

**Production of understorey vegetation
in relation to LAI and solar interception
under chirpine**

THESIS

by

VAISHNU DUTT

*Submitted in partial fulfilment of the requirements
for the degree of*

MASTER OF SCIENCE

in

AGROFORESTRY




COLLEGE OF FORESTRY

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Affectionately
dedicated
to my
mummy and papa

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CERTIFICATE-I

This is to certify that the thesis entitled "**Production of understorey vegetation in relation to LAI and solar interception under chirpine**", 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. VAISHNU DUTT (F-97-18-M)** under my guidance and supervision. No part of this thesis has been submitted for any other degree or diploma.

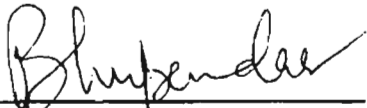
The assistance and help received during the course of investigations have been fully acknowledged.

Place : Nauni, Solan
Dated : December 16, 1999


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CERTIFICATE-II


This is to certify that the thesis entitled "**Production of understorey vegetation in relation to LAI and solar interception under chirpine**" submitted by Mr. VAISHNU DUTT (F-97-18-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.



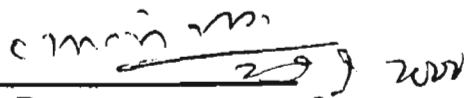
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To err is human ..

Nauni, Solan
December 16, 1999


(Vaishnu Dutt)

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INTRODUCTION

INTRODUCTION

India is an agriculturally dominant country and animal produce are important part of people economy. Indian farmers depend wholly or partially upon domestic cattle for agricultural practices and for many valuable products from them. Eighty per cent of our cattle population depend on grasslands to meet their fodder requirements and this percentage is some how more in hilly regions of India. Grassland management is one of the most neglected fields of the forest management in our country.

Silvipastoral system is the land use system in which trees or shrubs are combined with livestock and pasture production on the same unit of land. Within this broad category, several types of subsystems and practices can be identified depending on the role of tree/shrubs component viz. protein bank fodder production, live-fence of fodder trees and hedges, trees and shrubs on pasture (Nair, 1993). Silvipastoral systems 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 is in practice in various countries.

Chirpine (*Pinus roxburghii* Sargent) is one of the most important trees in the sub-tropical region of India. Its natural zone is spread over Jammu and Kashmir, Himachal Pradesh and Uttar Pradesh. It lies within an altitudinal range of 500 to 2300 m and grows in nearly pure formation in outer Himalayas and on the adjoining Siwalik ridges. This species is strong light demander and affects underneath grass production. In Himachal Pradesh, vast stretches of grassland support varying density of overstorey chirpine trees especially in

subtropical regions. Conversely in this zone, also the chirpine forest has variety of grasses forming the understorey vegetation. Thus, chirpine based grasslands forms a major vegetation type and is a primary source of fodder for cattle in this region.

The influence of trees in checking light underneath them is matter of common experience when one's eyes are relieved under the woods from the glare of sun. Light is one of the important climatic factors responsible for the growth and development of plants. The sun emits not only the light rays used for photosynthesis, but in addition, heat rays and ultraviolet rays also, both of which influence many other processes in the plant. Wavelengths between 0.49 and 0.76 μ are called light because the eye is sensitive only to these wavelengths and this is also the range of wavelengths primarily involved in photosynthesis. Out of the total radiation that reaches the surface of earth, 35 per cent is reflected and 17.5 per cent is absorbed by the atmosphere and clouds. Only about 47.5 per cent of the solar radiation is effective at the level of the biosphere (Linton, 1965). Production of understorey vegetation is affected by various factors like light intensity, aspect, phytochemicals released from plants. Light intensity affects the diversity, growth, development, productivity and quality of herbaceous vegetation growing under tree canopy (Hiroi and Monsi, 1963; Ramakrishna, 1984 and Hazra and Tripathi, 1986).

Leaf area and its distribution with height largely determine the radiation regime within and under vegetative canopies, and also greatly influence the turbulent exchange of mass and energy between plant canopies and the atmosphere. The growth of trees and their interaction with grass are greatly affected by the quantity of light intercepted by the tree canopy and thus by its leaf area per unit ground area (leaf area index or LAI). The leaf area index has been shown to be related to short term productivity (Chaturvedi, 1987).

Floristic richness of a region is closely related to the vegetational diversity of that region. Floristic composition of a forest area is one of the basic requirements for the study of forest ecosystem and classifying forest ground flora into different types. It is long term process to give any clear cut information on floristic composition of an area, as it is liable to change with season, biotic and abiotic components.

Study of phytomass in production ecology helps in insighting structural composition of the vegetation at a given time under the prevailing environmental conditions. The aboveground biomass especially grasses are of paramount importance due to their great utility to animals. Nutrient status of any grassland decides about its nutritional quality to meet out the fodder requirements of the cattle.

The structure and function of natural chirpine based silvipastoral system have not been fully studied and are insufficiently documented as yet especially in relation to LAI studies. Looking at the scarcity of data based on LAI and its relation to productive potentials of natural silvipastoral systems, the present study was carried out in regards to the production of grasses under chirpine in natural silvipastoral systems and evaluate the role of leaf area index and solar interception on understorey vegetation functioning with following objectives :

- i) Temporal variations in floristic composition and biomass production of understorey vegetation.
- ii) Changes in LAI of trees, understorey vegetation and solar interception by trees.
- iii) Nutrient status of grasses and soil.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Silvipastoral systems integrate woody species with grasses or grass-legume mixtures, simultaneously or sequentially, on the same piece of land. These systems involve woody species that can be grown at different canopy height and managed in a manner to obtain maximum benefit through efficient utilization of solar energy and other resources. LAI of different components of a silvipastoral system and their interactions has definite relation to the overall production. The present study pertains to floristic composition of pine based silvipastoral systems, the production potential of understory vegetation and the role of LAI of different components in the functioning of system. 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 LAI of trees, understory vegetation and solar interception
- 2.4 Nutrient content of herbage
- 2.5 Physico-chemical properties of soil

2.1 FLORISTIC COMPOSITION AND PHYTOSOCIOLOGY OF HERBAGE

Floristic composition and phytosociology has long been of principal interest especially to ecologists. Floristic composition refers to a measure of species diversity in community. Its study forms one of the fundamental prerequisite to classify the flora into different systematic types of any ecosystem

e.g. forest, agricultural land, rangeland etc. It is long term process to give any clear cut information on floristic composition of an area, as it is liable to change with season, effect of biotic as well as abiotic factors. It is the net result of their interaction in the form of any community (Whitakar, 1970).

McIntosh (1967) considered diversity as the number of species in a community including distribution of individuals among the species. He further opined that community stability was controlled by species diversity while dominance controls community productivity. According to Odum (1969), species diversity refers to the richness of species as well as balanced species distribution. George and Vergease (1985) reported that the site is the major factor which governs the dominance, structure, growth and species distribution. Available literature consulted in relation to floristic composition in different tree-grass associations has been reviewed as below:

Chopra (1956) reported *Stipa sibirica* and *Themeda anathera* as the principle grass species in pine forests of Kashmir. Lee and Monsi (1963) observed sparse herbaceous vegetation under red pine and remarked that failure of most of the species to flourish under red pine forests was due to inhibitory effects of overstorey leachates on seed germination and growth of herbaceous vegetation. Kartaninata and Dumbois (1972) described nine types of grass associations on the basis of dominant species from a study on phyto sociology and ecology of natural grass communities in Hawaii. Clewell (1973) studied floristic composition of a stand of *Pinus oocarpa* in Honduras and recorded 124 species of perennial grasses and legumes. Sajwan (1975) studied the ground flora in *Dalbergia sissoo*, *Acacia nilotica*, *Prosopis juliflora*, *Dendrocalamus strictus* and mixed plantations in Jamuna ravine in Agra region and concluded that *Apluda aristata* being the dominant herbage species possessing maximum frequency and density in *D. sissoo*, *A. nilotica* and mixed plantations.

Gill (1975) and Singh and Joshi (1979) in their studies on herbaceous communities, contended that floristic composition of herbaceous vegetation vary with varying climatic and biotic stresses. Rao and Kharkangar (1978) reported 28 grass species under *Pinus kesiya* of Shillong in Meghalaya and also mentioned that most of the indigenous ground vegetation was Killed by winter frosts. Singh *et al.* (1975) contended that the floristic composition of grasses varies greatly with altitude. They reported in their study on grasslands at different altitudes in Himachal Pradesh, that at and below 2360 m altitude the dominant grasses were *Heteropogon contortus* Beauv. *Arundinella nepalensis* Trin. *Chrysopogon gryllus* Trin. *Bothriochloa pertusa* and *A. camus*. Whereas, those at 2915 m consisted of *Agrostis cania* L.; *A. stolonifera* L.; *Festuca gigantea* L.; *Dactylis glomerata* L. and *Bromus inermis* Leyss. They also found that dominance of grasses and few legumes below 3515 m.

Sundryal *et al.* (1987) studied different grasslands of Western Himalaya and concluded that the composition of grass lands changed with altitude and various factors such as grazing, cutting and burning. They found a considerable impact of these factors on grassland vegetation functioning. Sajwan *et al.* (1980) reported maximum Importance Value Index (IVI) of *Chrysopogon fulvus* registered 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 per cent less grass under tree than the open, at Dudhwa National Park at Uttar Pradesh.

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

shedding of needles of chirpine trees. Adaptability of grasses under conifer varies considerably as observed by Singh (1987). He reported that *Cenchrus ciliaris* was dominant under conifer due to its high water use efficiency. Increased species diversity with increased light intensity was reported by Igboanuga *et al.* (1986). Park *et al.* (1986) studied the effect of shade level, >25 per cent shade markedly reduced the number of tillers. Rajvanshi *et al.* (1987) compared the herbage vegetation under different forests and concluded that herbage vegetation was maximum under Shola forests and poor under chirpine tree canopy.

Chaturvedi *et al.* (1988) studied the floral ecology of central Himalayan chirpine forests and reported *Arthraxon lancifolius* as the dominant grass species in chirpine forests. Noor Mohammad (1989) noticed that ground flora varies with the degree of canopy opening, the amount of needle cover, soil depth and light condition. Modgil and Kapil (1990) recorded inhibitory effect of chirpine needle leachates on seed germination of its understorey vegetation.

Gupta and Bhardwaj (1993) reported that composition of herbaceous layer was significantly affected by forest types, basal cover of tree and site conditions. Trivedi (1994) reported the effect of soil water availability on species diversity and found maximum species in September and minimum in May.

✓ Dass (1995) recorded that total population strength of grasses (density) under tree stand of chirpine ranged between 1825.17 m² to 2093.67 m². 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 Oachghat in Himachal Pradesh. In similar type of chirpine stand in Solan district of Himachal Pradesh, diversity of grasses

ranging from 0.618 to 0.656 under trees and 0.575 to 0.677 in open grasslands was recorded by Guleria (1996). Dalai (1997) reported that the diversity of grasses under chirpine stand varied from 0.377 to 0.573 at Solan in Himachal Pradesh. Rao (1998) reported that species diversity and IVI of vegetation was low under chirpine as compared to open grassland.

2.2 PRODUCTIVITY OF HERBAGE UNDER TREE SPECIES

The assessment of production of forest floor is of utmost importance to bring about any improvement in ground flora production. The work done on this aspect by various researchers has been reviewed as below:

Singh *et al.* (1975) reported the dry matter yield of grasslands of Himachal Pradesh as 250 to 518 g/m². Pearson (1975) found increase in grass yield under southern pine with frequent burning of leaf litter. Shankar (1980) recorded the highest biomass of range grasses as 2.3 t/ha under the canopy of *Tecomella undulata*, *Albizia 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 above ground biomass was obtained in the month of June for *C. setigerus* (28 g/m²) and in May for *C. ciliaris* (63.5 g/m²). Whereas, maximum above ground biomass was recorded in October for both the species. Ahuja *et al.* (1978) reported 1.4 to 1.5 t/ha air dry herbaceous biomass under three tree species viz. *Albizia lebbeck*, *Prosopis cineraria* and *Tecomella undulata*.

Pandey (1978) studied the seasonal variation in the biomass and productivity in protected grassland ecosystems of the Chakia Forest at Varanasi 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 ecosystems have also been reported by various scientists Das and Sahai, 1975; Bawa, 1986;

Gupta, 1988. Singh *et al.* (1980) assessed the effect of tree shade (full shade, partial shade and open area) on forage yield in a grassland planted with *Acacia catechu* and *D. sissoo*, in North India and noticed that forage yield was significantly higher in open than under partial shade or full shade of tree crowns.

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 increases markedly under protection from grazing. Ahuja *et al.* (1985) stated that forage production was highly influenced by quantity and distribution of rainfall. Singh *et al.* (1985) found that productivity of grasses is higher (4067 kg/ha) under younger plantation than under old plantations (3415 kg/ha) of *Pinus roxburghii*. Hazra and Patil (1986) reported that dry matter production of grasses under *Albizia lebbek*, *A. procera*, *Leucaena leucocephala* and *Acacia tortilis* was 665, 621, 565 and 608 g/m², respectively, compared with 600 g/m² in an open site. Igbounugo *et al.* (1986) reported increase in biomass of grasses with increase in light intensity. In his study, Singh (1987) recorded the dry matter production of local grasses as 3110 kg/ha/year under natural *Cedrus deodara* forest. The total biomass production of grasses varied with the tree species was reported by Rajvanshi *et al.* (1987). Chaturvedi *et al.* (1988) reported 241 g/m² of total dry matter production of herbaceous vegetation under chirpine and out of which 175 g/m² was contributed by aboveground biomass.

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

Bhatt *et al.* (1994) observed reduction in the 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. Gupta *et al.* (1994) registered maximum above ground biomass in rainy season and minimum in winter. Below ground biomass was maximum in winter season and minimum in summer.

Dass (1995) observed reduction in herbage production to the tune of 30-36 per cent under chirpine stands as compared to that in the open grassland. Similar trend was also observed by Guleria (1996) in chirpine stand. Grazing is another factor affecting structure and function of grassland ecosystem. The study conducted by Seth (1996) in a free grazing alpine pasture lands of Kashmir revealed that above ground biomass in grazed site was more (118.23 g/m²) than in the 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 adjacent open stand indicated that paragrass under mixed stand registered higher values than that of open stand in all the three parameters measured. Dalai (1997) registered maximum above and below ground biomass of herbage in August month under chirpine forests. Jackson and Ash (1998) reported that trees affected pasture yield on a woodland basis: yields were greater where the trees were killed than under intact woodland in north eastern Australia. Rao (1998) reported maximum biomass in September month under chirpine stand in Solan (HP).

2.3 LAI OF TREES, UNDERSTOREY VEGETATION AND SOLAR INTERCEPTION

Silvipastoral systems contain atleast three components: grass and other forage, live stock and trees. The growth of trees and their interactions with grasses are greatly affected by the quality of light intercepted by the tree canopy. The leaf area per unit ground area (leaf area index or LAI) of vegetation is important in the functional attributes of system. Suitable literature consulted on this aspect has been reviewed below:

Leaf area index can be defined as the leaf area per units of soil surface (Daughtry, 1990) and is a dimensionless value. Many physiological processes such as photosynthesis, transpiration and evapotranspiration are related to LAI (Mc Naughton and Jarvis, 1983; Pierce and Running, 1998). LAI is also correlated with productivity (Golley *et al.*, 1975; Lemee, 1975; Tadaki, 1977; Edwards and Grubb, 1977; Jordan and Uhl, 1978 and Gholz, 1982). Whittakar and Niering (1975) showed an association between net primary production (NPP) and leaf area index in water limited eco-systems in the Santa Catalina Mountains of Arizona.

Ramakrishna (1984) revealed that under silvipastoral system in 13 years old *Acacia tortilis* plantation, the total incident radiation just beneath the tree canopy was only 14 to 30 per cent of that received in open areas and was insufficient for good growth and productivity of grass (*Cenchrus ciliaris*). Hazra and Patil (1986) reported that light infiltration under four trees species viz. *Albizia lebbek*, *A. procera*, *Leuceana leucocephala* and *Acacia tortilis* varied from 74-93 per cent of the PAR on open sites while studying forage production under silvipastoral system, light and temperature interaction. In another study Hazra and Tripathi (1986) observed that *Leucaena* canopy reduces the forage yield of oat due to different light conditions. Igboanugo *et al.* (1986) reported that an increase in light intensity increases the productivity

while studying pasture and floristic composition of different *Eucalyptus* sp. plantation in some parts of Northern Guinea Savanna zone of Nizeria.

Chaturvedi (1987) reported maximum LAI (3.57) for 81-100 cm girth class and minimum (0.03) for 40-60 cm girth class of chirpine forests of Kumaun Himalaya of Uttar Pradesh. Jack and Long (1991) examined the relationship between density and both leaf area index and mean leaf area for lodgepole pine (*Pinus contorta* var. *latifolia* and subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.) in the Bear River Range of Northern Utah, United States and reported that in lodgepole pine, leaf area index tended to be constant over a wide range of absolute and relative densities, but in sub-alpine fir, leaf area index increased with density. Gratini (1997) while studying the canopy structure, vertical radiation profile and photosynthetic function in a *Quercus ilex* evergreen forest observed that high LAI drastically modified the quality and quantity of solar radiation on the forest understorey/ground vegetation.

Dass (1995) reported relative light intensity (%) as 33.62, 18.65 and 50.24 in sapling, pole and tree stands of chirpine, respectively when compared to the open grassland in Solan (HP). Rao (1998) reported that relative light intensity (%) varied from 47.76 to 86.17 in different crown classes of chirpine stand as compared to the open grassland in Solan (H.P.).

Reynolds *et al.* (1997) reported that available light (PAR) decreased as LAI increased ($r=-0.90$) while studying effect of conifer on leaf area index of competing vegetation and available light for seedlings in the Falling Snow Ecosystem Project, Ontario. McCrady and Jokela (1998) reported that the relationship between ANPP and leaf area index (LAI) was both significant and curvilinear, with an apparent optimum level of production (42.6 mg ha^{-1}) achieved at a LAI of about 13 at all sides in February and a strong linear relationship ($r^2 = -0.74$) was found between ANPP and intercepted PAR.

2.4 NUTRIENT CONTENTS OF HERBAGE

Herbage play an important role in cattle rearing. Vegetation assessment without its nutritive status is likely to prove meaningless. Thus the importance of qualitative status of grassland eco-system need to be taken into consideration. The available literature consulted for the study of nutrient content of herbage is presented below:

Hughes (1970) reported 10-12 per cent crude protein content in *Aristida strictata*, a 'three awned grass' in fresh herbage growth, grown under slash pine. They further observed a decrease in crude protein content to 8 per cent with onset 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 Pal and Negi (1978) reported that at maturity, percentage nitrogen and phosphorus decreased in high altitude Himalayan pasture (Pal and Negi, 1978).

Dogra *et al.* (1979) found that crude protein content of grasses of Himachal Pradesh at 1300 m altitude varied significantly with the season and species and they observed highest crude protein content in local grasses during July & August and which decreased gradually in September and October.

Joshi and Gupta (1984) noticed that phosphorus was 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 in different grasses at Sikkim. (Seo *et al.* (1985) reported 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 affect P. Whereas, in another study Seo *et al.* (1989) observed that grass nitrate content increased on account of high grazing intensity and found higher nitrate in grasses in summer and autumn than in spring.]

Bawa (1986) noticed seasonal variations in N, P and K per cent grasses in different seasons and reported maximum nitrogen (%) of grasses in September near Shimla, Himachal Pradesh. Gupta (1988) reported that N, P and K was maximum in aboveground biomass of grasses at peak biomass stage (September) and they varied from 0.63 to 1.68, 0.05 to 0.16 and 0.26 to 0.58 per cent, respectively in grasslands around Shimla, Himachal Pradesh.

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 the understorey of *Acacia tortilis* and *A. digitata* in comparison to open grass land whereas, East and Felkar (1993) concluded that digestibility of grasses in open was more than the grasses growing under tree canopy.

Guleria (1996) opined that there was not much difference in nutrients of grasses under chirpine and in open grasslands around Solan, Himachal Pradesh. He further noticed that the N, P and K in aboveground biomass of different grasses ranged from 0.93 to 1.40, 0.12 to 0.30 and 0.50 to 0.92 per cent, respectively at the time of peak biomass stage 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) and Rao (1998) for Solan grasslands. Jackson and Ash (1998) reported that pasture N concentration was higher under trees than in inter-tree areas and plants under trees produced a similar amount of biomass as plants in inter-tree areas.

2.5 PHYSICO-CHEMICAL PROPERTIES OF SOIL

Soil physico-chemical properties are related to field morphology and regulate to a considerable degree the qualitative and quantitative aspects of plant growth. The behavior of biomass of grassland ecosystem without a knowledge of these characteristics are likely to prove meaningless. Thus, the importance of physico-chemical properties of soil in the domain of system analysis need to be taken into consideration.

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 increased soil pH and decreased organic C, N and base cations with increased distance from tree trunks. Yadav and Singh (1963) reported that soils under conifers in moist temperate climate of Dehradun were low in pH but high in organic matter and nitrogen.

According to a study carried out by Singh and Raman (1982) pH ranged from 5.3 to 7.8 upto a depth of 40 cm in north-east Himalayan forest soils. He also observed decreasing K content in forest soils with increasing depth. However, Sood and Kanwar (1986) observed pH range of 6.1 to 8.0 in all the climatic zones of Himachal Pradesh.

Gupta (1988) while studying the nutrient cycling in grasslands near Shimla noticed the content of Nitrogen and Potassium in soil increased while Phosphorus decreased with advancement of growing season of herbage. He further contended that with the advancement of growing season the release of nitrogen and potassium to the soil was more as compared to their uptake by

herbage and it was vice versa in the case of phosphorus. Similar findings in monsoonal grass lands of Himachal Pradesh were also reported by Bawa (1986).

Singh *et al.* (1990) evaluated effect of different plant cover on physico-chemical properties of soil in Doon Valley. Amount of organic carbon, total N, available P and K were highest in soil under eucalyptus hybrid plantations N was lowest in soils under agricultural land use. While P and K were lowest in soils under chirpine. The lowest value of C:N ratio was found under chirpine, indicating that the lowest production of easily decomposing leaf litter in soils under chirpine.

Sharma (1991) analysed the soil under chirpine forest of Solan Forest Division for its chemical properties and found that the soil had 5.0 to 8.4 pH, 0.17 to 3.37 per cent organic carbon, 94.0 to 233 ppm available N, 10.0 to 25.0 ppm available P and 87 to 112 ppm available K.

Singh *et al.* (1991) reported pH of soil ranging from 6.5 to 7.8 in mid-hills of Himachal Pradesh. Soni (1991) recorded that the organic carbon ranged from 1.31 to 5.54 per cent in the forest soils of wet temperate zone of Himachal Pradesh.

Kaushal (1992) found positive and significant correlation of organic matter with increase in altitude and available nitrogen. Malik (1992) reported that available nitrogen varied from 94.0 to 233 ppm under different associations of chirpine in Solan district. { Guleria (1996) compared the soils under and outside the canopy of chirpine stand of Solan Forest Division of Himachal Pradesh and found that available N and organic carbon were more whereas available P, K were less in soil under chirpine stand as compared to open. Overall pH ranged from slightly acidic to neutral but the pH was acidic under chirpine as compared to open grassland. } Dalai (1997) analysed the soil for its chemical properties under chirpine forest and found that the soil had average pH

values 5.87 and 5.74, organic carbon, 1.34 and 1.05, nitrogen 337.98 and 324.05 kg/ha, phosphorus 30.42 and 27.33 kg/ha and potassium 562.95 and 425.98 kg/ha for Oachghat and Kandaghat, respectively. Rao (1998) reported that soil chemical characteristics in general showed relatively higher values under chirpine trees as compared to open grassland except pH in soil of Solan (HP).

MATERIALS & METHODS

The present investigation entitled "Production of understorey vegetation in relation to LAI and solar interception under chirpine" was carried out at four locations in Solan Forest Division (H.P.), during the year 1998. The details of the experimental sites, materials used and methodology adopted for this study are discussed in this chapter.

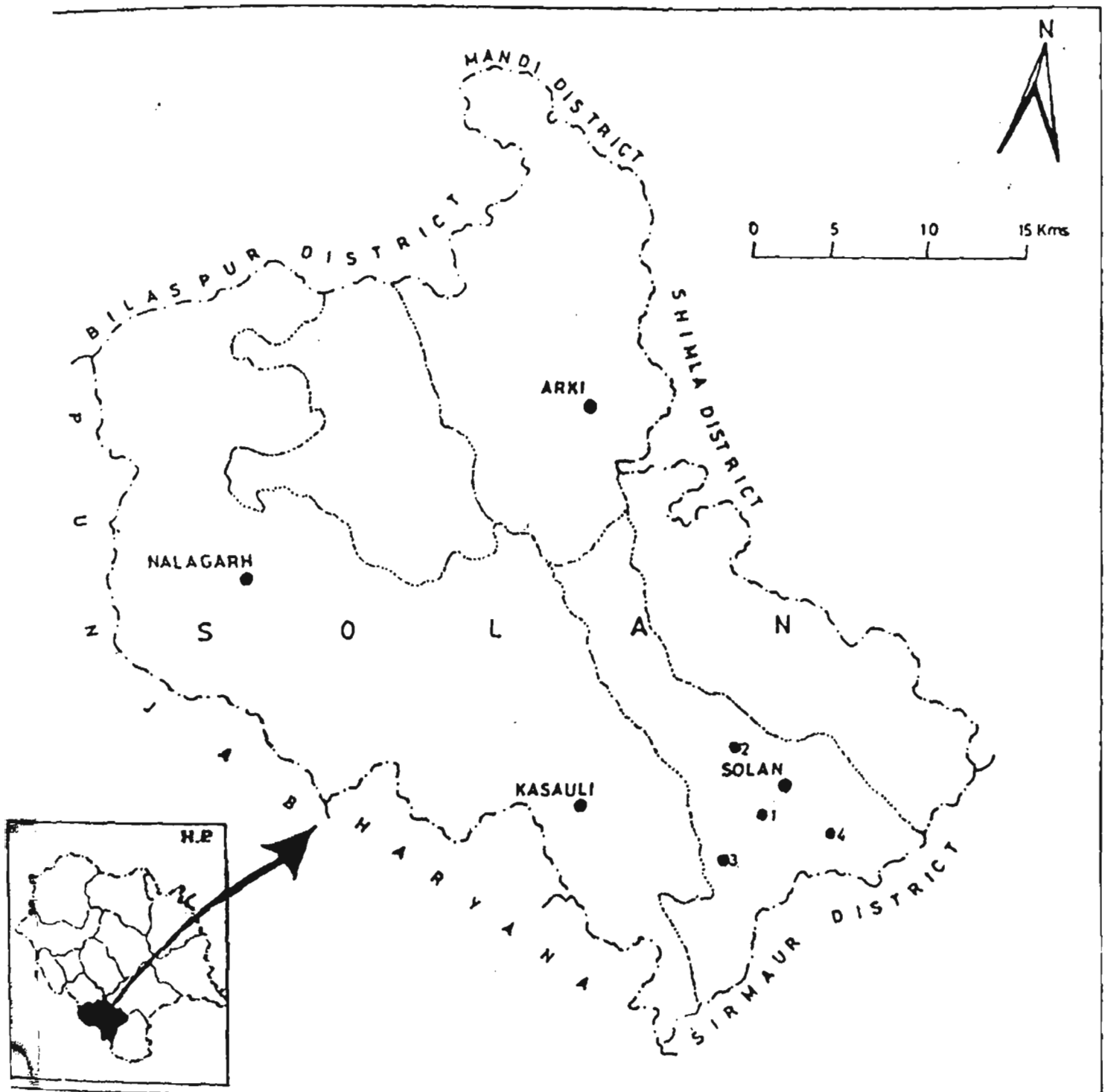
3.1 DESCRIPTION OF THE STUDY AREA

3.1.1 Location

Solan Forest Division forms the western part of Southern Himachal Pradesh having latitudes 30°05' and 31°15' N and longitudes 76°42' and 77°20' E and covers an area of 541.4 km² of which 22 per cent is under forest cover (Working plan of Solan Forest Division 1987-1996). The area under chirpine plantation in this Division is 4363.40 ha. Grasses growing under the trees especially chirpine and grasslands (Ghasnis) is common vegetation type. They are specifically used for rearing cattle. Four different locations inhabiting chirpine, were selected viz. Barog, Deothi, Dharampur and Tatul (Fig. 1). The study sites were on private lands in Deothi and Tatul whereas, others were government areas. In Barog the forest was R-31 Barog c8a and in Dharampur D-154 Dawla Dharampur.

3.1.2 Climate

The climate of the Solan district is transitional between subtropical and sub-temperate. There is considerable variation in the temperature and May to



1. Site - Barog
2. Site - Deothi
3. Site - Dharampur
4. Site - Tatul

Fig. 1. Map showing the locations of study

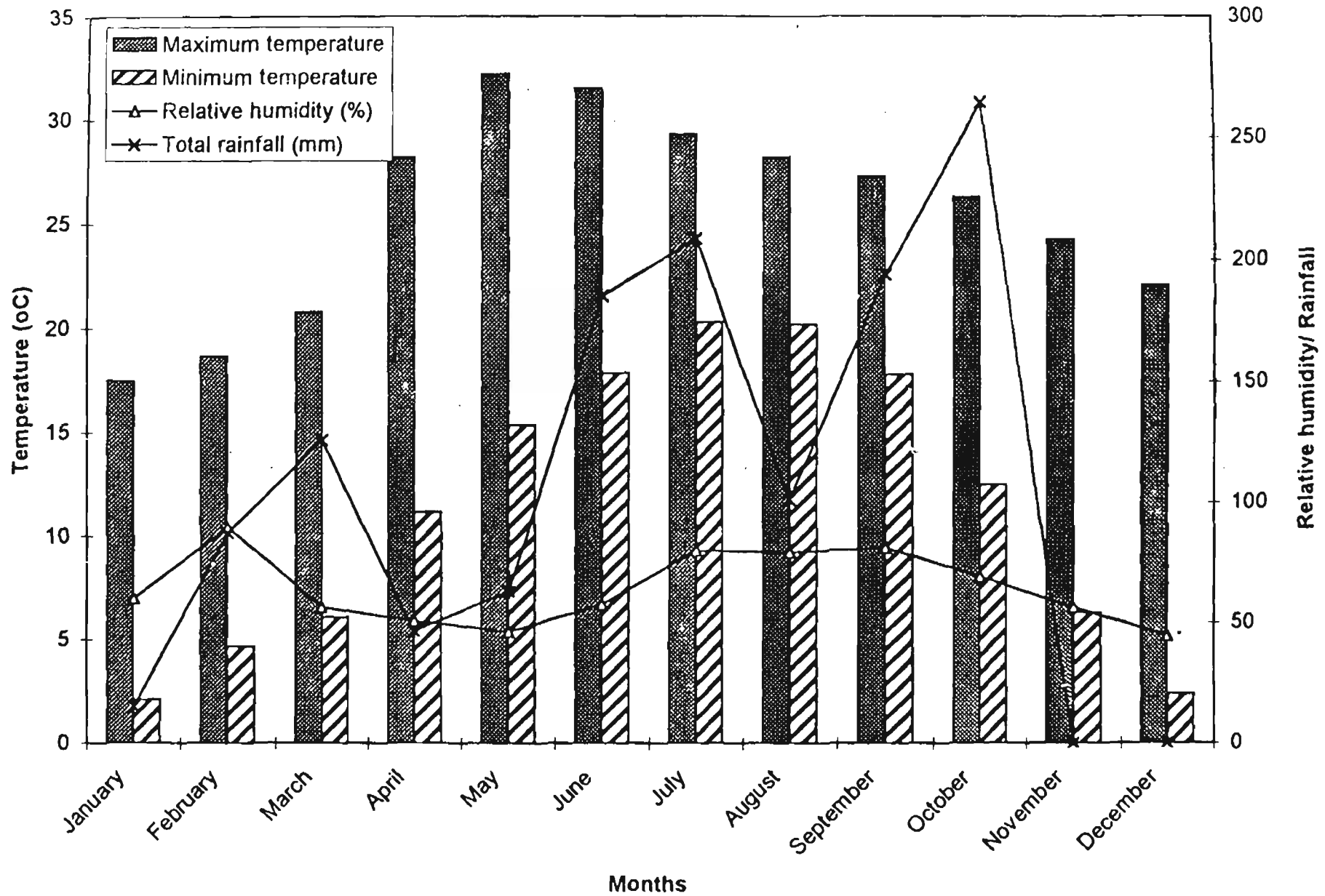


Fig. 2. Ombrothermic diagram of Solan region for the year 1998

(Source: Meteorological Observatory, Deptt. of SWM, UHF, Nauli, Solan, (H.P.)

June are the hottest months with temperature varying between 31.5-32.2°C whereas December is the coldest month experiencing temperature as low as 2.4°C. The area received an annual rainfall of 1280 mm from January 1998 to December 1998. Most of which was received in the month of July and August. The relative humidity varied from 35 to 80 per cent with yearly average 56 per cent. The meteorological data for study sites during the year 1998 is presented in Fig 2.

3.1.3 Topography and soil

The district Solan as a whole is mountaneous in nature with rolling and undulating topography except for few valleys i.e. Saproon in Solan, Doon in Nalagarh and Kunihar in Arki Tehsil, respectively. Geological structure of Shali-Deoban, Shimla group and Muree series are mostly prevailing in this district. The soils of Solan Forest Division can be broadly categorised as brown hill podzolic soils.

3.2 DEMARCATION OF RESEARCH PLOTS

A thorough survey of the chirpine forests around Solan town was done in the month of March-April. The field observations were correlated with Solan Forest working plan. To meet out the objectives of our study, four locations were selected viz. Barog, Deothi, Dharampur and Tatul. In each location sampling plots of 0.1 ha were marked. The understorey vegetation data was recorded under three tree stages viz. sapling crop stage, pole crop stage and tree crop stage. Open grass lands of 0.1 ha area each were selected adjacent to chirpine forests in each of the four locations.

3.3 OBSERVATIONS

Observations were recorded for tree components and herbage vegetation and nutrients in plants as well as soil from July to November, 1998.



3.3.1 Tree components

Height

The height of trees of pole and tree crop stages were measured using Spiegel Relaskope while in sapling crop stage height was measured with wooden rod with the help of a tape.

Crown height

Crown height of trees in pole and tree crop stages were determined from the base of the tree up to the mid point of lowest green branch and the dead branch adjacent to it by using spiegel relaskope and in sapling crop stage it was determined using measuring tape in all four locations.

Crown diameter

In all the chirpine stands, crown diameter was recorded in north-south and east-west directions by projecting the perimeter of the crown vertically to the ground.

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.

Solar influx

Relative light illumination under marked sample trees in each stage was recorded by lux meter under and out side the canopy during the day (5 times a day) on every sampling.

LAI of Trees

The observations for LAI in all the four locations for each chirpine stage were made every month beginning from the month of July till November during 1998. The observations were made with the help of LAI-2000 Canopy Analyzer. Before initiating the observations, proper calibration of the instrument was done following precautions laid out in instrument manual. A 45° view cap was used to restrict the view of the sensor. For estimating LAI values at any instant time nine readings viz., one above canopy and eight below canopy were taken. The above canopy reading was taken by holding the instrument (sensor rod) parallel to the eyes and away from any shade causing object nearby. Below canopy readings were taken under the tree crown in all the four directions in similar manner. In each chirpine crop stage, the LAI estimation procedure was repeated four times at different points on each sampling date. After completing the data recording in the field the same was downloaded into computer.

3.3.2 Herbaceous vegetation analysis

In each location sampling plots (sites) of 20x20 m were marked in three tree stages viz. tree crop stage, pole crop stage, sapling crop stage and an open grass land. Thus in all sixteen number of sampling plots (sites) were taken. In each plot (site), herbage vegetation from five quadrats of size 50x50 cm was harvested at ground level at monthly interval following Milner and Hughes (1968). The sampling was done from 15th July to 15th November and the samples were utilized for herbage analysis.

3.3.2.1 Phytosociological analysis of grasses

Phytosociological attributes of grasses in four locations were evaluated from harvested samples. The samples so collected were brought to the laboratory, washed properly with fresh running water and segregated species

wise.. The individuals of each species from different quadrats were counted separately and their basal area were calculated following Phillips (1959). The Importance Value Index (IVI) for each site was worked out by following Misra (1969).

$$IVI = RF + RD + RA$$

where,

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

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

$$RA \text{ (Relative abundance)} = \frac{\text{Abundance of individual species}}{\text{Total abundance}} \times 100$$

3.3.2.2 Herbage diversity

The herbage diversity was determined by using shannon index of general diversity as detailed by Margalef (1968)

$$\bar{H} = -\sum \left[\frac{n_i}{N} \right] \log \left[\frac{n_i}{N} \right]$$

where,

\bar{H} = Shannon index of general diversity

n_i = Importance value index of individual species

N = Importance value index of all the species

3.3.2.3 Biomass estimation of herbage

The herbage samples brought to the laboratory for phytosociological study were sorted out species wise and washed properly with fresh running water and stored in different paper bags. They were oven dried to a constant weight at 80°C for 48 hours. After attaining a constant weight each sample was weighed for biomass recorded.

For estimation of below ground biomass, the roots from each monolith of size 25x25x25 cm were brought to the laboratory, separated out species wise and washed with tap water. Roots of different grasses were kept in separate bags and oven dried to constant weight at 80°C for 48 hours and weighed for further analysis.

3.3.2.4 Nutrient analysis of herbage vegetation

The N, P and K contents of different herbage species present on different sampling dates on each location were determined by thorough grinding of oven dried samples used for biomass estimation from July to November, 1998. The common species in different quadrats in each site were mixed to make a composite sample in all the locations.

For the estimation of P & K content in plant, 0.5 gram of the ground material was digested in 4:1 Nitro-perchloric acid ($\text{HNO}_3:\text{HClO}_4$) mixture. In order to have a complete transfer of digested material, three washings of digestion flask were given with distilled water and final volume of the digest was made to 100 ml. Phosphorus was determined by Vanado-molybdate yellow colour method using Spectronic-20D. Potassium was estimated with Flame photometer. For the estimation of Nitrogen, 0.5 g of plant sample was digested in concentration H_2SO_4 using standard digestion mixture K_2SO_4 .

CuSO_4 (3.5:0.4). After digestion, nitrogen was estimated in Kjeltac Auto 1030 Analyser.

3.3.2.5 Leaf Area Index of herbage vegetation

The observation for LAI of herbage vegetation of different sites at all four locations were made every month beginning from the month of July till November during 1998. The observations were made with the help of LAI-2000 Canopy Analyser. For LAI values at any instant time nine readings viz., one above herbage vegetation and eight at the base of herbage vegetation of 1 m x 1 m size of quadrat in all the four sites at four locations. After that similar procedure was applied as far measuring LAI of chirpine crop.

3.3.2.6 Litter

On every month, the litter was collected from each quadrat of size 50 x 50 cm, packed in paper bag, oven dried and weighed.

3.4 PHYSICO-CHEMICAL PROPERTIES OF SOIL

3.4.1 Preparation of soil samples

A composite sample of soil from all the five quadrats in each site was made by collecting soil from top 0-25 cm depth. Finally, approximately 1 kg of soil was taken to the laboratory in polythene bags. The soil samples thus collected, were air dried, crushed, passed through 2 mm sieve and stored in cloth bags for physico-chemical analysis.

3.4.2 Soil analysis

Soil analysis was done to estimate soil texture, pH and EC before the start of experiment. Organic carbon (%), available nitrogen, phosphorus, potassium (kg/ ha) were estimated at monthly interval from July to November

1998, The various methods used to determine these parameters/nutrients are given in Table 1.

Table 1. Methods for analysis of different soil parameters

Parameter	Method employed
• Soil texture	Hydrometer method (Piper, 1950)
• Soil pH	1:2.5 soil : Water suspension with the help of digital pH meter (Jackson, 1973)
EC	Jackson (1973)
• Organic carbon (%)	Walkley and Black (1934)
• Available nitrogen (kg/ha)	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
• Available phosphorus(kg/ha)	Olsen <i>et al.</i> (1954)
• Available potassium (kg/ha)	Merwin and Peech (1951), and extract determined on flame photometer.

EXPERIMENTAL RESULTS

EXPERIMENTAL RESULTS

The present investigation "Production of understorey vegetation in relation to LAI and solar interception under chirpine" was carried out in four different locations in Solan, H.P. during July 1998 to November 1998. 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 LAI of chirpine trees, understorey vegetation and solar interception
- 4.4 Nutrient contents of herbage
- 4.5 Physico-chemical properties of soil

4.1 FLORISTIC COMPOSITION AND PHYTOSOCIOLOGY OF HERBAGE

4.1.1 Floristic composition

The presence or absence of a herbage species under three chirpine crop stages (sapling, pole and tree) and open grassland at four locations on every sampling date is depicted in Table 2. There were, in all, ten grass species viz. *Chrysopogon montanus*, *Heteropogon contortus*, *Themeda anathera*, *Panicum maximum*, *Cymbopogon martinii*, *Apluda mutica*, *Chrysopogon gryllus*, *Pollinia argentea*, *Hemarthria fasciculata*, and *Panicum prostratum*, two sedges viz. *Carex meiogyna* and *Cyprus rotundus*, two legumes viz. *Atylosia mollis* and *Indigofera pulchella* and two non legumes viz. *Cissampelos pareira* and *Plectranthus gerardianus* (Appendix-II). Monthly variations in total number of species in different sampling months on different locations did not vary much.

Table 2. Monthly variation in floristic composition vis-à-vis presence (+) or absence (-) of different species in the four study sites (sapling, pole and tree crop stage and open grassland) at different locations (Barog, Deothi, Dharampur and Tatul) during the study period

Species	Sapling crop stage					Pole crop stage					Tree crop stage					Open grassland				
	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov
Barog																				
<i>Themeda anathera</i>	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
<i>Panicum maximum</i>	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
<i>Apluda mutica</i>	-	-	-	-	-	-	-	+	-	+	+	-	-	-	-	+	+	+	-	-
<i>Chrysopogon gryllus</i>	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Hemarthria fasciculata</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-
<i>Pollinia argentea</i>	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
<i>Panicum prostratum</i>	+	-	-	-	+	+	+	-	-	-	-	-	-	-	+	-	-	+	-	-
<i>Carex meioyga</i>	+	+	+	-	+	-	+	+	-	-	+	+	-	-	-	-	+	+	-	+
Total no. of species	5	5	4	3	4	5	5	5	4	4	5	4	3	3	4	5	6	6	4	4
Deothi																				
<i>Chrysopogon montanus</i>	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
<i>Heteropogon contortus</i>	-	+	+	+	+	-	+	+	-	-	+	+	-	-	-	+	+	+	+	+
<i>Themeda anathera</i>	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-
<i>Panicum maximum</i>	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
<i>Cymbopogon martinii</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
<i>Apluda mutica</i>	-	-	-	-	-	-	-	-	-	-	-	+	+	+	-	-	-	-	-	-
<i>Chrysopogon gryllus</i>	-	+	+	-	+	+	+	+	-	-	-	-	-	-	-	-	-	+	+	+
<i>Hemarthria fasciculata</i>	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Cyperus rotundus</i>	+	-	-	-	-	+	-	-	-	-	+	+	+	-	-	-	-	-	-	-
Total no. of species	4	5	6	4	5	5	5	5	3	3	5	6	5	4	3	4	4	5	4	4

Contd...

Species	Sapling crop stage					Pole crop stage					Tree crop stage					Open grassland				
	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov
Dharampur																				
<i>Chrysopogon montanus</i>	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+
<i>Heteropogon contortus</i>	+	+	+	+	-	-	-	-	-	-	-	+	-	+	-	+	+	+	+	+
<i>Themeda anathera</i>	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
<i>Panicum maximum</i>	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
<i>Apluda mutica</i>	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	-	-
<i>Chrysopogon gryllus</i>	-	+	+	-	-	-	-	-	-	-	+	-	-	-	-	-	-	+	-	-
<i>Panicum prostratum</i>	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total no. of species	5	6	6	5	3	4	4	4	4	4	5	5	4	5	4	4	4	5	4	4
Tatul ✓																				
<i>Chrysopogon montanus</i>	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
<i>Heteropogon contortus</i>	-	+	+	+	-	+	-	+	+	-	-	-	+	+	+	+	+	+	+	+
<i>Themeda anathera</i>	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-
<i>Panicum maximum</i>	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	-	+	+	+
<i>Cymbopogon martinii</i>	-	-	-	-	-	-	+	-	-	-	-	+	-	-	-	+	+	-	-	-
<i>Apluda mutica</i>	-	-	-	-	+	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-
<i>Chrysopogon gryllus</i>	-	-	-	-	-	-	+	-	-	-	-	-	-	-	+	+	+	+	-	-
<i>Atylosia mollis</i>	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
<i>Indigofera pulchella</i>	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	+	-	-	-
<i>Cissampelos pareira</i>	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
<i>Plectranthus gerardianus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
Total no. of species	3	5	4	4	4	4	6	4	4	4	5	4	4	4	5	6	7	5	5	3

Also, it evinced from the data that total number of species in open grassland was not distinctly higher as compared to pine inhabited sites on respective sampling months revealing that pines did not effect the floristic composition. However, maximum number of species were observed in August and September months at Barog, Deothi and Dharampur. In Tatul more number of species were recorded in July and August among different sampling months.

4.1.2 Phytosociology of herbage

a) Density (tillers/m²)

Population strength of different species in the four locations/sites is presented in Table 3.

Barog

The total population (tillers/m²) of vegetation in Barog revealed that under sapling crop it ranged from 440.80 to 731.20, under pole crop stage from 536.80 to 737.60, under tree crop stage from 465.60 to 711.20 and in open grassland from 675.20 to 1051.20. A perusal of data explicated that total population strength increased gradually from July to September under tree crop stage & open grassland, whereas, increasing trend was recorded from July to October under sapling crop stage, thereafter it decreased. But, in pole crop stage no distinct trend was noticed. Three species viz. *T. anathera*, *P. maximum* and *P. argentea* contributed the maximum to the total density of vegetation. Among the individual species, under sapling crop stage, *P. maximum* and *P. prostratum* attained the highest (302.40 tillers/m², November) and lowest (16.80 tillers/m², November) density. In pole crop stage, *T. anathera* and *C. meiogyna* attained the highest and lowest densities as 437.60 and 6.40 tillers/m² respectively in August. Whereas, in tree crop stage, *P. argentea* showed the highest (462.40 tillers/m², September) and *C. meiogyna* & *P. prostratum* the lowest (4.80 tillers/m², July and November) density. In open

Table 3. Monthly variation in density (tillers/m²) of different species in four study sites (sapling, pole and tree crop stage and open grassland) at different locations (Barog, Deothi, Dharampur and Tatul) during study period

Species	Sapling crop stage					Pole crop stage					Tree crop stage					Open grassland				
	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov
Barog																				
<i>Themeda anathera</i>	185.60	157.60	160.00	284.00	215.20	180.00	437.60	302.40	269.60	280.00	110.40	120.00	148.80	225.60	183.20	354.40	216.80	360.00	254.40	326.40
<i>Panicum maximum</i>	140.00	171.20	208.00	248.80	302.40	44.00	118.40	94.40	180.80	234.40	23.20	111.20	100.00	196.80	173.60	137.60	37.60	56.80	162.40	150.40
<i>Apluda mutica</i>	-	-	-	-	-	-	-	8.00	-	12.80	57.60	-	-	-	-	59.20	32.00	80.80	-	-
<i>Chrysopogon gryllus</i>	-	30.40	-	-	-	96.80	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Hemarthria fasciculata</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	43.20	22.40	-	-	-
<i>Pollinia argentea</i>	73.60	51.20	153.60	204.80	-	193.60	140.80	248.80	122.40	108.00	269.60	287.20	462.40	228.80	265.60	80.80	437.60	42.40	226.40	250.40
<i>Panicum prostratum</i>	19.20	-	-	-	16.80	22.40	28.00	-	-	-	-	-	-	-	4.80	-	-	199.20	-	-
<i>Carex melogyna</i>	22.40	71.20	44.00	-	26.40	-	6.40	12.80	-	-	4.80	12.80	-	-	-	-	6.40	12.00	-	6.40
Total	440.80	481.60	565.60	737.60	560.80	536.80	731.20	666.40	572.80	635.20	465.60	531.20	711.20	651.20	627.20	675.20	752.80	1051.20	743.20	733.60
Deothi																				
<i>Chrysopogon montanus</i>	126.40	132.80	347.20	267.20	174.40	118.40	192.80	249.60	228.00	256.80	128.80	64.80	135.20	212.00	188.80	133.60	376.80	148.80	113.60	238.40
<i>Heteropogon contortus</i>	-	22.40	116.00	156.80	132.00	-	10.40	32.00	-	-	10.40	24.80	-	-	-	296.00	248.00	376.00	221.60	108.00
<i>Themeda anathera</i>	98.40	359.20	291.20	95.20	86.40	175.20	225.60	278.40	245.60	165.60	156.00	416.00	173.60	200.80	120.80	164.00	28.00	-	-	-
<i>Panicum maximum</i>	188.00	112.00	248.80	220.80	52.80	122.40	156.00	160.80	123.20	126.40	188.80	96.00	102.40	196.00	176.00	216.80	182.40	479.20	345.60	203.20
<i>Cymbopogon martinii</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.80	-	-
<i>Apluda mutica</i>	-	-	-	-	-	-	-	-	-	-	-	35.20	45.60	40.80	-	-	-	-	-	-
<i>Chrysopogon gryllus</i>	-	35.20	40.80	-	30.40	61.60	26.40	22.40	-	-	-	-	-	-	-	-	-	230.40	123.20	36.80
<i>Hemarthria fasciculata</i>	-	-	58.40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Cyprus rotundus</i>	15.20	-	-	-	-	37.60	-	-	-	-	17.60	15.20	10.40	-	-	-	-	-	-	-
Total	428.00	661.60	1102.40	740.00	476.00	515.20	611.20	743.20	596.80	548.80	501.60	652.00	667.20	649.60	485.60	810.40	835.20	1239.20	804.00	586.40

Contd...

Species	Sapling crop stage					Pole crop stage					Tree crop stage					Open grassland				
	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov
Dharampur																				
<i>Chrysopogon montanus</i>	296.00	80.80	260.00	280.00	220.80	-	245.60	420.80	380.00	264.00	344.80	140.00	144.80	228.00	197.60	418.40	500.00	600.00	351.20	360.00
<i>Heteropogon contortus</i>	40.00	302.40	61.60	48.00	-	-	-	-	-	-	-	10.40	-	19.20	-	247.20	95.20	134.40	84.80	118.40
<i>Themeda anathera</i>	138.40	128.00	80.80	161.60	181.60	185.60	286.40	204.80	155.20	146.40	50.40	288.80	260.80	311.20	148.80	137.60	116.00	108.00	122.40	10.40
<i>Panicum maximum</i>	105.60	100.80	62.40	48.00	-	195.20	54.40	29.60	52.00	20.00	84.80	25.60	69.60	48.00	46.40	35.20	36.00	72.00	168.80	161.60
<i>Apluda mutica</i>	66.40	41.6	181.60	98.40	64.00	126.40	257.60	32.00	70.40	132.00	120.00	164.00	229.60	80.80	220.00	-	-	-	-	-
<i>Chrysopogon gryllus</i>	-	12.80	12.80	-	-	-	-	-	-	-	44.00	-	-	-	-	-	-	8.80	-	-
<i>Panicum prostratum</i>	-	-	-	-	-	115.20	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	646.40	666.40	659.20	636.00	466.40	622.40	844.00	687.20	657.60	562.40	644.00	628.80	704.80	687.20	612.80	838.40	747.20	923.20	727.20	650.40
Tatul																				
<i>Chrysopogon montanus</i>	227.20	301.60	374.40	317.60	253.60	210.40	422.40	420.80	289.60	302.40	271.20	268.80	378.40	302.40	299.20	420.00	486.40	536.00	384.00	354.40
<i>Heteropogon contortus</i>	-	4.80	112.00	223.20	-	86.40	-	59.20	135.20	-	-	-	100.00	118.40	20.00	234.40	278.40	268.80	142.40	188.80
<i>Themeda anathera</i>	228.00	295.20	260.80	100.80	300.00	304.00	293.60	256.00	144.00	174.40	224.80	312.80	175.20	120.80	189.60	76.20	258.40	15.20	76.00	213.60
<i>Panicum maximum</i>	122.40	50.40	106.40	68.00	72.00	179.20	52.80	21.60	24.00	171.20	112.00	127.20	108.80	153.60	90.40	219.20	-	262.40	151.20	-
<i>Cymbopogon martinii</i>	-	-	-	-	-	-	8.80	-	-	-	-	24.00	-	-	-	6.40	12.80	-	-	-
<i>Apluda mutica</i>	-	-	-	-	28.00	-	-	-	-	17.60	-	-	-	-	-	-	-	-	-	-
<i>Chrysopogon gryllus</i>	-	-	-	-	-	-	6.40	-	-	-	-	-	-	-	21.60	135.20	68.00	64.00	-	-
<i>Alysicia mollis</i>	-	4.80	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.40	-	-	-
<i>Indigofera pulchella</i>	-	-	-	-	-	-	3.20	-	-	-	-	-	-	-	-	-	10.40	-	-	-
<i>Cissampelos pareira</i>	-	-	-	-	-	-	-	-	-	-	4.00	-	-	-	-	-	-	-	-	-
<i>Plectranthus gerardianus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	25.60	-
Total	577.60	656.80	853.60	709.60	653.60	780.00	787.20	757.60	592.80	656.60	612.00	732.80	762.40	695.2	620.80	1091.40	1116.80	1146.40	779.20	756.80

grassland, *P. argentea* and *C. meiogyna* exhibited highest (437.60 tillers/m², August) and lowest (6.40 tillers /m², August and November) density respectively.

Deothi

During the study period, total density (tillers/m²) of different species in Deothi revealed that under sapling crop stage it ranged between 428.00 to 1102.40, under pole crop stage from 515.20 to 743.20, under tree crop stage from 485.60 to 667.20 and in open grassland from 586.40 to 1239.20. A perusal of data revealed that total density increased consistently from July to September and thereafter decreased in all the sites. Four species viz. *C. montanus*, *H. contortus*, *T. anathera* and *P. maximum* were major contributors to the total density. Among the individual species, under sapling crop stage, *T. anathera* and *H. contortus* had the highest and lowest density as 359.20 and 22.40 tillers/m² respectively in August and in pole crop stage *T. anathera* attained maximum (278.40 tillers/m² in September) and *H. contortus* the minimum (10.40 tillers/m² in August). In tree crop stage, *T. anathera* attained the maximum (416.00 tillers/m², August) and *H. contortus* and *C. rotundus* minimum (10.40 tillers/m², July and September) density whereas, *P. maximum* and *C. martinii* showed the highest and lowest (479.20 and 4.80 tillers/m², respectively in September) density in open grassland.

Dharampur

The total density (tillers/m²) of different species at Dharampur revealed that under sapling crop stage it ranged from 466.40 to 666.40, under pole crop stage from 562.40 to 844.00, under tree crop stage from 612.80 to 704.80 and in open grassland from 650.40 to 923.20. A perusal of data elucidated that total density increased gradually from July to August under sapling and pole crop stages and thereafter it decreased but in tree crop stage and in open grassland,

no distinct trend was noticed. Major contribution among the different species to the total density was from three species viz. *C. montanus*, *T. anathera* and *P. maximum*. Among the individual species, under sapling crop stage *H. contortus* attained the highest density as 302.40 tillers/m² in August and *C. gryllus* the lowest density as 12.80 tillers/m² in August and September. In pole crop stage, *C. montanus* attained the highest (420.80 tillers/m², September) and *P. maximum* had the lowest (20.00 tillers/m², November) density, whereas, in tree crop stage *C. montanus* and *H. contortus* attained the highest (344.80 tillers/m², July) and lowest (10.40 tillers/m², August) density, respectively. In open grassland, *C. montanus* and *C. gryllus* attained the maximum and minimum (600.00 and 8.80 tillers/m², September, respectively) density.

Tatul

During the study period total density (tillers/m²) of different species in Tatul revealed that under sapling crop stage it ranged from 577.60 to 853.60, under pole crop stage from 592.80 to 787.20, under tree crop stage from 612.00 to 762.40 and in open grassland from 756.80 to 1146.40. A perusal of data explicated that total density increased constantly from July to September under sapling crop stage, pole stage and open grassland, thereafter it decreased. But, in pole crop stage no distinct trend was noticed. *C. montanus*, *T. anathera* and *P. maximum* contributed significantly to the total density of vegetation. Among the individual species under sapling crop stage, *C. montanus* attained the highest (374.40 tillers/m², September) and both, *H. contortus* and *A. mollis* the lowest (4.80 tillers/m², August) density. In pole crop stage, *C. montanus* and *I. pulchella* attained the highest and lowest densities in August as 422.40 and 3.20 tillers/m², respectively, whereas in tree crop stage *C. montanus* and *C. pareira* attained the maximum (378.40 tillers/m², September) and minimum (4.00 tillers/m², July) density, respectively. In open grassland *C. montanus* and *A. mollis* attained the highest (536.00 tillers/m², September) and lowest (2.40 tillers/m², August) density, respectively.

b) Basal area (cm²/m²)

The basal area of different species in four locations/sites is presented in Table 4.

Barog

The total basal area (cm²/m²) of different species in Barog under sapling crop stage ranged from 31.25 to 49.64, under pole crop stage from 38.72 to 57.13, under tree crop stage from 45.98 to 71.43 and in open grassland from 58.39 to 99.79. A perusal of data revealed that total basal area of different species in open grassland increased steadily from July to September, thereafter decreased but in other sites no distinct trend was noticed. *T. anathera*, *P. maximum* and *P. argentea* contributed significantly to the total basal area of vegetation. Among the individual species under sapling crop stage, *T. anathera* attained the highest (21.11 cm²/m², October) and *P. prostratum* the lowest (0.23 cm²/m², November) basal area. In Pole crop stage *T. anathera* and *A. mutica* attained the highest (34.49 cm²/m², August) and lowest (0.23 cm²/m², September) basal area, respectively. Whereas, in tree crop stage, *P. argentea* attained the highest (50.78 cm²/m², September) and *P. prostratum* had lowest (0.21 cm²/m², November) basal area. In open grassland *P. argentea* and *C. rotundus* attained the highest and lowest (43.28 cm²/m² and 0.89 cm²/m², August) basal area, respectively.

Deothi

The total basal area (cm²/m²) of different species under sapling crop stage ranged between 34.95 to 93.46, under pole crop stage between 37.91 to 55.28, under tree crop stage between 43.61 to 63.68 and in open grassland between 59.16 to 104.69. A perusal of data showed that total basal area of different species under sapling and tree crop stages increased steadily from July

Table 4. Monthly variation in basal area (cm²/m²) of different species in four study sites (sapling, pole and tree crop stage and open grassland) at different locations (Barog, Deothi, Dharampur and Tatul) during study period

Species	Sapling crop stage					Pole crop stage					Tree crop stage					Open grassland				
	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov
Barog																				
<i>Themeda anathera</i>	14.67	11.85	9.73	21.11	12.55	16.84	34.49	24.25	14.60	22.78	10.16	11.66	14.18	19.95	12.98	38.89	18.03	32.61	29.50	19.95
<i>Panicum maximum</i>	10.94	9.81	10.73	15.24	16.51	3.69	5.71	7.90	11.61	16.45	1.45	5.78	6.48	14.04	12.39	9.56	2.39	32.11	16.45	12.15
<i>Apluda mutica</i>	-	-	-	-	-	-	-	0.23	-	0.63	1.84	-	-	-	-	2.90	1.21	6.54	-	-
<i>Chrysopogon gryllus</i>	-	2.99	-	-	-	3.83	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Hemarthria fasciculata</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.84	1.59	-	-	-
<i>Pollinia argentea</i>	7.29	5.51	13.68	13.29	-	23.90	14.18	19.84	12.51	9.80	33.50	27.33	50.78	22.36	21.33	10.83	43.28	8.27	17.56	25.26
<i>Panicum prostratum</i>	0.26	-	-	-	0.23	0.89	2.14	-	-	-	-	-	-	-	0.21	-	-	8.15	-	-
<i>Carex melogyna</i>	2.00	7.95	3.20	-	1.96	-	0.61	2.24	-	-	0.39	1.21	-	-	-	-	0.89	2.11	-	1.03
Total	35.16	38.11	37.34	49.64	31.25	49.15	57.13	54.46	38.72	49.65	47.34	45.98	71.43	56.35	46.91	64.02	67.38	99.79	63.51	58.39
Deothi																				
<i>Chrysopogon montanus</i>	11.79	8.15	30.20	25.48	18.94	11.78	12.94	21.62	12.06	19.61	10.43	4.58	17.58	21.31	14.01	16.66	33.00	14.21	8.93	22.60
<i>Heteropogon contortus</i>	-	1.03	12.15	13.04	12.94	-	0.44	2.69	-	-	0.40	1.40	-	-	-	21.10	15.56	31.28	17.26	14.50
<i>Themeda anathera</i>	4.74	29.64	21.65	6.24	4.38	13.90	20.08	20.10	16.84	14.60	16.93	31.61	31.51	14.10	12.71	9.74	1.98	-	-	-
<i>Panicum maximum</i>	17.34	10.99	22.08	19.66	2.23	12.04	14.18	8.06	9.01	12.01	15.10	11.05	6.75	18.49	16.89	14.43	8.63	38.09	26.18	18.19
<i>Cymbopogon martinii</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.13	-	-
<i>Apluda mutica</i>	-	-	-	-	-	-	-	-	-	-	-	3.81	6.55	4.93	-	-	-	-	-	-
<i>Chrysopogon gryllus</i>	-	3.95	3.33	-	2.14	5.18	3.46	2.80	-	-	-	-	-	-	-	-	-	20.98	8.09	4.18
<i>Hemarthria fasciculata</i>	-	-	4.05	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Cyprus rotundus</i>	1.08	-	-	-	-	4.08	-	-	-	-	2.64	3.01	1.29	-	-	-	-	-	-	-
Total	34.95	53.76	93.46	59.41	40.63	46.98	51.10	55.28	37.91	46.22	45.50	55.46	63.68	58.83	43.61	61.93	59.16	104.69	60.45	59.67

Contd...

Species	Sapling crop stage					Pole crop stage					Tree crop stage					Open grassland				
	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov
Dharampur																				
<i>Chrysopogon montanus</i>	22.25	5.48	19.49	19.58	18.56	-	13.98	27.68	24.40	19.65	26.70	15.86	15.08	19.83	16.33	30.84	32.91	42.29	25.30	25.65
<i>Heteropogon contortus</i>	2.29	18.69	4.34	3.40	-	-	-	-	-	-	-	0.44	-	0.96	-	21.88	13.46	11.48	5.16	11.56
<i>Themeda anathera</i>	10.41	8.79	8.20	12.54	18.18	12.20	30.49	16.64	7.69	8.45	4.20	16.59	22.80	23.73	11.85	5.38	12.39	12.33	12.13	0.48
<i>Panicum maximum</i>	7.39	4.58	5.88	4.28	-	15.98	3.79	3.74	2.55	1.36	2.70	3.70	10.24	4.00	3.78	1.29	3.95	3.18	12.10	12.75
<i>Apluda mutica</i>	6.95	1.75	15.39	4.64	5.53	8.54	11.56	3.83	5.91	13.80	4.24	9.50	18.69	2.26	13.81	-	-	-	-	-
<i>Chrysopogon gryllus</i>	-	0.66	0.96	-	-	-	-	-	-	-	1.74	-	-	-	-	-	-	0.49	-	-
<i>Panicum prostratum</i>	-	-	-	-	-	5.10	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	49.29	39.95	54.20	44.44	42.27	41.82	59.81	51.89	40.55	43.26	39.58	46.09	66.81	50.78	45.77	59.39	62.71	69.77	54.69	50.44
Tatul																				
<i>Chrysopogon montanus</i>	13.86	15.10	30.99	19.60	17.39	12.73	31.38	26.11	20.00	16.49	20.14	17.63	37.46	26.36	18.93	27.68	25.10	43.95	29.56	23.73
<i>Heteropogon contortus</i>	-	0.10	5.01	20.16	-	4.98	-	7.03	11.34	-	-	-	13.85	8.55	1.59	15.66	23.79	23.30	21.86	22.35
<i>Themeda anathera</i>	11.70	27.69	17.88	8.06	14.43	18.28	11.71	19.88	9.04	9.86	16.43	15.13	10.94	11.09	14.74	3.59	22.78	1.63	10.11	-
<i>Panicum maximum</i>	7.80	1.09	8.03	5.28	7.16	12.81	1.58	1.23	-	10.89	7.45	11.84	10.24	11.33	6.89	17.00	-	10.99	16.00	18.01
<i>Cymbopogon martinii</i>	-	-	-	-	-	-	0.13	-	-	-	-	1.91	-	-	-	0.16	0.23	-	-	-
<i>Apluda mutica</i>	-	-	-	-	2.20	-	-	-	1.51	1.29	-	-	-	-	-	-	-	-	-	-
<i>Chrysopogon gryllus</i>	-	-	-	-	-	-	0.13	-	-	-	-	-	-	-	1.51	9.36	3.45	5.61	-	-
<i>Alylosia mollis</i>	-	0.13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.13	-	-	-
<i>Indigofera pulchella</i>	-	-	-	-	-	-	1.23	-	-	-	-	-	-	-	-	-	1.68	-	-	-
<i>Cissampelos pareira</i>	-	-	-	-	-	-	-	-	-	-	0.14	-	-	-	-	-	-	-	-	-
<i>Plectranthus gerardianus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.90	-
Total	33.36	44.11	61.91	53.10	41.18	48.80	46.16	54.35	41.89	38.53	44.16	46.51	72.49	57.33	43.66	73.45	77.16	85.21	78.43	64.12

to September, thereafter it decreased but in pole crop stage and open grassland no particular trend was noticed. *C. montanus*, *T. anathera* and *P. maximum* were the major contributors to the total basal area. Among the individual species, under sapling crop stage, *C. montanus* and *H. contortus* attained the highest (30.20 cm²/m², September) and lowest (1.03 cm²/m², August) basal area, respectively. In pole crop stage *C. montanus* attained the highest (21.63 cm²/m², September) and *H. contortus* had lowest (0.44 cm²/m², August) basal area, whereas, in tree crop stage, *T. anathera* and *H. contortus* attained the highest (31.61 cm²/m², August) and lowest (0.40 cm²/m², July) basal area, respectively. In open grassland *P. maximum* and *C. martinii* showed the maximum and minimum based area as 38.09 and 0.13 cm²/m², respectively in September.

Dharampur

The total basal area (cm²/m²) of vegetation under sapling crop stage varied from 39.95 to 54.20, under pole crop stage from 40.55 to 59.81, under tree crop stage from 39.58 to 66.81 and in open grassland from 50.44 to 69.77. A perusal of data elucidated that total basal area of different species under sapling and pole crop stages did not show any particular trend but under tree crop stage and in open grassland, it increased from July to September and thereafter decreased steadily. *C. montanus*, *T. anathera* and *P. maximum* contributed maximum to the total basal area. Among the individual species under sapling crop stage, *C. montanus* and *C. gryllus* attained the highest (22.25 cm²/m², July) and lowest (0.66 cm²/m², August) basal area, respectively, whereas in pole crop stage *T. anathera* attained the highest (30.49 cm²/m², August) and *P. maximum* had lowest (1.36 cm²/m², November) basal area. In tree crop stage *C. montanus* and *H. contortus* showed the highest (26.70 cm²/m², July) and lowest (0.44 cm²/m², August) basal area, respectively and in open grassland *C. montanus* and *T. anathera* attained the maximum (42.29 cm²/m², September) and minimum (0.48 cm²/m², November) basal area, respectively.

Tatul

During the study period the total basal area (cm^2/m^2) of different species under sapling crop stage ranged from 33.36 to 61.91, under pole crop stage from 38.53 to 54.35, under tree crop stage from 43.66 to 72.49 and in open grassland from 64.12 to 85.21. A perusal of data revealed that total basal area of different species under sapling and tree crop stages and in open grassland increased from July to September and thereafter it decreased steadily, but in pole crop stage no particular trend was noticed. *C. montanus*, *T. anathera* and *P. maximum* were the major contributors to the total basal area. Among the individual species under sapling crop stage *C. montanus* and *H. contortus* attained the highest ($30.99 \text{ cm}^2/\text{m}^2$, September) and lowest ($0.10 \text{ cm}^2/\text{m}^2$, August) basal area, respectively whereas, in pole crop stage *C. montanus* attained the maximum ($31.28 \text{ cm}^2/\text{m}^2$, August) and both *C. martinii* and *C. gryllus* had the minimum ($0.13 \text{ cm}^2/\text{m}^2$, August) basal area. In tree crop stage *C. montanus* and *C. pareira* attained the highest ($37.46 \text{ cm}^2/\text{m}^2$, September) and lowest ($0.14 \text{ cm}^2/\text{m}^2$, July) basal area, respectively and in open grassland *C. montanus* and *A. mollis* attained the highest ($43.95 \text{ cm}^2/\text{m}^2$, September) and lowest ($0.13 \text{ cm}^2/\text{m}^2$, August) basal area, respectively.

c) Frequency

The total frequency of different species in different locations/ sites is presented in Table 5.

Barog

The total frequency of different species in Barog under sapling crop stage varied from 2.20 (October and November) to 3.60 (September), under pole crop stage from 1.80 (October) to 2.80 (August), under tree crop stage from 1.60 (September) to 2.20 (July) and in open grassland from 1.80 (November) to

Table 5. Monthly variation in frequency of different species in four study sites (sapling, pole and tree crop stage and open grassland) at different locations (Barog, Deothi, Dharampur and Tatul) during study period

Species	Sapling crop stage					Pole crop stage					Tree crop stage					Open grassland				
	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov
Barog																				
<i>Themeda anathera</i>	1.00	0.60	1.00	0.80	0.80	1.00	1.00	0.60	0.80	1.00	0.60	0.60	0.40	0.60	0.40	1.00	1.00	1.00	0.80	0.60
<i>Panicum maximum</i>	0.60	0.80	1.00	0.80	0.80	0.20	0.80	0.40	0.60	1.00	0.40	0.40	0.40	0.60	0.60	0.60	0.60	1.00	0.60	0.20
<i>Apluda mutica</i>	-	-	-	-	-	-	-	0.20	-	0.20	0.20	-	-	-	-	0.20	0.20	0.40	-	-
<i>Chrysopogon gryllus</i>	-	0.20	-	-	-	0.20	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Hemarthria fasciculata</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.20	0.20	-	-	-
<i>Pollinia argentea</i>	0.40	0.20	0.80	0.60	-	0.80	0.40	0.40	0.40	0.20	0.80	0.60	0.80	0.60	0.80	0.80	1.00	0.20	0.80	0.80
<i>Panicum prostratum</i>	0.20	-	-	-	0.20	0.20	0.40	-	-	-	-	-	-	-	0.20	-	-	0.80	-	-
<i>Carex meiogyna</i>	0.40	0.60	0.80	-	0.40	-	0.20	0.40	-	-	0.20	0.20	-	-	-	-	0.20	0.60	-	0.20
Total	2.60	2.40	3.60	2.20	2.20	2.40	2.80	2.00	1.80	2.40	2.20	1.80	1.60	1.80	2.00	2.80	3.20	4.00	2.20	1.80
Deothi																				
<i>Chrysopogon montanus</i>	0.60	0.60	1.00	0.80	1.00	0.60	0.60	0.60	0.60	0.80	0.40	0.40	0.60	0.80	1.00	0.40	0.60	0.20	0.20	0.80
<i>Heteropogon contortus</i>	-	0.20	0.80	0.60	0.60	-	0.20	0.20	-	-	0.20	0.40	-	-	-	0.60	0.60	1.00	0.60	0.40
<i>Themeda anathera</i>	0.60	1.00	1.00	0.20	0.20	0.80	0.60	1.00	0.80	0.60	0.80	0.80	1.00	0.60	0.40	0.60	0.20	-	-	-
<i>Panicum maximum</i>	0.80	0.40	1.00	0.80	0.80	0.60	0.40	1.00	0.60	0.60	0.80	0.40	0.40	0.20	0.80	1.00	0.60	1.00	0.60	0.40
<i>Cymbopogon martinii</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.20	-	-
<i>Apluda mutica</i>	-	-	-	-	-	-	-	-	-	-	-	0.20	0.40	0.40	-	-	-	-	-	-
<i>Chrysopogon gryllus</i>	-	0.20	0.40	-	0.60	0.40	0.20	0.20	-	-	-	-	-	-	-	-	-	1.00	0.60	0.20
<i>Hemarthria fasciculata</i>	-	-	0.40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Cyperus rotundus</i>	0.60	-	-	-	-	0.60	-	-	-	-	0.40	0.20	0.20	-	-	-	-	-	-	-
Total	2.60	2.40	4.60	2.40	3.20	3.00	2.00	3.00	2.00	2.00	2.60	2.40	2.60	2.00	2.20	2.60	2.00	3.40	2.00	1.80

Contd...

Species	Sapling crop stage					Pole crop stage					Tree crop stage					Open grassland				
	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov
Dharampur																				
<i>Chrysopogon montanus</i>	1.00	0.40	0.80	0.80	0.80	-	0.40	1.00	0.80	1.00	0.80	0.20	0.40	0.80	0.80	1.00	1.00	1.00	0.80	0.80
<i>Heteropogon contortus</i>	0.60	1.00	0.60	0.40	-	-	-	-	-	-	-	0.20	-	0.20	-	0.80	0.60	1.00	0.80	0.80
<i>Themeda anathera</i>	0.80	0.80	0.80	0.60	0.60	0.80	0.60	1.00	0.60	0.60	0.40	1.00	1.00	0.60	0.40	0.60	0.80	0.80	0.60	0.20
<i>Panicum maximum</i>	0.60	0.40	0.40	0.20	-	0.60	0.20	0.20	0.40	0.20	0.40	0.20	0.40	0.20	0.40	0.20	0.20	0.60	0.60	0.60
<i>Apluda mutica</i>	0.40	0.20	0.40	0.40	0.60	0.40	0.60	0.20	0.40	0.80	0.60	0.80	0.80	0.40	0.80	-	-	-	-	-
<i>Chrysopogon gryllus</i>	-	0.20	0.20	-	-	-	-	-	-	-	0.40	-	-	-	-	-	-	0.20	-	-
<i>Panicum prostratum</i>	-	-	-	-	-	0.20	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	3.40	3.00	3.20	2.40	2.00	2.00	1.80	2.40	2.20	2.60	2.60	2.40	2.60	2.20	2.40	2.60	2.60	3.60	2.80	2.40
Tatul																				
<i>Chrysopogon montanus</i>	0.80	1.00	0.60	0.60	0.60	0.60	0.80	0.60	0.60	0.40	0.80	0.80	0.60	0.80	1.00	0.60	1.00	1.00	0.80	0.80
<i>Heteropogon contortus</i>	-	0.20	0.20	0.40	-	0.04	-	0.20	0.40	-	-	-	0.20	0.40	0.20	0.80	0.80	1.00	0.40	0.40
<i>Themeda anathera</i>	1.00	0.80	0.60	0.40	1.00	1.00	1.00	0.60	0.40	1.00	0.80	1.00	0.60	0.20	0.80	0.20	0.40	0.20	0.20	0.60
<i>Panicum maximum</i>	0.60	0.80	0.40	0.40	0.20	0.80	0.60	0.20	-	0.80	0.80	0.60	0.20	0.40	0.40	1.00	-	0.80	0.20	-
<i>Cymbopogon martinii</i>	-	-	-	-	-	-	0.20	-	-	-	-	0.40	-	-	-	0.20	0.20	-	-	-
<i>Apluda mutica</i>	-	-	-	-	0.60	-	-	-	0.02	0.20	-	-	-	-	-	-	-	-	-	-
<i>Chrysopogon gryllus</i>	-	-	-	-	-	-	0.20	-	-	-	-	-	-	-	0.02	0.60	0.40	0.20	-	-
<i>Alyosia mollis</i>	-	0.20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.20	-	-	-
<i>Indigofera pulchella</i>	-	-	-	-	-	-	0.20	-	-	-	-	-	-	-	-	-	0.20	-	-	-
<i>Cissampelos pareira</i>	-	-	-	-	-	-	-	-	-	-	0.40	-	-	-	-	-	-	-	-	-
<i>Plectranthus gerardianus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.20	-
Total	2.40	3.00	1.80	1.80	2.40	2.80	3.00	1.60	1.60	2.40	2.80	2.80	1.60	1.80	2.60	3.40	3.20	3.20	1.80	1.80

4.00 (September). The data on total frequency did not show any particular trend.

Deothi

The total frequency of different species in Deothi under sapling crop stage ranged from 2.40 (August and October) to 4.60 (September), under pole crop stage from 2.00 (August, October and November) to 3.00 (July and September), under tree crop stage from 2.00 (October) to 2.60 (July and September) and in open grassland from 1.80 (November) to 3.40 (September). The data on total frequency did not show any particular trend.

Dharampur

The total frequency of different species under sapling crop stage varied from 2.00 (November) to 3.40 (July), under pole crop stage from 1.80 (August) to 2.60 (November), under tree crop stage from 2.20 (October) to 2.60 (July and September) and in open grassland from 2.40 (November) to 3.60 (September). A perusal of data revealed that total frequency of different species in open grassland remained same in July and August, then increased in September and thereafter, decreased till November.

Tatul

The total frequency of different species under sapling crop stage varied from 1.80 (September and October) to 3.00 (August), under pole crop stage from 1.60 (September and October) to 3.00 (August), under tree crop stage from 1.60 (September) to 2.80 (July and August) and in open grassland from 1.80 (October and November) to 3.40 (July). Irregular increase and decrease in frequency of species was observed during the study period.



d) Importance Value Index

Numeric values of Importance Value Index (IVI) attained by different species and their dominance in different locations/sites has been presented in Table 6.

Barog

A careful scrutiny of the IVI values of the individual species revealed that under sapling crop stage *P. maximum* and *P. prostratum* maintained the highest (143.12, November) IVI. In pole crop stage *T. anathera* showed the highest (155.93, August) IVI. Whereas, under tree crop stage *P. argentea* attained the highest (186.11, September) IVI and in open grassland *P. argentea* had the maximum IVI (153.61, August). The dominant grasses were: *T. anathera*, *P. maximum* and *P. argentea* as they registered more IVI than other species.

Deothi

The monthly variation in IVI values of different species did not show consistent pattern. A perusal of data of IVI values of individual species revealed that under sapling crop stage and pole crop stage *T. anathera* attained the highest IVI as 122.31 (July) and 155.93 (August), respectively. In tree crop stage, *T. anathera* showed the highest (154.13, August) IVI and in open grassland, *C. montanus* attained the highest (130.89) IVI. *C. montanus*, *T. anathera* and *P. maximum* registered more IVI values than others species showing their dominance over others.

Dharampur

The perusal of data on IVI revealed that among the individual species under sapling crop stage, *C. montanus* attained the highest (131.25, November)

Table 6. Monthly variation in IVI of different species in four study sites (sapling, pole and tree crop stage and open grassland) at different locations (Barog, Deothi, Dharampur and Tatul) during study period

Species	Sapling crop stage					Pole crop stage					Tree crop stage					Open grassland				
	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov
Barog																				
<i>Themeda anathera</i>	122.31	88.82	82.12	117.39	114.89	109.47	155.93	119.92	129.22	131.62	72.45	81.29	65.77	103.37	76.88	148.93	86.80	101.95	130.50	111.99
<i>Panicum maximum</i>	85.95	94.63	93.29	100.79	143.12	24.03	54.76	48.68	94.88	111.70	26.22	55.71	48.13	88.46	84.09	56.78	27.28	91.12	75.02	52.42
<i>Apluda mutica</i>	-	-	-	-	-	-	-	11.61	-	11.61	25.34	-	-	-	-	20.44	12.30	24.24	-	-
<i>Chrysopogon gryllus</i>	-	22.48	-	-	-	34.14	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Hemarthria fasciculata</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	16.42	11.59	-	-	-
<i>Pollinia argentea</i>	52.82	33.41	86.02	81.81	-	118.05	58.36	61.44	75.90	45.07	165.04	146.83	186.11	108.16	127.82	57.44	153.61	8.26	94.47	121.84
<i>Panicum prostratum</i>	12.78	-	-	-	12.81	14.31	21.86	-	-	-	-	-	-	-	11.22	-	-	47.11	-	-
<i>Carex meiogyna</i>	26.14	60.65	38.57	-	29.17	-	9.09	58.35	-	-	10.94	16.16	-	-	-	-	8.42	27.32	-	13.74
Deothi																				
<i>Chrysopogon montanus</i>	86.35	60.23	85.55	109.01	114.51	68.05	86.86	92.70	100.02	129.22	63.98	34.86	70.94	108.86	116.46	58.78	130.89	31.46	38.89	123.14
<i>Heteropogon contortus</i>	-	13.63	40.91	66.44	78.33	-	12.56	15.84	-	-	10.64	22.99	-	-	-	93.68	85.99	89.63	86.12	65.02
<i>Themeda anathera</i>	59.63	151.10	71.33	30.88	35.18	90.27	106.21	107.15	125.56	91.76	99.08	154.13	143.95	84.88	72.20	59.05	16.69	-	-	-
<i>Panicum maximum</i>	124.31	54.04	67.93	93.68	41.58	69.39	73.37	69.56	74.41	79.01	101.60	51.31	41.33	71.60	111.33	88.50	66.42	104.46	116.29	87.46
<i>Cymbopogon martinii</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.40	-	-
<i>Apluda mutica</i>	-	-	-	-	-	-	-	-	-	-	-	20.61	32.50	34.66	-	-	-	-	-	-
<i>Chrysopogon gryllus</i>	-	21.00	15.96	-	30.41	36.31	21.10	14.75	-	-	-	-	-	-	-	-	-	68.04	58.70	24.39
<i>Hemarthria fasciculata</i>	-	-	18.23	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Cyprus rotundus</i>	29.71	-	-	-	-	35.97	-	-	-	-	24.70	16.09	11.27	-	-	-	-	-	-	-

Contd...

Species	Sapling crop stage					Pole crop stage					Tree crop stage					Open grassland				
	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov
Dharampur																				
<i>Chrysopogon montanus</i>	120.34	39.16	100.40	121.42	131.25	-	74.69	156.25	154.32	130.82	151.78	65.01	58.49	108.58	101.26	140.30	157.86	153.39	123.12	139.55
<i>Heteropogon contortus</i>	28.48	125.50	36.09	31.87	-	-	-	-	-	-	-	10.93	-	13.78	-	97.09	57.29	58.78	49.67	74.45
<i>Themeda anathera</i>	66.07	67.88	52.39	78.63	111.95	99.02	118.23	103.54	69.83	68.64	33.82	123.59	109.59	119.29	66.84	48.54	66.04	51.59	60.43	10.87
<i>Panicum maximum</i>	48.98	39.92	32.81	25.50	-	99.56	23.89	19.84	32.38	14.39	35.37	20.44	40.59	23.95	32.50	14.06	18.81	29.02	66.77	75.13
<i>Apluda mutica</i>	36.13	17.29	68.45	42.58	56.80	60.72	83.18	20.36	43.47	86.14	52.42	80.02	91.33	34.40	99.40	-	-	-	-	-
<i>Chrysopogon gryllus</i>	-	10.25	9.85	-	-	-	-	-	-	-	26.60	-	-	-	-	-	-	7.21	-	-
<i>Panicum prostratum</i>	-	-	-	-	-	40.71	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tatul																				
<i>Chrysopogon montanus</i>	114.22	113.49	127.25	115.00	106.03	74.48	148.34	141.10	134.10	104.90	118.49	103.15	138.81	133.93	130.02	93.81	107.34	129.59	131.41	128.34
<i>Heteropogon contortus</i>	-	7.63	32.33	91.64	-	35.57	-	33.24	74.88	-	-	-	44.73	54.16	14.55	66.33	80.77	82.04	68.37	82.03
<i>Themeda anathera</i>	116.21	134.40	92.76	51.61	122.61	112.14	96.02	108.05	70.87	93.47	102.51	110.93	75.57	47.83	95.07	17.74	65.17	9.18	33.75	89.64
<i>Panicum maximum</i>	69.57	36.81	47.65	41.74	36.74	77.80	30.11	17.60	-	87.31	63.74	64.25	40.89	64.07	45.72	72.64	-	60.78	50.91	-
<i>Cymbopogon martinii</i>	-	-	-	-	34.62	-	8.05	-	-	14.31	-	21.68	-	-	-	6.69	7.69	-	-	-
<i>Apluda mutica</i>	-	-	-	-	-	-	-	-	20.16	-	-	-	-	-	14.63	-	-	-	-	-
<i>Chrysopogon gryllus</i>	-	-	-	-	-	-	7.75	-	-	-	-	-	-	-	-	42.79	23.06	18.42	-	-
<i>Alyosia mollis</i>	-	7.67	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.62	-	-	-
<i>Indigofera pulchella</i>	-	-	-	-	-	-	9.72	-	-	-	-	-	-	-	-	-	9.35	-	-	-
<i>Cissampelos pareira</i>	-	-	-	-	-	-	-	-	-	-	15.26	-	-	-	-	-	-	-	-	-
<i>Plectranthus gerardianus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15.55	-

IVI, whereas, in pole crop stage *C. montanus* attained the highest (156.25, September) IVI. In tree crop stage *C. montanus* showed the maximum (151.78, July) IVI and in open grassland *C. montanus* maintained the highest (157.86, August) IVI. The monthly variation in IVI values of different species did not show consistent pattern. The dominant grasses were: *C. montanus*, *T. anathera* and *P. maximum*.

Tatul

The monthly variation in IVI values of different species did not show consistent pattern. A perusal of data on IVI values of the individual species revealed that under sapling crop stage *T. anathera* attained the highest (134.40, August) IVI, in pole crop stage *C. montanus* had the highest (148.34, August) IVI. In tree crop stage, *C. montanus* showed the highest (138.81, September) IVI and in open grassland, *C. montanus* attained the maximum (131.41, October) IVI. The dominant grasses were: *C. montanus*, *T. anathera* and *P. maximum* as they registered more IVI values than other species.

4.1.3 Shannon's index of species diversity

The monthly variation in species diversity at Barog, ranged from 0.470 to 0.645 under sapling crop stage, 0.467 to 0.621 under pole crop stage, 0.401 to 0.527 under tree crop stage and 0.466 to 0.669 in open grassland. At Deothi, under sapling crop stage it varied from 0.553 to 0.710, under pole crop stage from 0.468 to 0.672, under tree crop stage from 0.468 to 0.622 and in open grassland from 0.459 to 0.601. At Dharampur, under sapling crop stage species diversity varied from 0.454 to 0.702, under pole crop stage from 0.464 to 0.576, under tree crop stage from 0.568 to 0.592 and in open grassland from 0.503 to 0.573. At Tatul, under sapling crop stage it varied from 0.466 to 0.568, under pole crop stage from 0.492 to 0.572, under tree crop stage from 0.527 to 0.568 and in open grassland from 0.468 to 0.682. However, the average values of

Table 7. Shannon's Index of species diversity in study sites (sapling, pole and tree crop stage and open grassland) at four locations (Barog, Deothi, Dharampur and Tatul) during study period

Sampling months	Study sites															
	Barog				Deothi				Dharampur				Tatul			
	S	P	T	O	S	P	T	O	S	P	T	O	S	P	T	O
July	0.598	0.577	0.527	0.574	0.553	0.672	0.602	0.592	0.640	0.576	0.592	0.503	0.466	0.572	0.527	0.682
August	0.645	0.550	0.510	0.554	0.566	0.604	0.622	0.527	0.658	0.552	0.588	0.504	0.509	0.541	0.545	0.667
September	0.582	0.621	0.401	0.669	0.710	0.596	0.578	0.601	0.702	0.464	0.573	0.556	0.547	0.492	0.547	0.573
October	0.472	0.467	0.476	0.466	0.564	0.468	0.572	0.569	0.626	0.522	0.576	0.573	0.568	0.534	0.561	0.608
November	0.470	0.495	0.518	0.512	0.641	0.468	0.468	0.459	0.454	0.523	0.568	0.508	0.538	0.536	0.568	0.468
Mean	0.553	0.542	0.486	0.555	0.607	0.562	0.568	0.540	0.616	0.527	0.579	0.529	0.526	0.535	0.550	0.600

S = Sapling crop stage

P = Pole crop stage

T = Tree crop stage

O = Open grassland

Shannon's diversity index of different species were 0.553, 0.542, 0.486 and 0.555 at Barog, 0.607, 0.562, 0.568 and 0.540 at Deothi, 0.616, 0.527, 0.579 and 0.529 at Dharampur and 0.526, 0.535, 0.550 and 0.600 at Tatul under sapling crop stage, pole crop stage, tree crop stage and open grassland, respectively (Table 7).

4.2 BIOMASS PRODUCTION OF DIFFERENT SPECIES IN DIFFERENT LOCATIONS

4.2.1 Aboveground biomass

Total aboveground biomass (q/ha) at different locations/ sites during the study period is presented in Table 8.

Barog

The total aboveground biomass (q/ha) of different species under sapling crop stage varied from 10.23 to 12.46 under pole crop stage from 11.50 to 16.13, under tree crop stage from 10.08 to 24.14 and in open grassland from 15.63 to 30.88. A perusal of data explicated that the total aboveground biomass production during the study period increased gradually from July to September in all chirpine crop stages and open grassland. After that a gradual decrease was observed except in pole and tree crop stages. *T. anathera*, *P. maximum* and *P. argentea* were the major contributor, to the community aboveground biomass. Among the individual species, under sapling crop stage *P. maximum* and *P. prostratum* attained the highest (6.57) and lowest (0.20) aboveground biomass respectively in November. Whereas, in pole crop stage *T. anathera* attained the highest (8.97, August) and *Aplluda mutica* the lowest aboveground biomass (0.23, September). In tree crop stage, *P. argentea* had the highest (15.84, September) and *P. prostratum* the lowest (0.10, November) above ground biomass and in open grassland, *T. anathera* showed the maximum (13.24,

Table 8. Monthly variation in aboveground biomass (q/ha) of different species in four study sites (sapling, pole and tree crop stage and open grassland) at different locations (Barog, Deothi, Dharampur and Tatul) during study period

Species	Sapling crop stage					Pole crop stage					Tree crop stage					Open grassland				
	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov
Barog																				
<i>Themeda anathera</i>	4.80	4.29	3.78	3.95	3.10	3.41	8.97	7.66	5.58	6.10	2.33	2.19	5.83	3.89	3.30	9.37	5.45	13.24	8.62	5.62
<i>Panicum maximum</i>	1.78	3.02	3.54	3.99	6.57	1.47	2.21	2.12	4.05	5.70	0.53	3.03	2.47	4.51	2.70	2.70	1.00	8.34	4.10	2.70
<i>Apluda mutica</i>	-	-	-	-	-	-	-	0.23	-	0.50	0.95	-	-	-	-	1.55	1.37	3.72	-	-
<i>Chrysopogon gryllus</i>	-	1.65	-	-	-	0.97	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Hemarthria fasciculata</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.35	0.48	-	-	-
<i>Pollinia argentea</i>	1.94	1.14	3.70	3.86	-	4.83	1.98	5.24	2.59	2.16	6.09	6.39	15.84	4.39	7.20	1.75	7.31	1.54	4.70	6.95
<i>Panicum prostratum</i>	0.53	-	-	-	0.20	0.82	0.50	-	-	-	-	-	-	-	0.10	-	-	3.13	-	-
<i>Carex meioyena</i>	1.18	1.76	1.44	-	0.90	-	0.35	0.88	-	-	0.18	0.50	-	-	-	-	0.28	0.91	-	0.36
Total	10.23	11.86	12.46	11.80	10.77	11.50	14.01	16.13	12.22	14.46	10.08	12.11	24.14	12.79	13.30	15.72	15.89	30.88	17.42	15.63
Deothi																				
<i>Chrysopogon montanus</i>	3.04	2.55	7.94	5.01	5.48	2.86	3.16	7.10	6.15	8.23	2.80	0.74	2.72	4.20	5.41	2.99	8.91	3.46	3.17	7.14
<i>Heteropogon contortus</i>	-	0.26	3.38	4.40	3.51	-	0.22	1.25	-	-	0.20	1.28	-	-	-	6.60	6.10	8.95	5.04	3.70
<i>Themeda anathera</i>	1.09	6.09	7.06	2.01	1.37	3.51	3.44	7.64	5.80	3.10	3.13	10.15	10.13	3.75	2.35	1.55	0.58	-	-	-
<i>Panicum maximum</i>	4.05	2.03	5.27	3.86	1.43	1.68	3.08	5.87	4.34	2.31	2.92	1.35	1.07	3.96	6.14	3.93	2.81	12.89	8.74	5.01
<i>Cymbopogon martinii</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.35	-	-
<i>Apluda mutica</i>	-	-	-	-	-	-	-	-	-	-	-	0.75	1.92	1.20	-	-	-	-	-	-
<i>Chrysopogon gryllus</i>	-	0.59	0.68	-	0.44	1.03	0.60	0.82	-	-	-	-	-	-	-	-	-	7.01	2.83	1.79
<i>Hemarthria fasciculata</i>	-	-	1.16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Cyprus rotundus</i>	0.45	-	-	-	-	1.01	-	-	-	-	1.50	0.78	0.78	-	-	-	-	-	-	-
Total	8.63	11.52	25.49	15.28	12.23	10.09	10.50	22.68	16.29	13.64	10.55	15.05	16.62	13.11	13.90	15.07	18.40	32.66	19.78	17.64

Contd..

Species	Sapling crop stage					Pole crop stage					Tree crop stage					Open grassland				
	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov
Dharampur																				
<i>Chrysopogon montanus</i>	5.80	1.07	6.43	4.17	4.75	-	4.73	8.75	6.74	6.04	6.79	2.11	1.22	3.54	3.90	7.76	8.08	9.19	6.95	6.82
<i>Heteropogon contortus</i>	0.39	3.93	1.76	1.38	-	-	-	-	-	-	-	0.19	-	0.25	-	4.07	7.40	4.30	2.70	2.79
<i>Themeda anathera</i>	2.84	2.85	2.50	3.52	3.33	2.77	4.56	4.96	3.53	2.06	1.11	7.39	8.00	6.36	2.94	1.14	1.85	2.79	1.53	0.26
<i>Panicum maximum</i>	1.69	1.66	1.94	1.29	-	3.91	0.42	0.43	0.62	0.47	1.33	1.20	1.30	1.85	1.85	0.29	0.95	1.73	5.03	5.93
<i>Apluda mutica</i>	1.30	0.56	4.25	2.11	1.05	2.48	3.28	0.59	1.83	4.21	2.46	4.31	6.29	3.02	5.38	-	-	-	-	-
<i>Chrysopogon gryllus</i>	-	0.15	0.30	-	-	-	-	-	-	-	0.72	-	-	-	-	-	-	0.25	-	-
<i>Panicum prostratum</i>	-	-	-	-	-	1.16	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	12.02	10.22	17.18	12.47	9.13	10.32	12.99	14.73	12.72	12.78	12.41	15.20	16.81	15.02	14.07	13.26	18.28	18.26	16.21	15.80
Tatul																				
<i>Chrysopogon montanus</i>	3.97	5.40	7.38	5.10	4.60	4.70	7.35	9.82	7.24	9.20	6.27	5.32	10.54	8.54	8.76	6.31	9.78	16.08	8.14	10.01
<i>Heteropogon contortus</i>	-	0.12	2.55	4.91	-	0.89	-	1.37	2.90	-	-	-	3.06	2.10	0.32	3.15	3.50	4.26	2.24	4.29
<i>Themeda anathera</i>	3.68	4.69	6.27	3.05	6.10	5.42	6.54	6.20	3.29	3.30	4.73	4.88	5.42	1.58	3.41	0.47	3.77	0.64	2.14	-
<i>Panicum maximum</i>	2.48	0.80	1.67	2.00	2.30	3.00	1.48	0.66	-	3.22	3.40	2.45	4.37	2.92	1.98	2.45	-	5.33	2.76	4.10
<i>Cymbopogon martinii</i>	-	-	-	-	-	-	0.27	-	-	-	-	0.75	-	-	-	0.12	0.35	-	-	-
<i>Apluda mutica</i>	-	-	-	-	1.50	-	-	-	0.50	0.20	-	-	-	-	-	-	-	-	-	-
<i>Chrysopogon gryllus</i>	-	-	-	-	-	-	0.28	-	-	-	-	-	-	-	0.30	5.53	0.83	1.93	-	-
<i>Alyosia mollis</i>	-	0.20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.10	-	-	-
<i>Indigofera pulchella</i>	-	-	-	-	-	-	0.17	-	-	-	-	-	-	-	-	-	0.80	-	-	-
<i>Cissampelos pareira</i>	-	-	-	-	-	-	-	-	-	-	0.33	-	-	-	-	-	-	-	-	-
<i>Plectranthus gerardianus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.87	-
Total	10.13	11.21	17.87	15.06	14.50	14.01	16.09	18.05	13.93	15.92	14.73	13.40	23.39	15.14	14.77	18.03	19.13	28.24	16.15	18.40

September) and *C. meiogyna* had the minimum (0.28, August) aboveground biomass.

Deothi

The total aboveground biomass (q/ha) of different species at Deothi under sapling crop stage varied from 8.63 to 25.49, under pole crop stage from 10.09 to 22.68, under tree crop stage from 10.55 to 16.62 and in open grassland from 15.07 to 32.66. A rummage of data revealed that the total aboveground biomass production increased constantly from July to September in all chirpine crop stages and in open grassland, after that it decreased till November, except in tree crop stage. *C. montanus*, *T. anathera* and *P. maximum* contributed significantly to the total aboveground biomass of the community. Among the individual plant species under sapling crop stage *C. montanus* and *H. contortus* attained the highest (7.94, September) and lowest (0.26, August) aboveground biomass, respectively. Whereas, under pole crop stage *C. montanus* and *H. contortus* had the maximum (8.23, November) and minimum (0.22, August) aboveground biomass, respectively. In tree crops stage, *T. anathera* attained the highest (10.15, September) and *H. contortus* had the lowest (0.20, July) aboveground biomass and in open grassland *P. maximum* and *C. martinii* had the highest (12.89) and lowest (0.35) aboveground biomass, respectively in September.

Dharampur

The total aboveground biomass (q/ha) of different species under sapling crop stage varied from 9.13 to 17.18, under pole crop stage from 10.32 to 14.73, under tree crop stage from 12.41 to 16.81 and in open grassland from 13.26 to 18.26. A perusal of data explicated that under tree crop stage the total aboveground biomass increased constantly from July to September and then decreased till November. In open grassland, it increased from July to August

and thereafter it decreased. In others tree crop stages no particular trend was noticed. *C. montanus*, *T. anathera* and *P. maximum* contributed the major amount of aboveground biomass to the total aboveground biomass of the community. Among the individual species under sapling crop stage *C. montanus* and *C. gryllus* attained the highest (6.43, September) and lowest (0.15, August) aboveground biomass, respectively whereas, in pole crop stage *C. montanus* and *P. maximum* attained the highest (8.75, September) and lowest (0.42, August) above ground biomass, respectively. In tree crop stage *T. anathera* and *P. maximum* attained the maximum (8.00, September) and minimum (0.19, August) above ground biomass, respectively and in open grassland *C. montanus* achieved the highest (9.19) and *C. gryllus* the lowest (0.25) aboveground biomass in September.

Tatul

The total aboveground biomass (q/ha) of different species at Tatul revealed that under sapling crop stage it varied from 10.13 to 17.87, under pole crop stage from 13.93 to 18.05, under tree crop stage from 13.40 to 23.39 and in open grassland from 16.15 to 28.24. A perusal of data revealed that the total aboveground biomass increased from July to September and thereafter, decreased constantly under sapling crop stage, but in others no particular trend was noticed. *C. montanus*, *T. anathera* and *P. maximum* contributed significantly to the total aboveground biomass of the community. Among the individual species under sapling crop stage, *C. montanus* and *H. contortus* attained the highest (7.38, September) and lowest (0.12, August) aboveground biomass, respectively whereas, under pole crop stage *C. montanus* had the highest (9.82, September) and *I. pulchella* the lowest (0.17, August) aboveground biomass. In tree crop stage *C. montanus* and *C. gryllus* showed the maximum (10.54, September) and minimum (0.30, November) aboveground biomass, respectively and in open grassland *C. montanus* and *A. mollis* attained

highest (16.08, September) and lowest (0.10, August) aboveground biomass, respectively.

4.2.2 Belowground biomass

Total belowground biomass in different locations/sites during the study period is presented in Table 9.

Barog

Total belowground biomass (q/ha) of different species at Barog under sapling crop stage varied from 7.77 to 10.37, under pole crop stage from 10.86 to 13.96, under tree crop stage from 9.51 to 18.79 and in open grassland from 11.10 to 21.89. A perusal of data explicated that total belowground biomass increased from July to September and after that it decreased constantly in sapling crop stage and open grassland, but in others, no particular trend was noticed. *T. anathera*, *P. maximum* and *P. argentea* contributed the major amount of belowground biomass to the total belowground biomass of the community. Among the individual species, under sapling crop stage, *P. maximum* and *P. prostratum* attained the highest and lowest (4.93 and 0.19, November) belowground biomass, respectively whereas, in pole crop stage *T. anathera* and *C. meiogyna* attained the maximum and minimum (6.29 and 0.21, August) belowground biomass, respectively. In tree crop stage *P. argentea* attained the highest (13.60, September) and *C. meiogyna* had the lowest (0.11, July) belowground biomass and in open grassland *T. anathera* attained the highest (8.19, September) and *P. maximum* the lowest (0.22, August) belowground biomass.

Deothi

Total belowground biomass (q/ha) different species at Deothi revealed that under sapling crop stage it varied from 7.26 to 22.04, under pole crop stage

Table 9. Monthly variation in belowground biomass (q/ha) of different species in four study sites (sapling, pole and tree crop stage and open grassland) at different locations (Barog, Deothi, Dharampur and Tatul) during study period

Species	Sapling crop stage					Pole crop stage					Tree crop stage					Open grassland				
	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov
Barog																				
<i>Themeda anathera</i>	3.72	3.22	2.16	2.62	1.38	2.64	6.29	5.28	4.50	4.50	1.87	1.89	3.59	3.58	2.64	3.84	3.05	8.19	6.14	4.73
<i>Panicum maximum</i>	1.11	1.63	2.44	2.59	4.93	2.56	1.67	2.04	4.07	4.18	0.40	2.82	1.60	3.14	2.56	3.07	0.22	7.05	3.97	1.64
<i>Apluda mutica</i>	-	-	-	-	-	-	-	0.81	-	0.49	0.63	-	-	-	-	1.24	1.10	3.66	-	-
<i>Chrysopogon gryllus</i>	-	0.88	-	-	-	0.78	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Hemarthria fasciculata</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.29	0.61	-	-	-
<i>Poliinia argentea</i>	1.82	0.80	3.04	3.42	-	4.55	2.37	5.14	2.91	2.12	6.56	5.19	13.60	3.50	6.32	2.66	5.65	1.22	2.91	6.08
<i>Panicum prostratum</i>	0.37	-	-	-	0.19	0.63	0.32	-	-	-	-	-	-	-	0.48	-	-	1.44	-	-
<i>Carex meio gyn a</i>	1.56	2.34	2.74	-	1.28	-	0.21	0.69	-	-	0.11	0.31	-	-	-	-	0.81	0.32	-	0.40
Total	8.58	8.87	10.37	8.64	7.77	11.15	10.86	13.96	11.48	11.28	9.51	10.22	18.79	10.22	12.00	11.10	11.43	21.88	13.02	12.85
Deothi																				
<i>Chrysopogon montanus</i>	2.05	2.79	6.97	4.19	4.68	1.65	2.50	4.16	3.36	7.74	1.92	0.59	1.86	3.23	3.87	1.28	8.61	2.92	3.87	6.11
<i>Heteropogon contortus</i>	-	0.45	2.98	3.98	2.99	-	0.61	1.28	-	-	0.19	1.02	-	-	-	5.22	5.12	7.42	5.17	3.30
<i>Themeda anathera</i>	1.86	5.20	5.02	1.81	1.30	3.55	1.73	6.29	3.97	2.86	3.52	8.14	8.13	1.98	0.30	2.24	0.82	-	-	-
<i>Panicum maximum</i>	2.99	1.22	5.22	2.44	1.09	1.75	3.42	3.46	3.20	2.02	1.58	1.56	0.93	2.89	8.82	3.06	2.19	9.84	7.41	4.69
<i>Cymbopogon martinii</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.67	-	-
<i>Apluda mutica</i>	-	-	-	-	-	-	-	-	-	-	-	0.67	2.21	1.50	-	-	-	-	-	-
<i>Chrysopogon gryllus</i>	-	0.92	1.12	-	0.61	2.26	0.49	0.95	-	-	-	-	-	-	-	-	-	2.72	1.93	2.56
<i>Hemarthria fasciculata</i>	-	-	0.74	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Cyprus rotundus</i>	0.36	-	-	-	-	0.82	-	-	-	-	0.99	1.89	0.99	-	-	-	-	-	-	-
Total	7.26	10.57	22.04	12.42	10.67	10.04	8.75	16.13	10.53	12.62	9.19	13.88	14.11	9.60	12.99	12.79	16.74	23.57	17.38	16.66

Contd...

Species	Sapling crop stage					Pole crop stage					Tree crop stage					Open grassland				
	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov
Dharampur																				
<i>Chrysopogon montanus</i>	4.74	0.58	4.18	3.58	3.82	-	2.99	5.25	5.57	5.45	5.46	1.60	1.02	2.61	2.53	6.11	8.13	7.90	4.26	5.08
<i>Heteropogon contortus</i>	0.84	3.28	1.62	0.65	-	-	-	-	-	-	-	0.32	-	0.67	-	3.10	4.66	3.22	2.08	1.73
<i>Themeda anathera</i>	1.57	1.90	1.54	2.60	3.59	2.38	3.55	3.89	1.73	2.98	1.18	5.94	6.20	3.20	1.67	1.50	1.54	1.38	1.38	1.08
<i>Panicum maximum</i>	1.30	1.29	1.55	0.95	1.26	4.11	0.48	0.48	0.58	0.69	1.06	0.96	1.82	1.95	2.66	0.23	0.89	1.26	4.88	5.44
<i>Apluda mutica</i>	1.40	1.54	3.40	1.77	-	1.18	2.88	1.15	1.66	3.18	2.69	2.89	4.54	1.95	4.40	-	-	-	-	-
<i>Chrysopogon gryllus</i>	-	1.13	0.29	-	-	-	-	-	-	-	0.60	-	-	-	-	-	-	0.50	-	-
<i>Panicum prostratum</i>	-	-	-	-	-	0.48	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	9.85	8.71	12.57	9.55	8.67	8.15	9.91	10.77	9.54	11.47	10.99	11.70	13.58	10.38	10.26	10.95	15.22	14.25	12.59	13.33
Tatul																				
<i>Chrysopogon montanus</i>	2.94	5.79	5.98	4.73	3.20	2.56	5.85	6.69	4.31	6.08	5.03	4.33	8.73	4.70	8.06	4.78	7.31	12.37	6.50	9.38
<i>Heteropogon contortus</i>	-	0.91	9.04	3.77	-	1.28	-	1.01	1.12	-	-	-	2.41	7.27	0.56	2.08	2.65	2.21	1.79	3.08
<i>Themeda anathera</i>	4.00	3.44	5.43	1.89	4.08	3.48	5.13	4.96	3.17	1.92	3.02	3.73	3.20	1.86	1.50	0.37	2.82	0.50	1.73	2.74
<i>Panicum maximum</i>	2.56	0.87	1.67	1.20	2.84	3.42	1.18	0.32	-	2.48	2.54	1.57	2.40	1.66	1.64	2.47	-	2.92	2.56	-
<i>Cymbopogon martinii</i>	-	-	-	-	-	-	0.12	-	-	-	-	0.52	-	-	-	0.91	0.21	-	-	-
<i>Apluda mutica</i>	-	-	-	-	1.29	-	-	-	0.49	0.19	-	-	-	-	-	-	-	-	-	-
<i>Chrysopogon gryllus</i>	-	-	-	-	-	-	0.21	-	-	-	-	-	-	-	-	3.41	0.45	1.45	-	-
<i>Alyosia mollis</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.24	-	0.10	-	-	-
<i>Indigofera pulchella</i>	-	-	-	-	-	-	0.91	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Cissampelos pareira</i>	-	-	-	-	-	-	-	-	-	-	0.59	-	-	-	-	-	-	-	-	-
<i>Plectranthus gerardianus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.90	-
Total	9.50	11.01	15.12	11.58	11.41	10.74	13.40	12.98	9.09	10.67	11.20	10.14	16.74	10.50	11.70	14.02	13.55	19.45	13.48	15.20

from 8.75 to 16.13, under tree crop stage from 9.19 to 14.11 and in open grassland from 12.79 to 23.57. *C. montanus*, *T. anathera* and *P. maximum* were the major contributors to the total belowground biomass. A perusal of data explicated that total belowground biomass under sapling crop stage and in open grassland increased from July to September and thereafter it decreased constantly upto November, but in other chirpine stages no particular trend was observed. Among the individual species, under sapling crop stage *C. montanus* attained the highest (6.97, September) belowground biomass while, *C. rotundus* had the lowest (0.36, July), whereas, in pole crop stage *C. montanus* attained the highest (7.74, November) and *C. gryllus* the lowest (0.49, August) belowground biomass. In tree crop stage, *P. maximum* had the highest (8.82, November) and *H. contortus* the lowest (0.19, July) belowground biomass and in open grassland *P. maximum* and *C. martinii* had the highest and lowest (9.84 and 0.67, September) belowground biomass, respectively.

Dharampur

Total belowground biomass (q/ha) of different species at Dharampur showed that under sapling crop stage, it varied from 8.67 to 12.57, under pole crop stage from 8.15 to 10.77, under tree crop stage from 10.26 to 13.58 and in open grassland from 10.95 to 15.22. A perusal of data explicated that under tree crop stage total belowground biomass of herbage increased from July to September and thereafter, it decreased. *C. montanus*, *T. anathera* and *P. maximum* were the major contributors to the total belowground biomass of the community. Among the individual species under sapling crop stage *C. montanus* attained the highest (4.74, July) and *C. gryllus* the lowest (0.29, September) belowground biomass, whereas, in pole crop stage *C. montanus* had the maximum (5.57, October) and *P. prostratum* the minimum (0.48, September and July) below ground biomass. In tree crop stage, *T. anathera* showed the highest (6.20, September) and *H. contortus* the lowest (0.32, August) belowground biomass and in open grassland, *C. montanus* attained the highest (8.13, August) and *P. maximum* the lowest (0.23, July) belowground biomass.

Tatul

Total belowground biomass (q/ha) of different species at Tatul revealed that under sapling crop stage it varied from 9.50 to 15.12, under pole crop stage from 9.09 to 13.40, under tree crop stage from 10.14 to 16.74 and in open grassland it varied from 13.48 to 19.45. A perusal of data explicated that total belowground biomass in sapling crop stage increased from July to September and after that it decreased constantly, but in other sites no particular trend was noticed. *C. montanus*, *T. anathera* and *P. maximum* contributed the major belowground biomass towards the total belowground biomass of the community. Among the individual species, under sapling crop stage, *H. contortus* attained the highest belowground biomass (9.04) in September and lowest (0.87) in August whereas, under pole crop stage *C. montanus* showed the highest (6.69, September) and *C. martinii* the lowest (0.12, August) belowground biomass. In tree crop stage *C. montanus* attained the highest (8.73, September) and *A. mollis* the lowest (0.24, November) belowground biomass whereas, in open grassland *C. montanus* recorded the highest (12.37 q/ha, September) and *A. mollis* the lowest (0.10 q/ha, August) belowground biomass.

In all the four locations aboveground and belowground biomass increased from July to September and thereafter, they decreased in all sites. Biomass production was more in open grasslands than in pine inhabited sites on all sampling dates.

4.3 LAI OF CHIRPINE TREES, UNDERSTOREY VEGETATION AND SOLAR INTERCEPTION

4.3.1 LAI of chirpine trees

Monthly variations in mean LAI of chirpine trees of different growth stages at different locations is presented in Table 10.

Table 10. Monthly variation in mean LAI of chirpine trees in study sites (sapling, pole and tree crop stage) at four locations (Barog, Deothi, Dharampur and Tatul) during study period

	Sapling crop stage					Pole crop stage					Tree crop stage				
	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov
Barog															
LAI	1.25	1.63	1.63	1.76	1.34	1.11	1.81	1.61	1.80	1.54	1.04	1.30	1.53	1.01	1.09
SE	± 0.11	± 0.16	± 0.16	± 0.17	± 0.11	± 0.07	± 0.13	± 0.16	± 0.16	± 0.13	± 0.03	± 0.12	± 0.58	± 0.09	± 0.07
Deothi															
LAI	1.54	1.69	1.61	1.58	1.74	1.27	1.87	1.70	1.49	1.47	1.21	1.71	1.51	1.42	1.65
SE	± 0.09	± 0.12	± 0.21	± 0.19	± 0.22	± 0.15	± 0.20	± 0.13	± 0.14	± 0.18	± 0.09	± 0.16	± 0.12	± 0.14	± 0.14
Dharampur															
LAI	1.30	1.94	1.76	1.45	1.69	1.13	1.75	1.69	1.12	1.63	1.29	1.40	1.39	1.41	1.54
SE	± 0.19	± 0.29	± 0.38	± 0.13	± 0.12	± 0.12	± 0.19	± 0.11	± 0.11	± 0.15	± 0.09	± 0.14	± 0.14	± 0.12	± 0.14
Tatul															
LAI	1.86	2.04	2.20	2.16	1.90	1.18	1.44	1.99	1.95	1.43	1.37	1.68	1.51	1.76	1.49
SE	± 0.16	± 0.13	± 0.25	± 0.20	± 0.24	± 0.16	± 0.14	± 0.20	± 0.26	± 0.13	± 0.14	± 0.16	± 0.21	± 0.12	± 0.22

Barog

The mean LAI of chirpine trees of sapling crop stage varied from 1.25 to 1.76, pole crop stage from 1.11 to 1.81 and tree crop stage from 1.01 to 1.53 during the study period. It was evident from the data that mean LAI increased gradually from July to October in sapling crop stage, from July to August in pole crop stage and from July to September in tree crop stage. Thereafter, it increased or decreased in irregular manner. On each sampling date, the mean LAI of tree crop stage was less than Sapling and pole crop stage but no distinct trend was observed in the difference of LAI of sapling and pole crop stages on different sampling dates.

Deothi

The mean LAI of chirpine trees varied from 1.54 to 1.74 in sapling crop stage, 1.27 to 1.87 in pole crop stage and 1.21 to 1.71 in tree crop stage. A perusal of data revealed that mean LAI increased from July to August, then decreased gradually in September and October. However, in November again showed an incline except in pole crop stage. No distinct relationship was observed when sapling, pole and tree crop stages were compared for their LAI on different sampling dates.

Dharampur

It evinced from the data that mean LAI varied from 1.30 to 1.94 in sapling crop stage, from 1.13 to 1.75 in pole crop stage and from 1.29 to 1.54 in tree crop stage. It increased or decreased irregularly in succeeding months, thus, no particular trend was recorded in LAI variation among different months. LAI of sapling crop stage was more than pole and tree crop stages on each sampling date.

Tatul

The mean LAI of chirpine trees varied from 1.86 to 2.20 in sapling crop stage, from 1.18 to 1.99 in pole crop stage and from 1.37 to 1.76 in tree crop stage. The data revealed that the mean LAI increased gradually from July to September in sapling and pole crop stages and thereafter, it decreased slightly, but in tree crop stage no particular trend was observed. LAI of sapling crop stage was more than pole and tree crop stages in each sampling date.

4.3.2 LAI of understorey vegetation

LAI (Leaf area index) of understorey vegetation in all sites at four locations is presented in Table 11.

Barog

The mean LAI of understorey vegetation in Barog revealed that it varied from 0.25 to 3.66 in sapling crop stage, from 2.78 to 3.68 in pole crop stage, from 2.36 to 3.50 under tree crop stage and from 2.94 to 4.37 in open grassland. A perusal of data in Table 8 revealed that, mean LAI of herbage increased steadily from July to August in the sites inhabiting pole crop and tree crop stages and from July to September in sapling crop stage & open grassland, thereafter, it decreased gradually. On every sampling date it was recorded that the mean LAI of understorey vegetation in open grassland was higher than the mean LAI under chirpine. The peak values of mean LAI of herbage were observed in August/September in all the sites.

Deothi

It evinced from the data that in Deothi, the mean LAI of understorey vegetation under sapling crop stage varied from 2.14 to 2.80, under pole crop stage from 2.21 to 3.24, under tree crop stage from 1.97 to 3.15 and in open

Table 11. Monthly variation in mean LAI of understorey vegetation in study sites (sapling, pole and tree crop stage and open grassland) at four locations (Barog, Deothi, Dharampur and Tatul) during study period

	Sapling crop stage					Pole crop stage					Tree crop stage					Open grassland				
	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov
Barog																				
LAI	2.25	3.42	3.66	3.33	2.90	2.78	3.68	3.63	3.43	2.88	2.85	3.50	3.45	3.40	2.36	2.94	4.05	4.37	3.80	3.31
SE	± 0.18	± 0.17	± 0.28	± 0.26	± 0.26	± 0.16	± 0.17	± 0.36	± 0.37	± 0.25	± 0.17	± 0.20	± 0.19	± 0.21	± 0.30	± 0.16	± 0.17	± 0.25	± 0.30	± 0.31
Deothi																				
LAI	2.14	2.51	2.79	2.80	2.52	2.21	3.24	3.11	2.99	2.61	1.97	2.91	3.15	2.77	2.65	2.50	3.41	3.57	3.39	3.05
SE	± 0.20	± 0.32	± 0.17	± 0.21	± 0.17	± 0.17	± 0.22	± 0.21	± 0.27	± 0.30	± 0.13	± 0.27	± 0.20	± 0.16	± 0.26	± 0.16	± 0.19	± 0.30	± 0.29	± 0.14
Dharampur																				
LAI	1.82	3.06	2.81	2.57	2.22	2.07	3.29	2.67	2.76	2.31	1.85	3.58	2.54	2.57	2.48	2.59	3.75	3.71	2.95	2.74
SE	± 0.11	± 0.24	± 0.21	± 0.21	± 0.12	± 0.12	± 0.25	± 0.29	± 0.21	± 0.12	± 0.19	± 0.21	± 0.26	± 0.26	± 0.26	± 0.22	± 0.22	± 0.27	± 0.22	± 0.20
Tatul																				
LAI	2.35	2.60	2.66	2.60	2.49	2.73	2.92	2.65	2.77	2.27	2.31	2.90	2.87	2.22	2.11	2.85	3.36	4.39	3.50	2.65
SE	± 0.19	± 0.19	± 0.23	± 0.18	± 0.16	± 0.15	± 0.22	± 0.26	± 0.18	± 0.27	± 0.22	± 0.26	± 0.19	± 0.11	± 0.25	± 0.19	± 0.22	± 0.20	± 0.17	± 0.19

grassland from 2.50 to 3.57. It was clear from the data that, mean LAI of understorey vegetation increased gradually from July to August in pole crop stage, from July to September in tree crop stage & open grassland whereas in sapling crop stage it increased from July to October. Thereafter, it decreased slightly upto November in all the sites. The mean LAI of herbage in open grassland was higher than LAI of understorey vegetation in three chirpine crop stages on different sampling dates.

Dharampur

In Dharampur, the mean LAI of understorey vegetation under sapling crop stage varied from 1.82 to 3.06, in pole crop stage from 2.07 to 3.29, in tree crop stage from 1.85 to 3.58 and in open grassland from 2.59 to 3.57. LAI of herbage showed a gradual increasing trend from July to August, then, a marked decrease was recorded in it upto November in all the sites. Mean LAI of herbage in open grassland was higher than LAI of understorey vegetation under chirpine stages in all the sampling dates. The peak values of mean LAI were observed in August in all the sites.

Tatul

During the study period at Tatul the mean LAI of understorey vegetation under sapling crop stage varied from 2.35 to 2.66, under pole crop stage from 2.27 to 2.92, under tree crop stage from 2.11 to 2.90 and in open grassland from 2.65 to 4.39. A gradual increase in LAI of herbage was recorded from July to August and/or September and thereafter, it declined slowly in all the sites, except in October in pole crop stage. The peak values of mean LAI of herbage were observed in August/September.

In all four sites LAI of understorey vegetation increased upto August/September and then decreased gradually. At each location mean LAI of

open grassland vegetation was higher than mean LAI of understorey vegetation under chirpine crop on each sampling month.

4.3.3 Relationship of LAI of understorey vegetation with LAI of chirpine

Barog

Extrapolation of data revealed that relationships between LAI of understorey vegetation and LAI of chirpine trees (Fig. 3a) were significant and showed that 55.16 per cent variations in LAI of herbage in sapling crop stage, 52.22 per cent variations in pole crop stage and 28.25 per cent variations in tree crop stage were on account of change in LAI of chirpine. The relationships thus obtained are as follows:

$$\text{Sapling crop stage : } Y = 1.156 X + 1.3116; \quad R^2 = 0.5516 \\ (0.2456)$$

$$\text{Pole crop stage : } Y = 1.288 X + 1.2537, \quad R^2 = 0.5222 \\ (0.2904)$$

$$\text{Tree crop stage : } Y = 1.1118 X + 1.8170, \quad R^2 = 0.2825 \\ (0.4177)$$

where, Y = LAI of understorey vegetation and X = LAI of chirpine trees.

Deothi

In Deothi, it evinced from Fig. 3b that LAI of chirpine trees explained 51.92 per cent variations in LAI of understorey vegetation in sapling crop stage, 65.02 per cent in pole crop stage and 46.20 per cent in tree crop stage.

The relationships thus obtained are as follows :

$$\text{Sapling crop stage : } Y = 1.2552 X + 0.5001, \quad R^2 = 0.5192 \\ (0.2847)$$

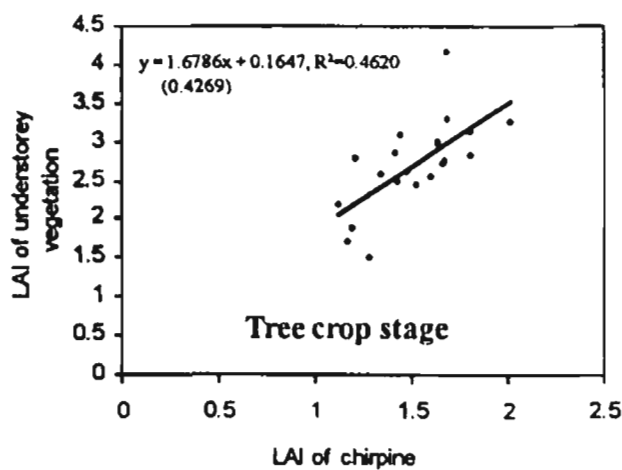
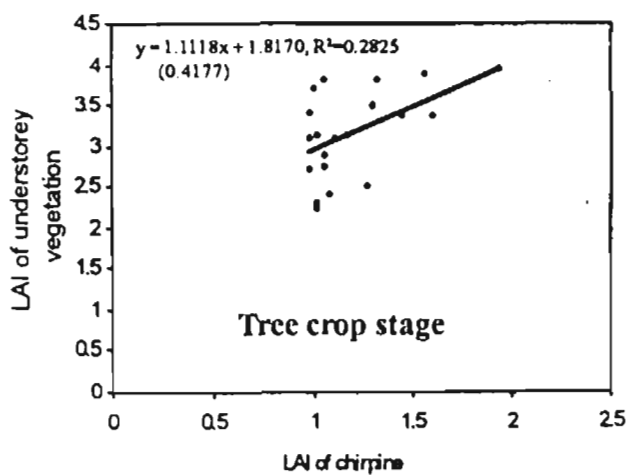
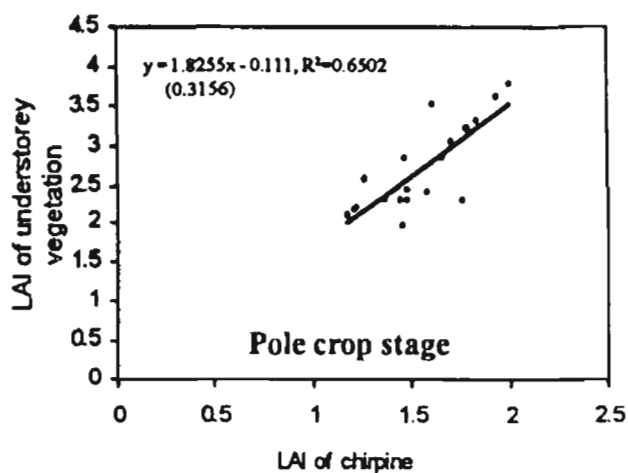
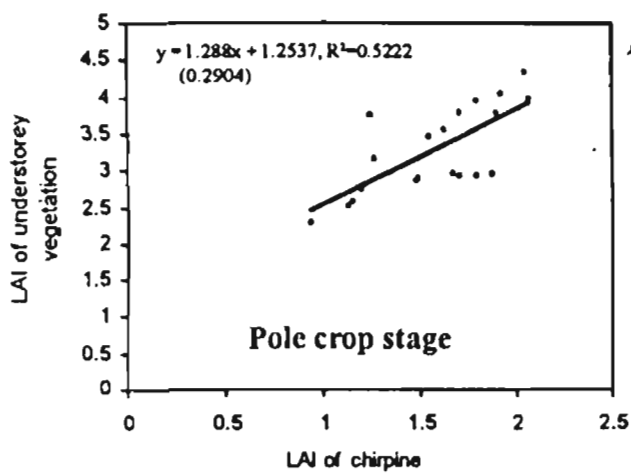
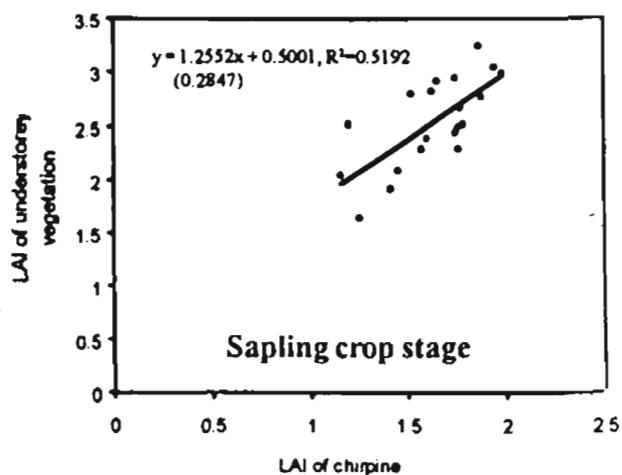
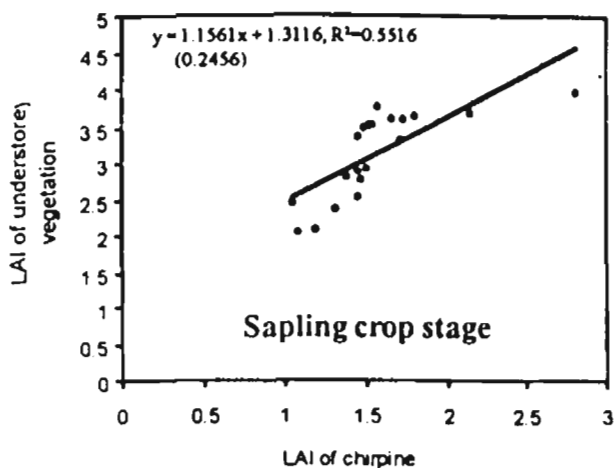


Fig. 3a. Allometric relationships between leaf area index of understorey vegetation and leaf area index of chirpine at Barog,

Fig. 3b. Allometric relationships between leaf area index of understorey vegetation and leaf area index of chirpine at Deothi

Pole crop stage : $Y = 1.8255 X - 0.1110, R^2 = 0.6502$
(0.3156)

Tree crop stage : $Y = 1.6786 X + 0.1647, R^2 = 0.4620$
(0.4269)

where, Y = LAI of understorey vegetation and X = LAI of chirpine trees.

Dharampur

The relationship between LAI of understorey vegetation and LAI of chirpine trees (Fig. 3c) showed that in sapling crop stage 58.29 per cent variations, in pole crop stage 35.63 per cent variations and in tree crop stage 22.34 per cent variations in LAI of understorey vegetation could be explained by the respective variations in LAI of chirpine trees. The relationships thus obtained are as follows:

Sapling crop stage : $Y = 1.3707 X + 0.2697, R^2 = 0.5829$
(0.2733)

Pole crop stage : $Y = 1.0115 X + 1.1426, R^2 = 0.3563$
(0.3204)

Tree crop stage : $Y = 1.4803 X + 0.5600, R^2 = 0.2234$
(0.6150)

where, Y = LAI of understorey vegetation and X = LAI of chirpine trees.

Tatul

The relationships between LAI of understorey vegetation and LAI of chirpine trees (Fig. 3d) showed that in sapling crop stage 44 per cent variations, in pole crop stage 33.53 per cent variations and in tree crop stage 31.15 per cent variations in the LAI of understorey vegetation were explained by the respective variations in LAI of chirpine trees. The relationships obtained are as follows :

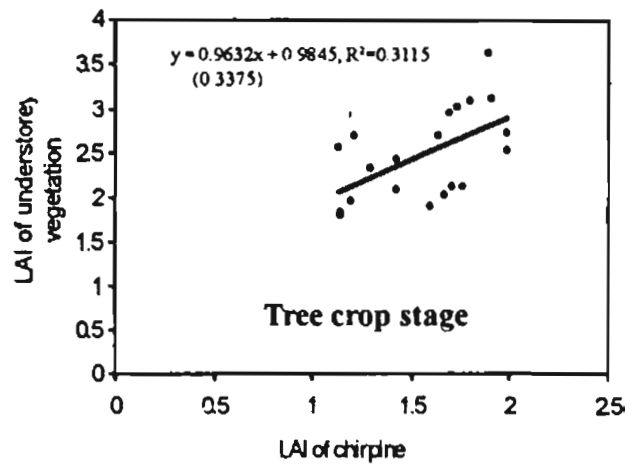
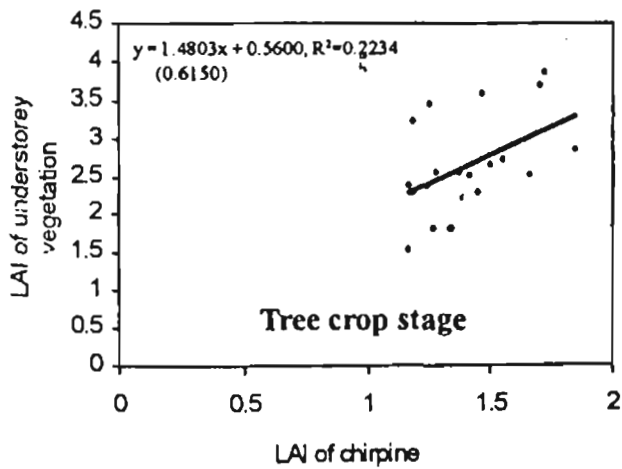
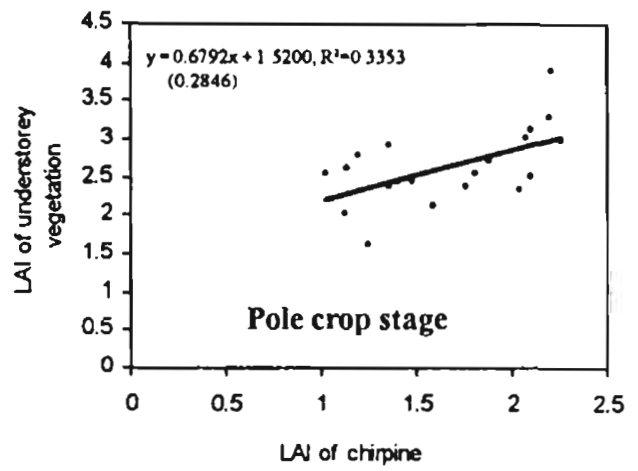
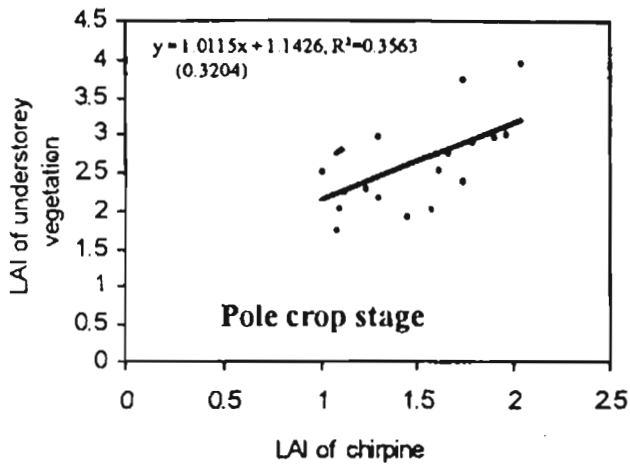
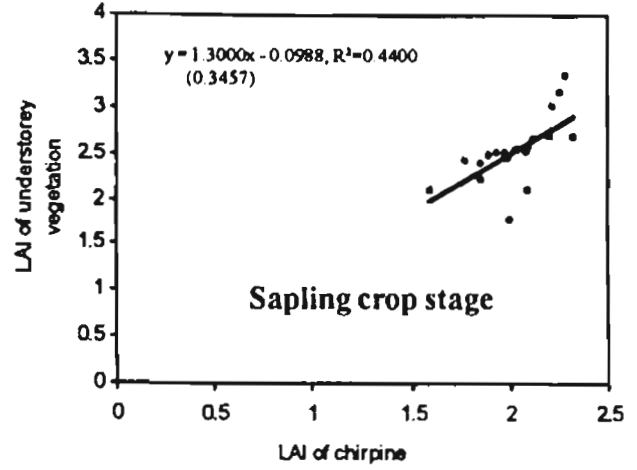
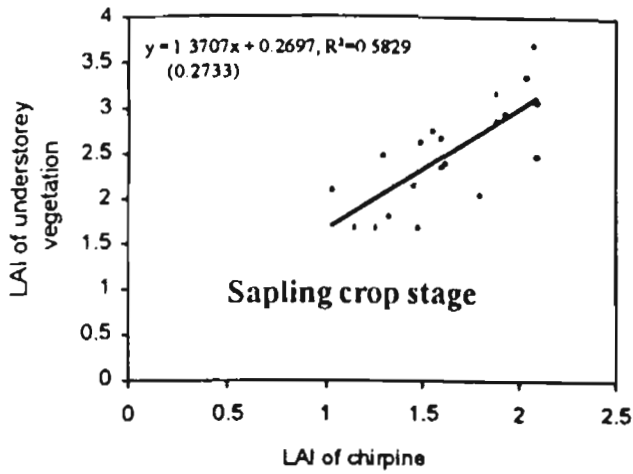


Fig. 3c. Allometric relationships between leaf area index of understorey vegetation and leaf area index of chirpine at Dharampur

Fig. 3d. Allometric relationships between leaf area index of understorey vegetation and leaf area index of chirpine at Tatul

Sapling crop stage	:	$Y = 1.3000 X - 0.0988,$	$R^2 = 0.4400$
		(0.3457)	
Pole crop stage	:	$Y = 0.6792 X + 1.5200$	$R^2 = 0.3353$
		(0.2846)	
Tree crop stage	:	$Y = 0.9632 X + 0.9845,$	$R^2 = 0.3115$
		(0.3375)	

where, Y = LAI of understorey vegetation and X = LAI of chirpine trees.

It was evident from the results that, in Barog and Deothi prediction models developed for sapling and pole crop stages were more reliable as compared to the model for tree crop stage. However, in Dharampur and Tatul, prediction models were more reliable for sapling crop stage as compared to pole and tree crop stages.

4.3.4 Relationships of density, basal area and aboveground biomass of understorey vegetation with LAI of understorey vegetation in different sites at four locations

4.3.4.1. Allometric relationship between density and LAI of understorey vegetation

a) Sapling crop stage

Allometric relationships between density and LAI of understorey vegetation in sapling crop stage (Fig. 4) showed that in Barog 55.53 per cent of total variations in the density was explained by LAI, whereas in Deothi LAI was responsible for 39.74 per cent of total variations in density. In Dharampur, 26.74 per cent and in Tatul 25.19 per cent of variations in density of understorey vegetation were explained by their LAI's. The relationships thus derived are as follows:



Barog	:	$Y = 161.16X + 68.823,$ (33.991)	$R^2 = 0.5553$
Deothi	:	$Y = 421.89X + 369.82,$ (122.45)	$R^2 = 0.3974$
Dharampur	:	$Y = 93.579X + 377.20,$ (36.513)	$R^2 = 0.2674$
Tatul	:	$Y = 214.11X + 167.53,$ (86.976)	$R^2 = 0.2519$

where, Y = Density of understorey vegetation and
X = LAI of understorey vegetation,

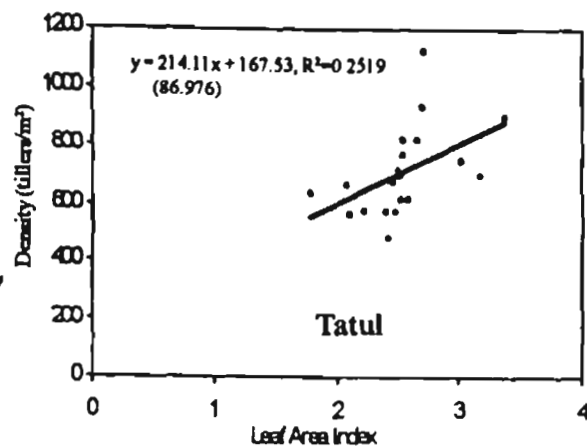
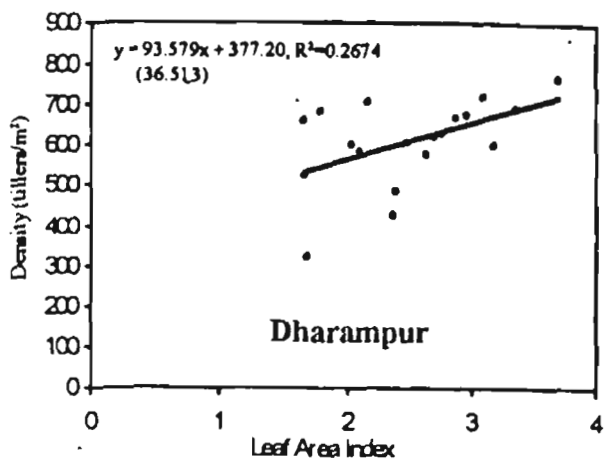
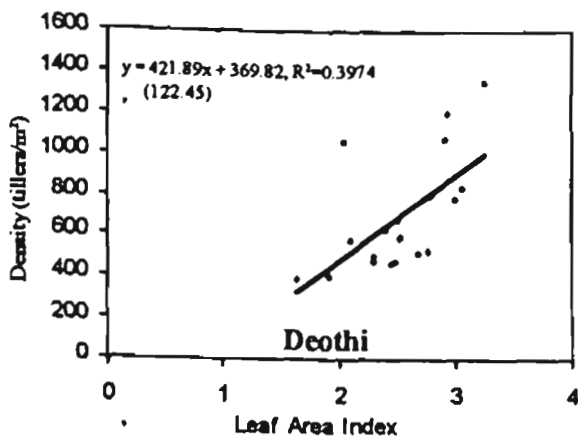
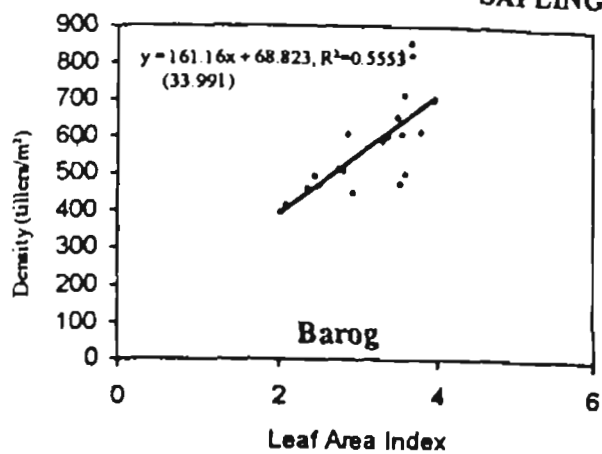
Pole crop stage

The relationships between density and LAI of understorey vegetation in pole crop state (Fig. 4) showed that in Barog, 39.99 per cent of total variations in density were explained by changes in LAI of understorey vegetation, whereas, in Deothi 71.48 per cent variations in density were explained by LAI of understorey vegetation. In Dharampur, 70.86 per cent and in Tatul, 36.47 per cent of total variation in density of understorey vegetation were explained by change in LAI of understorey vegetation. The relationships thus obtained are as follows:

Barog	:	$Y = 113.19 X + 253.64,$ (32.686)	$R^2 = 0.3999$
Deothi	:	$Y = 206.99 X - 75.07,$ (30.821)	$R^2 = 0.7148$
Dharampur	:	$Y = 209.1 X + 122.31,$ (31.602)	$R^2 = 0.7086$
Tatul	:	$Y = 138.46 X + 354.00,$ (43.07)	$R^2 = 0.3647$

where, Y = Density of understorey vegetation and
X = LAI of understorey vegetation

SAPLING CROP STAGE



POLE CROP STAGE

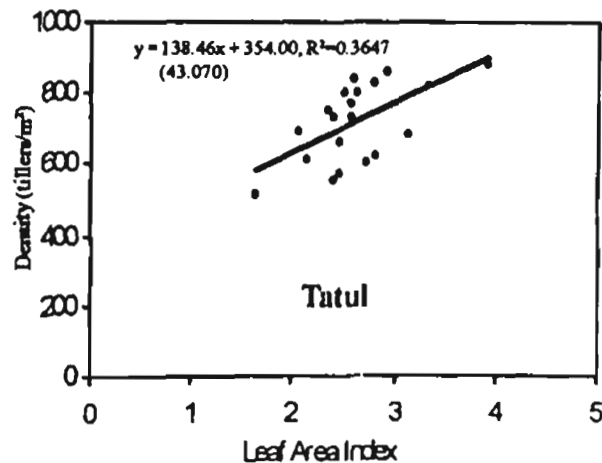
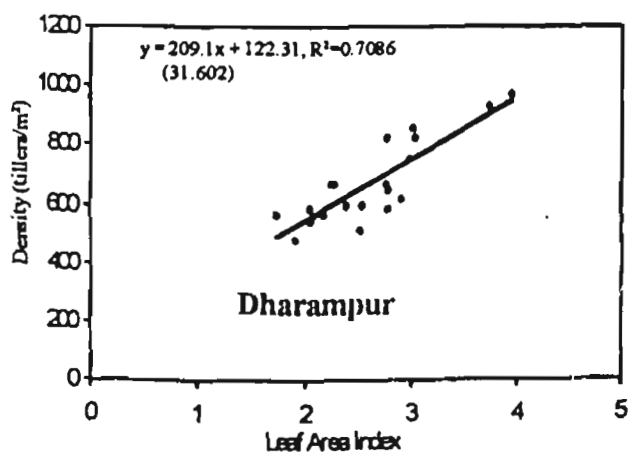
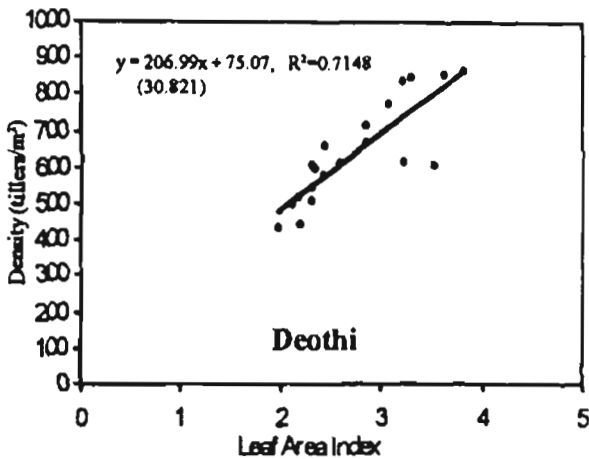
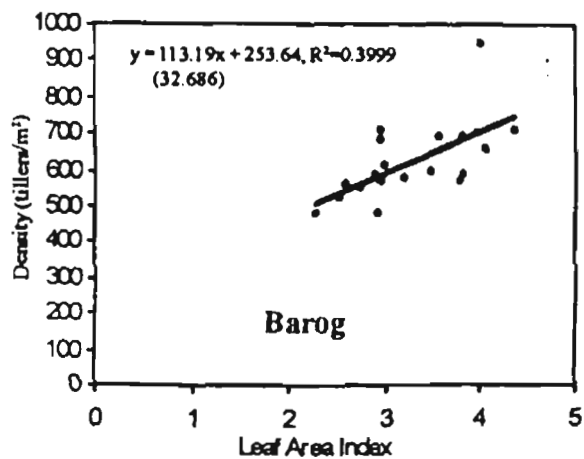


Fig. 4. Allometric relationships between density and LAI of understory vegetation in different sites

c) Tree crop stage

Allometric relationship between variation in density and LAI of understorey vegetation in tree crop stage at four locations is presented in Fig. 5.

The relationship between changes in density of understorey vegetation and their respective LAI showed that in Barog 25.55 per cent, in Deothi 56.71 per cent, in Dharampur 29.94 per cent and in Tatul 75.24 per cent of total variations in herbage densities were explained by their respective LAI. The relationships thus obtained are as follow:

Barog	:	$Y = 117.67 X + 253.00,$ (47.350)	$R^2 = 0.2555$
Deothi	:	$Y = 141.35 X + 220.24,$ (29.109)	$R^2 = 0.5671$
Dharampur	:	$Y = 89.89 X + 451.15,$ (35.206)	$R^2 = 0.2994$
Tatul	:	$Y = 151.29 X + 310.50,$ (20.455)	$R^2 = 0.7524$

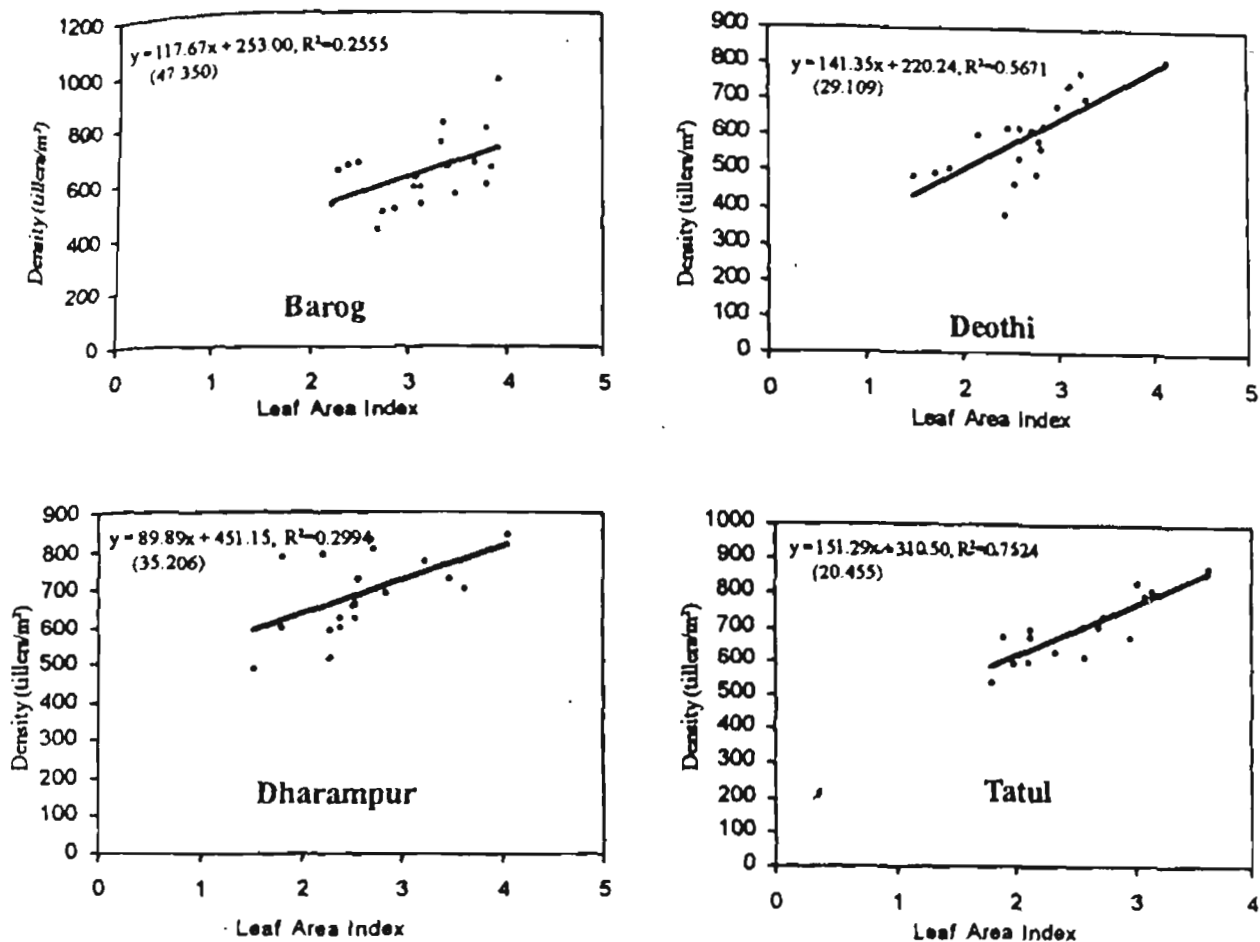
where, Y = Density of understorey vegetation and
X = LAI of understorey vegetation

d) Open grassland

The relationships between density and LAI (Fig. 5) showed that in Barog 69.87 per cent, in Deothi 31.65 per cent, in Dharampur 36.94 per cent and in Tatul 39.93 per cent of total variations in density of herbage vegetation were explained by the respective LAI. The relationships thus obtained are follows:

Barog	:	$Y = 244.66X - 117.58,$ (37.832)	$R^2=0.6987$
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TREE CROP STAGE



OPEN GRASSLAND

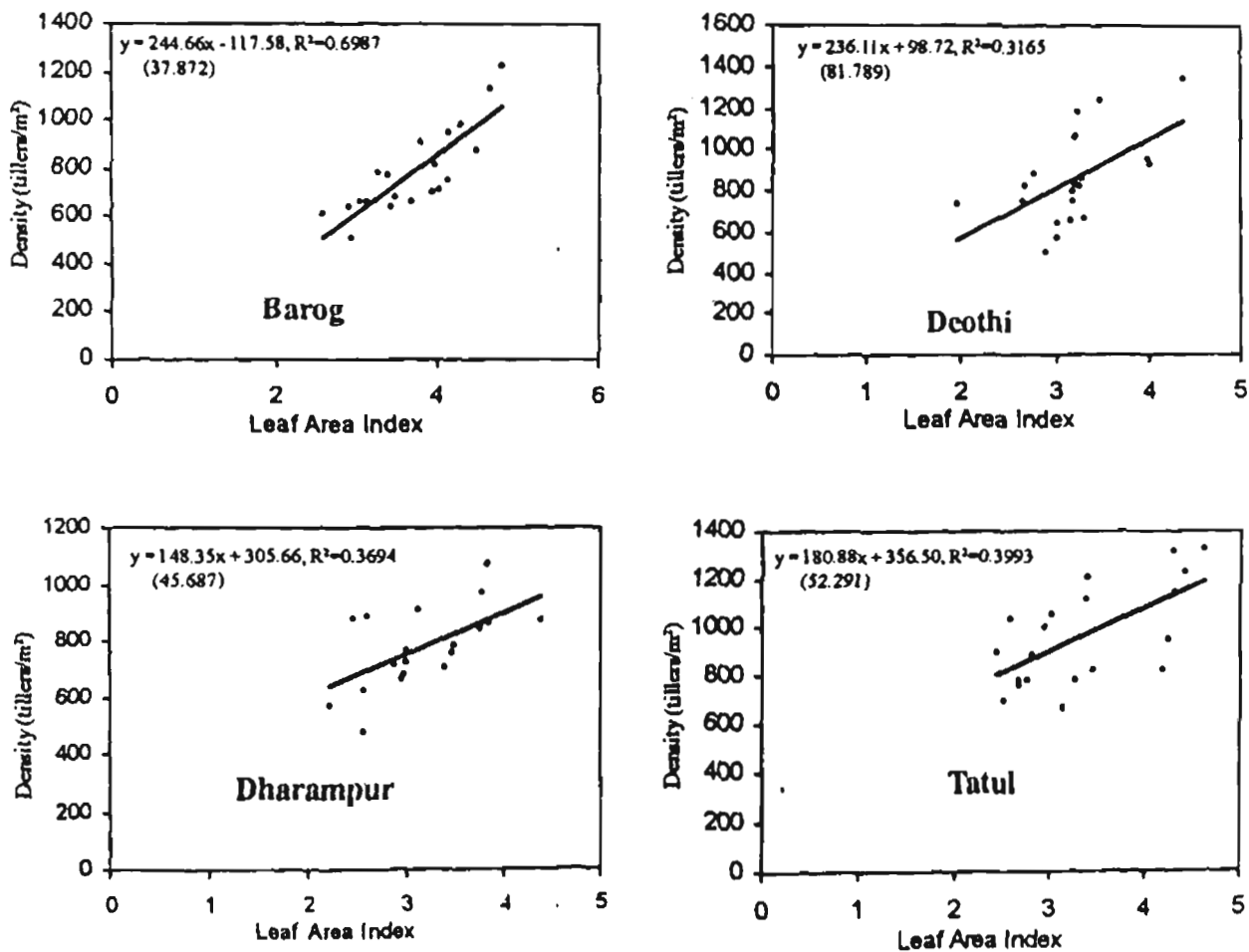


Fig. 5. Allometric relationships between density and LAI of understory vegetation/herbage in different sites

Deothi	:	$Y = 236.11X + 98.72,$ (81.789)	$R^2=0.3165$
Dharampur	:	$Y = 148.35X + 305.66,$ (45.687)	$R^2=0.3694$
Tatul	:	$Y = 180.88X + 356.50,$ (52.291)	$R^2=0.3993$

where, Y = Density of herbage vegetation and
X = LAI of herbage vegetation

In all four locations, the relationships between density and LAI of understorey vegetation/herbage showed, that, in sapling crop stage, the relationship was more reliable in Barog than other locations, whereas, in pole crop stage more reliability in the relationship was found in Deothi and Dharampur than other locations. In tree crop stage prediction model was more reliable in Deothi and Tatul than Barog and Dharampur. Whereas, in open grassland the relationship in Barog was more reliable than other locations.

4.3.4.2 Relationships between basal area and LAI of understorey vegetation

a) Sapling crop stage

Allometric relationships between basal area and LAI of understorey vegetation in sapling crop stage is presented in Fig. 6. The relationship between basal area and LAI of understorey vegetation showed that in Barog 44.59 per cent of total variations in basal area was explained by LAI, whereas, in Deothi LAI was responsible for 47.63 per cent of total variations in basal area. Similarly, in Dharampur 22.93 per cent of total variations in the basal area of understorey vegetation was explained by LAI and in Tatul 38.78 per cent of total variation in basal area of understorey vegetation was explained by LAI. Relationships thus obtained are given as follows:

Barog	:	$Y = 9.9864X + 9.7820,$ (2.6239)	$R^2=0.4459$
Deothi	:	$Y = 37.331X - 6.990,$ (9.2264)	$R^2=0.4763$
Dharampur	:	$Y = 7.8224X + 30.185,$ (3.5350)	$R^2=0.2293$
Tatul	:	$Y = 21.8120X - 5.5520,$ (6.5978)	$R^2=0.3778$

where, Y = Basal area of understorey vegetation and
X = LAI of understorey vegetation

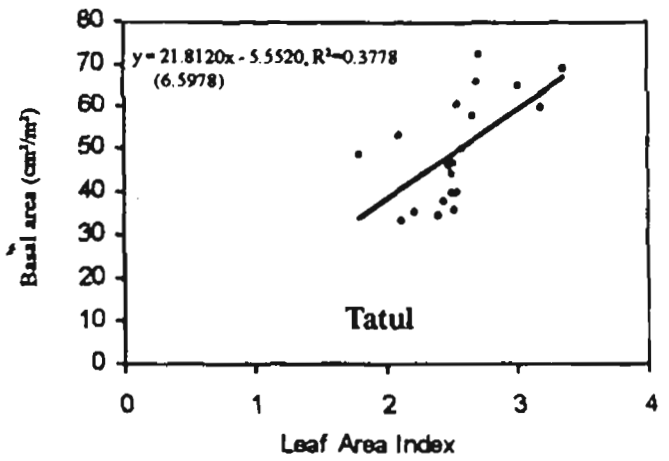
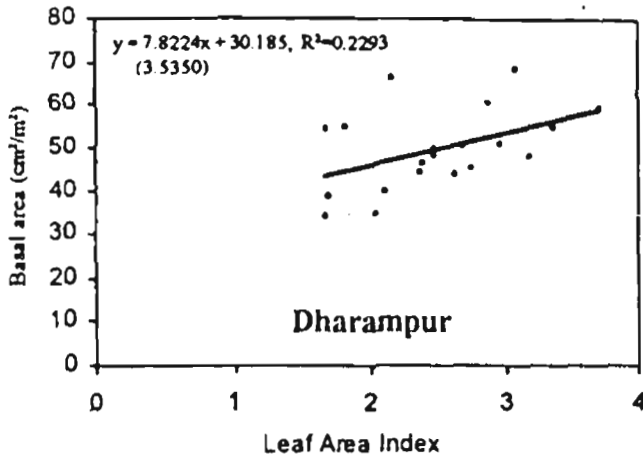
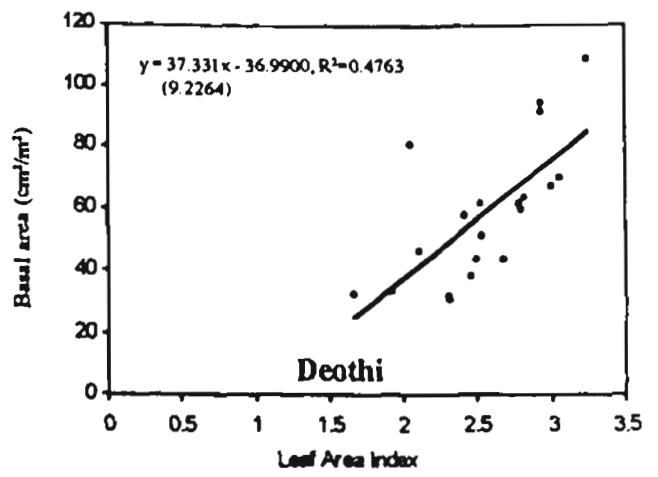
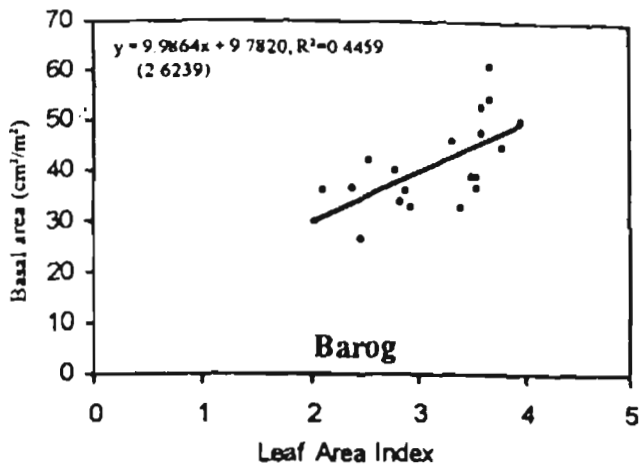
b) Pole crop stage

The relationships between basal area and LAI of understorey vegetation (Fig. 6) showed that in Barog 43.95 per cent, in Deothi 54.88 per cent, in Dharampur 79.72 per cent and in Tatul 36.98 per cent variations in basal area of understorey vegetation were correlated with variations in LAI. The relationships thus obtained are given as follows:

Barog	:	$Y = 8.8041X + 23.050,$ (2.3433)	$R^2=0.4395$
Deothi	:	$Y = 11.06X - 18.90,$ (2.3635)	$R^2=0.5488$
Dharampur	:	$Y = 18.7550X - 0.2330,$ (2.2297)	$R^2=0.7972$
Tatul	:	$Y = 11.669X + 17.350,$ (3.5903)	$R^2=0.3698$

where, Y = Basal area of understorey vegetation and
X = LAI of understorey vegetation

SAPLING CROP STAGE



POLE CROP STAGE

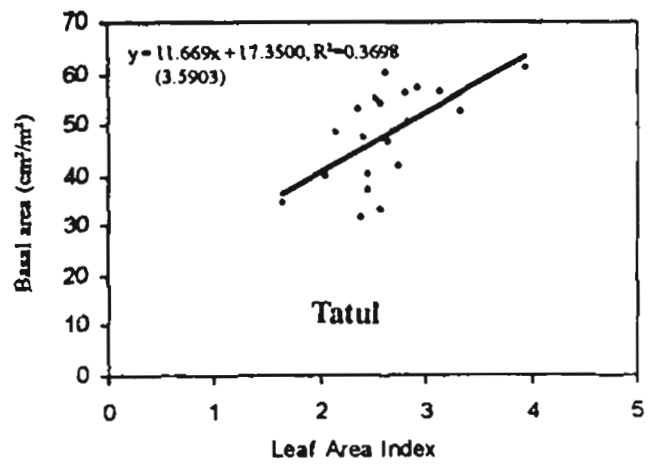
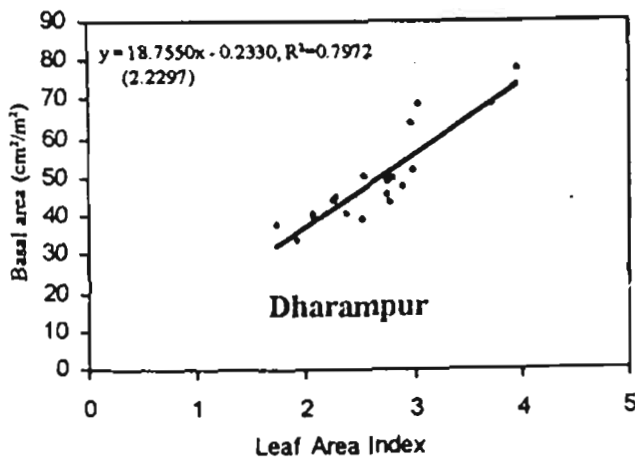
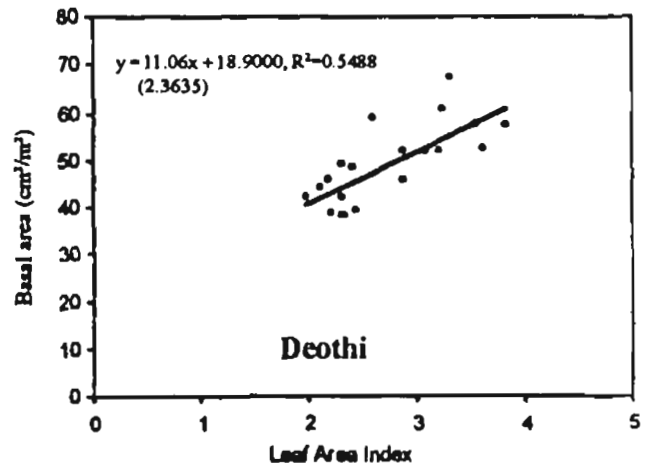
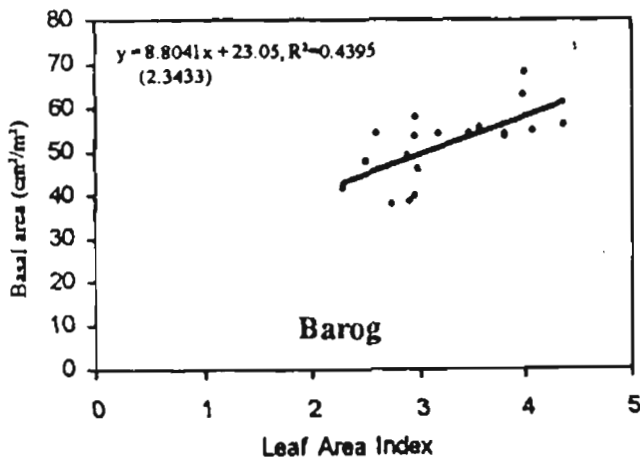


Fig. 6. Allometric relationships between basal area and LAI of understorey vegetation in different sites

c) Tree crop stage

Allometric relationships between basal area and LAI of understorey vegetation in tree crop stage is presented in Fig. 7. In Barog 37.57 per cent, in Deothi 64.45 per cent, in Dharampur 35.96 per cent and in Tatul 49.00 per cent of total variations in the basal area of herbage could be explained by LAI. The relationships thus obtained are as follows:

Barog	:	$Y = 16.098X + 11.066,$ (4.9092)	$R^2=0.3757$
Deothi	:	$Y = 15.322X + 12.90,$ (2.6824)	$R^2=0.6445$
Dharampur	:	$Y = 8.8328X + 28.918,$ (2.7785)	$R^2=0.3596$
Tatul	:	$Y = 17.5950X + 11.100,$ (4.2307)	$R^2=0.4900$

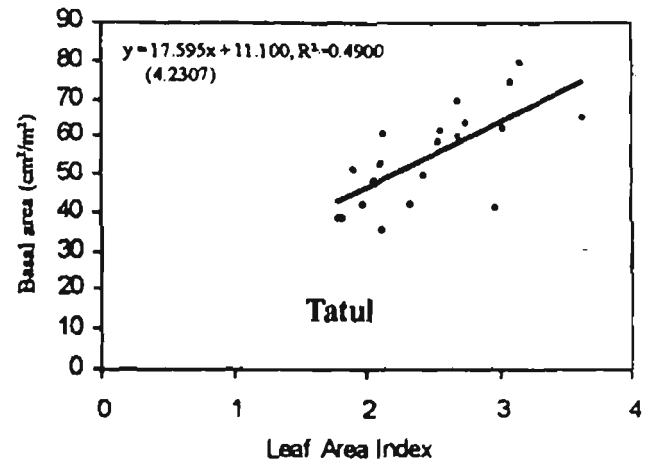
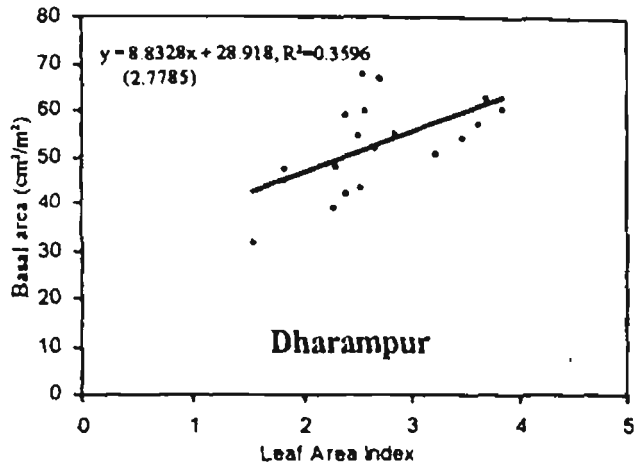
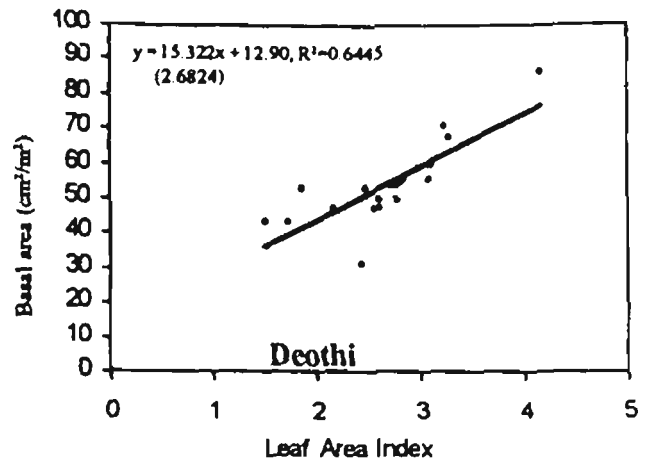
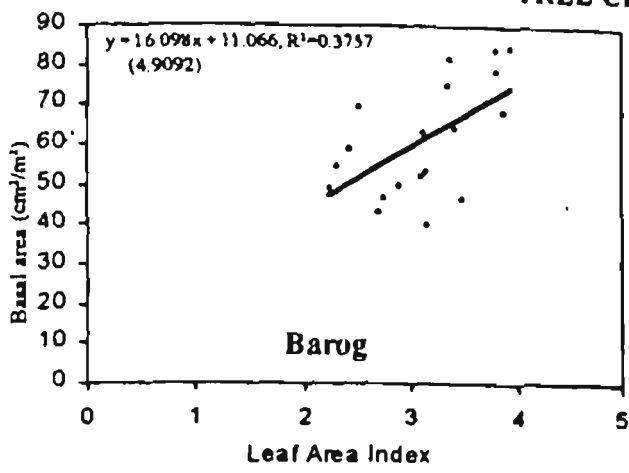
where, Y = Basal area of understorey vegetation and
X = LAI of understorey vegetation

d) Open grassland

The relationships between basal area and LAI of herbage vegetation in open grassland (Fig. 7) showed that in Barog 56.44 per cent, in Deothi 26.33 per cent, in Dharampur 45.20 per cent and in Tatul 65.56 per cent of total variations in the basal area of herbage were explained by the LAI. The relationships obtained are as follows:

Barog	:	$Y = 23.521X - 15.000,$ (4.8704)	$R^2=0.5644$
Deothi	:	$Y = 18.697X + 10.530,$ (7.3712)	$R^2=0.2633$
Dharampur	:	$Y = 12.5266X + 12.880,$ (3.2509)	$R^2=0.4520$

TREE CROP STAGE



OPEN GRASSLAND

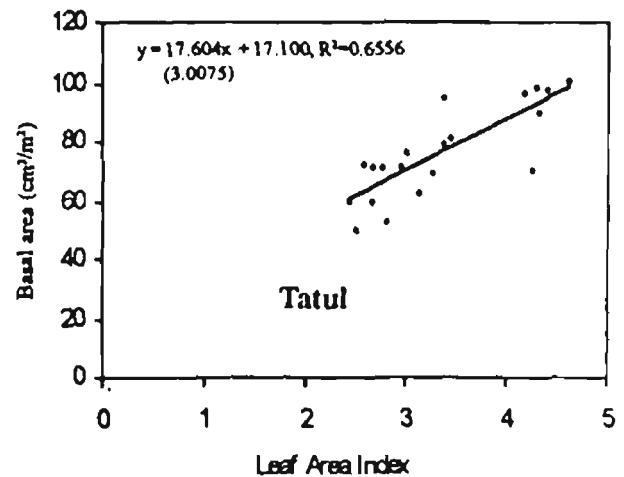
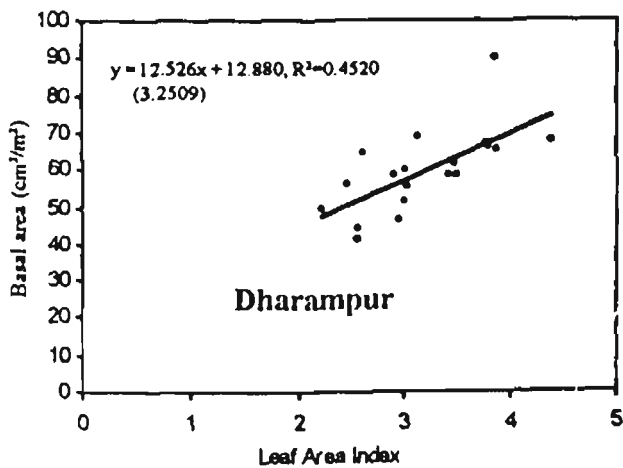
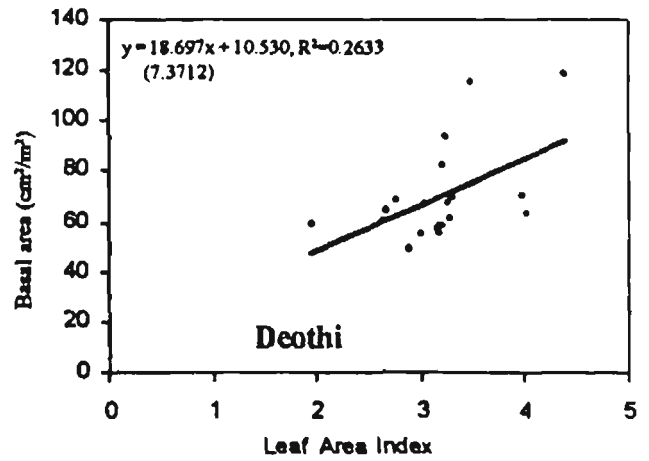
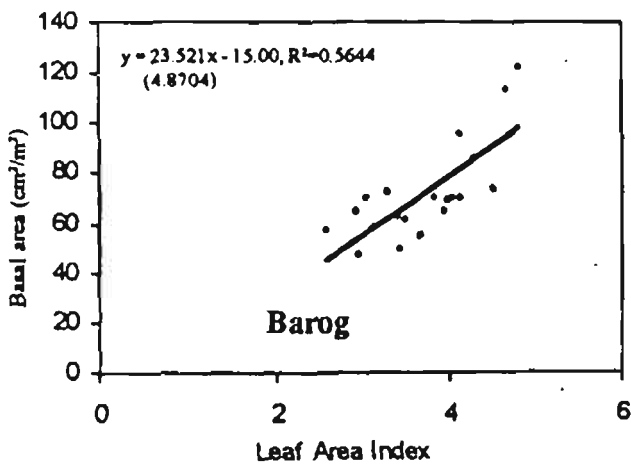


Fig. 7. Allometric relationships between basal area and LAI of understorey vegetation/herbage in different sites

$$\text{Tatul} \quad : \quad Y = 17.604X + 17.100, \quad R^2=0.6556 \\ (3.0075)$$

where, Y = Basal area of herbage vegetation and X = LAI of herbage vegetation

Thus, the relationships between basal area and LAI of understorey vegetation/herbage in four locations showed that in sapling crop stage, the relationships were more reliable in Barog and Deothi than Dharampur and Tatul, whereas, in pole crop stage they were more reliable in Deothi and Dharampur than Barog and Tatul. In tree crop stage, more reliability in relationships were found in Deothi and Tatul than Barog and Dharampur and in open grassland, the relationships were more reliable in Tatul, Barog and Dharampur than Deothi.

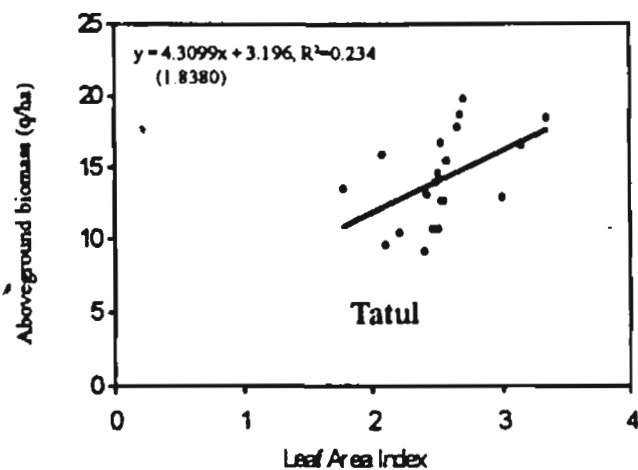
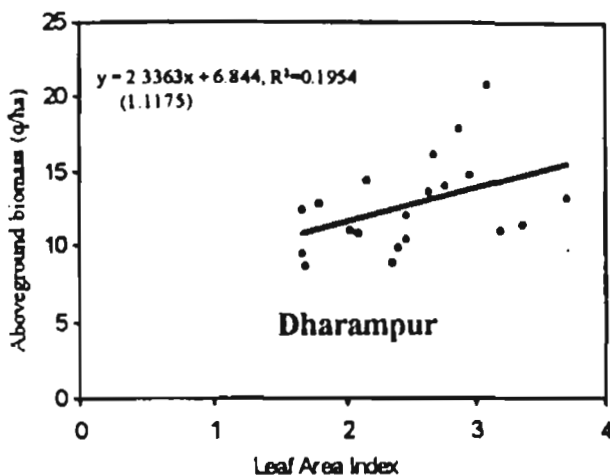
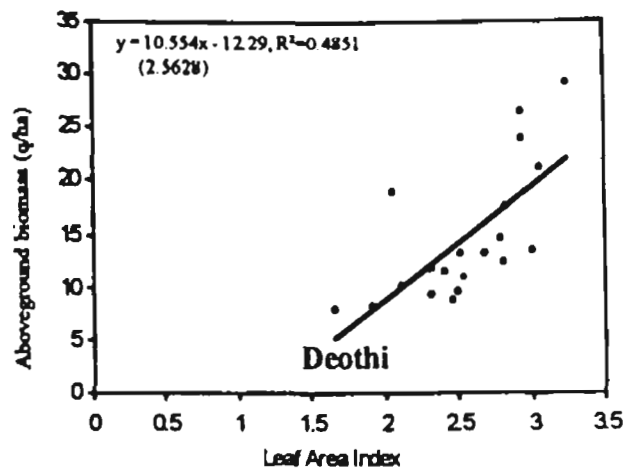
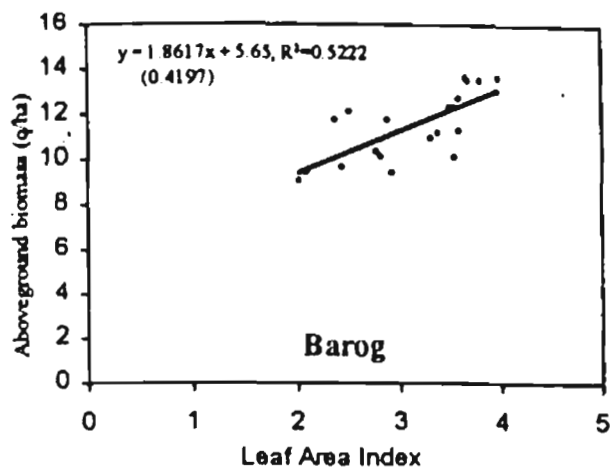
4.3.4.3 Relationships between aboveground biomass and LAI of understorey vegetation

a) Sapling crop stage

Allometric relationships between aboveground biomass and LAI of understorey vegetation in sapling and pole crop stage is presented in Fig. 8. The relationships between aboveground biomass of understorey vegetation and their LAI showed that in Barog 52.22 per cent, in Deothi 48.51 per cent, in Dharampur 19.54 per cent and in Tatul 23.40 per cent variations in aboveground biomass were explained by the respective LAI of understorey vegetation. Relationships thus obtained are as follows:

Barog	:	$Y = 1.8617X + 5.6500,$ (0.4197)	$R^2=0.5222$
Deothi	:	$Y = 10.554X - 12.29,$ (2.5628)	$R^2=0.4851$
Dharampur	:	$Y = 2.3363X + 6.8444,$ (1.1175)	$R^2=0.0.1954$

SAPLING CROP STAGE



POLE CROP STAGE

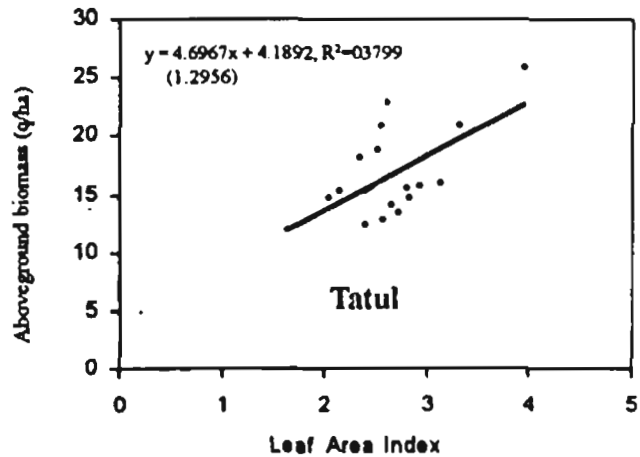
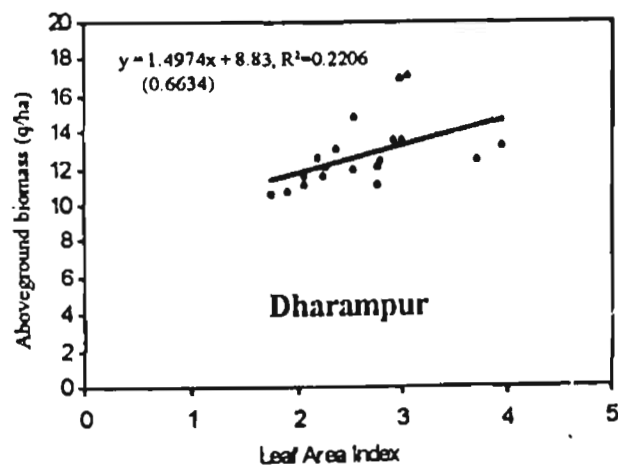
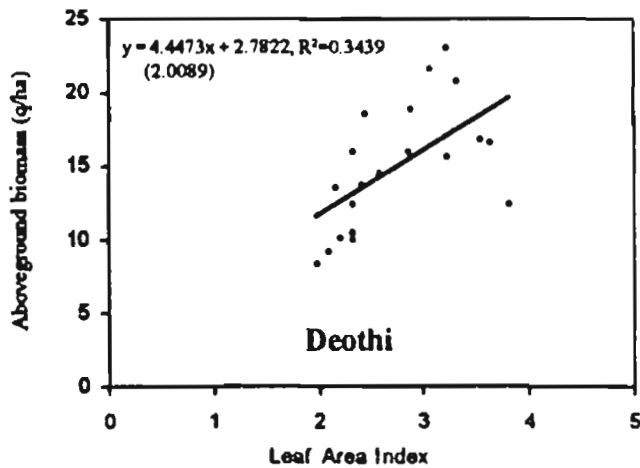
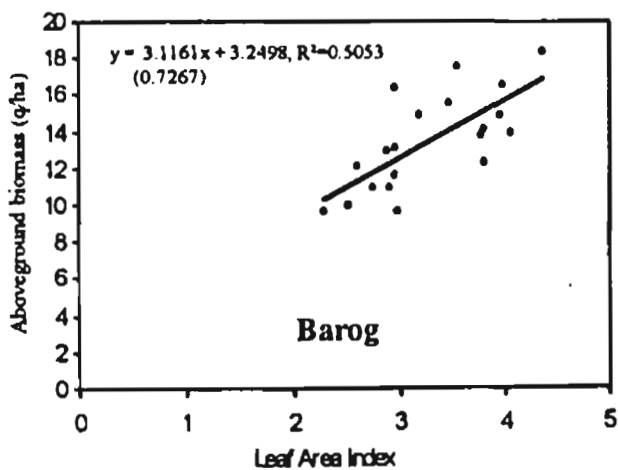


Fig. 8. Allometric relationships between aboveground biomass and LAI of understorey vegetation in different sites

Tatul : $Y = 4.3099X + 3.1960,$ $R^2=0.2340$
 (1.8380)

where, Y = Aboveground biomass of understorey vegetation and
 X = LAI of understorey vegetation

b) Pole crop stage

The relationships between aboveground biomass and understorey vegetation (Fig. 8) showed that LAI could explain 50.53 per cent variations aboveground biomass in Barog, 34.39 per cent variations in Deothi, 22.06 per cent variations cent variations in Tatul. The relationships thus obtained are as follows:

Barog : $Y = 3.1161X + 3.2498,$ $R^2=0.5053$
 (0.7267)

Deothi : $Y = 4.4473X + 2.7822,$ $R^2=0.3439$
 (2.0089)

Dharampur : $Y = 1.4974X - 8.8300,$ $R^2=0.2206$
 (0.6634)

Tatul : $Y = 4.6967X + 4.1892,$ $R^2=0.3799$
 (1.2956)

where, Y = Aboveground biomass of understorey vegetation and
 X = LAI of understorey vegetation

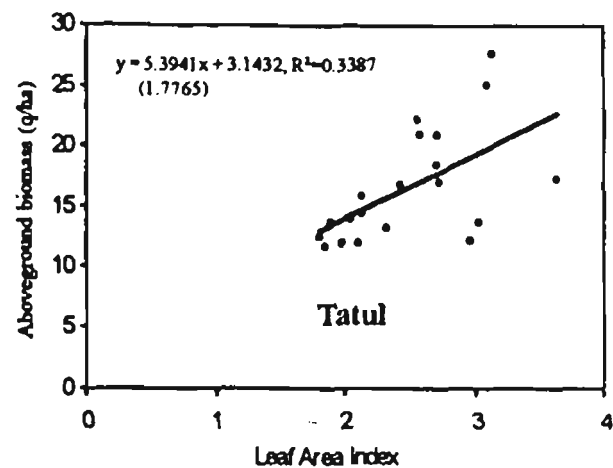
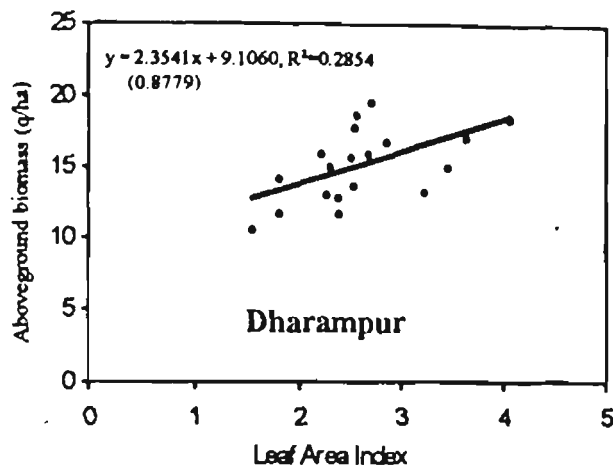
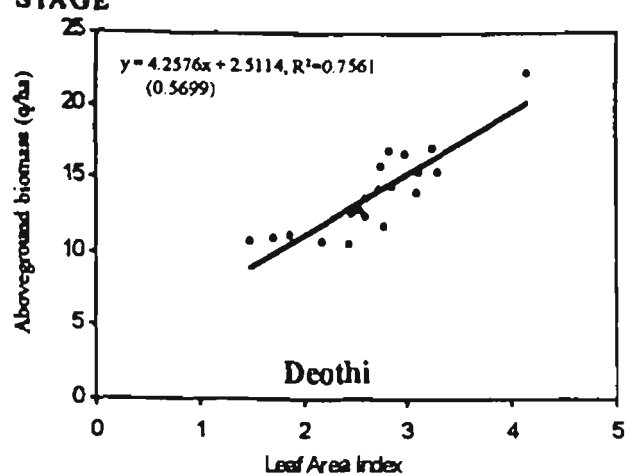
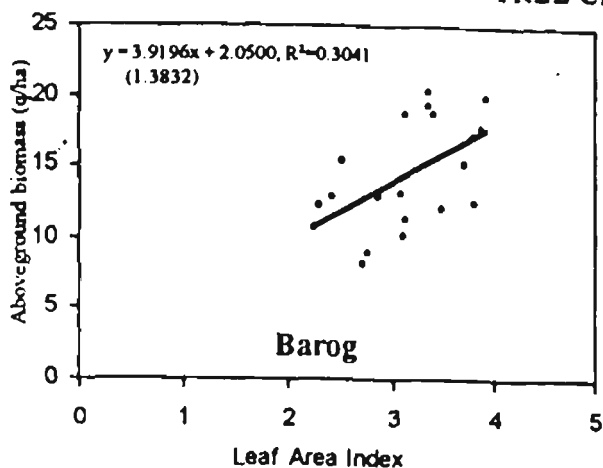
c) Tree crop stage

Allometric relationships between aboveground biomass and LAI of understorey vegetation in tree crop stage is presented in Fig. 9.

The relationships between aboveground biomass and LAI of understorey vegetation showed that in Barog 30.41 per cent, in Deothi 75.61 per cent, in



TREE CROP STAGE



OPEN GRASSLAND

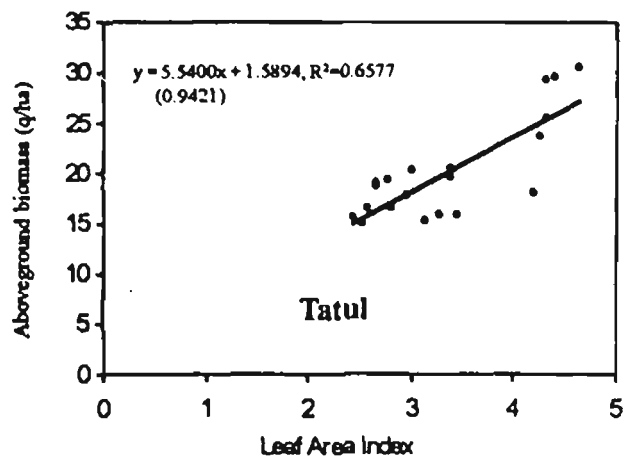
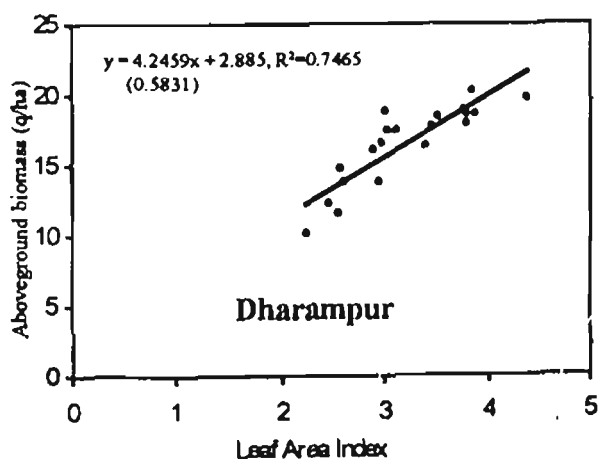
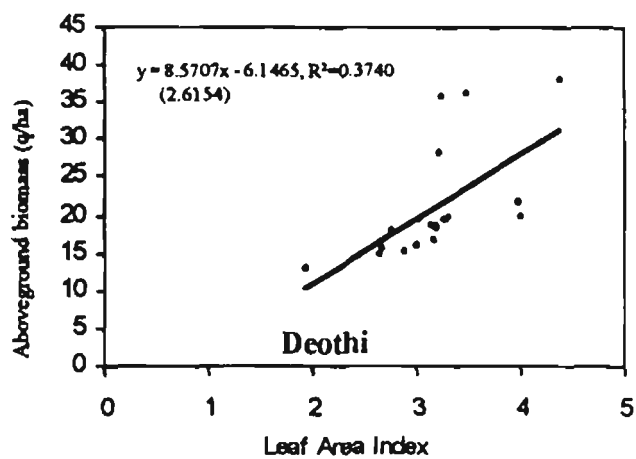
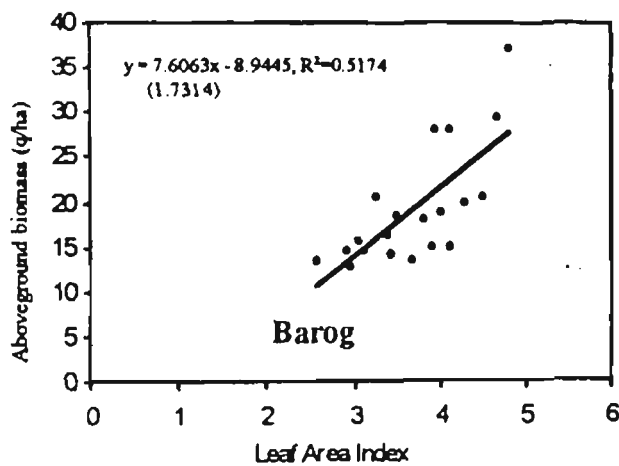


Fig. 9. Allometric relationships between aboveground biomass and LAI of understory vegetation/herbage in different sites

Dharampur 28.54 per cent and in Tatul 33.87 per cent variations in aboveground biomass were explained by the LAI of vegetation. The relationships thus obtained are as follows:

Barog	:	$Y = 3.9196X + 2.0500,$ (2.3744)	$R^2=0.3041$
Deothi	:	$Y = 4.2576X + 2.5114,$ (0.5699)	$R^2=0.7561$
Dharampur	:	$Y = 2.3541X + 9.1060,$ (0.8779)	$R^2=0.2854$
Tatul	:	$Y = 5.3941X + 3.1432,$ (1.7765)	$R^2=0.3387$

where, Y = Aboveground biomass of understorey vegetation and
X = LAI of understorey vegetation

d) Open grassland

The relationships between aboveground biomass and LAI herbage at different locations (Fig. 9) showed that LAI of herbage vegetation explained 51.74 per cent variations in aboveground biomass in Barog, 37.40 per cent in Deothi, 74.65 per cent in Dharampur and 65.77 per cent in Tatul. The relationships obtained are as follows:

Barog	:	$Y = 7.6063X - 8.9445,$ (1.7314)	$R^2=0.5174$
Deothi	:	$Y = 8.5707X - 6.1465,$ (2.6154)	$R^2=0.3740$
Dharampur	:	$Y = 4.25496X + 2.885,$ (0.5831)	$R^2=0.7465$
Tatul	:	$Y = 5.5400X + 1.5894,$ (0.9421)	$R^2=0.6577$

where, Y = Aboveground biomass of herbage vegetation and
X = LAI of herbage vegetation

In all the four locations, the relationships between aboveground biomass and LAI of understorey vegetation/herbage showed that in sapling crop stage, the relationships more reliable in Barog and Deothi than Dharampur and Tatul, whereas, in pole crop stage more reliability was more in Deothi than other locations. In tree crop stage in Deothi reliability was more than other locations and in open grassland, the relationships were more reliable in Barog, Dharampur and Tatul than Deothi.

4.3.5 Relative light intensity (RLI)

Monthly variations in relative light intensity at different chirpine sites in different locations are given in Table 12.

Barog

The relative light intensity (%) under sapling crop stage varied from 21.52 to 37.08 per cent, under pole crop stage from 22.78 to 35.86 per cent and under tree crop stage from 28.00 to 38.07 per cent. Monthly variation in relative light intensity did not show much difference among different sampling dates in the three crop stages.

Deothi

The relative light intensity (%) under sapling crop stage varied from 27.06 to 32.22, under pole crop stage from 22.30 to 28.82 and under tree crops stage from 31.08 to 40.30. During the study period monthly variations in relative light intensity did not show much difference among different sasampling dates in three crop stages.

Dharampur

A perusal of data revealed that the relative light intensity (%) under sapling crop stage varied from 27.95 to 32.68, under pole crop stage from 21.40

Table 12. Monthly variation in relative light intensity at different locations (Barog, Deothi, Dharampur and Tatul) during the study period

	July			August			September			October			November		
	M	SE	RLI	M	SE	RLI	M	SE	RLI	M	SE	RLI	M	SE	RLI
Barog															
Sapling crop stage	5896	344.88	36.29	4160	236.82	30.68	4062	265.94	31.64	2100	357.77	26.58	3320	292.57	28.05
Pole crop stage	5826	608.82	35.86	4086	297.34	30.09	3378	297.08	26.31	1800	263.24	22.78	3210	631.19	27.12
Tree crop stage	6186	428.00	38.07	5074	329.28	37.42	4640	381.37	36.14	2212	327.07	28.00	4000	367.33	33.79
Open grassland	16246	695.46	-	13560	471.59	-	12840	538.89	-	7900	89.442	-	11836	350.94	-
Deothi															
Sapling crop stage	4084	548.95	32.22	3696	440.67	31.70	3738	600.51	31.11	2960	57.68	27.06	2420	462.17	30.48
Pole crop stage	3181	211.70	25.12	2936	208.29	25.22	2934	342.56	24.42	2440	205.91	22.30	2280	481.64	28.82
Tree crop stage	4450	521.31	35.14	4086	386.76	35.05	4260	596.15	35.45	3400	589.92	31.08	3200	282.84	40.30
Open grassland	12664	874.29	-	11640	475.82	-	12016	592.71	-	10940	224.50	-	7940	274.36	-
Dharampur															
Sapling crop stage	3756	391.19	32.68	3762	441.38	29.17	3200	562.14	28.96	2700	244.95	27.95	2734	247.57	28.11
Pole crop stage	2980	379.57	25.93	2760	645.35	21.40	2960	344.09	26.78	2420	232.66	25.05	23.58	320.71	24.25
Tree crop stage	4480	260.77	38.98	3776	642.58	29.28	3620	479.17	32.76	2736	245.55	28.32	2790	407.92	28.69
Open grassland	11492	472.65	-	12896	579.08	-	11050	657.65	-	9660	440.91	-	9724	469.58	-
Tatul															
Sapling crop stage	3046	671.88	33.01	4894	522.06	32.67	3606	399.28	30.15	3190	377.25	29.88	3290	368.05	33.78
Pole crop stage	2924	451.78	31.69	3766	338.03	25.14	3050	203.37	25.50	2614	368.80	24.48	2966	400.28	30.45
Tree crop stage	51.38	446.96	55.68	6978	391.98	46.58	6342	568.56	53.03	5775	511.98	54.09	5078	575.66	52.13
Open grassland	9228	452.98	-	14980	346.97	-	11960	431.74	-	10676	513.95	-	9740	255.57	-

M = Mean light intensity (lux), SE = Standard error; RLI = Relative light intensity

to 26.78 and under tree crop stage from 28.32 to 38.98. Monthly variations in relative light intensity did not show much difference among the three crop stages.

Tatul

It was evident from the data that relative light intensity varied from 29.88 to 33.78 per cent under sapling crop stage, from 24.48 to 31.69 per cent under pole crop stage and from 46.58 to 55.68 under tree crop stage.

In all the four locations, the maximum light interception was found in pole crop stage followed by sapling crop stage and tree crop stage. In general, maximum solar influx was noticed in July month under all stages and it decreased in August, thereafter, no particular trend in its variation was observed.

4.4 NUTRIENT CONTENT OF HERBAGE

4.4.1 Nitrogen content of herbage

Barog

Nitrogen content of aboveground biomass and belowground biomass of herbage in Barog during the study period is presented in Table 13a.

a) Nitrogen content of aboveground biomass

The average nitrogen content (%) of aboveground biomass at Barog under sapling crop stage ranged from 0.75 to 0.99, under pole crop stage from 0.80 to 1.05, under tree crop stage from 0.75 to 1.06 and in open grassland from 0.83 to 1.07. A perusal of data indicated that the average nitrogen content of aboveground biomass increased gradually from July to September and thereafter decreased. Among the individual species, *T. anathera*, *P. maximum* and *P.*

Table 13a. Monthly variation in nitrogen per cent in aboveground biomass of different species in four study sites (sapling, pole and tree crop stage and open grassland) at Barog during study period (Values in parentheses represent nitrogen per cent in belowground biomass)

Species	Sapling crop stage					Pole crop stage					Tree crop stage					Open grassland				
	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov
Barog																				
<i>Themeda anathera</i>	0.84 (0.82)	1.02 (0.83)	1.12 (0.96)	0.86 (0.71)	0.76 (0.59)	0.95 (0.81)	0.94 (0.86)	1.09 (0.89)	0.82 (0.68)	0.80 (0.61)	0.78 (0.69)	0.93 (0.79)	1.03 (0.80)	0.86 (0.75)	0.69 (0.61)	0.98 (0.78)	1.14 (1.02)	1.10 (0.98)	0.94 (0.81)	0.84 (0.52)
<i>Panicum maximum</i>	0.89 (0.62)	0.92 (0.90)	1.00 (0.60)	0.96 (0.51)	0.86 (0.53)	0.72 (0.46)	0.78 (0.50)	1.04 (0.62)	0.86 (0.60)	0.88 (0.56)	0.90 (0.63)	0.99 (0.41)	1.09 (0.95)	0.91 (0.55)	0.79 (0.61)	0.90 (0.49)	1.00 (0.64)	1.07 (0.80)	0.85 (0.70)	0.89 (0.69)
<i>Apluda mutica</i>	-	-	-	-	-	-	-	0.95 (0.89)	-	0.72 (0.64)	0.86 (0.69)	-	-	-	-	0.95 (0.81)	1.08 (0.98)	0.88 (0.75)	-	-
<i>Chrysopogon gryllus</i>	-	0.88 (0.68)	-	-	-	0.81 (0.53)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Hemarthria fasciculata</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.51 (0.43)	0.85 (0.53)	-	-	-
<i>Pollinia argentea</i>	0.90 (0.72)	0.90 (0.63)	1.03 (0.85)	0.89 (0.45)	-	1.01 (0.98)	1.07 (0.97)	1.24 (1.05)	0.91 (0.65)	0.80 (0.58)	0.90 (0.72)	0.91 (0.64)	1.06 (0.98)	0.83 (0.71)	0.76 (0.65)	0.80 (0.65)	0.84 (0.81)	1.20 (1.01)	0.92 (0.85)	0.87 (0.71)
<i>Panicum prostratum</i>	1.02 (0.73)	-	-	-	0.68 (0.59)	1.09 (0.89)	1.37 (1.12)	-	-	-	-	-	-	-	-	-	-	1.19 (1.01)	-	0.73 (0.53)
<i>Carex meioyga</i>	0.83 (0.61)	0.78 (0.81)	0.81 (0.58)	-	0.70 (0.69)	-	1.01 (0.91)	0.91 (0.79)	-	-	0.72 (0.82)	1.06 (1.01)	-	-	-	-	0.79 (0.65)	0.95 (0.71)	-	-
Average	0.90 (0.70)	0.90 (0.77)	0.99 (0.75)	0.90 (0.56)	0.75 (0.60)	0.92 (0.73)	1.03 (0.87)	1.05 (0.85)	0.86 (0.64)	0.80 (0.60)	0.83 (0.71)	0.97 (0.71)	1.06 (0.91)	0.87 (0.67)	0.75 (0.62)	0.83 (0.63)	0.95 (0.77)	1.07 (0.88)	0.90 (0.79)	0.83 (0.61)

argentea showed gradual increase in nitrogen (%) till September, thereafter nitrogen (%) decreased. Other species attained peak nitrogen (%) in August and/or September.

b) Nitrogen content of belowground biomass

The average nitrogen content (%) of belowground biomass of vegetation under sapling crop stage varied from 0.60 to 0.77, under pole crop stage from 0.60 to 0.87, under tree crop stage from 0.62 to 0.91 and in open grassland it varied from 0.61 to 0.88. During the study period the nitrogen content of belowground biomass increased gradually from July to August in sapling and pole crop stages and from July to September in tree crop stage and open grassland thereafter, it decreased in all the sites. On every sampling date the average nitrogen content of belowground biomass was less as compared to their aboveground biomass counterpart. Among the individual species, a continuous increase in nitrogen (%) of belowground biomass was observed upto September in *T. anathera*, *P. maximum* and *P. argentea* other species showed highest nitrogen (%) at different times.

Deothi

a) Nitrogen content of above ground biomass

The average nitrogen content (%) of aboveground biomass at Deothi (Table 13b) under sapling crop stage fluctuated from 0.83 to 1.06, under pole crop stage from 0.81 to 1.02, under tree crop stage from 0.79 to 1.08 and in open grassland from 0.87 to 1.16. A perusal of data revealed that, average nitrogen content of different species increased gradually from July to August in sapling crop stage, pole crop stage and open grassland whereas, it increased from July to September in tree crop stage. Thereafter, a steady decreased in nitrogen content was observed upto November in all the sites. Among the individual species, the highest (1.33%, September) and lowest (0.64%, July)

Table 13b. Monthly variation in nitrogen per cent in aboveground biomass of different species in four study sites (sapling, pole and tree crop stage and open grassland) at Deothi during study period (Values in parentheses represent nitrogen per cent in belowground biomass)

Species	Sapling crop stage					Pole crop stage					Tree crop stage					Open grassland				
	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov
Deothi																				
<i>Chrysopogon montanus</i>	0.89 (0.58)	1.07 (0.75)	1.20 (1.08)	0.95 (0.80)	0.93 (0.67)	0.92 (0.58)	1.16 (0.90)	1.17 (0.80)	1.01 (0.61)	0.85 (0.32)	1.05 (0.75)	1.05 (0.60)	1.08 (0.79)	0.98 (0.50)	0.81 (0.67)	1.02 (0.65)	1.20 (0.60)	1.33 (1.00)	0.96 (0.50)	0.92 (0.48)
<i>Heteropogon contortus</i>	-	1.16 (0.79)	1.01 (0.68)	0.95 (0.58)	0.81 (0.56)	-	1.06 (0.80)	0.97 (0.58)	-	-	0.97 (0.76)	1.20 (0.81)	-	-	-	1.20 (0.87)	1.22 (0.89)	1.02 (0.56)	0.86 (0.52)	0.83 (0.51)
<i>Themeda anathera</i>	0.93 (0.48)	1.07 (0.69)	0.88 (0.69)	0.86 (0.59)	0.61 (0.51)	0.75 (0.49)	1.03 (0.89)	1.09 (0.76)	0.76 (0.71)	0.79 (0.58)	0.91 (0.51)	1.18 (0.68)	0.98 (0.89)	0.91 (0.84)	0.68 (0.58)	1.03 (0.85)	1.21 (0.90)	-	-	-
<i>Panicum maximum</i>	0.89 (0.49)	0.97 (0.56)	1.11 (0.61)	0.96 (0.60)	0.88 (0.48)	0.64 (0.53)	0.87 (0.61)	0.95 (0.89)	0.92 (0.50)	0.79 (0.50)	0.71 (0.64)	0.95 (0.55)	1.20 (0.75)	0.89 (0.61)	0.89 (0.59)	0.81 (0.71)	1.01 (0.60)	0.98 (0.91)	0.95 (0.53)	0.88 (0.43)
<i>Cymbopogon martinii</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.20 (0.89)	-	-
<i>Apluda mutica</i>	-	-	-	-	-	-	-	-	-	-	-	1.08 (0.88)	1.25 (0.95)	0.92 (0.69)	-	-	-	-	-	-
<i>Chrysopogon gryllus</i>	-	1.05 (0.95)	0.97 (0.77)	-	0.91 (0.64)	0.92 (0.89)	1.00 (0.98)	0.89 (0.86)	-	-	-	-	-	-	-	-	-	0.96 (0.81)	0.89 (0.69)	0.86 (0.71)
<i>Hemarthria fasciculata</i>	-	-	1.01 (0.70)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Cyprus rotundus</i>	1.01 (0.91)	-	-	-	-	1.16 (0.80)	-	-	-	-	1.26 (1.01)	0.91 (0.78)	0.89 (0.76)	-	-	-	-	-	-	-
Average	0.93 (0.62)	1.06 (0.75)	1.03 (0.76)	0.93 (0.60)	0.83 (0.57)	0.88 (0.67)	1.02 (0.84)	1.01 (0.78)	0.90 (0.61)	0.81 (0.47)	0.98 (0.73)	1.06 (0.72)	1.08 (0.83)	0.93 (0.66)	0.79 (0.61)	1.02 (0.77)	1.16 (0.75)	1.10 (0.83)	0.92 (0.56)	0.87 (0.53)

nitrogen contents were recorded in open grassland and pole crop stage, respectively. The peak value of nitrogen per cent in different species were observed in August/September, except in *C. rotundus* which showed highest nitrogen (%) in July in all chirpine stages and open grassland.

b) Nitrogen content of belowground biomass

The average nitrogen content (%) of belowground biomass of different species at Deothi (Table 13b) showed that it varied from 0.57 to 0.75 under sapling crop stage from 0.61 to 0.83 under pole crop stage, from 0.47 to 0.84 under tree crop stage and from 0.53 to 0.83 in open grassland. A perusal of data indicated that the nitrogen content of belowground biomass increased from July to August/September in all the sites of four locations, thereafter it decreased up to November. Among the individual species, *C. montanus* attained the highest (1.08, September) and lowest (0.32, November) nitrogen (%) in sapling crop stage and pole crop stage, respectively. The peak value of Nitrogen per cent was observed in August/September in all the species, except for *C. rotundus*, in all the sites.

Dharampur

a) Nitrogen content to aboveground biomass

The average nitrogen content (%) of aboveground biomass at Dharampur (Table 13c) revealed that under sapling crop stage nitrogen (%) in aboveground biomass ranged from 0.87 to 1.05, under pole crop stage from 0.83 to 1.14, under the crop stage from 0.78 to 1.14 and in open grassland it ranged from 0.81 to 1.08. During the study period, the nitrogen content of aboveground biomass increased gradually from July to September in all sites. In open grassland it remained content in August/September and thereafter decreased. Among the individual species *P. maximum* and *C. montanus* showed the highest (1.30%, September) and lowest (0.68%, July) nitrogen per cent in tree

Table 13c. Monthly variation in nitrogen per cent in aboveground biomass of different species in four study sites (sapling, pole and tree crop stage and open grassland) at Dharampur during study period (Values in parentheses represent nitrogen per cent in belowground biomass)

Species	Sapling crop stage					Pole crop stage					Tree crop stage					Open grassland				
	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov
Dharampur																				
<i>Chrysopogon montanus</i>	0.68 (0.58)	1.02 (0.92)	1.05 (0.95)	0.99 (0.86)	0.97 (0.81)	-	0.95 (0.88)	1.02 (0.91)	0.82 (0.75)	0.81 (0.70)	0.85 (0.83)	1.01 (0.81)	1.15 (1.01)	0.91 (0.79)	0.85 (0.71)	0.95 (0.90)	1.10 (0.87)	1.27 (0.95)	0.97 (0.91)	0.82 (0.79)
<i>Heteropogon contortus</i>	0.82 (0.70)	1.11 (1.00)	0.91 (0.86)	0.86 (0.79)	-	-	-	-	-	-	-	1.07 (1.05)	-	0.90 (0.78)	-	1.20 (1.11)	0.99 (0.85)	0.89 (0.79)	0.88 (0.81)	0.79 (0.67)
<i>Themeda anathera</i>	0.85 (0.75)	0.93 (0.91)	1.02 (0.85)	0.91 (0.75)	0.91 (0.64)	0.80 (0.69)	1.04 (0.94)	1.20 (0.89)	0.89 (0.71)	0.86 (0.54)	0.92 (0.68)	0.96 (0.84)	1.17 (1.01)	0.95 (0.81)	0.81 (0.69)	0.86 (0.81)	0.99 (0.85)	1.07 (0.95)	0.99 (0.75)	0.93 (0.81)
<i>Panicum maximum</i>	1.02 (0.85)	1.11 (0.91)	1.19 (1.14)	0.89 (0.88)	-	1.09 (0.65)	1.15 (1.01)	1.26 (1.01)	0.91 (0.89)	0.84 (0.71)	0.83 (0.81)	1.06 (0.94)	1.30 (0.95)	0.85 (0.71)	0.78 (0.68)	0.98 (0.79)	1.24 (1.11)	1.12 (0.91)	0.97 (0.91)	0.71 (0.88)
<i>Apluda mutica</i>	0.98 (0.75)	1.06 (0.91)	1.00 (0.90)	0.95 (0.81)	0.94 (0.68)	0.88 (0.79)	0.98 (0.85)	1.08 (0.92)	0.89 (0.69)	0.79 (0.71)	0.99 (0.80)	1.15 (1.01)	0.92 (0.85)	0.84 (0.83)	0.69 (0.55)	-	-	-	-	-
<i>Chrysopogon gryllus</i>	-	0.92 (0.65)	1.10 (0.89)	-	-	-	-	-	-	-	0.80 (0.62)	-	-	-	-	-	-	1.07 (0.91)	-	-
<i>Panicum prostratum</i>	-	-	-	-	-	0.86 (0.71)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Average	0.87 (0.73)	1.03 (0.88)	1.05 (0.93)	0.92 (0.82)	0.94 (0.71)	0.91 (0.71)	1.03 (0.92)	1.14 (0.93)	0.88 (0.76)	0.83 (0.67)	0.89 (0.75)	1.05 (0.93)	1.14 (0.96)	0.89 (0.78)	0.78 (0.66)	1.00 (0.90)	1.08 (0.92)	1.08 (0.90)	0.95 (0.85)	0.81 (0.99)

crop stage and sapling crop stage, respectively. The peak values of nitrogen per cent was observed in August/September in all the species in all chirpine stages and open grassland.

b) Nitrogen content of belowground biomass

The average nitrogen content (%) of belowground biomass (Table 13c) explicated that under sapling crop stage nitrogen (%) varied from 0.71 to 0.93, under pole crop stage from 0.67 to 0.93, under tree crop stage from 0.66 to 0.96 and in open grassland from 0.79 to 0.92. It was clear that nitrogen content of below ground biomass increased from July to September in all chirpine stages and from July to August in open grassland, thereafter, it decreased gradually. Among the individual species, *P. maximum* and *T. anathera* attained the highest (1.14%, September) and lowest (0.54%, November) nitrogen (%) in sapling crop stage and pole crop stage, respectively. The peak value of nitrogen per cent were observed in August/September in all the species.

Tatul

a) Nitrogen content of aboveground biomass

The average nitrogen content (%) of aboveground biomass at Tatul (Table 13d) showed that under sapling crop stage it varied from 0.88 to 1.12, under pole crop stage from 0.84 to 1.07, under tree crop stage from 0.86 to 1.05 and in open grassland from 0.81 to 1.29. A perusal of data revealed that average nitrogen content of aboveground biomass increased gradually from July to August and thereafter decreased in all the sites. Among the individual species, *A. mollis* and *T. anathera* attained the highest (1.92%, August) and lowest (0.70%, July) nitrogen per cent in open grassland. The peak values of nitrogen per cent was observed in August/September in all the species in all chirpine stages and in open grassland.

Table 13d. Monthly variation in nitrogen per cent in aboveground biomass of different species in four study sites (sapling, pole and tree crop stage and open grassland) at Tatul during study period (Values in parentheses represent nitrogen per cent in belowground biomass)

Species	Sapling crop stage					Pole crop stage					Tree crop stage					Open grassland				
	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov
Tatul																				
<i>Chrysopogon montanus</i>	0.99 (0.56)	1.11 (0.67)	1.01 (0.90)	1.01 (0.68)	0.85 (0.58)	0.85 (0.98)	1.16 (0.95)	0.90 (0.78)	0.98 (0.75)	0.91 (0.80)	0.87 (0.48)	1.05 (0.98)	1.05 (1.01)	0.89 (0.81)	0.95 (0.68)	1.21 (1.07)	0.87 (0.70)	0.96 (0.86)	0.95 (0.75)	0.94 (0.71)
<i>Heteropogon contortus</i>	-	1.02 (0.95)	1.11 (0.97)	0.98 (0.68)	-	0.97 (0.67)	-	1.09 (0.85)	0.87 (0.81)	-	-	-	0.94 (0.79)	0.89 (0.64)	0.81 (0.56)	1.09 (1.02)	0.86 (0.56)	1.04 (0.88)	0.93 (0.69)	0.74 (0.62)
<i>Themeda anathera</i>	0.80 (0.72)	1.00 (0.90)	1.09 (0.79)	0.92 (0.86)	0.86 (0.70)	0.83 (0.50)	0.85 (0.81)	0.87 (0.80)	1.09 (0.96)	0.79 (0.62)	0.81 (0.71)	0.94 (0.79)	1.10 (0.89)	0.85 (0.71)	0.81 (0.68)	1.09 (0.89)	0.70 (0.43)	1.24 (1.05)	0.95 (0.81)	0.76 (0.71)
<i>Panicum maximum</i>	1.02 (0.79)	1.05 (0.84)	0.99 (0.80)	0.96 (0.90)	0.95 (0.79)	0.94 (0.82)	1.21 (0.96)	1.09 (1.00)	-	0.85 (0.80)	1.09 (0.84)	1.11 (0.95)	0.85 (0.85)	0.98 (0.98)	0.90 (0.83)	1.34 (1.06)	1.04 (0.92)	1.04 (0.91)	0.89 (0.80)	-
<i>Cymbopogon martinii</i>	-	-	-	-	-	-	1.17 (0.98)	-	-	-	-	1.08 (0.92)	-	-	-	1.10 (0.90)	1.01 (0.72)	-	-	-
<i>Apluda mutica</i>	-	-	-	-	0.87 (0.65)	-	-	-	0.90 (0.73)	0.81 (0.70)	-	-	-	-	-	-	-	-	-	-
<i>Chrysopogon gryllus</i>	-	-	-	-	-	-	0.90 (0.79)	-	-	-	-	-	-	-	0.81 (0.52)	-	0.89 (0.65)	1.04 (0.96)	-	-
<i>Atylosia mollis</i>	-	1.13 (1.09)	-	-	-	-	-	-	-	-	-	-	-	-	-	1.92 (1.84)	-	-	-	-
<i>Indigofera pulchella</i>	-	-	-	-	-	-	1.14 (0.09)	-	-	-	-	-	-	-	-	1.31 (1.20)	-	-	-	-
<i>Cissampelos pareira</i>	-	-	-	-	-	-	-	-	-	-	0.81 (0.79)	-	-	-	-	-	-	-	-	-
<i>Plectranthus gerardianus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.96 (0.71)	-
Average	0.94 (0.69)	1.07 (0.89)	1.05 (0.87)	0.97 (0.78)	0.88 (0.68)	0.90 (0.74)	1.05 (0.93)	0.99 (0.86)	0.96 (0.81)	0.84 (0.73)	0.90 (0.71)	1.29 (0.97)	0.99 (0.89)	0.90 (0.79)	0.86 (0.65)	1.05 (1.14)	1.06 (0.60)	1.06 (0.93)	0.94 (0.75)	0.81 (0.68)

b) Nitrogen content of belowground biomass

The average nitrogen content (%) of belowground biomass (Table 13d) under sapling crop stage varied from 0.68 to 0.89, under pole crop stage from 0.73 to 0.93, under tree crop stage from 0.65 to 0.91 and in open grassland from 0.60 to 1.14. A perusal of data revealed that average nitrogen content of belowground biomass increased gradually from July to August and thereafter decreased in all the sites. Among the individual species, *A. mallis* attained the highest (1.84%, August) and *T. anathera* had the lowest (0.43%, July) nitrogen per cent in open grassland. The average nitrogen (%) of below ground biomass was less than the nitrogen (%) of aboveground biomass on each sampling date.

Not distinct pattern in nitrogen per cent variation was noticed in the four sites at different locations. The peak values of nitrogen (%) of different species was noticed in August/September in all four sites.

4.4.2 Phosphorus content of herbage

Barog

a) Phosphorus content of aboveground biomass

A scrutiny of the data on phosphorus content (%) of vegetation in Barog (Table 14a) evinced that the average phosphorus content (%) of aboveground biomass under sapling crop stage ranged from 0.08 to 0.17, under pole crop stage from 0.09 to 0.15, under tree crop stage from 0.09 to 0.18 and in open grassland from 0.11 to 0.20. The average phosphorus content increased gradually from July to September and thereafter decreased. Among the individual species *P. maximum* attained the highest phosphorus (%) value (0.28, September) in open grassland and *Polinia argentea* the lowest (0.06, July) in pole crop stage. The peak values of phosphorus (%) were observed in September for different species except for *C. meiogyna* which showed the peak in July month in tree crop stage.

Table 14a. Monthly variation in phosphorus per cent in aboveground biomass of different species in four study sites (sapling, pole and tree crop stage and open grassland) at Barog during study period (Values in parentheses represent phosphorus per cent in belowground biomass)

Species	Sapling crop stage					Pole crop stage					Tree crop stage					Open grassland				
	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov
Barog																				
<i>Themeda anathera</i>	0.11 (0.09)	0.16 (0.06)	0.16 (0.11)	0.11 (0.09)	0.11 (0.09)	0.10 (0.08)	0.16 (0.08)	0.18 (0.11)	0.09 (0.07)	0.08 (0.09)	0.08 (0.06)	0.17 (0.08)	0.19 (0.12)	0.08 (0.07)	0.06 (0.06)	0.12 (0.11)	0.19 (0.09)	0.20 (0.16)	0.10 (0.10)	0.08 (0.07)
<i>Panicum maximum</i>	0.08 (0.05)	0.15 (0.07)	0.21 (0.13)	0.18 (0.11)	0.11 (0.10)	0.10 (0.09)	0.09 (0.11)	0.18 (0.11)	0.17 (0.09)	0.10 (0.14)	0.08 (0.06)	0.10 (0.12)	0.16 (0.12)	0.17 (0.07)	0.13 (0.09)	0.11 (0.08)	0.17 (0.15)	0.28 (0.17)	0.13 (0.17)	0.12 (0.14)
<i>Apluda mutica</i>	-	-	-	-	-	-	-	0.13 (0.09)	-	0.09 (0.09)	0.10 (0.10)	-	-	-	-	0.13 (0.09)	0.16 (0.11)	0.19 (0.11)	-	-
<i>Chrysopogon gryllus</i>	-	0.11 (0.08)	-	-	-	0.10 (0.06)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Hemarthria fasciculata</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.12 (0.10)	0.19 (0.09)	-	-	-
<i>Pollinia argentea</i>	0.08 0.06	0.11 0.08	0.15 0.14	0.12 (0.10)	-	0.06 0.08	0.12 0.06	0.16 (0.09)	0.11 (0.09)	0.10 (0.12)	0.08 0.07	0.11 0.09	0.19 (0.13)	0.17 (0.09)	0.11 (0.14)	0.10 0.06	0.14 0.09	0.21 (0.15)	0.19 (0.11)	0.09 (0.06)
<i>Panicum prostratum</i>	0.06 (0.09)	-	-	-	0.11 (0.09)	0.12 (0.08)	0.09 (0.06)	-	-	-	-	-	-	-	-	-	-	0.12 (0.09)	-	-
<i>Carex meioyga</i>	0.09 (0.07)	0.09 (0.12)	0.14 (0.12)	-	0.13 (0.14)	-	0.08 (0.06)	0.12 (0.09)	-	-	0.15 (0.08)	0.14 (0.07)	-	-	-	-	0.15 (0.11)	0.19 (0.12)	-	0.14 (0.11)
Average	0.08 (0.07)	0.12 (0.08)	0.17 (0.13)	0.14 (0.10)	0.12 (0.11)	0.10 (0.08)	0.11 (0.07)	0.15 (0.10)	0.12 (0.08)	0.09 (0.11)	0.09 (0.07)	0.13 (0.09)	0.18 (0.12)	0.14 (0.08)	0.10 (0.10)	0.12 (0.09)	0.17 (0.11)	0.20 (0.13)	0.14 (0.13)	0.11 (0.09)

b) Phosphorus content of belowground biomass

The average phosphorous content (%) of belowground biomass of vegetation (Table 14a) revealed that under sapling crop stage it varied from 0.07 to 0.13, under pole crop stage from 0.08 to 0.10, under tree crop stage from 0.07 to 0.12 and in open grassland from 0.09 to 0.13. It evinced from the data that phosphorus content of belowground biomass increased from July to September and thereafter decreased. Among the individual species *P. maximum* attained the highest phosphorus (%) (0.17, September) in open grassland and *C. montanus* lowest (0.05, July) in sapling crop stage.

Deothi

a) Phosphorus content of aboveground biomass

It evinced from the Table 14b that the average phosphorus content (%) of aboveground biomass of herbage in sapling crops stage varied from 0.10 to 0.18, in pole crop stage from 0.09 to 0.18, in tree crop stage from 0.10 to 0.15 and in open grassland 0.11 to 0.21. A constant increase in average phosphorus content was recorded from July to September in sapling crop stage and open grassland whereas, it increased from July to August in pole and tree crop stages. Thereafter, a decrease in average phosphorus content of aboveground biomass was recorded. Among the individual species, the highest (0.26%, September) and lowest (0.07, September) phosphorus contents were observed for *P. maximum* and *C. rotundus* in open grassland and tree crop stage, respectively. The peak values of phosphorus (%) were observed in August/September in all the species.

b) Phosphorus content of belowground biomass

Average phosphorus content (%) of belowground biomass at Deothi (Table 14b) varied from 0.07 to 0.11 in sapling and pole crop stages, 0.06 to

Table 14b. Monthly variation in phosphorus per cent in aboveground biomass of different species in four study sites (sapling, pole and tree crop stage and open grassland) at Deothi during study period (Values in parentheses represent phosphorus per cent in belowground biomass)

Species	Sapling crop stage					Pole crop stage					Tree crop stage					Open grassland				
	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov
Deothi																				
<i>Chrysopogon montanus</i>	0.09 (0.05)	0.16 (0.08)	0.21 (0.09)	0.19 (0.12)	0.11 (0.06)	0.12 (0.06)	0.20 (0.07)	0.16 (0.07)	0.16 (0.08)	0.09 (0.07)	0.10 (0.06)	0.17 (0.11)	0.19 (0.11)	0.14 (0.08)	0.12 (0.08)	0.10 (0.08)	0.21 (0.12)	0.23 (0.15)	0.19 (0.11)	0.09 (0.06)
<i>Heteropogon contortus</i>	-	0.11 (0.07)	0.14 (0.11)	0.14 (0.11)	0.08 (0.05)	-	0.19 (0.09)	0.16 (0.08)	-	-	0.11 (0.05)	0.18 (0.08)	-	-	-	0.09 (0.05)	0.14 (0.07)	0.19 (0.11)	0.16 (0.11)	0.09 (0.05)
<i>Themeda anathera</i>	0.10 (0.06)	0.14 (0.11)	0.13 (0.10)	0.11 (0.06)	0.09 (0.06)	0.11 (0.06)	0.21 (0.14)	0.14 (0.09)	0.09 (0.08)	0.08 (0.06)	0.09 (0.04)	0.19 (0.10)	0.13 (0.07)	0.08 (0.06)	0.09 (0.07)	0.14 (0.09)	0.21 (0.18)	-	-	-
<i>Panicum maximum</i>	0.09 (0.08)	0.15 (0.08)	0.21 (0.14)	0.21 (0.11)	0.17 (0.12)	0.14 (0.09)	0.17 (0.13)	0.22 (0.13)	0.20 (0.10)	0.11 (0.09)	0.09 (0.05)	0.14 (0.10)	0.24 (0.12)	0.17 (0.07)	0.09 (0.08)	0.10 (0.07)	0.17 (0.11)	0.26 (0.17)	0.19 (0.10)	0.14 (0.10)
<i>Cymbopogon martinii</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.17 (0.13)	-	-
<i>Apluda mutica</i>	-	-	-	-	-	-	-	-	-	-	-	0.11 (0.08)	0.20 (0.14)	0.12 (0.10)	-	-	-	-	-	-
<i>Chrysopogon gryllus</i>	-	0.11 (0.09)	0.19 (0.11)	-	0.09 (0.06)	0.10 (0.07)	0.13 (0.11)	0.16 (0.10)	-	-	-	-	-	-	-	-	-	0.18 (0.10)	0.11 (0.09)	0.10 (0.08)
<i>Hemarthria fasciculata</i>	-	-	0.18 (0.11)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Cyprus rotundus</i>	0.12 (0.08)	-	-	-	-	0.09 (0.07)	-	-	-	-	0.09 (0.10)	0.10 (0.12)	0.07 (0.06)	-	-	-	-	-	-	-
Average	0.10 (0.07)	0.13 (0.09)	0.18 (0.11)	0.16 (0.10)	0.11 (0.07)	0.11 (0.07)	0.18 (0.11)	0.17 (0.09)	0.15 (0.09)	0.09 (0.07)	0.10 (0.06)	0.15 (0.10)	0.14 (0.10)	0.13 (0.08)	0.10 (0.08)	0.11 (0.07)	0.18 (0.12)	0.21 (0.13)	0.16 (0.10)	0.11 (0.07)

0.10 under tree crop stage and 0.07 to 0.13 in open grassland. The phosphorus content of belowground biomass increased from July to September in sapling and open grassland whereas, it showed an increasing trend from July to August in pole and tree crop stages and thereafter it decreased in all sites. The peak values of different species was recorded in August/September. *T. anathera* attained the maximum and minimum phosphorus content as (0.18%, August) and (0.04%, July) in open grassland and tree crop stage, respectively.

Dharampur

a) Phosphorous content of aboveground biomass

It was revealed from the Table 14c that average phosphorus content of aboveground biomass ranged from 0.11 to 0.17 in sapling crop stage, 0.10 to 0.18 in pole crop stage, 0.09 to 0.21 in tree crop stage and 0.10 to 0.21 in open grassland. It was seen from the data that phosphorus content increased gradually from July to September in pole & tree crop stages and open grassland whereas it showed the increasing trend from July to August in Sapling crop stage, thereafter, decreased in all the sites. The peak values of phosphorus content were observed in August/September. *P. maximum* attained the highest (0.27%, September) and *T. anathera* lowest (0.07%, November) phosphorus content in open grassland and pole crop stage, respectively.

b) Phosphorus content of belowground biomass

The average phosphorus content (%) of belowground biomass of vegetation of Dharampur (Table 14c) showed that in sapling crop stage it ranged from 0.07 to 0.12, under pole crop stage from 0.08 to 0.13, under tree crop stage from 0.06 to 0.14 and in open grassland it ranged from 0.08 to 0.13. A scrutiny of data evinced that phosphorus content of belowground biomass increased from July to September in open grassland and pole & tree crop stages and whereas, it showed increasing trend from July/August in sapling stage,

Table 14c. Monthly variation in phosphorus per cent in aboveground biomass of different species in four study sites (sapling, pole and tree crop stage and open grassland) at Dharampur during study period (Values in parentheses represent phosphorus per cent in belowground biomass)

Species	Sapling crop stage					Pole crop stage					Tree crop stage					Open grassland				
	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov
Dharampur																				
<i>Chrysopogon montanus</i>	0.13 (0.09)	0.19 (0.16)	0.19 (0.14)	0.16 (0.11)	0.11 (0.08)	-	0.13 (0.07)	0.12 (0.12)	0.15 (0.09)	0.13 (0.10)	0.09 (0.06)	0.18 (0.09)	0.18 (0.14)	0.17 (0.10)	0.14 (0.11)	0.10 (0.08)	0.15 (0.08)	0.23 (0.13)	0.19 (0.12)	0.16 (0.11)
<i>Heteropogon contortus</i>	0.12 (0.07)	0.18 (0.12)	0.11 (0.11)	0.12 (0.08)	-	-	-	-	-	-	-	0.11 (0.08)	-	0.11 (0.10)	-	0.09 (0.08)	0.14 (0.09)	0.16 (0.10)	0.12 (0.09)	0.11 (0.06)
<i>Themeda anathera</i>	0.10 (0.07)	0.17 (0.12)	0.13 (0.07)	0.11 (0.09)	0.08 (0.06)	0.09 (0.07)	0.12 (0.11)	0.18 (0.11)	0.10 (0.07)	0.07 (0.07)	0.09 (0.04)	0.15 (0.08)	0.19 (0.10)	0.14 (0.09)	0.09 (0.07)	0.11 (0.09)	0.14 (0.10)	0.19 (0.18)	0.11 (0.10)	0.10 (0.09)
<i>Panicum maximum</i>	0.12 (0.05)	0.18 (0.09)	0.20 (0.13)	0.09 (0.08)	-	0.10 (0.06)	0.19 (0.14)	0.25 (0.17)	0.16 (0.10)	0.14 (0.08)	0.09 (0.06)	0.24 (0.11)	0.22 (0.14)	0.19 (0.14)	0.11 (0.09)	0.11 (0.10)	0.21 (0.14)	0.27 (0.14)	0.23 (0.11)	0.09 (0.06)
<i>Apluda mutica</i>	0.11 (0.08)	0.12 (0.11)	0.19 (0.15)	0.17 (0.09)	0.14 (0.10)	0.09 (0.08)	0.14 (0.07)	0.18 (0.11)	0.15 (0.11)	0.13 (0.09)	0.10 (0.07)	0.18 (0.09)	0.24 (0.16)	0.14 (0.07)	0.11 (0.08)	-	-	-	-	-
<i>Chrysopogon gryllus</i>	-	0.15 (0.09)	0.14 (0.10)	-	-	-	-	-	-	-	0.10 (0.09)	-	-	-	-	-	-	0.19 (0.11)	-	-
<i>Panicum prostratum</i>	-	-	-	-	-	0.13 (0.11)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Average	0.13 (0.07)	0.17 (0.12)	0.16 (0.12)	0.13 (0.09)	0.11 (0.08)	0.10 (0.08)	0.15 (0.10)	0.18 (0.13)	0.14 (0.09)	0.12 (0.09)	0.09 (0.06)	0.17 (0.09)	0.21 (0.14)	0.15 (0.10)	0.11 (0.09)	0.10 (0.09)	0.16 (0.10)	0.21 (0.13)	0.16 (0.11)	0.12 (0.08)

thereafter, it decreased in all sites. Among the individual species *T. anathera* attained the highest and lowest (0.18%, September and 0.04%, July, respectively) phosphorus content in open grassland and tree crop stage. The peak values of phosphorus content in all the species were observed in August/September months.

Tatul

a) Phosphorus content of aboveground biomass

A perusal of data from the Table 14d revealed that average phosphorus content (%) of aboveground biomass in Tatul fluctuated from 0.09 to 0.20 under sapling crop stage, from 0.10 to 0.18 under pole crop stage, from 0.08 to 0.18 under tree crop stage and from 0.10 to 0.22 in open grassland. A consistent increase in phosphorus content was observed from July to September in sapling & tree crop stages and in open grassland, whereas, the increasing trend was from July to August in tree crop stage. After that a consistent decrease in phosphorus (%) was recorded in all the sites. Among the individual species both *C. montanus* and *P. maximum* attained the highest phosphorus content (0.25%, September) in open grassland and *T. anathera* had lowest phosphorus content (0.07%, July) in tree crop stage. The peak values of phosphorus content was noticed in August/September months.

b) Phosphorus content of belowground biomass

It is seen from the Table 14d that average phosphorus content (%) of belowground biomass ranged from 0.08 to 1.14 under sapling crop stage, from 0.08 to 0.11 under pole crop stage, from 0.06 to 0.13 under tree crop stage and from 0.08 to 0.14 in open grassland. It revealed from the data that phosphorus content increased from July to August in pole and tree crop stages, and from July to September in sapling and open grassland thereafter decreased in all the sites except the pole crop stage in September where it remained at par with

Table 14d. Monthly variation in phosphorus per cent in aboveground biomass of different species in four study sites (sapling, pole and tree crop stage and open grassland) at Tatul during study period (Values in parentheses represent phosphorus per cent in belowground biomass)

Species	Sapling crop stage					Pole crop stage					Tree crop stage					Open grassland				
	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov
Tatul																				
<i>Chrysopogon montanus</i>	0.10 (0.09)	0.14 (0.09)	0.23 (0.17)	0.14 (0.12)	0.09 (0.10)	0.11 (0.08)	0.19 (0.14)	0.19 (0.12)	0.12 (0.11)	0.11 (0.10)	0.09 (0.06)	0.21 (0.12)	0.18 (0.11)	0.13 (0.10)	0.13 (0.07)	0.10 (0.09)	0.17 (0.12)	0.25 (0.19)	0.16 (0.09)	0.11 (0.07)
<i>Heteropogon contortus</i>	-	0.13 (0.09)	0.19 (0.15)	0.12 (0.08)	-	0.09 (0.06)	-	0.18 (0.11)	0.14 (0.10)	-	-	-	0.15 (0.12)	0.11 (0.07)	0.10 (0.09)	0.13 (0.08)	0.12 (0.08)	0.20 (0.15)	0.14 (0.09)	0.12 (0.08)
<i>Themeda anathera</i>	0.10 (0.09)	0.12 (0.08)	0.19 (0.10)	0.15 (0.11)	0.09 (0.06)	0.08 (0.06)	0.15 (0.11)	0.18 (0.09)	0.12 (0.09)	0.08 (0.07)	0.07 (0.06)	0.13 (0.09)	0.17 (0.11)	0.13 (0.10)	0.11 (0.09)	0.09 (0.07)	0.17 (0.11)	0.21 (0.14)	0.14 (0.11)	0.14 (0.12)
<i>Panicum maximum</i>	0.09 (0.08)	0.19 (0.11)	0.19 (0.12)	0.19 (0.13)	0.10 (0.09)	0.13 (0.11)	0.16 (0.12)	0.17 (0.11)	-	0.13 (0.12)	0.08 (0.06)	0.18 (0.18)	0.19 (0.14)	0.17 (0.15)	0.11 (0.11)	0.10 (0.09)	-	0.25 (0.13)	0.20 (0.08)	-
<i>Cymbopogon martinii</i>	-	-	-	-	-	-	0.13 (0.10)	-	-	-	-	0.49 (0.14)	-	-	-	0.08 (0.07)	0.21 (0.19)	-	-	-
<i>Apluda mutica</i>	-	-	-	-	0.09 (0.06)	-	-	-	0.14 (0.10)	0.13 (0.11)	-	-	-	-	-	-	-	-	-	-
<i>Chrysopogon gryllus</i>	-	-	-	-	-	-	0.14 (0.09)	-	-	-	-	-	-	-	0.08 (0.07)	0.08 (0.10)	0.17 (0.11)	0.19 (0.11)	-	-
<i>Atylosia mollis</i>	-	0.17 (0.19)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.15 (0.13)	-	-	-
<i>Indigofera pulchella</i>	-	-	-	-	-	-	0.13 (0.11)	-	-	-	-	-	-	-	-	-	0.12 (0.09)	-	-	-
<i>Cissampelos pareira</i>	-	-	-	-	-	-	-	-	-	-	0.13 (0.05)	-	-	-	-	-	-	-	-	-
<i>Plectranthus gerardianus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.11 (0.08)	-
Average	0.10 (0.09)	0.15 (0.11)	0.20 (0.14)	0.15 (0.11)	0.09 (0.08)	0.10 (0.08)	0.15 (0.11)	0.18 (0.11)	0.13 (0.10)	0.11 (0.10)	0.08 (0.06)	0.18 (0.13)	0.17 (0.12)	0.14 (0.11)	0.11 (0.09)	0.10 (0.08)	0.16 (0.12)	0.22 (0.14)	0.15 (0.09)	0.12 (0.09)

August. Among the individual species, *C. montanus* and *P. maximum* attained the highest (0.19%, September and August) phosphorus content in open grassland. *C. montanus* also exhibited the lowest (0.07%, July) phosphorus content in belowground biomass in tree crop stage. The peak values of phosphorus content were recorded in August/September months.

At all four locations, no distinct pattern in phosphorus (%) variations in aboveground and belowground biomass was noticed in different sites. The peak values of phosphorus (%) were noticed in August/September months in all species in all the four sites. The average content of phosphorus in belowground biomass was less than the phosphorus content in aboveground biomass during each sampling date except tree crop stage in November month at Barog.

4.4.3 Potassium content of herbage

Barog

The data relating to monthly changes in potassium content in aboveground and belowground biomass at Barog is presented in Table 15a.

a) Potassium content of aboveground biomass

As is evident from the data, the average potassium content (%) in different species under sapling crop stage varied from 0.51 to 0.60, under pole crop stage from 0.44 to 0.61, under tree crop stage from 0.42 to 0.63 and in open grassland from 0.49 to 0.66. A perusal of data further revealed that average potassium content increased gradually from July to September in sapling crop stage, tree crop stage and open grassland whereas in pole crop stage it increased from July to August. Thereafter, it decreased in all the sites. The performance of individual species showed that *C. meiogyna* attained the maximum potassium content 0.78 per cent in August in sapling crop stage and *T. anathera* and *P. maximum* had the minimum in November in pole and tree

Table 15a. Monthly variation in potassium per cent in aboveground biomass of different species in four study sites (sapling, pole and tree crop stage and open grassland) at Barog during study period (Values in parentheses represent potassium per cent in belowground biomass)

Species	Sapling crop stage					Pole crop stage					Tree crop stage					Open grassland				
	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov
Barog																				
<i>Themeda anathera</i>	0.41 (0.28)	0.45 (0.21)	0.57 (0.39)	0.54 (0.29)	0.49 (0.23)	0.43 (0.24)	0.49 (0.21)	0.66 (0.32)	0.49 (0.17)	0.39 (0.21)	0.51 (0.21)	0.53 (0.23)	0.61 (0.32)	0.46 (0.29)	0.41 (0.21)	0.48 (0.24)	0.65 (0.44)	0.69 (0.41)	0.54 (0.33)	0.42 (0.29)
<i>Panicum maximum</i>	0.48 (0.14)	0.47 (0.34)	0.63 (0.32)	0.60 (0.31)	0.58 (0.30)	0.41 (0.24)	0.69 (0.31)	0.48 (0.29)	0.51 (0.29)	0.48 (0.38)	0.53 (0.18)	0.52 (0.29)	0.61 (0.39)	0.51 (0.31)	0.39 (0.21)	0.47 (0.20)	0.49 (0.30)	0.64 (0.41)	0.58 (0.39)	0.49 (0.27)
<i>Apluda mutica</i>	-	-	-	-	-	-	-	0.51 (0.21)	-	0.41 (0.19)	0.40 (0.20)	-	-	-	-	0.49 (0.23)	0.49 (0.26)	0.53 (0.39)	-	-
<i>Chrysopogon gryllus</i>	-	0.62 (0.39)	-	-	-	0.46 (0.31)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Hemarthria fasciculata</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.49 (0.21)	0.52 (0.38)	-	-	-
<i>Pollinia argentea</i>	0.51 (0.19)	0.59 (0.31)	0.67 (0.32)	0.58 (0.21)	-	0.49 (0.22)	0.60 (0.26)	0.63 (0.40)	0.49 (0.29)	0.46 (0.23)	0.57 (0.11)	0.57 (0.49)	0.66 (0.46)	0.51 (0.31)	0.47 (0.26)	0.57 (0.31)	0.61 (0.44)	0.69 (0.52)	0.59 (0.33)	0.52 (0.24)
<i>Panicum prostratum</i>	0.49 (0.21)	-	-	-	0.50 (0.29)	0.51 (0.31)	0.48 (0.29)	-	-	-	-	-	-	-	-	-	-	0.71 (0.31)	-	-
<i>Carex meioyga</i>	0.64 (0.31)	0.78 (0.42)	0.53 (0.39)	-	0.54 (0.49)	-	0.77 (0.69)	0.52 (0.31)	-	-	0.60 (0.44)	0.73 (0.39)	-	-	-	-	0.70 (0.51)	0.69 (0.51)	-	0.52 (0.41)
Average	0.51 (0.23)	0.58 (0.33)	0.60 (0.36)	0.57 (0.27)	0.53 (0.33)	0.46 (0.26)	0.61 (0.35)	0.56 (0.31)	0.50 (0.25)	0.44 (0.25)	0.52 (0.23)	0.59 (0.35)	0.63 (0.39)	0.49 (0.30)	0.42 (0.23)	0.50 (0.24)	0.58 (0.39)	0.66 (0.43)	0.57 (0.35)	0.49 (0.30)

crop stages. The peak values of potassium content was observed in August/September in all the species.

b) Potassium content of belowground biomass

The data in Table 15a revealed that the average potassium content (%) in the roots of vegetation in sapling crop stage ranged from 0.23 to 0.36, from 0.25 to 0.35 in pole crop stage, from 0.23 to 0.39 in tree crop stage and from 0.24 to 0.43 in open grassland. A scrutiny of data showed that average potassium content increased from July to September in open grassland and sapling & tree crop stages. In pole crop stage it however, increased from July to August and thereafter, it decreased in all the sites. The individual performances of individual species showed that *C. meiogyna* registered the highest (0.69%, August) in pole crop stage and *P. maximum* lowest (0.14%, July) in sapling crop stage.

Deothi

a) Potassium content in aboveground biomass

The average potassium content (%) in aboveground biomass at Deothi (Table 15b) varied from 0.43 to 0.57 under sapling crop stage, from 0.40 to 0.64 under pole crop stage, from 0.46 to 0.57 under tree crop stage and from 0.48 to 0.66 in open grass land. It was clear from the data that average potassium content increased gradually from July to September and thereafter, it decreased in all the sites. Among the individual species, the maximum potassium content of 0.76 per cent was registered for *C. gryllus* in September in pole crop stage and minimum 0.36 per cent in July in sapling crop stage for *C. montanus*

b) Potassium content of belowground biomass

The average potassium content (%) of belowground biomass (Table 15b) of vegetation varied from 0.23 to 0.33 in sapling crop stage, 0.19 to 0.35 in pole

Table 15b. Monthly variation in potassium per cent in aboveground biomass of different species in four study sites (sapling, pole and tree crop stage and open grassland) at Deothi during study period (Values in parentheses represent potassium per cent in belowground biomass)

Species	Sapling crop stage					Pole crop stage					Tree crop stage					Open grassland				
	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov
Deothi																				
<i>Chrysopogon montanus</i>	0.36 (0.29)	0.52 (0.28)	0.48 (0.28)	0.52 (0.30)	0.42 (0.29)	0.49 (0.31)	0.48 (0.21)	0.61 (0.27)	0.57 (0.26)	0.41 (0.20)	0.51 (0.27)	0.54 (0.22)	0.64 (0.32)	0.57 (0.23)	0.51 (0.19)	0.49 (0.29)	0.59 (0.26)	0.62 (0.33)	0.51 (0.21)	0.49 (0.20)
<i>Heteropogon contortus</i>	-	0.50 (0.35)	0.48 (0.31)	0.59 (0.24)	0.41 (0.20)	-	0.53 (0.28)	0.59 (0.39)	-	-	0.47 (0.20)	0.51 (0.21)	-	-	-	0.45 (0.24)	0.49 (0.35)	0.64 (0.29)	0.50 (0.20)	0.46 (0.21)
<i>Themeda anathera</i>	0.42 (0.19)	0.53 (0.24)	0.53 (0.23)	0.49 (0.19)	0.46 (0.18)	0.47 (0.21)	0.49 (0.29)	0.61 (0.33)	0.46 (0.21)	0.39 (0.18)	0.51 (0.21)	0.58 (0.31)	0.58 (0.37)	0.51 (0.28)	0.45 (0.21)	0.48 (0.22)	0.48 (0.31)	-	-	-
<i>Panicum maximum</i>	0.41 (0.09)	0.51 (0.21)	0.63 (0.38)	0.49 (0.24)	0.51 (0.19)	0.59 (0.19)	0.66 (0.31)	0.60 (0.32)	0.52 (0.29)	0.39 (0.19)	0.56 (0.14)	0.59 (0.27)	0.58 (0.29)	0.41 (0.31)	0.41 (0.23)	0.60 (0.27)	0.62 (0.31)	0.66 (0.35)	0.48 (0.26)	0.46 (0.21)
<i>Cymbopogon martinii</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.70 (0.41)	-	-
<i>Apluda mutica</i>	-	-	-	-	-	-	-	-	-	-	-	0.49 (0.21)	0.66 (0.39)	0.39 (0.21)	-	-	-	-	-	-
<i>Chrysopogon gryllus</i>	-	0.46 (0.29)	0.59 (0.40)	-	0.46 (0.31)	0.48 (0.34)	0.50 (0.30)	0.76 (0.42)	-	-	-	-	-	-	-	-	-	0.68 (0.31)	0.56 (0.26)	0.52 (0.19)
<i>Hemarthria fasciculata</i>	-	-	0.70 (0.36)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Cyprus rotundus</i>	0.51 (0.41)	-	-	-	-	0.61 (0.39)	-	-	-	-	0.49 (0.31)	0.48 (0.28)	0.40 (0.23)	-	-	-	-	-	-	-
Average	0.43 (0.25)	0.52 (0.27)	0.57 (0.33)	0.52 (0.24)	0.45 (0.23)	0.53 (0.29)	0.53 (0.29)	0.64 (0.35)	0.52 (0.25)	0.40 (0.79)	0.51 (0.23)	0.53 (0.25)	0.57 (0.32)	0.47 (0.26)	0.46 (0.21)	0.51 (0.26)	0.55 (0.31)	0.66 (0.34)	0.51 (0.23)	0.48 (0.20)

crop stage, 0.21 to 0.32 in tree crop stage and 0.20 to 0.34 in open grassland, showing a gradual increase upto September. Then a marked decrease in potassium content was recorded upto November in all the sites. Among the individual species, the highest potassium per cent of 0.42 was registered by *C. gryllus* in September in pole crop stage and lowest of 0.09 by *C. montanus* in July in sapling crop stage.

Dharampur

a) Potassium content of aboveground biomass

The average potassium content (%) of aboveground biomass at Dharampur (Table 15c) under sapling crop stage ranged from 0.43 to 0.63, from 0.46 to 0.65 under pole crop stage, from 0.44 to 0.67 under tree crop stage and from 0.49 to 0.66 in open grassland, showing a gradual increase from July to September in all chirpine stages and from July to August in open grassland. Thereafter, a marked decrease in potassium content was observed upto November in all the sites. Among the individual species the peak values of potassium content were observed in August/September. *C. montanus* attained the highest potassium content (0.72%, August) in open grassland and *A. mutica* the lowest (0.38%, November) in tree crop stage.

b) Potassium content in belowground biomass

The average potassium content (%) in belowground biomass ranged from 0.23 to 0.28 under sapling crop stage, from 0.23 to 0.32 under pole crop stage, from 0.20 to 0.32 under tree crop stage and from 0.21 to 0.32 in open grassland showing a gradual increase from July to September in open grassland and sapling & pole crop stages whereas it increased from July to August in tree crop stage, then it decreased upto November in all the sites. Among individual species, *A. mutica* attained the highest potassium content (0.41%, August) in

Table 15c. Monthly variation in potassium per cent in aboveground biomass of different species in four study sites (sapling, pole and tree crop stage and open grassland) at Dharampur during study period (Values in parentheses represent potassium per cent in belowground biomass)

Species	Sapling crop stage					Pole crop stage					Tree crop stage					Open grassland				
	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov
Dharampur																				
<i>Chrysopogon montanus</i>	0.42 (0.25)	0.48 (0.21)	0.65 (0.33)	0.58 (0.26)	0.44 (0.21)	-	0.41 (0.19)	0.67 (0.35)	0.61 (0.23)	0.49 (0.22)	0.55 (0.28)	0.61 (0.31)	0.67 (0.29)	0.52 (0.23)	0.51 (0.19)	0.57 (0.24)	0.72 (0.26)	0.70 (0.39)	0.59 (0.31)	0.55 (0.26)
<i>Heteropogon contortus</i>	0.60 (0.28)	0.60 (0.22)	0.71 (0.31)	0.50 (0.26)	-	-	-	-	-	-	-	0.61 (0.39)	-	0.48 (0.20)	-	0.57 (0.24)	0.65 (0.38)	0.68 (0.34)	0.51 (0.20)	0.43 (0.21)
<i>Themeda anathera</i>	0.39 (0.21)	0.66 (0.36)	0.71 (0.30)	0.51 (0.28)	0.44 (0.22)	0.41 (0.35)	0.62 (0.37)	0.69 (0.32)	0.46 (0.22)	0.45 (0.28)	0.60 (0.36)	0.71 (0.34)	0.71 (0.22)	0.54 (0.20)	0.39 (0.19)	0.60 (0.22)	0.69 (0.29)	0.68 (0.39)	0.56 (0.26)	0.47 (0.20)
<i>Panicum maximum</i>	0.41 (0.18)	0.53 (0.19)	0.58 (0.25)	0.52 (0.18)	-	0.53 (0.23)	0.57 (0.28)	0.57 (0.22)	0.60 (0.23)	0.50 (0.22)	0.39 (0.31)	0.49 (0.22)	0.66 (0.28)	0.57 (0.28)	0.47 (0.21)	0.49 (0.21)	0.59 (0.24)	0.69 (0.23)	0.55 (0.19)	0.50 (0.18)
<i>Apluda mutica</i>	0.45 (0.21)	0.48 (0.28)	0.56 (0.23)	0.49 (0.25)	0.40 (0.28)	0.40 (0.23)	0.49 (0.41)	0.66 (0.38)	0.40 (0.35)	0.39 (0.19)	0.58 (0.30)	0.58 (0.33)	0.65 (0.36)	0.50 (0.30)	0.38 (0.21)	-	-	-	-	-
<i>Chrysopogon gryllus</i>	-	0.61 (0.31)	0.58 (0.25)	-	-	-	-	-	-	-	0.47 (0.29)	-	-	-	-	-	-	0.51 (0.27)	-	-
<i>Panicum prostratum</i>	-	-	-	-	-	0.50 (0.30)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Average	0.45 (0.23)	0.56 (0.26)	0.63 (0.28)	0.52 (0.25)	0.43 (0.24)	0.46 (0.28)	0.52 (0.31)	0.65 (0.32)	0.52 (0.26)	0.46 (0.23)	0.52 (0.31)	0.60 (0.32)	0.67 (0.29)	0.51 (0.24)	0.44 (0.20)	0.56 (0.23)	0.66 (0.29)	0.65 (0.32)	0.55 (0.25)	0.49 (0.21)

pole crop stage and *P. maximum* the lowest (0.18%, October and November in sapling crop stage and open grassland.

Tatul

The average potassium content of above and belowground biomass of different species in Tatul is presented in Table 15d.

a) Potassium content of aboveground biomass

A perusal of data indicated that the average potassium content in aboveground biomass varied from 0.47 to 0.61 under sapling stage, 0.50 to 0.66 in pole crop stage, 0.52 to 0.65 in tree crop stage and 0.53 to 0.67 in open grassland showing gradual increase from July to September and thereafter, it decreased in all the sites. Among the individual species, *C. pareira* attained the highest potassium content (0.74%, July) in tree crop stage and *C. montanus* the lowest (0.42%, July) in sapling crop stage. The peak values of different species were recorded at different times during study period.

b) Potassium content of belowground biomass

It was evident from the Table 15d, the average potassium content (%) of belowground biomass of vegetation in sapling crop stage varied from 0.22 to 0.34, in pole crop stage from 0.26 to 0.36, in tree crop stage from 0.25 to 0.35 and in open grassland from 0.26 to 0.39. A rummage of data explicated that average potassium content increased from July to September in all the sites except in pole crop stage where the increase was recorded from July to August only. Thereafter, a marginal decrease in average potassium content was recorded in all the sites. The peak values of potassium content in different species were observed in August/September.

Table 15d. Monthly variation in potassium per cent in aboveground biomass of different species in four study sites (sapling, pole and tree crop stage and open grassland) at Tatul during study period (Values in parentheses represent potassium per cent in belowground biomass)

Species	Sapling crop stage					Pole crop stage					Tree crop stage					Open grassland				
	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov	Jul	Aug	Sep	Oct	Nov
Tatul																				
<i>Chrysopogon montanus</i>	0.42 (0.25)	0.53 (0.21)	0.58 (0.29)	0.54 (0.33)	0.50 (0.23)	0.47 (0.30)	0.59 (0.31)	0.65 (0.37)	0.65 (0.31)	0.48 (0.20)	0.49 (0.35)	0.55 (0.33)	0.68 (0.35)	0.59 (0.27)	0.57 (0.22)	0.51 (0.34)	0.60 (0.29)	0.69 (0.36)	0.63 (0.24)	0.59 (0.24)
<i>Heteropogon contortus</i>	-	0.49 (0.32)	0.59 (0.33)	0.61 (0.30)	-	0.51 (0.30)	-	0.63 (0.29)	0.64 (0.29)	-	-	-	0.69 (0.38)	0.62 (0.31)	0.52 (0.31)	0.48 (0.19)	0.53 (0.31)	0.72 (0.41)	0.59 (0.20)	0.47 (0.24)
<i>Themeda anathera</i>	0.43 (0.21)	0.61 (0.22)	0.66 (0.38)	0.62 (0.30)	0.60 (0.22)	0.56 (0.19)	0.60 (0.31)	0.69 (0.34)	0.59 (0.21)	0.50 (0.31)	0.49 (0.30)	0.57 (0.33)	0.61 (0.33)	0.55 (0.26)	0.53 (0.21)	0.55 (0.31)	0.63 (0.29)	0.70 (0.41)	0.65 (0.31)	0.58 (0.30)
<i>Panicum maximum</i>	0.57 (0.21)	0.65 (0.31)	0.61 (0.37)	0.54 (0.29)	0.57 (0.27)	0.45 (0.37)	0.61 (0.33)	0.68 (0.35)	-	0.51 (0.29)	0.48 (0.25)	0.49 (0.27)	0.62 (0.32)	0.58 (0.27)	0.52 (0.24)	0.58 (0.19)	-	0.67 (0.40)	0.55 (0.29)	-
<i>Cymbopogon martinii</i>	-	-	-	-	-	-	0.64 (0.31)	-	-	-	-	0.50 (0.30)	-	-	-	0.57 (0.33)	0.60 (0.35)	-	-	-
<i>Apluda mutica</i>	-	-	-	-	0.62 (0.31)	-	-	-	0.69 (0.38)	0.55 (0.25)	-	-	-	-	-	-	-	-	-	-
<i>Chrysopogon gryllus</i>	-	-	-	-	-	-	0.72 (0.35)	-	-	-	-	-	-	-	0.48 (0.29)	0.50 (0.31)	0.52 (0.28)	0.59 (0.35)	-	-
<i>Atylosia mollis</i>	-	0.43 (0.21)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.70 (0.42)	-	-	-
<i>Indigofera pulchella</i>	-	-	-	-	-	-	0.71 (0.45)	-	-	-	-	-	-	-	-	-	0.68 (0.31)	-	-	-
<i>Cissampelos pareira</i>	-	-	-	-	-	-	-	-	-	-	0.74 (0.41)	-	-	-	-	-	-	-	-	-
<i>Plectranthus gerardianus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.61 (0.36)	-
Average	0.47 (0.22)	0.54 (0.25)	0.61 (0.34)	0.58 (0.31)	0.57 (0.26)	0.50 (0.29)	0.65 (0.34)	0.66 (0.34)	0.64 (0.30)	0.51 (0.26)	0.55 (0.33)	0.55 (0.31)	0.65 (0.35)	0.59 (0.28)	0.52 (0.25)	0.53 (0.21)	0.61 (0.32)	0.67 (0.39)	0.61 (0.28)	0.55 (0.20)

In all the four locations no distinct pattern in potassium (%) variation was noticed in different sites. Mostly the peak values of potassium content was observed in August/September months in all species. The average potassium content of belowground biomass of vegetation were less as compared to the respective average potassium content in aboveground biomass.

4.5 PHYSICO-CHEMICAL PROPERTIES OF SOIL

The physico-chemical properties of the soil of different locations/sites is presented in Table 16.

4.5.1 Texture

In Barog, the texture was silty clay loam in sapling crop stage silty loam in pole crop stage, silty loam in tree crop stage and sandy loam in open grassland. In Deothi, it was sandy clay loam in sapling crop stage, loamy in pole crop stage, sandy clay loam in tree crop stage and sandy loam in open grassland. In Dharampur, the soil was loamy, silty clay loam, loam and silty loam in sapling crop stage, pole crop stage, tree crop stage and open grassland, respectively. In Tatul, the texture of the soil was loamy in sapling crop stage, silty loam in pole crop stage, loamy in tree crop stage and sandy loam in open grassland.

4.5.2 pH

A careful scrutiny of the data revealed that, in general, the soil under open grassland registered higher pH values in comparison to the soil under chirpine sites at all the four locations during the study period. In tree crop stage, pH was less as compared to other stages in all the four locations. The pH varied from 5.85 to 6.10 in Barog, from 6.10 to 6.40 in Deothi, from 6.28 to 6.54 in Dharampur and from 5.80 to 6.42 in Tatul in chirpine sites and their

Table 16. Soil physico-chemical properties of the study sites (sapling, pole and tree crop stage and open grassland) at four locations (Barog, Deothi, Dharampur and Tatul) during study period

	Study sites															
	Barog				Deothi				Dharampur				Tatul			
	S	P	T	O	S	P	T	O	S	P	T	O	S	P	T	O
Texture	SiCL	SiL	SiL	SL	SCL	L	SCL	SL	L	SiCL	L	SiL	L	SiL	L	SL
PH	6.00	6.10	5.85	6.40	6.40	6.32	6.10	6.76	6.54	6.44	6.28	6.65	6.22	6.42	5.80	6.59
EC (dsm ⁻¹)	0.226	0.215	0.23	0.195	0.249	0.254	0.210	0.260	0.284	0.250	0.310	0.198	0.252	0.232	0.255	0.182
Organic carbon(%)																
July	2.45	2.48	2.89	2.10	2.10	2.43	2.10	1.95	2.04	2.16	2.37	1.95	2.28	1.95	2.34	1.95
August	2.95	2.61	3.10	2.14	2.23	2.75	2.40	2.00	2.27	2.43	2.49	2.08	2.57	2.19	2.35	2.18
September	2.62	2.58	3.16	1.92	2.39	2.26	2.19	2.08	2.25	2.12	2.27	2.04	2.37	2.40	2.48	2.25
October	2.23	2.51	2.90	1.91	2.13	2.18	2.18	1.86	2.18	2.09	2.17	2.02	2.31	2.21	2.18	2.15
November	2.21	2.46	2.51	1.80	2.06	2.17	2.06	1.82	2.01	2.02	1.98	1.88	2.20	2.15	2.12	2.09
Mean	2.49	2.53	2.91	1.97	2.20	2.36	2.19	1.94	2.15	2.16	2.26	1.99	2.35	2.18	2.29	2.12
Available N (kg/ha)																
July	548.45	573.54	588.54	425.50	381.50	491.50	410.85	371.50	364.00	460.75	461.50	341.50	489.57	428.58	501.25	445.31
August	592.70	580.35	601.88	476.67	450.75	501.50	445.49	410.82	412.59	500.87	502.46	410.82	515.36	462.28	530.25	461.50
September	581.60	551.95	615.58	425.50	471.50	465.60	425.50	413.95	397.50	483.47	490.50	390.58	495.25	510.40	539.04	482.94
October	525.25	508.54	598.54	423.36	442.88	432.35	401.23	390.68	381.50	420.64	468.56	383.20	471.87	488.58	518.50	425.45
November	490.75	470.40	592.70	390.50	391.20	425.00	389.50	382.60	354.72	410.82	435.55	349.55	458.21	470.40	495.54	417.44
Mean	547.75	536.96	599.45	433.37	427.57	463.19	414.51	393.91	382.06	455.11	471.71	375.13	486.05	472.05	516.92	446.53
Available P (kg/ha)																
July	34.26	31.07	20.00	37.25	30.71	31.50	30.00	38.58	31.76	28.60	28.80	36.00	28.90	38.89	27.00	42.75
August	39.00	39.02	25.00	39.50	39.57	32.50	32.10	40.15	34.50	31.00	29.80	39.96	30.40	41.28	29.32	43.12
September	36.00	32.02	29.00	34.75	41.71	30.20	27.50	42.58	33.15	24.10	24.50	29.17	29.90	47.15	31.50	46.12
October	24.26	28.50	19.00	31.10	38.00	27.80	24.00	37.15	29.58	24.21	25.20	28.00	26.10	30.80	23.12	39.75
November	22.56	21.04	18.00	28.30	28.60	23.80	21.00	32.40	21.50	22.20	21.10	24.50	23.20	28.10	22.50	31.00
Mean	31.22	30.33	22.20	34.18	35.72	29.16	26.92	38.26	30.10	27.02	26.88	31.53	27.70	37.24	26.69	40.55
Available K (kg/ha)																
July	268.80	190.40	201.60	235.20	403.20	358.40	313.60	246.40	421.12	246.40	313.60	403.20	425.60	380.80	403.20	425.60
August	309.12	216.40	237.44	280.00	425.60	392.00	347.20	260.20	436.80	290.40	336.00	436.80	481.60	407.68	414.40	459.20
September	295.68	212.80	313.60	218.62	448.00	302.40	302.40	264.00	425.60	246.40	324.80	425.60	430.60	414.40	425.60	481.60
October	224.00	201.60	219.52	212.80	380.80	380.00	257.60	237.44	380.80	224.00	291.20	353.92	392.00	324.80	403.20	443.52
November	221.76	204.72	210.56	197.12	392.00	246.40	257.60	210.56	347.20	208.00	257.60	347.20	387.00	291.20	380.80	436.80
Mean	263.87	205.18	236.54	228.75	409.92	315.84	295.68	243.71	402.30	243.04	304.64	393.34	423.36	363.78	405.44	449.34

S = Sapling crop stage P = Pole crop stage T = Tree crop stage O = Open grassland

SiCL = Silty clay loam; L=Loam; SiL = Silty loam; SL = Sandy loam; SCL = Sandy clay loam

corresponding values for open grassland were 6.40, 6.76, 6.65 and 6.59, respectively.

4.5.3 EC

A perusal of data revealed that in general EC of soil was higher in open grasslands than chirpine sites in all four locations under study. The EC was less in tree crop stage as compared to sapling crop stage & pole crop stage in all locations, but no particular difference was observed in sapling crop stage and pole crop stage.

4.5.4 Organic carbon content (%)

The organic carbon (%) increased from July to August/ September and thereafter decreased in all locations. In chirpine sites, it ranged from 2.21 to 3.16, 2.06 to 2.75, 1.98 to 2.49 and 1.95 to 2.57 per cent in Barog, Deothi, Dharampur and Tatul, respectively, whereas, in open grasslands it varied from 1.80 to 2.14, 1.82 to 2.08, 1.88 to 2.08 and 1.95 to 2.25 in Barog, Deothi, Dharampur and Tatul, respectively during the study period.

4.5.5 Available nitrogen (kg/ha)

Available nitrogen (kg/ha) content of soil increased gradually from July to August/ September and thereafter, decreased upto November. In chirpine sites, available nitrogen (kg/ha) ranged from 470.4 to 615.58 at Barog, from 381.50 to 501.50 and Deothi, from 354.72 to 502.46 at Dharampur and from 428.58 to 539.04 at Tatul, while in open grasslands, available nitrogen ranged from 390.50 to 476.67 at Barog, from 371.50 to 413.95 at Deothi, from 341.50 to 410.82 at Dharampur and from 417.44 to 482.94 at Tatul. From the data, it was observed that mean nitrogen (kg/ha) was less in open grasslands as compared to chirpine inhibited sites at all four locations.

4.5.6. Available phosphorus (kg/ha)

The available phosphorus (kg/ha) varied from 18.00 to 39.02, 21.00 to 41.71, 21.10 to 34.50 and 22.50 to 47.15 in Barog, Deothi, Dharampur and Tatul respectively in chirpine sites whereas in open grasslands it ranged from 28.30 to 39.50, 32.40 to 42.58, 24.50 to 39.96 and 31.00 to 46.12 in Barog, Deothi, Dharampur and Tatul respectively. Available phosphorus content of soil increased from July to August and/or September and then showed a decreased until November in all four locations. Mean phosphorus was higher in open grasslands as compared to chirpine inhibited sites.

4.5.7 Available potassium (kg/ha)

Available potassium content increased from July to August/ September and then decreased upto November. Available potassium content in Barog varied from 201.60 to 313.60, in Deothi from 245.40 to 448.00, in Dharampur from 208.00 to 436.80 and in Tatul it varied from 291.20 to 481.60 in chirpine sites, whereas in open grasslands it varied from 197.12 to 280.00 in Barog, 210.56 to 264.00 in Deothi, 347.20 to 436.80 in Dharampur and from 481.60 to 425.60 in Tatul.

DISCUSSION

The results emerged that out of the present investigation entitled "Production of understorey vegetation in relation to LAI and solar interception by chirpine" have been discussed in this chapter with a suitable cause and effect relationship, wherever necessary or feasible in the light of the available literature under the following headings :

- 5.1 Floristic composition and phytosociology of herbage
- 5.2 Productivity of herbage
- 5.3 LAI of chirpine trees, understorey vegetation and solar interception
- 5.4 Nutrient content of herbage
- 5.5 Physico-chemical properties of soil

5.1 FLORISTIC COMPOSITION AND PHYTOSOCIOLOGY OF HERBAGE

5.1.1 Floristic composition

Floristic composition is one of the major distinguishing characters of a community (Dansereau, 1960). The degree of diversity is a function of adaptability of the species to the particular micro-habitat as well as various other biotic and abiotic factors. In the present study, the variations in floristic composition of the different sites showed higher number of species in August/September which can be related to higher rainfall in these months which might have initiated the germination of constituent species. Among grasses, the common species in all the four locations were : *T. anathera*, *P. maximum*, *A. mutica* and *C. gryllus*. *C. montanus* and *H. contortus* were however absent in



Barog. The number and types of species recorded in present study in four locations are similar as reported by Dalai (1997) and Rao (1998) for similar plant communities around Solan. However, Dass (1995) and Guleria (1996) reported relatively higher number of species for similar grasslands in Solan area of Himachal Pradesh. The comparatively low number of species in the present study sites can be attributed to differences in microhabitat on account of deposition of litter, characteristics of the overgrowing trees, amount of release of allelochemicals (Johnson, 1995) and yearly variations in abiotic variables (Berg and Staaf, 1981). Such variation in floristic composition of herbaceous vegetations in an area can also be related to various climatic and biotic stresses as reported by Gill (1975) and Singh and Joshi (1979). The present study also revealed that presence of pines in grasslands did not affect the type and number of species in understorey vegetation.

5.1.2 Phytosociology

In a plant community different species grow in association with each other. Each species play a definite role and possess its structural and functional individualism in the community (Singh, 1975). So it is necessary to study numerical abundance and spatial distribution of all the species in understanding the community organisation. The phytosociology of the herbage layer in the present context has been dealt under density, basal area, frequency, IVI and herbage diversity.

5.1.2.1 Density (tillers/m²)

With onset of monsoon in June, sequel to the sporadic germination and development of grasses an exponential increase in density of various species occurred and peak peak values were recorded in the months of August/September and thereafter, it declined upto November in all the sites (Table 3). Similar pattern of variations in density of the vegetation with its

dependence on rainfall pattern has been reported by Bawa (1986), Gupta (1988), Singh and Yadava (1974) and Trivedi (1994) for monsoonal grasslands. The values of density of different species recorded in the present study were comparable with earlier studies carried out by Dass (1995), Guleria (1996), Dalai (1997) and Rao (1998) on similar type of grasslands in Solan, Himachal Pradesh. The consistent increase in density upto August/September can be ascribed to congenial growth conditions in terms of nutrient availability, soil moisture, humidity and temperature keeping in view that most of the annual rainfall was received during rainy season (Fig. 2). The decline in density of species after August/September upto November in all the sites correlates with completion of growth of most of the species by September. They proceeded towards senescence by October and November, thereby converting live tillers into dead ones. Similar results have been reported by Dass (1995), Guleria (1996) and Rao (1998) in similar type of grasslands in H.P. The density of vegetation, in general, was higher in open grasslands as compared to the chirpine inhabited sites in all the sampling months (Table 3) which may be attributed to reduced illumination (Table 12), low LAI of understorey vegetation (Table 11), difference in micro-habitat under chirpine (Table 16 and Appendix-I). Park *et al.* (1986) also reported reduction in tillers/m² with the shade level greater than 25 per cent. Thus, the present study revealed that though the pine trees did not affect floristic composition but changed the functional attribute i.e. density of different species. The present study also revealed that density of understorey vegetation was not distinctly affected by the overgrowing pine trees of three different growth stages. Further, it was evident that in Barog, *T. anathera*, *P. maximum* and *P. argentea* whereas, in Deothi, Dharampur and Tatul *C. montanus*, *T. anathera* and *P. maximum* were the major contributors to the total density of herbage in all the sites which confirms their better growth and adaptability to the prevailing environment.

5.1.2.2 Basal area (cm²/m²)

Basal area of herbage vegetation enhanced with advancement of growing season in all the sites and attained peak values in August/September and then declined (Table 4). The increase and decrease of basal area of herbage vegetation in different months can be related to corresponding changes in density as have been reported by many researchers (Singh and Yadava, 1974; Misra, 1973; Singh, 1975; Bawa, 1986; Gupta, 1988) for different grasslands of India. Open grasslands displayed superiority over the chirpine inhabited sites in respect to the basal area of herbage in different months. The possible reasons for such difference are same as reported for density. Different chirpine stages did not reveal any effect of age of the trees on basal area of understorey vegetation.

In Barog, *T. anathera*, *P. maximum* and *P. argentea* while, in Deothi, Dharampur and Tatul *C. montanus*, *T. anathera* and *P. maximum* contributed substantially to the total basal area of herbage in all sites, which is the manifestation of their better growth behaviour and suitability to the environment. The comparatively higher values of basal area of one or two species in a community has also been reported by Chaturvedi *et al.* (1988), Sajwan *et al.* (1980), Singh *et al.* (1985) and Bawa (1986), Kapoor (1987) and Gupta (1988), Dass (1995), Dalai (1997) and Rao (1998) for different grasslands.

5.1.2.3 Frequency and importance value index

A close observation on these attributes i.e. frequency (Table 5) and IVI (Table 6) in different sites showed that there was irregular increase or decrease of these attributes in subsequent months. *T. anathera*, *P. maximum* and *P. argentea* in Barog, while, *C. montanus* and *T. anathera* in Deothi, Dharampur and Tatul showed their dominance over other species. Thus, the results showed

that the community can be designated as *Themeda-Pollinia* in Barog, *Chrysopogon-Panicum-Themeda* in Deothi, *Chrysopogon-Themeda* grasslands in Dharampur and Tatul. The dominance of one or two species in community is due to their better adaptability and growth in particular environment.

It was evident from the Table 6 that *C. gryllus* and *H. fasciculata* in Barog, *C. martinii*, *A. mutica* and *H. fasciculata* in Deothi, *C. gryllus* and *P. prostratum* in Dharampur and *A. mutica*, *A. mollis*, *I. pulchella*, *C. pariera* and *P. gerardianus* in Tatul, were the rare species. 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), Guleria (1996), Dalai (1997) and Rao (1998) in their studies on sub-tropical grasslands of Western Himalaya. According to Chopra (1956), *T. anathera* is a grass species which forms the under growth in chirpine forest. In another study under chirpine, Melkania and Tandon (1983) have also recognised the community as *Heteropogon contortus* - *Chrysopogon fulvus* type. In the present study also these species have shown major contribution to the different phytosociological attributes.

5.2.1.4 Herbage diversity

Species diversity of different species in chirpine inhabited sites varied from 0.486 to 0.553 in Barog, from 0.568 to 0.607 in Deothi, from 0.527 to 0.616 in Dharampur and from 0.526 to 0.550 in Tatul and their corresponding values for open grasslands were 0.555, 0.540, 0.529 and 0.600 respectively. Thus, the findings of present study are in consonance with the findings of Dass (1995), Guleria (1996) Dalai (1997) and Rao (1998) in similar type of grasslands in Himachal Pradesh. Low species diversity in some stages may be due to equal dominance of more number of species in particular community. Higher values of Shannons index indicates a low concentration of dominance.

Higher diversity reduces the oscillations and increase the stability of the community (Margalef, 1968).

5.2 PRODUCTIVITY OF HERBAGE

The aboveground biomass of the herbage vegetation increased from July to September in all the sites. The peak biomass values were found to be 12.46, 16.13, 24.14 and 30.88 q/ha in Barog, 25.49, 22.68, 16.62 and 32.66 q/ha in Deothi, 17.18, 14.73, 16.81 and 18.28 q/ha in Dharampur and 17.87, 18.05, 23.39 and 28.24 q/ha in Tatul in sapling crop stages, pole crop stages, tree crop stages and in open grasslands respectively (Table 8). The increase in aboveground biomass production with the advancement of rainy season might be related to spurt of growth with the advent of monsoon in June as rainfall, relative humidity and soil moisture increased from June onwards, which showed that climate play significant role in growth and development of vegetation. Similar observations were made by Singh and Yadava (1974), Singh (1976), Singh and Joshi (1979), Dass (1995), Guleria (1996), Dalai (1997) and Rao (1998) for monsoonal grasslands of India. A marked increase in aboveground biomass from July onwards can also be related to increase in phytosociological characters of grasses like density and basal area.

The appreciably low aboveground biomass under chirpine, in all the four locations in comparison to their respective open grasslands can be the manifestation of reduction in rate of transpiration, leaf temperature and stomatal conductance of grasses under canopy caused by lower relative light intensity which ultimately led to low biomass production as reported by Bhatt *et al.* (1994). The present study (Table 12) showed that 21.40 to 55.68 per cent relative light intensity was received by understorey vegetation in chirpine sites as compared to open grasslands. Reduction in light intensity under chirpine has been held as main factor for low production of herbage under trees by many workers (Grelan and Whrey, 1978, Singh *et al.*, 1980, Ramakrishna, 1984,

Hazra and Patil, 1986, Chaturvedi *et al.*, 1988 and Sharma and Dhiman, 1994). Allelopathy, increased acidity and interference of undecomposed needle biomass with the growth of grasses under chirpine have been advocated by Dass (1995). Low LAI of understorey vegetation in chirpine inhabited sites than LAI of vegetation in open grassland as recorded in present study can be the another reason for low biomass production in chirpine inhabited sites.

Among different herbage species, *T. anathera* and *P. maximum* were the prominent contributors to the community aboveground biomass besides them, *C. montanus* (except in Barog) and *P. argentea* (only in Barog) were also noticeable. The major contribution towards total biomass by only few species has been reported by many researchers (Blaisdella, 1958; Pearson, 1965 and Singh, 1968). The higher biomass production of these species is also a manifestation of their better growth as is evident from their higher basal area and density too.

Total belowground biomass (Table 9) also increased from July to August/September in all the sites. The peak values were recorded as 10.37, 13.96, 18.79 and 21.89 in Barog, 22.04, 16.13, 14.11 and 23.57 in Deothi, 12.57, 10.77, 13.58 and 15.22 in Dharampur and 15.12, 13.40, 16.74 and 19.45 in Tatul in sapling crop stages, pole crop stages, tree crop stages and open grasslands respectively. An abrupt increase in belowground biomass from July onwards was due to profuse growth and development of different species. A continuous decrease in belowground biomass after attaining the 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). The observations of the present investigations for belowground biomass are in accordance with the results reported by Guleria (1996) and Dalai (1997), Singh and Yadava (1974), Kapoor (1987) and Gupta (1988) for monsoonal grasslands.

5.3 LAI OF CHIRPINE TREES, UNDERSTOREY VEGETATION AND SOLAR INTERCEPTION

In the present study, leaf area index of chirpine trees (Table 10) ranged from 1.01 to 2.20. The range of leaf area index of chirpine recorded in present study at four locations is in consonance with that reported by Chaturvedi (1987). However, Jack and Long (1991) reported higher range of LAI for Lodgepole pine and subalpine fir. It may be due to difference in species morphology. LAI of sapling crop stage was higher in Tatul as compared to other sites in four locations. It may be due to the compact crown dimensions and more density of the trees in sapling crop stage at Tatul (Appendix I). Stands at high relative densities showed more LAI for species in given environment (Long and Smith, 1984, Smith, 1986 and Jack and Long, 1991). Very little difference in LAI was observed among other sites. Sehgal (1998) reported less range of LAI for deciduous trees than the present study. Pine forests and evergreen broad leaved forests have twice or thrice as much foliage and LAI as the deciduous forests (Tadaki, 1977). Tadaki (1966) ascribed the differences in LAI among different forest types to the longevity affecting directly leaf biomass and size of the foliage.

At the four location, LAI of understorey vegetation varied from 1.82 to 3.68 in pine inhabited sites whereas in open grasslands LAI of herbage vegetation ranged from 2.50 to 4.39 (Table 11). The peak values of LAI were observed in August/September months in all the sites. The peak LAI for live biomass in tropical grasslands in India have been reported from 3.4 for *Dicanthium* community to 7.9 for *Sehima* community (Mall, Misra and Billore, 1973). In the present study comparatively low range of LAI variations of herbage was recorded which can be related to difference in community structure and abiotic conditions. Knight (1973) evaluated the sunlight interception and LAI of short grass prairie in Colorado and found that the peak LAI (0.55) occurred in mid-June. However, Conant and Rissar (1974) found that live

material had a maximum LAI of 6.8 on ungrazed treatment and 5.4 on a grazed treatment with the maxima occurring in late summer. Thus, the variations in LAI of vegetation can be attributed to difference in community structure, locality and abiotic and biotic conditions. It was recorded that LAI of understorey vegetation increased from July to August/ September and thereafter it decreased upto November. It seemed that it had direct effect on density, basal area, biomass production and nutrient contents of vegetation as they increased or decreased in similar manner in all the sites. LAI of understorey vegetation was less as compared to LAI of the herbage in open grasslands in respective months at four locations. It evinced from the data that the overstorey trees had an adverse impact on LAI of understorey vegetation and thereby on growth attributes viz. density, basal area and biomass at all the four locations. Similar effect was reported by Hughes *et al.* (1990) as they recorded that LAI of upperstorey madrone was inversely related to diameter of Douglas fir seedling and index of forb and grass density.

In present study the allometric relationships between LAI of chirpine and LAI of understorey vegetation (Figs. 3a,b,c and d) were significant and similarly, the relationships between LAI of understorey vegetation/ herbage and density (Figs. 4 and 5), basal area (Fig. 6 and 7) and aboveground biomass (Figs. 8 and 9) of understorey vegetation/herbage were significant. Whittakar and Niering (1975) showed an association between net primary production (NPP) and leaf area index (LAI) in water limited ecosystems in the Santa catalina mountains of Arizona. Similarly, McCrady and Jokela (1998) reported that relationship between LAI and ANPP was significant and also a strong linear relationship was found between ANPP and intercepted PAR.

In all chirpine sites (Table 12) at four locations, the relative light intensity ranged from 21.40 to 55.68 per cent. Maximum light was intercepted by pole crop stage followed by sapling crop stage and least by tree crop stage among the three chirpine crop stages. Low values of density, basal area and

biomass production of understorey vegetation in comparison to open grassland can also be related to low relative light intensity. Hiroi and Monsi (1966) reported that leaf area index at which optimal crop growth rate was obtained depended upon the light intensity in a community of sunflower plants (100 plants per square meter). The optimum LAI was 7 under full sun, 5 under 60 per cent full sun and only 1.5 under 23 per cent full sun. In present study, light intensity was maximum in open grasslands as compared to 21.40 to 55.68 per cent of solar influx in pine inhabited sites at four locations. Interception of light by trees and its adverse effect on productivity of understorey vegetation has also been documented by Ramakrishna (1984), Hazra and Patil (1986) and Hazra and Tripathi (1986) and Igboanugo *et al.* (1986). Gratini (1997) observed that in *Quercus ilex* evergreen forest, high LAI drastically modified the quality and quantity of solar radiation on the forest understorey/ ground vegetation.

5.4 NUTRIENT CONTENT OF HERBAGE

5.4.1 Nitrogen per cent

During the present study nitrogen (%) in aboveground biomass of different species at different sites ranged from 0.51 to 1.37 (Table 13a) in Barog, from 0.64 to 1.33 (Table 13b) in Deothi, from 0.68 to 1.30 (Table 13c) in Dharampur and from 0.70 to 1.92 (Table 13d) in Tatul. The nitrogen per cent for different species recorded in present study falls within the range recorded for grasses by Bawa (1986), Kapoor (1987), Gupta (1988), Sharma (1988), Dass (1995), Guleria (1996), Dalai (1997) and Rao (1998) for similar type of grasses in sub-tropical regions of Himachal Pradesh. The variations in nitrogen concentration with time revealed that nitrogen (%) in aboveground biomass of grasses attained maximum values in August/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 the post-bloom stage. Similar variations of nitrogen (%) in vegetation

with growth and development of vegetation have been reported for Indian monsoonal grasslands (Bawa, 1986, Sharma, 1988, Gupta, 1988, Verma, 1989, Guleria, 1996, Dalai, 1997 and Rao, 1998). The reasons for higher nitrogen content during peak vegetative phase 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 the 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 full bloom stage may be attributed of 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). Among the individual species, different species showed the highest values of Nitrogen (%) at different times in different sites in the four locations. The range of nitrogen (%) in vegetation was more in Tatul as compared to other locations. It was due to the presence of legumes in the site and legumes have higher nitrogen contents.

The belowground biomass showed the highest nitrogen per cent in August/September in all the sites at four locations (Tables 13a,b,c and d). 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 continued translocation of nitrogen to shoots during the growing period (McGill *et al.*, 1981). The difference in nitrogen (%) in belowground biomass of different species at different sites and locations can be related to differences in nitrogen availability in soil and its uptake by grasses.

5.4.2 Phosphorus per cent

During the present study, the phosphorus content (%) in different species varied from 0.06 to 0.28 (Table 14a) in Barog, from 0.07 to 0.26 (Table 14b) in Deothi, from 0.07 to 0.27 (Table 14c) in Dharampur and from 0.07 to 0.25

(Table 14d) in Tatul, which falls within the range as reported by Bawa (1986), Kapoor (1987), Gupta (1988), Guleria (1996), Dalai (1997) and Rao (1998) for similar type of grasslands in H.P. The phosphorus (%) of the vegetation increased from July with the onset of growing season and the peak values were recorded in August and/or September at the bloom stage in different species. The increase in phosphorus (%) in grasses along the rainy season has been reported by Cole *et al.* (1977), Bawa (1986), Gupta (1988), Guleria (1996) and Dalai (1997). Maximum phosphorus content at pre-bloom stage of grasses has 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 different species showed the highest values of phosphorus (%) at different times in different chirpine crop stages, and open grasslands at four locations. The differences in phosphorus (%) 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) and Rao (1998).

The phosphorus (%) in belowground biomass was less as compared to its respective aboveground biomass in all chirpine crop stages and open grasslands at different locations 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) and Dalai (1997). The difference in phosphorus (%) in aboveground and belowground biomass of a species at different sites and locations 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.

5.4.3 Potassium per cent

Potassium content showed similar trend of increase and decrease in aboveground biomass as in case of phosphorus at all locations in all the chirpine crop stages and open grasslands. In the present study potassium (%) in

aboveground biomass of different species ranged from 0.39 to 0.78 (Table 15a) in Barog, from 0.36 to 0.76 (Table 15b) in Deothi, from 0.38 to 0.72 (Table 15c) in Dharampur and from 0.42 to 0.74 (Table 15d) in Tatul. Potassium (%) in aboveground biomass of different species showed a abrupt increase with the start of growth of vegetation in July. The average potassium content increased from July to August/September and thereafter it decreased upto November. Decrease in potassium content with advancement of maturity 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). Different species showed maximum potassium (%) at different times in different sites.

Regarding belowground biomass, it contained less potassium than the aboveground biomass at all sites which may be due to active utilization of the element during in vigorous growth of aerial parts. The difference in potassium (%) recorded in the present study for aboveground and belowground biomass of herbage vegetation in three chirpine crop stages and open grassland at four locations 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) and Dalai (1997) for monsoonal grasslands.

5.5 PHYSICO-CHEMICAL PROPERTIES OF SOIL

Physico-chemical parameters of soil play a dominant role in characterising the quality and growth of the vegetation. The results obtained for these parameters (Table 16) have been discussed below :

The soil texture showed wide variation among different sites which shows the different stages of profile development in different locations. The

soil pH varied in chirpine inhabited sites from 5.85 to 6.10 in Barog, from 6.10 to 6.40 in Deothi, from 6.28 to 6.54 in Dharampur and from 5.80 to 6.42 in Tatul and their respective values for open grasslands were : 6.40, 6.76, 6.65 and 6.59, respectively. Thus, pH values were higher in open grassland as compared to chirpine sites. This can be attributed to vegetational effects as conifers supporting soils are acidic than hardwood species and soils of open grasslands (Pritchett, 1980). Reduction in soil pH under tree canopies has been advocated by several workers (Pathak and Gupta, 1987, Hazra, 1990, Sharma, 1991, Garg and Jain, 1992, Kaushal, 1992 and Bholra, 1995). Further, it was observed pH was less in tree crop stage than sapling crop stage and pole crop stage. It may be due to more litter decomposition under tree crop stage (Appendix-I) whereas, no particular trend was observed in sapling crop and pole crop stages.

The electrical conductivity values of soils were higher in open grasslands than chirpine sites at all the four locations. The EC was less in tree crop stage as compared to sapling crop stage and pole crop stage at all the four locations. The EC, however, showed no fixed trend in sapling crop stage and pole crop stage. The present results on EC of soils are in consonance with the findings of Sharma (1991), Kaushal (1992) and Malik (1992) for soils of Himachal Pradesh.

The overall organic carbon (%) under chirpine sites was more (2.49, 2.53 and 2.91 in Barog, 2.20, 2.36 and 2.19 in Deothi, 2.15, 2.16 and 2.26 in Dharampur and 2.35, 2.18 and 2.29 in Tatul in sapling crop, pole crop and tree crop stages respectively) as compared to their respective values in open grasslands (1.97, 1.94, 1.99 and 2.12 respectively). It may be due to the accumulation of chirpine litter on the surface in chirpine sites. Similar results have been reported by Minhas (1986), Mazumdar (1988), Sharma (1991), Kaushal (1992) and Malik (1992) for soils of Himachal Pradesh. Maximum organic carbon content in soil was observed during August and/or September months at all locations probably due to higher decomposition rate of litter on



account of congenial moisture, humidity, soil temperature for microbes activity as reported by Singh and Joshi (1982).

The perusal of data presented in Table 16 revealed that nitrogen content in soil increased with the increase in organic carbon content and reached the peak during August/ September. Thus, revealing that increase in nitrogen is closely related to organic matter content. The substantial decrease in nitrogen content in soils after September at all locations may be attributed to volatilization and leaching losses as contended by Mazumdar, 1988. The organic carbon and nitrogen were more in Barog as compared to other locations. The positive and significant correlation of organic matter with available nitrogen has been reported by Kaushal (1992).

The overall phosphorus contents in soils were found to be lower under chirpine sites as compared to open grasslands at all locations which may be due to more acidic condition under chirpine than in open grasslands (Pritchett, 1980). In general, the soils in the present sites were phosphorus rich. Similar results were found by Mazumdar (1988), Sharma (1991) and Malik (1992) for soils of Himachal Pradesh.

The available potassium content increased from July till the peak in August and/or September. Similar trend of increase in available potassium during August and/or September has also been made by Anderson *et al.* (1970), Sharma (1991) and Malik (1992). In general, the higher amounts of K content in all sites may be ascribed to presence of illite type of mineral in Himachal soils as reported by Singh (1987).

SUMMARY & CONCLUSIONS

In order to fulfill the objectives of the study entitled "Production of understorey vegetation in relation to LAI and solar interception under chirpine" research was carried out at four locations in Solan Forest Division (H.P.), during the year 1998. The results of the investigation have been summarised under the following heads :

6.1 FLORISTIC COMPOSITION AND PHYTOSOCIOLOGY OF HERBAGE

A thorough review of floristic composition showed that there were ten grass species, two sedges, two legumes and two non-legumes in all the sites of four locations. The number of species in chirpine sites did not differ much as compared to open grasslands revealing that chirpine did not affect the floristic composition. Density and basal area of vegetation increased gradually from July to August/September and thereafter it declined on all the sites at four locations. Frequency of species did not show any particular trend. Total density and basal area of different species was higher in open grasslands as compared to chirpine sites at all the four locations: Among the different species *Themeda anathera* and *Panicum maximum*, *Chrysopogon montanus* (except in Barog) and *Pollinia argentea* (only in Barog) were the major contributors to the total density and basal area of the vegetation. As per the IVI values, the grassland of Dharampur and Tatul were designated as *Chrysopogon - Themeda* grasslands, Deothi as *Chrysopogon - Panicum - Themeda* and Barog as *Themeda - Pollinia* grassland. Little variation was observed in regards to species diversity in different sites at four location.

6.2 PRODUCTIVITY OF HERBAGE

During the study period the total aboveground and belowground biomass of the herbage vegetation increased from July to September and thereafter, it declined upto November in all the sites at four locations. Biomass production was more in open grasslands than in pine inhabited sites at all four locations. The total aboveground biomass was higher as compared to belowground biomass on each sampling date. Among the different species, *Themeda anathera* and *Panicum maximum*, *Chrysopogon montanus* (except in Barog) and *Pollinia argentea* (only in Barog) contributed maximum to the total biomass production of the community.

6.3 LAI OF CHIRPINETREES, UNDERSTOREY VEGETATION AND SOLAR INTERCEPTION

In general, the LAI of chirpine crop increased from July to August and thereafter, no particular trend was observed in its variation at different sites at four locations. The LAI of sapling crop stage in Tatul was higher on all sampling dates as compared to other chirpine crop stages. No such difference was observed at other locations. Leaf area index of understorey vegetation/herbage varied from 1.82 to 3.68 under chirpine sites and from 2.50 to 4.39 in open grasslands. Thus, LAI of open grasslands were higher as compared to chirpine sites at four locations but no particular difference was observed in LAI of understorey vegetation among different chirpinè crop stages.

LAI of chirpine and LAI of understorey vegetation had positive and significant relationship between them. LAI of understorey vegetation/herbage was positively & significantly related to density, basal area and aboveground biomass of understorey vegetation/herbage. Under chirpine trees 21.40 to 55.68 per cent relative light intensity was recorded at four location during the study



period. Thus, low biomass of understorey vegetation was on account of the hampered solar influx in chirpine inhabited sites.

6.4 NUTRITIONAL CONTENTS OF HERBAGE

In the present study, nutrient contents (N, P and K) increased from July to August/September and thereafter they decreased upto November in all the sites at four locations. There was not much difference in nutrients of different species under chirpine and in open grasslands. The belowground biomass of different species had less amount of nitrogen, phosphorus and potassium as compared to their aboveground biomass in all the sites at four location. Among the different species, legumes had more nitrogen content as compared grasses, sedges and non-legumes at Tatul.

6.5 PHYSICO-CHEMICAL PROPERTIES OF SOIL

Different sites had different soil texture at four locations. The pH of soil was acidic in all sites. The pH and EC was less in chirpine sites as compared to open grasslands at four locations. The organic carbon and available nitrogen were more under chirpine sites as compared to open grasslands, whereas, available phosphorus was less in chirpine crop sites as compared to open grasslands. No particular difference was observed among different sites in relation to potassium in soil. In general, organic carbon, available nitrogen, phosphorus and potassium increased from July to August/September and thereafter, they decreased upto November in all sites at four locations.

CONCLUSIONS

The following conclusions emerged out of the present study :

- ❖ The number of species in chirpine inhabited sites did not vary much as compared to open grassland revealing that pines did not affect the floristic composition.
- ❖ Herbage diversity was almost similar in all the pine inhabited sites and open grasslands.
- ❖ In general, *Chrysopogon montanus* and *Themeda anathera* were the dominant and co-dominant species, respectively in Deothi, Dharampur and Tatul, whereas, *Themeda anathera* and *Pollinea argentea* were dominant and co-dominant species, respectively in Barog. *Panicum maximum* was the main associate species in all the sites under four locations.
- ❖ Different species had varying phytosociological attributes. Density and basal area of vegetation increased with the growth and development of vegetation and declined after vegetative growth had completed. Density and basal area of vegetation were higher in open grasslands as compared to chirpine inhabited sites on different sampling dates. Among the different species, *Themeda anathera* and *Panicum maximum*, *Chrysopogon montanus* (except in Barog) and *Pollinea argentea* (only in Barog) were the major contributors to the total density and basal area of vegetation.
- ❖ Aboveground and belowground biomass of community increased with the onset of rainy season and attained maximum values in September and thereafter, they declined. Their values were higher in open grasslands as compared to chirpine inhabited sites.



- ❖ LAI of chirpine trees was positively and significantly related to LAI of understorey vegetation. LAI of chirpine affected the LAI of understorey vegetation and thereby the biomass production. LAI of understorey vegetation/herbage was positively and significantly correlated with density, basal area and aboveground biomass.
- ❖ 21.40 to 55.68 per cent of incoming solar radiations were recorded under chirpine trees of different growth stages. Thus, it can be inferred from it that low biomass production of understorey vegetation was on account of hampered solar influx.
- ❖ The nutrient contents of the grasses increased as growing season progressed and maximum values were recorded in August/September. However, no significant difference was visible in nutrient contents of species in open grasslands and chirpine inhabited sites at four locations.

Thus, from the present study, it can be concluded that chirpine trees had an adverse effect on the functional aspects of understorey vegetation viz., density, basal area, aboveground and belowground biomass. Solar interception by trees and reduced LAI of understorey vegetation on account of overgrowing trees are responsible for poor growth and production of ground vegetation.



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APPENDICES

APPENDIX-I

Silvological characteristics of chirpine crop stages at different sites at four locations

Parameters	Barog			Deothi			Dharampur			Tatul		
	S	P	T	S	P	T	S	P	T	S	P	T
Density (no. of trees/ ha)	1075	412.5	141.70	2266.70	468.70	283.30	2400	712.50	200	3700	870	137.50
Tree height (m)	2.06	8.25	19.66	2.23	12.08	21.0	1.81	9.43	16.33	1.80	13.90	26.50
Crown height (m)	0.97	4.42	12.10	0.72	8.66	13.90	0.65	5.36	8.00	1.22	9.12	10.10
Crown diameter (m)	2.18	3.35	6.92	2.10	5.10	8.38	1.86	4.26	8.04	1.76	6.24	8.44
Litter (kg ha ⁻¹)												
July	1120	1140	2060	1200	1180	2320	1460	1580	2660	1120	1920	1920
August	880	1570	1660	1260	1400	2040	1360	1640	2020	1560	1600	1820
September	960	2000	1540	980	840	2560	1240	1560	1800	1240	1640	2240
October	1080	1180	1800	1040	1580	1940	960	1760	2200	840	1280	1840
November	940	1240	1992	960	1000	2240	1200	1280	1800	1360	1720	1560
Mean	996	1427	1810.4	1080	1200	1820	1164	1564	2096	1224	1632	1876

S = Sapling crop stage

P = Pole crop stage

T = Tree crop stage

APPENDIX-II

SPECIES RECORDED IN PRESENT STUDY SITES

Grasses

Apluda mutica Linn.
Chrysopogon gryllus (Linn.) Trin.
Chrysopogon montanus Keen.ex. Trin
Cymbopogon martinii (Roxb.) Wats.
Hemarthria fasciculata (Lamk.) Kunth.
Heteropogon contortus (Linn.) P. Beauv.
Panicum maximum Jacq.
Panicum prostratum Lamk.
Pollinea argentea Trin.
Themeda anathera (Nees) Hack.

Sedges

Carex meiogyna Strachey
Cyprus rotundus Linn.

Legumes

Atylosia mollis Benth.
Indigofera pulchella Roxb.

Non-Legumes

Cissampelos pareira Linn.
Plectranthus gerardianus Benth.

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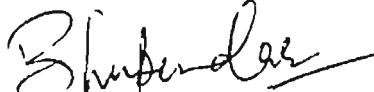
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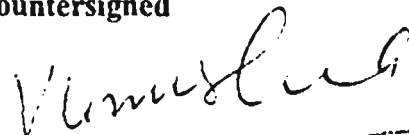
ABSTRACT

The present investigation was carried out at four locations of Solan Forest Division, Himachal Pradesh from July to November, 1998. Each location had four study sites, three representing different ages of chirpine like sapling, pole & tree crop stage and an open grassland. Vegetational analysis was done by harvesting five quadrats of size 50x50 cm from each site on every sampling month. In all, ten grass species, two sedges, two legumes and two non-legumes were recorded during present study. Floristic composition/herbage diversity was almost similar in all the chirpine inhabited sites and open grasslands. Understorey vegetation characteristics viz. total density, basal area, biomass production and LAI increased from July to August/September and thereafter decreased upto November in all sites. Among the different species, *Themeda anathera* and *Panicum maximum*; *Chrysopogon montanus* (except in Barog) and *Pollinia argentea* (only in Barog) were the major contributors to the different phytosociological attributes and biomass production of vegetation. Values for total density, basal area and biomass production were higher in open grasslands as compared to chirpine inhabited sites. LAI of herbage under chirpine crop stages was less as compared to LAI of herbage in open grassland during different sampling intervals. LAI of chirpine trees was positively and significantly related to LAI of understorey vegetation. LAI of understorey vegetation/herbage showed significant relationships with density, basal area and aboveground biomass. 21.40 to 55.68 per cent of incoming solar radiations were available under chirpine trees for understorey vegetation. Thus, it can be inferred that low biomass production of understorey vegetation was on account of hampered solar influx accompanied by decrease in LAI of understorey vegetation. The nutrient contents (N, P and K) of different species increased as growing season progressed and peak values were recorded in August/September. However, no significant difference was visible in nutrient contents of species in open grasslands and chirpine sites at four locations.


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