Regeneration and Plant Diversity of Natural and Planted Sal (*Shorea robusta* Gaertn.F.) Forests in the Terai – Bhabhar of Sohagibarwa Wildlife Sanctuary, India

D.S. Chauhan, Bhupendra Singh, Shashi Chauhan, C.S. Dhanai & N.P. Todaria

Department of Forestry, Post Box No. 59, H. N. B Garhwal University (Central University), Srinagar (Garhwal) –246174, Uttarakhand, India, e-mail: dschauhan2008@gmail.com; nptfd@yahoo.com

Abstract. We compared regeneration, tree diversity and floristic diversity of natural and planted tropical deciduous Sal (*Shorea robusta*) forest in Northeastern Uttar Pradesh, India. Species richness (105 and 95 species in natural and planted forests respectively) as well as species evenness was higher in natural forests than in planted forests. Natural forests also had higher mature tree, pole, sapling, and seedling densities compared to planted forest sites. In spite of differences in diversity, natural and planted forests did not differ significantly in species composition and 84 species occurred on both forests. Natural and planted forests did differ in soil moisture%, organic carbon%, available Nitrogen, Phosphorus, Potassium and soil pH. Dominant families in both forests types are Fabaceae (14 species), Mimosaceae, Euphorbiaceae and Moraceae (7 species each) followed by Verbenaceae and Caesalpiniaceae. Tree species dominated the flora (63 %). Of the 196 species found in both sites, 49% species showed good reproductive success, 40% species appeared poor and no seedling & sapling stages. The remaining 11% species were present as seedlings but not as adult individuals. Good quality timber species are not regenerating, with the exception of *Shorea robusta*, although mortality at seedling stages of this species is high. Our results suggest that the species richness and evenness differed between natural and planted forests and regeneration of some important tree species also varied from natural to planted forests due to differences in microclimate and soil characteristics. Moreover, the good reproductive success of both types of forests indicates the potential of forestry plantations in tropical deciduous forests. This study will help in the formation of effective forest management and conservation strategies. [Journal of American Science 2010;6(3):32-45]. (ISSN: 1545-1003).

Key words. *Shorea robusta, diversity, regeneration, natural forest, planted forest and density.*

Introduction

The species composition of forests depends on the regeneration of species composing the forest in space and time. Several types of disturbances affect the abundance and composition of seedlings in the forest understory (Benitez-Malvido 1998). An increasing interest in the development and management of mixed plantations, uneven-aged stands and natural forests has given rise to the need to understand the regenerative process that ensure maintenance of the community structure and ecosystem stability (Moravie *et al*. 1997). As floristic and structural composition change, the competitive relationship of species may change with corresponding changes in opportunities for regeneration (Barker & Kirkpatrick 1994).

The diversity of Sohagibarwa Wildlife Sanctuary is of prime importance because of its interesting flora and fauna. In the sanctuary, 75% of the area covered by Sal (*Shorea robusta*) is either natural or planted forests (Manikant 1994). More than half of the remaining forest in the Terai-Bhabhar of U.P. is dominated naturally by *Shorea robusta* Gaertn. f. (Dipterocarpaceae, locally called "Sal"). The Terai Sal forest is highly valuable timber species both commercial and subsistence purposes and also important for livestock nutrition, animal bedding & compost and biologically diversity (Glimour and Fisher, 1991; Webb and Sah, 2003). Although timber production is key component to sustainable management of sal forests, whether by industry or communities (Sah, 2000b). Plantation is considered to hold potential for timber production and in some cases site amelioration (Jackson, 1994).

Some studies on Indian Sal communities are available (Gupta & Shukla 1991, Panday & Shukla 1999, 2001) and have compared the *taungya* plantation with natural forest stand in Darjeeling Himalaya with greater emphasis on the alteration of landscape, loss of species and recovery of the system (Uma Shankar 2001) and in Nepal Terai Sal forests have been studies by Webb & Shah 2002; Rautiainen & Suoheimo 1997; Matherma 1991. The present study is an attempt to compare the regeneration, diversity and other community attributes in natural and planted Sal forest in the Terai–Bhabhar forest of Sohagibarwa Wildlife Sanctuary Forest Division (U.P.), India. We wished to examine how species diversity, tree regeneration and soil parameters differed in planted forests vs. natural forests. We hypothesized that regeneration differ in natural and planted forests and natural regeneration of existing species in planted forests. Such information may be useful for formulating conservation strategies for this wildlife Sanctuary and this hypothesis will provide important community-level information on natural and planted sal forest and its diversity. This information will be help full to the species which diversity and regeneration were high could be considered for afforestaion programme in future and to conserve the biological diversity in the sanctuary.

Methods

Study area: We carried out our study in the Sohagibarwa Wildlife Sanctuary, which is located in the Maharajganj district of Uttar Pradesh, India. The Indo-Nepal border constitutes the northern boundary of the WLS. It is located between 27^0 05' & 27^0 25'N latitudes and 83^0 20' & 84^0 10' E longitudes and at 95 m above mean sea level. The forest belts adjacent to foothills of Central Himalaya fall under Terai region (foot hills of sub-mountain Himalaya are mainly composed of silt and clay soil transported by rivers), the major part of which covers forested zone of Northeastern U.P. under Sohagibarwa Forest Division (Management and administrative unit of forest area). The area of Sanctuary is 428 km^2 (42,820 ha) (Manikant 1994). These forests boast some of the finest stands of Sal in this bio-geographic zone (Rodgers & Panwar 1988). This division comprises seven ranges- Lachhimipur, North Chauk, South Chauk, Madhualia, Nichlaul, Pakri and Sohagibarwa.

The forest cover is generally dominated by plantations of Sal (*Shorea robusta*) followed by Teak (*Tectona grandis*), Jamun (*Syzygium cumini*) and Khair (*Acacia catechu*). There are few stands of fast growing tree species such as *Trewia nudiflora, Albizia lebbek, Bauhinia* spp. *Terminalia tomentosa, T. arjuna* and a few others. The climate is seasonal and subtropical. The average annual rainfall is about 1814 mm, 87% of which occurs during the wet summer (April to June) or monsoon season (July to September). During the relatively dry period of about 8 months, i.e. January-June and November-December the monthly rainfall is less than 100 mm. The soil is old gangetic alluvium, texture is sandy loam and the soil p^H is neutral (Panday & Shukla 2001). The area falls under the Terai – Bhabar biogeographic subdivision of upper Gangetic plain (7A) following the biogeographic classification of Rodgers & Panwar (1988). Sanctary forests is characterized by following forest types (i) Group 2 - Tropical semi evergreen forest, sub group (ii) Group 3 - Tropical moist deciduous forest (iii) Group 4 - Tropical littoral and swamp forest (iv) Group 5 - Tropical dry deciduous forest (Champion & Seth's 1968). The present study was concentrated only sal dominated three types forests i.e Group 2,3 and 5.

Sal had been planted in the Sanctuary mostly using the *taungya* system. Sal plantation continued to become established between 1933 to 1994 using the *taungya* system. However, clear felling was not carried out after 1993-94 in this area. Under early working plans, old Sal forests were clear felled and Teak was planted through *taungya* system. In this system, *Syzygium cumini, Terminalia tomentosa*, *T. arjuna* and other species have also been planted (Ahassan 1984, Manikant 1994). Mixed species plantation comprising of *Tectona grandis, Dalbergia sissoo, Acacia catechu, Trewia nudiflora, Kydia calycina, Syzygium cumini* and *Terminalia* spp. etc. were established as early as in 1944-45 to 1953-54 (Ahassan 1984). In the years 1984-85 to 1991-92, gap planting (*Syzygium cumini* and *Terminalia tomentosa*) was carried out in grass free areas (Manikant 1994).

Field inventory: We conducted our studies during 2001-2002 at seven forest sites under above mentioned forest types. At each site, we surveyed both natural and planted forests using a stratified random sampling technique. About 1% of the area in each site was sampled. Within each forest, we sampled 0.2 ha plots (50m x 40m = 2000 m^2) for a total of 326 sample plots (215 natural + 111 planted forests). Within each sample plot, we surveyed nested in 2000 m^2, 20 quadrats (10 x 10m = 100 m^2) for mature trees and poles (young tree of 2 to 13 m. height and 10 to 30 cm dbh) (density of all stems and size) and 80 quadrats (5 x 5 m = 25 m^2) for shrub, sapling and seedlings (density and identity) nested in 2000 m^2. We define mature trees as stems > 30 cm dbh and >13 m height, poles as individuals >10 cm to < 30 cm dbh and > 2 to < 13 m height, sapling are individuals of > 1 cm to < 10 cm dbh and > 0.5 m to < 2 m height and seedling > 1 cm collar diameter and upto 0.5 m height. All sampled plants were counted and analyzed in each sample plot. The species sampled in the four layers of vegetation were classified into the following four growth forms: upper storey tree, under storey tree**,** shrub and climber.

The canopy cover of the trees was measured directly in the filed by spherical densiometer. Soil p^H and soil moisture were measured by the Kelway soil acidity and moisture meter (No. 221175, Ben Meadows Company, USA) directly in the field. In each forest inventory plot, four soil samples were for analyzed for Soil p^H. However, soil samples were collected only at every second species inventory plots on the Sanctuary sites. The samples were taken using an auger with a diameter of five cm. The samples representing topsoil were taken 0-20 cm beneath the ground surface and those representing subsoil were taken 20 – 50 cm beneath the ground. The soil samples were analyzed in the laboratory of the Forestry Department of HNB Garhwal University, Srinagar (Garhwal) and GB Pant Himalayan Institute & Development unit Srinagar (Garhwal), Uttarakhand, India. Available Nitrogen, Phosphorus, Potassium and Organic carbon were determined in the laboratory using the standard method of "Tropical Soil Biology and Fertility" (TSBF) (Anderson & Ingram, 1993).

Data analysis:. Frequency, density, basal area, and importance value index (IVI) were determined for each species following Mueller – Dombois & Ellenberg (1974).

The diversity indices was calculated are richness, Shannon's diversity index (*H),* Simpson's index (λ), evenness index (P) and Hill diversity index (N_1, N_2; i.e the number of dominating species). The data were analyzed statistically. In all comparison between tree and seedling density between natural and planted forest sites the t-test was used. A multivariate regression model of species richness and six explanatory variables such as soil characters in 326 plots in natural and planted forest sites were used. Linear regression analysis of seedling density vs adult density among all the plots was also made. Multiple regression analysis is widely used and considered one of the most efficient parametric tests (Hader & Grandage, 1958).

Results

Floristic composition, species richness and diversity: We found one hundred eighteen species in our plots (50 upperstory trees, 24 understorey trees, 36 shrubs and 8 climbers); with 105 species in natural forest and 94 in planted forest (Table 1) however, 84 species were found common to both types of forests.

The best-represented families in both forests were Fabaceae (14 species 12% of the total number of species), Mimosaceae, Euphorbaceae and Moraceae (7 species each), Verbenaceae and Caesalpiniaceae (6 species each), Rubiaceae (5 species), Combretaceae and Tiliaceae (4 species each). Fabaceae constituted 12% of the total number of species, followed by Mimosaceae, Euphorbiaceae and Moraceae with 6%, respectively. Species diversity as well as richness was higher in natural forests than in planted forest (Table 1). Similarly, the Hill diversity index was relatively higher in natural forest (Table 1). Species evenness (Pielou index) had relatively higher values in planted forests than in natural forests.

Table 1. Regeneration, soil parameters (mean ± S.D.), tree structure and diversity Indices of Sohagibarwa Wildlife Sanctuary.

Parameters	**Natural forests**	**Planted forests**
No. of plots	215.0	111.0
Tree density ha^{-1}	136.4 ± 42.0	107.4 ± 30.6
Pole density ha^{-1}	114.1 ± 37.2	61.3 ± 20.8
Sapling density ha^{-1}	158.7 ± 32.3	116.6 ± 13.0
Seedling density ha^{-1}	496.0 ± 163.0	276.0 ± 80.6
Species richness	105.0	94.0
No. of genera	81.0	74.0
No. of Families	49.0	47.0
Population density	23,522	15,275
Diversity index		
Shannon (H')	3.53	3.26
Simpson (C)	0.212	0.174
Evenness (E_1)	0.0346	0.0354
Hill diversity index		
N0	105.0	94.0
N1	29.75	28.83
N2	4.72	5.75
Canopy cover %	50-60	30-40
Soil moisture %	37.2 ± 1.5	26.3 ± 11.8
Soil organic Carbon %	2.2 ± 0.3	1.5 ± 0.3
Soil pH	7.2 ± 0.1	6.8 ± 0.1
Available Soil Nitrogen kg ha^{-1}	209.2 ± 18.3	170.0 ± 18.3
Available Soil Phosphorus kg ha^{-1}	10.7 ± 2.3	8.4 ± 1.3
Available Soil Potassium kg ha^{-1}	331.0 ± 21.4	294.5 ± 21.6

Stand structure, density, basal area and soil characteristics: Tree density and average pole density significantly differed ($P<0.05$) between natural and planted forests. Sapling density was not significantly different in natural and planted forests, while seedling density significantly differed ($P<0.05$) in natural and planted forests (Table 1). Total population densities of natural and planted forests were 23,522 and 15,275 individuals, respectively, in all the studied areas. Average canopy cover ranged from 50-60% in natural forest and 30-40.5% in planted forests. The soil moisture %, organic carbon %, soil p^H, available Nitrogen, Phosphorus and Potassium, however, were slight higher in natural forests than in planted forests in Sohagibarwa Wildlife Sanctuary (Table 1).

Upperstorey tree density: In natural forest tree species was found higher (23.40 %) as compared to the planted forests. The mature as pole density was 45.72 % higher in natural forest as compared to the planted forest. Similarly, sapling and seedling densities were also higher (41.68 %) in natural forest as compared to planted forests. In natural forests, the genera *Terminalia* (4 spp.), *Ficus* (3 spp.), *Syzygium*, *Lagerstroemia Albizia* and *Acacia* were represented by two species each and remaining 32 genera by one species each in natural forest (Table 2). Whereas, *Terminalia* (3 species), *Acacia, Ficus* and *Syzygium* were represented by two species each and remaining 27 genera by one species each in planted forests (Table 2). Density of *Shorea robusta* (Dipterocarpaceae) in mature and pole strata was highest as compared to other tree species while lowest tree density was recorded for *Terminalia chebula* in natural forests. However, *Tectona grandis* (Verbenanceae) and *Shorea robusta* density for mature tree and pole was highest in planted forests. While minimum mature tree and pole density was recorded for *Alangium salvifolium* in planted forests (Table 2). Sapling and seedling density of *Shorea robusta* was also recorded highest in natural forests, whereas, lowest sapling and seedling density was recorded for *Ficus religosa*. In planted forests, maximum sapling and seedling density was recorded again for *Shorea robusta*, while minimum density was observed for *Streblus asper* (Table 2).

Understorey tree density: In understory tree species number of tree were higher (26.08 %) in natural forest as compared to the planted forests. The mature and pole densities were maximum (49.95 %) in natural forest compared to the planted forest. Similarly sapling and seedling density was highest in natural forest which was 36.34 % greater than planted forest. The genera *Bauhinia* and *Ficus* had three species each; *Bridelia* and *Miliusa* (two species each) and rest 13 genera were represented by one species each in natural forests. Whereas, in planted forests *Ficus* (3 species), *Bridelia, Cassia* and *Miliusa,* (Two species each) and 8 other genera were represented by one species each (Table 2). *Mallotus philippensis* (Euphorbiaceae) was highest in mature tree and pole density in natural forests and lowest density was recorded for *Bauhinia recemosa*. While maximum mature tree and pole density was also recorded for *Bauhinia recemosa* in planted forests but minimum density was recorded for *Casearia graveolens* (Table 2). In sapling and seedling strata, highest density was recorded for *Bridelia retusa* and lowest density for *Ficus palmata* in natural forests. Whereas, maximum sapling and seedling density was observed for *Mallotus philippensis* and minimum density was recorded for *Casearia graveolens* in planted forests (Table 2).

Shrub and climber density: The shrub species that are characterized by short stature, armed, including annual or biannual herbs with spiny structures (thorns and prickles) and climbers included species that were shade- loving, are mentioned in table 2 only in sapling and seedling categories. The shrub species was 23.53 % greater in planted forest than natural forest. A total seedling and sapling density was higher (20.48 %) in natural forests as compared to the planted forests. In natural forests, the genera *Desmodium* and *Moghania* were represented by three species each, *Grewia* and *Smilax* by two species each and by 16 other genera with one species each. Whereas, in planted forests genera *Desmodium* was represented by 4 species *Moghania* by 3 species, *Grewia, Smilax* and *Trumfetta* by 2 species each and rest of 21 genera were represented by one species each (Table 2). The highest density was recorded for *Helictres iosra* in both types of forests and lowest density was recorded for *Leea sambussina* in natural forests. The number of climber species was also highest (12.5 %) in natural forest as compared to the planted forest. The total climber density was higher in natural forest which was 45.78 % greater than planted forest. In natural and planted forests all the genera were represented by one species each (Table 2). The highest density for *Lachrocarpus fruntasens* and lowest density was recorded for *Gloriosa superba* in natural forests. Whereas, maximum density was recorded for *Clerodendrum viscosum* and minimum density for *Gloriosa superba* in planted forests (Table 2).

Table 2. Floristic composition and density (Seedling, Sapling, Pole and Mature trees ha^{-1}) (Mean± S.D.) in Natural and Planted forests of Sohagiberwa Wildlife Sanctuary.

Species	Family	Mature tree and Pole density ha^{-1}		Sapling and seedling Density ha^{-1}	
		Natural forest	Planted forest	Natural forest	Planted forest
Upperstorey Trees					
Acacia catechu	Mimosaceae	145.22±40.20	14.50±4.50	217.38±27.12	48.75±25.13
Acacia nilotica	Mimosaceae	16.00±6.25	26.14±10.12	9.67±1.50	0.00
Adina cordifolia	Rubiaceae	139.25±27.52	41.10±15.36	200.2±94.19	49.35±13.03
Aegle marmelos	Rutaceae	85.15±29.51	0.00	58.86±20.98	0.00
Alangium salvifolium	Alangiaceae	185.15±78.26	12.67±0.94	0.00	17.00±5.00
Albizzia lebbek	Mimosaceae	58.50±8.50	0.00	0.00	0.00
Albizzia procera	Mimosaceae	18.00±9.25	0.00	0.00	0.00
Anthocephalus cadamba	Rubiaceae	90.00±42.16	170.00±81.85	0.00	0.00
Bombax ceiba	Bombaceae	66.67±34.09	35.25±16.53	0.00	20.00±1.25
Buchanania lanzan	Anacardiaceae	0.00	15.00±4.53	0.00	0.00
Butea monosperma	Fabaceae	49.33±23.12	0.00	0.00	0.00
Celtis tetrandra	Ulmaceae	132.50±17.50	21.80±5.25	250.0±65.46	109.00±33.66
Cordia dichotoma	Ehretiaceae	79.00±21.00	55.60±7.11	0.00	21.50±12.05
Dalbergia sissoo	Fabaceae	91.43±8.29	206.50±66.50	0.00	0.00
Dillenia pentagyna	Dilleniaceae	54.67±33.08	35.00±17.52	0.00	0.00
Diospyros tomentosa	Ebenaceae	0.00	120.67±18.50	79.00±16.05	180.37±57.15
Ehretia laevis	Ehretiaceae	77.00±40.77	53.73±7.41	616.00±51.14	0.00
Ficus glomerata	Moraceae	51.58±16.35	109.33±27.04	0.00	35.00±15.00
Ficus ramphii	Moraceae	75.20±24.72	29.00±7.12	0.00	37.50±15.19
Ficus religiosa	Moraceae	63.50±3.50	0.00	5.71±1.25	0.00
Gamelina arborea	Verbenaceae	83.33±37.14	0.00	0.00	0.00
Garuga pinnata	Burseraceae	190.50±70.50	0.00	0.00	30.50±3.50
Grewia subinaequalis	Tiliaceae	0.00	0.00	487.75±184.4	46.67±15.06
Holarrhena antidysenterica	Apocynaceae	0.00	0.00	569.20±48.72	330.45±97.84
Holopetela integrifolia	Ulmaceae	75.40±24.92	75.77±36.83	141.50±58.50	78.00±35.84
Kydia clycina	Malvaceae	55.00±27.00	0.00	0.00	0.00
Lagerstroemia parviflora	Lythraceae	134.83±34.41	74.50±26.47	14.78±9.05	170.00±62.31.00
Lagerstroemia speciosa	Lythraceae	29.00±16.58	0.00	0.00	0.00
Lannea cormendelica	Anacardiaceae	111.86±50.85	0.00	0.00	0.00
Madhuca indica	Sapotaceae	52.50±22.69	0.00	0.00	150.00±45.0
Mitragyna parviflora	Rubiaceae	86.80±46.48	0.00	97.00±18.92	91.58±10.50

Ougeinia oojeinensis	Fabaceae	27.00±12.03	67.1±8.12	93.50±51.62	18.00±6.00
Pongamia pinnata	Fabaceae	41.25±14.81	0.00	0.00	80.00±21.25
Pterocarpus marsupium	Fabaceae	25.00±12.42	0.00	0.00	0.00
Drypetes roxburghii	Euphorbiaceae	22.25±10.78	75.50±45.50	140.00±43.20	17.25±4.76
Schleichera oleosa	Sapindaceae	167.00±77.04	0.00	329.6±127.73	191.8±150.73
Semecarpus anacardium	Anacardiaceae	109.00±27.03	40.00±29.25	0.00	0.00
Shorea robusta	Depterocarpaceae	328.56±41.73	242.08±20.60	1045.44± 514.77	785.45± 419.98
Stereospermum suaveolens	Bignoiaceae	59.00±6.98	0.00	0.00	0.00
Streblus asper	Moraceae	141.50±58.50	32.00±8.116	88.25±15.64	12.0±4.00
Syzygium cerasoides	Myrtaceae	100.00±35.00	233.50±16.56	0.00	0.00
Syzygium cumini	Myrtaceae	271.69±85.94	43.43±18.18	693.0±150.38	420.42±97.66
Tectona grandis	Verbenaceae	135.25±58.49	259.08±88.47	64.00±10.42	208.62±66.1
Terminalia arjuna	Combretaceae	87.60±15.87	0.00	0.00	17.50±5.50
Terminalia bellirica	Combretaceae	28.12±6.12	30.25±11.25	0.00	0.00
Terminalia chebula	Combretaceae	14.00±2.45	0.00	0.00	0.00
Terminalia tomentosa	Combretaceae	140.71±61.05	67.75±16.10	53.50±20.62	0.00
Toona ciliate	Meliaceae	36.25±15.26	23.28±11.26	56.25±29.56	0.00
Trewia nudiflora	Euphorbiaceae	59.27±33.36	66.00±43.12	119.79±36.27	0.00
Understorey Trees					
Antidesma ghaesembilla	Euphorbiaceae	15.14±8.13	0.00	0.00	0.00
Barringtonia acutangula	Lecythidaceae	0.00	9.50±2.29	49.15±16.25	75.00±33.94
Bauhinia malabarica	Caesalpiniaceae	72.00±42.74	52.50±19.20	0.00	0.00
Bauhinia recemosa	Caesalpiniaceae	13.14±6.12	148.40±34.74	0.00	36.00±8.00
Bauhinia purpurea	Caesalpiniaceae	14.28±8.04	0.00	0.00	0.00
Bridelia retusa	Euphorbiaceae	87.80±12.72	79.83±32.50	619.01±79.25	36.00±24.00
Bridelia stipularis	Euphorbiaceae	18.37±6.12	0.00	241.3±37.79	80.00±20.00
Caesalpinia crista	Caesalpiniaceae	0.00	0.00	26.42±14.12	19.00±2.00
Casearia graveolens	Flacourtiaceae	0.00	6.33±2.05	34.00±9.33	13.00±4.32
Cassia fistula	Caesalpiniaceae	31.00±17.12	0.00	375.5±70.38	152.78±20.56
Cassia siamea	Caesalpiniaceae	0.00	0.00	0.00	111.25±34.36
Ficus hipsida	Moraceae	0.00	0.00	40.00±16.25	37.50±15.19
Ficus lacon	Moraceae	123.67±12.69	17.00±8.69	0.00	0.00
Ficus palmate	Moraceae	0.00	16.00±1.12	9.43±2.45	0.00
Litsea glutinosa	Lauraceae	28.50±17.50	0.00	312.50±75.89	60.00±35.00

Leucaenea luecocephala	Mimosaceae	33.67±16.54	0.00	0.00	0.00
Mallotus philippensis	Euphorbiaceae	321.43±191.33	102.30±23.22	422.5±33.53	581.4±267.27
Miliusa tomentosa	Anonaceae	55.67±4.12	64.00±13.95	334.33±70.25	75.80±26.32
Miliusa velutina	Anonaceae	0.00	0.00	112.00±64.19	470.00±215.
Phyllanthus emblica	Euphorbiaceae	20.25±12.05	0.00	0.00	0.00
Pithecelliobium dulce	Mimosaceae	32.25±18.91	0.00	0.00	0.00
Pygmaeopermna herbecea	Verbenaceae	120±67.93	0.00	0.00	0.00
Randia dumetorum	Rubiaceae	0.00	11.00±2.12	186.67±18.01	31.67±8.22
Salix tetrasperma	Sailiceaea	25.40±5.00	0.00	0.00	0.00
Shrubs					
Ardisia solanacea	Myrinaceae	0.00	0.00	513.0±192.25	306.13±79.12
Asparagus racemosa	Liliaceae	0.00	0.00	170.00±81.85	36.00±17.00
Ageratum conyzoides	Asteraceae	0.00	0.00	0.00	17.86±3.07
Aristolochia spp.	Aristolochiaceae	0.00	0.00	14.12±6.12	16.50±5.30
Berleria prioitis	Acanthaceae	0.00	0.00	0.00	208.00±41.5
Calamus tennis	Arecaceae	0.00	0.00	254.18±93.69	50.25±14.77
Callicarpa macrophylla	Verbenaceae	0.00	0.00	215.01±34.88	92.98±32.32
Calotropis procera	Asclepiadaceae	0.00	0.00	0.00	45.00±39.10
Carissa spinarum	Apocynaceae	0.00	0.00	213.00±13.94	39.50±11.29
Colebrookea oppositifolia	Lamiaceae		0.00	287.57±190.28	0.00
Curculigo orchioides	Ammaryllidaceae	0.00	0.00	0.00	77.67±11.50
Desmodium gangeticum	Fabaceae	0.00	0.00	60.14±19.26	31.50±10.50
Desmodium heterocarpon	Fabaceae	0.00	0.00	21.00±8.52	16.00±6.00
Desmodium latifolium	Fabaceae	0.00	0.00	220.00±10.92	130.00±50.50
Desmodium pulchellum	Fabaceae	0.00	0.00	0.00	104.00±32.00
Glycosmis pentaphylla	Rutaceae	0.00	0.00	698.6±189.67	242.6±49.81
Grewia hirsute	Tiliaceae	0.00	0.00	212.50±96.89	14.50±2.50
Grewia tiliaefolia	Tiliaceae	0.00	0.00	44.12±19.12	44.00±23.00
Helicteres iosra	Sterculiaceae	0.00	0.00	791.0±191.50	1371.0±711.5
Hymenodictyon spp.	Rubiaceae	0.00	0.00	434.2±273.46	25.50±10.50
Indigofera cassioides	Fabaceae	30.00±10.00	64.50±17.50	400.0±212.13	104.00±12.00
Lantana camara	Verbenaceae	0.00	0.00	0.00	1191.00±89.5
Leea sambussina	Tamaricaceae	0.00	0.00	10.00±6.25	11.00±2.00
Moghania chappar	Fabaceae	0.00	0.00	374.0±160.02	158.8±29.51

Moghania lineate	Fabaceae	0.00	0.00	20.00±11.26	29.50±2.50
Moghania prostrate	Fabaceae	0.00	0.00	618.0±181.33	60.00±10.0
Murraya koenigii	Rutaceae	0.00	0.00	384.56±56.8	114.75±64.97
Rawolifia serpentine	Apocynaceae	0.00	0.00	0.00	188.67±8.09
Rosa invducrata	Rosaceae	0.00	0.00	0.00	28.83±12.73
Smilax macrophylla	Smilaceaeae	0.00	0.00	652.1±162.15	221.50±21.50
Smilax prolifera	Smilacaceae	0.00	0.00	185.33±84.98	27.50±4.50
Tamarix dioice	Tamaricaceae	0.00	0.00	194.33±95.87	0.00
Tiliacora acuminate	Menispermaceae	0.00	0.00	274.64±52.32	148.68±47.76
Triumfetta pentandra	Tiliaceae	0.00	0.00	0.00	10.5±01.50
Triumfetta rhomboidea	Tiliaceae	0.00	0.00	0.00	332.25±113.5
Ziziphus mauritina	Rhamnaceae	0.00	0.00	296.00±26.70	473.8±237.67
Climbers					
Abrus precatorius	Fabaceae	0.00	0.00	250±91.25	0.00
Acacia concinna	Mimosaceae	0.00	0.00	45.60±15.29	250.00±91.25
Bauhinia vahlii	Caesalpiniaceae	0.00	0.00	319.2±169.26	84.73±25.04
Clerodendrum viscosum	Verbenaceae	0.00	0.00	810.4±110.33	699.0±62.10
Gloriosa superba	Liliaceaea	0.00	0.00	33.14±6.12	43.00±17.19
Lchnocarpus frutesens	Apocynaceae	0.00	0.00	811.0±201.85	136.50±20.50
Milletia auriculata	Fabaceae	0.00	0.00	57.00±11.26	112.67±43.39
Tinospora cordifolia	Menispermaceae	0.00	0.00	211.5±114.04	50.00±28.12

Regeneration: In natural forests eight new species were regenerating in sapling and seedling stages including two upperstorey tree species (*Grewia subinaequalis* and *Holarrhena antidysenterica*) and six understorey tree species (*Baringtonia accutangula, Caesalpinia crista, Casearia graveolens, Ficus hipsida, Ficus plamata and Randia dumetorum*). Similarly, in planted forests, fifteen new species were also regenerating in sapling and seedling stages including eight upperstorey tree species *(Grewia subinaequalis, Cordia dichotoma, Holarrhena antidysenterica, Madhuca indica, Mitragyna parviflora Pongamia piñnata, Schleichera oleosa* and *Terminalia arjuna*) and seven understorey tree species (*Bridelia stipularia, Caesalpinia crista, Cassia fistula, Cassia siamea, Ficus hipsida, Litsea glutinosa and Miliusa velutina*). Of all 105 species in natural forest, 46% species was found in all three stages i.e. seedlings, sapling and mature tree and 45% species appeared poor & no seedling and sapling stages. The remaining 9% species seems to be either reappearing or immigrating in natural forests. In planted forests, out of total 91 species, 52% species was found seedling, sapling and mature stages and 32% species showed poor & no seedling and sapling stages and remaining 16 % seems to be either reappearing or immigrating.

The multiple regression data computed between few important tree species, tree and seedling density and six explanatory variables (soil moisture, soil organic carbon, soil pH, N.P & K) for natural and planted forests are given in table 3 and 4. The multiple regression models revealed significant impact of soil characteristics on tree and seedling density in natural forest (Table 3)**.** The value of F-ratio is significant at 1% for *Bauhinia malabarica, Cassia fistula, Garuga pinnata, Holoptelea integrifolia, Lannea cormendelica, Miliusa tomentosa, Drypetes roxburghii, Shorea robusta, Schleichera oleosa, Streblus asper, Terminalia arjuna* and *T. tomentosa* trees densities and *Bridelia retusa, Celtis tetrandra, Cassia fistula, Diospyrous tomentosa, Lagerstroemia parviflora, Randia dumetroum, Syzygium cumini* and *Tectona grandis* seedlings densities. It shows that the systematic variation is considerably more than should be explained by chance. The multiple regression models revealed significant impact of soil characteristics on tree and seedling density in planted forest also (Table 4)**.** The value of F-ratio is significant at 1% for *Adina cordifolia, Bauhinia malabarica, Bridelia retusa, Mallotus philippensis, Terminalia tomentosa* trees densities and *Bauhinia recemosa, Garuga pinnata, Litsea glutinosa, Streblus asper, Syzygium cumini, Tectona grandis* seedling densities.

Discussion

The flora of Sohagibarwa Wildlife Sanctuary forest is characterized by overwhelming dominance of the tree species (74 tree species including understorey) as compared to shrub and climbers. Of all individuals, 63% belong to trees. The dominance of upperstorey and understorey species appears to be the characteristic features of dry deciduous forests (Seethram *et al*. 2000). The Sanctuary forest appears unusually rich in number of tree species compared to other Indian dry deciduous forest (Gupta & Shukla 1991) with 105 and 94 species in natural and planted forests across all the study sites. Generally tropical deciduous forests generally are remarkably consistent in their taxonomic composition (Uma Shankar 2001) with Leguminosae the most specious family followed by Bignoniaceae (Gentry 1995). This trend seems somewhat different for Indian deciduous forests wherein the Leguminosae is a dominant family (Sukumar *et al*. 1997, Uma Shankar 2001), followed by Euphorbiaceae and not Bignonaceae. Besides these, Moraceae, Verbenaceae, Rubiaceae, Tiliaceae and Combretaceae were the next, in that order, in the present study.

The total number of species under four categories: upperstorey tree, understorey tree, shrub and climber were significantly higher in the natural forests. The species richness was recorded greater in natural forests than natural Terai Sal forest of Nepal (Webb & Sah 2003), Central Himalayan forests (Singh & Singh 1992), deciduous forest in the Western Ghats (Sukumar *et al*. 1997). Shannon's diversity index (H') was higher in the study area (3.26 for planted forests and 3.53 for natural forests) than the 1.58- 3.53 index value recorded for Old Sal plantations in Gorakhpur (Panday & Shukala 1999, Shukala & Panday 2000), 2.65 - 2.94 for Western Ghats (Arunachalam 2002) and a tropical dry evergreen forest (2.28) in Southern India (Parthasarathy & Sethi 1997). This also indicates that the Sal forests in Eastern Himalaya are more or less similar to the present study sites in terms of species richness, but less diverse than the present study sites in terms of different life forms. It is perhaps due to rich transported soil of Tarai – Bhabhar. Historically Tarai – Bhabhar forest area is mainly composed of gangetic alluvium with a succession of beds of sands and loam of varying depth (Champion & Seth's 1968)**.** The surface soil in the low alluvium is very recent, but that in the high alluvium is mostly loamy sand varying in depth

Table 3. Regression equations for the tree species under study using parameters such as Soil Moisture, Soil Organic Carbon, p^H, Nitrogen, Phosphorus and Potassium with tree and seedling density in Natural Forest of SBWLS. No. of soil sample was 215.

Species		Regression equation coefficients		
		Intercept (SE)	R^2 (adjusted r^2)	F ratio (significance level)
Acacia catechu	Tree	955.088 (477.606)	0.022 (-0.035)	0.386 (0.886)
	Seedling	165.918 (67.475)	0.037 (0.015)	1.347 (0.238)
Adina cordifolia	Tree	-6.480 (77.301)	0.028 (-0.001)	0.999 (0.427)
	Seedling	-27.269 (229.65)	0.047 (0.019)	1.715 (0.119)
Alangium salvifolium	Tree	372.686 (215.979)	0.046 (0.019)	1.681 (0.127)
Anthocephalus cadamba	Tree	70.413 (107.402)	0.210 (-0.007)	0.744 (0.615)
Bauhinia racemosa	Tree	10.918 (8.033)	0.023 (-0.005)	0.817 (0.557)
Bauhinia malabarica	Tree	-43.791 (61.234)	0.229 (0.207)	10.322 (5.280)
Bridelia retusa	Tree	152.935 (94.165)	0.031 (0.003)	1.098 (0.364)
	Seedling	-357.195 (430.308)	0.297 (0.276)	14.661 (0.000)
Celtis tetrandra	Tree	164.686 (47.895)	0.044 (0.016)	1.576 (0.156)
	Seedling	304.128 (118.937)	0.087 (0.060)	3.286 (0.004)
Cassia fistula	Tree	112.91 (33.725)	0.111 (0.086)	4.360 (0.000)
	Seedling	-142.373 (193.403)	0.195 (0.172)	8.419 (0.000)
Dalbergia sissoo	Tree	50.844 (73.851)	0.018 (-0.011)	0.628 (0.707)
Diospyrous tomentosa	Seedling	266.787 (64.206)	0.098 (0.073)	3.789 (0.001)
Ficus lacon	Tree	83.531 (37.963)	0.019 (-0.009)	0.669 (0.674)
Garuga pinnata	Tree	-7.069 (122.255)	0.085 (0.059)	3.238 (0.004)
Holoptelea integrifolia	Tree	-11.009 (60.170)	0.137 (0.112)	5.504 (0.000)
	Seedling	96.761 (113.49)	0.048 (0.021)	1.752 (0.110)
Lagerstroemia parviflora	Tree	261.465 (120.927)	0.034 (0.006)	1.211 (0.302)
	Seedling	57.889 (22.940)	0.229 (0.208)	10.340 (5.080)
Lannea cormendelica	Tree	200.248 (91.820)	0.099 (0.073)	3.804 (0.001)
Litsea glutinosa	Tree	34.010 (31.256)	0.047 (0.020)	1.728 (0.115)
	Seedling	433.589 (172.707)	0.017 (-0.011)	0.615 (0.718)
Miliusa tomentosa	Tree	139.493 (37.776)	0.171 (0.147)	7.178 (0.000)
	Seedling	499.341 (76.098)	0.015 (-0.013)	0.543 (0.775)
Milusa velutina	Seedling	56.500 (137.58)	0.009 (-0.019)	0.327 (0.921)
Mallotus philippensis	Tree	608.206 (274.709)	0.013 (-0.015)	0.462 (0.835)
Drypetes roxburghii	Tree	7.764 (26.62)	0.191 (0.168)	8.179 (5.950)
	Seedling	114.387 (78.016)	0.018 (-0.011)	0.621 (0.713)
Randia dumetorum	Seedling	702.551 (165.297)	0.107 (0.081)	4.144 (0.000)
Shorea robusta	Tree	510.765 (179.489)	0.132 (0.107)	5.282 (4.33)
	Seedling	2946.011 (1212.5)	0.049 (0.022)	1.816 (0.097)
Schleichera oleosa	Tree	18.364 (178.73)	0.104 (0.078)	4.013 (0.001)
Streblus asper	Tree	244.796 (74.965)	0.139 (0.115)	5.631 (1.940)
	Seedling	160.709 (57.627)	0.0127 (-0.016)	0.447 (0.846)
Syzygium cumini	Tree	366.423 (82.606)	0.045 (0.017)	1.636 (0.138)
	Seedling	306.971 (390.418)	0.199 (0.176)	8.616 (2.240)
Tectona grandis	Tree	183.165 (85.309)	0.022 (-0.006)	0.795 (0.575)
	Seedling	-70.718 (45.283)	0.082 (0.055)	3.093 (0.006)
Trewia nudiflora	Tree	166.335 (83.088)	0.077 (0.051)	2.914 (0.009)
	Seedling	22.082 (92.965)	0.026 (-0.002)	0.942 (0.465)
Terminalia arjuna	Tree	75.176 (70.515)	0.302 (0.282)	15.013 (2.970)
Terminalia tomentosa	Tree	186.417 (135.516)	0.321 (0.302)	16.416 (1.850)
	Seedling	77.375 (26.859)	0.044 (0.017)	1.607 (0.147)

Table 4. Regression equations for the tree species under study using parameters such as Soil Moisture, Soil Organic Carbon, p^H, Nitrogen, Phosphorus and Potassium with tree and seedling density in planted Forest of SBWLS. No. soil sample was 111.

Species		Regression equation coefficients		
		Intercept (SE)	R^2 (adjusted r^2)	F ratio (significance level)
Acacia catechu	Tree	22.198 (8.390)	0.104 (0.052)	2.023 (0.069)
	Seedling	44.633 (45.89)	0.026 (-0.029)	0.479 (0.822)
Adina cordifolia	Tree	158.573 (36.134)	0.296 (0.256)	7.297 (0.000)
	Seedling	212.339 (50.241)	0.119 (0.068)	2.349 (0.036)
Alangium salvifolium	Tree	-0.147 (9.000)	0.059 (0.005)	1.098 (0.368)
	Seedling	-7.290 (14.287)	0.048 (-0.007)	0.876 (0.515)
Anthocephalus cadamba	Tree	204.522 (83.970)	0.116 (0.065)	2.278 (0.041)
Bauhinia racemosa	Tree	317.178 (84.138)	0.069 (0.016)	1.295 (0.266)
	Seedling	93.852 (20.738)	0.217 (0.172)	4.815 (0.000)
Bauhinia malabarica	Tree	85.708 (32.791)	0.197 (0.150)	4.242 (0.000)
Bridelia retusa	Tree	83.266 (34.532)	0.151 (0.102)	3.074 (0.008)
	Seedling	50.782 (35.82)	0.047 (-0.008)	0.846 (0.537)
Celtis tetrandra	Tree	10.217 (16.977)	0.061 (0.007)	1.130 (0.349)
	Seedling	133.300 (77.964)	0.080 (0.027)	1.514 (0.180)
Cassia fistula	Seedling	13.768 (58.961)	0.028 (-0.027)	0.514 (0.796)
Dalbergia sissoo	Tree	67.873 (114.033)	0.030 (-0.026)	0.539 (0.777)
Diospyrous tomentosa	Tree	30.154 (41.762)	0.032 (-0.023)	0.576 (0.748)
	seedling	139.95 (100.731)	0.036 (-0.019)	0.657 (0.684)
Ficus lacon	Tree	6.833 (13.611)	0.062 (0.007)	1.142 (0.343)
Garuga pinnata	Seedling	49.331 (11.409)	0.163 (0.114)	3.380 (0.004)
Holoptelea integrifolia	Tree	52.799 (45.640)	0.088 (0.036)	1.677 (0.133)
	Seedling	87.697 (35.849)	0.063 (0.008)	1.161 (0.332)
Lagerstroemia parviflora	Tree	21.710 (43.849)	0.137 (0.087)	2.760 (0.015)
	Seedling	229.270 (52.808)	0.105 (0.054)	2.043 (0.066)
Litsea glutinosa	Seedling	-133.173 (50.336)	0.249 (0.205)	5.744 (0.000)
Miliusa tomentosa	Tree	72.799 (34.095)	0.062 (0.008)	1.150 (0.338)
	Seedling	93.054 (36.775)	0.035 (-0.019)	0.641 (0.697)
Milusa velutina	Seedling	955.088 (477.606)	0.022 (-0.034)	0.386 (0.886)
Mallotus philippensis	Tree	-30.126 (50.667)	0.258 (0.215)	6.042 (0.000)
	Seedling	551.823 (313.431)	0.046 (-0.009)	0.830 (0.549)
Drypetes roxburghii	Tree	17.884 (62.528)	0.022 (-0.34)	0.393 (0.882)
	Seedling	3.577 (13.978)	0.069 (0.16)	1.30 (0.263)
Shorea robusta	Tree	329.111 (125.744)	0.118 (0.067)	2.322 (0.038)
	Seedling	847.796 (125.359)	0.123 (0.073)	2.436 (0.030)
Schleichera oleosa	Seedling	-436.061 (206.872)	0.1117 (0.066)	2.297(0.040)
Streblus asper	Tree	19.496 (20.237)	0.118 (0.067)	2.311 (0.039)
	Seedling	-19.338 (9.792)	0.230 (0.186)	5.188 (0.000)
Syzygium cumini	Tree	61.096 (29.789)	0.045 (-0.010)	0.813 (0.563)
	Seedling	158.149 (214.376)	0.191 (0.144)	4.079 (0.001)
Tectona grandis	Tree	106.255 (134.659)	0.118 (0.067)	2.312 (0.039)
	Seedling	-70.707 (77.994)	0.246 (0.202)	5.645 (0.000)
Trewia nudiflora	Tree	88.207 (43.120)	0.019 (-0.038)	0.033 (0.919)
Terminalia arjuna	Seedling	18.613 (12.461)	0.079 (0.026)	1.496 (0.187)
Terminalia tomentosa	Tree	2.221 (41.659)	0.164 (0.116)	3.395 (0.004)

and composition (Champion & Seth's 1968). However, these comparisons convey limited meaning since the sample area is variable across studies sites and forest are mostly restricted to the protected area network.

Simpson's index for tropical Sal forests plantation in Gorakhpur ranged between 0.042-0.211 (Shukala & Panday 2000). In the present study, the Simpson value of 0.212 for natural forest and 0.174 for planted forest. The Pielou's evenness indices were 0.03460 and 0.354 for natural and planted forests respectively, which were (Table 1) lower than 0.9 on an average reported for Western Ghats (Arunachalam 2002) indicating low dominance and a more or less regular distribution of plant species in the study sites. Hill diversity numbers were relatively low in planted forests and significant variation could be observed between the two study areas, while in Western Ghats no significant variation was observed (Arunchalam 2002). A similarity in species richness and diversity indices is reflected in 84 species common in both sites, the similarity index indicating less variation in the species composition. This could also be attributed to no major variations among soil type and available soil nutrients between natural and planted forests of present study sites. There were slight variations in the soil moisture, pH, organic carbon, nitrogen, potassium and phosphorus among both types of forests.

It has been recorded that regeneration of tree species is affected by fire (Sukumar *et al*. 1997, Murthy *et al*. 2002), grazing, light, canopy density, soil moisture, soil nutrients and anthropogenic pressure (Teketay 1997, Cierjacks & Hensen 2004, Shrestha et al. 2007, Sagar & Singh 2005, Mishra *et al.* 2004). In general, regeneration of species is also affected by natural phenomena such as light gaps (Teketay 1997). In our study, planted forest sites showed low species density and diversity and high light penetration but no significant variation among soil characteristics (Table 1) as compared to the natural forest sites. The tree density and seedling density in natural forest are significantly influenced by soil characteristics as revealed by multiple regression models.

A few ecological studies (Sukumar *et al.* 1997, Murthy *et al*. 2002, Teketay 1997, Cierjacks & Hensen 2004, Shrestha *et al.* 2007, Sagar & Singh 2005, Mishra *et al.* 2004) have determined how regeneration of specific species relate to fire, grazing, light, canopy density, soil moisture, soil nutrients and anthropogenic disturbance. The species richness and seedling and sapling density of the natural forest sites were significantly higher compared to planted forests. In natural forest sites, two tree species, *Shorea robusta* and *Syzygium cumini,* were regenerating well with greater density in seedling and sapling populations. Sal forests have two important associated species everywhere *Syzygium cumini* and *Mallotus philippensis*. The study area is a Sal dominated natural forests and Sal is one of the most important timber species in India. *Syzygium cumini* is an important fruit resource for herbivores within the protected area. *Tectona grandis* had higher seedling and sapling densities in planted forests. The greater number of saplings in the stands indicates the composition of future vegetation (Swaine & Hall 1988). According to Jones *et al*. (1994), seedling layers differ in composition from their respective overstories. Regeneration of species is dependent on internal community processes and exogenic disturbance (Barker & Kirpatrick 1994). Seedlings of three dominant overstorey species (*Shorea robusta, Syzygium cumini* and *Mallotus philippensis*) were found in most of the study plots, while for some other dominant species such as *Ailanthus excelsa*, *Streblus asper* and *Cordia dichotoma* seedling and sampling were not recorded in the study plots. The lack of juveniles of some of the primary species has also been reported from the rain forest of Khade, Ghana (Swain & Hall 1988). The low grade timber species, such as *Ehretia leavis* and *Syzygium cumini;* shrub species, such as *Helicteres iosra, Gylcosmis pentaphylla;* and climbers such as *Ichnocarpus frutesens, Clerodendrum visosum* were regenerating well.

The planted forest is still in the evolving stage. Some of the natural species such as *Grewia subinaequalis, Legerstroemia parviflora, Miliusa tomentosa, Shorea robusta, Syzgium cumini,* and *Mallotus philippensis* were regenerating in the planted forests as well. Similar findings were also reported by other workers indicating that natural species have regenerated automatically under the plantations (Shah 1992). Interestingly, some natural species have been found regenerating automatically in planted forest thereby indicating that good management prescription has been carried out. This is an indication that protection carried by the Sanctuary authority has been enhancing the natural species regeneration in plantations.

Acknowledgements

We thank TERI, New Delhi and Forest Department of U.P., Lucknow for financial support. We also thank the Sohagibarwa Wildlife Sanctuary authority for their help in procuring data and the range officers and the field station staff for their assistance.

Correspondence to:
Dr. D.S. Chauhan
Senior Lecturer
Department of Forestry, H.N.B. Garhwal University,
Post Box-59, Srinagar Garhwal, 246 174
Uttarakhand India
Telephone -91-1346267529
Cellular Phone 91-9412949549
Email: dschauhan2008@gmail.com

References

1. Benitze-Malvido, J. Impact of forest fragmentation on seedling abundance in a tropical rain forest. Conservation Biology 1998; 2: 380-389.
2. Moravie, M.A., Pascal, J.P., & P. Auger. Investigating canopy regeneration process through individual based models: application to a tropical rain forest Ecological Modeling 1997;104: 241-260.
3. Barker, P. C. J., & J.B. Krikpatrik.. *Phyllocladus asplenifolius:* variability in the population structure the regeneration niche an dispersion pattern in Tasmanian forest. Australian Journal of Botany 1994; 42: 163-190.
4. Manikant, C. L. Working plan of Sohagi Barwa Wildlife Sanctaury (South Gorakhpur division) for the years 1994-95 to 2003-2004. Department of Forest, Govt. of Uttar Pradesh, India, Pp. 119 unpublished. 1994.
5. Gilmour, D.A., & R.J. Fisher.. Villagers, Forests and Foresters. Sahayogi Press, Kathmandu, Nepal. 1991.
6. Webb, E.L., & R.N. Sah. Structure and diversity of natural and managed sal (*Shorea robusta* Gaertn. f.) forest in the Terai of Nepal. Forest Ecology and Management 2003; 176: 337-353.
7. Sah, S. P. Management options for sal forest (*Shorea robusta* Gaertn.) in the Nepal, Terai. Selbyyana 2000; 21: 112-117.
8. Jackson, J. R. Manual of afforestaion in Nepal. 2nd Edition. Forest Research and Survey Center, Kathmandu. 1994.
9. Gupta, O.P., & R.P. Shukla. The composition and dynamics of associated plant communities of Sal plantation. Tropical Ecology 1991; 32(2), 296-309.
10. Panday, S.K., & R.P. Shukla.. Plant diversity and community pattern along the disturbance gradient in plantation forests of Sal (*Shorea robusta* Gaertn.). Current Science 1999; 77(6): 814-818.
11. Panday, S.K., & R.P. Shukla. Regeneration strategy and plant diversity status in degraded Sal forests. Current Science 2001;81(1): 95-102.
12. Uma Shankar. A case of high tree diversity in a Sal (*Shorea robusta*)- dominated lowland forest of Eastern Himalaya: Floristic composition, regeneration and Conservation. Current Science 2001;81(7): 776-786.
13. Rautiainen, O., & J Suoheimo. Natural regeneration potential and early development of *Shorea robusta* Gaertn.f. forest after regeneration felling in the Bhabar-Terai zone in Nepal. Forest Ecology and Management 1997; 92: 243-251.
14. Matherma, P. Sal regeneration and management. Nepal J For. 1991; 6: 112-114.
15. Rodgers, W. A., & H.S. Panwar.. Planning a Protected Area Network In India. Volume I. The Report, Dehradun: Wildlife Institute of India. 1988.
16. Champion, H. G., & S. K. Seth. A revised survey of the Forests types of India, Publication division, Govt. of India, New Delhi pp 404. 1968.
17. Ahassan, M. Working plan of South Gorakhpur forest division for the year 1984-85 to 1993-94, unpublished. 1984.
18. Anderson, J.M., & J.S.I. Ingram. Tropical Soil Biology and Fertility: A Handbook of Methods. CABI International, Wallingford, U.K. pp 39-99. 1993.
19. Mueller- Dombois. D., & H. Ellenberg. Amis and Methods of vegetation Ecology, John-Wiley, New York, 547pp. 1974.
20. Hader, R.S. & A.H.E. Grandage. Simple and multiple regression analysis. Pp. 108-137. In: V.Chew (ed.) Experimental Design in Industry. John Wiley & Sons, Inc. New York. 1958.
21. Seetharam, Y.N., Haleshi, C., & Vijay. Structure and Floristic composition of a dry deciduous forest of Bidar district, Karnataka. Indian Journal of Forestry 2000; 23 (3): 241-247.
22. Gentry, H. A. Diversity and floristic composition of neotropical dry forests. In: S.H. Bullock, H. A. Mooney & E. Medina (eds.) Seasonally Dry Tropical Forests. Cambridge University, Press, Cambridge, pp. 146-194. 1995.
23. Sukumar, R., Suresh, H.S., Dattaraja, H.S., & N.V. Joshi.. In Forest Diversity Research, Monitoring and Modeling: Conceptual Background and Old World Case Studies, (eds. Dallmeier, F. and Comiskey, J.A.), Parthenon Publishing, Vol. I, pp. 529-540. 1997.
24. Singh, J.S., & S.P. Singh. Forests of Himalaya, Gyanodaya Prakashan. 1992.

25. Shukla, R. P., & S.K. Panday. Plant diversity and community features of the forested landscape adjacent to foot-hills of Central Himalayas. In: S.C. Tiwari, & P.P. 2000.
26. Arunachalam, A. Species diversity in two different forest types of Western Ghats, India. Ann. Forestry 2002; 10 (2): 204-213.
27. Parthasarathy, N., & P. Sethi. Trees and Liana species diversity and population structure in a tropical evergreen forest in south India. Tropical Ecology 1997;38: 19-30.
28. Murthy, I.K., MuralI, K.S., Hegde, G.T., Bhat, P.R., & N.H. Ravindranath. A comparative analysis of regeneration in Natural Forest and Joint Forest Management Plantations in Uttara Kannada Dist., Western Ghats. Current Science 2002; 83(11):1358-1364.
29. Teketay Demel. Seedling populations and regeneration of woody species in dry Afromontane forests of Ethiopia. For. Ecol. & Manage. 1997; 98:149-165
30. Cierjacks, A., & I. Hensen. Variation of stand structure and regeneration of Mediterranean Holm oak along a grazing intensity gradient. Plant Ecology 2004; 173: 215-223.
31. Shrestha, B.B., Ghimire, B., Lekhak, H.D., & P.K. Jha. Regeneration of Treeline Birch (*Betula utilis* D. Don) Forest in a Trans-Himalayaa Dry valley in Central Nepal. Mountain Research and Development . 2007; 27 (3): 259-267.
32. Sagar, R., & J.S. Singh. Structure, diversity, and regeneration of tropical dry deciduous forest of northern India. Biodiversity and Conservation 2005;14: 935-959.
33. Mishra, B.P., Tripathi, O.P., Tripathi, R.S., & H.N. Pandey. Effects of anthropogenic disturbance on plant diversity and community structure of a sacred grove in Meghalaya, northeast India. Biodiversity and Conservation 2004; 13: 421-436.
34. Swaine, M.D., & J.B. Hall. The mosaic theory of forest regeneration and the determination of forest composition in Ghana. J. Trop. Ecol. 1988; 4: 253-269.
35. Jones, R.H., Sharitz, R.R., Dixon, P.M., Segal, P.S., & R.L. Sachneider. Woody plant regeneration in four flood plain forests. Ecological Monographs 1994; 64:345-367.
36. Shah, S.A. New Voices in Indian Forestry (Ed. Kurup, V.S.P.), SPWD, 1996 New Delhi. Pp. 49-82.

Dr. D.S. Chauhan is Senior Lecturer in the Department of Forestry. He has been actively involved in research and teaching of undergraduate and post graduate students of Forestry. Dr. Chauhan has supervised 10 students leading to M.Sc. thesis and 03 students leading to PhD. Degree. He has contributed more than 30 research papers in International and National Journal of repute and edited books. He has been published as co-edited book “Concepts in Forestry Research” (IBD Publishing, Dehradun). Presently he is Principal Investigator of a major research project on “Regeneration and plant diversity status along disturbance gradient on Oak natural forests in Garhwal Himalaya” funded by MoEF, Govt. of India, New Delhi and Co-PI of three other research project in the Department. He is also associated as Consultant with a group of interdisciplinary experts for consultancy research project in EIA & EMP of various river valley projects in Uttarakhand. His field of specialization is Natural Resource Management, Forest Ecology & Biodiversity. His other research interest includes RS & GIS, forest regeneration and Agroforestry.

Submission date: 20 Oct. 2009