Structure and composition of trees and their effect on crop yield in existing agrihortisilvicultural and agrihorticultural systems of Garhwal Himalaya

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ABSTRACT : The paper summarizes with structure and composition of tree species and productivity of agricultural crop under existing agroforestry systems viz. agrihortisilviculture (AHS) and agrihorticulture (AH) systems in mid hill situation of Garhwal Himalaya between 1000 to 2000m asl during Rabi and Kharif seasons in the year 2004-2006. The northern aspect was more diverse and formed good vegetation composition. In the northern aspect 21 tree species were recorded in AHS system compared to 13 in southern, whereas in AH system the reported tree species were 11 and 9 in northern and southern aspects respectively. In the northern aspect of AHS system, *Quercus leucotrichophora* was observed as dominant tree species followed by *Celtis australis* and *Grewia optiva* while in southern aspect *Grewia optiva* was reported as dominant species. In AH system *Malus domestica* (apple) and *Prunus armeniaca* (wild apricot) were dominant fruit trees in northern and southern aspect respectively. In the agricultural crop (Rabi + Kharif) the grain yield was recorded highest 1197 kg/ha/yr and biological yield 4110 kg/ha/yr under AHS in northern aspect as compared to 2027 and 6070 kg/ha/yr in sole cropping. Overall there is an average reduction of 46.38 percent in gain yield and 39.93 percent in biological yield compared to sole agricultural cropping but this reduction is supplemented by multipurpose benefits of wood production which is supporting life of the rural community of this hilly region.

Keywords : Biological yield, grain yield, Importance Value Index (IVI), Northern aspect, Southern aspect

1. INTRODUCTION

Agroforestry is a unique and very common practice in the Garhwal Himalayan region of Uttarakhand, India. Presence of forest and horticultural (fruit) trees alongwith agricultural crops are noticed in the arrangement of agrisilviculture (agricultural crops + forest trees), agrihorticulture (agricultural crops + horticultural trees) and agrihortisilviculture (agricultural crops + horticulture tree + forest tree) systems on the same piece of land. In hilly regions the existence without agroforestry is difficult because trees not only supplement the fodder, fuel, fiber, fruits etc but also check land sliding in the fields, protect crops to adverse wind and climatic condition, conserve the moisture, improve the soil quality through nitrogen fixing and adding organic matter in terms of leaf fall. In the Himalayan region a number of traditional agroforestry system have been documented from Himachal Pradesh and Uttarakhand (Atul *et al.*, 1990) out of which agrisilviculture, agrihorticulture and agrihortisilviculture are very common. Also Singh *et al.* (1980), Dadhwal *et al.*(1989) and Toky *et al* (1989) have identified these three agroforestry systems for their various benefits.

The selection and retaining the trees on the bunds of the agricultural field is farmers friendly and well-suited. Selection of intercrops depends mainly on edapho-climatic conditions of the area, farmer's need/traditions and resource availability (Saroj and Dadhwal, 1997). Among the forest trees *viz. Grevia optiva, Melia azedarach, Ficus roxburghii, Celtis australis* etc found to be more prominent while in horticultural trees the *Malus domestica, Prunus armeniaca, Juglans regia* etc. are very common. Singh (1986) found that *Grewia optiva, Celtis australis, Robinia pseudoacacia, Sapindus mukorossii, Melia azedarach,* etc. as the prominent tree species raised by farmers on bunds in the Himalayan region of Himanchal Pradesh between 1000 to 2000m asl. The present study is an attempt to analyze the aspectwise structure and composition of trees in existing agrihortisilvi and agrihorticulture systems and their impact on agricultural yield in the Garhwal Himalayan region of Uttarakhand.

2. MATERIALS AND METHODS

The study was carried out in the existing agroforestry systems of four selected villages (Dabri, Semwalgaon, Kanatal and Kafalpani) in Thauldhar block under mid hill situation of Garhwal Himalaya district Tehri Garhwal (Uttarakhand) between 1000 to 2000m asl elevation on northern and southern aspects during Rabi and Kharif seasons in the year 2004-2006. The study area lies between 77° 51' 30" to 80° 30" E longitudes and 29° 40' to 31° 28" N latitudes. Geographically the area falls between sub- tropical to temperate zone, with the luxuriant and green lush natural vegetation. The area receives an average annual rainfall of 1240 mm with most of the rain occurring during July to September. The mean annual temperature ranges from 9° to 33 °C with occurrence of snowfall during November to February. In the present study

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20 quadrates were laid in each site with 4 replication having sample size of 10x10 meter for trees and 0.5x0.5 meter for agricultural crops. The productivity of different existing agriculture crops were calculated and compared with the sole agricultural productivity (control).

The existing agrihortisilviculture (AHS) and agrihorticulture (AH) systems were selected for the study. The phytosociological analysis of trees under existing systems was carried out to analyze the impact of aspect (northern and southern aspects) on the vegetation in the existing systems. The frequency, density, abundance, A/F ratio, total basal cover (TBC) and importance value index (IVI) of existing trees were analyzed in different aspect following Curtis and Mc Intosh (1950) and Phillips (1959). Similarly, diversity parameters were also analyzed for the trees under studied agroforestry systems.

Tree diversity was quantified by following diversity indices.

a). Shannon-Weaver Index (Shannon & Weaver, 1963) was used for the calculation of species diversity as:

$$\bar{H} = -\sum_{i=1}^{s} (N_i/N)\log_2 (N_i/N)$$

Where N_i was the total number of individuals of species i

b). Concentration of dominance was measured by Simpson Index (Simpson, 1949)

$$Cd = \sum_{i=1}^{s} (N_i/N)^2$$

Where, Ni and N were same as explained above and it varies between 0-1.

c). Equitability (e) was calculated as suggested by Pielou (1975) as:

$$e = \bar{H} / \ln s$$

Where H is the Shannon-Wiener Index and s = Total number of species

d). Species richness was calculated by following the Margalef equation (1958) as:

$$d = s-1/\ln N$$

Where s = number of species present in the plot, and N = number of individuals of all species

e). Beta diversity was calculated as per Whittaker, (1977) as:

$$bd = Sc/\bar{s}$$

Where **Sc** = total number of species in all sites and **s** is average species per site

The assessment of productivity status of agricultural crops under AHS and AH systems was also estimated to understand the feasibility of the systems. The randomly selected of samples of agriculture crops were taken from farmers' fields. The agriculture crops from the quadrats were harvested at the maturity stage from the agroforestry systems as well as from sole agriculture system (controlled) to estimate the reduction in yield under agroforestry system as compared to pure agriculture system. The mature agriculture crop was harvested and separated in to grain (seeds) and straw (vegetative portion including shoots and leaves). Further, grain and straw were dried in natural conditions so as to obtain the net yield (kg/ha) on crop and season basis. The Harvest Index (HI) is used to denote the fraction of economically useful products of a plant in relation to its total productivity (grain to straw ratio) and calculated using following formula as given by Khandakar (1985).

$$HI = (EY/BY) \times 100$$

where; HI = Harvest Index, EY = Economic Yield (grain yield),

BY = Biological Yield (grain + straw)

3. RESULTS AND DISCUSSION

3.1 Phytosociology of tree crops

Data in table-1, shows the results on structural variations in horticulture and forest community in agrihortisilviculture (AHS) system on the northern aspect of Thauldhar block (site-N_1). Among the different species, the highest frequency (70 %), density (1.05 trees/100m^2), TBC (404.50 cm^2/100m^2) and IVI (47.24) values were recorded for *Quercus leucotrichophora*. The lower IVI values were recorded for *Prunus amygdalus* (3.08), *Citrus limon* (4.43), *Lyonia ovalifolia* (5.17) and *Pinus roxburghii* (5.75). In AHS system, a total of 21 species were observed. In AHS system on southern aspect of Thauldhar block (site-S_1) 13 tree species were reported, out of which the highest IVI values were obtained for *Grewia optiva* as 61.20 (Table-1). The *Quercus leucotrichophora, Emblica officinalis,* and *Pyrus pashia* had lower IVI values in this site (aspect), hence considered under suppressed category of tree community. The IVI values of present investigation were in concurrence with the studies conducted in the traditional agroforestry systems in the Bilaspur and Raipur districts of Chhattisgarh region (Sharma *et al.*, 2006). The earlier studies have also demonstrated that the aspect had a marked effect on structure and diversity of forest ecosystems (Lata and Bisht, 1991; Bijalwan, 2002; Dhanai and Panwar, 1999; Sharma and Baduni, 2000; Maikhuri *et al.*, 2000). Lata and Bisht (1991) had reported that phytosociological characters differ among

Table 1: Phytosociological analysis of tree layer in the Agrihortisilviculture (AHS) system

Species	% Freq. (F)	Density (Trees/100m^2)	Abund.(A)	A/F Ratio	TBC (cm^2/100m^2)	IVI
Northern aspect (site-N$_1$)						
Fodder Trees						
Quercus leucotrichophora	70	1.05	1.50	0.021	404.50	47.24
Celtis australis	35	0.65	1.86	0.053	319.20	29.24
Grewia optiva	35	0.55	1.57	0.045	332.23	28.15
Ficus roxburghii	15	0.25	1.67	0.111	122.77	11.65
Alnus nepalensis	15	0.25	1.67	0.111	103.91	11.05
Timber and fuelwood trees						
Myrica esculenta	15	0.30	2.00	0.133	236.37	16.04
Melia azedarach	15	0.25	1.67	0.111	122.77	11.65
Rhododendron arboreum	15	0.25	1.67	0.111	122.77	11.65
Cedrus deodara	10	0.20	2.00	0.200	165.98	10.96
Ficus palmata	15	0.20	1.33	0.089	98.21	10.11
Pinus roxburghii	10	0.15	1.50	0.150	26.52	5.75
Lyonia ovalifolia	10	0.15	1.50	0.150	8.18	5.17
Temperate fruit plants						
Malus domestica	25	0.70	2.80	0.112	252.55	25.24
Juglans regia	20	0.25	1.25	0.063	188.77	15.07
Prunus persica	20	0.25	1.25	0.063	86.63	11.82
Prunus armeniaca	15	0.25	1.67	0.111	122.77	11.65
Prunus domestica	5	0.25	5.00	1.000	188.77	11.13
Pyrus communis	10	0.15	1.50	0.150	73.66	7.25
Prunus amygdalus	5	0.10	2.00	0.400	7.86	3.08
Subtropical fruit plants						
Citrus sinensis	15	0.25	1.67	0.111	122.77	11.65
Citrus limon	5	0.15	3.00	0.600	26.52	4.43
Total		6.60			3133.70	
Southern aspect (site-S$_1$)						
Fodder Trees:						
Grewia optiva	45	0.85	1.89	0.042	437.28	61.20
Ficus roxburghii	25	0.40	1.60	0.064	357.99	37.63
Celtis australis	15	0.30	2.00	0.133	167.62	21.81
Quercus leucotrichophora	5	0.10	2.00	0.400	49.11	6.95
Timber and fuelwood trees						
Melia azedarach	20	0.35	1.75	0.088	134.83	23.79
Toona ciliata	10	0.15	1.50	0.150	118.18	13.66
Ficus palmata	10	0.20	2.00	0.200	79.53	13.04
Pyrus pashia	10	0.15	1.50	0.150	94.61	12.57
Temperate fruit plants						
Juglans regia	15	0.25	1.67	0.111	268.91	25.32
Subtropical fruit plants						
Musa paradisiaca	30	0.70	2.33	0.078	287.35	43.74
Citrus limon	15	0.35	2.33	0.156	40.55	17.09
Citrus aurantifolia	10	0.35	3.50	0.350	50.65	15.23
Emblica officinalis	5	0.10	2.00	0.400	70.71	7.96
Total		4.25			2157.36	

aspects and position even in the same vegetation type.

The agrihorticultural (AH) on the northern aspect of Thauldhar block (site-N_2) showed a total of 11 fruit tree species (Table-2) which exhibited the results on structural variations in horticulture tree community. Among the different species, the frequency (65%), density (3.60 trees/100m^2), TBC (1566.95 cm^2/100m^2) and IVI (111.37) values were found highest for *Malus domestica*. The lower IVI values were recorded for *Carica papaya* (4.75), *Pyrus communis* (8.16), *Prunus amygdalus* (9.65) and *Citrus limon* (10.21). In the AH system on southern aspect of Thauldhar block (site-S_2) a total of 9 fruit tree species were recorded, among which the highest frequency and TBC values were observed for *Citrus sinensis* (30 % and 480.42 cm^2/100m^2). The highest IVI value was recorded for *Prunus armeniaca* (60.50) and it was said to be the dominant fruit species in this site (Table-2). The *Carica papaya*, *Prunus amygdalus* and *Prunus persica* were observed with low IVI values.

The apple based AH and AHS systems were more frequent, because apple fruit provides additional benefits to agricultural crops. It was also concluded that on the sloppy land the sole agricultural practice were difficult, therefore, different agroforestry combinations were preferred by the farmers.

3.2 Diversity indices of trees

The data presented in Table-3 reveals that, Shannon index (diversity) values in tree species of AHS and AH systems ranged from 0.808 to 1.208. The diversity was highest (1.208) on northern aspect of AHS system (site-N_1), while it was lowest (0.808) on southern aspect of AH system (site-S_2). Contrary to this, the Simpson index values were found to be highest (0.213) in AH system on southern aspect (sit-S_2). The concentration of dominance was found to be lowest (0.072) in AHS system of site-N_1. The species richness in different agroforestry systems for trees ranged from 1.113 to 2.484. The highest species richness value was recorded in AHS system on site-N_1. Among the different agroforestry systems, the highest equitability (0.397) was observed in AHS system on site-N_1 and lowest on site-N_2 of AH systems. Beta diversity was highest (2.154) on site-S_1 in AHS system, while it was lowest (1.333) on site-N_1 of AHS systems.

The diversity parameters of these agroforestry systems are comparable with the diversity indices reported by different workers for other regions in agroforestry and non-agroforestry systems (Toky *et al.*, 1989; Sharma *et al.*, 2006; Ralhan *et al.*, 1982; Singh and Sigh, 1991). Tewari *et al.* (1999) reported the Shannon-Weaver index values from 0.41 to 2.31, concentration of dominance from 0.38 to 1.00 in the Thar desert under natural silvipastoral system which are higher than the present study. The Simpson Index for the Keralese home garden varied 0.44 to 0.86 (Mohan Kumar et al., 1994; Jose, 1992) which is quite higher than the present study. The higher diversity values on northern aspects may be due to the higher moisture content and low insolation rates as compared to southern aspects, which receive the Sun rays in later part of the day, when the atmosphere is sufficiently warmed. The effect of aspect on structure and diversity of vegetation was also quantified by several workers (Joshi and Tiwari, 1990; Singh *et al.*, 1991; Jha, 2001).

3.3 Productivity of agricultural crops

A significant difference in productivity of agricultural crops was observed under agroforestry systems (Kharif + Rabi), when compared with control/sole agriculture system. The productivity of agricultural crops includes three components *viz.* (i) productivity of grain or seeds (also referred to as economic productivity) (ii) straw, which includes other than the grain (shoot and leaves) (iii) biological productivity or total productivity (includes grain and straw). In an agroforestry systems, the agricultural crop production is generally lower due to competition with trees, but the biomass production is adequately compensated due to overall productivity (tree + crop), which is generally greater than sole agriculture system (Newaj *et al.*, 2003)

3.4 Biological productivity (Grain and straw)

Under AHS systems the biological yield of agriculture crops was 4110 kg/ha/yr on site-N_1 with a reduction of 33.85 percent as compared to the sole agriculture crops (6070 kg/ha/yr) (Table-4). In the site-S_1 the biological yield was recorded to be 3455 kg/ha/yr as compared to 6392 kg/ha/yr in the control. The biological yield under AH system (Table-5) in the northern aspect (site-N_2) was recorded 3423 kg/ha/yr while it was 5210 kg/ha/yr under sole cropping in the same site. The reduction in biological yield under agrihorticulture system was 34.29 percent when compared with sole cropping. In the southern aspect of site-S_2 the biological yield under AH was 2876 kg/ha/yr while in open condition it was 5836 kg/ha/yr.

It was observed that the biological yield was reduced under agroforestry systems as compared to the sole cropping. The reduction in crop yield under agroforestry systems was mainly due to competition for the light, water, nutrients and allelopathic affect etc. The competition may be interspecific or intraspecific (Carnell, 1990). Shading was found to be more important than below ground competition in an intercropping study of pearl millet and groundnut in India (Willey and Reddy, 1981).

Table 2 : Phytosociological analysis of fruit tree layer in the Agrihorticulture (AH) system

Species	% Freq. (F)	Density (Trees/100m^2)	Abund.(A)	A/F Ratio	TBC (cm^2/100m^2)	IVI
Northern aspect (site-N$_2$)						
Temperate fruit plants						
Malus domestica	65	3.60	5.54	0.085	1566.95	111.37
Prunus domestica	25	1.25	5.00	0.200	681.06	43.17
Prunus armeniaca	40	0.85	2.13	0.053	470.37	39.76
Castanea sativa	20	0.30	1.50	0.075	288.75	19.71
Juglans regia	20	0.25	1.25	0.063	240.63	17.91
Prunus persica	10	0.45	4.50	0.450	79.53	11.85
Prunus amygdalus	5	0.25	5.00	1.000	176.79	9.65
Pyrus communis	5	0.20	4.00	0.800	141.43	8.16
Subtropical fruit plants						
Citrus sinensis	20	0.65	3.25	0.163	270.17	23.46
Citrus limon	10	0.35	3.50	0.350	61.88	10.21
Carica papaya	5	0.15	3.00	0.600	29.05	4.75
Total		8.30			4006.61	
Southern aspect (site-S$_2$)						
Temperate fruit plants						
Prunus armeniaca	30	0.95	3.17	0.106	425.97	60.50
Prunus persica	15	0.40	2.67	0.178	70.71	20.71
Prunus amygdalus	10	0.40	4.00	0.400	113.46	20.32
Subtropical fruit plants						
Citrus sinensis	30	0.60	2.00	0.067	480.42	56.17
Citrus limon	20	0.75	3.75	0.188	147.73	35.16
Emblica officinalis	20	0.35	1.75	0.088	247.50	32.32
Mangifera indica	20	0.60	3.00	0.150	158.45	32.61
Citrus aurantifolia	25	0.40	1.60	0.064	49.11	25.06
Carica papaya	10	0.30	3.00	0.300	94.29	17.15
Total		4.75			1787.64	

Table 3 : Aspect wise diversity of trees in different AHS and AH systems

AF system/Aspect	Shannon Index	Simpson Index	Richness	Equitability	Beta Diversity
AHS/N$_1$	1.208	0.072	2.484	0.397	1.333
AHS/S$_1$	0.999	0.121	1.563	0.389	2.154
AH/N$_2$	0.877	0.171	1.261	0.366	1.455
AH/S$_2$	0.808	0.213	1.113	0.368	1.778

AHS = Agihortisilviculture, AH = Agrihorticulture system,

N$_1$, N$_2$, = Northern aspects, S$_1$, S$_2$, = Southern aspects, Quadrat size 10x10m

3.5 Productivity of grains (economic yield)

The economic productivity include grain /seeds or edible parts of the agriculture crops. Table-4, shows the economic yield of agriculture crops under AHS system as 1197 kg/ha/yr on site-N$_1$ with a reduction of 40.85 percent as compared to the sole agriculture crops (2087 kg/ha/yr). In the site-S$_1$ the economic yield was recorded to be 1169 kg/ha/yr as compared to 2297 kg/ha/yr in the control. The economic yield under AH system (Table-5) in the

Table 4 : Productivity of Agriculture crops (kg/ha/yr) under agrihortisilviculture (AHS) systems

Agricultural crops	AS system (Productivity in kg/ha/yr)*				Control/Sole Ag. crop (Productivity in kg/ha/yr)				% Decrease from control	
	Grain	Straw	B.Y.	H.I.	Grain	Straw	B.Y.	H.I.	Grain	B.Y.
Northern aspect (site-N_1)										
Kharif (Summer season)										
Zea mays	661	1887	2548	25.94	1002	2294	3296	30.40	34.03	22.71
Eleusine coracana	745	3360	4105	18.15	1487	4205	5692	26.12	49.88	27.88
Echinochloa frumentacea	983	1952	2935	33.49	1302	1704	3007	43.30	24.52	2.38
Amaranthus caudatus	519	2655	3174	16.35	784	4626	5410	14.49	32.80	41.33
Fagopyrum esculentum	745	2617	3362	22.16	953	3110	4063	23.46	21.84	17.26
Phaseolus vulgaris	466	523	989	47.12	958	1117	2075	46.17	51.37	52.34
Vigna umbellata	330	634	964	34.23	443	727	1170	37.86	25.44	17.58
Glycine max	542	576	1118	48.48	873	956	1829	47.73	37.92	38.87
Average	624	1776	2400	26.01	975	2343	3318	29.02	34.06	27.55
Rabi (Winter season)										
Triticum aestivum	929	1682	2611	35.58	1331	2129	3460	38.46	29.67	24.54
Brassica compestris	186	506	692	26.88	428	933	1361	31.45	56.59	49.18
Pisum sativum	605	1223	1828	33.10	1396	2038	3434	40.65	56.68	46.76
Average	573	1137	1710	33.51	1052	1700	2752	38.08	47.65	40.16
Total (Rabi + Kharif)	1197	2913	4110	29.12	2027	4043	6070	33.13	40.85	33.85
Southern aspect (site-S_1)										
Kharif (Summer season)										
Zea mays	528	1836	2364	22.34	938	2359	3297	28.42	43.72	28.29
Eleusine coracana	653	1438	2091	31.23	1461	4231	5692	25.67	55.28	63.26
Echinochloa frumentacea	911	1425	2336	39.00	1202	1703	2907	41.35	24.23	19.63
Amaranthus caudatus	457	2545	3002	15.22	774	4635	5411	14.30	40.98	44.51
Phaseolus vulgaris	481	532	1013	47.48	791	832	1623	48.74	39.19	37.56
Dolichos uniflorus	269	548	817	32.93	511	733	1244	41.08	47.36	34.32
Glycine max	585	698	1283	45.60	892	947	1839	48.50	34.37	30.24
Average	555	1289	1844	30.10	938	2207	3145	29.83	40.73	36.83
Rabi (Winter season)										
Triticum aestivum	603	1170	1773	34.01	1321	2139	3460	38.18	54.33	48.76
Pisum sativum	624	826	1450	43.03	1396	1638	3034	46.01	55.28	52.21
Average	614	997	1611	38.09	1359	1888	3247	41.85	54.81	50.48
Total (Rabi + Kharif)	1169	2286	3455	33.84	2297	4095	6392	35.94	47.77	43.66

BY- Biological Yield, HI- Harvest Index, Control- sole/pure agriculture crops

northern aspect (site-N_2) was recorded 1180 kg/ha/yr against 1962 kg/ha/yr under sole cropping in the same site. The reduction of grain yield under agrihorticulture system is 39.85 percent when compared with sole cropping. In the southern aspect of site-S_2 the economic yield under AH was 792 kg/ha/yr while in open condition it was 1845 kg/ha/yr that shows the net reduction in economic yield of 57.08 percent.

In the present study the reduction of grain yield under different agroforestry systems was in conformity with the findings of Wahua and Miller (1978), Shivaramu and Shivashankar (1992) and Sharma and Chauhan (2003), who had also recorded poor performance of soybean crop under tree species. The studies of Khybri *et al.* (1992) on tree-crop interaction under *Grewia optiva, Morus alba* and *Eucalyptus hybrid* with rice and wheat cropping systems showed that all tree species had adverse effects on crop yields, whereas, wheat was mainly affected by *Grewia optiva.* The deleterious effect on the average varied from 28 to 34 per cent, depending upon the species. It was observed that the agriculture crops yield increased with an increase of crop distance from the tree (Sharma *et al.*, 1996). Further it was also reported that in agroforestry systems the productivity was

Table 5 : Productivity of Agriculture crops (kg/ha/yr) under agrihorticulture (AH) systems

Agricultural crops	AH system (Productivity in kg/ha/yr)*				Control/Sole Ag. crop (Productivity in kg/ha/yr)				% Decrease from control	
	Grain	Straw	B.Y.	H.I.	Grain	Straw	B.Y.	H.I.	Grain	B.Y.
Northern aspect (site-N_2)										
Kharif (Summer season)										
Zea mays	642	1958	2600	24.69	829	1904	2733	30.33	22.56	4.87
Eleusine coracana	502	1139	1641	30.59	1105	2787	3892	28.39	54.57	57.84
Phaseolus vulgaris	559	537	1096	51.00	1147	1195	2342	48.98	51.26	53.20
Vigna umbellata	285	506	791	36.03	389	938	1327	29.31	26.74	40.39
Glycine max	577	622	1199	48.12	923	1075	1998	46.20	37.49	39.99
Average	513	952	1465	38.09	879	1579	2458	36.64	38.52	39.26
Rabi (Winter season)										
Triticum aestivum	628	1759	2387	26.31	907	2000	2907	31.20	30.83	17.90
Pisum sativum	707	822	1529	46.24	1259	1338	2597	48.48	43.84	41.11
Average	667	1291	1958	34.07	1083	1669	2752	39.35	37.33	29.50
Total (Rabi + Kharif)	1180	2243	3423	53.83	1962	3248	5210	38.13	39.85	34.29
Southern aspect (site-S_2)										
Kharif (Summer season)										
Amaranthus caudatus	291	1094	1385	21.01	730	5255	5985	12.20	60.09	76.86
Phaseolus vulgaris	237	406	643	36.86	655	905	1560	42.05	63.90	58.81
Dolichos uniflorus	323	566	889	36.33	638	936	1574	40.53	49.37	43.52
Glycine max	584	824	1408	41.48	1113	1065	2178	51.10	47.55	35.38
Average	359	722	1081	33.21	784	2041	2825	27.76	55.23	53.64
Rabi (Winter season)										
Triticum aestivum	553	1797	2350	23.53	1473	2343	3816	38.60	62.48	38.44
Coriandrum sativum	204	667	871	23.42	501	1275	1776	28.21	59.31	50.95
Pisum sativum	544	1620	2164	25.14	1209	2232	3441	35.14	55.01	37.13
Average	433	1362	1795	24.18	1061	1950	3011	35.24	58.93	42.17
Total (Rabi + Kharif)	792	2084	2876	27.54	1845	3991	5836	31.61	57.08	47.91

BY- Biological Yield, HI- Harvest Index, Control- sole/pure agriculture crops

improved as the distance from the tree is increased (Dhyani and Tripathi, 1999). Similarly in comparison to sole crop, linseed yielded 79, 73, 65 and 56 percent grain yield, when grown with Albizia, Mandarin, Alder and Cherry tree species (Dhyani *et al.*, 1994). Overall, the reduction in the yield of intercrops due to presence of trees may be attributed to differential patterns of canopy spread, resulting in variation in light interception, severe competitions of the tree roots for moisture and shade effects. The study carried by Newaj *et al.* (2003) showed that the grain yield of pure crops was higher as compared to the grain yield from the tree-crop systems.

3.6 Productivity of straw

The productivity of straw includes the yield of shoot and crop herbage from the unit area. Table-4, shows that under AHS systems the straw yield of agriculture crops was 2913 kg/ha/yr on site-N_1 as compared to 4043 kg/ha/yr in sole agriculture crops. In site-S_1 the straw yield was recorded to be 2286 kg/ha/yr as compared to 4095 kg/ha/yr in the control condition (sole cropping). The straw yield under AH system (Table-5) in the northern aspect (site-N_2) was recorded 2243 kg/ha/yr while 3248 kg/ha/yr under sole cropping in the same site. In the southern aspect of site-S_2 the straw yield under agrihorticulture was 2084 kg/ha/yr while in open condition it was 3991 kg/ha/yr. The straw yield was comparatively low under agroforestry systems, as compared to sole agriculture system. The higher straw yield in the sole cropping systems was attributed to the availability of high PAR (Photosynthetic Active Radiation), which helped in more reproductive phase development (Bellow, 2004).

REFERENCES

Atul., Punam. and Khosla, P.K. 1990. Cllasification of Traditional Agroforestry systems. Proc. IUFRO, 19th World Forestry Congress, Montreal. pp 24-27.

Bellow, J.G. 2004. Fruit-Tree-Based Agroforestry in the

Western Highlands of Guatemala: An evaluation of Tree-Crop Interactions and Socioeconomic characteristics. Ph.D. Thesis, Graduate School of the University of Florida, USA.

Bijalwan, A. 2002. Land use and vegetation analysis of Dry Tropical forest ecosystem in Balamdi watershed using satellite Remote Sensing Techniques and GIS. M.Sc. Thesis, Indira Gandhi Agriculture University, Raipur, India.

Carnell, J.H. 1990. "Apparent versus real" competition in plants. In: Grace, G.B. and Tilman, D (eds.), Perspective on plant competition, Academic Press, New York, USA. pp 9-26.

Curtis, J.T. and Mc Intosh, R. P. 1950. The interrelationship of certain analytic and synthetic phytosociological characters. *Ecology* 31: 434-455.

Dadhwal, K.S., Narain, P. and Dhyani, S.K. 1989. Agroforestry Systems in the Garhwal Himalayas of India. *Agroforestry Systems* 7: 213-225.

Dhanai, C.S. and Panwar, V.P. 1999. Role of aspect and soil on the structure and composition of *Quercus floribunda* natural stands in Garhwal Himalaya. *Indian Forester* 125(12): 1204-1213.

Dhyani, S.K. and Tripathi, R.S. 1999. Tree growth and crop yield under agrisilvicultural practices in north-east India. *Agroforestry Systems* 44: 1-12.

Dhyani, S.K., Singh, B.P., Chauhan, D.S. and Prasad, R.N. 1994. Evaluation of MPTs for agroforestry systems to ameliorate infertility of degraded acid alfisols on sloppy lands. In: Panjab Singh *et al.* (eds.) Agroforestry systems for degraded lands, New Delhi: Oxford and IBH Publishing. Vol I, pp 241-247.

Jha, S.K. 2001. On upper Bias in forest cover data of hilly terrain obtained through satellite imagery with special reference to Mizoram. *Indian Forester* 127(8): 871-878.

Jose, D. 1992. Structure and productivity of the homegardens of Kerala: a case study. Pp. 17-19. In: C.G.R. Ramachandran nair (ed.) Proceedings of the Fourth Kerala Science Congress. Feb. 27-29, 1992, Thrissure, Science, Technology and Environment Department of Kerala, Thiruvananthapuram.

Joshi, N.K. and Tiwari, S.C. 1990. Phytosociological analysis of woody vegetation along an altitudinal gradation in Garhwal Himalaya. *Indian Journal of Forestry* 13(4): 322-328.

Khandakar, A.L. 1985. Screening genotypes of higher Harvest Index. Ann. Report: pp158-165.

Khybri, M.L., Gupta, R.K., Ram, S. and Tomar, H.P.S. 1992. Crop yields of rice and wheat grown in rotation as intercrops with 3 tree species in the outer hills of Western Himalaya. *Agroforestry Systems* 17(3): 193-204.

Lata, k. and Bisht, N.S. 1991. Quantitative analysis and regeneration potential of moist temperature forest in Garhwal Himalayas. *Indian Journal of Forestry* 14(2): 98-106.

Maikhuri, R.K., Semwal, R.L., Rao, K.S., Singh, K. and Saxena, K.G. 2000. Growth and ecological impacts of traditional agroforestry tree species in Central Himalaya, India. *Agroforestry Systems* 48: 257-272.

Margalef, D.R. 1958. Information Theory in Ecology. *Yearbook of the society for General Systems Research* 3: 36-71.

Mohan Kumar, B, Suman Jacob, G and Chinnamani, S. 1994. Diversity, structure and standing stock of wood in the homegardens of Kerala in peninsular India. Agroforestry Systems 25: 243-262.

Newaj, R., Bhargava, M.K., Yadav, R.S., Ajit and Shanker, A.K. 2003. Tree-crop interaction in Albizia procera based agroforestry system in relation to soil moisture, light and nutrients. *Indian Journal of Agroforestry* 5(1&2): 17-29.

Phillips, E.A. 1959. Methods of vegetation study. A Holt Dryden Book Henry Hold & Co., Inc.

Pielou, E.C. 1975. Ecological Diversity. John Wiley and Sons. New York, pp 165.

Ralhan, P.K., Saxena, A.K. and Singh, J.S. 1982. An analysis of forest vegetation at and around Nainital in Kumaun Himalaya. *Proceedings of Indian National Science Academy* B48: 121-137.

Saroj, P.L. and Dadhwal, K.S. 1997. Present status and future scope of mango based agroforestry systems in India. *Indian Journal of Soil Conservation* 25(2): 118-127.

Shannan, C. and Weaver, W. 1963. The mathematical theory of communication. University of Illinois press, Urbana,U.S.A. pp 117.

Sharma, C.M. and Baduni, N.P. 2000. Structural attributes and growing stock variations on different aspects of high Himalayan and Siwalik chirpine forests. *Journal of Tropical Forest Science* 12(3): 482-492.

Sharma, K.K., Khanna, P. and Gulati, A. 1996. The growth and yield of wheat and paddy as influenced by *Dalbergia sissoo* Roxb. Boundary plantation. *Indian Forester* 122(12): 114-126.

Sharma, S.B., Pandry, S., Upadhyaya, S.D. and Agrawal, R. 2006. Phyto-sociological studies of tree species outside forest in traditional agroforestry of Chhattisgarh. *Indian Journal of Agroforestry* 8(1): 26-34.

Sharma, S.K. and Chauhan, S.K. 2003. Performance of soybean crop under tree species. *Indian Journal of Agroforestry* 5(1& 2): 137-139.

Shivaramu, H.S. and Shivashankar, K. 1992. Performance of sunflower and soybean (*Glycine max*) in intercropping with different plant populations and planting patterns. *Indian Journal of Agronomy* 37: 231-236.

Simpson, E.H. 1949. Measurement of diversity. *Nature* 163: 688.

Singh, L. and Singh, J.S. 1991. Species structure, dry matter dynamics and carbon flux of a dry tropical forest in India. *Annals of Botany* 68: 263-273.

Singh, R., Sood, U.K., Bhatia, M. and Thakur, G.C. 1991. Phytosociological studies on tree vegetation around Shimla, Himanchal Pradesh. *Indian Journal of Forestry* 14(3): 169-180.

Singh, R.V. 1986. People's participation in social forestry programme in Himachal Pradesh. F.R.I., Dehradun, pp 28.

Singh, K.A., Rao, R.N. Pitiram. and Bhutia, D.T. 1980. Large Cardamon Plantation: An age old agroforestry system in Eastern Himalayas. *Agroforestry Systems* 9: 241-257.

Tewari, J.C., Bohra, M.D. and Harsh, L.N. 1999. Structure and Production Function of Traditional Extensive Agroforestry Systems and Scope of Intensive Agroforestry in Thar Desert. *Indian Journal of agroforestry* 1(1): 81-94.

Toky, O.P., Kumar, P. and Khosla, P.K. 1989. Structure and function of traditional *Agroforestry Systems* in the western Himalaya. I. Biomass and productivity. *Agroforestry Systems* 9(1): 47-70

Wahua, T.A.T. and Miller, D.A. 1978. Effect of shading on the N_2 fixation, yield and place composition of field grown soybeans. *Agronomy Journal* 70: 387-392.

Whittaker, R.H. 1977. Evolution of species diversity in land communities. In: M.K. Hecht, W.C. Streere and B. Wallace (eds.). Evolutionary Biology, Vol. 10, Plenum, New York, pp 1-67.

Willey, R.W. and Reddy, M.S. 1981. A field technique for separating above and below ground interaction in intercropping: An experiment with pearl millet/groundnut. *Experimental Agriculture* 17: 257-264.