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# Structure and composition estimation of plant species around Khoh river of Garhwal Himalaya, India

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## Abstract

The present study was carried out along the Khoh river of Garhwal Himalaya with the aim to assess the species composition and diversity of plant species between the forest vegetation along the river and the forest, which was away from the river. Vegetational analysis was carried out by quadrat sampling method and a total of 30 quadrates along the river and 30 quadrates away from the river were laid out randomly and the size of quadrat was 10 m × 10 m. *Salix tetraseprma* tree species emerged as a dominant species along riverian vegetation with highest IVI (38.07) and highest density (1.03 trees/100m$^2$) values. The highest density values in shrubs and herb species were recorded for *Trachelospermum lucidum* and *Polygala erioptera* respectively. In the forest vegetation, located away from the river, *Toona hexandra* was found dominant species with IVI and density values 34.52 and 0.66 trees/100m$^2$ respectively and in shrub layer, the highest density was observed for *Uraria rufescens* and in herbs the highest density was recorded for *Persicaria capitata*. Tree species diversity was observed highest along the river while the lowest tree diversity was away from the river

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## Introduction

The Himalayan ranges of the India lying within geographical limits of 26°20' and 35°40' North and 74°50' and 95°40' East, about 2500 km long, covering an area of 2,36,900 sq. km. India's recognition as one of four `mega diversity' centers of Asia and as one of ten largest forested areas in the world derives partly from the Himalaya. The Himalaya, although cover only 18% of the geographical area of India accounts for more than 50% of the India's forest cover and 40% of the species endemic to the Indian sub-continent (Maikhuri *et al.,* 2000). Forest composition, community structure and diversity patterns are important ecological attributes significantly correlated with prevailing environmental as well as anthropogenic variables (Gairola *et al*., 2008; Ahmad *et al*., 2010). The Himalayan forest vegetation ranges from tropical dry deciduous forest in the foothills to alpine meadow above timberline (Singh and Singh, 1992). Composition of the forest is diverse and varies from place to place because of varying topography such as plains, foothills and upper mountains (Singh, 2006). Riparian systems are biologically important components of landscapes worldwide, supporting a disproportionate amount of ecosystem services and species diversity compared to adjacent terrestrial ecosystems (Ward 1998, Brauman et al. 2007). Riparian areas provide recreation opportunities, wildlife habitat, and essential ecosystem services required for sustainable landscapes (Naiman et al. 1993, Brauman et al. 2007). The riparian habitat is highly dynamic being at the meeting zone or ecotone of the flowing river and the riverside land subjected to anthropogenic influences. Riparian areas are the biological and physical link between terrestrial and aquatic ecosystems (Youngblood *et al.* 1985). These areas are used extensively for domestic livestock grazing, gravel mining, recreational purposes, and as transportation corridors. The ecology of riparian areas and their response to various land management practices is variable and often poorly understood. So keeping the importance of riverine vegetation in mind, the present study was taken to understand, whether there is a difference in species composition and species diversity between the vegetation along and away from the river.

## Material and methods

*Location and Climate*

The state of Uttarakhand is situated in the northern part of India and shares an international boundary with China in the north and Nepal in the east. It has an area of 53483 km² and lies between latitude 28° 43′ and 31° 28′ N and longitude 77° 34′ and 81° 03′ E. The present study was carried out in Duggada Kodtwar forest area, of district Pauri Garhwal region (Western Himalaya). The climate of the study area is divisible into summer season, rainy season and winter season and the Soils of the region are formed either through pedogenesis processes or are transported soils. These soils are derived from granite, gneissic, schistose and phyllite rocks. The climate of Pauri Garhwal is sub-tropical to temperate climate; maximum temperature (45°C) is recorded in the month of June at Kotdwar while minimal temperature (0.3°C) is observed in the month of January at the higher reaches of Dudhatoli. The mean monthly temperature ranges between 25°C to 35°C and the average rainfall in the district is 218cm.

*Vegetation sampling and data analysis*

Vegetational analysis along river and away from river was carried out by using 10 m × 10 m quadrate size and a total number of 60 quadrates were drawn in two vegetation (Along the river and Away from the river) stands, 30 from each vegetation stand. The quadrates were laid down randomly for plant species within the two selected vegetation stands. The plant species observed during the study were identified with the help of local and regional flora (Gaur, 1999). The size and the number of quadrates were determined following Mishra (1968) and Kershaw (1973). In each quadrate, the trees were measured individually with > 31.5 cm cbh (Circumference at breast height i.e. 1.37 m above the ground). The vegetation data were quantitatively analyzed for abundance, density, and frequency according to

Curtis and McIntosh (1950) and Mishra (1968). The relative values were summed up to represent important value index (IVI) given by Curtis (1959). The diversity index (H') was computed by using Shannon-Wiener information Index (Shannon and Wiener, 1963). Concentration of dominance (Cd = S (ni/N)/2) was calculated following Simpson (1949). Species richness index (d) indicating the mean number of species per sample (Margalef 1958) was calculated as SR = S-1/ln (N) Where, SR = Margalef index of Species richness; S = Total number of species; N = Total number of individuals. Equitability or evenness (E = H'/ lnS, where, H'= Shannon-Wiener diversity index and S = Number of species) was computed following Pielou (1966). Species distribution pattern was examined by abundance/frequency ratio (Curtis & Cottam 1956) and A/F ratio was categorized into regular, when (< 0.025), random (0.025 - 0.05) and contagious (> 0.05).

## Results

A total of 124 species were recorded which represented 109 genera belonging to 83 families from both the vegetation stands (Along the river and away from the river) in the study area. Among 124 species, 31 were tree species with 22 genera belonging to 17 families while 45 were shrub species with 42 genera belonging to 27 families and 48 herb species represented 31 families and 45 genera. The dominant family was Euphorbiaceae followed by Urticaceae and Asteraceae.

*Floristic diversity along river*

The species richness was found to be highest along river with 78 species belonging to 72 genera from 53 families. Out of these 78 species, 23 were tree species having 20 genera belonging to 13 families, 28 were shrub species belonging to 26 genera under 20 families and 27 were herbs belonging to 26 genera under 20 families.

**Table 1.** Different parameters/characterstics of trees, shrubs, and herbs in the study area

| Parameters | Along the river | | | Away from the river | | |
|---|---|---|---|---|---|---|
| | Tree | Shrub | Herb | Tree | Shrub | Herb |
| Species richness (S) | 23 | 28 | 27 | 19 | 27 | 25 |
| No. of genera | 20 | 26 | 26 | 18 | 26 | 24 |
| No. of families | 13 | 20 | 20 | 13 | 22 | 18 |
| Shannon Index (H') | 3.06 | 3.26 | 3.24 | 2.64 | 3.13 | 3.19 |
| Simpson Index (Cd) | 0.088 | 0.040 | 0.041 | 0.075 | 0.048 | 0.042 |
| Margalef Index (Species richness) | 3.07 | 4.56 | 4.50 | 2.75 | 4.38 | 4.45 |
| Berger-Parker Index | 0.10 | 0.07 | 0.15 | 0.15 | 0.09 | 0.08 |
| Evenness | 1.11 | 0.97 | 0.98 | 0.95 | 0.95 | 0.99 |

Tree layer

The highest (1.03 trees/100m$^2$) density was recorded for *Salix tetraseprma* followed by *Toona hexandra* with (0.56 trees/100m$^2$) density while the lowest density (0.16 trees/100m$^2$) was observed for *Butea monosperma* and M*angifera indica* respectively. The highest frequency (66.67%) was observed for *Salix tetraseprma* followed by *Toona hexandra* (43.33%) and the lowest frequency (10%) was recorded for *Mangifera indica*. The highest TBC (16.47 m$^2$/ha) was observed for *Toona hexandra* followed by *Emblica officinalis* (9.28 m$^2$/ha) whereas lowest value of TBC was observed for *Debregeasia longifolia* (3.74 m$^2$/ha). The dominant species was found *Salix tetraseprma* with IVI (38.07) followed by *Toona hexandra* with (26.45) IVI while the least dominant species was found *Mangifera indica* with IVI (8.91). The total density and TBC recorded was 6.6 trees/100m$^2$ and 123.74 m$^2$/ha respectively (Table 2). Two tree species were found randomly distributed whereas rest of the species was distributed contagiously. The diversity indices recorded for tree layer were Shannon (3.06), Simpson's (0.088), Berger Parker (0.10), Margalef (3.07), and evenness (1.11) (Table 1).

*Shrub layer*

The highest (0.71 shrubs/25m$^2$) density was recorded for *Trachelospermum lucidum* followed by *Barleria cristata* (0.60 shrubs/25m$^2$) whereas lowest (0.18 shrubs/25m$^2$) density was recorded for *Salvia hians*. The highest frequency (30%) was observed for *Barleria cristata* followed by

**Table 2.** Phytosociological status of tree species along and away from river.

| Name of species | Along the river | | | | Away from the river | | | |
|---|---|---|---|---|---|---|---|---|
| | **D** | **F** | **TBC** | **IVI** | **D** | **F** | **TBC** | **IVI** |
| *Acacia catechu* (L.f) Willd., | - | - | - | - | 0.66 | 40.00 | 6.93 | 28.90 |
| *Bischofia javanica* Blume | 0.26 | 20.00 | 6.76 | 12.18 | - | - | - | - |
| *Bombax ceiba* L., | - | - | - | - | 0.40 | 30.00 | 6.92 | 21.86 |
| *Buchanania lanzan* Sprengel | - | - | - | - | 0.56 | 33.33 | 4.45 | 22.88 |
| *Butea monosperma* (Lam.) Kuntze, | 0.16 | 13.33 | 6.16 | 10.65 | 0.43 | 23.33 | 8.15 | 21.90 |
| *Cassia fistula* L., | 0.43 | 30.00 | 4.74 | 18.43 | 0.26 | 26.66 | 3.85 | 15.58 |
| *Celtis eriocarpa* Decne., | 0.40 | 20.00 | 5.89 | 15.64 | - | - | - | - |
| *Cordia dichotoma* Forster f., | 0.30 | 20.00 | 8.11 | 16.65 | 0.40 | 23.33 | 3.74 | 16.72 |
| *Dalbergia sericea* G.Don, | 0.26 | 16.67 | 5.10 | 15.39 | | | | |
| *Dalbergia sissoo* Roxb., | 0.36 | 16.67 | 4.88 | 12.59 | 0.53 | 26.66 | 5.22 | 21.34 |
| *Debregeasia longifolia* ( Burm. f) Wedd., | 0.40 | 23.33 | 3.74 | 15.04 | - | - | - | - |
| *Emblica officinalis* Gaertner, Fruct. Sem. | 0.40 | 23.33 | 9.28 | 19.83 | 0.53 | 33.33 | 8.35 | 26.43 |
| *Ficus benghalensis* L., | - | - | - | - | 0.26 | 16.66 | 6.14 | 15.28 |
| *Ficus glaberrima* Blume., | 0.26 | 13.33 | 5.22 | 12.91 | - | - | - | - |
| *Ficus sarmentosa* Buch.-Ham.ex J.E. Smith | 0.40 | 23.33 | 7.19 | 19.16 | - | - | - | - |
| *Glochidion assamicum* (Muell.-Areg.) Hook.f., | 0.20 | 13.33 | 7.30 | 12.00 | - | - | - | - |
| *Grevillea robusta* A. Cunningham ex R. Br., | - | - | - | - | 0.26 | 10.00 | 5.88 | 13.21 |
| *Lagerstroemia parviflora* Roxb., | - | - | - | - | 0.23 | 13.33 | 6.82 | 14.55 |
| *Mallotus philippensis* (Lam.) Muell.-Arg | - | - | - | - | 0.36 | 20.00 | 6.36 | 18.03 |
| *Mangifera indica* L., | 0.16 | 10.00 | 3.91 | 8.91 | - | - | - | - |
| *Melia azedarach* L., | 0.23 | 13.33 | 4.30 | 11.00 | - | - | - | - |
| *Persea gamblei* (King ex Hook.f.) | 0.23 | 13.33 | 6.70 | 11.76 | - | - | - | - |
| *Psidium guajava* L., | - | - | - | - | 0.33 | 16.66 | 5.44 | 15.62 |
| *Salix tetrasperma* Roxb., | 1.03 | 66.67 | 6.88 | 38.07 | - | - | - | - |
| *Syzygium cumini* (L.,) Skeels | - | - | - | - | 0.23 | 13.33 | 5.47 | 13.13 |
| *Syzygium venosum* DC., | 0.20 | 13.33 | 4.94 | 10.58 | - | - | - | - |
| *Terminalia alata* Heyne ex Roth., | 0.30 | 13.33 | 6.08 | 12.68 | - | - | - | - |
| *Toona hexandra* (Wallich ex Roxb.) M. Roemer | 0.56 | 43.33 | 16.47 | 26.45 | 0.66 | 43.33 | 11.42 | 34.52 |
| **Total** | **6.6** | | **123.74** | | **6.61** | | **95.00** | |

D-Density 100 $m^2$, F- frequency (%), TBC- Total basal cover ($m^2$/ha, IVI- Important value Index

*Trachelospermum lucidum* with (28.33%) frequency and the lowest frequency was recorded for *Calotropis gigantea* and *Pyracantha crenulata* with (8.33%) for both the species followed by *Boehmeria rugulosa* and *Picrasma quassioides* with (10%) frequency. The dominant species was observed *Barleria cristata* with IVI (15.85) followed by *Trachelospermum lucidum* (15.43) while the least dominant species was *Salvia hians* with IVI (5.87) followed by *Pyracantha crenulata*. The total density recorded for shrubs was 10.65 Shrubs /25$m^2$ (Table 3). All the shrub species were distributed contagiously. The diversity indices recorded for shrub layer were Shannon (3.26), Simpson's (0.04), Berger Parker (0.07), Margalef (4.56), and evenness (0.97) (Table 1).

*Herb layer*

The highest density (0.80 herbs/$m^2$) was recorded for *Polygala erioptera* followed by *Commelina*

*diffusa* (0.75 herbs/m²) and the lowest value of density (0.27 herbs/m²) was observed for *Girardinia diversifolia*. The highest frequency was observed for *Centaurium pulchellum* and *Polygala erioptera* (28.30%), followed by *Commelina diffusa* (25.80 %) while the lowest frequency (9.17%) was observed for *Cyperus nutans*. *Polygala erioptera* was dominant with IVI (15.65) followed by *Commelina diffusa* (15.13) while as the least dominant species was *Persicaria lapathifolia* with (7.37) IVI (Table 4). Distribution pattern of all herbs was contagious. The different diversity indices recorded for herb layer were Shannon (3.24), Simpson's (0.041), Berger Parker (0.15), Margalef (4.50), and evenness (0.98) (Table 1).

*Floristic diversity away from river*

The species richness away from the river represents by 71 species belonging to 68 genera from 53 families. Out of these total 71 species, 19 were tree species represented 18 genera from 13 families, 27 were shrubs belonging 26 genera under 22 families, while herbs are represented by 25 species belonging 24 genera under 18 families.

*Tree layer*

The highest density was recorded for *Acacia catechu and Toona hexandra* with (0.66 trees/100m²) for both the species followed by *Buchanania lanzan* (0.56 trees/100m²) while as the lowest density (0.23 trees/100m²) was observed for *Syzygium cumini* and *Lagerstromia parviflora*. The highest frequency was observed for *Toona hexandra* (43.33%), followed by *Acacia catechu* (40%) and the lowest frequency (10%) was recorded for *Grevillea robusta*. *Toona hexandra* with IVI (34.52) was dominant species followed by *Acacia catechu* (28.90) while as, *Syzygium cumini* was found least dominant species with IVI (13.13) followed by *Grevillea robusta* (13.21). The highest value of TBC (11.42 m²/ha) was observed for *Toona hexandra* followed by *Emblica officinalis* (8.35 m²/ha) whereas lowest (3.74 m²/ha) TBC was recorded for *Cordia dichotoma*. The overall total density and TBC of trees along river was 6.16 trees/100m² and 95.00 m²/ha respectively (Table 2). Five tree species were found randomly distributed while as rest of the species were distributed contagiously. The different diversity indices recorded for tree layer were Shannon (2.64), Simpson's (0.075), Berger Parker (0.15), Margalef (2.75), and evenness (0.95) (Table 1).

*Shrub layer*

The highest (0.71 shrubs/25m²) density was recorded for *Uraria rufescens* followed by *Ricinus cummunis* with (0.70 shrubs/25m²) density while the lowest density (1.10 shrubs/25m²) was recorded for *Euphorbia royleana*. The highest frequency (30%) was observed for *Adhatoda zeylanica* followed by *Inula cappa* and *Uraria rufescens* and the lowest frequency (3.33%) was recorded for *Euphorbia royleana* followed by *Anisomeles indica, Bauhinia vahlii, Pogostemon benghalense* and *Rhamnus triqueter* with (5.00%) frequency for each. *Uraria rufescens* with IVI (17.35) was dominant species followed by *Adhatoda zeylanica* while the least dominant species was *Pogostemon benghalense* with IVI (5.69). The total density for shrubs was 9.40 shrubs/25m² (Table 3). All the species were found contagiously distributed except *Lantana camara* species, which was randomly distributed. The different diversity indices recorded for shrub layer were Shannon (3.13), Simpson's (0.048), Berger Parker (0.09), Margalef (4.38), and evenness (0.95) (Table 1).

*Herb layer*

The highest density (0.70 herbs/m²) was recorded for *Persicaria capitata* followed by *Sida cordata* while the lowest density (0.25 herbs/m²) was observed for *Catharanthus pusillus*. The highest frequency (21.70%) was observed for *Galinsoga parviflora*, followed by *Bryophyllum pinnatum, Persicaria capitata, and Sida cordata* with (20.80%) for each while as the lowest frequency (7.5%) was observed for *Artemisia nilagirica*. *Persicaria capitata* was dominant with IVI (15.68) followed by *Bryophyllum pinnatum* while the least

dominant species was *Catharanthus pusillus* (Table 2). All the herb species were found contagiously distributed. The different diversity indices recorded for herb layer were Shannon (3.19), Simpson's (0.042), Berger Parker (0.08), Margalef (4.45), and evenness (0.99) (Table 4).

**Table 3.** Phytosociological status of shrub species along and away from river.

| Name of species | Along the river | | | | Away from the river | | | |
|---|---|---|---|---|---|---|---|---|
| | D | F | A/F | IVI | D | F | A/F | IVI |
| *Adhatoda zeylanica* Medikus | - | - | - | - | 0.58 | 30.00 | 0.06 | 17.02 |
| *Agave americana* L., | - | - | - | - | 0.55 | 23.33 | 0.10 | 14.76 |
| *Anisomeles indica* (L.) Kuntze | - | - | - | - | 0.08 | 5.00 | 0.33 | 6.98 |
| *Asclepias curassavica* L., | 0.58 | 28.33 | 0.07 | 14.80 | - | - | - | - |
| *Barleria cristata* L., | 0.60 | 30.00 | 0.06 | 15.85 | 0.46 | 23.33 | 0.08 | 6.98 |
| *Bauhinia vahlii* Wight and Arn | - | - | - | - | 0.13 | 5.00 | 0.53 | 9.66 |
| *Berberis asiatica* Roxb. Ex Dc., | - | - | - | - | 0.28 | 13.33 | 0.15 | 9.65 |
| *Boehmeria platyphylla* D.Don, | 0.31 | 15.00 | 0.14 | 9.76 | 0.31 | - | - | - |
| *Boehmeria rugulosa* Wedd., | 0.25 | 10.00 | 0.25 | 7.84 | 0.25 | - | - | - |
| *Caesalpinia decaptala* (Roth) Alston | 0.55 | 16.66 | 0.19 | 12.19 | 0.55 | - | - | - |
| *Calotropis gigantea* (L.) Dryander | 0.21 | 8.33 | 0.31 | 7.48 | 0.21 | 6.66 | 0.48 | 7.96 |
| *Cocculus laurifolius* DC., | 0.35 | 16.66 | 0.12 | 10.08 | 0.21 | 15.00 | 0.09 | 9.19 |
| *Colebrookia oppositifolia* J.E. Smith, | - | - | - | - | 0.11 | 10.00 | 0.11 | 7.33 |
| *Eupatorium riparium* Regel, | 0.33 | 11.66 | 0.24 | 8.50 | | | | |
| *Euphorbia royleana* Boissier | - | - | - | - | 0.10 | 3.33 | 0.90 | 7.11 |
| *Ficus hispida* L. f., | 0.31 | 18.3 | 0.09 | 10.54 | - | - | - | - |
| *Ficus laminosa* Hardwicke | 0.23 | 11.66 | 0.17 | 8.41 | - | - | - | - |
| *Hoya lanceolata* Wallich ex D.Don | 0.58 | 25.00 | 0.09 | 13.99 | - | - | - | - |
| *Inula cappa* (Buch.-Ham. ex D.Dun) DC., | - | - | - | - | 0.41 | 28.33 | 0.05 | 15.57 |
| *Lantana camara* L., | - | - | - | - | 0.30 | 25.00 | 0.04 | 13.33 |
| *Lecanthus wallichii* Wedd., | 0.43 | 28.33 | 0.05 | 13.18 | - | - | - | - |
| *Maesa argentea* (Wallich) A. DC., | 0.20 | 16.66 | 0.07 | 8.42 | - | - | - | - |
| *Maoutia puya* (Hook.) Wedd., | 0.31 | 11.66 | 0.23 | 9.12 | - | - | - | - |
| *Marsdenia roylei* Wight | 0.28 | 15.00 | 0.12 | 10.01 | - | - | - | - |
| *Murraya koenigii* (L.) Spre ngel, | 0.40 | 20.00 | 0.10 | 12.02 | 0.36 | 13.33 | 0.20 | 11.26 |
| *Nyctanthes arbor-tristis* L., | - | - | - | - | 0.26 | 13.33 | 0.15 | 9.80 |
| *Oreocnide frutescens* (Thunb.) Miq., | - | - | - | - | 0.40 | 20.00 | 0.10 | 13.06 |
| *Pavetta indica* L., | 0.35 | 15.00 | 0.15 | 10.13 | - | - | - | - |
| *Picrasma quassioides* (D.Dun) Bennett, | 0.25 | 10.00 | 0.25 | 8.37 | - | - | - | - |
| *Pogostemon benghalense* (Burm.f.) Kuntze | - | - | - | - | 0.15 | 5.00 | 0.60 | 5.69 |
| *Porana racemosa* Roxb., | 0.48 | 18.33 | 0.14 | 11.97 | 0.20 | 6.66 | 0.45 | 8.69 |
| *Pyracantha crenulata* (D.Don) M. Roemer, | 0.23 | 8.33 | 0.33 | 7.14 | | | | |
| *Rhamnus triqueter* (Wallich) Lawson | - | - | - | - | 0.16 | 5.00 | 0.66 | 5.85 |
| *Ricinus cummunis* L., | - | - | - | - | 0.70 | 25.00 | 0.11 | 15.98 |
| *Rubus biflorus* Buch.-Ham. ex Smith, | 0.38 | 21.66 | 0.08 | 11.10 | 0.26 | 13.33 | 0.15 | 10.10 |
| *Rubus ellipticus* Smith., | 0.45 | 18.33 | 0.13 | 12.19 | 0.45 | 20.00 | 0.11 | 13.98 |
| *Rumex hastatus* D.Don., | 0.26 | 15.00 | 0.11 | 8.62 | 0.26 | 13.33 | 0.15 | 9.87 |
| *Sabia paniculata* Edgew. Ex Hook.f. & Thomson | 0.51 | 23.33 | 0.09 | 13.28 | - | - | - | - |
| *Salvia hians* Royle ex Benth., | 0.18 | 11.66 | 0.13 | 5.87 | - | - | - | - |
| *Scurrula cordifolia* (Wallich) G.Don., | 0.43 | 25.00 | 0.06 | 12.96 | 0.66 | 18.33 | 0.19 | 14.49 |
| *Solanum viarum* Dunal | - | - | - | - | 0.16 | 10.00 | 0.16 | 7.64 |
| *Trachelospermum lucidum* (D.Dun) H.Wolff, | 0.71 | 28.33 | 0.08 | 15.43 | 0.55 | 26.66 | 0.07 | 15.55 |
| *Typha angustata* Bor & Chaubard | 0.41 | 15.00 | 0.18 | 10.60 | - | - | - | - |
| *Uraria rufescens* (DC.) Schindler | - | - | - | - | 0.71 | 28.33 | 0.08 | 17.35 |
| *Woodfordia fruticosa* (L.) Kurz, | - | - | - | - | 0.60 | 21.66 | 0.12 | 15.14 |
| **Total** | **10.65** | | | | **9.40** | | | |

D-Density/25m², F- frequency (%), A/F- Abundance to frequency ratio, IVI- Important value Index

**Table 4.** Phytosociological status of herb species along and away from river.

| Name of species | Along the river | | | | Away from the river | | | |
|---|---|---|---|---|---|---|---|---|
| | **D** | **F** | **A/F** | **IVI** | **D** | **F** | **A/F** | **IVI** |
| *Acalypha ciliata* Forsk, | - | - | - | - | 0.33 | 12.50 | 0.21 | 11.30 |
| *Achyranthes aspera* L., | - | - | - | - | 0.44 | 15.80 | 0.17 | 12.16 |
| *Achyranthes bidentata* Blume, | 0.36 | 12.50 | 0.23 | 9.60 | - | - | - | - |
| *Aeginetia indica* L., | 0.38 | 11.70 | 0.23 | 8.82 | - | - | - | - |
| *Aerides multiflorum* Roxb., | - | - | - | - | 0.39 | 15.80 | 0.15 | 13.65 |
| *Ammannia baccifera* L., | 0.68 | 21.70 | 0.14 | 13.80 | | | | |
| *Artemisia capillaris* Thumb., | - | - | - | - | 0.39 | 11.70 | 0.28 | 12.70 |
| *Artemisia nilagirica* var. septentrionalis (C.B. Clarke) | 0.53 | 15.80 | 0.21 | 11.57 | 0.34 | 7.50 | 0.60 | 10.14 |
| *Athyrium pectinatum* (wall.) presl. | 0.42 | 10.80 | 0.36 | 9.44 | - | - | - | - |
| *Bacopa hamiltoniana* (Benth.) Wettstein | 0.35 | 17.50 | 0.11 | 10.49 | - | - | - | - |
| *Begonia picta* Smith, | 0.49 | 22.50 | 0.09 | 12.89 | - | - | - | - |
| *Bidens bipinnata* L., | 0.37 | 12.50 | 0.24 | 9.58 | - | - | - | - |
| *Blepharis maderaspatensis* (L.,) Roth | - | - | - | - | 0.40 | 18.30 | 0.12 | 12.03 |
| *Blumea lacera* (Burm.f.) DC., | - | - | - | - | 0.30 | 13.30 | 0.17 | 10.57 |
| *Bryophyllum pinnatum* (Lam) Oken, | - | - | - | - | 0.50 | 20.80 | 0.11 | 14.3 |
| *Catharanthus pusillus* (Murray) G.Don, | - | - | - | - | 0.25 | 11.70 | 0.18 | 9.40 |
| *Celosia argentea* L., | - | - | - | - | 0.47 | 15.80 | 0.18 | 12.77 |
| *Centaurium pulchellum* (Swartz) Druce | 0.67 | 28.30 | 0.08 | 15.08 | - | - | - | - |
| *Clematis roylei* Rehder | 0.28 | 11.70 | 0.20 | 7.98 | - | - | - | - |
| *Commelina diffusa* Burm. F., | 0.75 | 25.80 | 0.11 | 15.13 | - | - | - | - |
| *Crotalaria albida* Heyne ex Roth | - | - | - | - | 0.42 | 13.30 | 0.23 | 12.08 |
| *Cyperus nutans* Vahl | 0.29 | 9.17 | 0.34 | 7.17 | - | - | - | - |
| *Digera muricata* (L.) Martius | - | - | - | - | 0.30 | 10.80 | 0.26 | 9.54 |
| *Echinochloa furmentacea* Link | - | - | - | - | 0.36 | 10.80 | 0.31 | 10.8 |
| *Eleocharis tetraquetra* Nees | 0.47 | 16.70 | 0.17 | 11.20 | - | - | - | - |
| *Epilobium hirsutum* L., | 0.32 | 11.70 | 0.23 | 8.19 | - | - | - | - |
| *Euphorbia chamaesyce* L., | - | - | - | - | 0.35 | 11.70 | 0.25 | 10.91 |
| *Floscopa scandens* Lour., | - | - | - | - | 0.36 | 8.33 | 0.52 | 10.27 |
| *Galinsoga parviviflora* Cav., | - | - | - | - | 0.50 | 21.70 | 0.10 | 14.31 |
| *Gentiana aprica* Decne | 0.55 | 20.00 | 0.13 | 11.70 | - | - | - | - |
| *Girardinia diversifolia* (Link) | 0.27 | 6.67 | 0.61 | 7.91 | - | - | - | - |
| *Gonostegia hirta* (Blume) Miq., | 0.61 | 25.00 | 0.09 | 12.03 | - | - | - | - |
| *Ipomoea muricata* (L.,) Jacquin | - | - | - | - | 0.37 | 12.50 | 0.24 | 10.91 |
| *Leea asiatica* (L.,) Ridsdale | 0.30 | 10.00 | 0.30 | 6.96 | - | - | - | - |
| *Lindernia crustacea* (L.,) F.V.Mueller | - | - | - | - | 0.40 | 11.70 | 0.30 | 10.04 |
| *Murdannia edulis* (Stokes) Faden | 0.68 | 23.30 | 0.12 | 14.15 | - | - | - | - |
| *Oenanthe javanica* (Blume) DC., | 0.62 | 22.50 | 0.12 | 13.44 | - | - | - | - |
| *Persicaria capitata* (Buch.-Ham. ex D.Dun,) | 0.45 | 17.50 | 0.14 | 10.58 | 0.70 | 20.80 | 0.16 | 15.68 |
| *Persicaria lapathifolia* (L.,) S.F.Gray | 0.32 | 10.80 | 0.27 | 7.37 | - | - | - | - |
| *Physalis divaricata* D.Don | - | - | - | - | 0.51 | 17.50 | 0.16 | 12.71 |
| *Pilea scripta* (Buch.-Ham. ex D.Dun,) | 0.65 | 21.7 | 0.14 | 13.37 | - | - | - | - |
| *Pimpinella acuminata* (Edgew.) C.B. Clarke | 0.36 | 23.3 | 0.06 | 10.94 | 0.49 | 18.30 | 0.14 | 12.74 |
| *Polygala erioptera* DC., | 0.80 | 28.3 | 0.10 | 15.65 | 0.44 | 15.80 | 0.17 | 12.85 |
| *Salvia nubicola* Wallich ex Sweet | 0.73 | 25.0 | 0.11 | 14.46 | - | - | - | - |
| *Sida cordata* (Burm.f.) Borss. Waalk., | - | - | - | - | 0.58 | 20.80 | 0.13 | 14.29 |
| *Tinospora sinesis* (Lour) Merrill | - | - | - | - | 0.40 | 14.20 | 0.20 | 11.09 |
| *Vervascum thapsus* L., | - | - | - | - | 0.52 | 15.80 | 0.20 | 12.47 |
| *Wallichia densiflora* Martius., | 0.43 | 13.30 | 0.24 | 10.38 | - | - | - | - |
| **Total** | **13.19** | | | | **10.61** | | | |

D-Density/25m², F- frequency (%), A/F- Abundance to frequency ratio, IVI- Important value Index

**Discussion**

Species richness in a forest depends on climatic, edaphic and biotic factors (Ayappan & Parthasarathy 1999). A total of 124 plant species were recorded from the present study area representing 109 genera and 83 families. The species richness was highest along river forest than away from river forest. The species diversity of forest along river was found in the following order Herbs (48)> Shrubs (45)> Trees (31). Semwal *et al.,* (1999) reported a total of 81 species in which 20 species were trees, 24 species were shrubs and 37 species of herbs in the forests of Jardhar in Garhwal Himalaya. Kharkwal *et al.,* (2004) carried out a study in pine forest at different altitudes of central Himalaya and reported a total of 56 species comprising 51 genera and 28 families, which is lower than the present study. The reason behind high species richness might be due to the present study in the riverine forests. Tripathi and Singh (2009) worked in Katerniaghat Wildlife Sanctuary and reported that riverine forests had the highest species richness and diversity followed by miscellaneous forest and the high species richness in riverine forest may be attributed to higher soil moisture and nutrients.

The tree density in the present study was highest along river which ranged from 6.6 trees/100m$^2$ or (660 trees/ha) to 6.1 trees/100m$^2$ or (616 trees/ha). These values are within the values reported by Saxena and Singh (1982), Bargali *et al.* (1988), Pangtey *et al.* (1989), Bhandari *et al.,* (1997) for various forests of Garhwal Himalaya. However, Burton *et al.,* (2005) worked in riparian forest of two countries and observed the density values between 950 trees/ha to 1958 trees/ha, which is higher than the present study and the reason for higher density values might be because they have worked on a large scale and also the lower values of present study may be due to the anthropogenic pressure created by villagers for extraction of fuelwood and fodder. Total basal cover (TBC) for trees showed a range of 123.74 m$^2$/ha along river stretch to 95 m$^2$/ha away from river stretch forest. The present study values are supported by Pande *et al.,* (2001) who carried out a study on quantitative vegetation analysis as per aspect and altitude in Garhwal Himalayan forests and they observed TBC ranged from between 56.42-126 m$^2$/ha. Tripathi and Singh (2009) reported that basal area is an important indicator of tree stocking which reflects stand volume or biomass and observed 24.84 m$^2$ ha$^{-1}$ basal areas of trees in riverine forest of Katerniaghat Wildlife Sanctuary.

The higher values of shrub and herb density were observed along the river. Shrub density in the present study varied from 10.65 shrubs/25m$^2$ to 9.40 shrubs/25m$^2$, whereas herb density ranged between 13.19 plants/m$^2$ to 10.61 plants/m$^2$. The values are comparable to the reported values of (Kumar *et al.*, 2009), Uniyal *et al.,* (2010) for Garhwal Himalaya forests. A/F ratio is used to interpret the distribution pattern of species. Odum (1971) stated that clumped (contagious) distribution is the commonest pattern in nature, and random distribution is found only in uniform environment and the regular distribution occurs where severe competition between the individuals exists (Panchal and Pandey 2004). The above statement supports the findings of the present study. The analysis of distribution pattern along and away from river indicates that contagious distribution was more prominent than random distribution except three species e.g., *Salix tetraseprma, Toona hexandra* and *Cassia fistula* showed random distribution along riverine stand and five species away from the riverine stand e.g., *Acacia catechu, Bombax ceiba, Cassia fistula, Emblica officinalis* and *Toona hexandra* showed random distribution. Several workers (Kumar *et al.*, 2004, 2005, and 2009) have reported contagious distribution for different sub-tropical forest species in Garhwal Himalaya and they reported that regular distribution pattern was entirely absent. Shannon diversity index (H') for tree species were recorded highest (3.06) along river stand whereas lowest value (2.64) was recorded away from river stand. The values of present study are more or less similar to the values (2.26 - 2.92) calculated by Burton *et al.,* (2005) for Riparian woody plant diversity and forest structure along an urban rural gradient. The values

of present are higher than the values (2.27-1.44) calculated by Kris Van Looy *et al.,* (2003) on effect of river embankment and forest fragmentation on plant species and composition of flood plain forests in the Meuse valley Belgium. But the values of present study are higher than the values reported (1.4 - 0.8) by Pala *et al.,* (2011) in forests along river Ganga in Himalaya.

Shannon diversity index (H') for shrub species was found highest along riverine stand forest (3.26) and lowest (3.13) away from river stand. The present values are supported by the values given by (Ram *et al.,* 2004) and they reported shrub diversity between 2.6 to 3.8 for different forest types in Kumaun Himalaya. For herb layer higher values of Shannon diversity Index (H') were observed along riverine stand (3.24) whereas lower values was observed away from riverine stretch (3.19). The values of present study were within the values reported for different forests by many workers (Singh and Singh, 1986; Pande *et al*., 2002). The values of present study are also within the reported values (3.24 to 4.03) given by Kharkwal *et al*., (2005).

Another important attribute explaining community structure is evenness, which gives an idea regarding the equal abundance of species. High evenness occurs when species are equal in their distribution and abundance. For tree species, the value of evenness ranged from 1.11 to 0.95 in the present study. Highest values of evenness were found along the river and lower away from the river stand. The values of the present study is more or less similar to the values (0.73-085) reported by Lythryn (2008) for riparian areas of Northeastern Ohio. However, the values are higher than the values (0.69 - 0.81) recorded by Burton *et al.,* (2005) for riparian woody plant diversity and forest structure along an urban rural gradient.

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