Classificatory analysis and diversity relations in shrub layer of *Shorea robusta* Gaertn. f. forests of Doon Valley.

P.S. Chauhan and R.K. Manhas

Abstract: Vegetation data from eleven sites of *Shorea robusta* Gaertn. f. (Sal) forests in Doon Valley were analyzed for TWINSPAN (Two Way Indicator Species Analysis) and community diversity. TWINSPAN grouped these eleven sites into four clusters on the basis of vegetation type, regeneration potential and forest conditions. The first cluster separated the swamp vegetation from others; second cluster represents an open forest condition, third represented *S. robusta*-dominated forest and fourth had negligible *S. robusta* regeneration. The TWINSPAN also divided the 68 plant species into twenty three associations. Saplings of *S. robusta* showed association with *Urena lobata*. Dominant shrubs like *Clerodendrum viscosum* and *Murraya koneigii* were associated with *Milletia auriculata* and *Colebrookia oppositifolia*, respectively. Alpha and beta diversities ranged between 10 – 42 and 0.71 – 3.22 respectively. Shannon and Wiener's diversity index (H') was lowest (1.26) in Phandowala and highest (2.80) in Lachhiwala flat. Thano Monodominance was least disturbed site showing characters of a pure *S. robusta* stand, in climax stage. Thano Mortality was the most disturbed site.

Keywords: Cluster; Canonical Correspondence Analysis; Diversity; Doon Valley; Regeneration; Sal (*Shorea robusta*); TWINSPAN.

1. Introduction

In India, *Shorea robusta* Gaertn. f. (family, Dipterocarpaceae) occupies about 75, 372 km^2 of forest area which constitutes nearly 12% of the total forest cover of the country (Manhas et al., 2006). It is an intensively gregarious climax forest tree very often forming predominantly pure crops over extensive areas and is one of the most important timber species of the humid tropical zones of Asia.

P.S. Chauhan,
Department of Forest Biology & Tree Improvement,
College of Horticulture and Forestry,
(Agriculture University, Kota),
Jhalawar Rajasthan-326 001, India.

R.K. Manhas (✉)
Department of Botany,
Govt. Degree College,
Kathua– 184104, J & K, India.
Email: manhasrk@rediffmail.com

S. robusta is *k*-strategic tree and it selects the best progeny for the establishment through intra-specific competition at seedling and sapling level. The seed germinates soon after the arrival of rain, thus germination is not a problem for *S. robusta* but establishment of seedling into saplings is a difficult process. The interspecific competition (Bhatnagar, 1960; Seth and Bhatnagar, 1960; Gautam et al., 2007), soil moisture limitations (Yadav, 1966; Seth and Bhatnagar, 1960; Bisht and Sharma, 1987) and anthropogenic disturbances (Bisht, 1989; Pande, 1999; Chauhan, 2001; Chauhan *et al.*, 2001; Gautam et al., 2014; Gautam et al., 2016) are the major factors inhibiting the normal conversion of seedlings into saplings and next diameter classes. Once the seedlings get established into saplings then human interference and certain environmental factors like fog are the only obstacles.

Over the years the *S. robusta* forests of Doon valley have been studied by various workers (Puri, 1950; Bhatnagar, 1960; Seth and Bhatnagar, 1960; Srivastava, 1963, 1964; Bisht and Sharma, 1987; Bisht, 1989; Pande, 1999;

Chauhan, 2001; Chauhan *et al.*, 2001; Gautam et al., 2006; Gautam *et al.,* 2007; Gautam et al., 2008a,b; Manhas et al., 2009; Chauhan et al., 2010; Gautam et al., 2011; Gautam et al., 2014; Gautam et al., 2016) for structure, diversity, regeneration status, and ordination analysis. Bhatnagar (1960) analysed the *S. robusta*-dominated communities for their successional trends and the relationship amongst the different communities. Srivastava (1963) carried out detailed study on community analysis, indicator species for *S. robusta*, natural regeneration and successional trends. Puri (1950) has reported that *S. robusta* forests of Doon Valley are greatly disturbed by human activities. Due to these activities the equilibrium between primary producers and environmental conditions is deteriorating continuously. In the present study an attempt has been made to understand and analyze some of the characteristics of vegetation dynamics in *S. robusta* forests of Doon Valley.

In the present paper in addition to these aspects we have also used some latest ordination methods like Two Way Indicator Species Analysis (TWINSPAN) and Canonical Correspondence Analysis (CCA) to study eleven sites of *S. robusta* forests of Doon Valley, emphasizing more on shrub layer because by knowing the requirements, associations and competitors of *S. robusta* saplings one can think of better management of *S. robusta* regeneration in these forests. Gautam *et al.* (2007a) has also classified some of the regions of Doon valley by TWINSPAN classificatory analysis for all the three layers i.e. tree, shrub and herbaceous.

2. Material and Methods

2.1 Study Site

The study was carried out in eleven sites covering five forest ranges of Dehradun Forest Division. These includes Thano mortality (Site 1), Lachhiwala Flat (Site-II), Lachhiwala Ridge (III), Lachhiwala slope (Site-IV), Asarori (Site-V), Phandowala (Site-VI) Barkot (Site-VII), Rishikesh (Site-VIII), Golatapper flat (Site-IX) Golatappar slope (Site-X) and Thano Monodominance (Site-XI). The study area lies between latitudes 30° 02′ to 30° 21′ N and 77° 52′ to 78° 20′ E (Fig., 1).

Doon valley is surrounded by the outer Himalayas (Mussoorie hills) in the North, Shiwalik range in the South, river Yamuna in the west and Ganga in the East. The annual temperature of these sites varied from 1.8 °C (January) to 40 °C (June). The total rainfall was 1918 mm for the whole year (Anon., 2000).

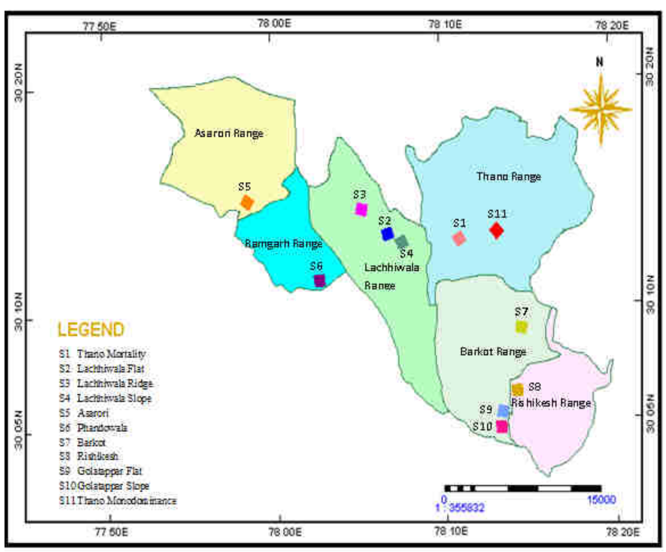

Fig. 1: Location map of the study site

Geologically, Doon valley is a synclinal basin, filled with coarse clastic fan Doon gravel of late Pleistocene and Holocene (Choubey *et al.*, 2001). The major part of the valley is occupied by younger Doon Gravels consisting of poorly sorted mixture of clay sand gravels and large boulders in the form of large fans and is known as principal Doon fans (Thakur and Pandey, 2004). Soils have been developed on the deep alluvial deposits with parent material derived from Doon alluvium consisting of accumulated beds of clays, boulders, pebbles and sand washed down from the hills (Singhal and Sharma, 1983). Main types of soils found in Doon valley are conglomerate, ferruginous clays with boulders, bouldery beds, shingle islands, gravels deposits etc. (Puri, 1950).

2.2 Methodology

Phytosociological studies were carried out in the period of September to November months in 1999 and 2000. Total 367 quadrats of 3m x 3m size were laid in the eleven study sites, using nested quadrat method (Khan, 1961), for the estimation of the vegetation composition of these site. In each quadrat all the individuals of a shrub species were counted and their diameter was measured. This data was used to calculate the following quantitative community characteristics. To determine the minimum/ appropriate size of the quadrat we used species area curve method (Cains, 1938).

2.2.1 Dominance

The dominance of the plant species was determined by the Importance Value Index (IVI) species and Concentration of dominance (C_d). The IVI was calculated by the summation of relative values of frequency, density and dominance (Curtis and McIntosh, 1950, 1951: Misra, 1968).

Concentration of dominance (C_d) was calculated for the observation of strongest control of species over space in different communities within the forest (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.

2.2.2 Richness, Diversity and Evenness

Alpha diversity is the number of species within a chosen area or community (Whittaker 1975). Two other richness indices viz. Margalef and Manhinick index (Ludwig and Reynolds, 1988) were also calculated.

Beta diversity was computed to measure the rate of species change across the sites (Whittaker, 1975) using the following formula:

$$\text{Beta diversity} = \frac{Sc}{S}$$

where Sc is the total number of species encountered in all communities and S is the average number of species per community.

Shannon-Wiener diversity index (Shannon and Wiener, 1963) was calculated from the IVI 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, and pi and s are same as in C_d.

Hill's diversity numbers (N_1 and N_2) given by Hill (1973) as the derivations of Shannon-Wiener diversity index were also calculated as measures of diversity. Evenness indices were calculated following Pielou (1975), Sheldon (1969), Help (1974) and Hill (1973).

Richness, diversity (except beta diversity) and evenness indices were calculated using SPDIVERS.BAS software run on GWBASIC language (Ludwig and Reynolds, 1988).

2.2.3 Ordination

Importance values of 68 species present in eleven sites were analyzed using Two Way INdicator SPecies ANalysis (Hill, 1979) and Canonical Correspondence Analysis (CCA) (Goodall, 1954) to classify both sites and plant species. The importance values of species were used for these analyses. TWINSPAN programme first converts these values according to its nomenclature (Hill, 1979) and then forms a dichotomy that can be represented in the form of Dendrogram. The CCA was performed on CANOCO for windows given by ter Braak and Šmilauer (1998) and Lepš and Šmilauer (1999).

2.2.4 Soil Analysis

Soil samples were collected from 0 –30cm depth. The texture analysis was done for all the sites by Hydrometer method (Black, 1965). These soil samples were oven dried at 105°C for 48 hours and weighed. The moisture content was expressed as a percentage of the oven dry weight (Mishra, 1968).

Water holding capacity was determined by the Keen-Raczkowski box experiment using the circular shaped boxes. Organic carbon was determined by Walkley and Black's Rapid Titration method and total Nitrogen % estimation was done by MacroKjeldhal Method (Piper, 1952).

3. Results

3.1 General Characteristics of the Study Area

Total 68 plant species were reported from eleven sites. *Clerodendrum viscosum*, *Murraya koenigii*, *Mallotus philippensis* (saplings) and *Ehretia laevis* were present in all the sites (Table 1). Site I was having maximum 42 number of plant species followed by Site II and IX, both were having 36 plant species each.

Table 1: Pooled important value index of plant species segregated into various groups after TWINSPAN classification.

Name of the plant species	Group I	Group II	Group III	Group IV
Adhatoda vasica Nees.	3.63	–	–	24.02
Adina cordifolia Hook.f.	0.75	–	–	0.63
Aegle marmelos Correa.	–	–	–	0.12
Albizzia lebbek Benth.	0.15	–	0.79	0.19
Ardisia solanacea Roxb.	8.18	–	25.21	0.14
Bauhinia racemosa Lam.	1.52	4.11	12.11	–
Bauhinia vahlii W. & A.	1.02	–	0.07	2.01
Calamus tenius Roxb.	0.54	–	–	–
Callicarpa macrophylla Vahl.	3.31	1.40	–	3.92
Carissa opaca Stapf.	1.08	6.77	0.87	3.33
Casearia tomentosa Roxb.	–	8.72	0.27	–
Cassia fistula Linn.	1.23	1.63	4.33	7.04
Ciltis tetrandra Roxb.	–	–	0.20	–
Cinnamomum camphora Linn.	–	–	–	0.06
Cinnamomum tamala Fr. Nees.	–	–	–	0.06
Clerodendrum viscosum Vent.	22.18	22.04	41.18	80.89
Coffea bengalensis Roxb.	12.95	11.60	8.51	2.08
Colebrookia oppositifolia Smith	–	–	4.28	2.62
Cordia obliqua Willd.	–	–	0.20	2.10
Dalbergia sissoo Roxb.	–	–	–	0.07
Desmodium cephalotes Wall.	0.90	6.42	0.57	4.23
Desmodium gangeticum DC.	0.70	–	0.93	3.11
Desmodium pulchellum Benth.	0.44	–	13.08	–
Diospyros malabaricum (Gtn.) Gurke	24.07	–	–	–
Ehretia laevis Roxb.	4.68	1.75	9.60	4.67
Eugenia operculata Roxb.	1.27	1.64	–	–
Euphorbia acualis Roxb.	–	–	3.93	1.10
Ficus bengalensis Linn.	–	–	–	0.08
Ficus religiosa Linn.	–	–	0.19	–
Flacourtia indica (Burm. f.) Merr.	19.18	–	10.16	2.65
Flamingia chappar Ham.	5.98	121.55	4.18	0.87
Garuga pinnata Roxb.	0.30	–	–	–
Grewia glabra Linn.	–	–	0.20	1.59
Grewia oppositifolia Roxb.	1.68	1.31	1.07	0.64
Holarrhena antidysentrica Wall.	3.01	2.40	0.67	2.21
Ichnocarpus frutescens Br.	0.91	–	0.05	0.85
Jasminum multiflorum (Burm. F.) Ander.	–	1.40	12.22	–

Lantana camara Linn.	–	–	2.29	–
Lantana indica Roxb.	–	–	0.37	1.91
Legerstomia parviflora Roxb.	–	1.69	0.11	0.22
Limonia crenulata Roxb.	2.50	–	–	3.71
Litsea glutinosa (Lour.) C.B. Robinson	–	–	7.93	4.90
Litsea monoptela (Roxb.) Pers.	7.43	1.38	6.67	6.01
Mallotus philippensis Muell. Arg.	19.02	16.90	19.56	27.93
Mangifera indica Linn.	–	–	0.05	–
Miliusa velutina Hook. f. & Th.	1.58	2.30	0.53	1.94
Milletia auriculata Baker.	2.64	7.83	23.51	29.54
Morus alba Linn.	–	–	–	0.07
Murraya koenigii Spreng.	4.64	2.95	28.05	30.58
Ougeinia oojeinensis (Roxb.) Hocht.	–	8.44	0.77	0.07
Persea gamblei Roxb.	37.88	–	–	–
Pogostemon plectranthoides Desf.	3.52	5.60	–	27.36
Pterospermum acerifolium Willd.	50.62	–	–	–
Randia uliginosa DC.	0.15	1.19	1.37	0.80
Rosa macrophylla Linn.	–	–	–	1.94
Rosa multiflora Thunb.	–	–	0.69	4.23
Schleichera oleosa (Lour.) Oken.	9.07	–	0.99	0.64
Shorea robusta Gaertn. f.	26.21	19.24	33.80	2.06
Sida alba Linn.	0.91	1.40	0.26	0.06
Smilax vaginata Decne.	–	1.19	–	–
Solanum berbascifolium Linn.	–	–	–	0.13
Solanum torvum Swartz.	–	–	1.44	2.57
Syzygium cumini (Linn.) Skeels	9.88	10.78	12.66	1.30
Tectona grandis Linn.	0.61	–	–	–
Terminalia alata Hyne.	–	1.56	0.50	–
Terminalia belerica Roxb.	0.75	–	0.43	0.19
Toona ciliata Roem.	–	–	–	0.36
Urena lobata Linn.	3.01	24.81	3.20	0.24

Clerodendrum viscosum was the most dominant plant species in Site III (IVI, 35.52), Site VI (IVI, 131.01), Site VII (IVI, 74.28) and Site XI (IVI, 79.04) and co-dominant in Site I (IVI, 20.35), Site II (IVI, 44.36) and Site IV (IVI, 44.54). The other dominant plant species were *Pogostemon plectranthoides* (Site-I), *Shorea robusta* (Site-II and IV), *Ardisia solanacea* (Site V), *Flamingia chapper* (Site VIII), *Pterospermum acerifolium* (Site X) and *Persea gamblei* (Site IX). The Co-dominant species were *Murraya koenigii* (Site, II, III, IV and VI), *Milletia auriculata* (Site-V, VI and VII), *Urena lobata* (Site-VIII), *Flacourtia indica* (X) and *Mallotus philippensis* (Site XI). The plant species with less than 1% of the total importance value were designated as rare species. Some of the rare species are *Adina cordifolia, Aegle marmelos, Albizzia lebbek, Calamus tenius, Ciltis tetrandra, Cinnamomum camphora, Cinnamomum tamala, Cordia oblique, Dalbergia sissoo, Eugenia operculata, Ficus bengalensis, Ficus religiosa, Garuga pinnata, Grewia glabra, Morus alba, Solanum berbascifolium, Tectona grandis, Terminalia belerica*, *Toona ciliata* etc.

3.2 TWINSPAN analysis

TWINSPAN classified the study sites into four groups. *S. robusta* (saplings) was the first indicator species. The first dichotomy formed with eigenvalue 0.321 divided the eleven sites into right hand side (7 sites) and left hand side (4 sites) groups. The left-hand side (LHS) with *Diospyros malabaricum* and *Flacourtia indica* as the indicator species divided further and formed group-I (2 sites), group-II (1 site) and group-III (4 sites). The RHS didn't divided further and all the 4 sites formed group-IV (Fig., 2).

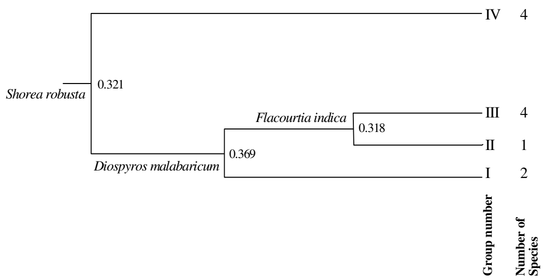

Fig. 2: Dendrogram explaining the TWINSPAN classification of sites on the basis of shrub layer.

Species and soil data was arranged according to these groups (Table, 2). Texture of the soil was sandy clayey loam except in group-II, where it was sandy loam. All the other soil attributes varied slightly within these groups. Correlation analysis between the soil parameters and *S. robusta* saplings was significant only in case of clay % (Table, 2). *S. robusta* and *D. malabaricum* were the dominant tree species of group-I and *S. robusta* and *Mallotus philippensis* of group- II, III and IV. In the shrub layer, however, all the groups had different dominant species viz. *P. acerifolium – P. gamblei* in group- I, *F. chappar – U. lobata* in group-II, *C. viscosum – S. robusta* in group-III, and *C. viscosum – P. plectranthoides* in group-IV. The main characteristics of these groups are as follows:

Table 2: Dominant species and Soil attributes for the TWINSPAN groups.

Dominant Tree Species	*S. robusta - D. malabaricum*	*S. robusta - M. philippensis*	*S. robusta - M. philippensis*	*S. robusta - M. philippensis*
Dominant Shrub Species	*P. acerifolium - P. gamblei*	*F. chappar - U. lobata*	*C. viscosum - S. robusta*	*C. viscosum - P. plectranthoides*
Texture	Sandy clayey loam	Sandy loam	Sandy clayey loam	Sandy clayey loam
Sand (%)	62.1	59.6	64.2	60.4
Silt (%)	17.0	22.0	17.0	18.3
Clay (%)[a]	20.9	18.4	18.9	21.3
Soil Moisture (%)	12.1	12.8	15.2	15.8
Water Holding Capacity (%)	49.9	46.1	49.7	48.7
Total Carbon (%)	1.23	1.27	1.5	1.53
Total Nitrogen (%)	0.11	0.08	0.12	0.13

[a]clay content was negatively correlated with saplings of *S. robusta* at P < 0.05.

Group-I was segregated on the basis of moist conditions and distinct vegetation of Golatappar Flat and Golatappar Slope sites. *C. tenuis, D. malabaricum, Garuga pinnata, P. gamblei, P. acerifolium* and *Tectona grandis* were the distinguishing species of this group. Other characteristics of the group includes absence of *Legerstoma parviflora* and *Ougeinia oojeinensis*, moderate regeneration of *S. robusta* (IVI, 26.21) and high water holding capacity (49.9%).

Group II comprised of only one site i.e. Rishikesh. *Smilax vaginata* was the characteristic feature of the group apart from the dominance of *F. chappar* and *U. lobata*. Soil attributes of the group read: clay content, 18.4%; moisture percentage, 12.8%; WHC, 46.1%; organic carbon, 1.27%, and nitrogen, 0.08%. This group again had moderate regeneration of *S. robusta* (19.24).

Group-III (Lachhiwala Flat, Lachhiwala Ridge, Lachhiwala Slope and Asarori) had high regeneration of *S. robusta* as the importance values of saplings was as high as 45.47 (pooled IVI, 33.80). The values of soil parameters were: sand, 64.2%; silt, 17.0%; clay content, 18.9%; moisture percentage, 15.2%; WHC, 49.7%; organic carbon, 1.5%, and nitrogen, 0.12%. Other distinguishing features of the group include the presence of *Ciltis tetrandra, Ficus religiosa, Lantana camara* and *Mangifera indica,* and absence of *Callicarpa macrophylla* and *P. plectranthoides.*

Group-IV (Thano Mortality, Thano Monodominance, Phandowala and Barkot) had less or negligible *S. robusta* saplings showing the climax stage (Thano Monodominance) or highly disturbed (Phandowala, Barkot and Thano Mortality) forest. No *S. robusta* saplings were found in Thano Monodominance and Phandowala and mere 1.41 and 6.68 importance values were reported in Thano Mortality and Barkot sites. The segregation of group was due to the presence of *Aegle marmelos, C. camphora, C. tamala, D. sissoo, F. bengalensis, Morus alba, Rosa macrophylla, Solanum berbascifolium* and *T. ciliata*, and absences of *B. racemosa.*

TWINSPAN grouped 68 plant species into twenty three associations. The eigenvalue ranged between 0.020 and 0.752 up to 5 level and was as low as 0.00 for 6th Level, indicating very less variation. The plant species were grouped according to the site classification. The vegetation in RHS associations (XIV-XXIII) represents the Group-IV of site classification whereas vegetation of LHS associations represents Group-I, II and III of site classification. Group XXII was the largest group comprising 10 plant species and group IV contained 8 plant species. Group-II, V, VIII, XII, XIII, XIV and XIX were having only one plant species each (Fig., 3).

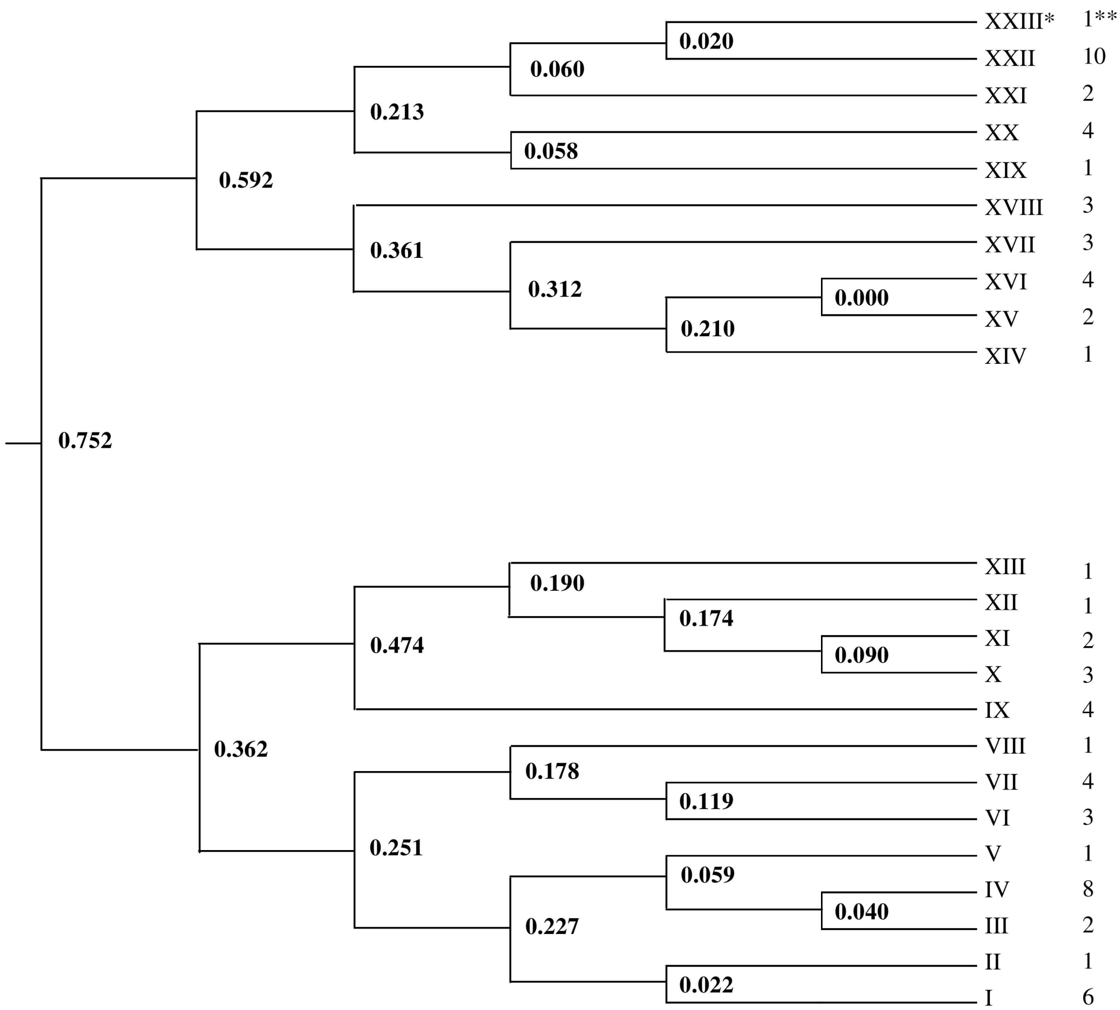

Fig. 3: Species classification of the shrub layer (* species associations and ** number of species in an association).

3.3 *Richness, Diversity and Evenness analysis*

N_0 or richness was highest in group-IV (51 plant species) closely followed by group-III (46 plant species) and group-I (41 plant species), and R_1 was the maximum in group-IV and R_2 in group-III. Species diversity (H′) ranged between 2.38 (group-II) and 3.16 (group-III) and beta diversity between 1.33 (group-IV) and 2.34 (group-II). Number of dominant (N_1) and very dominant species (N_2) were highest in group-III and lowest in group-II. Various evenness indices viz. E_1, E_2, E_3, E_4 and E_5 varied between 0.71-0.82, 0.37-0.51, 0.35-0.50, 0.49-0.78 and 0.44-0.77, respectively with minimum value in group-II and maximum in group-III for all the indices (Table 3).

Table 3: Phytosociological data of shrub layer in different study sites.

	Group I	Group II	Group III	Group IV
Richness indices				
N_0	41	29	46	51
R_1	7.01	4.91	7.70	8.13
R_2	2.37	1.67	2.48	2.35
Diversity indices				
Cd	0.08	0.19	0.05	0.07
H'	2.91	2.38	3.16	3.09
β	1.66	2.34	1.48	1.33
N_1	18.41	10.80	23.48	21.98
N_2	13.15	5.32	18.29	14.28
Evenness indices				
E_1	0.78	0.71	0.82	0.79
E_2	0.45	0.37	0.51	0.43
E_3	0.44	0.35	0.50	0.42
E_4	0.71	0.49	0.78	0.65
E_5	0.70	0.44	0.77	0.63

Discussion

Present study was conducted in the *S. robusta* forests of Doon valley. The dominance of *S. robusta* in these forests is due to various silvicultural and management operations carried out in the past to maintain pure crop of this gregarious and beautiful tree. These operations include removal of associate trees and saplings of associate species (popularly known as *kukats*) and shrubs. In some cases lopping was also used to increase the *S. robusta* regeneration. After the ban on green felling however, the associate species have started to come up and their dominance is increasing with time. These monocultures resulted due to past management strategies has become easy target for the *Hoplocerambyx spinicornis*, a beetle, resulting in large scale mortality in these and creation of large canopy gaps increasing the diversity of shrubs and reducing the regeneration of *S. robusta.*

Data from eleven sites was collected, which was further grouped into 4 groups by TWINSPAN on the basis of various species associations in the valley. The initial division of sites was based on the saplings of *S. robusta* and final on the basis of xerophytic species (*Flacourtia indica*). The canonical correspondence analysis (first two axes represents 80.9% variation) of the sites further clarified that this segregation of sites and formation of various associations of species was governed by clay percentage at first axis and water holding capacity at second (Fig., 4). The groups were arranged according to the clay percentage i.e. from group-IV>group-I>group-III>group-II. Yadav (1966), Seth and Bhatnagar (1960), Bisht and Sharma (1987) reported that soil moisture limitations are responsible for distribution of *S. robusta* and its associate species in Doon valley whereas Gautam *et al.* (2006b, 2007) reported that soil temperature is the main driving variable.

The importance values of *Shorea robusta* ranged between 2.06 and 33.80. These values are slightly higher than (9.1 – 25.1) the IVI reported by Pande (1999) and lower than (8.37 – 79.35), Bisht and Sharma (1987). Increasing *Murraya koenigii* and human interference are responsible for the poor regeneration of *S. robusta* in Doon Valley. Sal is a poor competitor in the initial stages of its development and expends more of its energy towards root system. Therefore, the saplings of the species need proper attention.

Clerodendrum viscosum was the dominant plant species in 4 sites with importance values ranging between 22.04 and 131.01. These values falls within the range of previous studies (Bisht, 1989; Pande, 1999), as they reported 92.67 to 204.85 and 64.4 to 236.4 importance values respectively for *Clerodendrum viscosum* in Doon valley. *C. viscosum* is a shade loving shrub with large leaves. This decrease in importance values of species may be due to widening of canopy gaps and high human interference.

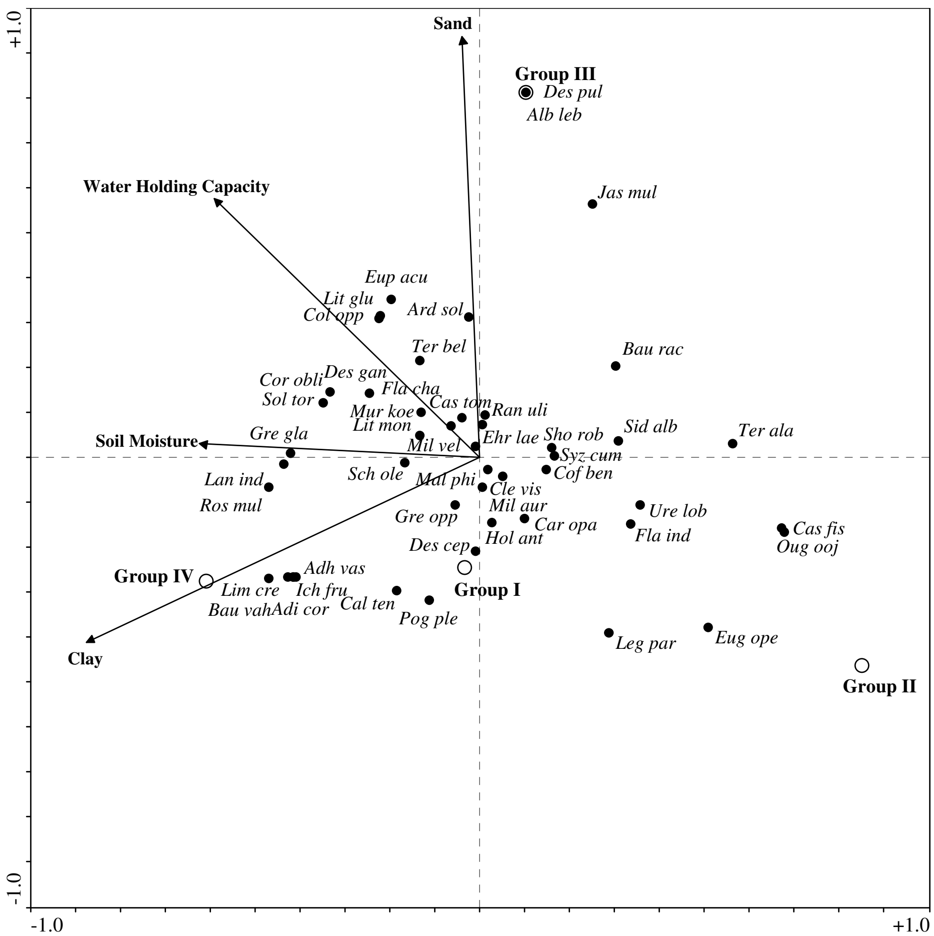

Fig. 4: Canonical correspondence analysis (CCA) ordination diagram for different groups with groups (o), plant species (•) and environmental variables (arrows). The canonical ordination axis 1 and 2 (eigenvalues of 0.22 and 0.15 respectively) explain the 80.9% of cumulative percentage variance in species data and species environment relationships.

Group-IV was the largest group with 51 plant species. High richness of the group may be ascribed to anthropogenic as well as other biotic disturbances. Human disturbances were generally in the form of lopping of tree species for fodder and fuelwood, harvesting of grasses and extraction of certain non-wood forest products. Other major disturbance prevailing in the region was mortality (26.7%) of Sal trees because of the infestation of *Hoplocerambyx spinicornis* (Sal borer) (Chauhan, 2001). The mortality of Sal trees has created wide canopy openings (216.30m^2), which affects the shade loving species such as *S. robusta* seedlings.

The richness values of the groups varied between 29 and 51 plant species. These values are higher than all the previous studies (Bisht and Sharma, 1987; Pande, 1999; Rawat and Bhainsora, 1999) of shrub layer and support our view that increased canopy gaps after the mortality of *S. robusta* are providing the opportunity to shrubs to grow and dominant the forest floor.

Knight (1975) calculated higher diversity index (5.06-5.40) for tropical forests in general. Singh and Singh (1984) have reported the diversity value (1.82 to 2.0) for *S. robusta* forest of the Central Himalaya. Bisht and Sharma (1987) have reported 0.597-2.42 diversity index for shrub layer. Pande (1999) calculated H′ values of shrub layer between 0.89 and 1.99. The present study has diversity index values varying from 2.38 – 3.16, which is higher than previous studies.

Risser and Rice (1971) reported 0.10 - 0.99 values for concentration of dominance (Cd) in temperate forests. Knight (1975) reported average 0.06 Cd for tropical forests. Pande (1999) reported 0.18 - 0.60 Cd and Bisht and Sharma (1987) 0.254 - 0.840 Cd for shrub layer in *S. robusta* forest. In the present study the Cd calculated (0.05-0.19) satisfies the early findings. The β-diversity calculated for present study ranges between 1.33 and 2.34, which is more than (1.37 - 1.39) the values reported by Bisht (1989). High β-diversity for shrub shows greater habitat specialization by shrubs.

When all the species in a sample are equally abundant, it seems intuitive that an evenness index should be the maximum and decrease towards zero as the relative abundances of the species diverge away from evenness (Ludwig and Reynolds, 1988). In the present study low values of evenness suggests that the number of very dominant species in these forests is high.

Conclusion

The findings of the present study can be concluded as:

(i) The saplings of *S. robusta* were not reported from Site VI and XI as the former was under high human interference and canopy cover whereas the later was a pure *S. robusta* forest in climax stage.

(ii) *Clerodendron viscosum* was the dominant plant species in most of the sites.

(iii) TWINSPAN formed 4 groups of the sites on the basis of *S. robusta* regeneration, which was poor (group-IV) to moderate (group-I, II and III).

(iv) Clay percentage was only soil parameter significantly correlated with *S. robusta* regeneration.

References

Anonymous. 2000. Annual Report. CSW and CR and TI (ICAR), Dehra Dun (U.P.) India, p 151.

Bhatnagar, H.P. 1960. Plant communities of *S. robusta* (*Shorea robusta)* forest in U.P. *Indian Forester*, 86: 139-151.

Bisht, A.P.S. 1989. *Microsite Mosaic and Under Canopy Vegetation Dynamics of S. robusta Communities in East and West Dehradun Forest Division.* D. Phil. Thesis, Garhwal University, Srinagar (Garhwal) India.

Bisht, A.P.S. and S.C. Sharma. 1987. Disturbance regimes in *S. robusta* (*shorea robusta)* forests of Dehradun Forest Division. *Int. J. Ecol. Environ. Sci*., 13: 87-94.

Black, C.A. 1965. *Methods of soil Analysis*. Amer. Soc. Agron., U.S.A.

Cain, S.A. 1938. The species area curve. *American Midland Naturalist* 21:146-181.

Chauhan, P.S. 2001. *Sal (Shorea robusta Gaertn. f.) Mosaic Characterization in Doon Valley.* D. Phil., Thesis, Deemed University, Forest Research Institute, Dehra Dun (Uttaranchal), India.

Chauhan, P.S., Manhas R.K., Negi J.D.S. 2001. Demographic and Diversity Analysis of Trees Species in Sal (*Shorea robusta* Gaertn. f.) Forests of Doon Valley. *Annals of Forestry* 9 (2): 188–198.

Chauhan, P.S., Manhas, R.K., Negi, J.D.S. and Singh, Lokender 2010. Dominance, Diversity and Regeneration status of a moist sub-tropical *Shorea robusta* Gaertn. f. (sal) forest of Doon valley, India. *Indian Forester,* 136 (4): 544-552.

Choubey, V.M., Bartarya, S.K.,Saini, N.K., Ramola, R.C. 2001. Radon measurements in groundwater of inter-montane Doon valley, Outer Himalaya; effects of geohydrology and neotectonic activity. *Environ. Geol.*, 40 (3): 257 –266.

Curtis J.T. and McIntosh, R.P. 1950. The interrelationship of certain analytic and synthetic phytosociological characters. *Ecology*, 31: 4343-445.

Curtis, J.T. and McIntosh, R.P. 1951. The upland forest Continuum in the prairie forest border region of Wisconsin. *Ecology*, 32: 476 – 496.

Gautam, M.K., Tripathi, A.K., Kamboj, S.K. and Manhas, R.K. 2006. Changes in the Scenario of Dominance and Diversity in *Shorea robusta* Gaertn. f. Forests of Lacchiwala, Doon Valley, India. *Indian Forester*, 132 (12): 1645 – 1652.

Gautam, M.K., Tripathi, A.K. and Manhas, R.K. 2007. Indicator species for the natural regeneration of *Shorea robusta* Gaertn. f. *Current Science*, 93 (10): 1359-1361.

Gautam, Mukesh Kumar, Tripathi, A.K. and Manhas, R.K. 2008a. Plant diversity and structure of sub-tropical *Shorea robusta* Gaertn. F. (Sal) forests of Doon valley, India. *Indian Journal of Forestry*, 31 (1): 131-140.

Gautam, Mukesh Kumar, Tripathi, A.K., Kamboj, S.K., and Manhas, R.K. 2008b. TWINSPAN classification of moist *Shorea robusta* Gaertn. f. (Sal) forests with respect to regeneration. *Annals of Forestry,* 16 (2): 173-177.

Gautam, M.K., Raina, A.K., Manhas, R.K., Tripathi, A.K. and Gupta, M.K. 2011. Sand and Clay Mineralogy of Sal Forest Soils of the Doon Siwalik Himalayas. *Journal of Earth System Science* 120 (1): 123-144.

Gautam, M.K., Manhas, R.K. and Tripathi, A.K. 2014. Plant species diversity in unmanaged moist deciduous forest of Northern India. *Current Science*, 106(2): 277-287.

Gautam, M.K., Manhas, R.K. and Tripathi, A.K. 2016. Patterns of diversity and regeneration in unmanaged moist deciduous forests in response to disturbance in Shiwalik Himalayas, India. *Journal of Asia-Pacific Biodiversity*, 9(2); 144–151.

Goodall, D.W. 1954. Vegetational classification and vegetational continna. *Angew Pflan,* 3 (1): 168-182.

Help, C. 1974. A new index measuring evenness. *Journal of Marine Biological Association,* 54: 555-557.

Hill, M.O. 1973. Diversity and evenness: A unifying notation and its consequences. *Ecology,* 54: 427-432.

Hill, M.O. 1979. *TWINSPAN: A FORTRAN Programme for arranging of individual and attributes.* Cornell University, Ithaca, New York.

Khan, M.A.W. 1961. Method of studying Forest types. *Proc. X Silva Conf.* FRI, Dehradun. I: 114-119.

Knight, D.N. 1975. A phytosociological analysis of Species rich tropical forest on Basso Colorado Island, Panama. *Ecological Monographs,* 45: 259-284.

Lepš, Jan and Petr Šmilauer. 1999. Multivariate Analysis of Ecological Data. University of South Bohemia, Ceské Budejovice.

Ludwig, J.A. and Reynolds, J.F. 1988. *Statistical Ecology- A Primer on Methods and Computing*. John Wiley and Sons, New York.

Magurran, A.E. 1988. *Ecological Diversity and its Measurement*. Prenceton University Press, New Jersey, pp. 145-146.

Manhas, R.K.; Negi, J.DS.; Kumar, Rajesh and Chauhan, P.S. 2006. Temporal Assessment of Growing Stock, Biomass and Carbon Stock of Indian Forests. *Climatic Change,* 74 (1-3): 191-221.

Manhas, R.K., Singh, Lokender, Chauhan, P.S. and Negi, J.D.S. 2009. Natural Recuperation in Sal (*Shorea robusta*) Mortality Affected Ecosystem through *Miliusa velutina. Indian Journal of Forestry*, 31 (3): 357-62.

Mishra, R. 1968. *Ecology Work Book.* Oxford and IBH Publishing Co. New Delhi, 244 pp.

Pande, P.K. 1999. Comparative vegetation analysis of *S. robusta* (S*horea robusta)* regeneration in relation to their disturbance magnitude in some *S. robusta* forests, *Tropical Ecology*, 40 (1): 51-61.

Pielou, E.C. 1975. *Ecological Diversity.* Wiley, New York.

Piper, C.S. 1952. *Soil and Plant Analysis.* Hans Publishers, Bombay.

Puri G.S. 1950. Soil pH and forest communities in the *Shorea robusta* forests of the Dehradun Valley U.P., *India. Ind. For.* July pp 1-18.

Rawat, G.S. and Bhainsora, N.S. 1999. Woody vegetation of Shivaliks & Outer Himalaya in North – Western India. *Tropical Ecology,* 401: 119 – 128.

Risser, P.G. and E.L. Rice. 1971. Diversity in tree species in Oklahoma upland forests. *Ecology,* 52: 876-880.

Seth, S.K. and Bhatnagar H.P. 1960. Indicator species of sal *Shorea robusta* natural regeneration. *Indian Forester* 86 (9): 520-530.

Shannon, C.E. and W. Wiener. 1963. *The Mathematical Theory of Communities.* University of Illinois Press, Urbana 117 pp.

Sheldon, A.L. 1969. Equitability indices: dependence on the species count. *Ecology,* 50: 466-467.

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

Singh, J.S. and S.P. Singh. 1984. Structures and functioning the Forest Ecosystems of Central

Himalayas. *Implications for management, Regeneration of Forest Trees: An Integrated Ecological Study of Eastern Kumaon Himalaya and emphasis on Natural Resources* (Eds., J.S. Singh and S.P. Singh). Final report (HCS/DST/187-176), Vol-II, Kumaon University, Nainital, India: 85 –113.

Singhal, R.M. and Sharma, S.D. 1983. Study of organic matter of some typical soils of Doon valley forests. *Ind. J. For.*, 6(4): 274-277.

Srivastava, P.B.L. 1963. *Phyposociological-Sociological Studies of S. robusta Forests of U.P. with special Reference to Regeneration.* Ph. d. Thesis, Agra University.

Srivastava, P.B.L. 1964. *Physiological – Ecological* studies of Sal *(Shorea robusta)* Forests of Uttar Pradesh with special reference to regeneration. Agra University*, J. Res.* Vol XIII. pp. 269-278.

ter Braak, C.J.F. and Šmilauer, P. 1998. *CANOCO Reference Manual and User's Guide to Canoco for Windows.* Microcomputer Power, Ithaca, U.S.A.: 352.

Thakur, V.C and Pandey, A.K. 2004. Late Quaternary tectonic evolution of Dun in fault bend/ propagated fold system, Garhwal Sub-Himalaya; *Current Science*, Vol. 87 (11): 1567-1566.

Whittaker, R.H. 1975. Evolution and measurement of species diversity. *Taxon* 21: 213-251.

Yadav, J.S.P.1966. Soil studies in Sal forests of Dehradun division. *Indian Forester,* 92: 240-251.