Caspian J. Env. Sci. 2009, Vol. 7 No.2 pp. 71~78

CJES
Caspian Journal of Environmental Sciences

[Research]

Fire Ecology of Ground Vegetation in *Pinus roxburghii* Sargent Plantations in North-West Himalaya - Floristic Composition and Species Diversity

B. Gupta*, R. Mehta and V. K. Mishra

Dept. of Silviculture and Agroforestry,UHF, Nauni, Solan(H.P.)-173230, India
** Corresponding author's E-mail: bgupta_1219@yahoo.co.in*

ABSTRACT
Effect of fire on phyto-sociology of understorey vegetation in chir pine forests of three different silvological characteristics was compared with pure grassland. 15 grasses, 1 sedge, 5 legumes and 21 non-legumes were recorded in the four study sites. Floristic composition gradually increased from June to August and then declined slowly by October in all the plots. Maximum number of species was in twice-burnt plots followed by once burnt and unburnt plots. Least similarity index was recorded for twice burnt plots and unburnt plots. Density of vegetation increased from June to mid-rainy season and thereafter decreased till October. Density of vegetation in four sites decreased in order: open grassland > sapling chir pine stand > pole stage chir pine stand > mature trees chir pine stand. Density of vegetation increased when fire was imposed in plots. It decreased in the order: twice burnt plots > once burnt plots > unburnt plots. It was recorded that fire in chir pine forests are good for herbage growth and development.

Keywords: Fire ecology, Phyto-sociology, *Pinus roxburghii*, North-West Himalaya

INTRODUCTION

Lower Himalaya, between latitudes 26°N to 36°N and longitudes 71°E to 93°E (Ghildiyal *et al* 2009) is home of chir pine (*Pinus roxburghii* Sargent) which is one of the most divergent and economically important plant species, providing valuable timber, resin, fuel and protect watersheds to sustain the water supply to millions residing in the Himalayan basin. In India chir pine covers an area of 8,69,000 hectares extending from Jammu and Kashmir, Haryana, Himachal Pradesh, Uttar Pradesh, parts of Sikkim, West Bengal and Arunachal Pradesh inhabiting areas at 450 to 2300m above msl (Anon. 2004) . In Himachal Pradesh around 1346 km² area is under chir pine providing vast grazing area. People in this area have acquired a faith over the years that summer-fires in chir pine forests enhance forage production. Thus, these forests are occasionally subjected to wild fires every year. Such fires vary in intensity and spread out, assume often the form of ground fire, surface fire and crown fire. The ultimate damage to vegetation (old and new regenerates) and environment is depending on fire type. Though chir pine is resistant to fires, yet these forests are highly vulnerable to the repeated fires. Occluded resin deposited on tapped tree surfaces, a thick mat of dry needles accumulated on ground, dried bushes and dried lower branches in un-thinned and un-pruned thick regenerations provide highly inflammable fuel load for fires. Fire has been reported to exercise positive and negative influences on physico-chemical properties of site, dry matter accumulation, species establishment, understorey light intensity, diversity and other community relations depending upon its intensity, spread and frequency (Anderson *et al*. 1969; Wright and Heinselman, 1973; Singh *et. al*., 1985; Hawke, 1991). The literature citing effect of fire on herbage under chirpine trees in western Himalaya is meager and there is need to generate adequate information in regard to site specific - species

effect on fire. Keeping this in view, the present study was undertaken in chir pine forests of subtropical regions of Himachal Pradesh to investigate the effect of fire on floristic diversity of ground vegetation

MATERIALS AND METHODS

The present study was undertaken at Solan, located at 30° 51'N latitude and 77° 11'E longitude at an altitude from 1200-1250m above m.s.l., during growing seasons (June to October) of years 2000 and 2001. The climate of the area is transitional between subtropical and sub-temperate. The area receives 100-120cm annual rainfall. The relative humidity varies from 35 to 80 per cent with yearly average of 50 per cent. The soil of the area comprise of carbonaceous shales, calcareous shales, dolomite limestone with bands of intermittent shales.

After survey of the area four sites each of approx. 0.3 to 0.4 ha. were studied i.e., S_1 - Pure natural grassland, S_2 - chir pine plantation at sapling stage, S_3 - chir pine plantation at pole stage and S_4 - chir pine plantation at tree stage. The characteristic of trees in different sites is given in Table-1. The study sites were free from any biotic interference for many years. Each site was divided into two equal halves and one of them was burnt during the month of April 2000 thus in all there were eight treatments in the year 2000 which are as follows:

T_1 and T_2: burnt and unburnt pure grasslands, respectively.

T_3 and T_4: burnt and unburnt chir pine plantations at sapling stage, respectively.

T_5 and T_6: burnt and unburnt chir pine plantations at pole stage, respectively.

T_7 and T_8: burnt and unburnt chir pine plantations at tree stage, respectively.

In the second year i.e., 2001 the burnt plots of the year 2000 were divided and re-burnt in such a way that we had the plots of once-burnt (burnt in 2000 only) and twice burnt plots (burnt in 2000 and 2001 as well). Thus, the various treatments in the second year were as follows:

T_2: Pure grassland unburnt

$T_{1.1}$: Pure grassland burnt in 2000 and 2001 as well

$T_{1.2}$: Pure grassland burnt in 2000 only.

T_4: Unburnt chir pine plantation at sapling stage

$T_{3.1}$: Chir pine plantation at sapling stage burnt in 2000 and 2001

$T_{3.2}$: Chir pine stand at sapling stage burnt in 2000 only

T_6: Unburnt chir pine at pole stage plantation

$T_{5.1}$: Chir pine plantation at pole stage burnt in 2000 and 2001

$T_{5.2}$: Chir pine stand at pole stage burnt in 2000 only

T_8: Unburnt chir pine at tree stage plantation

$T_{7.1}$: Chir pine at tree stage plantation burnt in 2000 and 2001

$T_{7.2}$: Chir pine stand at tree stage burnt in 2000 only

In each of the above treatments, a plot of around 0.1 ha area was marked for vegetation analysis. Standard methods were used to measure height, crown diameter, crown area and dbh of trees. Herbage sampling was done by harvest method at monthly interval, starting from June to October of each year. Phytosociological evaluations were done by the method given by Phillips (1959) and Misra (1969). Similarity index of herbage vegetation was estimated by the method of Sorenson (1949). Herbage diversity was calculated by the method given by Shannon & Weaver (1949). RBD factorial was used for statistical analysis of the data

Table 1. Silvological characteristics of chir pine stands at different sites

Parameters	Sapling stage chir pine stand **(S_2)**	Pole stage chir pine stand **(S_3)**	Mature trees chir pine stand **(S_4)**
Density (number of trees/ha)	1112.50	779.0	200.00
D. B. H. (cm)	3.29	17.33	32.75
Tree height (m)	1.46	15.04	18.45
Crown diameter (m)	1.19	4.24	6.92
Crown area (m^2)	1.14	14.26	37.59
Relative light intensity (% of open area)	38.87	18.83	17.34
Pine-needle litter production in burnt stand (Kg/ha)	420.80	630.40	740.00
Pine-needle litter production in unburnt stand (Kg/ha)	796.00	1472.00	1950.00

RESULTS

During 2000, in all, 12 grasses (*Chrysopogon montanus, C. gryllus, Heteropogon contortus, Themeda anathera, Panicum maximum, Apluda mutica, Urochloa panicoides, Pollinia fimbriata, Cymbopogon martinii, Eulaliopsis binata, Saccharum spontaneum and Pennisetum orientale),* 1 sedge (*Cyperus rotundus),* 5 legumes (*Flemingia fruticulosa, Lespedeza sericea, Atylosia scarabaeoides, Cassia mimosoides* and *Desmodium triflorum)* and 19 non-legumes (*Gerbera lanuginosa*, *Salvia lanata*, *Justicia simplex*, *Achyranthus aspera, Artemisia parviflora, Cynoglossum furcatum*, *Leucas lanata, Senecio graciliflorus, Galinsoga parviflora, Pimpinella diversifolia, Bidens pilosa, Barleria cristata, Thalictrum sp., Adianthus sp, Fadherbia sp. Viola odorata, Myrsine africana, Parthenium clandestinum* and *Trichodesma indicum)* were recorded. Whereas, during 2001, 15 grasses, 1 sedge, 5 legumes and 21 non-legumes were recorded in the above sites. Three new grass species recorded in the second year were: *Mnesithea laevis*, *Arundinella setosa* and *Bothriochloa pertusa*. Similarly, 2 new non-legumes viz., *Salvia lanata* and *Ficus palmata* were also recorded. The number of species recorded in the present study was relatively higher as compared to the reports by Dalai (1996), Guleria *et al.* (1999), Rao (1998) and Gupta *et al.* (2000) for similar grasslands of Solan area in H.P. Higher number of species can be ascribed to differences in micro-habitat (Sawarkar *et al*., 1986), management practice (imposing fire in present study), yearly variations in aboitic factors and characteristics of over-storey crops.

The species number was relatively more during June to August and thereafter declined towards the end of the growing period in all the sites (Tables 2 and 3). The distribution pattern of species in different treatments during different months was almost similar in 2000 and 2001. Higher number of species in early growing season is manifestation of congenial growth condition leading to germination and development of different species. Most of the species complete their life cycle by August, thus there is decline in species number after August. Similar trend in species variation have been reported by Dalai (1996), Guleria *et al.*(1999), Gupta *et al*. (2000) and Dutt & Gupta (2005) for sub-tropical grasslands of H.P. They have also reported the number of species of different plant-categories in order: grasses > non-legumes > legumes > sedges, similar to the findings of present study. Rao and Kharkanger (1978) also reported similar results for pine forests of Shillong and Meghalaya in India. However, the number of species recorded in the present study sites was relatively higher as compared to the reports by Guleria *et al.* (1999), Rao (1998) and Gupta *et al*. (2000) for similar sub-tropical grasslands of northwest Himalaya. Such a difference perhaps has emerged due to imposed fire-treatments in the present study, which reduced pine-needle litter deposition and curtailed release of allelochemicals besides enhancing nutrient release from fuel load.

Among the grasses, *C. montanus*, *H. contortus*, *T. anathera* and *P. maximum* were invariably recorded in all the treatments during different sampling months. The regular occurrence of only few species in a community at different intervals is an indicator of better adaptation of these species to microhabitat as reported by Bawa (1986), Kapoor (1987) and Gupta *et al*. (2000) in their studies on grassland ecosystems of H.P.

With few exceptions, the species number was more in twice-burnt plots followed by once-burnt plots and the least in un-burnt plots. Thus, it was evident that fire induced increased species germination and growth perhaps for the reasons as explained earlier. More species after burning have also been reported by Rikhari and Palni (1999) in oak mixed broad-leaved forests central Himalaya and Anita (2001) in chir pine forests of north-west Himalaya.

The similarity index of the vegetation among different plots was higher during mid-rainy season (Tables 4 and 5). Most of the species had germinated by mid-rainy season in all the plots composed of similar species. During 2000, maximum similarity index was recorded in burnt and unburnt pole stage plantation in July (Table 4). On an average the similarity index of the vegetation in burnt and unburnt plots had high values exceeding 0.74, whereas, in 2001, highest similarity index was recorded between once-burnt and unburnt pure grassland in October (Table 5). In general, lower similarity index was observed between burnt (once burnt or twice burnt) and unburnt plots at all sites

during 2001 as compared to the year 2000. It reflects that fire (for one year or more than one year) initiates floral changes in an area on account of reduction in inter-specific competition for space, nutrient and water following fire due to the reduction in vigor of other species as contended by Dix (1960). He also reported more variability in species composition between burnt and unburnt stands in the four year old burn than in the one-year old burn.

The density of herbage recorded in different sampling months revealed that in all the treatments, it increased with the onset of rainfall and peaked by mid-growing season, thereafter it decreased till end of the growing season (Table 6). Such a gradual increment in density of vegetation can be related to vigorous growth of vegetation, which is positively correlated with rainfall pattern and also find support of Singh and Yadava (1974), Bawa (1986), Kapoor (1987), Gupta *et al*., (2000) and Trivedi (1994). Comparing the four sites, total density depicted a distinct variation being maximum in pure grassland (S_1) followed by sapling pine stand (S_2), pole pine stand (S_3) and mature tree pine stand (S_4) during both the years (Tables 6 and 7). The low values of the total density of herbage in chir pine inhabited sites (S_2, S_3 and S_4) can be attributed to low physiological activity of constituent species on account of varied factors like interception of light by trees (Gupta *et al*. 2000), Low LAI of herbage (Dutt and Gupta 2005) and adverse effect allelochemical released by pine leaves (Anderson *et al*. 1969). Total density of vegetation was higher in burnt plots as compared to unburnt plots, further, it was also recorded that density was maximum in twice-burnt plots followed by once-burnt and un-burnt plots, respectively (Table 6). The increase in density of vegetation in twice-burnt and once-burnt plots as compared to unburnt plots reinforced the earlier findings (Trabaud, 1980; Brockway and Lewis, 1997), which suggested that due to reduction in fuel loading and less release of various allelochemicals from pine-needle litter and enhanced release of nutrients from burnt litter induced rapid growth of the vegetation on the onset of congenial conditions.

Shannon's diversity index demonstrated no specific variation with advancement of growing season except that it was generally low at the beginning and end of the growing season during the respective years of study (Table 8). The congenial growth conditions during the mid season may have contributed for higher diversity. The diversity index was recorded higher on burnt plots than unburnt ones in 2000, and during 2001 it was found maximum in twice-burnt plots by once-burnt and unburnt plots, respectively. The higher diversity index on burnt sites has also been reported by Sundriyal *et al*., (1987), Rikhari and Palni (1999) and Sawarker *et al*., (1986).

It can be concluded from the study that fire enhances floristic composition. Chir pine trees though curtail growth of forage under them but inducing controlled fire in these forests can increase the growth of herbage. The effect is more pronounced if prescribed burning is applied year after year.

Table 2. Number of plant species in once burnt (SB) and unburnt plots (UB) of *Pinus roxbughii* plantations and open grassland during 2000

Month		Grassland (S_1)					Sapling stand (S_2)					Pole stand (S_3)					Mature/tree stand (S_4)				
		G	**S**	**L**	**NL**	Total	**G**	**S**	**L**	**NL**	Total	**G**	**S**	**L**	**NL**	Total	**G**	**S**	**L**	**NL**	Total
June	SB	8	0	3	8	**19**	7	1	5	7	**20**	8	1	3	6	**18**	6	1	4	7	**18**
	UB	6	0	2	3	**11**	6	0	1	7	**14**	5	0	1	0	**6**	4	1	2	5	**12**
July	SB	8	1	4	7	**20**	9	1	4	3	**17**	6	0	2	4	**12**	6	1	4	8	**19**
	UB	4	0	2	4	**10**	6	2	2	5	**14**	6	0	1	2	**9**	6	1	2	4	**13**
August	SB	7	0	4	7	**18**	10	0	2	4	**16**	8	0	2	4	**14**	7	1	1	7	**16**
	UB	6	0	2	3	**11**	6	0	1	3	**10**	5	0	1	3	**9**	4	1	1	5	**11**
September	SB	6	0	0	0	**6**	8	0	0	0	**8**	5	1	2	3	**11**	5	1	0	0	**6**
	UB	5	0	0	0	**5**	5	0	0	0	**5**	5	1	0	0	**6**	3	1	0	0	**4**
October	SB	5	0	0	0	**5**	10	0	0	0	**10**	5	0	0	0	**5**	6	1	0	0	**7**
	UB	6	0	0	0	**6**	5	0	0	0	**5**	5	0	0	0	**5**	4	1	0	0	**5**

G = Grasses **S** = Sedges **L** = Legumes **NL** = Non-legumes

Table 3. Number of plant species in twice burnt (CB), once burnt (SB) and unburnt plots UB) of *Pinus roxbughii* plantations and open grassland during 2001

Month		Grassland (S_1)					Sapling stand (S_2)					Pole stand (S_3)					Mature/tree stand (S_4)				
		G	**S**	**L**	**NL**	Total	**G**	**S**	**L**	**NL**	Total	**G**	**S**	**L**	**NL**	Total	**G**	**S**	**L**	**NL**	Total
June	CB	6	1	4	8	**19**	11	1	2	5	**19**	10	0	1	6	**17**	6	0	4	7	**17**
	SB	8	1	4	8	**21**	10	1	2	4	**17**	8	2	1	5	**18**	9	1	2	5	**17**
	UB	9	0	2	3	**14**	7	1	0	3	**11**	6	0	1	2	**6**	6	1	1	4	**12**
July	CB	11	1	4	9	**25**	11	1	1	5	**18**	10	1	2	7	**20**	11	0	3	7	**21**
	SB	8	1	4	6	**19**	10	1	3	3	**17**	11	1	1	4	**17**	10	1	2	6	**18**
	UB	6	0	1	4	**11**	7	1	1	4	**13**	7	0	1	2	**10**	6	1	2	4	**13**
August	CB	10	1	4	8	**23**	12	1	1	4	**18**	6	2	2	7	**17**	10	0	1	5	**16**
	SB	8	0	4	41	**16**	10	1	1	4	**16**	12	1	1	2	**16**	7	1	1	4	**13**
	UB	11	0	2	2	**15**	6	0	1	1	**8**	5	0	1	2	**8**	6	1	1	3	**11**
Sept.	CB	11	0	0	0	**11**	9	0	1	0	**10**	5	0	0	0	**5**	7	0	2	2	**11**
	SB	7	0	1	3	**11**	9	2	1	0	**12**	7	0	0	0	**7**	8	1	1	2	**12**
	UB	7	0	0	0	**7**	9	0	0	0	**8**	4	1	0	0	**5**	6	1	1	1	**9**
October	CB	6	0	0	0	**6**	7	1	0	0	**8**	4	0	0	0	**4**	7		0	0	**7**
	SB	6	0	0	0	**6**	8	0	0	0	**8**	7	0	0	0	**7**	8	1	0	0	**9**
	UB	6	0	0	0	**6**	6	0	0	0	**6**	4	1	0	0	**5**	5	1	0	0	**6**

G = Grasses **S** = Sedges **L**= Legumes **NL** = Non-legumes

Table 4. Similarity index of herbage layer between burnt and unburnt treatments in the four study sites during 2000

Months	Similarity index				Mean
	Open grassland (S_1)	Sapling stage chir pine stand (S_2)	Pole stage chir pine stand (S_3)	Mature trees chir pine stand (S_4)	
June	0.71	0.75	0.75	0.77	0.75
July	0.71	0.73	1.00	0.94	0.85
August	0.88	0.78	0.80	0.85	0.83
September	0.77	0.76	0.71	0.80	0.76
October	0.72	0.67	0.80	0.83	0.76
Mean	0.76	0.74	0.81	0.83	

Table 5. Similarity index of herbage in twice burnt (CB), once burnt (SB) and unburnt (UB) treatments in the four study sites during 2001

Sites	June		July		August		September		October		Mean	
	SB	**UB**	**SB**	**UB**	**SB**	**UB**	**SB**	**UB**	**SB**	**UB**	**SB**	**UB**
S_1 CB	0.75	0.67	0.86	0.67	0.78	0.67	0.67	0.78	0.83	0.83	0.78	0.72
S_1 SB	-	0.67	-	0.67	-	0.53	-	0.71	-	1.00	-	0.71
S_2 CB	0.88	0.66	0.96	0.67	0.92	0.60	0.67	0.67	0.82	0.67	0.85	0.65
S_2 SB	-	0.70	-	0.70	-	0.67	-	0.70	-	0.85	-	0.72
S_3 CB	0.85	0.67	0.87	0.82	0.67	0.76	0.83	0.60	0.72	0.67	0.79	0.70
S_3 SB	-	0.63	-	0.70	-	0.56	-	0.67	-	0.67	-	0.65
S_4CB	0.87	0.62	0.85	0.75	0.78	0.70	0.62	0.85	0.62	0.76		0.74
S_4 SB	-	0.70	-	0.71	-	0.93	-	0.75	-	0.80	0.75	0.78
						Mean						
TB	0.87	0.66	0.89	0.73	0.79	0.68	0.69	0.72	0.75	0.73		
SB	-	0.68	-	0.69	-	0.67	-	0.70	-	0.83		

S_1 = Open grassland S_2 = Sapling stage chir pine stand
S_3 = Pole stage chir pine stand S_4 = Mature trees chir pine stand

Table 6. Effect of combination of site with burning (SB), sampling month and their Interaction on density ((number of tillers/m²) of herbage layer during 2000

Treatment (T)	Months (M)					
	June	**July**	**August**	**September**	**October**	**Mean**
S_1B_1	941.90	1126.00	979.50	878.80	672.80	919.80
S_1B_2	859.30	1100.00	898.40	850.40	596.80	861.00
S_2B_1	577.90	673.60	766.90	739.00	695.30	690.50
S_2B_2	504.80	573.60	703.90	683.60	666.20	626.40
S_3B_1	484.00	533.30	679.90	556.20	537.30	558.20
S_3B_2	470.40	498.40	666.20	512.10	490.40	527.50
S_4B_1	393.80	450.40	555.10	656.40	543.00	519.70
S_4B_2	346.40	403.20	549.60	603.20	534.00	487.30
Mean	572.32	669.81	724.90	685.00	592.00	
	SE(diff.)	$CD_{0.05}$				
T	5.72	11.40				
M	4.52	9.01				
T x M	12.81	25.49				
Within site burnt v/s unburnt						
S_1	131.46	NS				
S_2	143.18	NS				
S_3	68.54	NS				
S_4	61.20	NS				

S_1 = Pure grass land
S_2 = Sapling pine stand
S_3 = Pole pine stand
S_4 = Mature tree pine stand
B_1 = Burnt plots
B_2 = Unburnt plots

Table 7. Effect of combination of site with burning (CB, SB and UB), sampling month and their interaction on density ((number of tillers/m²) of herbage layer during 2001

Treatment (T)	Months (M)					
	June	**July**	**August**	**September**	**October**	**Mean**
S_1TB	946.66	1251.02	996.32	958.50	769.68	984.44
S_1SB	858.72	1176.66	951.65	926.00	661.80	914.97
S_1UB	807.20	1165.00	865.00	903.00	614.00	870.84
S_2TB	713.33	844.00	880.33	648.50	556.60	728.55
S_2SB	604.55	700.33	849.67	537.00	474.33	633.18
S_2UB	492.00	560.00	730.00	455.00	400.00	527.40
S_3TB	595.48	787.34	777.66	413.00	386.00	591.89
S_3SB	369.67	760.66	779.51	369.00	352.60	526.29
S_3UB	318.00	709.00	740.00	345.00	336.00	489.60
S_4TB	200.50	423.66	475.50	475.50	363.33	387.69
S_4SB	157.94	408.84	427.66	313.66	302.99	322.22
S_4UB	145.00	253.00	328.00	269.00	204.00	239.80
Mean	517.42	778.29	733.44	551.09	451.78	
	SE(diff.)	$CD_{0.05}$				
T	11.46	22.70				
M	7.39	14.65				
T x M	25.63	50.75				
Within site burnt v/s unburnt						
S_1	45.58	90.26				
S_2	42.15	NS				
S_3	39.05	NS				
S_4	37.01	NS				

S_1 = Pure grassland
S_2 = Sapling stage chir pine stand
S_3 = Pole stage chir pine stand
S_4 = Mature tree stage chir pine stand
CB = Twice burnt plots
SB = Once burnt plots
UB = Unburnt plots

Table 8. Shannon's diversity index in unburnt (UB), once burnt (SB) and twice burnt (TB) plots of *Pinus roxbughii* plantations and open grassland during 2000 and 2001

Site \ Month	Shannon's diversity index											
	June		July		August		September		October		Mean	
	2000	2001	2000	2001	2000	2001	2000	2001	2000	2001	2000	2001
Pure grassland (S_1)												
TB	0.667	0.867	0.739	0.835	0.682	0.924	0.536	0.859	0.577	0.804	0.640	0.858
SB	-	0.924	-	0.914	-	0.872	-	0.907	-	0.909	-	0.905
UB	0.469	0.869	0.554	0.699	0.629	0.857	0.597	0.732	0.682	0.724	0.586	0.776
Sapling chirpine stand (S_2)												
TB	0.694	0.660	0.873	0.950	0.407	0.878	0.651	0.879	0.731	0.714	0.671	0.816
SB	-	0.745	-	0.765	-	0.803	-	0.795	-	0.642	-	0.750
UB	0.731	0.848	0.713	0.734	0.676	0.851	0.565	0.770	0.531	0.733	0.643	0.787
Pole chirpine stand (S_3)												
TB	0.728	0.918	0.695	0.889	0.718	0.926	0.714	0.837	0.617	0.802	0.694	0.874
SB	-	0.898	-	0.914	-	0.921	-	0.916	-	0.803	-	0.890
UB	0.695	0.899	0.776	0.915	0.643	0.708	0.648	0.641	0.557	0.775	0.664	0.788
Mature tree chirpine stand (S_4)												
TB	0.738	0.966	0.827	0.834	0.714	0.802	0.670	0.593	0.692	0.549	0.728	0.749
SB	-	0.998	-	0.823	-	0.906	-	0.790	-	0.700	-	0.843
UB	0.610	0.720	0.835	0.756	0.689	0.688	0.506	0.622	0.594	0.552	0.647	0.668
Mean												
TB	0.707	0.853	0.784	0.877	0.630	0.882	0.643	0.792	0.654	0.717		
SB	-	0.891	-	0.854	-	0.876	-	0.852	-	0.764		
UB	0.626	0.834	0.720	0.776	0.659	0.776	0.579	0.691	0.591	0.696		

TB = Plots burnt in the years 2000 and 2001 **SB** = plots burnt in the year 2000 only **UB** = plots un-burnt

REFERENCES

Anderson, R. C., Loucks, O.L. and Swain, A.M. (1969) Herbaceous response to canopy cover, light intensity and throughfall precipitation in coniferous forests. *Ecology* **50**: 255-263.

Anita (2001) Effect of forest fire on species diversity of chirpine (*Pinus roxburghii* Sarg.) forests in mid-hills of Himachal Pradesh. *M.Sc Thesis*. Dr. Y. S. Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.), India.

Anonymous.2004. Indian Council of Forestry Research and Education, Dehradun. Chir pine (*Pinus roxburghii*). Dehradun, Forest Research Institute. 21p. National Forest Library and Information Centre, FRI Dehradun, India.

Bawa, R. (1986) Structural and functional studies of three semi-arid grassland communities near Shimla. *Ph.D. Thesis,* H. P. University Shimla, India**:** 404pp.

Brockway, D. G. and Lewis, C.E. (1997) Long-term effects of dormant season, prescribed fire on plant community diversity, structure and productivity in a long leaf pine wire grass ecosystem. *Forest Ecology and Management* **96**(1/2): 167-183.

Dalai, D. (1996) Productivity of grasses in relation to site quality in *Pinus roxburghii* Sargent plantations. *M.Sc Thesis*. Dr. Y. S. Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.), India. 74pp.

Dix, R. L. (1960) The effects of burning on the mulch structure and species composition of grasslands in western north Dakota. *Ecology* **41**(1): 49-56.

Dutt, V. and B. Gupta. 2005. Interaction between trees and ground flora in different aged chirpine stands of sub-tropical region in India–I: Density of herbage and LAI. *Indian J. of Forestry*. Vol. **28**(1):28-36.

Ghildiyal S K, Sharma C M and Gairola S. (2009) Environmental variation in seed and seedling characteristics of *Pinus roxburghii* Sarg. from Uttarakhand, India. *Applied Ecology and Environmental research* 7(2): 121-129.

Guleria, V., Nayital, R.K. and Gupta, B. **(**1999).. Phytosociological studies under chir pine stands in mid hills of Himachal Pradesh. *Range Mgmt. & Agroforestry* **20**(1): 47- 54.

Gupta, B., Chauhan, P.S. and Dass, B. (2000) Composition of herbage in *Pinus roxburghii* Sargent stands: species diversity and density. *J. Tropical Forest Science* **12**(3): 444 - 449.

Hawke, M. F. (1991) Pasture production and animal performance under pine agroforestry in New Zealand. *Forest Ecology and Management* **45**: 109 -118.

Kapoor, K. S. (1987) Species composition, plant biomass and primary production in certain grassland ecosystems of Shimla hills. *Ph.D. Thesis*, H. P. University Shimla (H.P.), India.

Misra, R. (1969) *Ecological Workbook*. Oxford I. B. H. Publishing Co. Calcutta, India.

Phillips, E. A. (1959) *Methods of Vegetation Study*. A Holtdryden book. Henry Holt & Co. Inc.

Rao, G. R. (1998) Studies on dynamics of herbage layer in pine and khair based natural silvipastoral system in north-west Himalaya. *Ph.D. Thesis*, Dr. Y. S. Parmar University and Forestry, Solan (H.P.), India.

Rao, R. R. and Kharkanger, P. (1978) Floristic composition and seasonal pattern of vegetation in pine forests of Shillong and Meghalaya. *J. Bombay Natural History Society* **75**(2): 173-285.

Rikhari, H. C. and Palni, L.M. (1999) Fire effects ground flora dynamics of forest ecosystem: A case study from central Himalaya. *Tropical Ecology* **40**(1): 145-151.

Sawarker, V. B., Rodzes, W. A. and Buerd, S.F.R.B. (1986) Fire and vegetation structure in sal forests, Dehra Dun. India. *Tropical Ecology* **27**: 49-61.

Shannon, C. E. and Weaver, W. (1949) *The Mathematical Theory of Communication*. University Illinois press, Urbana.USA. **pp** 117.

Singh, R. P., Gupta, M. K. and Mathur, H. N. (1985) Effect of *Pinus roxburghii* plantations on the yield and composition of grasses in temperate region. *Indian Forester* **111**(10): 787-793.

Singh, J. S. and Yadava, P.S. (1974) Seasonal variation in composition, plant biomass and net primary productivity of a tropical grassland. *Ecological Monograph* **44** (3): 360-375.

Sorenson, T. (1949) A method of establishing groups of equal amplitude in plant sociology based on similarity of species content. *Kgl. Danske Videnskab Seleskab Biol. Skrifter*. **4**: 1-34.

Sundriyal, R. C., Chauhan, B. B., Kandwal, S. K. and Joshi, A. P. (1987) Vegetation composition of certain grasslands of Garhwal Himalayas determined by soil profile and seasonal variation. *Indian J. Ecology* **14**(1): 37-46.

Trabaud, L. (1980) Impact biologique et ecalogique des feuxde vegetation surl organisation, la structure et l'evolution de la vegetation des zones desgarrigues du as-laguedac. Doct. Etat. Univ. Sci. Tech. Laguedac. Montpellier. 288pp.

Trivedi, B. K. (1994) Seasonal changes in composition of grassland communities in district of Jhansi. *Range Mgmt. & Agroforestry* **15**(2): 123-129.

Wright, H. E. and Hinselman (1973) Fire as a tool to manage Tobosa grasslands. *Tall Timbers Fire Ecol. Conf. Proc.* **89**(1): 18-38.

(Received: Jun. 10-2008, Accepted: Aug. 28-2009)