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ACKNOWLEDGEMENTS. The work was funded by the ICMR, DST, National Aids Control organization, and DBT. Dr George Babu, CMC Vellore, who participated in this study died in an accident. This paper is dedicated to his memory.

Received 22 October 2003; accepted 4 December 2003

Plant diversity in six forest types of Uttaranchal, Central Himalaya, India

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***Quercus* spp. (oaks) and *Pinus roxburghii* Sarg. (chir-pine) are the major forest-forming tree species in the Central Himalayan region. *P. roxburghii* forest is generally pure with low total species richness of shrubs and herbs, while mixed-broadleaved forest has high total species richness. Shrubs and herbs show high species richness in *P. roxburghii* mixed-broadleaved forest and low species richness in *Quercus semecarpifolia* Sm. forest. *Quercus leucotrichophora* A. Camus forest has high tree diversity, while shrub and herb diversity is highest in *Cupressus – Quercus* mixed forest. Anthropogenic disturbances are changing the species richness and diversity, which influence the soil and environmental conditions. Thus, the conservation and management of these forests will be important for the sustainability of human and land in the region.**

THE most striking feature of the earth is the existence of life, and the most striking feature of life is its diversity[1]. Topography, soil, climate and geographical location of a region influence the vegetation diversity of the forest ecosystem. The Himalayan forest vegetation ranges from tropical dry deciduous forests in the foothills to alpine meadows above timberline[2]. Forest diversity is the main source of livelihood of the people living in Uttaranchal, Central Himalaya. India is among the important mega-biodiversity centres of the world, with a lot of contribution from the Himalayan ecosystem. Biodiversity is used variously for fodder, fuel wood, timber, leaf litter for manuring crop fields, construction, industrial raw material and several non-timber forest produce. Forests of this region are mainly dominated by *Pinus roxburghii* Sarg. (Chir Pine) and *Quercus leucotrichophora* A. Camus. (Banj oak). Chir pine often forms a pure crop in this area, but sometimes it also mixes with certain broadleaved species like *Q. leucotrichophora*, *Quercus glauca* Thumb, *Pyrus pashia* Ham., *Myrica esculanta* Linn. and *Rhododendron arborium* Sm. *Q. leucotrichophora* prefers cooler aspects below 1900 m asl (ref. 3) and is found in either pure or mixed with other broadleaved species.

The increasing population trend over the last few decades and consequent dependence on plant products has led to the vast exploitation of natural flora and fauna of this region. The accelerating effects of human activities on biodiversity might impact ecosystem functioning[4]. This has renewed interest in the effect of diversity on ecosystem[5] and on ecosystem services essential to society[6].

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Several studies documented that the changes in the landuse, habitat fragmentation, nutrient enrichment and environmental stress often led to reduced plant biodiversity in natural ecosystem[7–9]. Forest biodiversity of Uttaranchal has been studied by different workers[10–13]. In the wake of efficient socio-economic development and for the betterment of soil, livestock and human, the conservation of biodiversity in the Himalaya is assumed to be of great significance. The present study deals with species richness and plant diversity in relation to anthropogenic disturbance in different forest types of Uttaranchal.

The study area (Uttranchal, Central Himalaya) is located between 79°23′ and 79°42′E, and 29°20′ and 29°30′N. The altitude ranges between 1300 and 2600 m asl. The climate is influenced by monsoon pattern of rainfall. Generally, the average annual rainfall ranges between 200 and 250 cm; three-fourth of this occurs in the rainy season (mid-June to mid-September). The mean monthly minimum temperature ranges between 2.0 (January) and 15.0°C (July) and mean maximum temperature ranges between 4.0 (January) and 28.0°C (May). The rocks of the study area are a complex mixture of mainly sedimentary, low-grade metamorphosed and igneous[14].

The study was conducted in six forest types of Uttaranchal Himalaya. Each forest type is named after the dominant tree species[12]. The size and number of the samples were determined[15]. Species composition for trees, shrubs and herbs was prepared after a thorough survey of different forests. Within each forest type, all the vegetation layers, i.e. trees, shrubs and herbs were analysed for species richness and diversity. The tree canopy cover was measured by randomly placing ten transects of 400 m^2 in each forest. Herbaceous cover was determined by line intercept method[16]. Trees were analysed in ten 100 m^2, shrubs in 25 m^2 and herbs in 1 m^2 plots randomly in each forest. Herbs were analysed during peak growing season. Plants and the flora were identified with the help of plant taxonomists[17–19].

Species richness was determined as the number of species per unit area[20,21]. Species diversity was calculated by using Shannon–Wiener information index[22]. Data were analysed for single factors by analysis of variance (ANOVA)[23]. Linear correlation was developed for tree cover and species richness. Correlation coefficient was also determined for various richness and diversity parameters.

A total of 132 species was recorded from the study area, out of which 22 were trees, 43 shrubs and 67 herbs. Highest tree diversity was found in the *P. roxburghii*-mixed-broadleaf forest. Maximum shrub and herb richness was 27 and 47, respectively, in *P. roxburghii*-mixed broadleaf forest and minimum in *Q. semecarpifolia* forest (9 shrubs and 13 herbs). Among tree species, *Q. leucotrichophora* was widely distributed and present in all the forest types, except in *Q. semecarpifolia* forest. Similarly, *Pyracantha crenulata* M. Roemer, a shrub, was present in all the forests except in *Q. semecarpifolia* forest. *Anaphalis contorta* Hook. f, an erect herb, and *Chrysopogon serrulatus*, a grass, showed their presence in all the forest types.

Maximum mean tree species richness per 100 m^2 was found in *Q. leucotrichophora* forest, whereas the highest mean shrub richness (25 m^2) was found in *P. roxburghii* mixed-broadleaf forest. Maximum herb species richness (1 m^2) was in *P. roxburghii* mixed-broadleaf forest and *Cupressus–Quercus* forest. ANOVA indicated that the mean tree richness was significantly higher ($P < 0.01$) in *P. roxburghii* mixed-broadleaf forests and *Q. leucotrichophora* forest compared to *Q. floribunda* and *Q. semecarpifolia* forests. Mean shrub richness was significantly higher ($P < 0.05$) in *P. roxburghii* mixed-broadleaf forest and *Cupressus–Quercus* forest compared to other forest types. Mean herb richness was significantly lower ($P < 0.01$)

Table 1. Mean species richness for all vegetation layers in different forest types of Uttaranchal, Central Himalaya

Forest type	Mean species richness		
	Tree (per 100 m^2)	Shrub (per 25 m^2)	Herb (per 1 m^2)
Pinus roxburghii mixed-broadleaf forest	3.4	9.4	20.0
Pinus roxburghii forest	1.0	3.3	8.90
Quercus leucotrichophora forest	4.3	5.3	14.0
Quercus floribunda forest	2.4	3.7	12.0
Cupressus–Quercus forest	3.0	7.8	20.0
Quercus semecarpifolia forest	2.1	3.8	6.6
ANOVA			
F	10.31	26.90	64.38
P	0.01	0.05	0.01
Correlation			
Tree vs shrub richness	$r = 0.87$	$P < 0.01$	
Tree vs herbs richness	$r = 0.83$	$P < 0.01$	
Shrub vs herbs richness	$r = 0.95$	$P < 0.01$	

in *Q. semecarpifolia* forest. The overall total and mean species richness were lowest in *Q. semecarpifolia* forest (Table 1). The total tree species richness was positively correlated ($P < 0.01$) with shrubs and herbs. Similarly, the total shrub richness was positively related ($P < 0.01$) with herb richness.

Q. floribunda and *Q. semecarpifolia* forests had the highest tree crown cover, while *P. roxburghii* mixed-broadleaf forest had the lowest (Figure 1). Forests around human habitation are lopped frequently for fodder and fuel wood. This may be one of the reasons for low crown cover. Total shrubs and herbs richness significantly decreased ($P < 0.01$) with increasing tree cover (Figure 2). Shrub cover significantly decreased ($r = -0.73$, $P < 0.01$) with increasing tree cover. Tree species diversity was positively correlated with shrub diversity ($r = 0.81$, $P < 0.01$) and herb diversity ($r = 0.67$, $P < 0.05$).

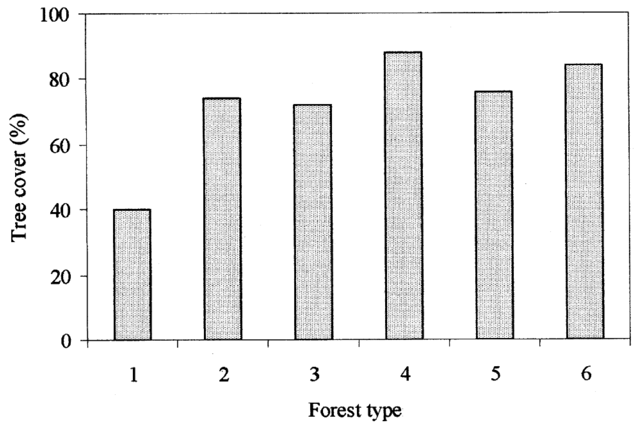

Figure 1. Relationship between forest type and tree crown cover in different forests. 1, *Pinus roxburghii* mixed-broadleaf forest; 2, *P. roxburghii* forest; 3, *Quercus leucotrichophora* forest; 4, *Quercus floribunda* forest; 5, *Cupressus–Quercus* forest, and 6, *Quercus semecarpifolia* forest.

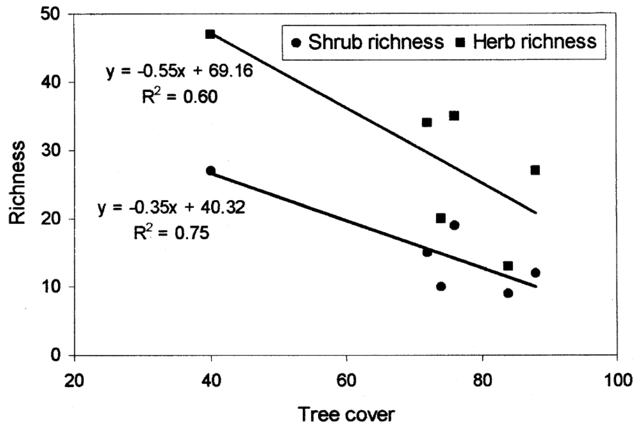

Figure 2. Relationship between tree cover, and shrub and herb diversity in forests of Uttaranchal, Central Himalaya.

Forest biodiversity is the main source of livelihood of the people of Uttaranchal. Agriculture is the main occupation around which all human activities are centred and is mainly managed at the cost of the surrounding natural forests. The forests present around the crop fields are highly degraded due to continuous anthropogenic disturbances. Thus, the biodiversity of these forests is under great anthropogenic pressure. *P. roxburghii* mixed-broadleaf forest is present around the crop fields in mid-elevation and has the highest anthropogenic disturbances. *Q. semecarpifolia* forest is situated on the higher elevations and has the least anthropogenic disturbances. High richness and diversity was reported in *P. roxburghii* mixed-broad leaf forest, while lower values were reported in pure *P. roxburghii* and high altitude forests[24,25]. Disturbances promote undergrowth species diversity, possibly by allowing several species to maintain their population in open canopy. More penetration of light in open-canopied forest may enable each species to develop large populations that may be less vulnerable to local extinction.

The frequent anthropogenic disturbances in *P. roxburghii* mixed-broadleaf forest were responsible for the low crown cover, while *Q. floribunda* and *Q. semecarpifolia* situated away from the human habitation were characterized by high crown cover. Canopy disturbance frequently enhances plant biodiversity[26]. This enhanced biodiversity could be related to environmental heterogeneity in the form of patchy light availability[27], spatial heterogeneity in soil resources[28,29] and local deposition of fallen trees[30]. Alternatively, the increased diversity could be caused by addition of colonizing species to a disturbed community, regardless of environmental heterogeneity – as long as the number of colonizing species exceeds the number of species lost to the disturbance[31]. The forest will be less protective if the canopy is concentrated only at the top. However, if the top-layer trees are supported by deep and dense canopies in lower strata, the vegetation will be more protective[32].

Thus, the anthropogenic disturbances play an important role in change, loss or maintenance of plant diversity of a region. Trees are lopped for fuel wood, fodder for the domestic animals, timber for house construction and industrial raw materials. Various produces like removal of forest floor biomass, edible fruits, fibre, gum, resin, dyes, tannin, spices and more importantly, medicines are exploited from these forests. These anthropogenic disturbances not only influence the soil, nutrient and water conditions, but also influence climatic conditions. The conservation and management of biodiversity of these forests will be important for the sustainability and improvement of soil nutrient and water conditions of the region.

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ACKNOWLEDGEMENT. We thank the Head, Department of Forestry, Kumaun University, Nainital for facilities and the anonymous reviewers for their critical comments.

Received 15 July 2003; revised accepted 18 October 2003

Characterization and screening of bacteria from rhizosphere of rice grown in acidic soils of Assam

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Three groups of rhizobacteria were isolated using three selective culture media from the rhizosphere of rice grown at fifteen locations in Assam. Four bacteria in each group were selected for taxonomic identification, characterization and also for screening the superior isolates to promote rice growth. The isolates of phosphate-solubilizing and fluorescent bacterial groups were found to be eight different species. The three isolates of azospirilla group were identified as *Azospirillum brasilense* and the fourth isolate was identified as *Azospirillum amazonense*. RAPD analysis of the *Azospirillum* isolates indicated that azospirilla were four distinct genotypes. These bacterial strains showed differences in growth pattern, IAA production level (2.0–21.6 μg/ml of culture supernatant), antibiotic resistance profile and nitrogenase activity (0.33–0.75 nmol C_2H_4 h^{-1} 100^{-cc} root volume) in the inoculated roots. *A. amazonense* A10 (MTCC 4716), *Bacillus pantothenticus* P4 (MTCC 4695) and *Pseudomonas piekettii* Psd6 (MTCC 4715) increased rice grain yield by 55.5, 12.2

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