Oecologia Montana 1998, 7, 21 - 31

Structure of Himalayan moist temperate cypress forest at and around Naini Tal, Kumaun Himalayas

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Abstract. The paper deals with the structural features of a subsidiary edaphic and seral type of Himalayan moist temperate cypress (*Cupressus torulosa* Don.) forest that occurs between 2100 - 2,325 m elevation in the exposed sites in Naini Tal, Kumaun Himalaya. The tree density ranged from 270 (ridge top) to 510 trees/ha (mid-hill slope) and total basal cover from 26.6 to 51.5 m^2/ha (both mid-hill slopes). The total tree layer phytomass ranged from 237 to 400 t/ha (both mid-hill slopes), of which dominant species accounted for about 41 to 89% (both on ridge top). The natural catastrophes (snowfall or heavy windstorms) lead to the distribution of tree density and phytomass of present study forests.

The root: shoot ratio ranged from 0.114-0.434 and photosynthetic:non photosynthetic ratio from 0.027-0.140. The total phytomass of present study forests ranged from 239 to 403 t/ha. The comparison of present studied cypress forests with other coniferous forests, viz., *Pinus, Abies, Picea* and *Pseudotsuga* has also been discussed.

Key words: aboveground phytomass (AGP), basal cover, cypress-oak mixed, root:shoot ratio

Introduction

Cypress (*Cupressus torulosa* Don.) is distributed throughout the Himalaya from Chamba (Himachal Pradesh) to Nepal, Bhutan, south-east Tibet and Arunachal Pradesh along an elevation range of 1,800-2,800 m (Sahni 1990). Cypress generally grow on limestone rocks (Troup 1921) and sometimes on limestone cliffs and shale (Sahni 1990), occasionally on other rock type. Among the cypress, *C. torulossa* grow alone on lower ranges, appear to be indigenous (Atkinson 1882) and a subsidiary edaphic and seral type of Himalayan moist temperate forest (Champion and Seth 1968b), but other species are occasionally cultivated in India, *C. cashmeriana* is possibly a form of *C. torulosa.*

In Kumaun, a major chunk of this forest is also near Madhkot (60 ha approx., R.S.Rawal pers. commu.). In Garhwal, it generally occurs on limestone formations, often crowning rugged limestone precipices on NE aspect between Lakandi and Moila peaks (Atkinson 1981). However, forest department use to regenerate through plantations between 1,600-2,200 m in Kumaun, as well as in Garhwal region. It generally occur in chunks of varying extent, such as purely, associated mainly with coniferous species deodar and broad-leaved species, such as *Quercus spp.* (evergreen) and *Acer spp.* (deciduous), have an undercanopy of *Rhododendron* and *Lyonia* on drier sites, while *Carpinus* and *Litsea* on mesic sites.

Materials and methods

Study sites

The present study sites are located in the north of Naini Tal city (just half km by the aerial distance) lies between 29°7′ N lat. and 79°15′ E long. at an elevation range of 2,100-2,325 m forming a highest part of Gaula catchment, a perennial river of the region. Although, Naini Tal is a tourist place, its verdancity is also due to the chunk of this forest.

The area occupied by this chunk of forest in Naini Tal is 44 ha, Rathore 1993).The use of forest by wild animals is rare. The sightings of wild boar, barking deer, goral and Himalayan black bear are occasional. In late summer (June) Kahal forest site provide a good habitat to Himalayan black bear for feeding on acorns as well as protection from virulent summer in foothill regions. Among the arboreal animals Himalayan yellow throated martin, common otter, flying squirrel, common languor is common. The Himalayan whistling thrush, common mania, jungle crow and spotted dove are among the common avian. Certain characteristics of study sites are given in Table 1.

Location	Elevation (m)	Aspect & site	Slope (°)	Dominant species
Nishant	2,200-2,275	S,HS	68	Cypress
Oak Park	2,100-2,200	S,HB-HS	49	Cypress
Tanki	2,250-2,325	S,HT	67	Cypress
Kahal	2,175-2,300	SE,HS-HT	54	Cypress-oak

S=south, SE=south-east, HS=Hill slope, HB=Hill base, HT= Hill top

Table 1. Details of the study sites.

Climate

On the basis of climatic parameters, the year is divided into three seasons, viz., winter, summer and rainy. The mean maximum temperature varied from 10° C (January) to 26°C (June) and mean minimum from 3.5°C (January) to 21.5°C (June). The total annual precipitation was 2,272 mm, of which 78 % was shared by rainy season (Dhaila 1991).

Geology

The present study sites fall within the Krol formation and Blaini formations, which are further divided into three subgroups, viz., lower, middle and upper krols; and two distinct members, such as the lower conglomerate calc-argillaceous-arenaceous unit developed under oxidizing condition and the upper argillaceous horizon indicating prevalence of euxinic condition in the basin of deposition, respectively (Valdiya 1988).

Soil

In sloppy regions a very thin soil layer was visible (Nishant and Tanki) due to their topographic feature (mainly slope) and recurrent landslides. However, in other sites (Oak Park and Kahal) the loose soil was deposited (Adhikari *et al.* 1996). Generally the soil is acidic in nature. The soil moisture and water holding capacity of cypress forest ranged between 14.1-27.4% and 30.9-40.7%, respectively. However, these values are higher in cypress-oak mixed forest.

Methods

The size and number of the quadrat needed for vegetation analysis (tree, sapling, seedling and shrub) were determined by using 10, 10x10 m randomly quadrates, by the species area curve method (Misra 1968) and running mean method (Kershaw 1973). For trees and saplings, individuals were measured at 1.37m cbh (circumference at breast height) ; with >31.5 cm cbh for trees, with 10.5-31.4 cm cbh for saplings and <10.4cm in diameter at ground level for seedlings. For shrubs, clumps of each clump and shrub basal girth were counted and measured, respectively just 10cm above the ground level. For herbs 10, 50x50 cm randomly distributed quadrats were used.

Following Curtis and McIntosh (1950), Philips (1959) and Curtis (1959) density, frequency, basal cover, relative values (density, frequency and dominance) and Importance Value Index (IVI) were calculated. The diversity index was calculated following Shannon and Weaner (1963) and beta-diversity following Wilson and Shmida (1984). Phytomass and canopy breakage due to heavy snowfall in winter season and windstorm in rainy season are very common phenomenon in Central Himalayas above 2,200 m. Relatively undamaged freshly fallen uprooted trees of *C. torulosa* (10 trees) and *C. deodara* (8 trees), representing entire girth classes were selected (distributed across girth classes ranging from 45 to 193 cm). The roots were dug out to one m depth within an area extending one m in radius around the base of each tree. This volume accounted for most of the root mass (approximately 70%). The morphometric measurements were taken and the belowground parts separated into stump root, lateral root and fine root, as well as aboveground components also, viz.,bole, bole bark, branch, twig and foliage. Fresh weights of each component (about 500 g fresh weight) were determined in the field and brought to the laboratory and dried at 80°C till the constant weight. The fresh weight multiplied by appropriate fresh:dry weight factors yielded the dry weight for different components.

From the dimension analysis approach of Whittaker (1961, 1962), Whittaker and Woodwell (1967) or allometry by Kira and Shidei (1967) the harvested data were subjected to regression analysis to relate the dry weight of each component with circumference at breast height (cbh) of trees. The regression equation used was:

$$\ln Y = a + b \ln X$$

where, ln = natural log, Y= dry weight of component (kg), X = cbh, a = the Y intercept and b = slope or regression coefficient.

Regression equations of *Q. floribunda*, *Q. leucotrichophora* and *R. arboreum*, and interspecies regression equations for *A. oblongum* and *B. alnoides* developed by Rawat and Singh (1988) were used to estimate phytomass. Mean cbh values for each species for a girth class was used in regression equation to get an estimate of mean phytomass for a particular component and the values obtained were multiplied by their respective density in that girth class. Finally, to get the phytomass estimate for a component the phytomass across the girth classes were summed up.

For sapling, mean phytomass of *C. torulosa*, *Q. floribunda*, *C. deodara* and *R. arboreum* (5 individuals each) were calculated component-wise by harvesting and digging out the saplings and samples were brought to the laboratory and the same process as for trees was repeated. The dry weight of components were multiplied by their respective densities, and thereafter were summed together to get total sapling phytomass.

The seedling phytomass was calculated by digging out 10 individuals of both *C. torulosa* and *Q floribunda*. The seedlings was divided into aboveground and belowground components and their respective densities to get the seedling phytomass at each site multiplied by their dry weight values.

For shrubs, 10 individuals representing all the classes of circumference at ground level (cgl) were harvested and fresh weight of different components, viz., foliage and root were taken separately in the field. Samples were brought to the laboratory and the same process was repeated as for trees. The total harvested data were subjected and the same process was repeated as for trees. The regression equations for *A. falcata*, *S. hookeriana*, *P. utilis*, *V. cotinifolium*, *B. asiatica* and *C. oxicantha* (have more or less same physiognomy) were taken from Adhikari (1992).

The herb layer phytomass was calculated by harvesting and digging out root of herbs in the month of September, 1992 (assuming peak biomass) by using 50x50cm randomly placed quadrats. Samples were brought to the laboratory and oven dried at 800c. The fresh:dry weight factor was used to determine herb phytomass.

At last, the phytomass of each layer was summed together to get the total phytomass of each forest site.

Results

The total tree density of cypress forest sites ranged between 270 and 510 trees/ha,however, in cypress-oak mixed forest site it was 290 trees/ha. At Nishant, Oak Park and Tanki dominant species was accounted for 78%, 81% and 82%, while at Kahal the proporion of dominant species was 31%. The basal cover of cypress forest sites ranged between 26.5 and 51.4 m^2/ha, of which dominant species accounted for 73%, 74% and 90% for Nishant, Oak Park and Tanki, respectively. However, the basal cover at Kahal was 35.2 m^2/ha, of which dominant species accounted for 53% (Table 2). The density values of sapling, seedling and shrubs are given in Table 3. The total herb density was 106.9, 97.8, 90.4 and 151.7 individuals/m^2 at Nishant, Oak Park, Tanki and Kahal, respectively. The total tree layer diversity ranged from 0.73 to 2.19, shrub layer from 0.757 to 2.044 and herb layer from 3.812 to 4.476. However, the beta-diversity of entire region was 2.0 for tree layer.

Linear regressions between the phytomass of components (Y, kg.tree^{-1}) and cbh (*X*, cm) of tree species are given in Table 4.

The total phytomass of *C. torulosa* was 171, 292, and 266 t/ha, of which bole accounted for about 44%, 59% and 61%, respectively at Nishant, Oak Park and Tanki. However, in Kahal the total phytomass of *C. torulosa* (dominant) was 138 t/ha and *Q. floribunda* 99t/ha, of which bole accounted for about 65% and 36% for *C. torulosa* and *Q. floribunda*, respectively. The crown (branch, twig and foliage) accounted for about 41%, 29% and 28% of the aboveground phytomass (AGP) for dominant species in Nishant, Oak Park and Tanki, however, in Kahal it was 25% and 58% for dominant and co-dominant species, respectively (Table 5).

The total tree layer phytomass was 237, 400 and 300 t/ha, of which dominant species accounted for 72%, 73% and 89% in Nishant, Oak Park and Tanki, respectively. However, in Kahal it was 340 t/ha with 41% for dominant and 29% for codominant species. Among the components, bole (range 42-58%) in aboveground and stump root (range 9-12%) in belowground parts accumulated maximum proportion of biomass (Table 6). The total sapling layer phytomass ranged between 0.3 and 3.7 t/ha, of which stem shared maximum proportion of AGP (82.2-84.3%). The total seedling layer phytomass ranged between 2.6 and 13.3 kg/ha, of which maximum proportion was accounted for belowground parts (56.1-58.0%). The total shrub layer phytomass varied from 259 to 487 kg/ha of which maximum proportion was accounted for

Species	Density tree (ha^{-1})	Basal cover (m^2ha^{-1})	Importance Value Index (IVI)
Nishant			
Cupressus torulosa Don.	400	19.3	203.6
Cedrus deodara Loud.	60	1.7	39.4
Quercus floribunda (Lindl.) Rehder	30	3.3	34.1
Quercus leucotrichophora A. Camus	20	2.3	22.9
Total	510	26.6	
Oak Park			
Cupressus torulosa	300	38.2	217.9
Quercus floribunda	20	3.1	23.8
Quercus leucotrichophora	40	7.7	44.6
Acer oblongum Wall	10	2.5	13.8
Total	370	51.5	
Tanki			
Cupressus torulosa	220	35.6	243.3
Quercus floribunda	20	2.6	28.3
Rhododendron arboreum Sm	30	1.2	28.5
Total	270	39.4	
Kahal			
Cupressus torulosa	90	18.7	107.6
Quercus floribunda	60	5.0	64.2
Quercus leucotrichophora	30	4.6	35.2
Rhododendron arboreum	80	1.7	56.0
Betula alnoides (Buch) Ham	30	5.3	37.0
Total	290	35.3	

Table 2. Compositional structure of cypress and cypress-oak mixed forests in different study sites.

Species	Nishant	Site Oak Park	Tanki	Kahal
Sapling				
Quercus floribunda	320 (71.1)	400 (75.5)	30 (30.0)	770 (95.1)
Cedrus deodara	80 (17.8)	-	-	-
Cupressus torulosa	50 (11.1)	130 (24.5)	30 (30.0)	-
Rhododendron arboreum	-	-	40 (40.0)	40 (4.9)
Total	**450**	**530**	**100**	**810**
Seedling				
Cupressus torulosa	70 (50.0)	40 (18.2)	80 (80.0)	-
Quercus floribunda	70 (50.0)	180 (81.8)	20 (20.0)	420 (100.0)
Total	**90**	**220**	**100**	**420**
Shrub				
Berberis asiatica Roxb.	260 (20.3)	100 (2.4)	150 (10.1)	70 (2.6)
Artemisia vulgaris Linn.	90 (7.0)	120 (2.9)	-	-
Rosa brunonii Lindl.	50 (3.9)	130 (3.1)	50 (3.4)	-
Sarcococca hookeriana Baill	640 (50.0)	1,910 (45.8)	-	-
Princepia utilis Royle	160 (12.5)	90 (2.2)	-	50 (1.8)
Cretagus oxicantha	80 (6.3)	-	-	-
Arundinaria falcata (Nees) Nakai	-	1,700 (40.8)	880 (59.5)	2,420 (0.9)
Viburnum cotinifolium Don.	-	40 (1.0)	30 (2.0)	-
Indigofera gerardiana Wall.	-	80 (1.9)	370 (25.0)	80 (2.9)
Debregeasia velutina Gaud.	-	-	-	50 (1.8)
Duetzia staminea Linn.	-	-	-	50 (1.8)
Total	**1,280**	**4,170**	**1,480**	**2,720**

Table 3. Density (individuals/ha) of sapling, seedling and shrub layers of different study sites. Values in paranthesis are the peercent of the total.

stem (45 to 58%). The herb layer phytomass ranged between 480 and 630 kg/ha, of which aboveground parts accounted maximum proportion (Table 6).

The total phytomass was 239, 403, 301 and 345 t/ha for Nishant, Oak Park, Tanki and Kahal, respectively. The distribution of phytomass among different layers of the vegetation was in the following order :

tree > sapling > herb > shrub > seedling.

Discussion

In the present study the tree density was high in mid-hill slope followed by hill base and low in ridge top. This may be leads to moisture of the sites and distribution of nutrients (Adhikari 1993). In mid-hill slopes the terrain was so undulating, due to surface runoff most of the nutrients can leach. In hill top region windstorms lead to the distribution of trees and as well as in winters snowfall. Although, in these undulated slopes the basal cover was high, as well as low due to the accumulation of nutrients in valley (unexposed sites) and less in undulating tops (exposed sites), where the wind velocity was also high. Phytomass also indicate the same trend as basal cover. In the present study sites natural disasters (snowfall and heavy windstorms) lead to the density, basal cover and phytomass distribution.

As the girth class increase, the root:shoot ratio of *C. torulaosa* (0.114 - 0.434) and *C.deodara* (0.132 - 0.242) decrease (Fig. 1a). A fairly constant root:shoot ratios and allocation to foliage in mid-girth classes of *C.torulosa* suggest the importance of a close physiological balance between leaves, root and shoot. The root:shoot ratio of present study are comparable with those reported for many temperate trees (0.16 - 0.28; Ovington 1962; Rodin and Bayilevich 1967; Whittaker and Woodwell 1968; Arts and Marks 1971) and for *Abies pindrow* (0.238; Adhikari 1992) and *Pinus roxburghii* (0.223, Chaturverdi and Singh 1987), a high and low altitude coniferous species of the Central Himalaya, respectively. The root:shoot ratio of both species indicate that *C. torulosa* required relatively smaller root system to support its aboveground structure.

In a forest community, the characteristic of light penetration through the forest canopy is a most important factor for determining rates of photosynthesis and the distribution of photosynthetic ratio of *C. torulosa* (0.027 - 0.140) and *C. deodara* (0.035 - 0.123) decreases with increasing girth (Fig.1b). Our values of lower side of the range in present study are comparable with values of low and high altitude coniferous species, *P. roxburghii* (0.044, Chaturvedi and Singh 1987) and *A.pindrow* (0.028; Adhikari 1992), respectively.

A positive linear relationships between $d^2.h$ and phytomass of components were observed ($P < 0.01$ for all).

A positive linear relationships between standing

Cupressus torulosa		
Bole	$\ln y = -5.2568 + 2.3762 \ln x$	($r^2 = 0.982$, $P < 0.01$)
Bole bark	$\ln y = -4.8379 + 1.5999 \ln x$	($r^2 = 0.929$, $P < 0.01$)
Branch	$\ln y = -1.5634 + 1.3825 \ln x$	($r^2 = 0.806$, $P < 0.01$)
Twig	$\ln y = 0.7641 + 0.5677 \ln x$	($r^2 = 0.863$, $P < 0.01$)
Foliage	$\ln y = -0.0433 + 0.7322 \ln x$	($r^2 = 0.918$, $P < 0.01$)
Stump root	$\ln y = -2.8713 + 1.5145 \ln x$	($r^2 = 0.903$, $P < 0.01$)
Lateral root	$\ln y = 1.6620 + 0.3638 \ln x$	($r^2 = 0.476$, $P < 0.01$)
Fine root	$\ln y = -1.5051 + 0.7495 \ln x$	($r^2 = 0.566$, $P < 0.01$)
Cedrus deodara		
Bole	$\ln y = -5.6628 + 2.3452 \ln x$	($r^2 = 0.988$, $P < 0.01$)
Bole bark	$\ln y = -7.9450 + 2.2078 \ln x$	($r^2 = 0.968$, $P < 0.01$)
Branch	$\ln y = -2.0590 + 1.2736 \ln x$	($r^2 = 0.943$, $P < 0.01$)
Twig	$\ln y = 0.0963 + 0.6103 \ln x$	($r^2 = 0.585$, $P < 0.05$)
Foliage	$\ln y = -0.0191 + 0.5572 \ln x$	($r^2 = 0.654$, $P < 0.05$)
Stump root	$\ln y = -2.2520 + 1.2570 \ln x$	($r^2 = 0.954$, $P < 0.01$)
Lateral root	$\ln y = -0.3328 + 0.6661 \ln x$	($r^2 = 0.778$, $P < 0.01$)
Fine root	$\ln y = -1.8519 + 0.5475 \ln x$	($r^2 = 0.500$, $P < 0.05$)

Table 4. Linear regression equations for different components of *Cupressus torulosa* and *Cedrus deodara*. y = kg.tree^{-1}, x = cbh (cm), ln = natural log

crop of trees (Y, t.ha) and stand basal cover (X, m²/ha) exists. The linear regression equation developed was:

$$\ln Y = 3.089 + 0.737 \ln X$$
$$(r^2 = 0.840,\ P < 0.05)$$

The AGP of tree layer in present study is 1.3 - 2.3 times lower than that reported for *A. pindrow* forest (Adhikari *et al.* 1995) and is comparable with the biomass of chir pine forest (92-232 t/ha) of Central Himalaya (Chaturvedi and Singh 1987). The AGP values of present study forest sites are comparable with the conifer forests of the world, such as *Picea abies* (133 - 311 t/ha) forest in Belgium, Germany, Sweden and USSR (Reichle 1981; Nihlgard 1972; Kestemont 1975) and *Pinus radiata* (271 t/ha) in New Zealand (Will 1966).

Although, the correlation among different parameters, such as AGP, bark mass, leaf mass and root mass indicate that for a given unit of bark mass it requires more AGP and for high per unit leaf mass it requires more root mass. It seems that basal cover is responsible for overall development of AGP distribution of these present forest sites. Data on density, basal cover, AGP,

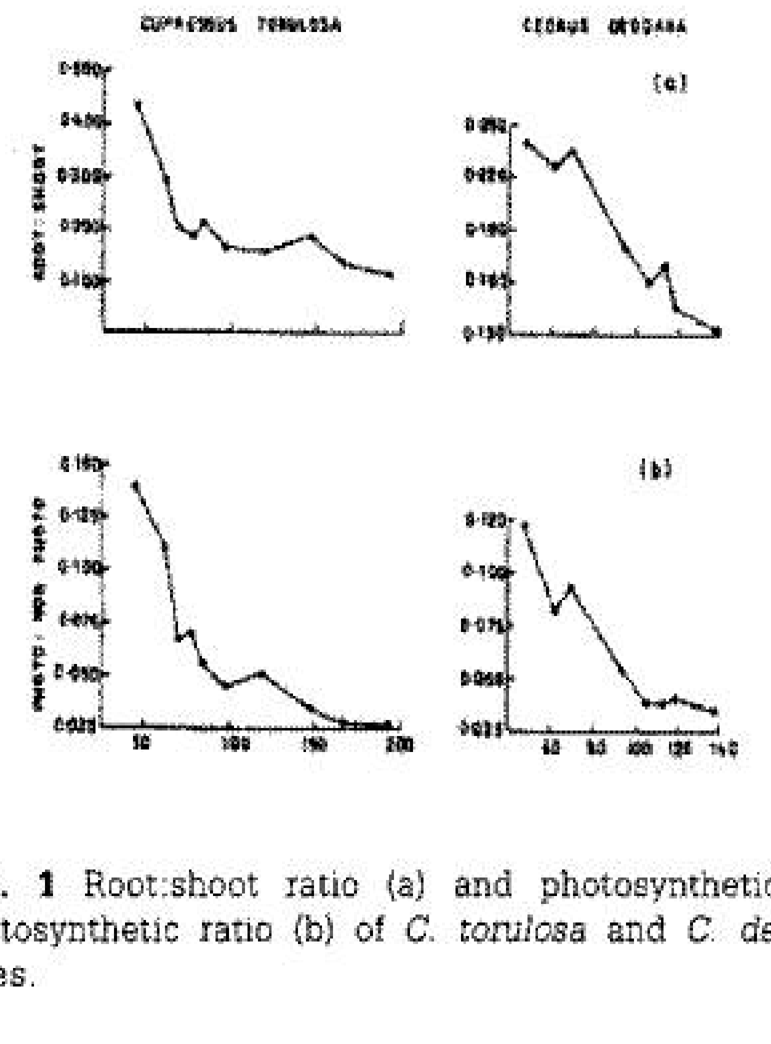

Fig. 1 Root:shoot ratio (a) and photosynthetic:non-photosynthetic ratio (b) of *C. torulosa* and *C. deodara* trees.

bark mass, foliage mass and root mass estimated for different aged coniferous forests by several workers (see appendix) in various regions of the world, were collected (Canell, 1982) for *Abies*, *Pinus*, *Picea* and *Pseudotsuga* and compared with present study forest stands.

The density is related positively with basal cover (a) and negatively with AGP (b) (Fig.2). However, in relation to basal cover the AGP increases and bark mass decrease when AGP increase, while increasing in AGP and finally it depends on basal cover. For these figures our value lies higher side of the range for AG and lower side of the range for bark mass, while for basal cover it is intermediate as reported by several workers for *Pinus* (Fig. 2).

The density does not affect the basal cover (a). However, AGP is negatively related (b), while with increasing basal cover the AGP increases (c) (Fig. 3). The leaf mass does not show any pattern, with AGP and root mass (d,e). It suggests that leaf mass and AGP are totally govern by root mass and basal cover leads to AGP. In the present study sites density and basal cover values are low, while intermediate for leaf mass and AGP and high for root mass for the range reported by several workers for *Abies* (Fig. 3).

In *Pinus* and *Abies*, with increasing root mass increases the leaf mass also increase. It is evident that the large mass of root supports fairly a good foliage mass. This is because of the fact that the large volume of the roots has a good absorption capacity for water (as indicated in Oak Park site). The roots of *Pseudotsuga* and *Picea* does not allow much foliar mass, it may be due to the fact that the roots of these species check the excessive transpiration.

The density does not play any role for basal cover, while AGP increases (a). However, for other values it is inversely related (b) (Fig. 4). As the basal cover increases the AGP also increase, however, for other forests of the world no such pattern was seen (c). With increasing AGP bark mass decrease (d), while leaf mass

Species	Component								Total
	Bole	Bole bark	Branch	Twig	Foliage	Stump root	Lateral root	Fine root	
Nishat									
Cupressus torulosa	74.34	9.73	35.27	14.98	9.19	17.13	7.87	2.30	170.81
Cedrus deodara	3.23	0.19	1.41	0.76	0.57	1.09	0.65	0.09	7.99
Quercus floribunda	13.96*	-	8.01	4.12	6.50	4.57	0.73	0.03	37.92
Quercus leucotrichophora	8.18*	-	4.93	1.54	0.72	4.01	0.70	0.06	20.14
Oak Park									
Cupressus torulosa	173.31	5.67	50.22	14.54	9.87	26.64	9.12	2.49	291.86
Quercus floribunda	12.02*	-	6.73	3.39	5.47	3.67	0.58	0.02	31.88
Quercus leucotrichophora	23.89*	-	14.11	3.90	2.03	10.20	7.94	0.13	62.20
Acer ablongum	6.70*	-	3.85	1.23	0.72	1.48	0.17	0.01	14.16
Tanki									
Cupressus torulosa	162.86	5.65	44.37	12.69	7.92	23.23	7.00	2.00	265.72
Quercus floribunda	10.47*	-	5.95	3.04	4.83	3.34	0.53	0.02	28.18
Rhododendron arboreum	1.83*	-	1.88	0.46	0.20	1.07	0.34	0.06	5.84
Kahal									
Cupressus torulosa	89.76	2.49	21.59	5.66	3.55	11.49	3.00	0.90	138.44
Quercus floribunda	35.92*	-	20.95	10.91	16.99	12.34	2.00	0.09	99.20
Quercus leucotrichophora	24.17*	-	14.40	4.21	1.99	11.01	1.89	0.15	57.82
Rhododendron arboreum	3.93*	-	2.06	1.10	0.51	2.18	0.68	0.14	10.60
Betula alnoides	15.82*	-	9.24	3.09	1.82	3.78	0.42	0.02	34.19

* including bole bark

Table 5. Component-wise tree species phytomass ($t.ha^{-1}$) on different sites.

Component	Site			
	Nishant	Oak Park	Tanki	Kahal
Tree				
Bole	99710.0 (42.1)	215920.0 (54.0)	175160.0 (58.4)	169600.0 (49.8)
Bole bark	9920.0 (4.2)	5670.0 (1.4)	5650.0 (1.9)	2490.0 (0.7)
Branch	49620.0 (20.9)	74910.0 (18.7)	52200.0 (17.4)	68240.0 (20.1)
Twig	21400.0 (9.0)	23060.0 (5.8)	16190.0 (5.4)	24970.0 (7.3)
Foliage	16980.0 (7.2)	18090.0 (4.5)	12950.0 (4.3)	24860.0 (7.3)
Aboveground	197630.0 (83.4)	337650.0 (84.4)	262150.0 (87.5)	290160.0 (85.3)
Stump root	26800.0 (11.3)	41990.0 (10.5)	27640.0 (9.2)	40800.0 (12.0)
Lateral root	9950.0 (4.2)	17810.0 (4.5)	7870.0 (2.6)	7990.0 (2.3)
Fine root	2480.0 (1.0)	2650.0 (0.7)	2080.0 (0.7)	1300.0 (0.4)
Belowground	39230.0 (16.6)	62450.0 (15.6)	37590.0 (12.5)	50090.0 (14.7)
Total	**236860.0 (98.92)**	**400100.0 (99.22)**	**299740.0 (99.64)**	**340250.0 (98.66)**
Sapling				
Stem	1012.30 (82.4)	1279.77 (82.9)	169.24 (84.3)	2200.17 (82.2)
Foliage	216.66 (12.6)	263.98 (17.1)	31.52 (15.7)	475.18 (17.8)
Aboveground	1228.96 (68.4)	1543.75 (71.7)	200.76 (72.3)	2675.35 (72.1)
Belowground	478.37 (31.6)	608.40 (28.3)	76.75 (27.7)	1037.08 (27.9)
Total	**1707.34 (0.71)**	**2152.15 (0.53)**	**277.51 (0.09)**	**3712.43 (1.08)**
Seedling				
Stem	1.04 (89.7)	2.55 (89.8)	1.05 (91.3)	5.00 (89.3)
Foliage	0.12 (10.3)	0.29 (10.2)	0.10 (8.7)	0.60 (10.7)
Aboveground	1.16 (42.4)	2.84 (42.3)	1.15 (43.9)	5.60 (42.0)
Belowground	1.56 (57.6)	3.86 (57.7)	1.46 (56.1)	7.73 (58.0)
Total	**2.72 (0.001)**	**6.69 (0.002)**	**2.61 (0.001)**	**13.31 (0.004)**
Shrub				
Stem	189.37 (72.1)	220.05 (70.1)	149.74 (71.2)	157.23 (73.4)
Foliage	73.37 (27.9)	93.71 (29.9)	60.49 (28.8)	56.84 (26.6)
Aboveground	262.74 (68.2)	313.76 (64.5)	210.23 (81.3)	214.07 (75.5)
Belowground	122.43 (31.8)	173.07 (35.5)	48.48 (18.7)	69.33 (24.5)
Total	**385.17 (0.16)**	**486.83 (0.12)**	**258.71 (0.09)**	**283.40 (0.08)**
Herb				
Aboveground	347.50 (72.5)	314.80 (65.3)	376.00 (70.3)	421.70 (67.0)
Belowground	132.00 (27.5)	167.20 (34.7)	158.70 (29.7)	208.10 (33.0)
Total	**479.50 (0.20)**	**482.00 (0.12)**	**534.70 (0.18)**	**629.80 (0.18)**
Grand Total	**239434.2 (100.0)**	**403227.7 (100.0)**	**300813.5 (100.0)**	**344888.1 (100.0)**

Table 6. Component-wise phytomass (kg.ha^{-1}) of different layers (tree, sapling, seedling, shrub and herb). Values in parethesis are the percent of the aboveground, belowground and total biomass.

increase (e), and with increasing root mass leaf increases but after have a constent root mass a gradual decrease in leaf mass (f) (Fig. 4).

Like *Pinus* and *Abies*, the root mass of *Picea* does not follow the same trend. However, AGP is solely responsible for low bark mass and high root mass. In case of *Picea* forest, our values lie lower side of the range for density and bark mass, and intermediate for leaf mass and root mass, while higher for AGP. Figure 5 shows that density for basal cover and AGP (a, b) and basal cover for AGP (c) does not contribute much, which directly affects the bark mass (d). However, with low AGP sites have high leaf mass (a), while root mass contributed lot for leaf mass (f). For these forests our values lie lower side of the range for density and basal cover, intermediate for AGP and root mass and higher for leaf mass for *Pseudotsuga* forests (Fig 5).

The tree density value of present study forest sites were low than that of all coniferous forests; basal cover values were low as compared to that of *Abies* and *Pseudotsuga* forests and high than *Pinus* forests; AGP and leaf mass values were high than that of *Pinus* and *Picea* forests; and root mass values were also higher than *Pinus* forests. The values of basal cover were comparable with *Picea* forest, while AGP and leaf mass with *Abies* and *Pseudotsuga* forests.

In nutshell, the distribution of trees in present study sites totally depend on abiotic factors, such as soil depth, less accumulation of nutrients, as well as natural catastrophe, which leads to low density with low basal cover. However, in mid - hill slopes deep soil and more nutrient accumulation and less catastrophical activities in

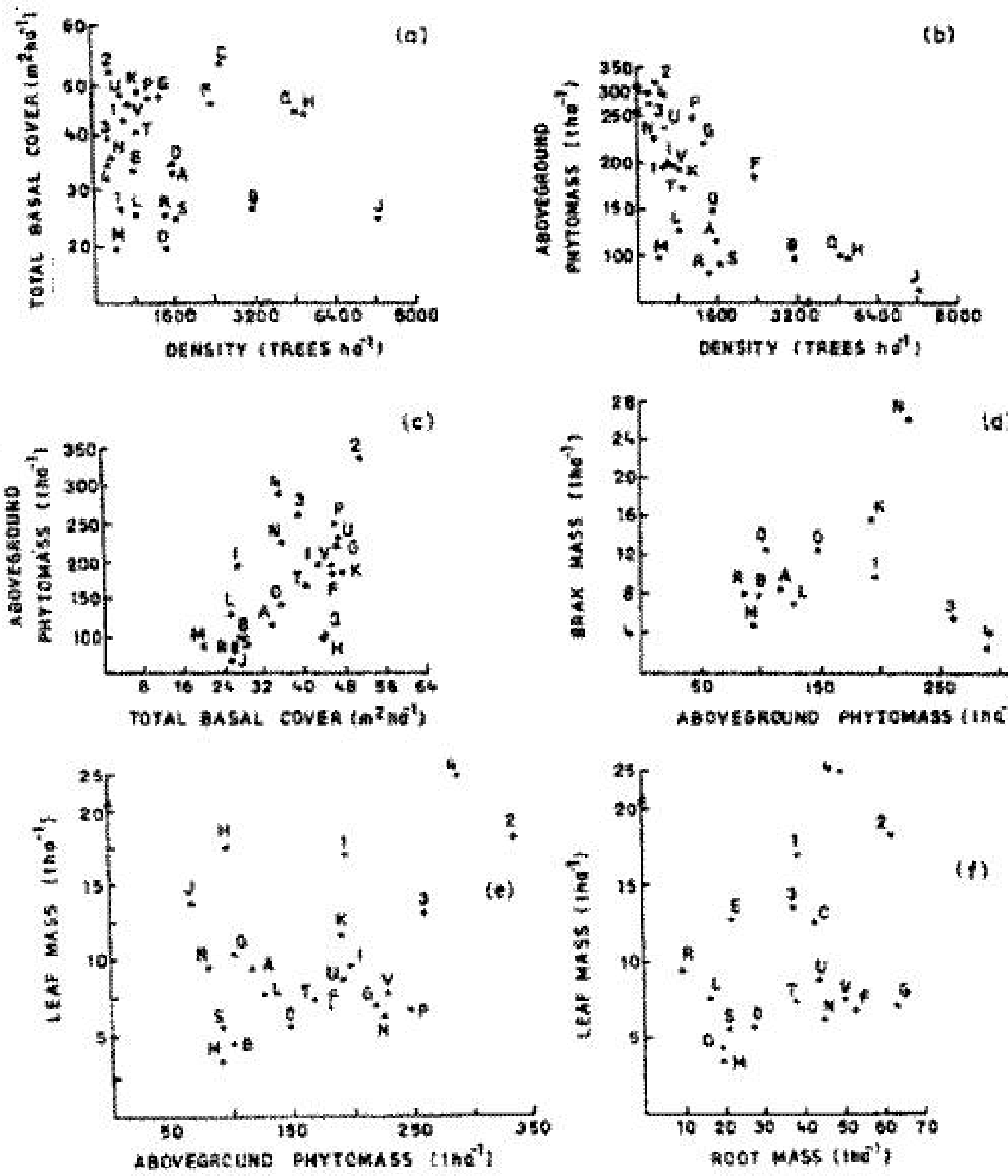

Fig. 2. Scattered diagram of density, basal cover, aboveground phytomass, leaf mass, bark mass and root mass of present *Cypress* forest sites with different *Pinus* forests of the world. For code see Appendix.

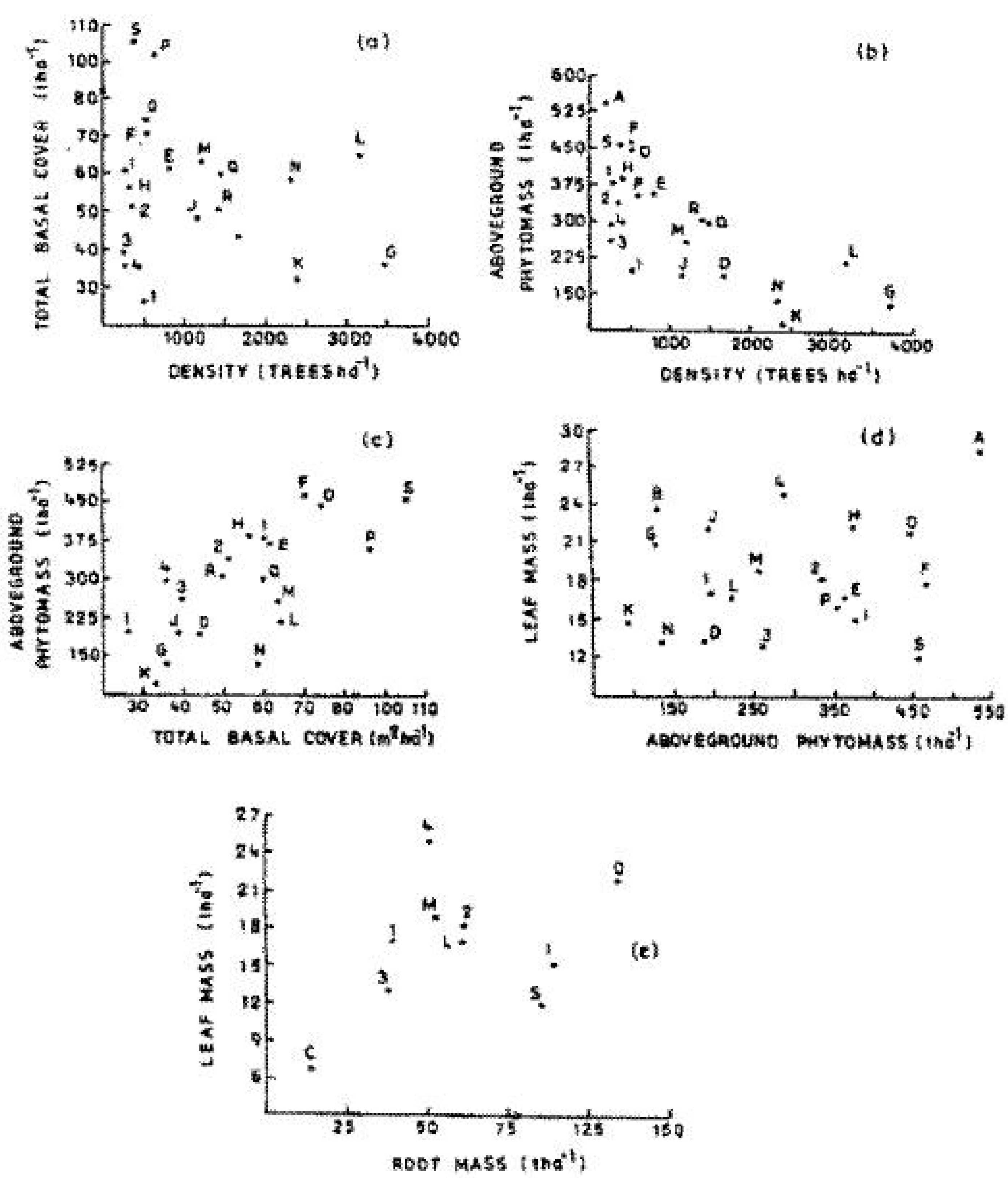

Fig. 3. Scattered diagram of density, basal cover, aboveground phytomass, leaf mass, bark mass and root mass of present *Cypress* forest sites with different *Abies* forests of the world. For code see Appendix.

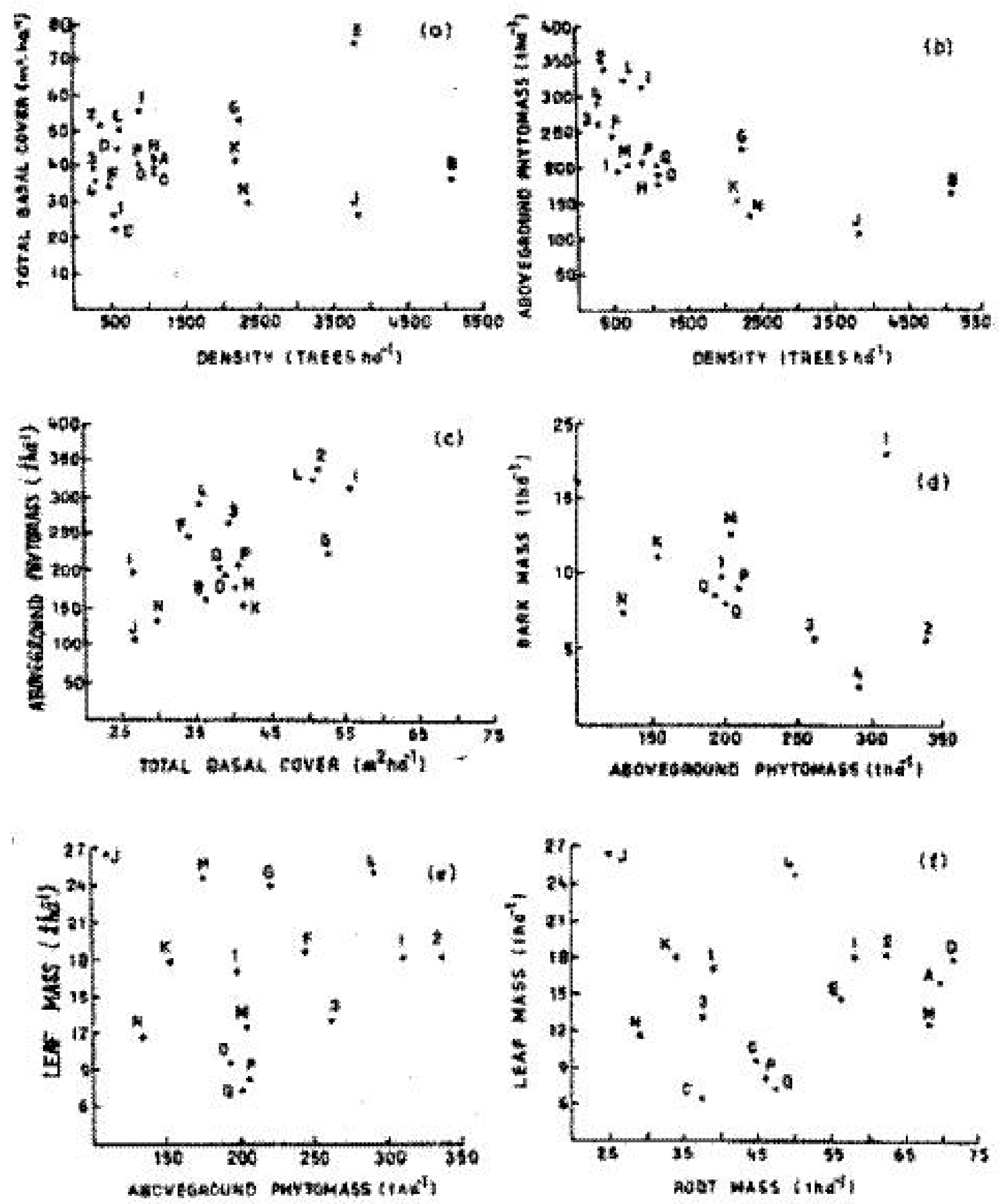

Fig. 4. Scattered diagram of density, basal cover, aboveground phytomass, leaf mass, bark mass and root mass of present *Cypress* forest sites with different *Picea* forests of the world. For code see Appendix.

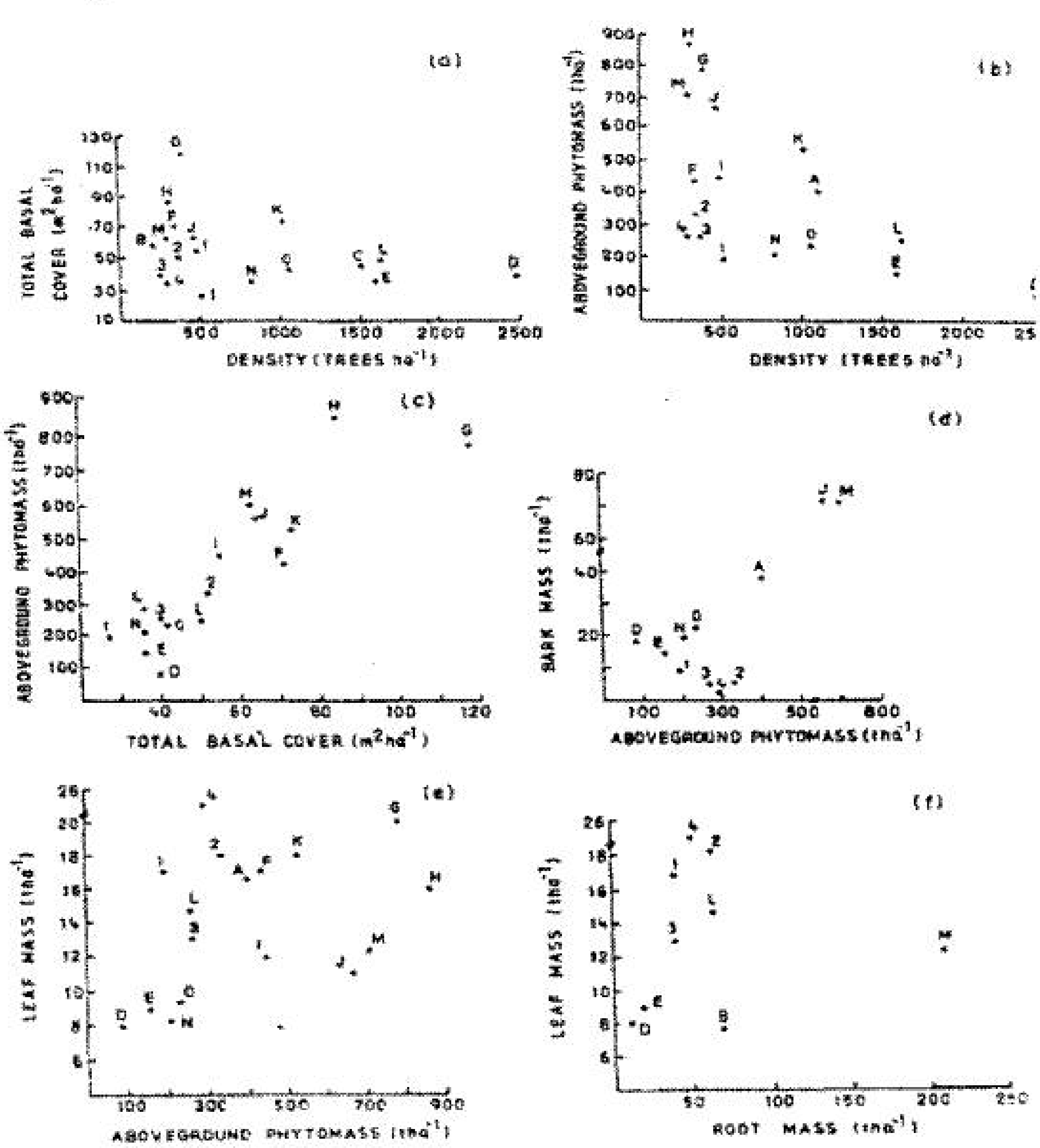

Fig. 5. Scattered diagram of density, basal cover, aboveground phytomass, leaf mass, bark mass and root mass of present *Cypress* forest sites with different *Pseudotsuga* forests of the world. For code see Appendix.

nature support good forest growth (density and basal cover). Ultimately, density and basal cover plays a great role for the distribution of phytomass in these sites. The comparison indicate that cypress forest stands need more AGP for a given unit of bark mass and root mass for a given unit of leaf mass than most of the coniferous forests of the world.

Aknowledgements

The authors (BSA & SDA) are gratefully acknowledge the financial support from the CSIR, New Delhi and thankful to Prof. S. P. Singh, Head, Department of Botany, Kumaun University, Naini Tal, for guidance and providing facilities. One of the author (BSA) is thankful to Director and Dr. G.S. Rawat, Scientist, Wildlife Institute of India, Dehra Dun for providing necessary facilities and suggestion, respectively. The authors would like to thank Anonymous Reviewers for correting the ms nicely.

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Received 12 November 1996; revised 17 February 1997; accepted 12 December 1998.

Code	Species			
	Pinus	*Abies*	*Picea*	*Psudotsuga*
A	Forrest & Ovington 1970' *	Kimmins & Krumlik 1973 *	Duvigneaud & Kestemont 1977 *	Turner 1980 *
B	Doucet et al. 1976 *	Weetman & Webber 1972 *	Moore & Verspoor 1973 *	Kestemont 1975 *
C	Johnstone 1972 *	Vyskot 1972 *	Havas 1981 *	Oswald & Parde 1981 *
D	Malkonen 1974 *	Gantiani 1974 *	Ellenberg 1981 **	Heilman & Gessel 1963 *
E	Cabanettes 1979 *	Gantiani 1974 *	Carey & O'Brien 1979 *	Heilman & Gessel 1963 *
F	Hatiya et al. 1965 *	Gantiani 1974 *	Satoo 1971 *	Whittaker & Niering 1975 *
G	Hatiya et al. 1965 *	Furuno & Kawanabe 1967 *	Satoo 1971 *	Whittaker & Niering 1975 *
H	Akai et al. 1970 *	Furuno et al. 1979 *	Yoshimura 1967 *	Gholz et al. 1979 *
I	Akai et al. 1972 *	Ando et al. 1977 *	Nihlgard & Lindgren 1981 *	Gholz et al. 1979 *
J	Ando 1965 *	Yammamoto & Sanada 1970 *	Deans 1981 *	Fujimori et al. 1976 *
K	Alvera 1973 *	Satoo 1973a *	Alban et al. 1978 *	Gholz 1982 *
L	Albrekstan 1980a *	Tadaki et al. 1967 *	Whittaker 1963, 1966 *	Fogel & Hunt 1979 *
M	Albrekstan 1980a *	Tadaki et al. 1970 *	Karpov 1973 *	Grier & Logan 1977 *
N	Miller et al. 1980 *	Oohata & Uniishii 1974 *	Kazimirov & Morozova 1981' **	Turner & Long 1975 *
O	Alban et al. 1978 *	Grier et al. 1981 *	Kazimirov & Morozova 1981' **	-
P	Whittaker & Niering 1975' *	Turner & Singer 1976' *	Kazimirov & Morozova 1981' **	-
Q	Madgwick et al. 1970' *	Whittaker 1966'	Kazimirov & Morozova 1981' **	-
R	Buckhart 1977' *	Whittaker 1966' *	-	-
S	Chaturvedi & Singh 1987	Adhikari et al. 1995	-	-
T	Chaturvedi & Singh 1987	-	-	-
U	Chaturvedi & Singh 1987	-	-	-
V	Chaturvedi & Singh 1987	-	-	-
1	Present study	Present study	Present study	Present study
2	Present study	Present study	Present study	Present study
3	Present study	Present study	Present study	Present study
4	Present study	Present study	Present study	Present study

Appendix. Sources used to describe different parameters of *Pinus, Abies, Picea* and *Pseudotsuga* forests of the world. * - see Cannell (1982), ** - see Reichle (1981)