Structure of Understorey Vegetation in Native and Exotic Plantations of Semi-Arid Regions of Punjab, India.

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Abstract: In the present study we have compared the native *Dalbergia sissoo* and exotic *Eucalyptus* hybrid plantations of semi-arid regions of Hoshiarpur. Total 37 plants were reported from both the sites. Exotic plantation sites reported higher number of species, genera and Shannon-Wiener's diversity. These sites were dominated by exotic weeds like *Lantana camara*, *Parthenium hysterophorus*, *Murraya koenigii* etc., which were using most of the resources. Native plantation sites on the other hand were dominated by *Cannabis sativa* and a good number of saplings (390 individuals ha^{-1}) and seedling (1000 individuals ha^{-1}) of native tree species. [Nature and Science 2009; 7(12):79-85]. (ISSN: 1545-0740).

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1. Introduction

An ecosystem occupies a volume, and distribution of individuals varies within this volume. Volume spacing of individuals of different species provides an ecosystem its structure. This structure is evolved on account of interactions of individuals with environmental factors, and is an essential tool to be familiar with the health status of any ecosystem. Biodiversity is an important constituent of structure of an ecosystem and is vital for human survival and economic well being, as it enhances productivity and stability of ecosystem (Tilman et al., 1996).

Plantations, as part of terrestrial ecosystems, are of immense value for their production and protection potential. They usually include exotic species, non-local native species, or native species typically forming extensive pure stands. There is a common belief that the managed forests negatively influence biodiversity, but recent studies (Parrotta, 1995; Otsoma, 2000; Viisteensari et al., 2000) have shown that they can help in enhancing the recruitment, establishment and succession of native woody species by functioning as foster ecosystem, as they stabilizes the soil and create conditions favourable for native animals and plants to re-colonize (Parrotta, 1995; Yirdaw, 2002).

Over the last twenty years the Forest Department on an average has been planting between 15-25 million plants per annum in Government/Private areas. But, without proper care and management, most of these plantations represent a highly disturbed fragment of vegetation. They are mainly explored for fuel-wood and cattle grazing. In the present study, understorey vegetation of *Eucalyptus* hybrid and *Dalbergia sissoo* were studied with an objective of knowing the dominance and diversity status of plant species under these plantations.

2. Material and Methods

2.1 Study site

Present study site is located between 30° 90' and 32° 05' N latitude and 75° 32' and 76° 12' E longitude. It has an average elevation of 296 metres (971 feet). May and June are the hottest months of the year during which the temperature rises to 45 °C. The average annual rainfall for the last five years is 832.32 mm. Hoshiarpur falls into two nearly equal portions of hill and plain country. Its eastern face consists of the westward slope of the Solar Singhi Hills; parallel with that ridge, a line of lower heights belonging to the Siwalik Range traverses the district from south to north, while between the two chains stretches a valley of uneven width, known as the Jaswan Dun. Its upper portion is crossed by the Sohan torrent, while the Sutlej sweeps into its lower end through a break in the hills, and flows in a southerly direction until it turns the flank of the central range, and debouches westwards upon the plains.

2.2 Methodology

Thirty quadrats each of 1m x 1m sized were plotted in all the plantation sites. Analytic and synthetic characteristics like frequency, density, abundance and basal cover, relative frequency, relative density, relative dominance and importance value index of plant species were calculated using formulas given by Misra (1968). The data collected from the quadrats was further analyzed for the alpha and other diversity indices, and evenness. Various formulas used for the calculation of diversity indices are as follows:

Shannon-Wiener diversity index (Shannon and Wiener, 1963) was calculated from the importance values using the formula as given in Magurran (1988):

$$H' = -\sum_{i=1}^{s} pi \ln pi$$

where

H' is Shannon-Wiener Index of species diversity,

pi is the proportion of *i*th species and

s is the number of individuals of all the species.

Concentration of dominance (C_d) was calculated for the observation of strongest control of species over space in different sites (Simpson, 1949).

$$C_d = \sum_{i=1}^{s} (pi)^2$$

where

pi is the proportion of *i*th species, and s is the number of individuals of all the species.

Evenness was calculated following Pielou (1966), which reads;

$$J = \frac{H'}{\ln s}$$

where

H' is the Shannon-Wiener diversity index, and s is the number of species.

2.3 Statistical Analysis

Student's t-test was applied to analyze significance of the data. SPSS was used for the statistical analysis.

3. Results

3.1 Taxonomic and life-form diversity

Total 37 plant species and 34 genera belonging to 21 families were found in the two plantations (Table 1). *Eucalyptus* hybrid plantation reported higher number of species and genera than *Dalbergia sissoo* plantation. *D. sissoo* reported higher number of families. Other than herbs, all the life-forms reported higher richness in *E.* hybrid plantation. Equal numbers of tree saplings (four) were present in both the plantations, whereas tree seedlings were present in native plantation only.

3.2 Density and total basal area

Density of shrub species in *Eucalyptus hybrid* plantation forest of Dholbah varied between 30 and 720 individuals ha^{-1} (Table 2). Contribution of top three species, all weeds, was 77.19%. Total basal area was the maximum for *Lantana camara* (0.950 m^2 ha^{-1}) and minimum for *Crataeva nurvala* (0.029 m^2 ha^{-1}). In herb layer, *Setaria glauca* was the most densely (17000 individuals ha^{-1}) distributed species, and maximum basal area (0.923 m^2 ha^{-1}) was recorded for *Dactyloctenum aegypticum*. In Nara (Table 3), only two shrubs (both exotic weeds) were present in the understorey of *E.* hybrid plantation forest. *L. camara* with 93.02% density and 83.91% basal area was the more represented species. Density of herb layer ranged between 100 and 9750 individuals ha^{-1}. Top five species, mostly weeds, contributed 81.48% to the total density of the stand.

Table 1. Taxonomical and life-form diversity under *Eucalyptus* hybrid and *Dalbergia sissoo* plantations

Parameters	Total	*E.* hybrid	*D. sissoo*	Percentage gain or loss (*E.* hybrid over *D. sissoo*)
Species	37	27	21**	22.22
Genera	34	25	20**	20.00
Families	21	15	16^{ns}	- 6.67
Herbs	10	6	8*	- 33.33
Shrubs	10	8	6^{ns}	25.00
Tree (seedlings)	1	0	1^{ns}	-
Tree (saplings)	6	4	4^{ns}	0.00
Grasses	8	7	4^{ns}	42.86
Sedges	1	1	0^{ns}	100.00
Climbers	1	1	0^{ns}	100.00

* & ** are significant changes in values at P<0.05 and 0.01, respectively & ns- non significant for two sample t-test.

Table 2. Density, total basal area (TBA), relative frequency, density and dominance, and importance values (IVI) of

understorey vegetation in *Eucalyptus* hybrid plantation of Dholbah, Hoshiarpur.

Name of Plant Species	Density (individuals/ ha)	TBA (m^2)	Relative Frequency	Relative Density	Relative Dominance	IVI
Shrub Layer						
Lantana camara Linn.	720	0.950	32.00	42.11	38.64	112.75
Murraya koenigii (Linn.) Spreng	270	0.448	16.00	15.79	18.24	50.03
Parthenium hysterophorus Linn.	330	0.457	8.00	19.30	18.58	45.88
Casearia tomentosa Roxb.	180	0.312	16.00	10.53	12.69	39.22
Butea monosperma (Lamk.) Taub.	60	0.118	8.00	3.51	4.79	16.30
Carissa cavandas Linn.	60	0.054	8.00	3.51	2.21	13.72
Holarrhena antidysenterica Wall.	30	0.054	4.00	1.75	2.21	7.96
Cassia fistula Linn.	30	0.036	4.00	1.75	1.46	7.21
Crataeva religiosa Forst.	30	0.029	4.00	1.75	1.17	6.93
Herb Layer						
Dactyloctenum aegyptium (Linn.) P. Beau.	814	0.923	5.17	10.47	34.00	49.64
Trumfetta rhomboidea Jacq.	10500	0.464	12.07	14.85	17.08	44.00
Setaria glauca (Linn.) P. Beauv.	17000	0.163	12.07	24.05	6.02	42.14
Sida cordifolia Linn.	9000	0.298	15.52	12.73	11.00	39.25
Poa annua. Linn.	10000	0.049	10.34	14.14	1.81	26.30
Setaria verticillata (Linn.) P. Beauv.	4100	0.322	5.17	5.80	11.86	22.83
Cynodon dactylon (Linn.) P. Beauv.	4800	0.094	3.45	6.79	3.47	13.71
Commelina benghalensis Linn.	1300	0.102	6.90	1.84	3.76	12.50
Ichnocarpus frutescens Br.	500	0.039	6.90	0.71	1.45	9.05
Oxalis corniculata Linn.	1200	0.034	5.17	1.70	1.25	8.12
Desmodium concinuum DC.	800	0.040	5.17	1.13	1.48	7.78
Bidens bipinnata Linn.	900	0.057	3.45	1.27	2.11	6.83
Setaria intermedia Roem. and Schult.	900	0.045	3.45	1.27	1.67	6.39
Cyperus niveus Retz.	1700	0.048	1.72	2.40	1.77	5.90
Aerva sanguinolenta (Linn.) Blume	500	0.025	1.72	0.71	0.93	3.36
Tribulus terrestris Linn.	100	0.009	1.72	0.14	0.35	2.22

Table 3. Density, total basal area (TBA), relative frequency, density and dominance, and importance values (IVI) of understorey vegetation in *Eucalyptus* hybrid plantation of Nara, Hoshiarpur.

Name of Plant Species	Density (individuals/ ha)	TBA (m^2)	Relative Frequency	Relative Density	Relative Dominance	IVI
Shrub Layer						
Lantana camara Linn.	1220	1.107	66.67	93.02	83.91	243.60
Parthenium hysterophorus Linn.	100	0.212	33.33	6.98	16.09	56.40
Herb Layer						
Achyranthes aspera Linn.	9750	0.765	11.76	24.22	50.17	86.16
Trumfetta rhomboidea Jacq.	2400	0.188	13.73	14.91	12.35	40.98
Bidens bipinnata Linn.	1900	0.149	13.73	11.80	9.78	35.30
Aerva sanguinolenta (Linn.) Blume	2400	0.092	13.73	14.91	6.05	34.68
Setaria verticillata (Linn.) P. Beauv.	2600	0.033	11.76	16.15	2.14	30.05
Poa annua. Linn.	400	0.166	5.88	2.48	10.89	19.25
Sida cordifolia Linn.	900	0.057	9.80	5.59	3.75	19.15
Cynodon dactylon (Linn.) P. Beauv.	600	0.012	5.88	3.73	0.77	10.38
Commelina benghalensis Linn.	500	0.057	3.92	3.11	3.70	10.73
Ichnocarpus frutescens Br.	200	0.004	3.92	1.24	0.26	5.42

Cyperus niveus Retz.	200	0.001	3.92	1.24	0.09	5.26
Digitaria bifasciculata	100	0.001	1.96	0.62	0.05	2.63

In *D. sissoo* plantation forest of Chaksadhu, *Cannabis sativa* was the main contributor towards density (83.46%) and basal area (66.57%) of shrub layer. *Setaria verticillata* (density, 10400 individuals ha^{-1}) and *Achyranthes aspera* (basal area, 0.502 m^2 ha^{-1}) were the main herbs (Table 4). In case of Nara (Table 5), again *C. sativa* with 565 individuals ha^{-1} (73.86%) and 0.600 m^2 ha^{-1} (91.47%) density and basal area, respectively was the most represented shrub. In herb layer, maximum density was recorded for *Cynodon dactylon* (7200 individuals ha^{-1}) and maximum basal area for *A. aspera* (0.789 m^2 ha^{-1}).

The density of shrub and herb layers of *E.* hybrid and *D. sissoo* plantation was significant different whereas total basal area did not varied significantly.

Table 4. Density, total basal area (TBA), relative frequency, density and dominance, and importance values (IVI) of understorey vegetation in *Dalbergia sissoo* plantation of Chaksadhu, Hoshiarpur.

Name of Plant Species	**Density** (individuals/ ha)	**TBA** (m^2)	**Relative Frequency**	**Relative Density**	**Relative Dominance**	**IVI**
Shrub Layer						
Cannabis sativa Linn.	1110	0.258	33.33	83.46	66.57	183.36
Dalbergia sissoo Roxb.	180	0.119	44.44	13.53	30.69	88.67
Ziziphus mauritiana Lamk.	20	0.009	11.11	1.50	2.34	14.95
Murraya koenigii (Linn.) Spreng	20	0.002	11.11	1.50	0.41	13.02
Herb Layer						
Setaria verticillata (Linn.) P. Beauv.	10400	0.131	20.00	34.55	9.72	64.27
Achyranthes aspera Linn.	2500	0.502	10.00	8.31	37.37	55.68
Peristrophe paniculata	4800	0.305	15.00	15.95	22.70	53.65
Perilla frutescens (Linn.) Brittom	2300	0.116	12.50	7.64	8.60	28.74
Setaria glauca (Linn.) P. Beauv.	3800	0.075	10.00	12.62	5.55	28.17
Sida cordifolia Linn.	1200	0.076	12.50	3.99	5.68	22.16
Oplismenus compositus (Linn.) P. Beauv.	3100	0.061	5.00	10.30	4.53	19.82
Aerva sanguinolenta (Linn.) Blume	900	0.057	10.00	2.99	4.26	17.25
Euphorbia hirta Linn.	1100	0.022	5.00	3.65	1.61	10.26

3.3 Dominance

In *Eucalyptus* hybrid plantation of Dholbah (Table 1), *Lantana camara* (IVI, 112.75) was the most dominant shrub. *Murraya koenigii, Parthenium hysterophorus* and seedlings of *Casearia tomentosa* with importance values 50.03, 45.88 and 39.22, respectively were the co-dominants, and *Crataeva nurvala* was the least dominant species. Herb layer was dominated by *Dactyloctenum aegypticum* with 49.64 importance value closely followed by *Trumfetta rhomboidea* and *Setaria glauca* with 44.00 and 42.14 importance values, respectively. *Aerva javanica* and *Tribulus terrestris* were the rare species having less than 1% of the total importance value. Similar to Dholbah, *Lantana camara* (IVI, 243.60) was the most dominant shrub in *E.* hybrid plantation site of Nara also, whereas *Achyranthes aspera* was the most dominant herb. *Digitaria bifasciculata* was the least dominant species (Table 2).

In case of *D. sissoo* plantation in Chaksadhu, *Cannabis sativa* was the most dominant and *Murraya koenigii* the least dominant shrubs (Table 3). Herb layer was dominated by *Setaria verticillata* and co-dominated by *A. aspera* and *Peristrophe* paricularis. In Nara, the understorey shrub layer of *D. sissoo* was again dominated by *C. sativus*. *A. aspera*, with 63.21 importance value, was the most dominant and *Setaria glauca* (IVI, 9.60) was the least dominant herbs (Table 4).

Table 5. Density, total basal area (TBA), relative frequency, density and dominance, and importance values (IVI) of

understorey vegetation in *Dalbergia sissoo* plantation of Nara, Hoshiarpur.

Name of Plant Species	**Density** (individuals/ha)	**TBA** (m^2)	**Relative Frequency**	**Relative Density**	**Relative Dominance**	**IVI**
Shrub Layer						
Cannabis sativa Linn.	565	0.600	33.33	73.86	91.47	198.66
Cassia tora Linn.	170	0.013	25.00	11.11	2.04	38.15
Ziziphus mauritiana Lamk.	120	0.009	12.50	7.84	1.44	21.78
Casearia tomentosa Roxb.	20	0.014	8.33	1.31	2.16	11.80
Lantana camara Linn.	30	0.008	8.33	1.96	1.16	11.46
Crataeva religiosa Forst.	30	0.007	8.33	1.96	1.04	11.33
Trumfetta rhomboidea Jacq.	30	0.005	4.17	1.96	0.70	6.83
Herb Layert						
Achyranthes aspera Linn.	3100	0.789	17.07	11.61	34.52	63.21
Cynodon dactylon (Linn.) P. Beauv.	7200	0.565	2.44	26.97	24.75	54.15
Setaria verticillata (Linn.) P. Beauv.	6900	0.135	19.51	25.84	5.93	51.28
Sida cordifolia Linn.	1600	0.102	17.07	5.99	4.45	27.52
Ageratum conyzoides Linn.	2800	0.108	12.20	10.49	4.72	27.40
Perilla frutescens (Linn.) Brittom	1300	0.102	9.76	4.87	4.47	19.09
Commelina benghalensis Linn.	1200	0.212	4.88	4.49	9.28	18.65
Bauhenia variegata Linn.	1000	0.201	4.88	3.75	8.80	17.42
Aerva sanguinolenta (Linn.) Blume	500	0.057	7.32	1.87	2.47	11.66
Setaria glauca (Linn.) P. Beauv.	1100	0.014	4.88	4.12	0.60	9.60

3.4 Diversity

Species richness and Shannon-Wiener's diversity index of shrub and herb layers was more in exotic (*E.* hybrid) than native (*D. sissoo*) plantation sites (Table 6). The values of Simpson's dominance index were slightly higher (statistically non-significant) in *E.* hybrid plantation forest. Evenness of shrub layer was higher in *E. hybrid* plantation and of herb layer was higher in *D. sissoo* plantation forest. Species richness of herb layer and Shannon-Wiener's diversity index of both shrub and herb layers were significantly different among exotic and native plantation forests.

Table 6. Species richness, diversity indices and evenness of vegetation under exotic and native plantations

Richness/Diversity parameters	***E.* hybrid plantation**		***D. sissoo* plantation**		**t-test**	**P value**
	Dholbah	**Nara**	**Chaksadhu**	**Nara**		
Shrub Layer						
Species richness	9	2	4	7	ns	
Shannon-Wiener's index	1.80	0.54	0.65	1.19	1.72	0.043
Simpson's dominance index	0.22	0.69	0.47	0.46	ns	
Pielou's evenness	0.82	0.72	0.68	0.61	ns	
Herb Layer						
Species richness	16	12	9	10	3.18	< 0.001
Shannon-Wiener's index	2.43	2.13	2.05	2.13	1.77	0.038
Simpson's dominance	0.11	0.15	0.14	0.14	ns	
Pielou's evenness	0.88	0.86	0.93	0.92	ns	

4. Discussion

It is widely thought that plantation forests are, on average, less favourable as habitat for a wide range of taxa, particularly in the case of even aged, single species stands involving exotic species (Hartley, 2002). But, in the semi-arid conditions of Punjab, where anthropogenic disturbances have destroyed almost all the natural forests, plantation forests can be very fruitful in reviving the biodiversity of indigenous flora.

Floristic diversity of present plantation forests is less than earlier studies of plantations in India by Pande et al. (1988) and Dogra et al. (2009). This may be due to soil moisture limitations and anthropogenic disturbances. Dominance of therophytes and grasses in these plantations also supports the drought like conditions prevailing in these plantations.

Species richness of both shrub and herb layers was higher in exotic *E.* hybrid plantation sites than native *D. sissoo* plantation sites. These results are different from various earlier studies (Kadavul and Parthasarthy, 1999; Martin, 1999; Christer et al., 2008; Dogra et al., 2009), which reported higher diversity in native plantation sites. The reason for this may be invasion of shade intolerant (heliophytes) weeds like, *Lantana camara, Parthenium hysterophorus, Bidens bipinnata, Trumfetta rhomboidea, Cyperus niveus, Murraya koenigii, Crataeva nurvala* etc. in the open conditions. In case of *D. sissoo* plantation sites, after the development of canopies shade loving species (sciophytes) like *Cannabis sativa*, *Commelina benghalensis, Oplismenus compositus* etc. started dominating the sites and due to this successional change the native plantation sites reported low species richness.

Although, species richness was higher in *E.* hybrid plantation sites but, they were full of weeds. *L. camara*, an obnoxious weed, was the most dominant shrub of the *E.* hybrid plantation forests. Domination of *L. camara* may be ascribed to its control at the first stage of succession (Molina Colon and Lugo, 2006), which is also supported by its exclusion from native forest.

In tropical forests, values of species diversity (H′) vary between 5.06 and 5.40 (Knight, 1975). In Indian forests however, H′ varies between 0.00 and 4.21 (Bisht and Sharma, 1987; Parthasarathy et al., 1992; Visalakshi, 1995; Pande, 1999; Gautam et al., 2008). The values of H′ reported in the present study (0.54 to 2.43) are well within these limits. Pielou's evenness of shrub layer was higher in exotic than native plantation sites and *vice versa* in herb layer. This represents greater dominance by few species in exotic sites than in native sites where the species were distributed more evenly, similar to results from other studies (Ramjohn, 2001; Molina Colon and Lugo, 2006).

Often the role of exotic trees in the recovery of degraded ecosystems has been ignored, especially in tropical dry forests due to the dramatic changes that come from a long history of anthropogenic abuses. They protect against erosion and fires caused by humans and also may serve to rehabilitate ecosystem properties when natives are not capable of recolonizing immediately. Their high growth rate and productivity is likely to replenish environmental conditions that can improve the conditions for establishment of native flora (Martínez, 2007). In the present study also, exotic plantation sites were by no means lesser than the native plantations. Although, the dominant taxa was exotic weeds but during successional development, if anthropogenic disturbances decrease, the saplings of native tree species present in these sites will increase the canopy cover and eliminate them (weeds) from these ecosystems.

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