



FLORAL BIODIVERSITY ALONG THE ALTITUDINAL GRADIENT IN NORTHWEST HIMALAYAS

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Abstract

The present investigation was carried out in Sirmour district of Himachal Pradesh during the year 2011-12 with the aim to assess floristic composition, and their structural attributes. Five different forests were selected along the altitude *viz.*, Acacia and Chir pine (Sub tropical forests) and Mixed, Deodar and Fir-Spruce (Temperate forests). Structural parameters of trees, shrubs and monthly herbaceous vegetation in each forest were studied by laying down five sample plot of 0.1 ha. These forests comprised of 122 plant species under 113 genera and 53 families. Monthly Shannon Weiner index of herbaceous vegetation in different forests ranged between 2.30 (October) to 3.02 (August) in Acacia forest, 2.54 (August) to 2.71 (October) in Chir pine forest, 2.60 (October) to 3.18 (August) in Mixed forest, 2.29 (July) to 2.81 (August) in Deodar forest and 2.65 (July) to 3.16 (August) in Fir-Spruce forest. The monthly diversity index value of herbaceous vegetation in different forests ranged between 0.52 (July) to 0.90 (August) for Acacia forest, 0.85 (August) to 0.90 (July) for Chir pine forest, 0.85 (July) to 0.94 (August) for Mixed forest, 0.70 (July) to 0.85 (October) for Deodar forest and 0.86 (July) to 0.93 (August) for Fir-Spruce forest. Monthly species richness index for herbaceous vegetation in different forests ranged between 2.39 (July) to 4.06 (August) for Acacia forest, 2.45 (September) to 3.33 (July) for Chir pine forest, 2.77 (October) to 4.82 (July) for Mixed forest, 2.62 (October) to 4.23 (August) and 3.14 (July) to 4.65 (August) for Fir—Spruce forest. Overall, vegetation indices *viz.*, Shannon Weiner, Simpson's diversity and Species richness exhibited maximum values in Mixed forest, whereas, Species Evenness and Concentration of Dominance were highest in Fir-Spruce and Chir pine forests, respectively. Similarity index among the forests decreased with increase in altitude.

Key words : Biodiversity, vegetation analysis, altitude and Himalayas.

Introduction

Floral composition, their distribution and abundance in a community is the measure of plant diversity (Dobzonky, 1950) indicated by simple and easily interpretable indicator called species richness (Peet, 1974). The spatial variations in biodiversity generally include species diversity in relation to size of the area, relationship between local and regional species diversity along gradients across space and environmental factors include altitude, insolation moisture etc. (Gaston, 2000). Floristic analyses are very useful for identifying spatial patterns in plant diversity and composition and when combined with environmental, geological and historical variables can provide important information on the process that maintains the high level of tree species diversity (Silk *et al.*, 2003). Along the altitude, the geographical and climatic conditions change sharply (Kharakwal, 2005). Along the

altitudinal gradient, the upper limit of species richness remains high up to a considerable altitudinal level and tree richness increases with increasing moisture in the Indian Himalayan region (Rikhari *et al.*, 1989). Singh *et al.* (1994) found that productivity does not change upto and approximately 2500m amsl in the Himalayan region. However, several other explanations have been given for a linear relationship between species richness and altitude. The present investigation was carried out in different forest stands representing sub tropical and temperate forests along the altitudinal gradient in north-west Himalaya to reveal species composition of different forests as well as species richness and biodiversity of different forests along the altitude.

Materials and Methods

The study was conducted in Sirmour district of Himachal Pradesh, during the year 2011-2012. Sirmour

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district comprises both plain as well as hilly area. The altitude varies from 400-3600m amsl. The vegetation of forest types of western Himalaya can be divided into tropical (upto 1000m), Sub tropical (1000-1800m), temperate (1800-3600m) and alpine (above 3600m). The study was conducted during the month of July-October. After the reconnaissance survey, five forest cover types having different species composition, altitude were identified and selected. Each forest type was named according to their composition of different tree species as per Ram prakash (1986), viz., $\geq 75\%$ as pure; 50-75% as mainly pure; 20-25% as mixed and $\leq 25\%$ as miscellaneous. A total of 25 plots (5 plots in each forest type) measuring 0.1 ha. each, were selected and sampled. In each these experimental plot, five sub plots of size 10m x 10m and fifteen quadrats of size 50cm x 50cm were selected and sampled for shrubs and herbs respectively. Quadrat method of sampling was followed in ground vegetation, while shrub vegetation was sampled using random stratified sampling method. The plant samples were collected during the study period, brought to the laboratory and dried using plant press. The plant resources of the study area were listed and recorded in a herbarium and every species was identified separately. The species were identified at department of forest product utilization and department of basic science, college of forestry, Dr. Y. S. Parmar university of Horticulture & Forestry, Nauni, Solan (H.P.), India. The species were also identified with the help of journals and research books.

The vegetation data were quantitatively analysed for basal area, relative density, relative frequency and relative dominance (Phillips, 1959).

Relative density = (Density of the species/Total density of all species) $\times 100$.

Relative frequency = (Frequency of the species / Total frequency of all species) $\times 100$.

Relative dominance = (Basal area of the species/ Total basal area for all species) $\times 100$.

Importance Value Index (IVI) = Sum of relative density + relative frequency + relative dominance.

Vegetation of the study area was analyzed for the various vegetation indices. Following vegetation indices were used to quantify the available data:

Shannon-Wiener index (1963) is a measure of the amount of information needed to describe every member of the community, where p_i is the proportion of individuals (from the sample total) of species i and diversity (H') is:

$$H' = - \sum (N_i/N) \times \ln (N_i/N)$$

Where, H' = Shannon-Wiener index, N_i = Total no.

of individuals of all the species

n_i = Total no. of individuals of i th species

Species evenness was calculated using the Shannon evenness index:

$$E = H' / \ln S$$

Where, H' is the Shannon–Wiener diversity index and S is species number.

The Shannon evenness index ranges from zero (when one species is dominant) to one (when all species are equally abundant).

Menhinick's (1964) species richness index was calculated as:

$$d = S / \text{under root of } N$$

Where, d = Species richness; S = Total no of species in a community; N = Total no of individuals of all the species in a community.

Simpson's diversity index (1949) gives the probability that two individuals selected at random will belong to the same species. It was calculated as:

$$D = N(N-1) / 2n(n-1)$$

Where, D = Diversity index; n = Number of individual of a species; N = Number of individual of all the species.

Results

Floristic composition

Flora of the forests constituted 122 species with 16 species of trees from 13 genera and 9 families, 17 species of shrubs with 16 genera and 12 families, 53 species of forbs from 50 genera and 30 families, 22 species of grasses with 19 genera and 1 family, 5 species of sedges under 4 genera and 1 family and 5 species of ferns from 5 genera and 4 families (table 1).

Divergence studies based on Genus composition in different forests

Genera and individual species in the vegetation of different forests revealed three clusters. Acacia forest is represented by maximum number of genera and species followed by Fir-Spruce forest (fig. 1).

The genus/species diversity revealed 113 genera, with *Quercus*, the largest genera, represented by 3 species closely followed by *Pinus*, *Berberis* and *Anaphalis*, each represented by 2 species. Further, 104 genera were represented by single species. The plants belonged to 53 different plant families, of which *Poaceae* was the largest family represented by 22 species followed by *Asteraceae* with 14 species and *Pinaceae*, *Lamiaceae* and *Cyperaceae* represented by 5 species each (table 2).

Table 1 : Plant distribution among plant categories, family, genera and species.

S. no.	Plant categories	Family	Genera	Species
1	Trees	9	13	16
2	Shrubs	12	16	17
3	Forbs	30	52	53
4	Grasses	1	19	22
5	Sedges	1	4	5
6	Legumes	2	4	4
7	Ferns	4	5	5
	Total	59	113	122

Floristic composition under different forest types

Khair Forest

In Khair forest, 60 species were recorded with 19 grasses, 2 legumes, 4 sedges and 22 forbs. Along with them 7 shrubs and 6 trees were also recorded in this forest (table 3).

Among the grasses, *Agrostis pilosula*, *Apluda mutica*, *Arundinella nepalensis*, *Avena fatua*, *Axonopus affinis*, *Brachiaria ramosa*, *Cenchrus ciliaris*, *Chrysopogon gryllus*, *Cymbopogon martinii*, *Cynodon dactylon*, *Dichanthium annulatum*, *Digitaria cruciata*, *Heteropogon contortus*, *Oplismenus compositus*, *Panicum maximum*, *Paspalum paspaloides*, *Themeda anathera*, *Trichloris pluriflora* and *Urochloa panicoides* were found. Legumes were represented by *Abrus precatorius* and *Desmodium floribundum* and forbs were: *Achyranthes aspera*, *Achillea millefolium*, *Amaranthus viridis*, *Anaphalis busua*, *Angelica glauca*, *Artemisia roxburghiana*, *Asclepias curassavica*, *Bidens pillosa*, *Cannabis sativa*, *Chenopodium album*, *Conyza stricta*, *Dicliptera bupleuroides*, *Erigeron annuus*, *Euphorbia hirta*, *Ipomea quamocilt*, *Lepidium ruderae*, *Solanum nigrum* and *Thalictrum foliolosum*. Shrub species were represented by *Adhathoda vasica*, *Asparagus adscendens*, *Carissa carandas*, *Lantana camara*, *Murraya koenigii* and *Woodfordia fruticosa*, while tree species were: *Acacia catechu*, *Aegle marmelos*, *Anogeissus latifolia*, *Bauhinia racemosa*, *Butea monosperma* and *Terminalia bellerica*.

Chir pine Forest

In Chir pine forest, 53 plant species were present. It includes 17 grasses, 3 legumes, 4 sedges and 20 forbs. Further, 2 species of ferns, 5 species of shrubs and 3 tree species were also recorded in this forest (table 3).

Plant species of Chir pine forest differed from Acacia forest with *A. affinis*, *C. ciliaris*, *T. pluriflora*, *P. flavescens*, *A. precatorius*, *A. millefolium*, *C. sativa*,

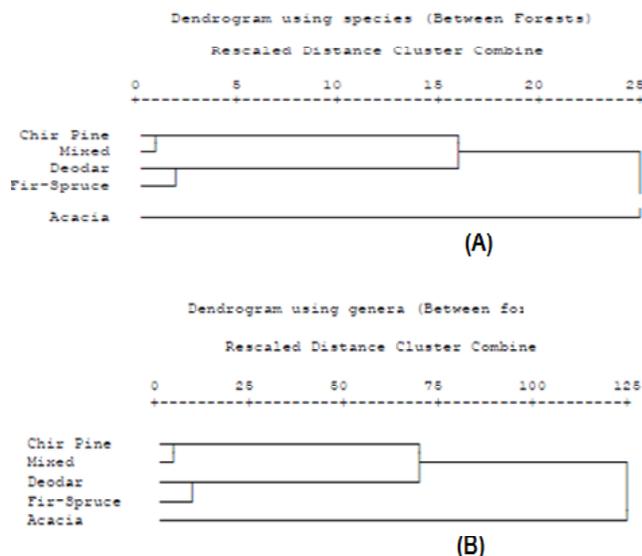


Fig. 1 : Cluster analysis of number of species (A) and genera (B) in different forests.

L. ruderae, *P. hysterothorus*, *S. nigrum*, *T. foliolosum*, *A. vasica*, *A. adscendens*, *C. carandas*, *L. camara*, *M. koenigii*, *W. fruticosa*, *A. catechu*, *A. marmelos*, *A. latifolia*, *B. racemosa*, *B. monosperma* and *T. bellerica* absent in it, while, *Chrysopogon montanus*, *Digitaria stricta*, *Fimbristylis rigidula*, *Lespedeza gerardiana*, *Trifolium repens*, *Barleria cristata*, *Gonanthus jamesonii*, *Origanum vulgare*, *Reinwardtia indica*, *Cheilanthes farinosa*, *Woodsia elongata*, *Berberis lycium*, *Inula cappa*, *Myrsine africana*, *Pyrus pashia*, *Zanthoxylum alatum*, *Acer oblongum*, *Pinus roxburghii* and *Quercus leucotrichophora* were recorded in Chir pine forest only.

Mixed Forest

This forest was composed of *Pinus roxburghii* and *Cedrus deodara* with associate tree species as *Rhododendron arboreum*, *Quercus semecarpifolia*, *Quercus leucotrichophora* and *Acer oblongum*. A total of 16 grasses, 4 sedges, 3 legumes, 24 forbs and 3 ferns were recorded in this forest (table 3).

Plant species of mixed forest differed from Acacia and Chir pine forests with *A. affinis*, *C. ciliaris*, *D. cruciata*, *P. maximum*, *P. paspaloides*, *T. pluriflora*, *P. flavescens*, *A. precatorius*, *A. millefolium*, *A. viridis*, *A. roxburghiana*, *C. sativa*, *E. hirta*, *G. jamesonii*, *L. ruderae*, *P. hysterothorus*, *S. nigrum*, *T. foliolosum*, *A. vasica*, *A. adscendens*, *C. carandas*, *L. camara*, *M. koenigii*, *P. pashia*, *W. fruticosa*, *A. catechu*, *A. marmelos*, *A. latifolia*, *B. racemosa*, *B. monosperma* and *T. bellerica* absent in it, while, *Agrostis royleana*, *Achyranthes aspera*, *Aster thomsonii*, *Delphinium denudatum*, *Galium aparine*, *Malaxis acuminata*,

Table 2 : Plant families, Genera (G) and Species (S) in forests.

S. no.	Plant Family	G	S	Name of the species
1	Acanthaceae	3		<i>Acanthus ilicifolius</i> , <i>Barleria cristata</i> , <i>Dicliptera bupleuroides</i>
2	Aceraceae	1	1	<i>Acer oblongum</i>
3	Amaranthaceae	2	2	<i>Amaranthus viridis</i> , <i>Achyranthes aspera</i>
4	Apiaceae	1	1	<i>Angelica glauca</i>
5	Apocynaceae	2	2	<i>Trachelospermum fragrans</i> , <i>Carissa carandas</i>
6	Araliaceae	1	1	<i>Hedera nepalensis</i>
7	Asclepidaceae	1	1	<i>Asclepias curassavica</i>
8	Asteraceae	15	15	<i>Anaphalis busua</i> , <i>Anaphalis margaritacea</i> , <i>Achillea millefolium</i> , <i>Ainsliaea pteropoda</i> , <i>Artemisia roxburghiana</i> , <i>Aster thomsonii</i> , <i>Bidens pillosa</i> , <i>Conyza stricta</i> , <i>Erigeron annuus</i> , <i>Gerbera jamesonii</i> , <i>Gonanthus speciosa</i> , <i>Parthenium hysterophorus</i> , <i>Sonchus oleraceus</i> , <i>Tagetes minuta</i> , <i>Inula cappa</i>
9	Berberidaceae	1	2	<i>Berberis aristata</i> , <i>Berberis lyceum</i>
10	Brassicaceae	1	1	<i>Lepidium ruderale</i>
11	Cannabaceae	1	1	<i>Cannabis sativa</i>
12	Cesalpiniaceae	1	1	<i>Bauhinia variegata</i>
13	Chenopodiaceae	1	1	<i>Chenopodium album</i>
14	Combretaceae	2	2	<i>Anogeissus latifolia</i> , <i>Terminalia bellerica</i>
15	Convolvulaceae	1	1	<i>Ipomea quamocilt</i>
16	Cryptogramaceae	2	2	<i>Onychium contiguum</i>
17	Cyperaceae	4	5	<i>Cyperus rotundus</i> , <i>Cyperus squarrosus</i> , <i>Eriophorum comosum</i> , <i>Fimbristylis rigidula</i> , <i>Pycneus flavescens</i>
18	Dryopteridaceae	2	2	<i>Cheilanthes farinosa</i> , <i>Dryopteris panda</i>
19	Ericaceae	1	1	<i>Rhododendron arboreum</i>
20	Euphorbiaceae	1	1	<i>Euphorbia hirta</i>
21	Fabaceae	2	2	<i>Abrus precatorius</i>
22	Fagaceae	1	3	<i>Quercus floribanda</i> , <i>Quercus leucotrichophora</i> , <i>Quercus semecarpifolia</i>
23	Geranaceae	1	1	<i>Geranium nepalensis</i>
24	Gesneraceae	1	1	<i>Chirta bifolia</i>
25	Haemodoraceae	1	1	<i>Ophiopogon intermedius</i>
26	Lamiaceae	5	5	<i>Prunella vulgaris</i> , <i>Origanum vulgare</i> , <i>Micromeria biflora</i> , <i>Thymus surphyllum</i> , <i>Plectranthus rugosus</i>
27	Liliaceae	1	1	<i>Asparagus adscendens</i>
28	Linaceae	1	1	<i>Reinwardtia indica</i>
29	Lythraceae	1	1	<i>Woodfordia fruticosa</i>
30	Mimosaceae	1	1	<i>Acacia catechu</i>
31	Myrsinaceae	1	1	<i>Myrsine africana</i>
32	Onagraceae	1	1	<i>Oenothera rosea</i>
33	Orchidaceae	1	1	<i>Malaxis acuminata</i>
34	Papilionaceae	1	1	<i>Butea monosperma</i> , <i>Indigofera pulchella</i>

Table 2 continued....

Table 2 continued....

35	Pinaceae	4	5	<i>Pinus roxburghii</i> , <i>Pinus wallichiana</i> , <i>Cedrus deodara</i> , <i>Abies pindrow</i> , <i>Picea smithiana</i>
36	Plumbaginaceae	1	1	<i>Plumbago zeylanica</i>
37	Poaceae	19	22	<i>Agrostis pilosula</i> , <i>Agrostis royleana</i> , <i>Chrysopogon montanus</i> , <i>Chrysopogon gryllus</i> , <i>Digitaria stricta</i> , <i>Apluda mutica</i> , <i>Arundinella nepalensis</i> , <i>Avena fatua</i> , <i>Axonopus affinis</i> , <i>Brachiaria ramosa</i> , <i>Cenchrus ciliaris</i> , <i>Cymbopogon martinii</i> , <i>Cynodon dactylon</i> , <i>Dichanthium annulatum</i> , <i>Heteropogon contortus</i> , <i>Oplismenus compositus</i> , <i>Panicum maximum</i> , <i>Paspalum paspaloides</i> , <i>Themeda anathera</i> , <i>Trichloris pluriflora</i> , <i>Urochloa panicoides</i>
38	Polygonaceae	1	1	<i>Bistorta amplexicaulis</i>
39	Primulaceae	1	1	<i>Primula denticulate</i>
40	Ranunculaceae	4	4	<i>Thalictrum foliolosum</i> , <i>Ranunculus hirtellus</i> , <i>Delphinium denudatum</i> , <i>Anemone rivularis</i>
41	Rosaceae	4	4	<i>Prinsepia utilis</i> , <i>Pyrus pashia</i> , <i>Rosa moschata</i> , <i>Rubus ellipticus</i>
42	Rubiaceae	1	1	<i>Galium aparine</i>
43	Rutaceae	4	4	<i>Boenninghausenia albiflora</i> , <i>Murraya koenigii</i> , <i>Zanthoxylum alatum</i> , <i>Aegle marmelos</i>
44	Saxifragaceae	1	1	<i>Bergenia ciliate</i>
45	Smilacaceae	1	1	<i>Smilax aspera</i>
46	Solanaceae	1	1	<i>Solanum nigrum</i>
47	Urticaceae	1	1	<i>Pouzolzia zeylanica</i>
48	Verbenaceae	1	1	<i>Lantana camara</i>
49	Violaceae	1	1	<i>Viola biflora</i>
50	Woosiaceae	1	1	<i>Woodsia elongate</i>
51	Valerianaceae	1	1	<i>Valeriana jatamansi</i>
52	Dennstaedtiaceae	1	1	<i>Polystichum squarrosus</i>
53	Leguminosae	3	3	<i>Desmodium floribundum</i> , <i>Lespedeza gerardiana</i> , <i>Trifolium repens</i>

Pouzolzia zeylanica, *Sonchus oleraceus*, *Thymus surphyllum*, *Trachelospermum fragrans*, *Dryopteris panda*, *Berberis aristata*, *Rubus ellipticus*, *Cedrus Deodara*, *Quercus semecarpifolia* and *Rhododendron arboreum* were recorded in Mixed forest only.

Deodar Forest

In Deodar forest, 56 plant species were present that include 12 grasses, 3 sedges, 3 legumes, 22 forbs and 4 ferns species. Among the tree species, *Cedrus deodara* was associated with *Pinus wallichiana*, *Quercus semecarpifolia* and *Rhododendron arboreum*. Further, 8 shrub species were also recorded in this forest (table 3).

Plant species of Deodar forest differed from Acacia, Chir pine and Mixed forests with: *A. affinis*, *B. ramosa*, *C. ciliaris*, *C. martinii*, *D. annulatum*, *D. cruciata*, *O. compositus*, *P. maximum*, *P. paspaloides*, *T. pluriflora*, *C. squarrosus*, *P. flavescens*, *A. precatorius*, *A.*

ilicifolius, *A. aspera*, *A. millefolium*, *A. viridis*, *A. glauca*, *A. roxburghiana*, *A. curassavica*, *A. thomsonii*, *C. sativa*, *C. stricta*, *E. annuus*, *E. hirta*, *G. jamesonii*, *I. quamaclit*, *L. ruderales*, *Malaxis acuminata*, *O. rosea*, *P. hysterothorus*, *P. zeylanica*, *S. aspera*, *S. nigrum*, *S. oleraceus*, *T. foliolosum*, *W. elongata*, *A. vasica*, *A. adscendens*, *C. carandas*, *L. camara*, *M. koenigii*, *P. pashia*, *W. fruticosa*, *A. catechu*, *A. oblongum*, *A. marmelos*, *A. latifolia*, *B. racemosa*, *B. monosperma*, *P. roxburghii*, *Q. leucotrichophora*, *Q. semecarpifolia* and *T. bellerica* absent in it, while, *Ainslea pteropoda*, *Anaphalis margaritacea*, *Anemone rivularis*, *Barleria cristata*, *Chirita biflora*, *Hedera nepalensis*, *Micromeria biflora*, *Primula denticulata*, *Valeriana jatamansi*, *Onychium contiguum*, *Polystichum squarrosus*, *Indigofera pulchella*, *Plectranthus rugosus*, *Pinus wallichiana* and *Quercus floribunda* were recorded in Deodar forest only.

Fir-Spruce Forest

In Fir-Spruce forest, 60 plant species were recorded that include 10 grasses, 3 legumes, 3 sedges, 30 forbs, 3 ferns, 7 shrubs and 4 trees (table 3).

Plant species of Fir-Spruce forest differed from Acacia, Chir pine, Mixed and Deodar forests with: *A. nepalensis*, *A. affinis*, *B. ramosa*, *C. ciliaris*, *C. martinii*, *C. dactylon*, *D. annulatum*, *D. cruciata*, *O. compositus*, *P. maximum*, *P. paspaloides*, *T. pluriflora*, *C. squarrosus*, *P. flavescens*, *A. precatorius*, *A. ilicifolius*, *A. aspera*, *A. millefolium*, *A. viridis*, *A. glauca*, *A. roxburghiana*, *A. curassavica*, *A. thomsonii*, *C. sativa*, *C. stricta*, *D. denudatum*, *E. annuus*, *Ehirta*, *I. quamaclit*, *L. ruderales*, *O. rosea*, *P. hysterothorus*, *P. zeylanica*, *S. aspera*, *S. nigrum*, *S. oleraceus*, *T. foliolosum*, *T. fragrans*, *C. farinosa*, *W. elongata*, *A. vasica*, *A. adscendens*, *C. carandas*, *I. pulchella*, *L. camara*, *M. koenigii*, *P. rugosus*, *P. pashia*, *W. fruticosa*, *Z. alatum*, *A. catechu*, *A. oblongum*, *A. marmelos*, *A. latifolia*, *B. racemosa*, *B. monosperma*, *P. roxburghii*, *Q. floribunda*, *Q. leucotrichophora*, *Q. semecarpifolia*, *R. arboreum* and *T. bellerica* absent in it, while, *Bistorta amplexicaulis*, *Boeninghausenia albiflora*, *Geranium nepalensis*, *Gerbera speciosa*, *Malaxis acuminata*, *Ophiopogon intermedius*, *Prunella vulgaris*, *Ranunculus hirtellus*, *Tagetes minuta*, *Viola biflora*, *Prinsepia utilis*, *Rosa moschata*, *Abies pindrow*, and *Picea smithiana* were recorded in Fir-Spruce forest only (table 3).

Number of species in forests was subjected to Non Hierarchical Euclidean Cluster Analysis that exhibited Acacia and Chir pine forests in one cluster and Mixed, Deodar and Fir-Spruce forests in another (fig. 2). Former contained higher number of species as compared to the later.

Vegetation indices

Various vegetation indices of vegetation in different forests were calculated for different plant categories viz., trees, shrubs and herbs. In general, vegetation indices were highest for herbaceous layer followed by shrub and tree layer. It was also observed that these vegetation indices were highest for Mixed forest for all the three layers. The results so obtained which are described below:

Shannon Weiner index

Shannon Weiner index for trees ranged from 0.81 (Chir pine forest) to 1.81 (Mixed forest) and for shrubs it varied from 1.58 (Chir pine forest) to 1.81 (Mixed forest). Monthly Shannon Weiner index of herbaceous vegetation

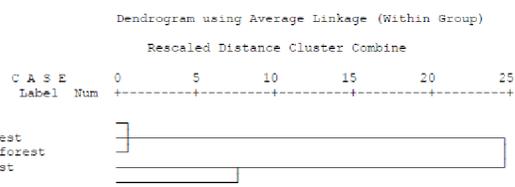


Fig. 2 : Cluster analysis of species composition in different forests.

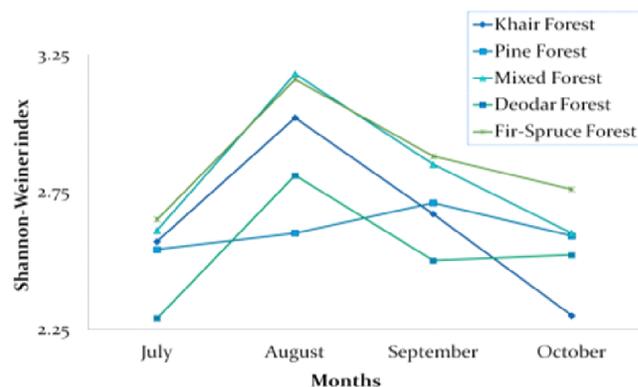


Fig. 3 : Monthly Shannon Weiner index of herbage in forests.

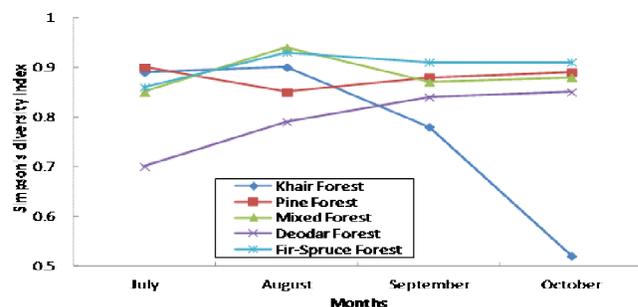


Fig. 4 : Monthly Simpson's diversity index of herbage in forests.

in different forests ranged between 2.30 (October) to 3.02 (August) in Acacia forest, 2.54 (August) to 2.71 (October) in Chir pine forest, 2.60 (October) to 3.18 (August) in Mixed forest, 2.29 (July) to 2.81 (August) in Deodar forest and 2.65 (July) to 3.16 (August) in Fir-Spruce forest (fig. 3).

Simpson's diversity index

Simpson's diversity index for trees ranged between 0.46 (Chir pine forest) to 0.73 (Deodar forest) and for shrubs it was highest in Acacia and Deodar forest (0.81) and lowest in Chir pine forest (0.52). The monthly diversity index value of herbaceous vegetation in different forests ranged between 0.52 (July) to 0.90 (August) for Acacia forest, 0.85 (August) to 0.90 (July) for Chir pine forest, 0.85 (July) to 0.94 (August) for Mixed forest, 0.70 (July) to 0.85 (October) for Deodar forest and 0.86 (July) to 0.93 (August) for Fir-Spruce forest (fig. 4).

Species richness index

Species richness index of trees in different forests

Table 3 : Species composition in forests.

GRASSES							
S. no.	Name of the species	Family	Acacia Forest	Pine Forest	Mixed Forest	Deodar Forest	Fir-Spruce Forest
1	<i>Agrostis pilosula</i> Trin.	Poaceae	+	+	+	+	+
2	<i>Agrostis royleana</i> Trin.	Poaceae	-	-	+	+	+
3	<i>Apluda mutica</i> Linn.	Poaceae	+	+	+	+	+
4	<i>Arundinella nepalensis</i> Trin.	Poaceae	+	+	+	+	-
5	<i>Avena fatua</i> Linn.	Poaceae	+	+	+	+	+
6	<i>Axonopus affinis</i> Chase	Poaceae	+	-	-	-	-
7	<i>Brachiaria ramosa</i> (Linn.)Stapf	Poaceae	+	+	+	-	-
8	<i>Cenchrus ciliaris</i> Linn.	Poaceae	+	-	-	-	-
9	<i>Chrysopogon gryllus</i> Linn.	Poaceae	+	+	+	+	+
10	<i>Chrysopogon montanus</i> Trin.	Poaceae	-	+	+	+	+
11	<i>Cymbopogon martinii</i> (Roxb.)Wats.	Poaceae	+	+	+	-	-
12	<i>Cynodon dactylon</i> (Linn.)Pers.	Poaceae	+	+	+	+	-
13	<i>Dichanthium annulatum</i> (Forssk.)Stapf	Poaceae	+	+	+	-	-
14	<i>Digitaria cruciata</i> (Nees ex Steud)	Poaceae	+	+	-	-	-
15	<i>Digitaria stricta</i> Roem & Schult.	Poaceae	-	+	+	+	+
16	<i>Heteropogon contortus</i> Linn.	Poaceae	+	+	+	+	+
17	<i>Oplismenus compositus</i> (Linn.)P.Beauv.	Poaceae	+	+	+	-	-
18	<i>Panicum maximum</i> Kunth	Poaceae	+	+	-	-	-
19	<i>Paspalum paspaloides</i> Scribn.	Poaceae	+	-	-	-	-
20	<i>Themeda anathera</i> (Nees ex Steud.)	Poaceae	+	+	+	+	+
21	<i>Trichloris pluriflora</i> Fourn.	Poaceae	+	-	-	-	-
22	<i>Urochloa panicoides</i> P.Beauv	Poaceae	+	+	+	+	+
TOTAL			19	17	16	12	10
SEDGES							
1	<i>Cyperus rotundus</i> Linn.	Cyperaceae	+	+	+	+	+
2	<i>Cyperus squarrosus</i> Linn.	Cyperaceae	+	+	+	-	-
3	<i>Eriophorum comosum</i> Wall.	Cyperaceae	+	+	+	+	+
4	<i>Fimbristylis rigidula</i> Nees.	Cyperaceae	-	+	+	+	+
5	<i>Pycreus flavescens</i> (Linn.) P.Beauv.ex. Rchb	Cyperaceae	+	-	-	-	-
TOTAL			04	04	04	03	03
LEGUMES							
1	<i>Abrus precatorius</i> Linn.	Fabaceae	+	-	-	-	-
2	<i>Desmodium floribundum</i> GDon	Leguminosae	+	+	+	+	+
3	<i>Lespedeza gerardiana</i> wallich ex Maximowiz	Leguminosae	-	+	+	+	+
4	<i>Trifolium repens</i> Linn.	Leguminosae	-	+	+	+	+
TOTAL			02	03	03	03	03

Table 3 continued....

Table 3 continued....

FORBS							
1	<i>Acanthus ilicifolius</i> Linn.	Acanthaceae	-	-	+	-	-
2	<i>Achyranthes aspera</i> Linn.	Amaranthaceae	+	+	+	+	-
3	<i>Achillea millefolium</i> Linn.	Asteraceae	+	-	-	-	-
4	<i>Ainsliaea pteropoda</i> Dc.	Asteraceae	-	-	-	+	+
5	<i>Amaranthus viridis</i> Linn.	Amaranthaceae	+	+	-	-	-
6	<i>Anaphalis busua</i> (Buch.-Ham.ex D. Don) DC.	Asteraceae	+	+	+	+	+
7	<i>Anaphalis margaritacea</i> (Linn.) Benth & Hook.f	Asteraceae	-	-	-	+	+
8	<i>Angelica glauca</i> Edgew.	Apiaceae	+	+	+	-	-
9	<i>Anemone rivularis</i> Buch-Ham ex Dc.	Ranunculaceae	-	-	-	+	+
10	<i>Artemisia roxburghiana</i> Bess.	Asteraceae	+	+	-	-	-
11	<i>Asclepias curassavica</i> Linn.	Asclepiadaceae	+	+	+	-	-
12	<i>Aster thomsoni</i> Cronquist	Asteraceae	-	-	+	-	-
13	<i>Barleria cristata</i> Linn.	Acanthaceae	-	+	+	+	+
14	<i>Bergenia ciliata</i> (Haw.)sternb	Saxifragaceae	-	-	-	+	+
15	<i>Bidens pillosa</i> Linn.	Asteraceae	+	+	+	+	+
16	<i>Bistorta amplexicaulis</i> (D. Don.) Green	Polygonaceae	-	-	-	-	+
17	<i>Boenninghausenia albiflora</i> Reichb.ex Meissn	Rutaceae	-	-	-	-	+
18	<i>Cannabis sativa</i> Linn.	Cannabaceae	+	-	-	-	-
19	<i>Chenopodium album</i> Linn.;Hook.f.	Chenopodiaceae	+	+	+	+	+
20	<i>Chirita bifolia</i> D.Don	Gesneriaceae	-	-	-	+	+
21	<i>Conyza stricta</i> Willd	Asteraceae	+	+	+	-	-
22	<i>Delphinium nudatum</i> Wall.	Ranunculaceae	-	-	+	+	-
23	<i>Dicliptera bupleuroides</i> Nees.	Acanthaceae	+	+	+	+	+
24	<i>Erigeron annuus</i> (Linn.)Pers.	Asteraceae	+	+	+	-	-
25	<i>Euphorbia hirta</i> Linn.	Euphorbiaceae	+	+	-	-	-
26	<i>Galium aparine</i> Linn.	Rubiaceae	-	-	+	+	+
27	<i>Geranium nepalensis</i> Sweet.	Geraniaceae	-	-	-	-	+
28	<i>Gerbera jamesonii</i> Linn.	Asteraceae	-	+	-	-	+
29	<i>Gonatanthus speciosa</i>	Asteraceae	-	-	-	-	+
30	<i>Hedera nepalensis</i> K.Koch	Araliaceae	-	-	-	+	+
31	<i>Ipomea quamocilt</i> Linn.	Convolvulaceae	+	+	+	-	-
32	<i>Lepidium ruderale</i> Linn.	Brassicaceae	+	-	-	-	-
33	<i>Malaxi acuminata</i> D.Don	Orchidaceae	-	-	+	-	+
34	<i>Micromeria biflora</i> Benth	Lamiaceae	-	-	-	+	+
35	<i>Oenothera rosea</i> W.Ait	Onagraceae	+	+	+	-	-
36	<i>Ophiopogon intermedius</i> D.Don	Haemodoraceae	-	-	-	-	+

Table 3 continued....

Table 3 continued....

37	<i>Origanum vulgare</i> Linn.	Lamiaceae	-	+	+	+	+
38	<i>Parthenium hysterophorus</i> Linn.	Asteraceae	+	-	-	-	-
39	<i>Plumbago zeylanica</i> Linn.	Plumbaginaceae	+	+	+	-	-
40	<i>Pouzolzia indica</i> Benn.&Br.	Urticaceae	-	-	+	+	+
41	<i>Primula denticulata</i> Sm.	Primulaceae	-	-	-	+	+
42	<i>Prunella vulgaris</i> Linn.	Lamiaceae	-	-	-	-	+
43	<i>Ranunculus hirtellus</i> Royle	Ranunculaceae	-	-	-	-	+
44	<i>Reinwardtia indica</i> Dum.	Linaceae	-	+	+	+	+
45	<i>Smilax aspera</i> Linn.	Smilacaceae	+	+	+	-	-
46	<i>Solanum nigrum</i> Linn.	Solanaceae	+	-	-	-	-
47	<i>Sonchus oleraceus</i> Linn.	Asteraceae	-	-	+	-	-
48	<i>Tagetes minuta</i> Roxb.	Asteraceae	-	-	-	-	+
49	<i>Thalictrum foliolosum</i> Dc.	Ranunculaceae	+	-	-	-	-
50	<i>Thymus serpyllum</i> Linn.	Lamiaceae	-	-	+	+	+
51	<i>Trachelospermum fragrans</i> (Wall.ex G. Don) Hook.f.	Apocynaceae	-	-	+	+	-
52	<i>Valeriana jatamansi</i> Jones	Valerianaceae	-	-	-	+	+
53	<i>Viola biflora</i> Linn.	Violaceae	-	-	-	-	+
TOTAL			22	20	24	22	30
FERNS							
1	<i>Cheilanthes farinosa</i> Linn.	Sinopteridaceae	-	+	+	+	-
2	<i>Dryopteris panda</i> Linn.	Sinopteridaceae	-	-	+	+	+
3	<i>Onychium contiguum</i> (Wall.) Hope	Cryptogrammaceae	-	-	-	+	+
4	<i>Polystichum squarrosus</i> (Linn.) Kuhn	Dennstaedtiaceae	-	-	-	+	+
5	<i>Woodsia elongate</i>	Woodsiaceae	-	+	+	-	-
TOTAL			00	02	03	04	03
SHRUB							
1	<i>Adhathoda vasica</i>		+	-	-	-	-
2	<i>Asparagus adscendens</i> Roxb.	Liliaceae	+	-	-	-	-
3	<i>Berberis aristata</i> Dc.	Berberidaceae	-	-	+	+	+
4	<i>Berberis lycium</i> Royle	Berberidaceae	-	+	+	+	+
5	<i>Carissa carandas</i> Linn. Hook.f.	Apocynaceae	+	-	-	-	-
6	<i>Indigofera gerardiana</i> Wall.ex Baker	Fabaceae	-	-	-	+	-
7	<i>Inula cappa</i> (Buch-Ham.ex D.Don)	Asteraceae	-	+	+	+	+
8	<i>Lantana camara</i> Linn.	Verbenaceae	+	-	-	-	-
9	<i>Murraya koenigii</i> (Linn.) spreng	Rutaceae	+	-	-	-	-
10	<i>Myrsine Africana</i> Linn.	Myrsinaceae	-	+	+	+	+
11	<i>Plectranthus rugosus</i> Wall.ex Benth	Lamiaceae	-	-	-	+	-
12	<i>Prinsepia utilis</i> Royle.	Rosaceae	-	-	-	-	+

Table 3 continued....

Table 3 continued....

13	<i>Pyrus pashia</i> Buch.-Ham ex D.Don	Rosaceae	-	+	-	-	-
14	<i>Rosa moschata</i> Herrm.	Rosaceae	-	-	-	-	+
15	<i>Rubus ellipticus</i> Smith.	Rosaceae	+	-	+	+	+
16	<i>Woodfordia floribunda</i> (Linn.) Kurz	Lythraceae	+	-	-	-	-
17	<i>Zanthoxylum alatum</i> Roxb.	Rutaceae	-	+	+	+	-
TOTAL			07	05	06	08	07
TREES							
01	<i>Abies pindrow</i> Royle	Pinaceae	-	-	-	-	+
02	<i>Acacia catechu</i> (Linn.) Willd	Mimosaceae	+	-	-	-	-
03	<i>Acer oblongum</i> Wall.ex.Dc.	Aceraceae	-	+	+	-	-
04	<i>Aegle marmelos</i> (Linn.)Correa ex Roxb.	Rutaceae	+	-	-	-	-
05	<i>Anogeissus latifolia</i> (Roxb.ex Dc.)	Combretaceae	+	-	-	-	-
06	<i>Bauhinia racemosa</i> Lam.	Cesalpiniaceae	+	-	-	-	-
07	<i>Butea monosperma</i> (Lam.) Taub.	Papilionaceae	+	-	-	-	-
08	<i>Cedrus Deodara</i> (Roxb.ex Lamb.)G.Don	Pinaceae	-	-	+	+	+
09	<i>Picea smithiana</i> (Wall.) Boiss	Pinaceae	-	-	-	-	+
10	<i>Pinus roxburghii</i> Sargent	Pinaceae	-	+	+	-	-
11	<i>Pinus wallichiana</i> A.B.Jacks.	Pinaceae	-	-	-	+	+
12	<i>Quercus floribanda</i> (A.Camus)Lindl.	Fagaceae	-	-	-	+	-
13	<i>Quercus leucotrichophora</i>	Fagaceae	-	+	+	-	-
14	<i>Quercus semecarpifolia</i> Smith.	Fagaceae	-	-	+	-	-
15	<i>Rhododendron arboreum</i> Smith.	Ericaceae	-	-	+	+	-
16	<i>Terminalia bellerica</i> (Gaertn. Roxb).	Combretaceae	+	-	-	-	-
TOTAL			06	03	06	04	04
Grand Total			61	53	62	56	60

Where: (+) = present and (-) = absent.

ranged from 0.12 (Chir pine forest) to 0.23 (Mixed forest) and it varied from 0.52 (Chir pine forest) to 0.82 (Acacia forest) for shrub layer. Monthly species richness index for herbaceous vegetation in different forests ranged between 2.39 (July) to 4.06 (August) for Acacia forest, 2.45 (September) to 3.33 (July) for Chir pine forest, 2.77 (October) to 4.82 (July) for Mixed forest, 2.62 (October) to 4.23 (August) and 3.14 (July) to 4.65 (August) for Fir–Spruce forest (fig. 5).

Species evenness index

Species evenness of trees in different forests fluctuated from 0.65 (Acacia forest) to 0.81 (Fir–Spruce forest) and for shrub layer from 0.85 (Acacia forest) to 0.93 (Mixed forest). In herbaceous vegetation it ranged between 0.50 (October) to 0.82 (July) for Acacia forest, 1.49 (July) to 1.54 (September) for Chir pine forest, 0.77 (September) to 0.84 (August) for Mixed forest, 0.80

(September) to 0.64 (July) for Deodar forest and 0.81 (July) to 0.89 (August) for Fir—Spruce forest (fig. 6).

The concentration of dominance index

Monthly concentration of dominance index value of different forests ranged between 0.05 (August) to 0.30 (October). Maximum value for dominance was observed in Acacia forest, while, the minimum value was observed in Mixed and Fir–Spruce forests. The dominance index ranged between 0.07 (August) to 0.30 (October) in Acacia forest, 0.08 (October) to 0.12 (August) in Chir pine forest, 0.05 (August) to 0.1 (August & October) in Mixed forest, 0.10 (October) to 0.19 (July) in Deodar forest and 0.05 (August) to 0.10 (July) in Fir—Spruce forest (fig. 7).

Similarity Index

Similarity index among different forests varied from 0.24 to 0.89. Acacia forest exhibited highest similarity

Table 4 : Index of similarity in vegetation of different forests.

Forest	Acacia forest	Chir pine forest	Mixedforest	Deodar forest	Fir- Spruce forest
Acacia forest	-	0.89	0.50	0.30	0.24
Chir pine forest	0.89	-	0.82	0.53	0.45
Mixed forest	0.50	0.82	-	0.70	0.56
Deodar forest	0.30	0.53	0.70	-	0.78
Fir-Spruce forest	0.24	0.45	0.56	0.78	-

Table 5 : Vegetation indices of trees, shrubs and herbs (peak value) in forests.

Forest	Plant categories	Vegetation indices			
		Shannon Weiner	Simpson's diversity	Species richness	Species evenness
Acacia Forest	Herbs	3.02	0.90	4.06	0.82
	Shrubs	1.65	0.81	0.82	0.85
	Trees	1.17	0.54	0.30	0.65
Chir pine Forest	Herbs	2.71	0.90	3.33	0.40
	Shrubs	1.58	0.52	0.52	0.88
	Trees	0.81	0.46	0.12	0.74
Mixed Forest	Herbs	3.18	0.94	4.82	0.84
	Shrubs	1.81	0.78	0.78	0.93
	Trees	1.25	0.64	0.23	0.70
Deodar Forest	Herbs	2.81	0.85	4.23	0.80
	Shrubs	1.80	0.81	0.81	0.92
	Trees	0.93	0.73	0.15	0.67
Fir – Spruce Forest	Herbs	3.16	0.93	4.65	0.89
	Shrubs	1.80	0.74	0.74	0.92
	Trees	1.12	0.61	0.15	0.81

index of 0.89 with Chir pine forest while it had least similarity value of 0.24 with Fir–Spruce forest (table 4). It was recorded that similarity index of Acacia forest decreased with other respective forests along the altitudinal gradient.

Chir pine forest exhibited least similarity index (table 5) with Fir-Spruce forest (0.44). Vegetation in Mixed forest showed highest similarity index with Chir pine forest (0.82) and least with Fir–Spruce forest (0.55). Deodar forest exhibited highest similarity index with Fir-Spruce forest (0.78) and lowest with Acacia forest (0.30).

Discussion

The present study conducted in five forests, located at different elevation along an altitudinal gradient of 600-2700m amsl extending from subtropical to temperate region, revealed that plant generic spectrum comprised of rich diversity made up of 122 species with 113 genera made up of 43.44% herbs, 22.14% graminoids, 4.09%,

ferns, 13.94% shrubs, 3.27% legumes (herbaceous) and 13.12% trees. These forests differed in plant species composition though the total number of plant species in each of them did not vary much (53 to 62 species), with Acacia forest having 61 plant species, Chir pine forest 53, mixed forest 62, Deodar forest 56 and Fir-Spruce forest 60 (table 4). Least number of species in Chir pine forest was due to pine needle-litter deposition on the forest floor which might have restricted germination of herbaceous flora (Gupta *et al.*, 2007). Diversity is an indicator of luxuriant growth of vegetation in different forest stands (Whitakkar, 1975). The number of species in different forests of present study indicates that the species richness did not decline as we move from 600m to 2700m altitude, but species composition did change as is evident from similarity index. The similar finding has been reported by Kharkwal *et al.* (2009) for Central Himalaya. Under storey species composition in these forests differed which is a manifestation of type (species

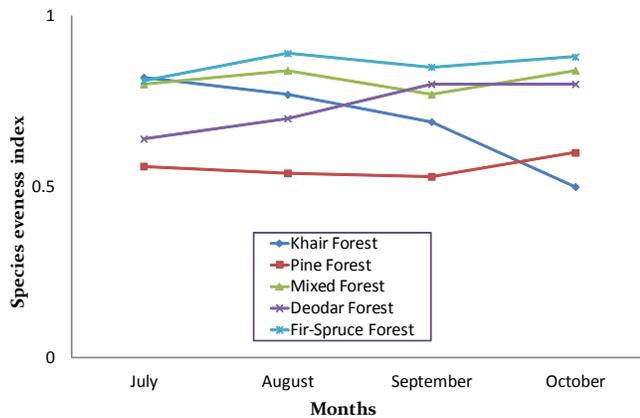


Fig. 5 : Monthly species richness index of herbage in forests.

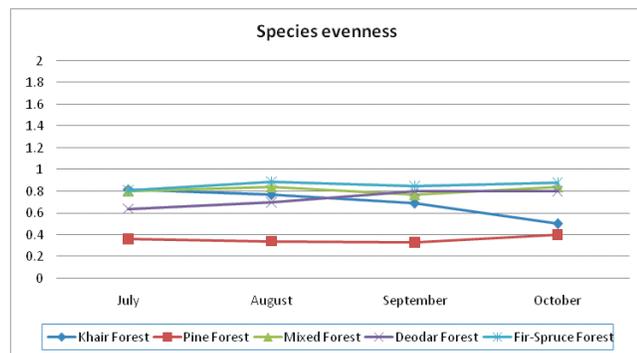


Fig. 6 : Monthly species evenness index of herb species of different forests.

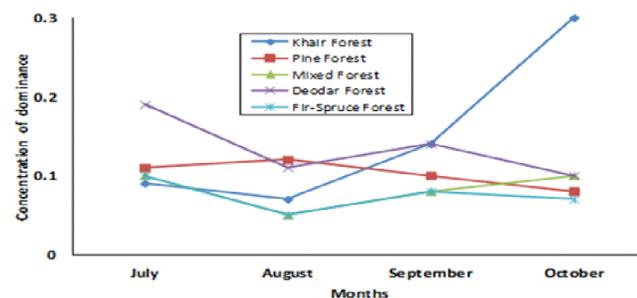


Fig. 7 : Monthly concentration of dominance of herbage in forests.

and density) of over storey trees and their influence likely to occur on herb layer diversity by modifying resource availability and environmental conditions relevant to herbs as opined by Vockenhuber *et al.* (2011), Alaback and Herman (1988) and Thomas *et al.* (1999). Further, altitude is one of the most important determinants of tree distribution due to its direct impact on micro climate of the habitat (Rawal and Pangtey, 1994; Singh *et al.*, 2009) the differences in species composition in tree, shrub and herb layer along the altitude can be expected. It was noticed that in the present study number of grasses in forests decreased along the altitude in different forests. This finding is similar to the result reported by Masoodi (2010) and Gupta (2007) for vegetation Species richness

of trees, shrubs and herbs was 0.30, 0.82 and 4.06 in Acacia forest, 0.12, 0.52 and 3.33 in Chir pine forest, 0.23, 0.78 and 4.82 in Mixed forest, 0.15, 0.81 and 4.23 in Deodar forest and 0.15, 0.74 and 4.65 in Fir-Spruce forest, respectively. Kharkwal (2009) contended that it increases and decreases with amount of rainfall and temperature. This is generally because of secondary succession when environmental and edaphic conditions are favorable with low fluctuations in north-west Himalaya. It was observed that similarity index of Acacia forest with other forests declined in the order: Chir pine > Mixed > Deodar > Fir-Spruce forests revealing that it decreased with altitude. It was also observed that higher similarity index values were observed among subtropical forests (Acacia and Chir pine) one hand and sub-temperate forests (Mixed conifer, Deodar and Fir-spruce forests) on the other. Suyal *et al.* (2010) opined that close proximity results in high similarity index of vegetation, the same could be related to grouping of forests based on similarity index in the present study.

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