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Research Paper

HERBAGE BIOMASS, CARRYING CAPACITY AND RELATIVE SILVIPASTORAL CLASS OF THE CHIRPINE (PINUS ROXBURGHII SARGENT) BASED NATURAL SILVIPASTORAL SYSTEM IN NORTH-WEST HIMALAYA

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Abstract

The study explored the effect of widely spaced naturally grown trees of chirpine *Pinus roxburghii* Sargent on aboveground biomass productivity and carrying capacity of herbage layer in natural silvipastoral system for two consecutive years. To explore the effect of individual trees on herbage dynamics, selected sample trees at each site were divided arbitrarily into three crown classes on the basis of crown width. It included three crown classes, four directions and three distances as treatments. Sampling of herbage was carried out at monthly intervals starting from July 15th to October 15th. The size of the quadrat was 30cm x 30cm and number of quadrats per each replicate were twelve under tree crown as well as four (one each/direction),outside the tree acting as control. The aboveground biomass of herbage increased from July to September, in both environments (under tree canopy and in open grassland) and declined thereafter in October. In both environments total aboveground biomass was higher in open grasslands as compared to that under tree canopies .The variation in aboveground biomass of herbage with respect to the crown class and direction effect was not perceptible, however with increase in distance from tree base it enhanced markedly. Statistical analysis of the aboveground biomass in dominant species evinced similar kind of response as observed for total aboveground biomass of the herbage i.e. it attained significantly higher values in open grassland and a substantial enhancement with increase in distance from tree base. With regards to grazing capacity and carrying capacity, they fallowed similar trend as was observed in case of aboveground biomass.

Key words: Aboveground, Crown spread, Grassland, Natural, Productivity, Scattered.

INTRODUCTION

Silvipastoral systems are land use systems 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 systems and practices can be identified depending on the role of the tree/shrub component; viz. cut and carries system, live-fence posts, browsing and grazing [19]. According to one estimate

[7], shrubs and trees in silvipastoral production systems constitute the basic feed resource of more than 500 million out of 660 million head of livestock in the tropics i.e. 165 out of 218 million tropical livestock units (TLU) (ITLU= approx, 250 kg live weight of animal).

In India, there are 67.1 m ha of forest land, 15.2m ha of cultivable waste land and 11.8mha of permanent pastures and other grazing lands. All this area of 94.1 m ha supports 180 million cattle, 62 million buffaloes, 41 million sheep, 75 million goats, 1 million camel, 2 million horses, mules, donkeys, 8 million pigs, 0.13 million other livestock [18],[15] has projected the availability and requirement of green fodder to the tune of 546 and 700 million tones respectively. In order to ensure high productivity, economic returns from livestock, the fodder requirement by 2000 AD can be as high as 1233 million tonnes on dry matter basis [27], [26] reported that the dry matter yield of grasslands of Himachal Pradesh varied from 250 to 518 g/m^2. [24] Assessed the effect of tree shade (full shade, partial shade and open area) on forage yield in grassland planted with *Acacia catechu and Dalbergia sissoo*, in North India. They noticed that forage yield was significantly higher in open than under partial shade or full shade of tree crowns. Average yield and clump diameter of grasses under partial shade of tree crowns edges were 86.7 and 38.0 percent, respectively, of that in the open patches, while under full shade of crowns the figures were 58.4, 29.4 per cent, respectively.

According to [12] the light infiltration under 4 trees species varied from 74-93 per cent of the PAR on open sites without trees. The tree cover also maintained higher air temperature and leaf temperature as compared to open sites. Dry matter production by grasses under *Albizzia lebbek, A. procera, Leucaena leucocephala and Acacia tortilis* was 665, 621, 565 and 608 g/m^2, respectively, compared with 660 g on open sites. [14] Reported increase in biomass of grasses with increase in light intensity. [6] Indicated that though the canopy was the major constraint in the productivity of herbaceous vegetation, however, the productivity also varied significantly with species of forage crops. [13] Had the same opinion while studying the changes in plant species richness over the last century in the eastern Swiss Alps [5] 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 [11] in chirpine stand. Average carrying capacity values, worked out for chirpine forest stands and open grassland were 9.05 ACU/ha/30 days and 15.96 ACU/ha/30 days respectively [5].

Improvement of these grasslands spread under tree canopy calls for an immediate attention. However, before launching any comprehensive programme of improvement, information on their present yield level appears an essential pre-requisite for implementing a concerted management of grasslands. So far, very little work is done on these aspects, in India or abroad. General convention is that grass yield decreases under tree [16], [28], [22] and so far little but inconclusive information is available in this regard. Looking at the paucity of data base on current productive potentials of natural silvipastoral systems, the present study was carried out with following objectives:

i) Estimate herbage productivity as a function of crown spread and direction from the tree trunk
ii) Determine the grazing capacity and carrying capacity of the system

MATERIALS AND METHODS

The present investigation was carried out in natural grasslands located in the Dr Y S Parmar University of Horticulture and Forestry, Nauni, Himachal Pradesh, during two consecutive years i.e. 1996 and 1997. The study site was situated about 13 km from Solan at 30^{o}51$'$N latitude and 77^{o}11$'$E longitude. The elevation is about 1300 m above m.s.l. The study area represents a transition between sub-tropical to sub-temperate climate. The area receives an average annual rainfall of 1100-1350 mm most of it concentrating during monsoon (mid June to mid September). The average annual temperature ranges from 3^{o}C to 32^{o}C with mean annual temperature (MAT) around 18^{o}C (Fig. 1). The study site is marked by an undulating topography mainly with south-west aspect. The whole area is well to excessively drained. Geologically, the

area has been reported to be a part of the outer Himalayas. The soil is loamy in texture derived from infer Karol series rocks mainly of Shimla group comprised by carbonaceous shales, calcareous shales, dolomitic limestone within bands of intermittent shales.
The trees in the system were widely scattered ranging from 15 m to 50 m distance. The sample trees were selected on the same aspect and as near as possible to minimize the effect of change of climate and other factors (Appendix 1). This site was protected from grazing and harvesting of grasses was practiced over it. To explore the effect of individual trees on herbage dynamics, selected sample trees at each site were divided arbitrarily into three crown classes on the basis of crown width (Appendix 1). Each crown class comprised of four trees with individual tree acting as a replicate. Under each tree four directions, viz., North, East, South and West were marked with the help of prismatic compass and ranging rods. In every direction, three distances from the trunk of each sample tree viz. up to 33%, 33 to 66% and 66 to 100% of portion of crown spread (crown radius) were selected (Fig. 2). Four controls (open area), one each per direction, were selected away from periphery of the tree canopy, where there was no effect of the tree shade. The design fallowed was RBD. Average of two years data is presented in the results.

OBSERVATIONS

Herbaceous vegetation:

In the system as described earlier, under the crown of each selected tree twelve quadrats of 30 cm x 30 cm size were harvested at ground level for herbage analysis by using harvest method proposed by [17], on each sampling dates starting from 15th July to 15th October, at monthly intervals.

Aboveground biomass estimation of herbage:

The herbage samples brought to the laboratory were sorted out for different species and washed properly with running water and stored in different paper bags. These samples were oven dried to a constant weight at 80^{o}C for 48 hours. After attaining a constant weight, each sample was weighed on top pan balance data was tabulated species wise. Carrying capacity and grazing capacity of two herbage production systems under study were expressed in Adult Cattle Units (ACU) and were worked out on the basis of body weight of adult cattle unit (320 kg av. body weight) using the following formula given by [30].

$$\text{Grazing capacity} = \frac{\text{Total dry matter production in herbage Production system (kg/ha)}}{\text{Daily intake of dry matter per ACU}}$$

$$\text{Carrying capacity} = \frac{\text{Total dry matter production in herbage Production system (kg/ha)}}{\text{Total intake of dry matter per ACU in 30 days}}$$

Where,

ACU = Adult Cattle Unit
Daily requirement of dry matter per ACU = 2.5% of body weight
Average body weight of indigenous cattle breed = 320 kg

Relative silvipastoral class

It was determined by giving numerical values to each of the system studied on the basis of pasture condition, grazing management and stand density following the method given by [8].

Statistical analysis:
The data generated from the present investigation was statistically analysed by Randomized Block Design in accordance with procedure outlined by [9].

RESULTS

Aboveground biomass

Aboveground biomass (pooled data) increased from July to September and declined thereafter in both the environments. It exceeded by 73.1, 83.2, 85.2 and 46.8 per cent in open environment as compared to that under chirpine, in the months of July, August, September and October, respectively. Similar pattern of increase in biomass yield from July to September and decline thereafter in October was also demonstrated by the data for dominant species as well as the total aboveground biomass of all the species. However, less dominant species and other grasses did not evince any particular pattern in biomass yield with regard to change in months.
The aboveground biomass in relation to crown class was recorded to be maximum in open grassland (27.50 q ha^{-1}) and reduced by 38.7, 41.8 and 40.6 per cent at C_1, C_2 and C_3 compared to C_0. The trend was almost identical in case of dominant species as well as total aboveground biomass (Table 2). The direction effect did not exercise a discernible variation in aboveground biomass; nonetheless, the yield in north was, in general, relatively lower as compared to other directions (Table 3). The aboveground biomass responded positively to increase in distance from tree base (Table 4). It showed a hike of 27.8 per cent from S_1 to S_2 and 20.2 per cent from S_2 to S_3 when data were pooled. Similar trend of increase in biomass yield as distance increased from tree trunk was also visible, for the individual grass species as well as total aboveground biomass of all the grasses.
Aboveground biomass of *C. montanus* was significantly affected due to crown class, crown class x direction as well as crown class x distance interactions. The aboveground biomass exceeded significantly at C_0 compared to C_1, C_2 and C_3. The values from C_1 to C_3 varied only slightly as such revealed no statistical differences. The interaction effect between crown classes x direction in elucidated maximum biomass at $C_0D_4$and minimum under C_3D_1. The C x S interaction indicated in general comparatively higher aboveground biomass in open compared to that under C_1, C_2 and C_3 at each distance. The change in distance at a particular crown class and vice-versa, however, displayed no consistent trend. The data for *P. maximum* showed a significant response to only crown class on the aboveground biomass. It responded to the effect of crown class, in identical manner, as that in *C. montanus* in both the years. Direction D_3 while remaining at par with D_4 registered significantly higher biomass than rest of the two directions i.e. D_1 and D_2. The interaction effect between crown class x direction displayed the maximum biomass under C_0D_3 which proved significantly higher to all other combinations.

Grazing capacity and carrying capacity of the system

A perusal of the data on grazing capacity and carrying capacity (Fig. 7&8) shows that the average pooled values of above attributes increased from July to September and declined thereafter. Similar trend was also recorded for individual years. Open environment registered higher values of these two attributes as compared to those under chirpine in all the months during both the years.

Relative silvipastoral class of the system

On the basis of the pasture condition class (per cent of palatable and non-palatable species), pasture use and tree density value calculated for chirpine based silvipastoral system for both the years, it was noticed that the system represented good relative silvipastoral class (Table 6).

DISCUSSION

Aboveground biomass

The aboveground biomass of the herbage layer increased from July to September in both the environments (in open grassland and below trees) in chirpine based system, where, peak biomass values were found to be 21.42 q/ha under trees and 39.66q/ha in open grassland(Table1). The values for aboveground biomass in both the environments were quite comparable.

The increase in aboveground biomass production may be related to spurt of growth with advent of monsoon in June as rainfall, relative humidity and soil moisture increased from June onwards and attained maximum in August-September. Significant role played by climate on growth and development of vegetation has been advocated by [25], [31], [2] for monsoonal grasslands of India. A marked increase in aboveground biomass can also be related to increase in phytosociological characters of grasses like density and basal area during this period. [10] contended that rainfall and intensity of light illumination were significantly related to herbage production under long leaf pine stands. Similar findings for a direct relation between aboveground biomass and phytosociological characters were also reported by [14], [23], [20], [32], [29], [6], and [33].

The appreciable decline of aboveground biomass under tree canopies, in comparison to their respective open grasslands is the manifestation of reduction in rate of transpiration, leaf temperature and stomatal conductance of grasses under canopy caused by lower relative illumination which ultimately led to low biomass production (Bhatt *et al*., 1994)[30]. Reduction in light intensity under crowns has been held as main factor for low production at herbage under trees as compared to open grassland by many workers [10], [12]. Allelopathy and interference of needle biomass to grass species under chirpine have been also advocated by [5].

Among different herbage species *C. montanus* and *P. maximum* were the dominant contributors in the aboveground biomass in the both the environments of the system investigated (Figs.3 to 6). The two dominant species i.e. *C. montanus* and *P.maximum* together contributed more than 70 per cent of the total aboveground biomass in each sampling month in both the environments (under trees and in open). Further it was observed that in general biomass of all the herbage species tended to decline after September in both the environments. However, biomass of *C. montanus* increased again in October owing to lessened competition from other species and its long life cycle. The major contribution towards total biomass by only few species has been reported by many researchers [4], [21].

The crown class did not exercise much variation in total aboveground biomass (Tables 2) likewise also direction influence was not perceptible (Table 3). Nonetheless, a positive relationship was observed between increase in distance from tree base and biomass in the system studied (Table 4). This can be ascribed to the fact that as one moves away from tree trunk the solar influx increased. These findings in the present study are in consonance with observations of [12], [14], [20]. The reduction in root competition with increasing distance may have also contributed for the same.

Statistical analysis of the aboveground biomass in dominant species in the system evinced similar kind of response as observed for total aboveground biomass (Table 5). It attained significantly higher values in open environment and a substantial increase with distance irrespective of crown class. The data, however, revealed no specific trend of increase or decrease with change in crown class at a particular distance.

Grazing Capacity and Carrying Capacity of the System

It is seen from Fig.7 and Fig.8 that the grazing capacity and carrying capacity characters varied from 133.75 to 266.76 ACU/ha and 4.46 to 8.89 ACU/ha/month under trees and in open, respectively, in chirpine based silvipastoral system. The increasing trend in these values was observed from July to September in chirpine based system. The probable reason may be referred to increase in dry matter production in these months in the system. Further, the grazing capacity as well as carrying capacity was recorded to be remarkably higher in open grassland compared to that under tree cover in the system which is again a function of difference in biomass production in two environments. The values for both these characters are well in agreement with those reported by [1] and [5] in different grassland of Himachal Pradesh.

Relative Silvipastoral Class of the System

[8] Evaluated the current silvipastoral practice at pine plantations in Central Highlands of Ecuador on the basis of pasture condition, grazing management and tree stand density in order to emphasize the need for more active silvicultural management of pine plantations for both wood and pasture production. By following the method given by [8] we used the relative silvipastoral classification of systems as the basis by which to study and evaluate their Silviculture conditions. The system studied has been grouped according to relative silvipastoral class (RSC).

In the present study chirpine based silvipastoral system received good silvipastoral rating (Tables 6). The difference in RSC ratings can be ascribed to higher percentage of palatable grasses in chirpine based system.

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FIGURES

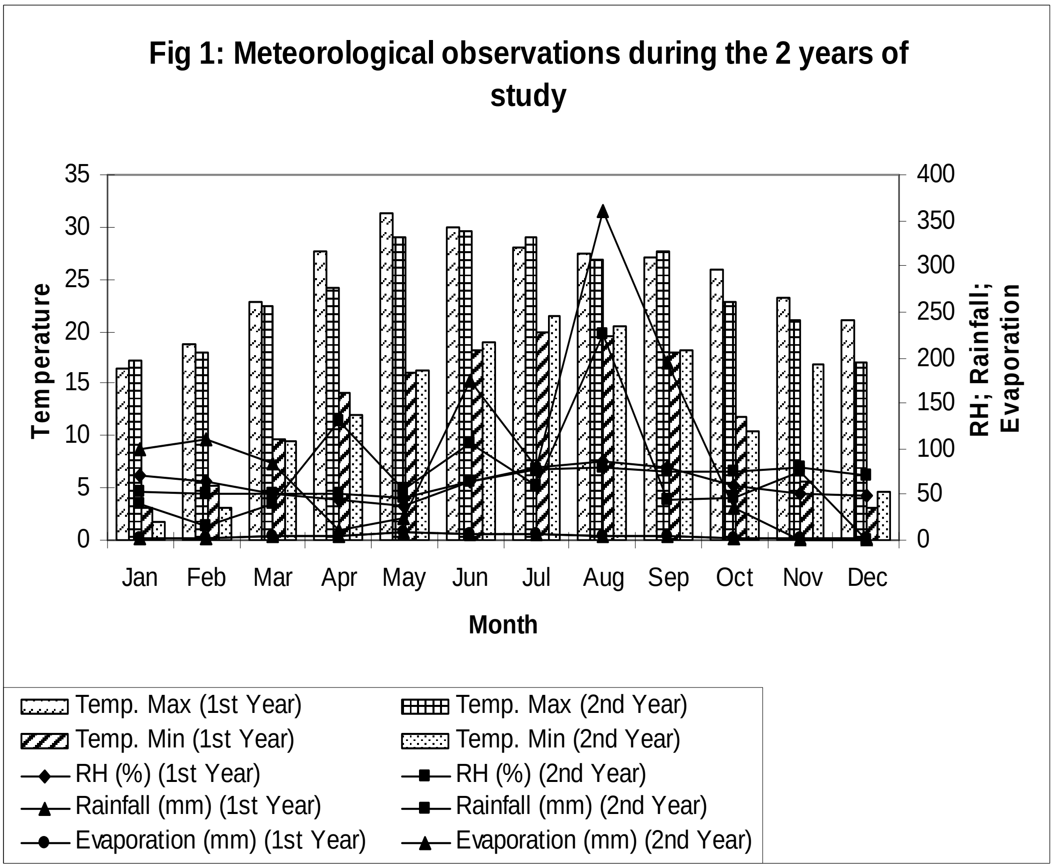

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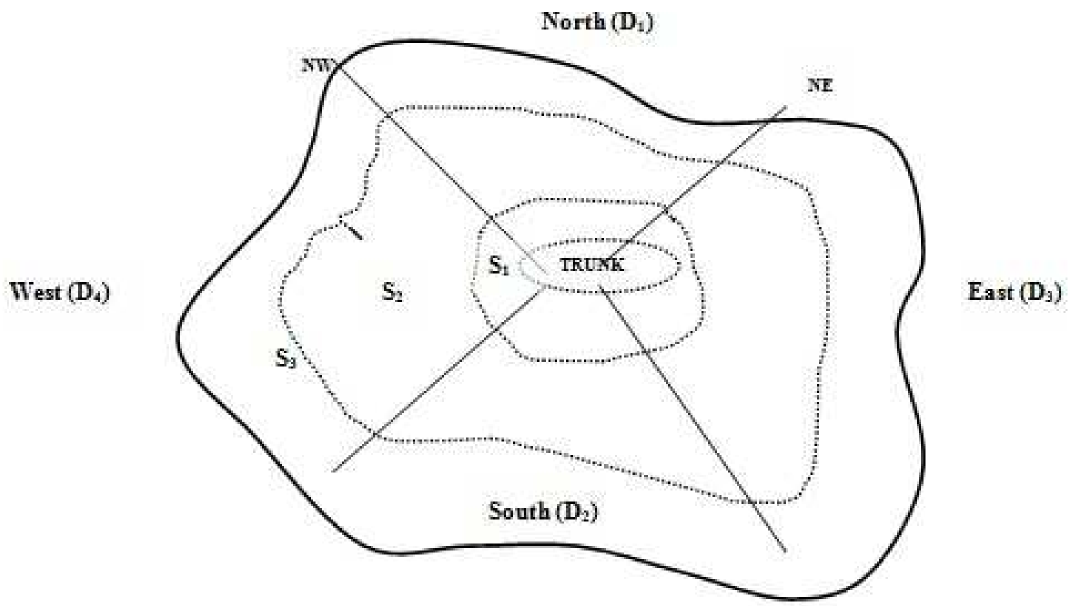
Fig 2: Figure showing combination of directions and distances under tree.



S1 = up to 33% of portion of crown
S2 = Up to 33-66% of portion of crown
S3 = Up to 66-100% of portion of crown

Fig. 3 Contribution of Various Species to total aboveground biomass during July

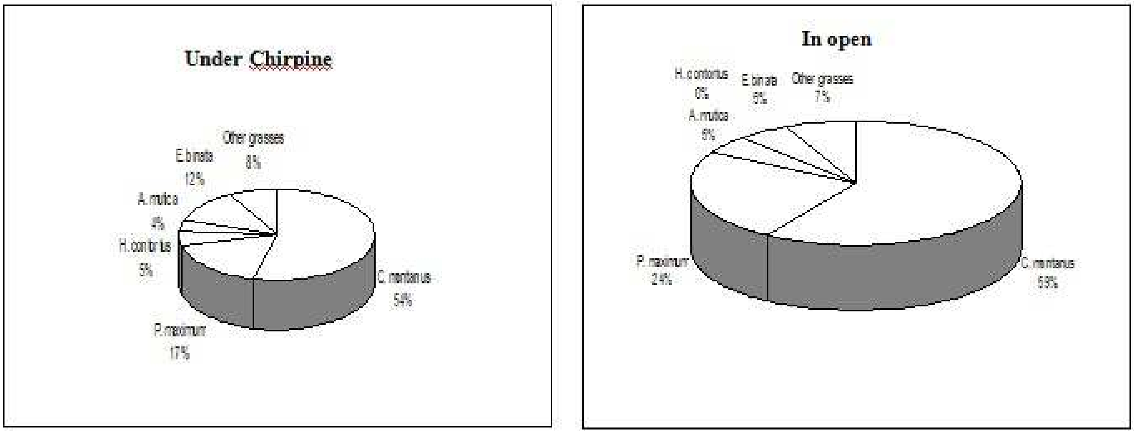


Fig. 4 Contribution of Various Species to total aboveground biomass during August

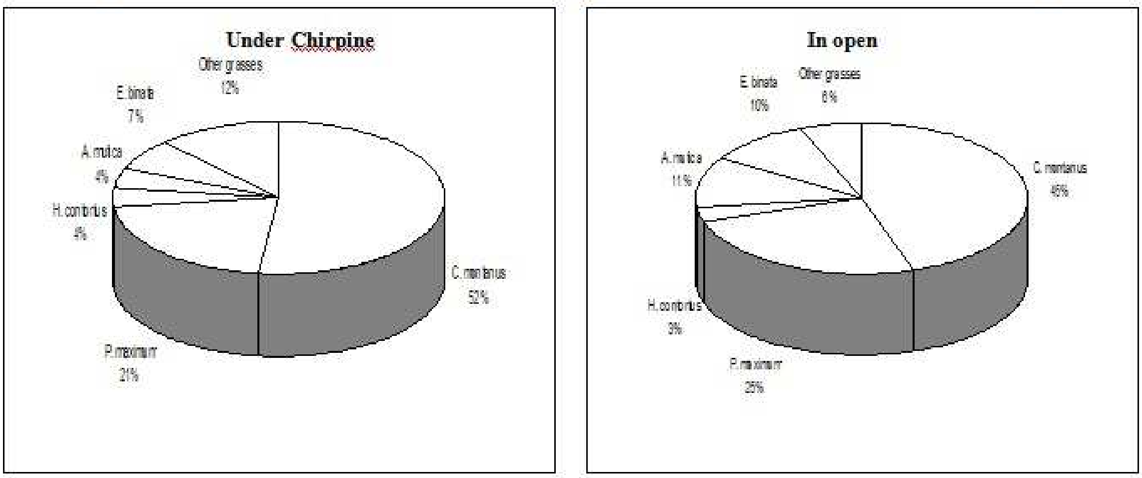


Fig. 5 Contribution of Various Species to total aboveground biomass during September

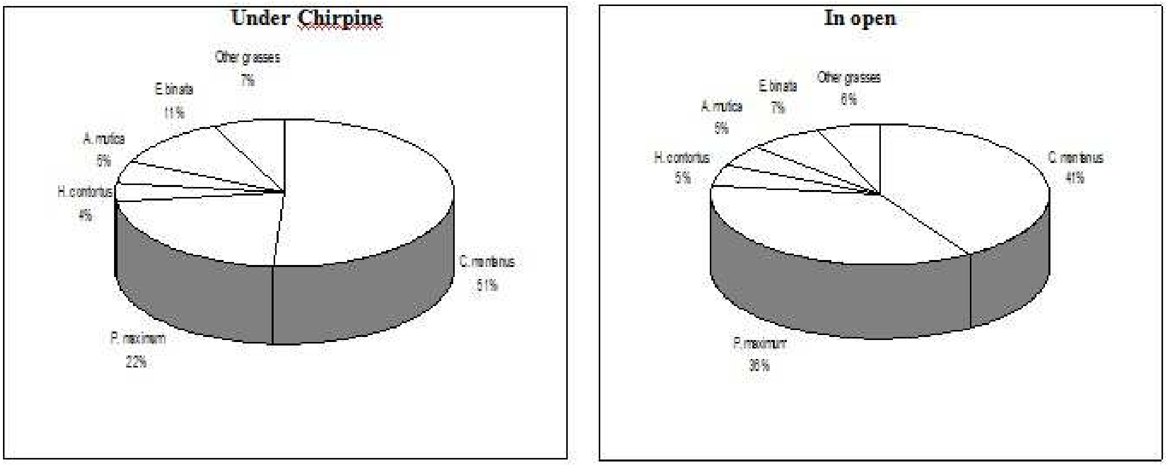
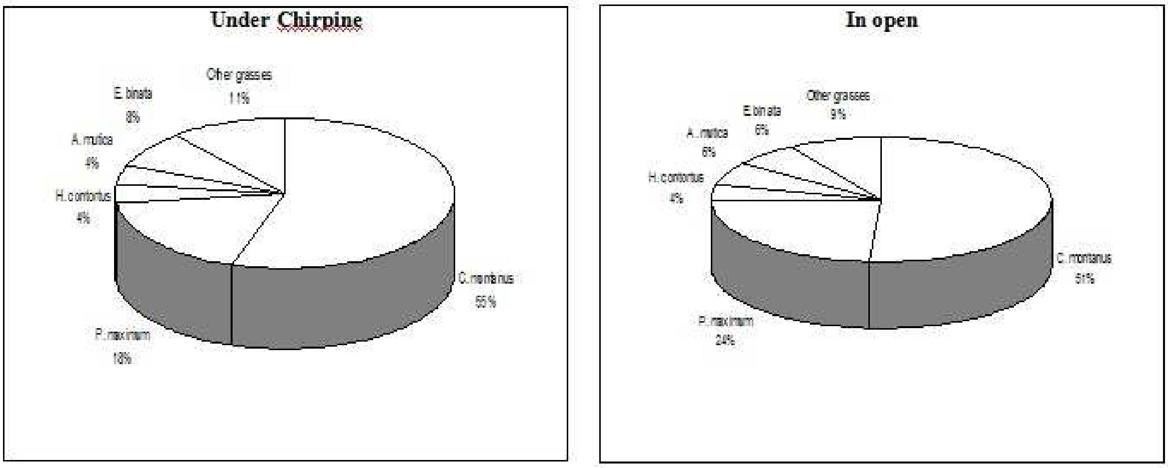
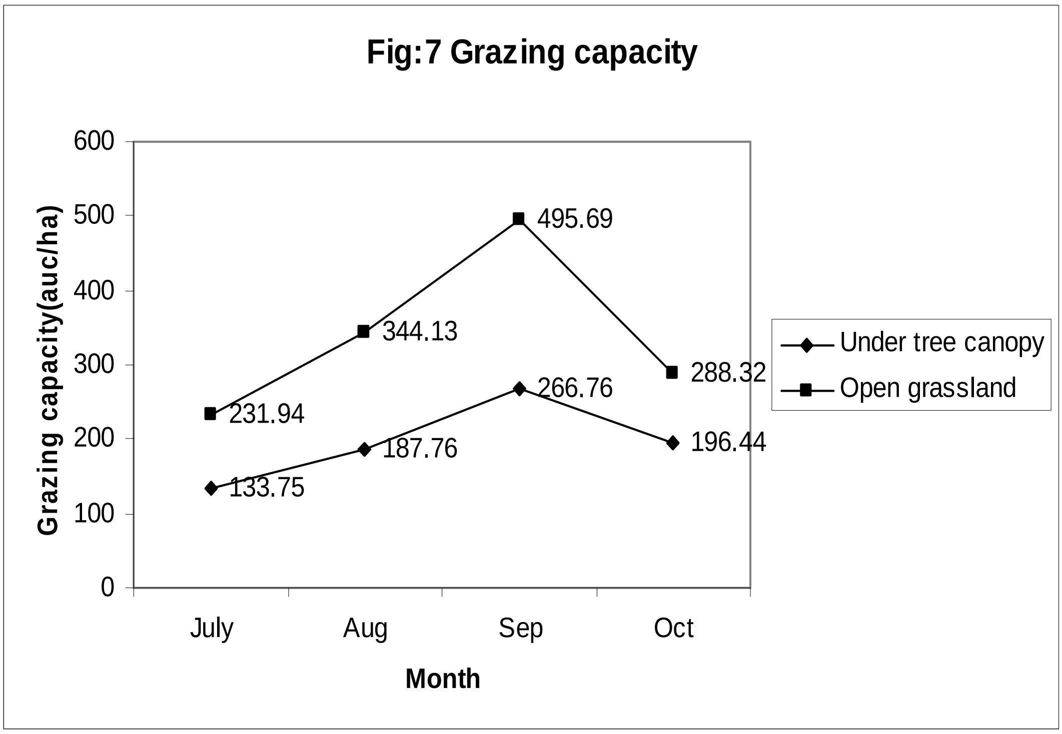


Fig. 6 Contribution of Various Species to total aboveground biomass during October





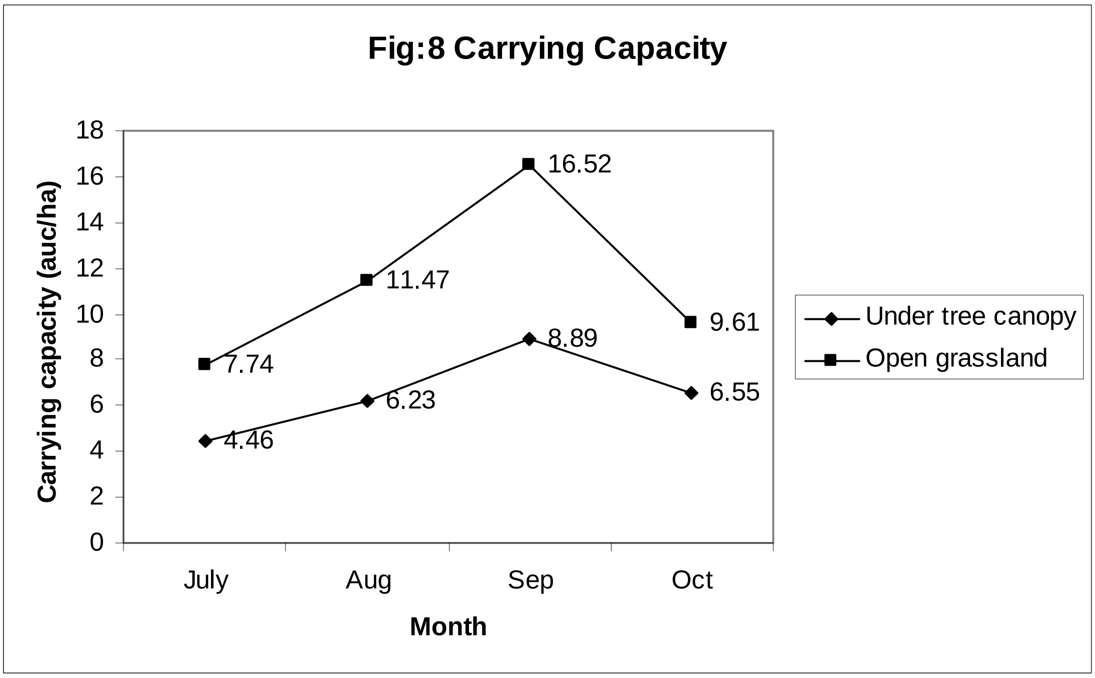


Table 1. Effect of month on aboveground biomass (q/ha) of grasses under chirpine and in open grassland

	C. montanus	*P. maximum*	*H. contortus*	*A. mutica*	*E. binata*	Other grasses	Total	Pooled
July	5.12	1.09	0.09	0.28	0.72	0.24	7.54	10.72
	(7.01)	(3.54)	(0.00)	(1.06)	(1.06)	(1.46)	(14.13)	(18.56)
Aug	6.80	2.06	0.34	0.35	0.82	0.91	11.28	15.03
	(5.96)	(6.04)	(1.73)	(3.36)	(3.01)	(1.84)	(21.94)	(27.54)
Sep	7.71	2.48	0.49	1.14	2.65	1.02	15.49	21.42
	(9.02)	(3.74)	(3.28)	(2.96)	(4.31)	(3.93)	(27.24)	(39.66)
Oct	6.42	1.55	0.31	0.68	1.15	0.55	10.66	15.72
	(10.34)	(1.46)	(1.15)	(1.65)	(1.48)	(2.42)	(18.5)	(23.08)

Values in parentheses indicate aboveground biomass in open grassland

Table 2. Effect of crown class on aboveground biomass (q/ha) of grasses under chirpine and in open grassland

Month	*C. montanus*	*P. maximum*	*H. contortus*	*A. mutica*	*E. binata*	Other grasses	Total	Pooled
C_0	8.27	4.05	1.54	2.26	2.46	2.41	20.98	27.50
C_1	6.40	1.69	0.53	0.71	0.23	0.62	10.18	16.84
C_2	7.10	1.86	0.37	0.12	1.38	0.33	11.06	15.99
C_3	6.11	3.14	0.03	1.01	2.39	1.09	13.77	16.33

Table 3. Effect of direction on aboveground biomass (q/ha) of grasses under chirpine

Month	*C. montanus*	*P. maximum*	*H. contortus*	*A. mutica*	*E. binata*	Other grasses	Total	Pooled
D_1	5.44	0.86	0.35	0.64	1.59	0.73	9.61	13.39
D_2	7.78	1.54	0.30	0.18	1.37	0.81	11.98	15.74
D_3	6.21	2.24	0.31	1.10	0.79	0.95	11.6	16.66
D_4	6.62	2.54	0.28	0.53	1.58	0.23	11.78	17.11

Table 4. Effect of distance on aboveground biomass (q/ha) of grasses under chirpine

Month	*C. montanus*	*P. maximum*	*H. contortus*	*A. mutica*	*E. binata*	Other grasses	Total	Pooled
S_1	5.46	1.12	0.42	0.56	0.85	0.70	9.07	12.35
S_2	6.29	1.81	0.41	0.54	1.56	0.53	11.03	15.78
S_3	7.79	2.45	0.10	0.73	1.58	0.80	13.47	18.96

Table 5. Effect of crown class, direction and distance on aboveground biomass (q/ha) at peak biomass stage (September) under chirpine and in open grassland during the two years of study

	Chrusopogon montanus					*Panicum maximum*				
	Crown class					Crown class				
	C_0	C_1	C_2	C_3	Mean	C_0	C_1	C_2	C_3	Mean
Direction										
D_1	8.14	6.05	5.93	4.64	6.19	4.19	0.34	1.70	2.23	2.37
D_2	7.18	7.03	8.74	8.07	7.75	3.85	1.20	1.18	2.79	2.25
D_3	6.66	7.28	6.52	5.73	6.55	4.96	1.90	1.28	3.65	2.95
D_4	11.10	5.24	7.23	6.01	7.40	3.22	3.30	3.28	2.86	3.17
Mean	8.27	6.40	7.10	6.11		4.05	1.69	1.86	3.14	
Distance										
S_1	8.27	4.75	6.72	5.61	6.34	4.05	0.98	1.48	2.55	2.26
S_2	8.27	7.40	6.02	6.36	7.14	4.05	1.70	1.64	2.64	2.51
S_3	8.27	7.05	8.56	5.87	7.44	4.05	2.39	2.45	4.22	3.28
Mean	8.27	6.40	7.10	6.11		4.05	1.69	1.86	3.14	

	SE(diff)	LSD(0.05)	SE(diff)	LSD(0.05)
C	0.67	1.32	0.54	1.07
D	0.67	NS	0.54	NS
S	0.58	NS	0.47	NS
C x D	1.35	2.65	1.09	NS
C x S	1.16	2.27	0.95	NS

Table 6. Relative silvipastoral class of chirpine based silvipastoral system

Year	*Pasture condition class scale (1)	** Pasture use (2)	*** Tree density (3)	Sum (1+2+3)	RSC
1996	Excellent (3)	No grazing management (0)	Very open (3)	6	Good
1997	Excellent (3)	No grazing management (0)	Very open (3)	6	Good

* Pasture condition class scale on the basis of per cent of palatable species

0-25%	=	Poor (0)
26-50%	=	Fair (1)
51-75%	=	Good (2)
76-100%	=	Excellent (3)

** Pasture use

No grazing management (0)
Some grazing management (1)

*** Tree density

Very open	(>3m) between crowns (3)
Open	(<3m) between crowns (2)
Closed	Crowns just touching (1)
Dense	Crowns overlapping and crowding (0)

APPENDIX-I

A. Silvological characteristics of Chirpine based systems*

Parameter	Crown classes		
	C_1	C_2	C_3
Height (m)	6.75	12.2	15.62
DBH (cm)	20.00	27.03	28.62
Crown cover (m^2)	21.25	39.60	69.42
Crown length (m)	2.25	3.50	5.25

B. Relative light intensity (% of open grassland)*

Distance	Directions			
	D_1	D_2	D_3	D_4
S_1	48.76	59.60	60.56	65.95
S_2	63.80	65.61	64.36	70.78
S_3	86.17	74.87	75.09	81.93

** Combined average of two years*

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