Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

**E-ISSN:** 2278-4136
**P-ISSN:** 2349-8234
JPP 2019; 8(6): 1735-1740
Received: 19-09-2019
Accepted: 21-10-2019

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# Community structure and diversity of natural forest along altitudinal gradient and aspects in western Himalaya

**Sonam Rajput, Dr. CL Thakur and Jayashree Behera**

**Abstract**
In this present study, we aimed to determine the plant diversity and floristic composition in temperate natural forest of western Himalaya. We selected three altitude range viz., lower, middle and higher altitudinal range on four aspects viz., northern, southern, western and eastern. Oak is the dominant tree species followed by pine in the case of tree species at the study site. *Berberis aristata* and *Sarcococca saligna* were dominant shrub species which belong to berberidaceae and buxaceae families. In the case of herb species, *Cyperus rotundas* and *Viola serpens* were most dominant herb species which belong to cyperaceae and violaceae families whereas, *Arisaema sp.* was inferior herb species which belong to araceae family. Higher number of tree and shrub species were observed at lower altitudinal range on western aspect and southern aspect whereas, least number of tree and shrub species were observed at higher altitudinal range on eastern aspect but in the herb species, maximum number were recorded at higher altitudinal range on northern aspect and minimum at lower altitudinal range on eastern aspect. In vegetation indices, tree species diversity ranged from 0.47 to 1.28, simpson's dominace between 0.51 to .021 and species richness from 1.08 to 0.35 and shrub species diversity ranged between 2.09 to 1.40, simpson's dominace from 0.98 to 057 and species richness ranged from 2.28 to 1.11. In herbaceous, species diversity ranged from 2.45 to 1.66, simpson's dominace from 093 to 0.51 and species richness between 2.59 to 1.34. A pattern of tree and shrub species reduced with increasing altitude on all aspect but herb species increased with increasing altitude with all aspects. However, tree and shrub species showed similar trend but herb species showed reversed pattern to the tree and shrub species.

**Keywords:** Altitude, aspect, species, pattern, family

## Introduction
The Himalayan forests are rich in biodiversity and distributed over a large extent from lower to higher elevation. The tree vegetation is the dominant components of these forests. Himalayan forests are crucial not only for the people for the living in the Himalaya but also for many more living in the adjoining plains. Various aspect of biodiversity of these forests has been studied by (Dhar, *et al*., 1997; Silori, 2001; Kumar, 2000; Khera, *et al*., 2001) [1, 2, 3, 4,]. Mountains are the most remarkable land forms on earth surface with prominent vegetation zones based mainly on altitudinal and climatic variations. Variations in aspects also enhance habitat heterogeneity and bring microenvironmental variation in vegetation pattern (Clapham, 1973; Khan, *et al*., 2011b) [5, 6] Himalayas are diverse with a variety of forest covers due to elevation and climatic gradients as the vegetation community had a direct relationship with altitude (Mani, 1978) [7]. The lower elevations of the temperate forests are occupied by oak-pine mixed forests and *Quercus semicarpifolia* with other coniferous at higher altitudes, normally form the climax vegetation. Other species of oak are found above the oak-pine mixed forests of Garhwal Himalaya (Osmostan, 1922) [8]. Oak (Quercus spp.) occupy most of the area from 1000 to 3000 m altitude in the central and western Nepal, Uttarakhand and Himachal Pardsesh. Banj oak (*Quercus leucotrichophora*) is the most common broadleaf tree in the mid - elevation central Himalaya in India. Chir – pine (*Pinus roxburghii* Roxb.) the dominant species from low to mid elevation and it is a frequent reproducer not only in its own forests but also in other forests where it has intruded following disturbance and creation of open canopy (Oliver and Larson 1990) [9]. Vegetation in the mountain area is affected by several factors of which altitude, aspect, slope and soil depth are predominant as they modify regimes of moisture and exposure to sun. Vegetation within forest is greatly affected by differences in the microclimate, aspect and altitude (Pande, *et al*., 1996) [10].
The physiographic features such as elevation and aspect have a profound influence on the distribution, growth, form and structure of tree species, as a result of which the individual tree species has different values for density and basal area at various altitudes and aspects (Wikum

and Wali 1974) [11]. Diversity of life-forms usually decreases with increasing altitude and only one or two life forms remain at extreme altitudes (Pavo´ n, *et al*., 2000) [12]. Altitude itself represents a complex combination of related climatic variables closely correlated with numerous other environmental properties (Ramsay and Oxley 1997) [13]. The plant community of a region is a function of time; however, altitude, slope, latitude, aspect, rainfall, and humidity play a role in the formation of plant communities and their composition (Kharkwal, *et al*., 2005) [14]. The most prominent of these changes along the altitudinal range is represented by the subalpine transition between temperate forests and alpine grassland ecosystems, termed as timberline zone.

## Material and method

We selected three altitudinal ranges lower (<1800m a.s.l.), middle (1800-2100m a.s.l.) and higher altitudinal range (>2100m) along with different aspects viz., northern, southern, western and eastern aspect at kandaghat forest division of solan district Himachal Pradesh. The Solan division lies between longitudes $76^0$56' and $77^0$12' East and latitudes $30^0$46' and $31^0$10' North. The geographical area of division is 721.30 sq. km. It is surrounded on the North by the Shimla Forest Division in the north by the Rajgarh Forest Division in the East, on the West by Kunihar Forest Division and South by Haryana State. The climate is sub-tropical and moist temperate. The rainy season come from the first week of July to the last week of August but sometime extends up to mid of September. Winter rains generally falls from the last week of December and continues up to end of February. Due to variation in this division, the temperature also varies considerably. In this present, we determined the diversity of plant categories viz., tree, shrub and herb species along different altitudinal range and aspects.

**Table 1:** Description of site area

| Altitudinal ranges (m a.s.l.)/ | Aspect | Latitude | Longitude |
|---|---|---|---|
| Lower (<1800m | North | $33^0$50'33'' to $30^0$75'86''N | $77^0$04'17'' to $77^0$05'81''E |
| | South | $30^0$56'16'' to $33^0$95'20'' N | $77^0$05'46'' to $77^0$08'78''E |
| | West | $33^0$57'42 to $30^0$57'82'' N | $77^0$5'41'' to $77^0$5'72''E |
| | East | $33^0$055'26''to$33^0$55'41'' N | $77^0$5'41'' to $77^0$5'72''E |
| Middle (1800-210m) | North | $30^0$56'43'' to $30^0$94'13'' N | $77^0$06'55'' to $77^0$10'99''E |
| | South | $30^0$95'21'' to $30^0$56'62'' N | $77^0$08'87'' to $77^0$05'49''E |
| | West | $33^0$95'34'' to $33^0$95'99'' N | $77^0$08'86'' to $77^0$09'84''E |
| | East | $33^0$55'50'' to $30^0$56'32'' N | $70^0$06'08'' to $70^0$06'11''E |
| Higher (>2100m) | North | $30^0$56'49'' to $33^0$56'63'' N | $77^0$12'08'' to $77^0$12'41''E |
| | South | $30^0$94'33'' to $30^0$94'37'' N | $77^0$09'39'' to $77^0$09'64''E |
| | West | $33^0$56'53'' to $33^0$56'72'' N | $77^0$09'39'' to $77^0$09'64''E |
| | East | $30^0$55'04'' to $30^0$56'05'' N | $77^0$06'16'' to $77^0$06'29''E |

## Result and discussion

The altitude and aspects play a key role in determining the temperature regime of any site. Within one altitude the cofactors like topography, slope, aspects and soil type also affect the forest composition (Shank and Noorie 1950) [15].

### Floristic composition of tree species

The floristic composition of tree species at different altitudinal gradients and aspects are summerized in table 2. In this present study, At the altitudinal range of <1800m, maximum number of tree species 6 were recorded on the western aspect followed by the northern and southern aspect 5 and minimum number of tree species 3 found on eastern aspect respectively. Maximum number of tree species 4 at 1800-2100m altitudinal range were recorded on the western aspect and least tree species 2 were found on eastern aspect. *Quercus leucotrichophora* was recorded at the 12 sites followed by the *Pinus roxburghii* at 10 sites and *Cedrus deodara* at 9 sites. Minimum number of tree species 2 were recorded at higher altitude (>2100m) on the western aspect. *Quercus leucotrichophora* was dominanat tree species followed by *Pinus roxburghii* and least dominant tree species were *Populus deltoides*, *Punica granatum* and *Acer oblungum* at different altitudinal ranges and aspects.

**Table 2:** Presence or absence of tree species at different altitudinal ranges and aspects

| Sr. No. | Tree species | Family | Altitudinal ranges (m a.s.l) | | | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | $E_1$ (<1800m) | | | | $E_2$ (1800-2100m) | | | | $E_3$ (>2100m) | | | | |
| | | | $A_1$ | $A_2$ | $A_3$ | $A_4$ | $A_1$ | $A_2$ | $A_3$ | $A_4$ | $A_1$ | $A_2$ | $A_3$ | $A_4$ | |
| 1. | *Acer oblungum* | Sapindaceae | - | - | + | - | - | - | - | - | - | - | - | - | 1 |
| 2. | *Bauhinia variegate* | Fabaceae | + | - | - | - | - | - | - | - | - | - | - | - | 1 |
| 3. | *Cedrus deodara* | Pinaceae | + | - | + | - | + | + | + | - | + | + | + | + | 9 |
| 4. | *Grewia optiva* | Malvaceae | - | - | - | + | - | - | - | - | - | - | - | - | 1 |
| 5. | *Myrica esculenta* | Myricaceae | - | + | - | - | - | - | - | - | - | - | - | - | 1 |
| 6. | *Pinus roxburghii* | Pinaceae | + | + | + | + | - | + | + | + | - | + | - | + | 9 |
| 7. | *Populus deltoids* | Salicaceae | - | - | - | + | - | - | - | - | - | - | - | - | 1 |
| 8. | *Punica granatum* | Lythraceae | - | - | + | - | - | - | - | - | - | - | - | - | 1 |
| 9. | *Pyrus pashia* | Rosaceae | + | - | - | - | + | - | - | - | - | - | - | - | 2 |
| 10. | *Pistacia integerrima* | Anacardiaceae | - | + | - | - | - | - | - | - | - | - | - | - | 1 |
| 11. | *Quercus leucotrichophora* | Fagaceae | + | + | + | - | + | + | + | + | + | + | + | + | 11 |
| 12. | *Rhododendron arboretum* | Ericaceae | - | - | - | - | - | - | + | - | - | - | - | - | 1 |
| 13. | *Toona ciliata* | Meliaceae | - | - | + | - | - | - | - | - | - | - | - | - | 1 |
| Total | | | 5 | 4 | 6 | 3 | 3 | 3 | 4 | 3 | 2 | 3 | 2 | 3 | |

$A_1$ (Northern aspect), $A_2$ (Southern aspect), $A_3$ (Western aspect), $A_4$ (Eastern aspect)

The biological diversity of the Himalaya is severely threatened by natural, as well as anthropogenic disturbances, such as, tree cutting, grazing, lopping, fuel wood, fodder and litter removal. There are large number of environmental factors which influence the species richness and composition, such as elevation and habitat (Chandra *et al.* 2010) [16]. The occurrence of *Quercus leucotrichophora* on almost all the sites along the temperate altitudinal range suggest their tolerance to biotic pressure and wider eccological amplitude. *Pinus roxburghii* is an early succesional species and Oak a climatic climax alluded by Champion and Seth (1968) [17].

**Floristic composition of shrub species**

The shrub species examined at different altitudinal ranges and aspects are given in Table 3. Maximum number of shrub species 13 were found at <1800m on southern aspect while minimum number species 4 were found at higher altitudianl ranges (1800-2100m) on eastern aspect which followed by western aspect. The prominent species are *Berberis aristata* and *Rubus ellipticus* where as, the least prominent shrub speices are *Cassia floribunda, Woodfordia fruticosa, Artemisia valgaris* and *Adhatoda vasica*. At the <1800m range maximum species13 were recorded on southern aspect which followed by northen aspect (11 tree species). At the middle altitudinal range (1800-2100m) represented by maximal 7 shrub species on northen and southern aspect and minimal shrub species 5 were found on eastern aspect. Highest number of shrub species 7 were found at >2100m on northen aspect which followed by southern aspect and lowest number of species 4 observed on eastern aspect respectively.

**Table 3:** Presence or absence of shrub species at different altitudinal ranges and aspects

| Sr. No. | Tree species | Family | Altitudinal ranges (m a.s.l) | | | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | $E_1$ (<1800m) | | | | $E_2$ (1800-2100m) | | | | $E_3$ (>2100m) | | | | |
| | | | $A_1$ | $A_2$ | $A_3$ | $A_4$ | $A_1$ | $A_2$ | $A_3$ | $A_4$ | $A_1$ | $A_2$ | $A_3$ | $A_4$ | |
| 1. | *Adhatoda vasica* | Acanthaceae | - | + | - | + | - | - | - | - | - | - | - | - | 2 |
| 2. | *Artemisia valgaris* | Asteraceae | - | + | - | - | - | - | - | - | - | - | - | - | 1 |
| 3. | *Berberis aristata* | Berberidaceae | + | + | - | - | + | + | + | + | + | + | + | + | 10 |
| 4. | *Berberis vulgaris* | Berberidaceae | + | + | - | - | - | - | - | - | - | - | - | - | 2 |
| 5. | *Boenninghausenia albiflora* | Rutaceae | + | - | - | + | - | + | - | - | - | - | - | - | 3 |
| 6. | *Carissa carandes* | Apocynaceae | - | + | - | - | - | - | - | - | - | - | - | - | 1 |
| 7. | *Cassia floribunda* | Fabaceae | + | - | - | - | - | - | - | - | - | - | - | - | 1 |
| 8. | *Coriaria nepalensis* | Coriariaceae | + | - | - | + | - | - | - | + | - | - | - | - | 3 |
| 9. | *Daphne cannabina* | Thymelaeaceae | + | + | - | + | + | - | - | - | + | + | - | - | 6 |
| 10. | *Hypercium ablongifolium* | Hypericaceae | - | + | - | - | - | - | - | - | - | - | - | - | 1 |
| 11. | *Indigofera pulchella* | Fabaceae | - | - | - | - | + | + | - | - | + | + | + | - | 5 |
| 12. | *Lantana camara* | Verbenaceae | - | - | - | + | - | - | - | + | - | - | - | + | 3 |
| 13. | *Myrsine africana* | Primulaceae | + | + | - | - | - | + | + | - | + | + | + | - | 7 |
| 14. | *Osyris arborea* | Santalaceae | + | - | + | - | - | - | - | - | - | - | - | - | 2 |
| 15. | *Prinsepia utilis* | Rosaceae | - | + | + | - | - | + | - | - | - | - | - | - | 3 |
| 16. | *Rabdosia rubescens* | Lamiaceae | - | + | + | + | - | - | + | - | - | - | - | - | 4 |
| 17. | *Randia tetrasperma* | Rubiaceae | - | + | - | + | - | + | - | + | - | - | - | + | 5 |
| 18. | *Rubus ellipticus* | Rosaceae | + | + | + | - | + | - | + | - | + | + | + | - | 8 |
| 19. | *Rubus niveus* | Rosaceae | + | - | - | - | + | - | + | - | + | - | - | - | 4 |
| 20. | *Sarcococca saligna* | Buxaceae | + | + | - | - | + | + | + | + | + | + | + | + | 10 |
| 21. | *Woodfrordia floribunda* | Lytharaceae | - | - | + | + | + | - | - | - | - | - | - | - | 3 |
| 22. | *Woodfordia fruticosa* | Lytharaceae | - | - | + | - | - | - | - | - | - | - | - | - | 1 |
| Total | | | 11 | 13 | 6 | 8 | 7 | 7 | 6 | 5 | 7 | 6 | 5 | 4 | 11 |

**Floristic composition of herb species**

Herbaceous vegetation recorded at different altitudinal ranges and aspects are given in Table 4. At the lower altitudinal range (<1800m), maximum number of herb species 6 recorded on northen aspect whereas, the minimum number of species 4 were recorded on southern and eastern aspects. At 1800-2100m, highly diversity herb species 8 were recorded on northern aspect and least persecence of species 5 were found on western and eastern aspects. In this represented table at higher altitudinal range (>2100m), maximum number of herb species 9 were reproted on northern aspect which followed by southern aspect and minimum number of species 6 were found on western aspect.

**Table 4:** Presence or absence of herb species at different altitudinal ranges and aspects

| Sr. No. | Tree species | Family | Altitudinal ranges (m a.s.l) | | | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | $E_1$ (<1800m) | | | | $E_2$ (1800-2100m) | | | | $E_3$ (>2100m) | | | | |
| | | | $A_1$ | $A_2$ | $A_3$ | $A_4$ | $A_1$ | $A_2$ | $A_3$ | $A_4$ | $A_1$ | $A_2$ | $A_3$ | $A_4$ | |
| 1. | *Artemisia roxburghiana* | Asteraceae | - | - | - | - | - | + | + | - | + | - | - | - | 3 |
| 2. | *Arisaema sp.* | Araceae | - | - | - | - | - | + | - | - | + | - | - | - | 2 |
| 3. | *Bidens pilosa* | Asteraceae | - | + | + | + | - | - | - | - | - | - | - | - | 3 |
| 4. | *Cyperus rotundas* | Cyperaceae | + | - | + | + | + | + | - | + | + | + | - | + | 9 |
| 5. | *Dioscorea esculenta* | Dioscoreaceae | + | + | - | + | - | - | - | - | - | - | - | - | 3 |
| 6. | *Fragaria indica* | Rosaceae | - | - | + | - | + | + | + | + | - | + | + | + | 8 |
| 7. | *Micromera bilflora* | Lamiaceae | - | + | - | - | - | + | - | - | - | + | - | - | 4 |
| 8. | *Polystichum discretum* | Dryopteridaceae | + | - | - | - | + | - | + | - | + | + | - | + | 6 |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9. | *Rubia cardifolia* | Rubiaceae | + | - | + | - | + | - | - | + | + | + | + | - | 7 |
| 10. | *Strobilanthus wallichii/alstata* | Acanthaceae | - | - | - | - | + | - | + | - | + | - | + | - | 4 |
| 11. | *Thalictrum foliolosum* | Ranunculaceae | + | - | - | + | + | + | - | - | + | + | + | + | 8 |
| 12. | *Viola canescens* | Violaceae | - | - | - | - | + | - | + | + | + | + | + | + | 7 |
| 13. | *Viola serpens* | Violaceae | + | + | - | - | + | + | - | + | + | + | + | + | 9 |
| Total | | | 6 | 4 | 5 | 4 | 8 | 7 | 5 | 5 | 9 | 8 | 6 | 6 | |

Maximum number of herb species 9 were recorded on northern aspect at higher altitudinal range (>2100m) followed by souhtern aspect (8 herb species) at same altitudinal range and southern aspect (8 herb species) at middle altitudinal range (1800-2100m). The dominant species were *Viola serpens* and *Cyperus rotundas* whereas, least dominamt herb species are *Arisaema sp.*, *Artemisia roxburghiana* and *Dioscorea esculenta* at different altitudinal ranges and aspects. Rawal and Pangtey 1994 [18]; Singh, *et al.*, 2009 [19] alluded that altitude is one of the most significant factor which examined the distribution of tree species due to its direct effect on the microclimatic conditions of the habitat.

**Table 5:** Family, Genus and species of plant categories at different altitudinal ranges and aspects

| Aspects | Altitudinal ranges (m a.s.l.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | $E_1$ (<1800m) | | | $E_2$ (1800-2100m) | | | $E_3$ (>2100m) | | |
| | Family | Genus | Species | Family | Genus | Species | Family | Genus | Species |
| | Tree Species | | | | | | | | |
| $A_1$ | 5 | 6 | 5 | 4 | 5 | 4 | 2 | 3 | 2 |
| $A_2$ | 5 | 6 | 5 | 3 | 5 | 4 | 2 | 4 | 3 |
| $A_3$ | 6 | 8 | 7 | 3 | 6 | 4 | 2 | 3 | 2 |
| $A_4$ | 4 | 4 | 4 | 3 | 4 | 3 | 2 | 4 | 3 |
| | Shrub Species | | | | | | | | |
| $A_1$ | 9 | 12 | 11 | 6 | 8 | 7 | 6 | 8 | 7 |
| $A_2$ | 11 | 14 | 13 | 7 | 7 | 7 | 6 | 7 | 6 |
| $A_3$ | 4 | 7 | 6 | 5 | 7 | 6 | 5 | 6 | 5 |
| $A_4$ | 8 | 8 | 8 | 5 | 5 | 5 | 4 | 4 | 4 |
| | Herb Species | | | | | | | | |
| $A_1$ | 6 | 6 | 6 | 7 | 8 | 8 | 8 | 9 | 9 |
| $A_2$ | 4 | 4 | 4 | 7 | 7 | 7 | 7 | 8 | 8 |
| $A_3$ | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 6 | 6 |
| $A_4$ | 4 | 4 | 4 | 4 | 5 | 5 | 5 | 6 | 6 |

$A_1$ (Northern aspect), $A_2$ (Southern aspect), $A_3$ (Western aspect), $A_4$ (Eastern aspect)

It is evident from data available in the Table (5) that the maximum number of tree species 7 were reported at <1800m altittude on western aspect which followed by northern aspect at same altitudinal range. The minimum number of tree species were found on eastern aspect at higher altitude.

In that case of shrub species, the highest number of species 13 were recorded at 1800-2100m altitude on sothern aspect whereas, the least number of shrub species 4 were recorded at >2100m altitude on eastern aspect. 9 herb species belonged to 8 families were found at higher altitude (>2100m) on northern aspect whereas, minimum number of species 4 found on eastern aspect at lower altitude (<1800m) which followed by southern aspect at same altitude respectively.

**Table 6:** Vegetation indices of tree, shrubs and herbs at different altitudinal ranges and aspects

| Parameter | | Shannnon-weiner index | | | | Simpson's dominance | | | | Species richness | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Aspects/ altitudinal ranges | Plant categories | $A_1$ | $A_2$ | $A_3$ | $A_4$ | $A_1$ | $A_2$ | $A_3$ | $A_4$ | $A_1$ | $A_2$ | $A_3$ | $A_4$ |
| $E_1$ | Tree | 0.91 | 1.28 | 1.25 | 0.58 | 0.51 | 0.47 | 0.49 | 0.35 | 0.78 | 0.79 | 1.08 | 0.64 |
| $E_2$ | | 0.88 | 0.79 | 0.82 | 0.51 | 0.42 | 0.46 | 0.39 | 0.41 | 0.61 | 0.58 | 0.51 | 0.41 |
| $E_3$ | | 0.66 | 0.78 | 0.69 | 0.47 | 0.32 | 0.21 | 0.29 | 0.33 | 0.54 | 0.42 | 0.41 | 0.35 |
| $E_1$ | Shrubs | 1.69 | 2.09 | 1.61 | 1.66 | 0.96 | 0.88 | 0.84 | 0.71 | 2.21 | 2.28 | 1.51 | 2.04 |
| $E_2$ | | 1.55 | 1.86 | 1.96 | 1.71 | 0.98 | 0.79 | 0.74 | 0.64 | 1.81 | 1.72 | 1.33 | 1.21 |
| $E_3$ | | 1.46 | 1.40 | 1.42 | 1.49 | 0.91 | 0.85 | 0.68 | 0.57 | 1.62 | 1.27 | 1.16 | 1.11 |
| $E_1$ | Herbs | 2.19 | 2.31 | 1.84 | 1.76 | 0.89 | 0.89 | 0.72 | 0.64 | 2.59 | 2.47 | 1.87 | 2.33 |
| $E_2$ | | 2.45 | 2.22 | 1.81 | 1.71 | 0.93 | 0.83 | 0.67 | 0.56 | 2.19 | 2.04 | 1.81 | 1.64 |
| $E_3$ | | 1.91 | 2.39 | 1.72 | 1.66 | 0.74 | 0.77 | 0.61 | 0.51 | 1.91 | 1.71 | 1.51 | 1.34 |

$E_1$ (<1800m a.s.l.), $E_2$ (1800-2100m a.s.l.) and $E_3$ (>2100m a.s.l.)
$A_1$ (Northern aspect), $A_2$ (Southern aspect), $A_3$ (Western aspect), $A_4$ (Eastern aspect)
E3 (>2100m a.s.l.)

**Species diversity**

The tree species diversity ranged from 0.47-1.28 was observed from different altitudinal ranges and aspects. The highest tree species diversity was 1.28 observed at <1800m on southern aspect and lowest 0.47 at >2100m on eastern aspect. Maximum shrub species diversity 2.09 was found at lower altitudinal range (<1800m) on southern aspect and minimum 1.40 was found at higher altitudinal range (>2100m) on southern aspect. The highest herbaceous vegetation species diversity 2.45 was recorded on northern aspect at 1800-2100m and lowest 1.66 was recorded on eastern aspect at higher altitudinal range. Sharma, *et al.*, 2009

[19] had also been explained the pattern decrease in species diversity with increasing altitudinal ranges and aspects. The recorded index value of this present study is similar to the range reported by Gairola, *et al.*, 2008 [20] for western Himalaya. The similar values of diversity index have also been reported by Monk, 1967 [21] and Risser and Rice 1971 [22]. They obtained the maximum value (2.3) of diversity index in temperate forests respectively. A higher diversity in the herb layer in the absence of a closed forest canopy has also been reported by Moral, 1972 [23]; Whittaker and Niering 1975 [24]; Zobel, *et al.*, 1976 [25].

**Simpson's dominance**

The tree species dominance ranged from 0.21-0.51 and it was highest 0.51 at lower altitudinal range on northern aspect and lowest 0.21 at higher altitudinal range on southern aspect. Maximum shrub species diversity 0.98 was found at 1800-2100m on northern aspect and minimum 0.57 was found at >2100m altitudinal range on eastern aspect. The highest herbaceous vegetation species dominance 0.93 was recorded on northern aspect at middle altitudinal range (1800-2100m) and lowest 0.51 was recorded on eastern aspect at higher altitudinal range (>2100m). Similar changes of species diversity along altitudinal ranges and aspects had also been reported by Sharma, *et al.*, 2009 [26]. The maximum value was observed lower altitudinal range and minimum value was found at higher altitudinal range. Whittaker, 1972 [27] alluded that the dominance of one stratum affects the diversity of other stratum. Simpson, 1949 [28] and Fisher 1960 [29] suggested that lower diversity values of temperate region might be due to the lower rate of evolution and diversification of plant community.

**Species richness**

The data pertaining to species richness for various plant categories ranged from 0.35-2.59 at different altitudinal ranges and aspects. The tree species richness ranged from 0.35-1.08 and it was highest 1.08 at lower altitude (<1800m) on western aspect whereas, lowest 0.35 was at higher altitude (>2100m) on eastern aspect. Maximum shrub species richness 2.28 was found at 1800-2100m altitudinal range on southern aspect and minimum 1.11 was found at >2100m altitudinal range on eastern aspect. The highest herbaceous vegetation richness 2.59 was observed on northern aspect at lower altitudinal range (<1800m) and lowest 1.34 on eastern aspect at higher altitudinal range (>2100m). Consequently, our study disclosed the maximum species richness at lower altitudinal ranges, compared to higher elevational forest as suggested by Kumar and Ram 2005 [30]. In further study, Singh, *et al.*, 1994 [31] investigated that *Pinus roxburghii* mixed broad-leaved forest had the highest species of plant categories, while higher elevational forest had lowest. Burns, 1995 [32] have inaugurated that total species richness was highest at lower altitudinal range and warmer sites. Pavon, *et al.*, 2000 [12] and Sharma, *et al.* 2009 [26]; Sharma and Raina 2013 [33] revealed that, the life forms diversity usually decreased with increasing altitudinal ranges and one or two life-forms remains at extreme altitudes.

**Conclusion**

The present study conducted in the Kandaghat forest division of Solan along different altitudinal ranges and aspects examined that the case of tree species decreased with the increasing altitude, the highest number of tree species were found at lower altitudinal range (<1800m) on western and northern aspect and least number of tree species were found at higher altitudinal range (>2100m). In the case of shrub species ranged from 4 to 13 at the study site. Maximum numbers of shrub species were recorded at lower altitudinal range on southern and northern aspect. Minimum numbers of shrub species were recorded at higher altitudinal range on eastern aspect. The herb species ranged between 4 to 8 at the study area. Highest number of the herb species were observed at higher altitudinal range (>2100m) on northern and southern aspect and least number of herb species were observed at lower altitudinal range (<1800m) on eastern aspect respectively. Maximum numbers of families 11 were reported to shrub category at lower altitudinal range on northern aspect whereas, minimum numbers of families 2 were reported from tree species at higher altitudinal range on all aspects. However, a decreasing pattern of tree and shrub species were observed along altitude range. On four aspects and herb species showed the reverse pattern to the tree and shrub species. In vegetation indices, tree and shrub species followed the same trend, its value increased with the increasing altitudinal ranges and on the aspects, its highest value was recorded on southern aspect and lowest on eastern aspect. In the herbaceous layer, followed the opposite pattern of vegetation indices to the tree and shrub species.

**References**


1. Dhar U, Rawal RS, Samant SS. Structure diversity and representatives of forest vegetation in a protected area of Kumaun Himalaya, India: implication for conservation. Biodiversity and Conservation. 1997; 6:995-1006.
2. Silori CS. Status and distribution of anthropogenic pressure in the buffer zone of Nanda Devi Biosphere Reserve in Western Himalaya. India. Biodiversity and Conservation. 2001; 10:1113-1130.
3. Kumar A. Plant biodiversity in forests of middle Central Himalaya in relation to various disturbances. Ph. D. thesis, Kumaun University, Nainital. 2000.
4. Khera N, Kumar A, Ram J, Tewari A. Plant biodiversity assessment in relation to disturbances in mid elevational forest of Central Himalaya. India. Tropical Ecology. 2001; 42:83-95.
5. Clapham WB. Natural ecosystems. Macmillan; Collier-Macmillan, New York; London. 1973, 248p.
6. Khan SM, Zeb A, Ahmad H. Medicinal Plants and Mountains: Long Established Knowledge in the Indigenous People of Hindu Kush VDM Verlag Dr. Müller, Germany. 2011, 144p.
7. Mani MS. Ecology and Phytogeography of the High Altitude Plants of the North West Himalaya. Oxford & IBH Publishing Company, New Delhi, 1978.
8. Osmaston AE. Notes on the forest communities of the Garhwal Himalaya. Journal of Ecology. 1922; 10:129-187.
9. Oliver CD, Larson BC. Forest stands dynamics. Mcgraw Hill inc. New York, 1990.
10. Pande PK, Negi JDS, Sharma SC. Species diversity, turn over resource apportionment among various plant species in western-Himalaya forests. Abstract. First Indian Ecological Congress, New Delhi. 1996, 27-31.
11. Wikum DA, Wali MK. Analysis of North Dakota Gallery forest vegetation in relation to topographic and soil gradients. Ecological Monography. 1974; 44:441-464.
12. Pavon NP, Hernandez-Trejo H, Rico-Gray V. Distribution of plant life forms along an altitudinal

gradient in the semi arid valley of Zopotitlan, Mexico. Journal of Vegetation Science. 2000; 11:39-42.
13. Ramsay PM, Oxley ERB. The growth form composition of plant communities in the Ecuadorian paramos. Plant Ecology. 1997; 131:173–192.
14. Kharkwal G, Mehrotra P, Rawat YS, Pangtey YPS. Phytodiversity and growth form in relation to altitudinal gradient in the Central Himalayan (Kumaun) region of India. Current Science. 2005; 89:873-878.
15. Shank RE, Noorie EN. Microclimate vegetation in a small valley in eastern Tennessee. Ecology. 1950; 11:531-539.
16. Chandra J, Rawat VS, Rawat YS, Ram J. Vegetational diversity along an altitudinal range in Garhwal Himalaya. International Journal of Biodiversity and Conservation. 2010; 2:014-018.
17. Champion HG, Seth SK. A revised survey of the forest types of India. Manager of publication, Govt. of India, New Delhi, India. 1968, 404.
18. Rawal RS, Pangety YPS. High altitude forest vegetation with special reference to timber line in Kumaun central Himalaya. In: Pangtey YPS & Rawal RS (eds) High Altitudes of the Himalaya. Nainital, India. Gyanodaya Prakashan, Nainital. 1994, 353-399.
19. Singh H, Kumar K, Sheikh M. Distribution pattern of Oak and Pine along altitudinal gradients in Garhwal Himalaya. Nature and Science. 2009; 7:81-85.
20. Gairola S, Rawat RS, Todaria NP. Forest vegetation patterns along altitudinal gradient in sub alpine zone of west Himalaya, India. African Journal of Plant Science. 2008; 2:042-048.
21. Monk CD. Tree species diversity in eastern deciduous forest with particular reference to north central Florida. American Naturalist. 1967; 101:173-187.
22. Risser PG, Rice EL. Diversity in tree species in Oklahoma upland forests. Ecology. 1971; 52:876-880.
23. Moral R. Diversity patterns in forest vegetation of the Wenatchee Mountains, Washington. Bull. Torrey Bot. Club. 1972; 99:57-64.
24. Whittaker RH, Niering WA. Vegetation of the Santa Catalina Mountains, Arizona. V. Biomass, produc tion, and diversity along the elevation gradient. Ecology. 1975; 56:771-790.
25. Zobel DB, McKee A, Hawk GM, Dyrness CT. Relationship of environment to composition, structure, and diversity of forest communities of the central western Cas cades of Oregon. Ecology Monography. 1976; 46:135-156.
26. Sharma CM, Suyal S, Gairola S, Ghildiyal SK. Species richness and diversity along an altitudinal gradient in moist temperature forest of Garhwal Himalya. Journal of American Science. 2009; 5:119-28.
27. Whittaker RH. Evolution and measurement of species diversity. Taxon. 1972; 21:213-251.
28. Simpson EH. The measurement of diversity. Nature. 1949; 163:688.
29. Fisher AG. Latitudinal variation in organic diversity. Evolution. 1960; 14:64-81.
30. Kumar A, Ram J. Anthropogenic disturbances and plant biodiversity in forests of Uttaranchal, Central Himalaya. Biodiversity Conservation. 2005; 14:309-31.
31. Singh SP, Adhikari BS, Zobel DB. Biomass productivity, leaf longevity and forest structure in central Himalaya. Ecological Monograph. 1994; 64:401-21.
32. Burns BR. Enviornment correlates of species richness at Waipoua Forest sanctuary. New Zealand. New Zealand Journal of Ecology. 1995; 19:153-62.
33. Sharma N, Raina AK. Composition, structure and diversity of tree species along an elevational gradient in Jammu province of north-western Himalayas, Jammu and Kashmir, India. Journal of Biodiversity and Environmental Sciences. 2013; 3:12-23.