July to 2nd fortnight of October. The highest average calcium content (1.90%) was

recorded in 1st fortnight of July while in natural grassland, pine based silvipastoral and hortipastoral systems, the highest values were recorded in 2nd fortnight of July. The lowest (1.39%) average calcium content was recorded in 2nd fortnight of October similar to natural grassland, pine based silvipastoral and hortipastoral systems. The performances of individual species showed that *Chrysopogon montanus* attained highest (2.52%) calcium content in 1st fortnight of July and lowest (1.36%) was recorded for the same species in 2nd fortnight of October.

v) Fodder trees based silvipastoral system

a) Above ground biomass

The data in Table 15 showed that the average calcium content of community above ground biomass in fodder trees based silvipastoral system varied from 1.74 to 2.59 per cent. A perusal of data revealed that the average calcium content decreased from 1st fortnight of July to 2nd fortnight of October similar as in case of improved grassland but in other systems it started to decrease from 2nd fortnight of July. The highest average calcium content of herbage (2.59%) was recorded in 1st fortnight of October. Among individual species *Dactylis glomerata* attained highest (2.88%) calcium content in 1st fortnight of July and lowest (1.36%) was recorded for *Chrysopogon montanus* in 2nd fortnight of October.

b) Below ground biomass

The average calcium content of community below ground biomass of herbage under fodder trees based silvipastoral system ranged from 1.46 to 2.06 per cent. It was evident from data that the average calcium content decreased from 1st and/or 2nd fortnight of July to October. The highest average calcium content (2.06%) was recorded in 1st fortnight of August, while, lowest (1.46%) was recorded in 2nd fortnight of October. The performances of individual species showed that *Festuca rubra* attained highest (2.96%) calcium content in 2nd fortnight of July, while, lowest (1.38%) calcium content was recorded for *Oplismenus compositus* in 2nd fortnight of October. The values of calcium per cent was less in below ground biomass as compared to their respective above ground counterparts in all the species.

4.3.5 Magnesium content of herbage

The data relating to fortnightly changes in magnesium content in aboveground and belowground biomass in different systems is presented in Table 16.

i) Natural grassland

a) Aboveground biomass

It was evident from the data that the average magnesium content of aboveground biomass in natural grassland fluctuated from 0.42 to 0.60 per cent during the study period. It was recorded that average magnesium content of herbage aboveground biomass increased steadily from 1st fortnight of July to 1st fortnight of October. The highest average magnesium content was recorded (0.60^) in 1st fortnight of October, while, the lowest was recorded (0.42%) in 1st fortnight of September. Performance of individual grass species showed that *Panicum maximum* attained the highest magnesium content (0.73%) in 1st fortnight of September, while, the lowest magnesium content (0.25%) was recorded for *Heteropogon contotrum* in 1st fortnight of July.

b) Belowground biomass

The average magnesium content of belowground biomass in natural grassland fluctuated from 0.24 to 0.33 per cent during the study period. A perusal of data revealed that variations in average magnesium content of community in belowground biomass along the season did not show any particular trend. The highest average magnesium content (0.33%) was recorded in 2nd fortnight of September, while, lowest (0.24%) average magnesium content was recorded in 2nd fortnight. *Bronus inermis* attained the highest magnesium content (0.50%) in 1st fortnight of July, while, the lowest (0.148%) magnesium content was recorded for *Heteropogon contortus* in 1st fortnight of July. The values for the magnesium content in belowground biomass was less as compared to their respective aboveground counterparts in all the species on different sampling dates.

ii) **Pine based silvipastoral system**

a) **Aboveground biomass**

The data in the Table 16 revealed that the average magnesium content of community aboveground biomass in pine based silvipastoral system varied from 0.38 to 0.53 per cent during the study period. It was recorded that the average magnesium content gradually increased from 1st fortnight of July to 2nd fortnight of October similar to natural grassland. The highest average magnesium content was recorded (0.53%) in 2nd fortnight of October and the lowest (0.38%) average magnesium content was recorded in 1st fortnight of September. Among the individual grass species, *Festuca rubra* attained the highest (0.58%) magnesium content in 2nd fortnight of August, while, *Heteropogon controtus* exhibited the lowest (0.32%) magnesium content in 1st fortnight of July.

b) **Belowground biomass**

The average magnesium content of community belowground biomass in pine based silvipastoral system during the study period varied from 0.26 to 0.40 per cent. A scrutiny of data in Table 16 revealed that the average magnesium content increased from July to October. The highest average magnesium content was recorded (0.40%) in 2nd fortnight of October, while, the lowest average magnesium content (0.26%) was recorded in 1st fortnight of July. Among the individual species, *Festuca rubra* attained the highest (0.40%) magnesium content in 2nd fortnight of October, while, lowest (0.20%) magnesium content for same species was recorded in 1st fortnight of July.

iii) **Hortipastoral system**

a) **Aboveground biomass**

The average magnesium content of community belowground biomass in hortipastoral system ranged from 0.33 to 0.46 per cent during the study period. It was clear from results that the average magnesium content increased gradually from 1st fortnight of July to 2nd fortnight of September, thereafter, it decreased, but in natural grassland it increased upto 1st fortnight of October and in pine based silvipastoral system

Table 16. Variation in magnesium (%) of different grass species in systems I (natural grassland), II (pine based silvipastoral system), III (horti-pastoral system), IV (improved grassland), V (fodder trees based silvipastoral system) during the study period at different sampling intervals. (Values in parentheses represent magnesium per cent in belowground biomass)

Species	JULY										AUGUST									
	1st Fortnight					2nd Fortnight					1st Fortnight					2nd Fortnight				
	System					System					System					System				
	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V
Heteropogon contortus	0.25 (0.148)	0.32 (0.23)	0.32 (0.24)	0.22 (0.14)	0.46 (0.27)	0.56 (0.31)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Themeda triandra	-	-	-	-	-	-	-	-	-	-	-	-	-	0.44 (0.28)	-	0.19 (0.15)	-	-	0.37 (0.23)	-
Festuca rubra	0.29 (0.17)	0.35 (0.20)	0.33 (0.20)	0.23 (0.15)	0.36 (0.22)	0.35 (0.19)	0.39 (0.23)	0.23 (0.16)	0.27 (0.16)	0.33 (0.23)	0.43 (0.25)	0.43 (0.32)	0.24 (0.17)	0.25 (0.18)	0.35 (0.23)	0.49 (0.28)	0.37 (0.20)	0.25 (0.18)	0.31 (0.19)	0.37 (0.24)
Panicum maximum	0.51 (0.33)	0.34 (0.27)	0.27 (0.14)	0.48 (0.33)	-	0.55 (0.32)	0.45 (0.28)	0.33 (0.20)	-	-	0.53 (0.30)	0.50 (0.32)	0.34 (0.22)	-	0.42 (0.24)	0.71 (0.28)	0.58 (0.33)	0.29 (0.18)	0.58 (0.39)	0.40 (0.23)
Bromus inermis	0.66 (0.50)	-	-	-	-	-	-	0.22 (0.16)	0.34 (0.16)	-	-	-	-	-	-	-	-	-	-	-
Oplismenus compositus	0.64 (0.47)	-	-	-	0.32 (0.17)	0.54 (0.33)	-	-	-	0.32 (0.20)	-	-	-	-	-	-	-	-	-	-
Chrysopogon montanus	0.61 (0.27)	0.43 (0.26)	0.32 (0.17)	0.42 (0.27)	0.25 (0.19)	0.64 (0.30)	0.49 (0.27)	0.37 (0.18)	0.63 (0.48)	0.38 (0.23)	0.65 (0.37)	0.56 (0.30)	0.39 (0.19)	0.76 (0.49)	0.38 (0.23)	0.46 (0.24)	0.49 (0.31)	0.38 (0.30)	0.79 (0.52)	0.40 (0.25)
Hemarthria protensa	0.47 (0.29)	0.45 (0.27)	0.43 (0.27)	0.45 (0.39)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dactylis glomerata	-	-	0.29 (0.17)	0.26 (0.19)	0.42 (0.23)	-	-	0.34 (0.18)	0.41 (0.27)	0.39 (0.19)	-	-	0.40 (0.29)	0.28 (0.19)	0.38 (0.23)	-	-	0.46 (0.38)	0.33 (0.23)	0.44 (0.27)
Miscellaneous	-	0.45 (0.32)	-	-	-	0.66 (0.46)	0.47 (0.34)	0.50 (0.33)	-	-	0.55 (0.32)	0.50 (0.35)	-	0.58 (0.43)	-	-	0.51 (0.39)	0.53 (0.46)	0.29 (0.27)	-
Average	**0.49 (0.31)**	**0.39 (0.26)**	**0.33 (0.20)**	**0.34 (0.25)**	**0.36 (0.22)**	**0.49 (0.27)**	**0.45 (0.28)**	**0.33 (0.20)**	**0.41 (0.27)**	**0.36 (0.21)**	**0.55 (0.28)**	**0.50 (0.32)**	**0.34 (0.22)**	**0.46 (0.31)**	**0.38 (0.23)**	**0.46 (0.24)**	**0.49 (0.31)**	**0.38 (0.30)**	**0.45 (0.29)**	**0.40 (0.25)**

Species	SEPTEMBER										OCTOBER									
	1st Fortnight					2nd Fortnight					1st Fortnight					2nd Fortnight				
	System					System					System					System				
	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V
Heteropogon contortus	0.27 (0.18)	-	-	0.41 (0.25)	-	-	-	-	-	-	-	-	-	-	-	0.27 (0.19)	-	-	-	-
Themeda triandra	0.20 (0.16)	0.44 (0.22)	-	0.46 (0.38)	-	0.28 (0.18)	-	-	0.47 (0.40)	-	0.45 (0.22)	-	-	-	-	0.49 (0.23)	-	-	-	-
Festuca rubra	0.46 (0.28)	0.43 (0.34)	0.32 (0.21)	0.38 (0.20)	0.37 (0.25)	0.41 (0.29)	0.46 (0.25)	0.30 (0.22)	0.38 (0.23)	0.45 (0.26)	0.57 (0.33)	0.47 (0.37)	0.39 (0.25)	0.42 (0.21)	0.42 (0.27)	0.57 (0.35)	0.53 (0.40)	0.37 (0.26)	0.57 (0.37)	0.55 (0.27)
Panicum maximum	0.73 (0.36)	0.38 (0.32)	0.52 (0.19)	-	-	0.73 (0.40)	0.50 (0.32)	-	-	-	0.79 (0.40)	-	-	-	-	-	-	-	-	-
Bromus inermis	-	-	-	-	-	-	-	0.61 (0.19)	-	-	-	-	-	-	-	-	-	-	-	-
Oplismenus compositus	-	-	-	0.30 (0.18)	0.41 (0.24)	-	-	0.37 (0.18)	0.34 (0.19)	0.43 (0.30)	-	-	-	-	0.48 (0.37)	-	-	-	-	0.51 (0.46)
Chrysopogon montanus	-	-	-	-	-	0.70 (0.43)	0.52 (0.34)	-	-	-	0.60 (0.32)	-	0.38 (0.25)	-	-	0.78 (0.42)	0.46 (0.37)	0.37 (0.28)	0.60 (0.25)	0.44 (0.30)
Hemarthria protensa	-	-	-	-	-	-	-	-	-	-	-	-	-	0.45 (0.39)	-	-	-	-	-	-
Dactylis glomerata	-	-	0.54 (0.39)	0.37 (0.23)	0.43 (0.29)	-	-	0.55 (0.43)	0.37 (0.25)	0.48 (0.32)	-	-	0.57 (0.43)	0.39 (0.26)	0.49 (0.36)	-	-	0.55 (0.44)	0.53 (0.48)	0.51 (0.37)
Miscellaneous	-	0.57 (0.41)	-	-	-	-	0.55 (0.40)	-	-	-	-	0.56 (0.42)	-	-	-	-	0.59 (0.43)	-	-	-
Average	**0.42 (0.25)**	**0.38 (0.32)**	**0.46 (0.26)**	**0.38 (0.25)**	**0.40 (0.26)**	**0.53 (0.33)**	**0.51 (0.32)**	**0.46 (0.26)**	**0.39 (0.27)**	**0.45 (0.29)**	**0.60 (0.32)**	**0.52 (0.40)**	**0.45 (0.31)**	**0.42 (0.29)**	**0.46 (0.33)**	**0.53 (0.30)**	**0.53 (0.40)**	**0.43 (0.33)**	**0.57 (0.37)**	**0.50 (0.35)**

it increased upto 2nd fortnight of October. The highest average magnesium content (0.46%) was recorded in 2nd fortnight of September, while, lowest (0.33%) was recorded in 1st fortnight of July. Among the individual species, *Bromus inermis* exhibited highest (0.61%) magnesium in 2nd fortnight of September, while, lowest (0.27%) was recorded for *Panicum maximum* in 1st fortnight of July.

b) Belowground biomass

It was evident from the data that average magnesium content of community belowground biomass in this system ranged from 0.20 to 0.33 per cent during the study period. A scrutiny of data revealed that the average magnesium content of belowground biomass increased gradually from 1st fortnight of July to 2nd fortnight of October similar to pine based silvipastoral system. The highest average magnesium content for belowground biomass was recorded (0.33%) in 2nd fortnight of October, while, the lowest (0.20%) average magnesium content was recorded in 1st fortnight of July. The performance of individual grass species revealed that *Dactylis glomerata* exhibited the highest magnesium content (0.44%) in 2nd fortnight of October and the same species attained the lowest (0.17%) magnesium content in 1st fortnight of July.

iv) Improved grassland

a) Aboveground biomass

It was clear from the data in Table 16 that the average magnesium content of community aboveground biomass in improved grassland varied from 0.34 to 0.57 per cent during the study period. It was recorded that the average magnesium content increased gradually from 1st fortnight of July to 2nd fortnight of October similar to natural grassland, pine based silvipastoral and hortipastoral systems. However, the highest average magnesium content was recorded as 0.57 per cent in 2nd fortnight of October, while, the lowest (0.34%) average magnesium content was recorded in 1st fortnight of July. Among individual species, *Chrysopogon montanus* attained the highest (0.79%) magnesium content in 2nd fortnight of August, while, lowest (0.22%) magnesium content was recorded for *Heteropogon controtus* in 1st fortnight of July.

b) **Belowground biomass**

The average magnesium content of community belowground biomass of herbage in improved grassland fluctuated from 0.25 to 0.37 per cent during the study period. It was evident from data that the average magnesium content of belowground biomass increased gradually from 1st fortnight of July to 2nd fortnight of October similar to pine based silvipastoral and hortipastoral systems, but in natural grassland there was no particular trend. The highest average magnesium content (0.37%) was recorded in 2nd fortnight of October and lowest (0.25%) was recorded in 1st fortnight of July. Among the performances of individual grass species *Chrysopogon montanus* attained the highest (0.52%) magnesium content in 2nd fortnight of August and lowest (0.14%) magnesium content was recorded for *Heteropogon contortus* in 1st fortnight of July.

v) **Fodder trees based silvipastoral system**

a) **Aboveground biomass**

Magnesium content of aboveground biomass in fodder trees based silvipastoral system ranged from 0.36 to 0.50 per cent during the study period. A scrutiny of the data revealed that the average magnesium content increased gradually from 1st fortnight of July to 2nd fortnight of October similar to all other systems. The highest average magnesium content (0.50%) was recorded in 1st fortnight of October, while, the lowest average magnesium content was recorded as 0.36 per cent in 1st fortnight of July. The performance of individual species revealed that *Festuca rubra* attained highest magnesium per cent 0.55 per cent in 2nd fortnight of October, while, the lowest magnesium per cent 0.25 per cent was recorded for *Chrysopogon montanus* in 1st fortnight of July.

b) **Belowground biomass**

The average magnesium content of belowground biomass of vegetation in fuel/fodder tree based silvipastoral system ranged from 0.21 to 0.35 per cent. During the study period, it was recorded that the average magnesium content of belowground

biomass increased gradually from 2nd fortnight of July to 2nd fortnight of October, similar to systems II, III and IV. The highest average magnesium content was observed (0.35%) in 2nd fortnight of October, while the lowest (0.21%) was recorded in 2nd fortnight of July. Among the individual species *Oplismensus compositus* attained the highest magnesium per cent (0.46%) in 2nd fortnight of October, while, the lowest was recorded (0.17%) for the same species in 1st fortnight of July. The values of magnesium per cent were less in belowground biomass as compared to their aboveground counterparts in all the species during different sampling dates.

4.4 PHYSICO-CHEMICAL PROPERTIES OF SOIL

The physico-chemical properties of the soils of the sites under different system is presented in Table 17.

Table 17. Soil physico-chemical properties of different system I (natural grassland), II (pine based silvipastoral sustem), III (hortipastoral system), IV (improved grassland), V (fodder trees based silvipastoral system)

Systems	N (kg/ha)	P (kg/ha)	K (kg/ha)	OC (%)	BD (g/cm^3)
I	351.232	20.23	195.77	0.83	1.47
II	331.712	22.63	253.83	0.71	1.38
III	326.446	21.28	215.53	0.79	1.33
IV	388.512	21.18	283.33	0.85	1.45
V	485.792	22.13	246.76	0.93	1.35

4.4.1 Available nitrogen (kg/ha)

The available nitrogen content (kg/ha) of soil in all the system fall under medium class. The highest nitrogen content 485.79 kg/ha was recorded in the fodder trees based silvipastoral system. While, the lowest available nitrogen content (326.45 kg/ha) in soil was recorded in hortipastoral system. The available nitrogen content of soil in natural grassland, pine based silvipastoral system and improved grassland were recorded as 351.23, 331.71 and 388.51 kg/ha, respectively.

4.4.2 Available phosphorus (kg/ha)

The available phosphorus in all the systems can be classified as medium category except pine based silvipastoral system. In pine based silvipastoral system the available phosphorus content was highest (22.63 kg/ha) falling under high category. The available phosphorus, content in natural grassland, hortipastoral system, improved grassland and fodder trees based silvipastoral system was recorded as 20.23, 21.28, 21.18 and 22.13 kg/ha, respectively.

4.2.3 Available potassium (kg/ha)

The data revealed that the available potassium content of soil fall under medium category in all the systems. In natural grassland, pine based silvipastoral system, hortipastoral system, improved grassland and fodder trees based silvipastoral system the available potassium content was recorded as 195.77, 253.83, 215.53, 283.33 and 246.67 kg/ha, respectively. The highest available potassium content (283.33 kg/ha) was recorded for improved grassland, while, lowest (195.77 kg/ha) was recorded for natural grassland.

4.4.4 Organic carbon (%)

It was recorded that the highest organic carbon per cent (0.93%) was recorded for fodder trees based silvipastoral system, while, lowest organic carbon per cent (0.71%) was recorded in pine based silvipastoral system. The organic carbon per cent in natural grassland, hortipastoral system and improved grassland was recorded as 0.83, 0.79, and 0.85 per cent, respectively.

4.4.5 Bulk density (g/cm^3)

It was evident from the data that highest bulk density was recorded (1.47 g/cm^3) in natural grassland, while, lowest (1.33 g/cm^3) bulk density was recorded for hortipastoral system. The bulk density in pine based silvipastoral system, improved grassland and fodder trees based silvipastoral system was recorded as 1.38, 1.45, 1.35 g/cm^3, respectively.

DISCUSSION

Chapter-5

DISCUSSION

The results obtained from present investigation entitled, "Floristic and productivity variations in different tree based pasture systems vis-a-vis grasslands in temperate region" have been discussed in this chapter, establishing the cause and effect relationship where feasible in the light of available literature under the following heads:

5.1 Floristic composition and phytosociology of herbage

5.2 Productivity of herbage

5.3 Nutrient contents of herbage

5.4 Physico-chemical properties of soil

5.1 Floristic composition and phytosociology of herbage

Floristic composition is a measure of species diversity in a community. The degree of diversity is a function of adaptability of the species to the particular microhabitat as well as various other biotic and abiotic factors. Dansereau (1960) described floristic composition as one of the anatomical character of a community. In the present study, the variation in floristic composition of different systems showed higher number of species in 1st and 2nd fortnight of July which can be related to onset of rainfall season in June which initiated the germination of constituent species. Among grasses, common species in all the systems were: *Festuca rubra, Chrysopogon montanus* and *Panicum maximum,* while, *Dactylis glomerata* which is an exotic grass and was introduced in grasslands in 1992 was present only in hortipastoral system, improved grassland and fodder trees based silvipastoral system. The number and types of species recorded in present study in different systems were almost similar as indicated by

similarity index in Table 9. More than 70 per cent species were common among the five systems. However, hortipastoral and improved grassland systems were more similalr compared to other systems. Little variation in constituent species of some grassland of HP around 2360 m elevation have also been reported by Singh *et al.* (1975), he however, reported relatively higher number of species. The comparatively low number of species in the present study sites can be attributed to the differences in microhabitats (Johnson, 1995) and yearly variations in abiotic variables (Berg and Staaf, 1981). Such variations in an area can also be related to various climatic stresses as reported by Gill (1975) and Singh and Joshi (1979). Besides grasses, only three non-legumes constituted the floristic composition of natural grassland, pine based silvipastoral system and improved grassland and these species showed sparse distribution. These species were absent in other two systems. A critical examination of data in Table 9a and 9b revealed that similarity index of different systems was maximum in the early growth stages in July/August, thereafter, it decreased. Such variations in appearance of species in different systems may be attributed to the differences in micro-habitat influencing the growth behaviour of plants.

In a plant community different species grow in association with each other. The interactions between plants and environment in an area ultimately gives definite structure to the community. Habitat characteristics also play a vital role in determining the kind of community, that is why plant species varies from habitat to habitat. Thus, each species play a definite role and possess its structural and functional individualism in a community (Singh, 1975). In addition there is a definite quantitative relationship between abundant and rare species in a community. As such it is necessary to study numerical abundance and spatial distribution of all the species in understanding the community organization of herbage.

In the present study, with the onset of monsoon in June, sporadic germination and development of plants resulted in exponential growth during July/August in all the systems, thereby increase in density and basal area of various species were recorded and peak values were recorded in the month of August, thereafter, it declined upto October in all the systems (Table 4, 5). This pattern of growth of herbage species clearly reveals

their dependence on rainfall pattern, as has been reported by Gill (1975), Bawa (1986), Gupta (1988), Singh and Yadava (1974) and Trivedi (1994) for monsoonal grasslands of India. Decline in these attributes after August may be due to the fact that the grasses proceeded towards senescence by October, thereby converting live tillers to dead ones. Similar results have been reported by Singh and Yadava (1974), Misra (1973), Singh (1975), Bawa (1986), Gupta (1988), Dass (1995), Guleria (1996), Rao (1998) and Dutt (1999) for grasslands of India. The present study also revealed that the improved grassland showed highest total density and basal area of herbage than all other systems. It may be attributed to the tillage practices done earlier on the site. Looking at the structural parameters of vegetation i.e. density and basal area at different time interval it can be inferred that the values of these parameters in the five systems decreased in the order : system IV > system V > system III > system I > system II.

The total basal area and density in all the systems remained higher in the beginning of the rainy season and showed varying decline with the advancement of growing season in September/October. Such variations in density and basal area of herbage shows strong relation with rainfall variations in the region during July to October, since high rainfall was recorded in July and August there was exponential growth of vegetation during these months, whereas, in September and October less/no rainfall may be the reason for restricting the growth of vegetation thereby resulting in low density and basal area.

Moreover, variations in basal area of vegetation are closely related to density as reported by Singh and Yadava (1974). The present study also revealed positive and significant relationship between these two attributes in all the systems. In natural grassland 63 per cent variation in basal area has been explained by density with a relation as:

$$BA = \underset{(21.13)}{21.38} + \underset{(0.028)}{0.10}\ \text{density}, \quad \bar{R}^2 = .0.63$$

In pine based silvipastoral system 68 per cent of variations in basal area has been explained by density with relation as:

$$BA = 16.65 + 0.101 \text{ density}, \quad \bar{R}^2 = 0.68$$
$$(15.14) \quad (0.026)$$

In hortipastoral system, 94 per cent variations in basal area has been explained by density with a relation as:

$$BA = 5.42 + 0.12 \text{ density}, \quad \bar{R}^2 = 0.94$$
$$(7.37) \quad (0.011)$$

In improved grassland 65 per cent variation in basal area has been explained by density with a relation as:

$$BA = -21.96 + 0.157 \text{ density}, \quad \bar{R}^2 = 0.65$$
$$(31.91) \quad (0.042)$$

In fodder trees based silvipastoral system, 64 per cent variations in basal area has been explained by density with a relation as:

$$BA = 15.47 + 0.11 \text{ density}, \quad \bar{R}^2 = 0.64$$
$$(19.16) \quad (0.028)$$

Pine based silvipastoral system showed comparatively low values of density and basal area in relation to other four systems endorses the results of Anderson *et al.* (1969), Gupta *et al.* (1997), Guleria (1996), Dass (1995), Rao (1998) and Dutt (1999) who have recorded that pines affect understorey vegetation by changing the soil acidic, low light availability under trees and leaching. Irregular variations in density and basal area of vegetation under pine based silvipastoral system can be related to varying pine needle floor and its decomposition rate along the season thereby affecting the growth of vegetation during different sampling time. Trend in variations of community density and basal area along the growing season in five systems in the present study revealed that not only the rainfall pattern but also management of system has some role to play in structural variations of herbage thus highest values of these parameters were recorded in 1st fortnight of July in systems I and II, whereas, these parameters increased gradually to

achieve highest values in August in systems III to IV. Analysing this difference among the five systems it seems that *Dactylis glomerata* being one of the dominant species in systems III to V, led to gradual increase in these structural parameters achieving their highest values by September/October. Thus the variation in total basal area and density of vegetation in systems III to V showed different trend from systems I and II, where this species was absent.

In systems I and II, *Festuca rubra, Panicum maximum* and *Chrysopogon montanus*, while, in systems III, IV and V *Festuca rubra, Chrysopogon montanus* and *Dactylis glomerata* contributed substantially to the density and basal area of herbage vegetation, which is the manifestation to their growth behaviour and suitability to the environment. The comparatively higher values of density and basal area of one or two species in a community has been reported by Chaturvedi *et al.* (1988), Sajwan *et al.* (1980), Singh *et al.* (1985), Bawa (1986), Kapoor (1987), Gupta (1988), Dass (1995), Dalai (1997), Rao (1998) and Dutt (1999) for different grasslands.

A close observation on frequency and IVI (Table 6, 7) in different systems showed that there was irregular increase or decrease of these parameters in subsequent sampling intervals. In systems I and II, *Festuca rubra*, *Panicum maximum* and *Chrysopogon montanus*, while in systems III, IV and V, *Dactylis glomerata, Festuca rubra* and *Chrysopogon montanus* showed their dominance over other species. Hence, system I and II can be identified as *Festuca - Chrysopogon - Panicum* type, and systems III, IV and V can be designated as *Festuca - Dactylis - Chrysopogon* type. The dominance of one or two species in community can be attributed to their better adaptability and growth in particular environment. Similar type of observations i.e. dominance of one or two species in any grassland ecosystem were made by Dabadghao and Shankarnarayan (1973), Dass (1995), Gulcria (1996), Dalai (1997), Rao (1998) in their studies on grasslands of India. The equal dominance of more number of species in particular community leads to the low species diversity. Higher values of Shannon's index indicates a low concentration of dominance. Higher diversity reduces the oscillations and increase the stability of the community (Margalef, 1968; Sahai and

Asthana, 1976). In the present study, the Shannon's index of diversity in different systems was found to be higher in early stages of growth in July. This can be attributed to the low concentrations of dominance of different species in the systems. As the growth proceeded the Shannon's index of species diversity decreased, when *F. rubra, C. montanus, Panicum maximum* and *D. glomerata* showed their superiority over other species for various growth parameters which may be due to their better competitive ability. The results obtained for species diversity in the present study are in consonance with the reports of Dass (1995), Gupta *et al.* (1997) and Singh *et al.* (1994) for similar vegetation.

5.2 PRODUCTIVITY OF HERBAGE

The aboveground biomass of herbage vegetation increased from 1st fortnight of July to 2nd fortnight of September in all the systems. The peak values of total aboveground biomass were found to be 34.90, 28.30, 40.28, 42.08 and 38.18 q/ha for natural grassland, pine based silvipastoral, hortipastoral system, improved grassland and fodder trees based silvipastoral system, respectively (Table 10). The increment in aboveground biomass production in all the systems along the season may be related to spurt of growth with advent of monsoon in late June resulting in high relative humidity and soil moisture in July/August. Thus, enough soil moisture availability for optimum nutrient flow in soil - plant system and congenial air temperature manifested itself in luxurious vegetative growth of plants accompanied by enhanced tillering and basal area coverage of vegetation leading to gradual increase in biomass upto September in all the systems. An important role played by climate on growth and development of vegetation have been advocated by researchers like Singh and Yadava (1974), Singh (1975), Bazilevich *et al.* (1970), Singh and Joshi (1979), Trivedi (1994), Dass (1995), Guleria (1996), Dalai (1997), Rao (1998) and Dutt (1999) for monsoonal grasslands of India.

The appreciable low aboveground biomass of herbage in system II in comparison to other systems can be due to the reduction in rate of transpiration, leaf temperature and stomatal conductance of grasses under pine trees caused by low relative illumination

which ultimately led to low biomass production (Bhatt *et al.*, 1994). Reduction in light intensity under crowns has been held as main factor for low production of herbage under trees (Grelan and Whrey, 1978; Singh *et al.*, 1980; Ramakrishna, 1984; Hazra and Patil, 1986; Chaturvedi *et al.*, 1988 and Sharma and Dhiman, 1994). Allelopathy and interference of needle biomass to grass species under pine trees have also been advocated by Dass (1995). Higher aboveground biomass of herbage in systems III, IV and V as compared to system I and II can be ascribed to different management of systems. In systems III to V *Dactylis glomerata* played significant role in structural parameters and also showed better production potential as compared to indigenous grasses may have resulted in better biomass production in them as compared to systems I and III. System V further revealed the highest biomass among system III, IV and V which can be related to the effect of leguminous trees like *Robinia pseudocacia* and *Acacia mollissima* planted in this system which may have played a distinct role in enhancing the nitrogen in soil as revealed by the highest soil nitrogen in this site among the five systems. High organic carbon in this site can also be related to better performance of herbage in terms of biomass production.

Among the grass species, *Festuca rubra, Panicum maximum* and *Chrysopogon montanus* were major contributors to the total aboveground biomass in systems I and II, while *Festuca rubra, Chrysopogon montanus* and *Dactylis glomerata* contributed maximum to the total aboveground biomass of herbage in systems III, IV and V. The major contribution towards total biomass by only few species has been reported by many researchers (Blaisdell, 1958; Pearson, 1975 and Singh, 1968). The higher biomass production of these species is also a manifestation of their better growth as is evident from their consistently higher basal area and density throughout the study period.

Total below ground biomass (Table 11) also increased from July to August in all the systems. The peak values were recorded as 13.25, 11.55, 12.91, 14.68 and 13.39 q/ha in natural grassland, pine based silvipastoral system, hortipastoral system, improved grassland and fodder trees based silvipastoral system. The gradual increase in belowground biomass from July to August was due to profuse growth and development

of different species. Thus, continuous decrease in belowground biomass after attaining peak values may be ascribed to the death of roots, their detachment from grass species and their mineralization as reported by Aggarwal *et al.* (1978). Belowground biomass production of different species are in accordance with the results reported by Guleria (1996), Singh and Yadava (1974), Dalai (1997), Kapoor (1987) for monsoonal grasslands. Aboveground biomass production variations along the growing season in the five systems can be gradaded as: system V > system IV > system III > system I > system II.

5.3 NUTRIENT CONTENT OF HERBAGE

During the study period the average nitrogen content of aboveground biomass ranged from 0.74 to 0.97 per cent in natural grassland, 0.95 to 1.50 per cent in pine based silvipastoral system, 0.85 to 1.32 per cent in hortipastoral system, 0.83 to 1.23 per cent in improved grassland and 0.85 to 1.44 per cent in fodder trees based silvipastoral system. The nitrogen per cent of different species recorded in present study fall in the range recorded for grasses by Bawa (1986), Kapoor (1987), Gupta (1988), Sharma (1988), Dass (1995), Guleria (1996), Dalai (1997), Rao (1998) and Dutt (1999) for the grasses of monsoonal grasslands of Himachal Pradesh. The variations in nitrogen concentration with time revealed that nitrogen (%) in aboveground biomass of grasses attained the maximum values in 1st and/or 2nd fortnight of September. The results showed that with the growth and germination of grasses, nitrogen (%) in vegetation started increasing and attained highest nitrogen (%) at the time of peak vegetative growth in August/September, thereafter,it declined as the vegetation entered post-bloom stage. Similar variations in nitrogen (%) in plants with growth and development of vegetation have been reported for monsoonal grasslands by many researchers like Bawa, 1986; Sharma, 1988; Gupta, 1988; Verma, 1989; Guleria, 1996; Dalai, 1997; Rao, 1998. The reasons for higher nitrogen content during peak vegetative growth in rainy season can be ascribed to the higher nitrogen uptake from soil as reported by Singh and Joshi (1979). Further, during the active growth period plants absorb ammonia present near the ground surface as reported by Denmead *et al.* (1976) which may result in higher nitrogen in plants. The decline in nitrogen (%) after September may be due to the completion of active growth of plants

and thereby lower nitrogen uptake accompanied by excessive loss of nitrogen through leaching (Jones *et al.*, 1977 and Jones and Woodmansee, 1979).

The belowground biomass showed the highest nitrogen per cent in 1st and/or 2nd fortnight of September (Table 11). However, the average nitrogen (%) of belowground biomass was less as compared to aboveground biomass, which may be due to faster rate of translocation of carbon from shoots to roots in comparison to the uptake rate of nitrogen by plants and its continuous translocation to shoots during the growing period (McGill *et al.*, 1981). Such variations have also been reported by Billore and Mall, 1976; Aggarwal *et al.*, 1978 for tropical grasslands in India. They contended that amount of rainfall have positive significant relationship for higher shoot/root nitrogen. The difference in nitrogen(%) in belowground biomass various constituent species in different systems can be related to differences in availability of soil nitrogen and its uptake by grasses.

Average phosphorus content (%) in aboveground biomass varied from 0.07 to 0.14% in natural grassland, 0.09 to 0.13% in pine based silvipastoral system, 0.07 to 0.11% in hortipastoral system, 0.07 to 0.12% in improved grassland and 0.08 to 0.13% in fodder trees based silvipastoral system, which falls with in the range as reported by Bawa (1986), Kapoor (1987), Gupta (1988), Guleria (1996), Dalai (1997), Rao (1998) and Dutt (1999) for the grasslands of H.P. The phosphorus (%) of the vegetation increased from July with the onset of growing season and the peak values were recorded in 1st and/or 2nd fortnight of September in different species. The increase in phosphorus (%) in grasses along the growing season has been reported by Cole *et al.* (1977), Bawa (1986), Gupta (1988), Guleria (1996) and Dalai (1997). Maximum phosphorus content at pre-bloom state of grasses has also been observed by Joshi and Gupta (1984) and Sharma (1991), while, Verma (1989) reported maximum phosphorus content of grasses at bloom stage under chirpine. The differences in phosphorus content of different species with time is due to differences in their growth and development as reported by Aggarwal (1978), Bawa (1986), Kapoor (1987), Gupta (1988), Guleria (1996), Dalai (1997), Rao (1998) and Dutt (1999).

The phosphorus (%) in belowground biomass was less as compared to its respective aboveground biomass in all the systems which may be due to the active utilization of the element in aerial parts with the growth of grasses as contended by Bawa (1986), Kapoor (1987), Guleria (1996), Dalai (1997) and Dutt (1999). The differences in phosphorus (%) in above ground and below ground biomass of a species in different sites as recorded in present study may be due to the differences in the availability of the element in the soil and its uptake by grasses.

In the present study the average potassium content ranged between 0.64 to 1.11% in natural grassland, 0.69 to 1.42% in pine based silvipastoral system, 0.70 to 1.30% in hortipastoral system, 0.73 to 1.10% in improved grassland and 0.80 to 1.21% in fodder trees based silvipastoral system. The potassium(%) in aboveground biomass of different species showed an increasing trend with the start of growth of vegetation in July. The average potassium content increased from July to September and thereafter, it decreased upto October. Decrease in potassium content with advancement of growth may be due to the loss of potassium through litterfall and leaching losses which is more in old tissues than the young ones as reported by Wallace (1930) and Turkey (1970). Higher potassium (%) at pre-bloom stage than full-bloom stage has been reported by Blaser and Kimbrought (1968).

The potassium (%) in belowground biomass was less as compared to its respective aboveground biomass in all the sites which may be due to active utilization of the element during growth of aerial parts. The difference in potassium (%) recorded in the present study for aboveground and belowground biomass of herbage vegetation in all the systems may be attributed to the differences in efficiency of absorption and utilization of this element. The results thus obtained in the present study are in consonance to the findings of Bawa (1986), Gupta (1988), Sharma (1988), Guleria (1996), Dalai (1997) and Dutt (1999) for monsoonal grasslands of H.P.

Calcium content in aboveground biomass registered a decreasing trend along the growing season almost in all the systems (Table 15). The average calcium content varied

from 0.86 to 1.68% in natural grassland, 1.06 to 2.07% in pine based silvipastoral system, 1.50 to 2.58% in hortipastoral system, 1.59 to 2.36% in improved grassland, and 1.74 to 2.59% in fodder trees based silvipastoral system. Under fodder trees based silvipastoral system more calcium content was recorded in the aboveground biomass than other systems. The aboveground biomass registered more calcium content than below ground biomass in all the species occurring in different systems. Our results fall within the range of calcium (%) in grasses observed by Bawa (1986), Kapoor (1987), Gupta (1988), Guleria (1996) and Dalai (1997) for the grasslands of Himachal Pradesh. A continuous decline in calcium (%) with the growth of vegetation may be ascribed to the phenological changes as noticed by Bokhari and Singh (1975). Decrease in calcium content with the advancement of growth of vegetation has also been reported by Fleming and Coulter (1963), Sharma (1966) and Joshi and Gupta (1984).

During the study period the average magnesium (%) of aboveground biomass of vegetation in different systems ranged between 0.42 to 0.60 per cent in natural grassland, 0.38 to 0.53% in pine based silvipastoral system, 0.33 to 0.46% in hortipastoral system, 0.34 to 0.57% in improved grassland and 0.36 to 0.50% in fodder trees based silvipastoral system. The highest average magnesium (%) was recorded for natural grassland. The magnesium per cent recorded in the grasses in present study are in consonance with the results reported by Sharma (1988), Guleria (1996) and Dalai (1997) for grasslands of Himachal Pradesh. A gradual increase in magnesium (%) in aboveground biomass of grasses was noticed in all the systems during the study period. Joshi and Gupta (1984) reported that magnesium per cent increase in grasses as they reach maturity. The magnesium (%) of belowground biomass of grasses was less as compared to the aboveground biomass in all the systems. These findings are in line with the results reported by Sharma (1988), Guleria (1996) and Dalai (1997).

5.4 PHYSICO-CHEMICAL PROPERTIES OF SOIL

The data presented in Table 12 revealed that nitrogen content in soil increased with increase in organic carbon content. Thus, revealing that increase in nitrogen content

is closely related to organic matter content as reported by Kaushal (1992. The highest nitrogen content (485.79 kg/ha) was recorded for the soil of fodder tree based silvipastoral system which may be attributed to the nitrogen fixing ability of fodder trees like *Robinia pseudocacia, Acacia mollissima* present in the site and high organic matter content recorded in the soil of this system. The positive and significant correlation of organic matter with available nitrogen has been reported by Kaushal (1992). The comparatively less nitrogen content in soils of other systems may be attributed to the volatilization and leaching losses as contended by Mazumdar (1988).

The overall organic carbon per cent in different systems was in medium range. The highest organic carbon per cent was recorded for fodder tree based silvipastoral system. It may be due to the accumulation of leaf litter on the surface of site. Organic carbon of medium range have also been reported by Minhas (1986); Mazumdar (1988); Sharma (1991); Kaushal (1992) and Malik (1992) for the soils of Himcahal Pradesh.

In general, the soils in the present sites are rich in phosphorus content. Similar results were found by Mazumdar (1988); Sharma (1991) and Malik (1992) for the soils of Himachal Pradesh. The available potassium content in the soils were in medium range, but can be considered rich in potassium which can be due to the presence of illite type of mineral in Himachal Pradesh soils (Singh, 1987). Similar range of values for soil potassium have been reported by Sharma (1991); Malik (1992). The value of bulk density of the soils in present study were slightly low than the values recorded for soils of similar vegetation by Minhas (1986); Malik (1992) for the soils of Himachal Pradesh. The possible region for low bulk density in present sites can be related to low organic matter as contended by Kaushal (1992).

SUMMARY & CONCLUSION

Chapter-6

SUMMARY AND CONCLUSION

In order to fulfill the objectives of the present study "Floristic and productivity variations among different tree based pasture systems vis-a-vis grasslands in temperate region" was conducted in district Shimla at Regional Horticultural Research Station, Mashobra under Dr Y S Parmar University of Horticulture and Forestry, Nauni, Solan (HP). The results of the investigation have been summarized under following heads:

6.1 FLORISTIC COMPOSITION AND PHYTOSOCIOLOGY OF HERBAGE

A scrutiny of floristic composition showed that in all, there were nine grass species, one fern and two non-legumes in different systems. In the present study, the variation in floristic composition of different systems showed higher number of species in 1st and 2nd fortnight of July. Among grasses, the common species in all the systems were *Festuca rubra, Chrysopogon montanus, Panicum maximum. Dactylis glomerata* which is an exotic grass and introduced in grasslands was present only in hortipastoral system, improved grassland and fodder trees based silvipastoral system. Density and basal area of vegetation in all the systems decreased from July to October. Total density and basal area of different species was higher in natural grassland and improved grassland as compared to other systems. Frequency of species did not show any particular trend. Among the different species, *Festuca rubra, Panicum maximum* and *Chrysopogon montanus* were major contributors to the total density and basal area in system I and II, while *Festuca rubra, Chrysopogon montanus* and *Dactylis glomerata* were major contributor to total density and basal area in system III, IV and V. According to the values of IVI of different species, systems I and II can be designated as *Festuca - Panicum - Chrysopogon* type of community, system III and IV can be designated as *Festuca - Chrysopogon - Dactylis*, system V can be designated as *Festuca - Oplismenus -*

Dactylis type community. There was not much variations in average values of species diversity in all the systems. Highest similarity index was recorded for system III and IV.

6.2 PRODUCTIVITY OF HERBAGE

During the study period the total aboveground and belowground biomass of herbage vegetation increased from July to September and thereafter, it decreased till October in all the systems. The biomass production was highest in system IV, while lowest was recorded in system II. The total above ground biomass of individual species was higher as compared to their belowground biomass on each sampling date in all the systems. Among different grass species, *Festuca rubra, Panicum maximum* and *Chrysopogon montanus* were major contributors to the total biomass production in system I and II, while, *Festuca rubra, Dactylis glomerata* and *Chrysopogon montanus* were major contributors to total biomass production in systems III, IV and V. In general the total biomass production in different systems can be rated as : system IV > system V > system III > system I > system II.

6.3 NUTRIENT CONTENTS OF HERBAGE

In the present study, the herbage was analysed for N, P, K, Ca and Mg. The N, P and K contents of herbage increased from July to August/September, thereafter it decreased till October end. The Ca content of herbage was maximum in July and showed decreasing trend throughout the study period, while, Mg content of herbage revealed increasing trend throughout the study period. The aboveground biomass of different species had higher nutrient contents (N, P, K, Ca and Mg) than their belowground counterparts in all the systems on different sampling dates.

6.4 PHYSICO-CHEMICAL PROPERTIES OF SOIL

The available nitrogen content in the soils of all the systems fall under medium category. Highest available nitrogen content among the five systems was recorded in fodder trees based silvipastoral system. The available phosphorus content of soil in all the

systems fall under medium category and highest phosphorus content was recorded in pine based silvipastoral system. Similarly the available potassium content of soil in all the systems fall under medium category and highest potassium content was recorded for improved grassland. There was not much variation in organic carbon content in different systems, however, highest organic carbon was recorded in fodder trees based silvipastoral system. Similarly, there was not much variations in the bulk density of soils of different systems, however, the highest bulk density was recorded for natural grassland.

CONCLUSION

1. It is evident that in monsoonal climate the grassland vegetation starts its germination and growth as the pre-monsoon showers are received in June. Various structural parameters of vegetation like, floristic composition, herbage diversity, density and basal area are regulated in accordance with the rainfall pattern. Forbs generally complete their life cycle by mid-rainy season.

2. Density and basal area of vegetation achieve the peak values by August, thereafter, there is decline in values of these parameters.

3. Herbage diversity in managed systems is less as compared to natural systems, thus, in the present study natural grassland showed higher diversity compared to improved grassland, hortipastoral system and fodder trees based silvipastoral system. *Pinus wallichiana* adversely effects the herbage diversity.

4. On the basis of IVI values of species grasslands of systems I and II can be recognized as *Festuca - Chrysopogon - Panicum* type and similarly grasslands of system III to V can be designated as *Festuca - Dactylis - Chrysopogon* type.

5. Aboveground biomass follows the increasing trend with the advent of rainfall in June and achieves peak biomass in late August/early September comparing the five systems of the present study it can be inferred that biomass production at different time was in the order : System IV > system V > system III > system I >

system II. *Pinus wallichiana* adversely affects the biomass production of understorey vegetation.

6. *Dactylis glomerata* has higher biomass production potential and thus resulted in high aboveground biomass in systems III to V.

7. Nutrient contents of vegetation (N, P and K) of grasses increase with the growth of vegetation and achieves peak value at peak vegetative growth in August/September. Calcium decreases with growth of grasses. Magnesium is highest at post-bloom stage.

8. Nitrogen fixing trees in grasslands increase soil nitrogen and thereby biomass production too.

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APPENDICES

Appendix I. Relative density of different grass species in systems I (natural grassland), II (pine based silvipastoral system), III (horti-pastoral system), IV (improved grassland), V (fodder trees based silvipastoral system) during the study period at different sampling intervals

Species	JULY										AUGUST									
	1st Fortnight					2nd Fortnight					1st Fortnight					2nd Fortnight				
	System					System					System					System				
	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V
Heteropogon contortus	15.81	28.49	4.99	35.07	35.85	17.63	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Themeda triandra	-	-	-	-	-	-	-	-	-	-	-	-	-	6.84	-	8.61	-	-	3.46	-
Festuca rubra	24.50	35.59	20.72	26.63	16.53	25.72	40.41	35.28	49.20	32.15	62.75	49.02	25.66	42.46	29.79	47.26	54.42	37.14	40.40	29.41
Panicum maximum	16.73	6.99	7.12	13.52	-	30.93	25.17	4.61	-	-	14.56	12.66	12.50	-	9.22	9.32	14.20	17.89	15.92	30.56
Bromus inermis	7.31	-	-	-	-	-	-	20.15	23.27	-	-	-	-	-	-	-	-	-	-	-
Oplismenus compositus	9.60	-	-	-	25.40	2.59	-	-	-	14.50	-	-	-	-	-	-	-	-	-	-
Chrysopogon montanus	14.80	23.47	16.85	10.36	8.59	21.42	31.10	18.43	14.44	36.52	20.86	35.79	16.28	19.84	31.45	34.81	29.28	22.77	22.02	23.47
Hemarthria protensa	11.25	5.46	19.22	5.63	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dactylis glomerata	-	-	31.10	8.79	13.63	-	-	19.42	13.09	16.83	-	-	32.86	30.11	29.55	-	-	19.73	40.02	16.66
Miscellaneous	-	2.60	-	-	-	1.71	3.32	2.11	-	-	1.83	2.53	-	0.75	-	-	2.10	2.47	4.18	-

Species	SEPTEMBER										OCTOBER									
	1st Fortnight					2nd Fortnight					1st Fortnight					2nd Fortnight				
	System					System					System					System				
	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V
Heteropogon contortus	15.36	-	-	11.16	-	-	-	-	-	-	-	-	-	-	-	4.39	-	-	-	-
Themeda triandra	23.55	27.77	-	11.24	-	6.13	-	-	6.41	-	21.58	-	-	-	-	28.89	-	-	-	-
Festuca rubra	17.73	54.24	46.34	46.89	41.95	41.29	70.92	60.48	67.50	48.56	47.30	87.42	56.58	48.67	18.13	35.30	47.50	18.99	22.69	31.10
Panicum maximum	43.36	10.03	6.48	-	-	42.04	10.71	-	-	-	15.12	-	-	-	-	-	-	-	-	-
Bromus inermis	-	-	-	-	-	-	-	5.64	-	-	-	-	-	-	-	-	-	-	-	-
Oplismenus compositus	-	-	-	9.79	29.37	-	-	8.75	6.74	25.59	-	-	-	-	18.57	-	-	-	-	24.11
Chrysopogon montanus	-	-	-	-	-	10.54	11.06	-	-	-	16.00	-	22.14	-	-	31.42	47.74	32.78	31.48	24.26
Hemarthria protensa	-	-	-	-	-	-	-	-	-	-	-	-	-	11.79	-	-	-	-	-	-
Dactylis glomerata	-	-	47.18	20.92	28.68	-	-	25.13	19.35	25.85	-	-	21.28	39.54	63.30	-	-	48.23	45.83	20.53
Miscellaneous	-	7.96	-	-	-	-	7.51	-	-	-	-	12.58	-	-	-	-	4.76	-	-	-

Appendix II. Relative basal area of different grass species in systems I (natural grassland), II (pine based silvipastoral system), III (horti-pastoral system), IV (improved grassland), V (fodder trees based silvipastoral system) during the study period at different sampling intervals

Species	JULY										AUGUST									
	1st Fortnight					2nd Fortnight					1st Fortnight					2nd Fortnight				
	System					System					System					System				
	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V
Heteropogon contortus	15.93	24.77	8.40	3.39	24.50	18.62	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Themeda triandra	-	-	-	-	-	-	-	-	-	-	-	-	-	19.92	-	20.52	-	-	10.23	-
Festuca rubra	21.18	28.26	20.37	21.24	16.92	23.78	38.84	29.56	39.44	30.53	53.37	49.56	30.16	34.27	33.13	36.87	49.55	30.87	31.05	26.99
Panicum maximum	17.14	16.74	10.10	15.27	-	25.91	31.00	9.92	-	-	16.79	16.82	20.45	-	16.10	15.62	23.68	20.79	17.35	29.91
Bromus inermis	10.87	-	-	-	-	-	-	21.65	25.56	-	-	-	-	-	-	-	-	-	-	-
Oplismenus compositus	9.76	-	-	-	20.11	3.95	-	-	-	17.27	-	-	-	-	-	-	-	-	-	-
Chrysopogon montanus	15.05	20.83	16.29	10.82	19.44	26.41	27.84	17.47	11.97	31.79	26.21	30.93	20.15	21.04	26.09	26.99	25.01	26.15	24.35	25.64
Hemarthria protensa	10.07	8.06	18.45	9.13	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-
Dactylis glomerata	-	-	26.39	13.15	17.03	-	-	19.98	17.23	20.41	-	-	29.24	23.64	24.68	-	-	20.05	14.34	17.46
Miscellaneous	-	1.34	-	-	-	1.33	2.02	1.42	-	-	1.63	2.69	-	1.13	-	-	1.76	2.14	2.68	-

Species	SEPTEMBER										OCTOBER									
	1st Fortnight					2nd Fortnight					1st Fortnight					2nd Fortnight				
	System					System					System					System				
	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V
Heteropogon contortus	16.79	-	-	11.26	-	-	-	-	-	-	-	-	-	-	-	11.06	-	-	-	-
Themeda triandra	21.11	22.33	-	11.59	-	16.24	-	-	18.02	-	18.18	-	-	-	-	24.02	-	-	-	-
Festuca rubra	36.52	46.71	24.03	44.51	46.22	39.46	60.38	53.83	51.90	47.76	46.61	78.63	55.98	50.96	21.34	31.13	45.40	22.11	24.16	30.61
Panicum maximum	25.58	19.27	12.26	-	-	34.28	20.94	-	-	-	21.11	-	-	-	-	-	-	-	-	-
Bromus inermis	-	-	-	-	-	-	-	10.33	-	-	-	-	-	-	-	-	-	-	-	-
Oplismenus compositus	-	-	-	10.18	27.08	-	-	10.36	8.67	23.52	-	-	-	-	19.76	-	-	-	-	24.29
Chrysopogon montanus	-	-	-	-	-	10.02	9.45	-	-	-	16.10	-	22.14	-	-	33.79	42.48	37.37	36.30	23.96
Hemarthria protensa	-	-	-	-	-	-	-	-	-	-	-	-	-	16.10	-	-	-	-	-	-
Dactylis glomerata	-	-	39.51	22.46	26.70	-	-	24.48	21.41	28.72	-	-	21.88	32.94	58.90	-	-	40.52	39.54	21.14
Miscellaneous	-	11.69	-	-	-	-	9.23	-	-	-	-	21.37	-	-	-	-	13.12	-	-	-

Appendix III. Relative frequency of different grass species in systems I (natural grassland), II (pine based silvipastoral system), III (horti-pastoral system), IV (improved grassland), V (fodder trees based silvipastoral system) during the study period at different sampling intervals

Species	JULY										AUGUST									
	1st Fortnight					2nd Fortnight					1st Fortnight					2nd Fortnight				
	System					System					System					System				
	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V
Heteropogon contortus	21.43	23.53	14.29	28.57	21.43	14.29	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Themeda triandra	-	-	-	-	-	-	-	-	-	-	-	-	-	14.29	-	18.18	-	-	12.50	-
Festuca rubra	28.57	17.65	-	21.43	14.28	28.58	33.33	21.08	28.58	29.41	41.67	44.44	33.33	35.71	35.71	36.37	27.27	45.45	31.25	35.71
Panicum maximum	14.29	17.65	7.14	21.43	-	35.71	25.00	7.70	-	-	16.67	22.22	11.11	-	14.29	18.18	36.36	9.09	18.75	21.43
Bromus inermis	7.14	-	-	-	-	-	-	7.70	21.43	-	-	-	-	-	-	-	-	-	-	-
Oplismenus compositus	14.28	-	-	-	21.43	7.14	-	-	-	17.65	-	-	-	-	-	-	-	-	-	-
Chrysopogon montanus	7.14	11.76	14.29	7.14	21.43	14.29	25.00	21.08	28.58	29.41	25.00	11.11	22.22	14.29	28.58	27.27	18.18	18.18	12.50	21.43
Hemarthria protensa	7.14	11.76	21.43	14.29	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dactylis glomerata	-	-	21.42	7.14	21.43	-	-	21.08	21.41	23.53	-	-	33.34	28.57	33.34	-	-	36.37	12.50	21.43
Miscellaneous	-	17.65	-	-	-	14.29	16.67	7.69	-	-	16.66	22.22	-	7.14	-	-	18.19	9.09	12.50	-

Species	SEPTEMBER										OCTOBER									
	1st Fortnight					2nd Fortnight					1st Fortnight					2nd Fortnight				
	System					System					System					System				
	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V
Heteropogon contortus	20.00	-	-	7.69	-	-	-	-	-	-	-	-	-	-	-	8.33	-	-	-	-
Themeda triandra	26.67	25.00	-	15.38	-	14.29	-	-	16.67	-	33.33	-	-	-	-	33.33	-	-	-	-
Festuca rubra	20.00	33.33	41.67	30.77	35.71	35.71	50.00	38.46	41.67	33.33	33.33	50.00	45.45	12.50	10.00	33.34	25.00	45.45	20.00	20.00
Panicum maximum	33.33	8.33	16.66	-	-	35.71	20.00	-	-	-	16.67	-	-	-	-	-	-	-	-	-
Bromus inermis	-	-	-	-	-	-	-	15.39	-	-	-	-	-	-	-	-	-	-	-	-
Oplismenus compositus	-	-	-	15.38	28.58	-	-	7.69	8.33	33.33	-	-	-	-	40.00	-	-	-	-	26.66
Chrysopogon montanus	-	-	-	-	-	14.29	20.00	-	-	-	16.67	-	9.10	-	-	25.00	50.00	9.10	30.00	26.66
Hemarthria protensa	-	-	-	-	-	-	-	-	-	-	-	-	-	25.00	-	-	-	-	-	-
Dactylis glomerata	-	-	41.67	30.78	35.71	-	-	38.46	33.33	33.34	-	-	45.45	62.50	50.00	-	-	-	-	26.68
Miscellaneous	-	33.34	-	-	-	-	10.00	-	-	-	-	50.00	-	-	-	-	25.00	45.45	50.00	-

CURRICULUM VITAE

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THESIS ABSTRACT

Title of Thesis	:	Floristic and productivity variations among different tree based pasture systems vis-à-vis grasslands in temperate region
Name of the Student	:	Anil Kumar
Admission Number	:	F-99-01-M
Major Advisor	:	Dr. B. Gupta (Scientist)
Major Field	:	Agroforestry
Minor Field	:	i) Silviculture ii) Soil Science
Degree Awarded	:	Master of Science in Agroforestry
Year of Award of Degree	:	2001
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Number of words in Abstract	:	350

The present investigations were carried out to study the floristic and productivity variations among different tree based pasture systems vis-à-vis grasslands in temperate region during 2000 in district Shimla at RHRS, Mashobra. In all five different systems viz., natural grassland, pine based silvipastoral system, hortipastoral system, improved grassland and fodder trees based silvipastoral system, were selected and compared for their floristic and productivity variations during study period. The floristic composition showed that in all there were nine grass species, one fern and two non-legumes. There were higher number of species in 1st and 2nd fortnight of July. Density and basal area of vegetation in all the systems decreased from July to October. Total density and basal area of different species was higher in natural grassland and improved grassland. Among grasses, the common species in all the systems were *Festuca rubra*, *Chrysopogon montanus* and *Panicum maximum*. *Dactylis glomerata* was present only in hortipastoral system, improved grassland and fodder trees based silvipastoral system. According to the values of IVI of different species, systems I and II can be designated as *Festuca – Panicum – Chrysopogon* type, system III and IV can be designated as *Festuca – Chrysopogon – Dactylis* type and system V can be designated as *Festuca – Oplismenus – Dactylis* type community. Average values of species diversity in all the systems were almost similar. Higher similarity index was recorded for systems III and IV. The total aboveground and belowground biomass of herbage vegetation increased from July to September and thereafter, it decreased till October in all the systems. In general total aboveground biomass production in different systems can be graded as : system IV > system V > system III > system I > system II. The N,P and K contents of herbage in these systems increased from July to August/September, thereafter it decreased. The Ca content of herbage showed decreasing trend while Mg content showed an increasing trend along the study period. The available N, P and K contents in the soils of all the systems were under medium category. There was not much variations in organic carbon content and bulk density of different systems.

Signature of Major Advisor

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