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Pattern of Species Distribution and Community Characters Along a Moisture Gradient within an Oak Zone of Kumaun Himalaya

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Oak forest communities distributed along a soil moisture gradient within an elevational range of 1450-2450 m in the Central Himalaya were studied. Between the two major oak species which realized most of the importance values in the stands, *Quercus leucotrichophora* had its centre towards the lower part of the moisture gradient, whereas *Q. floribunda* mixed with this species, towards the higher part of the moisture gradient. Species diversity increased with increasing soil moisture and its values were in the range of 0.33-2.91 for trees and 1.80-2.87 for shrubs.

Key Words: Beta diversity; Mixed forest; Ordination; *Quercus floribunda—Quercus leucotrichophora* forest; Soil moisture

Introduction

One of the major formations in the Central Himalaya (also in the Western Himalaya) is low to mid-montane hemisclerophyllous broadleaf forest dominated by one or other oak species (*Quercus* spp.) (Singh & Singh 1987a). It is the zone of these evergreen type of forest communities where most of the human settlements are in the Central Himalaya. Consequently they have been more affected by man than other forest types (Singh & Singh 1986).

Within an elevational belt, patterns of species populations and communities are often influenced by soil moisture, in addition to elevational changes (Whittaker 1967). Whittaker and Niering (1975) have reported that along a wide moisture gradient (that encompasses ecosystems such as desert, grassland, woodland and forest), plant diversity peaks in its middle part.

The present study deals with forest vegetation within an elevational range of 1450-2450 m, where the lower altitude oaks, *Quercus leucotrichophora* and *Q. floribunda* are regarded as the climax species (Singh & Singh 1986). The major objective of this study was to analyse the community structure of oak forests along a soil moisture gradient.

Materials and Methods

Description of study sites

The 18 study sites were selected between 29°26'-29°20' N lat. and 79°25'-79°35' E long. at 1450-2450 m altitudes in the Kumaun Himalaya, India. The predominant species are *Q. leucotrichophora* and *Q. floribunda*. These 18 sites varied in elevation, aspect, position on hill slope and the degree of biotic disturbances, though within a limited range (table 1). Only the relatively undisturbed sites were considered for sampling, but some moderately disturbed sites had to be included for want of undisturbed sites. Disturbance in them were mainly due to limited grazing, collection of fodder and occasional lopping and felling of trees. The hill base stands of the north-west aspect at the Ghughukhan site and that of the east aspect were distinctly more mesic than other stands of those aspects because streams passed along their lower boundaries.

The year is divisible into three distinct seasons: rainy (mid June-September), winter (October-March), and summer (April-mid June). On the average (based on data from 1978-1984) total annual rainfall is 2488 mm, of which 86% occurs during the rainy season. Mean monthly maximum temperature ranges from 5.0°C (January) to 20.0°C (May). In accordance with the precipitation Effectiveness (P-E) index of Thornthwaite (1931) the sites lie within the humid category (P-E index 93.0-119.0 on the basis of annual values) (Singh & Singh 1984).

The soils are reported to have originated from slates, phyllites, sand stone and limestone of the kroll series, and they are generally brown in colour, sandy loam in texture and slightly acidic with *p*H 6.3.

Methods

Avoiding substantially disturbed sites, stands were selected on three position of a hill slope, viz. hill base (HB), hill slope (HS) and hill top (HT). Each sand was homogenous in species composition and habitat character. Three replicates of soil samples from 0-10, 10-20 and 20-30 cm depth were taken out at weekly intervals in November about five weeks after the last rain strom and soil moisture was determined gravimetrically, and values were averaged across the three depths.

The phytosociological analysis of each stand was carried out by 10 randomly placed, 10 x 10 m quadrats. The number and size of the quadrat was determined by the running mean method (Kershaw 1973) and the species area curve (Misra 1968). Diameter at breast height (dbh at 1.37 m from the ground) of all the trees $\geq$ 3.2 cm dbh in each quadrat was measured and recorded individually. The shrubs were sampled in 20, 2 x 2 m randomly placed quadrats. Vegetational data were analysed following Curtis and McIntosh (1950), Phillips (1959) and Curtis (1959). Species diversity for different stands was computed by using the Shannon-Wiener information function (H) (Shannon & Weaver 1963). Following Whittaker (1975), beta diversity was computed to measure the rate of species change along the moisture gradient. The expression is given as:

$$\text{Beta diversity } S = \frac{S_c}{s}$$

where S_c is the total number of species encountered in all stands counting each species only once whether or not it occurs more than once and *s* is the average number of species per stand.

The stands were ordinated according to the polar ordination method (Bray & Curtis 1957). Importance values were double standarized before computing for percent similarity.

Results and Discussion

Soil Moisture

The soil moisture contents varied from 17.3-40.1%, values being generally higher in *Q. leucotrichophora-Q. floribunda* forest stands (28.1-40.1%) than *Q. leucotrichophora* stands (17.3-26.5%). Presence of a stream rendered the soil of stands of the north-west aspect of Ghughukhan particularly moist (table 1). Similarly, the soil moisture content of the hill base stand of the east aspect (stand 13) was distinctly moister than that of the other stands of this aspect because of the proximity to a stream.

Ordination

Representation of 18 forest stands in a two-dimensional ordination graph indicated that they were arranged along a soil moisture gradient (figure 1a), running diagonally across the ordination field. From high to low soil moisture (low X-values and high y-values) the following patterns became evident: (i) with decreasing soil moisture, the IVI of *Q. leucotrichophora* increased (from 36.2-72.2 in stands 16, 17 and 18 to 250.6-300.0 in 1-3 stands) and that of *Q. floribunda* decreased (from 95.7-117.5 in 16, 17 and 18 stands to zero in 1-5 stands) (figure 1b and c); (ii) Among the species of lower importance values (less than 70.0 IVI), *Pinus roxburghii* occurred in some of the drier and disturbed stands (figure 1) and *Lyonia ovalifolia* in relatively dry stands located in the lowest part of elevational range; (iii) The disturbance factor also seemed to influence the distributional pattern of some shrubs. While the relationship between the distribution of *Daphne canabina* and moisture was still identifiable, the importance value being centered in the higher part of the moisture gradient (but not on the highest moisture level) and declined rapidly towards the lower soil moisture values (figure 2a), in case of other species it was confounded by distur-

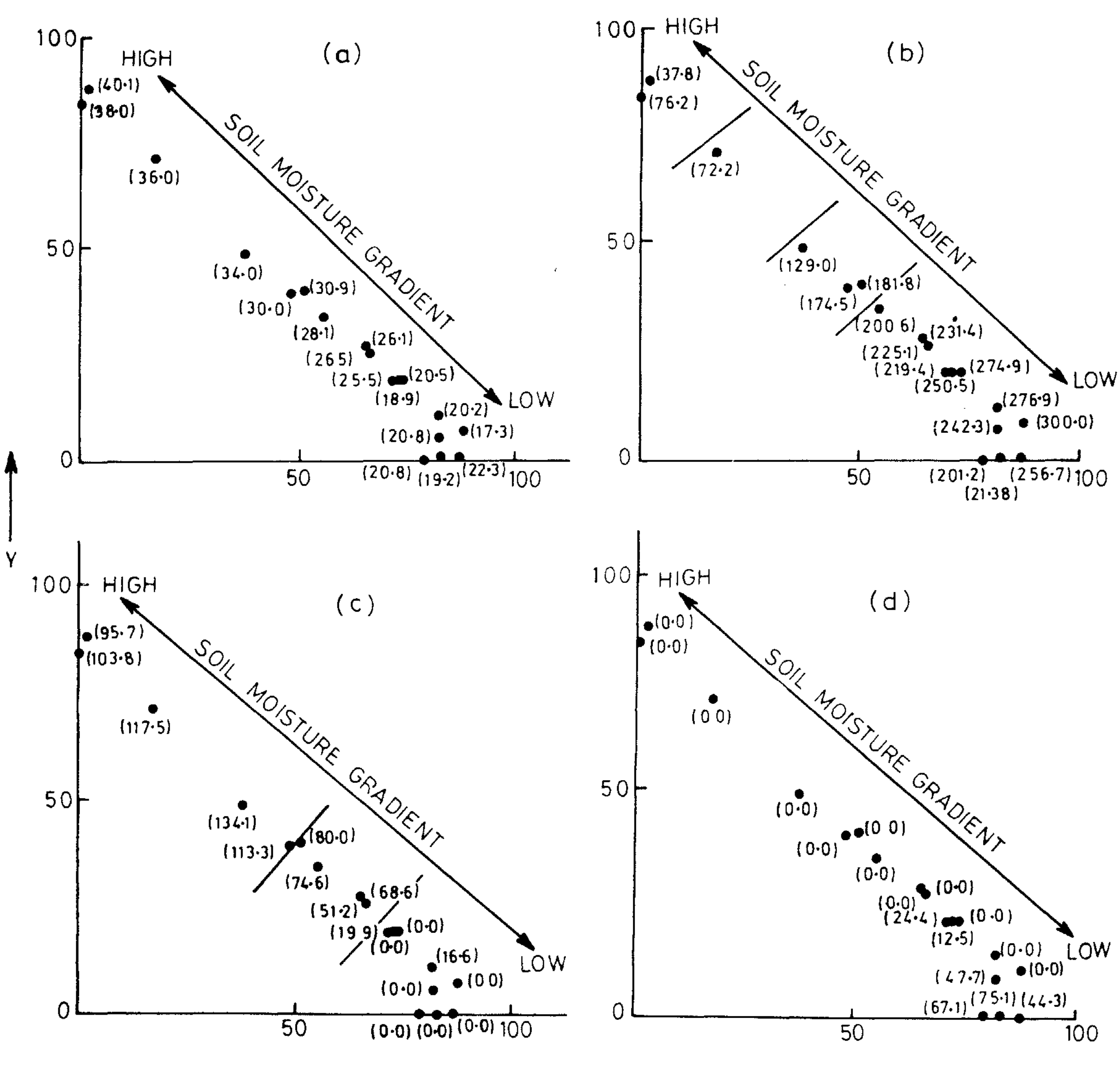

Figure 1 Ordination of 18 forest stands based on the basis of tree species composition. Values in parentheses represent: (a) soil moisture, (b) IVI of *Quercus leucotrichophora*, (c) IVI of *Quercus floribunda*, and (d) IVI of *Pinus roxburghii*

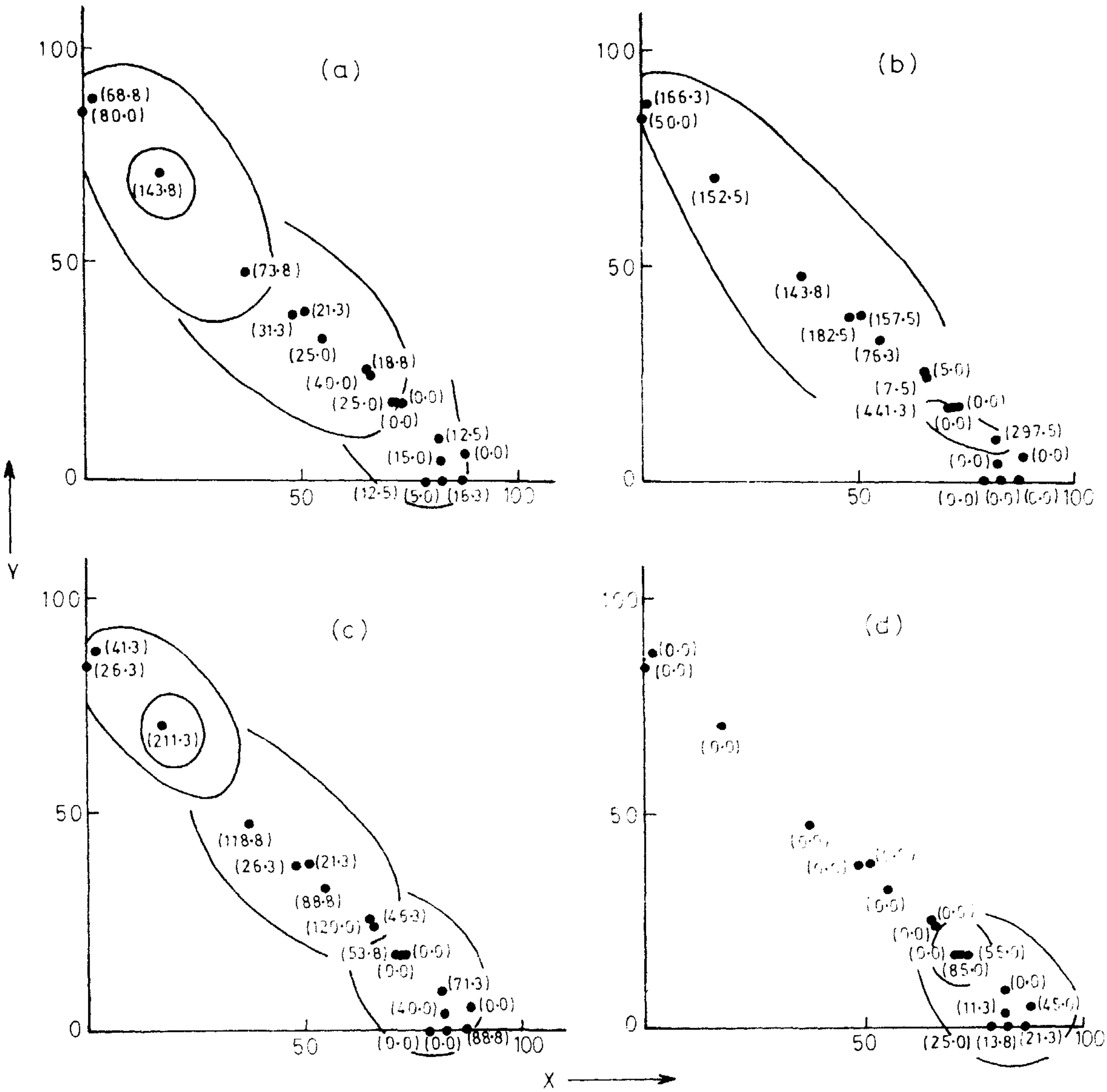

Figure 2 Quantitative distribution of important shrubs in terms of density (shrubs 100 m^{2}) in x-y ordination graph of 18 forest stands based on tree species composition. Values in parentheses represent value of shrub density of: (a) *Daphne cannabina*, (b) *Rhamnus triqueter*, (c) *Boenninghausenia albiflora*, and (d) *Randia tetrasperma*

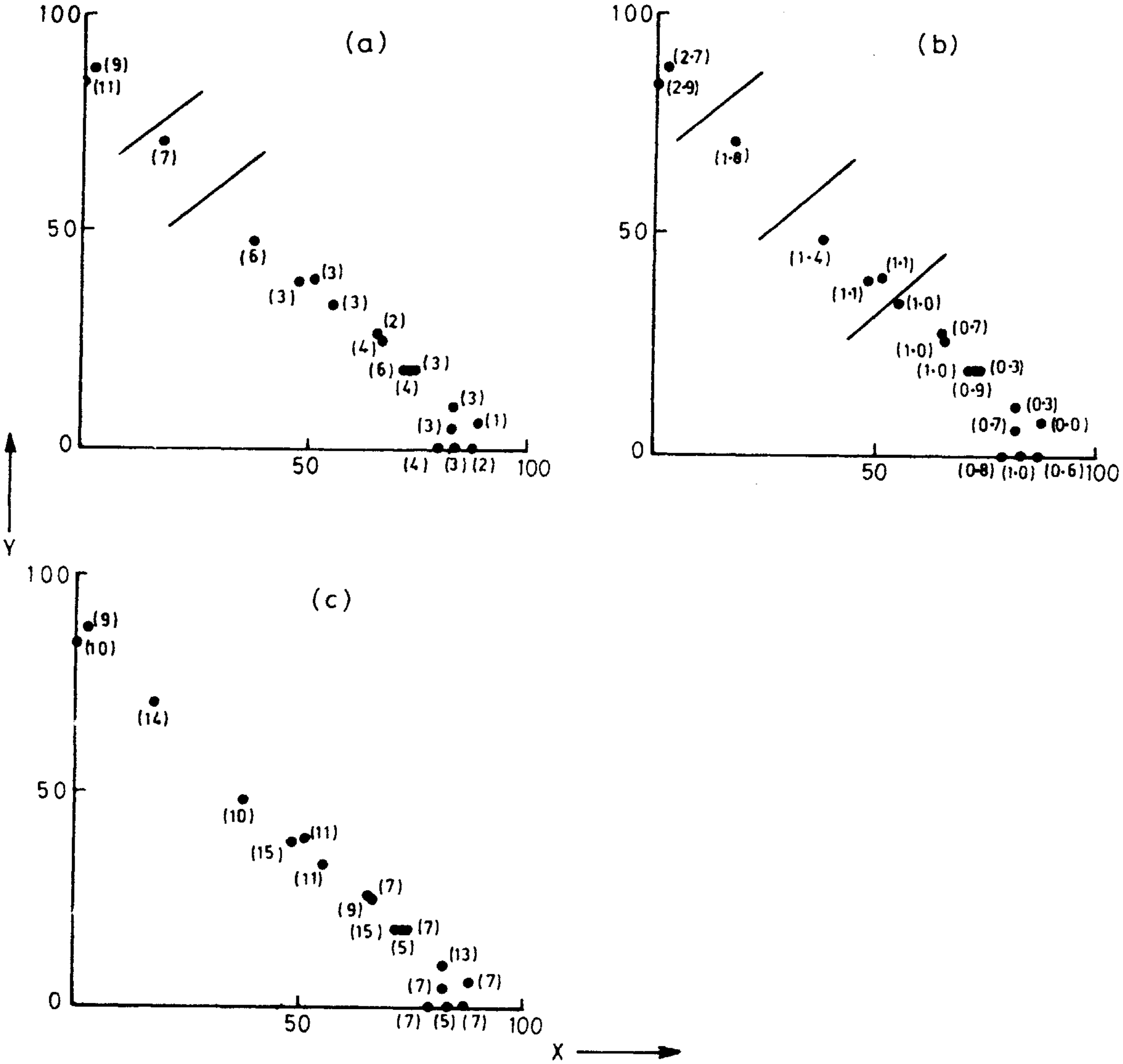

Figure 3 The dimensional ordination of 18 forest stands based on the basis of tree species composition. Values in parentheses represent: (a) tree species richness for tree layer, (b) Shannon-Wiener diversity for tree layer, and (c) shrub species richness for shrub layer

bance factor. Regardless of the soil moisture level *Rhamnus triqueter* and *Boenninghausenia albiflora* were absent in most of the disturbed stands (figure 2b and c), whereas *Randia tetrasperma* predominantly occurred in disturbed stands (figure 2d), (iv) For trees, both the species richness (1-11) and species diversity (0.00-2.91) increased from low to high soil moisture level (figure 3a and b). (v) The shrub species richness appeared to be related to both soil moisture and disturbance: the number being 5-7 in relatively disturbed stands (1-8) (figure 3c) which were also drier (soil moisture 17.3-26.1%), and 9-15 in relatively less disturbed stands (9-18), which were more moist (22.3-40.1% soil moisture). This supports the observation that the diversity of one growth-form is unrelated to that of another (Whittaker 1975).

Table 1 *Altitude, aspect, hill position and soil moisture of the selected stands*

Site name	Stand number	Altitude (m)	Aspect and position on hill slope		Soil moisture (% $\pm$ SE)
Naukuchiatal	1	1450–1500	NW-1	HB	20.5 $\pm$ 0.55
	2	1500–1550	NW-1	HS	18.9 $\pm$ 0.70
	3	1550–1600	NW-1	HT	17.3 $\pm$ 0.99
Pangot	4	1800–1950	SSW	HB	19.2 $\pm$ 0.49
	5	1950–2100	SSW	HS	20.8 $\pm$ 1.00
	6	2100–2250	SSW	HT	26.1 $\pm$ 0.32
Pangot	7	1800–1950	S	HB	20.8 $\pm$ 0.64
	8	1850–2100	S	HS	22.3 $\pm$ 0.30
	9	2100–2250	S	HT	26.5 $\pm$ 0.25
Pangot	10	1700–1900	NE	HB	25.5 $\pm$ 0.32
	11	1900–2100	NS	HS	20.2 $\pm$ 0.21
	12	2100–2300	NE	HT	30.0 $\pm$ 0.35
Ghughukhan	13	1900–2070	E	HB	34.0 $\pm$ 0.41
	14	2070–2240	E	HS	30.9 $\pm$ 0.26
	15	2240–2410	E	HT	28.1 $\pm$ 0.55
Ghughukhan	16	1900–2080	NW-2	HB	40.1 $\pm$ 1.09
	17	2080–2260	NW-2	HS	38.0 $\pm$ 0.26
	18	2260–2440	NW-2	HT	36.0 $\pm$ 0.40

NW North West; *SSW* South South West; *S* South; *NE* North East; *E* East
HB Hill Base; *HS* Hill Slope; *HT* Hill Top
Stand 1 to 9 = Disturbed Stands; 10 to 18 = Undisturbed Stands

Table 2 *Beta diversity for different points of soil moisture gradient for trees and shrubs*

Soil moisture gradient	Beta diversity	
	Trees	Shrubs
Lower part of gradient (17.3-26.5%)	3.45	3.96
Higher part of gradient(26.5-40.1%)	2.17	2.01
Entire gradient (17.3-40.1%)	3.74	3.62

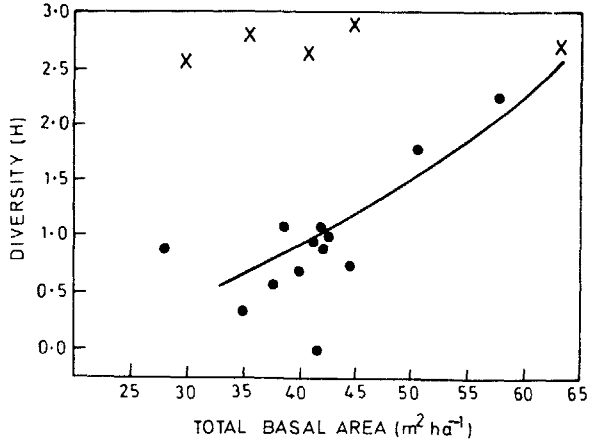

Figure 4 Relationship between total basal cover and Shannon-Wiener index for tree layer in 18 forest stands, x-indicates mixed forest stands

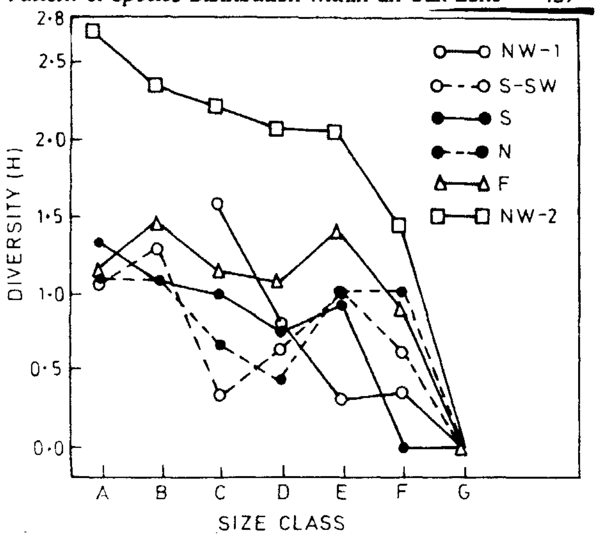

Figure 5 Distribution of Shannon-Wiener diversity for tree layer for different size class. Size class A, B, C, D, E, F and G are having dbh 3.2-10 cm, 10.1-20 cm, 20.1-30 cm, 30.1-40 cm, 40.1-50 cm, 50.1-60 cm, and $\geq$ 60.1 cm, respectively.

Generally, stands were not clustered in the ordination field, indicating that relationship among them were, largely continuous. Relatively more clustering of stands towards the lower part of the moisture gradient may have resulted from the selective man-made disturbances. Since the nature of disturbance is uniform (lopping and removal of similar trees and shrub plants for fodder and firewood) in the region (Singh et al. 1988), it leads to the development of similar stands in an area.

Our results indicate that within the moisture range, that favours forests as potential vegetation, the tree diversity increases with increasing moisture. However the moisture range, considered in this study is narrow and fall within the humid climate.

Values of *beta* diversity (table 2) were similar for the two growth-forms, trees (3.74) and shrubs (3.62), indicating that they responded in similar fashions to changes with soil moisture in regard to degree of change in species composition. Interestingly, *beta* diversity for the two growth forms was significantly higher along the lower part of the moisture gradient (3.45 and 3.96 for trees and shrubs, respectively) than along the higher part of the gradient (2.17 and 2.01 for trees and shrubs, respectively). Firstly, this indicates that with the increasing moisture the degree of floristic changes in woody forms of the region was rapid up to an intermediate moisture level, and then slowed down with further rise in soil moisture. Secondly, though both species richness (*alpha* diversity) and values of Shannon-Wiener index were higher for mixed forests, occupying the higher part of the moisture gradient, floristic changes between their stands were lower than in *Q. leucotrichophora* forest stands.

The tree diversity generally ranged from 0.33 to 2.91 which is comparable with the values generally reported for the forests of this region (0.00-2.95 by Saxena & Singh 1982, Tewari & Singh 1985, Upreti et al. 1985, Rikhari et al. In Press). The lower limit of the range of shrub diversity was higher (1.80) than that of tree diversity, but the upper limit (2.87) was similar. These values of shrub diversity was found in the range of earlier reported values in these forests (0.00-2.66 by Saxena & Singh 1982; 0.74-3.05 by Tewari & Singh 1985).

Figure 4 shows the relationship between the total basal cover and tree diversity. If the mixed forest stands were to be excluded, diversity increased from low to high tree basal cover. In mixed forests, diversity was considerably higher in all stands, regardless of total tree basal cover. A similar observation was also made by Saxena and Singh (1982).

Size class distribution of diversity is shown in figure 5. In general, diversity was high in the first two youngest classes (A and B), then declined in next two higher classes (C and D) to rise again in the following class

(40.1-50.0 cm dia.). It declined sharply subsequently with increasing size class and in the highest size class (G). High diversity in the youngest size class indicates that young trees of few species are able to reach the next higher size class. This may be partly due to the selective removal of small-sized plants for firewood because they are easy to transport. Another factor can be periodic nature of regeneration of the species. In most of the species of oak forests, a good seed crop is followed by years of low seed production, and coincidence of a good seed crop year and good rainfall occurs after a still longer time interval (Singh 1987). This also partly explains the constitution of the high tree diversity in the intermediate size class (E). Disappearance of old growth forest in a large part of the Central Himalaya has been reported by Saxena et al. (1984). Occurrence of single tree species in the oldest size class was due the absence of old growth forests in this region.

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