COMPARATIVE STUDY OF HERB LAYER DIVERSITY IN PINE FOREST STANDS AT DIFFERENT ALTITUDES OF CENTRAL HIMALAYA

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Abstract. Species richness of pine forest along with elevation varying from 1800 m (site A) to 1500 m (site B) at central Himalaya was compared to judge the ecological significance. A total of 56 species comprising 51 genera and 28 families were recorded. Alpha-diversity and equitability or evenness was significantly higher at site A as compared to the site B. The number of families, genera and species observed in site A were also higher than site B. Very few herb species were found common in both the forest sites and indicated lower values of similarity index. Asteraceae and Lamiaceae were the most dominant family at both the sites. The percentage contribution of annuals and perennials were 48.1% and 51.9%, respectively. Species diversity at site A was more than at site B. This may be due to more gentle slope at site A than at site B. The ability of retention of more water in the soil provides favourable condition for plant growth. The study revealed that the forest site A is more diverse, old and stable in comparison to site B.
Key words: *herb species, family, pine forest, species diversity, species-area curve*

Introduction

The species presently inhabitating Earth are the result of over 3 billion years of natural selection likely favoured efficiency, productivity and specialization (Tilman, 2000) and natural communities differ greatly in the proportion of species performing different ecological functions (Haola and R. Dhand, 2000). Mohamed et al. (2000) also stated that the variety and variability of plant and animal species are the most distinguished feature of life, which reflects the complexity, uniqueness and intactness of natural ecosystems.

Most theoretical and empirical work on functional consequences of changing biodiversity has focused on the relationship between species richness and ecosystem functioning [2]. Several studies using experimental species assemblage have shown that annual rate of primary productivity and nutrient retention increases with increasing plant species richness. Changes in species evenness deserve increased attention, because they usually respond more rapidly to human activities than do changes in species richness and because they have important consequences to ecosystem long before a species threatened by extinction [2]. The different bio-geographic zones with the diverse climate and edaphic factors not only have been a storehouse of a variety of plant species, but also a centre of diversification of taxa. The diversification of taxa has a multitude of facets. The most commonly considered facet of biodiversity is species richness. Even these two attributes of biodiversity, species richness and endemism have attracted particular attention from the international conservation community: [1], because these two attributes reflect the complexity, uniqueness and intactness of natural ecosystems. It is well known that the abundance of a particular species changes over time in progress, which may be due to dispersal but others will be the product of initial condition [4]. Every factors and mech-

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anisms, which stimulate and accelerate speciation and maintenance of high species diversity such as habitat heterogeneity, favourableness, and local medium disturbances, are active.

The unique pattern of spatial and temporal species distribution has attracted the attention of several workers [9, 10, 11, 13, 14]. Diversity indices have been developed to convey the extent to which individuals are distributed evenly among species. Most but not all combine evenness with species, losing information by reducing two dimensions to one. Therefore, evenness is another important factor of biodiversity. Present study deals with two levels of diversity namely alpha and beta and its three concepts i.e. species richness (S), equatibility (Ec) i.e. species per log index and synthetic diversity of Shannon-Wiener (H), which incorporates the measure of species richness and equitability and, species composition between two pine forests in different altitudinal range.

Study-sites: The study-sites are located between 1500-1800 m altitudes in central Himalaya (29°22' N latitude and 79°26' E longitude). Both the sites are dominated by chir-pine (Pinus roxburghii) forest. Site A is located between 1700-1800 m altitudes and site B at 1580-1700 m altitudes. The climatic condition is monsoon temperate, and annual rainfall of the area is 2668 mm/year. The mean monthly temperature ranges from 11.5 °C in winter to 18.5 °C during summer. Limestone and quartzite are the principle rock types. Soil texture is sandy loam and it was acidic in nature (5.6-5.9). The physiochemical properties of soil are given in Table 1.

Methods

A general reconnaissance was made from June -September 2000. Based on frequent surveys of the area, sites were selected for sampling, which was also carried out in the following year.

The phytosociological analysis of herbaceous flora at two sites was carried out by using random sampling quadrat method. The species-area curves were developed for both the sites by using nested plot technique [7]. It was found that gradual increase in the number of species occurring up to 64 m^2 (8mx8m) size (plot) for site A, while for site B the curve showed gradual increase in the number of species up to 32 m^2 (4mx8m) size (plot) (Figure 1). At each site, the quadrats were placed randomly. The herbaceous vegetation was analysed by 30, 1 m×1 m randomly placed quadrats at the time (during rainy season because maximum species were present in that season) of peak herbaceous cover in the first week of September 2000. Each shoot of herb was considered as an individual plant [13].

The index of diversity was calculated by using Shannon-Wiener information index.

$$H' = \sum_{n=1}^{i} (Ni/N) \log 2 \, (Ni/N)$$

where, Ni is the total number of species i and N is the number of individuals of all species in that site. Concentration of dominance was measured by Simpson's index [12] where Ni and N were the same as for the Shannon-Weiner information function.

$$E = S / (\log Ni - \log Ns)$$

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***Table 1.** Certain important soil characteristics of the study sites*

Characters	Site A	Site B
Elevation	1700-1800	1580-1700
Forest site	Chir-pine	Chir-pine
Slope (0)	50	42
Aspect	East	South-west
Dominant tree species	P. roxburghii	P. roxburghii
Sand (%)	61.67	62.37
Silt (%)	21	20.3
Clay (%)	15.3	17.8
Moisture (%)	32.8	32.3
pH	5.6	5.9
C (%)	1.4	1.9
N (%)	0.22	0.19
Organic matter (%)	4.67	4.43

where, S is the total number of species, Ni is the number of individuals of most important species, Ns is the number of individuals of least important species and E is the evenness index.

Beta diversity was calculated by following Whittaker (1975) [18] as:

$$\beta = Sc / s$$

where, Sc is the total number of species encounter in all quadrats and s is the average number of species per quadrat.

Results and Discussion

The sites were dominated by chir-pine forests with varying different altitudes. Slight differences in physio-chemical properties of soil has been obtained in site B than site A. Percentage of nitrogen content and organic matter were observed maximum at site A than site B.

A total of 56 species comprising 51 genera and 28 families were recorded from the two study sites (Table 2). Across the sites, 42 species were encountered belonging to 22 families and 37 genera (Tables 2 and 3). Asteraceae and Lamiaceae were the most dominant family (with eight species), followed by Rubiaceae (with three species), Apiaceae, Cyperaceae, Poaceae and Fabaceae (with two species). The remaining 15 families were represented by one species each. Taxonomically, Lamiaceae (with eight genera), were the most dominant family followed by Asteraceae (with seven genera) was, Apiaceae, Poaceae, and Fabaceae (with two genera each) and remaining 16 families were represented by a single genus only at site A.

At site B, a total of 29 species belonging to 17 families and 29 genera (Tables 2 and 3) were observed. Taxonomically, well-represented families were Asteraceae (eight species), followed by Lamiaceae (three species), Apiaceae, Cyperaceae and

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Table 2. *Herb species composition of the study-sites*

Species	Family	Site-A	Site-B
Agrimonia pilosa	Rosaceae	+	-
Arthraxon prionodes	Poaceae	+	-
Anaphalis contorta	Asteraceae	+	+
Ageratum houstonianum	Asteraceae	-	+
Ajuga parviflora	Lamiaceae	+	+
Bupleurum tenue	Apiaceae	+	-
Bidens biternata	Asteraceae	+	+
B. pilosa	Asteraceae	+	-
Begonia picta	Begoniaceae	-	+
Conyza japonica	Asteraceae	+	+
Carex nubigena	Cyperaceae	+	+
C. condensata	Cyperaceae	+	-
Carpesium cernuum	Asteraceae	+	-
Commelina benghalensis	Commelinaceae	+	+
Carum anathifolium	Apiaceae	+	+
Cassia mimosoides	Caesalpiniaceae	-	+
Centella asiatica	Apiaceae	-	+
Crotalaria sessiliflora	Fabaceae	+	-
Campanula colorata	Campanulaceae	+	-
Erigeron karvinskianus	Asteraceae	+	+
E. bonariensis	Asteraceae	+	-
Flemingia bracteata	Fabaceae	+	-
Galium rotundifolium	Rubiaceae	+	-
G. aparina	Rubiaceae	+	+
Gerbera gossypina	Asteraceae	+	+
Sedum sinuatum	Crassulaceae	+	+
Justicia simplex	Acanthaceae	-	+
Leucas lanata	Lamiaceae	+	-
Lindenbergia indica	Scrophulariaceae	-	+
Lepidium virginianum	Brassicaceae	+	+
Micromeria biflora	Lamiaceae	+	+
Neanotis calycina	Rubiaceae	+	+
Origanum vulgare	Lamiaceae	+	-
Oxalis corniculata	Oxalidaceae	-	+
Plectranthus japonicus	Lamiaceae	+	-
Pouzolzia hirta	Utricaceae	+	+
Polygonum hygropiper	Polygonaceae	+	+
Setaria homonyma	Poaceae	-	+
Swertia tetragona	Gentianaceae	+	-
Stachys sericea	Lamiaceae	+	+
Cynoglossum lanceolatum	Borginaceae	+	-
Scutellaria angulosa	Lamiaceae	+	-
Setaria glauca	Poaceae	+	-

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Seigesbeckia orientalis	Asteraceae	+	-
Thalictrium foliolosum	Ranunculaceae	+	-
Torenia cordiflora	Scrophulariaceae	-	+
Teucrium royleanum	Lamiaceae	+	-
Roscecea procera	Zingeberaceae	+	-
Polycarpa corymba	Caryophyllaceae	+	-
Urena lobata	Malvaceae	-	+
Nervillea crispata	Orchidaceae	-	+
Platystemma violoides	Gosneriaceae	-	+
Artimesia nilagarica	Asteraceae	+	-
Calamintha umbrosum	Lamiaceae	+	-
Satyrium nepalensis	Orchidaceae	+	-
Viola canascens	Violaceae	-	+

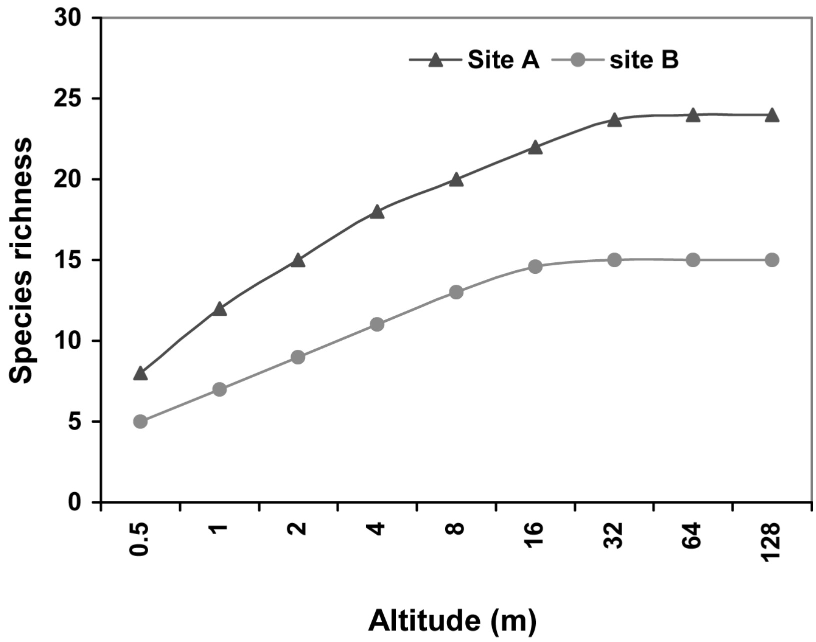

Figure 1. *Species-area curve for site A and site B*

Scrophulariaceae (two species each), whereas twelve families were represented by a single species. Taxonomically Asteraceae was the most dominant family (with eight genera), followed by Lamiaceae (with three genera), Apiaceae and Scrophulariaceae (with two genera each), and the remaining eight families were represented by single genus only.

The proportions of families to genera, families to species and genera to species were observed higher in case of site A than the site B (Table 4). The percentage of growth form and life forms of herbaceous flora are given in Figures 3. and 4.

Between the sites, site A showed higher maximum species richness than site B. The number of families was more in site A than site B. Between the sites, Asteraceae and

***Table 3.** Family-wise distribution of species in the study-sites*

Species	**Site A**		**Site B**	
	Genus	Species	Genus	Species
Asteraceae	7	8	8	8
Acanthaceae	0	0	1	1
Apiaceae	2	2	2	2
Borginaceae	1	1	0	0
Begoniaceae	0	0	1	1
Brassicaceae	1	1	1	1
Commelinaceae	1	1	1	1
Crassulaceae	1	1	0	0
Caryophyllaceae	1	1	0	0
Companulaceae	1	1	0	0
Cyperaceae	1	2	1	2
Fabaceae	2	2	0	0
Gentianaceae	1	1	0	0
Gosneriaceae	0	0	1	1
Lamiaceae	8	8	3	3
Malvaceae	0	0	1	1
Orchidaceae	1	1	1	1
Oxalidaceae	0	0	1	1
Poaceae	2	2	1	1
Polygonaceae	1	1	1	1
Rosaceae	1	1	0	0
Rubiaceae	3	3	1	1
Ranunculaceae	1	1	0	0
Scrophulariaceae	0	0	2	2
Utricaceae	1	1	0	0
Violaceae	1	1	1	1
Caesalpiniaceae	1	1	0	0
Zingiberaceae	1	1	0	0

Lamiaceae were the most dominant families, and comprising maximum species richness in both sites.

The number of family, genera and species present at site B were less than that of site A (Tables 2 and 3). This was also reflected by the species-area curve (Figure 1). Though Asteraceae and Lamiaceae showed maximum number of genera and species at both the sites, it was also observed that a few species were dominant in both the sites.

Species richness (per m^2) was higher (7.23) at site A as compared to site B (5.7) (Table 4). However, β-diversity and Shannon-Wiener index values were more or less similar for both sites. Simpson's index value was higher (0.62) for site B than site A (0.11). (Table 5). Evenness or Equitability ratio of species diversity was higher for site A (28.77) than site B (13.80) (Table 4), which indicates maximum diversity at that site.

Percent contribution of annuals at site B was greater than at site A, while contribution of perennials was comparatively higher at site A than at site B (Fig 2). Annuals are able

Table 4. *Ratio of species and family in the study-sites*

Forest site	Family: genera	Family: species	Genera: species
Site A	1.86	1.95	1.05
Site B	1.57	1.00	1.00

Table 5. *Comparison in diversity parameters in the study-sites*

Parameters	Site A	Site B
Total number of species present in the site	42	29
Species richness (per m^2)	7.23	5.7
Beta-diversity	2.82	2.60
Shannon-Wiener index	3.92	3.37
Concentration of dominance	0.11	0.62
Evenness / Equitability	28.77	13.80

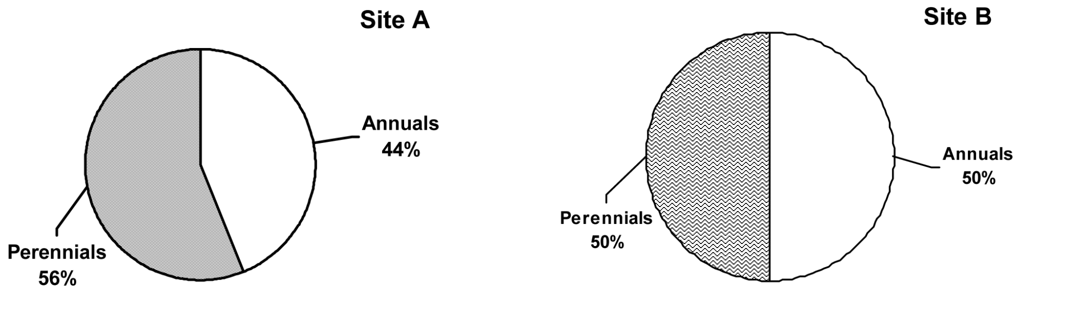

Figure 2. *Growth form composition of the study-sites*

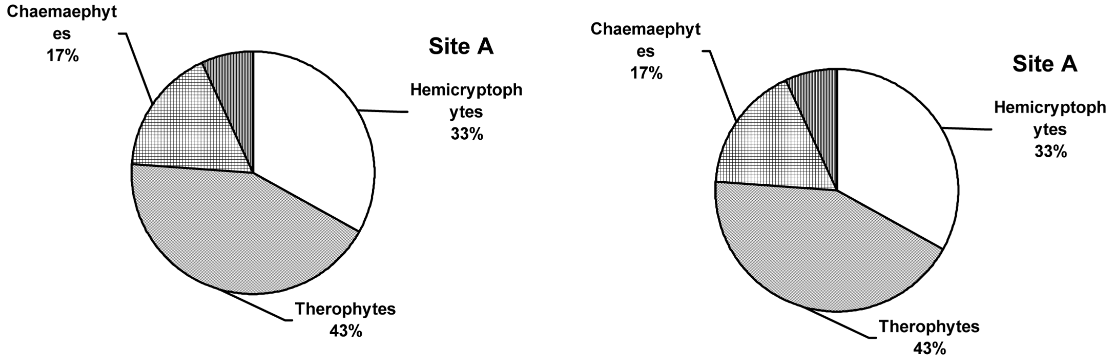

Figure 3. *Growth form composition of the study-sites*

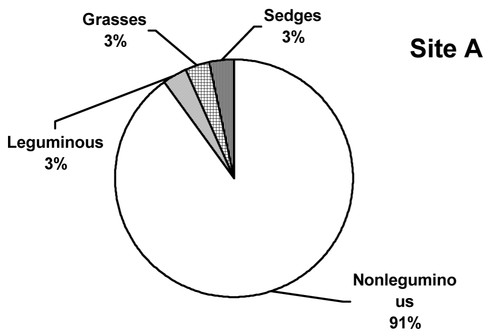

Figure 4. (a)

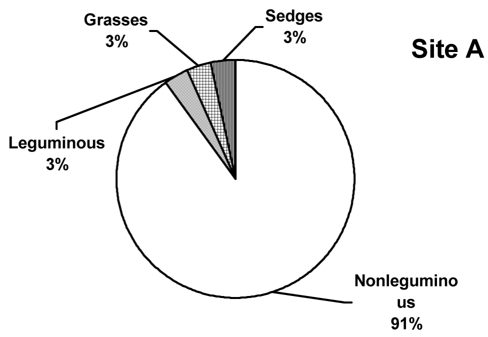

Figure 4. (b)

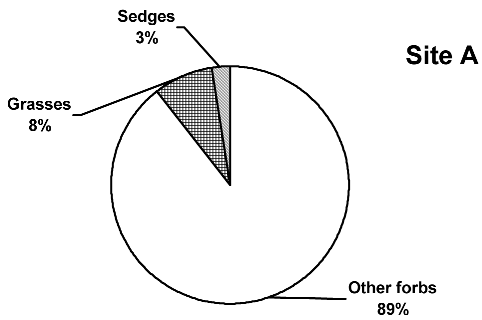

Figure 4. (c)

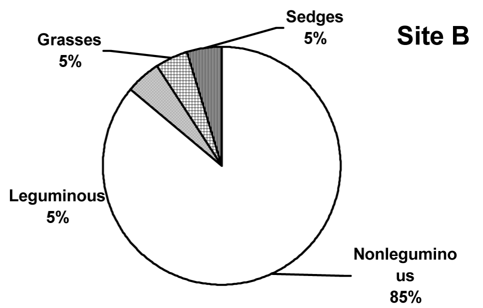

Figure 4. (d)

***Figures: (Fig. 4 (a-d):** Life form composition of the study-sites*

to produce large number of seeds to disperse them efficiently. They contribute their life span in short duration due to escaping nature from harsh conditions. The perennials occupied the study sites and shared dominance with the annuals. Perennial grasses have ability to conserve soil. The extensive root systems of perennial grasses also add more organic matter to the soil than annuals can do and this may due to more favourable conditions for plant growth for site A. This reason may be the main cause for the higher diversity at site A than at site B.

The percentage of growth forms was shown maximum by forbs which was followed by sedges and grasses at site A, and, forbs showed also maximum contribution but followed by grasses and sedges at site B (Fig. 4: a-d).

The contribution of therophytes was maximum at both of the study sites followed by hemicryptophytes, chaemaephytes and cryptophytes (Fig. 3). The higher therophytic character of both the sites is undoubtedly due to strong periodic climate and grazing which keeps the communities open for further invasion by therophytes. The nonleguminous forms were followed by leguminous, grasses, sedges and ferns at site A whereas, at site B, only nonleguminous forms were present (Fig. 4).

The species diversity of the forest ecosystem of this region is influenced by; topography, soil characteristics, climate and geographical location of the area. Results show that species had dissimilarity in both the sites. It can be stated that species composition changed with respect to altitude and varied in similar forest types.

The species diversity at site A was higher than site B. This may be due to more gentle slope at site A than at site B. The ability of retention of more water in the soil provides favourable condition for plant growth. The Western part of the Himalayan region is characterised by maximum diversity of plant species in comparison to other parts. This region also represents maximum diversity of leguminous flora, which in general diminishes as the altitude increases. As a pioneer species on many disturbed areas, various species in addition to their fast growth and multiple uses play role on providing fertility to land on which other species will colonize later. Therefore, any change in their community structure and function in changing climate at different elevations will influence other vegetation profoundly.

These observations also indicate that at site A forest trees were older and more stable than at site B. Variation in herb species composition in both sites may be due to change in local abiotic factors such as soil, temperature, moisture and altitude. The above study shows that the herb species diversity was higher at site A was more than at the site B, which may be due to the effects of many physical factors. The herb diversity data analysis of pine forest will serve as base-line information for the researchers.

Conclusion

Distribution is one of the most significant objectives. Spatial heterogeneity and species richness in particular, is an obvious feature of the natural world. Understanding of its determinants will impinge on applied issue for the role of biodiversity in ecosystem process (Gaston, 2000).

Earlier Gaston et al., (1996) stated that a substantial proportion of regional variation in species richness can be explained in terms of a few experimental variables. The numbers of species were also influenced by birth, death, immigration and emigration rates in an area (Gaston, 2000). Species composition has strong effects on ecosystem processes by directly mediating energy and material fluxes or by altering abiotic conditions that regulate the rates of these process (Hooper et al., 1997; Tilman, et al., 1997). This is because species alteration can change the availability of limiting resources, by which disturbance regime and the climate can have particularly strong effects on ecosystem processes. Species composition of an area is important because it seems that the multiple factors doubtlessly contribute to, or influence the biodiversity of an area. So all concerned will need to remember that no single process can adequately explain a given pattern.

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REFERENCES

[1] Caldecott, J. O. Jenkins, M. D., Johnson, T, H. and Groombridge, B., (1996): Biodiversity and Conservation. – 5: 699-727.
[2] Chapin, F. S. III, F. Stuart, Erika S. Zavaleta, Valerie T. Eviner, rosamond L. Naylor, Peter M. Vitousek, Heather L. Reynolds, David U. Hooper, Sandra Lavorel, Osvaldo E. Sala, Sarah E. Hobbie, Michelle C. Mack and Sandra Daiz (2000): Consequences of changing biodiversity. – Nature 405: 234-242.
[3] Khoshoo, T. N. (1992): Plant Diversity in the Himalaya. – Conservation and utilization. G. B. Pant Memorial Lecture II. GBIHED Kosi Katarmal- Almora, India.
[4] Margaules, C.R. and R.L. Pressey (2000): Systematic conservation. – Planning, Nature, 405: 243-253.
[5] Mohamed, A. Ayyad, Amal, M. Fakhry and Abdel- Raouf A. Moustafa, (2000): Biodiversity and Conservation. – 9, 265-281.
[6] Moustafa, A. A. (1990): Environmental Gradient and Species Distribution on Sinai Mountains. – PhD Thesis, Botany Department, Faculty of Science, Seuez Canal University, Egypt, 115pp
[7] Muller-Dombois, D. and H. Ellenberg (1974): Aims and Methods of Vegetation Ecology. – John Wiley & Sons, New York, London, Sydney. Toronto. 547pp.
[8] Odum, E. P., (1963): Fundamentals of Ecology, W. B. Saunders, Philadelphia.
[9] Osmaston, A. E. (1927): A forest Flora for Kumaun. Govt. – Press, United Provinces, Allahabad, 605 pp.
[10] Pangtey, Y. P. S., Rawat, R. S., Bankoti, N. S. and S. S. Samant (1990): Phenology of high altitude plants of Kumaun in central Himalaya. – Int. J. Biometeorol, 34: 122-127.
[11] Rawal, R. S., Bankoti, N. S., Samant, S. S. and Y.P.S. Pangtey (1991) Phenology of tree layer species from the timberline around Kumaun in central Himalaya. – India. Vegetatio, 93: 109-118.
[12] Simpson, E. H. (1949): Measurement of Diversity. – Nature, 163: 688.
[13] Singh, J. S. and P. S. Yadava (1974): Seasonal variation in composition, plant biomass and net primary productivity of tropical grassland of Kurukshetra. – India, Ecological monograph, 44: 351-376.
[14] Singh, J. S. and S. P. Singh (1987): Forest vegetation of the Himalaya. – Botanical Review, 52: 80-192.
[15] Singh, J.S. and S. P. Singh (1992): Forest if Himalaya: Structure, Functioning and Impact of man. – Gynodaya Prakashan, Nainital, India.
[16] Vitousek, P. M., Mooney, H. A., Lubchenko, J. and J. M. Melillo, (1997): Human domination of Earth's ecosystems. – Science, 277:494-499.
[17] Whittaker, R. H. (1972): Evolution and measurements of species diversity. – Taxon, 21: 213-251.
[18] Whittaker, R. H. (1975): Community and Ecosystems. – IInd ed. McMillan, New York.
[19] Whittaker, R. H. and W. A. Niering (1975): Vegetation of the Santa Catalina Mountains, Arizona. – V. Biomass production and diversity along the elevation gradient. Ecology, 56:771-790.