PINUS PATULA PLANTATIONS IN KUMAUN HIMALAYA. I. DRY MATTER DYNAMICS

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BARGALI, S.S. & SINGH, R.P. 1997. *Pinus patula* plantations in Kumaun Himalaya. I. Dry matter dynamics. The present paper reports on the biomass, forest floor biomass, litterfall and net primary productivity in different aged plantations of *Pinus patula* in Kumaun Himalaya. Biomass increased from 108.9 t ha^{-1} at a stand age of 15 years to 151.3 t ha^{-1} at 21 years. The forest floor biomass was 6.9 t ha^{-1} at 15-y-old and 8.9 t ha^{-1} at 21-y-old plantations. Annual litterfall ranged from 2 t ha^{-1} at 15 years to 3 t ha^{-1} at 21 years. Net primary productivity was 13.5 t ha^{-1} y^{-1} at age 21 and 12.1 t ha^{-1} y^{1} at 15 years. The biomass accumulation ratio of these plantations was between 10.3 and 12.7.

Key words: Biomass - net primary productivity - turnover - biomass accumulation ration

BARGALI, S.S. & SINGH, R.P. 1997. Ladang *Pinus patula* di Kumaun Himalaya. I. Dinamik bahan kering. Laporan ini menerangkan mengenai biojisim, biojisim lantai hutan, jatuhan sarap dan produktiviti primer bersih di ladang *Pinus patula* yang berbeza umur di Kumaun Himalaya. Biojisim bertambah daripada 108.9 t ha^{-1} pada umur dirian 15 tahun hingga 151.3 t ha^{-1} pada umur 21 tahun. Biojisim lantai hutan ialah 6.9 t ha^{-1} bagi ladang berumur 15 tahun dan 8.9 t ha^{-1} bagi ladang berumur 21 tahun. Luruhan sarap tahunan berjulat daripada 2 t ha^{-1} pada umur 15 tahun hingga 3 t ha^{-1} pada umur 21 tahun. Produktiviti primer bersih ialah 13.5 t ha^{-1} y^{-1} pada umur 21 tahun dan 12.1 t ha^{-1} y^{-1} pada umur 15 tahun. Nisbah pengumpulan biojisim terletak di antara 10.3 dan 12.7 daripada ladang tersebut.

Introduction

In India the continuous decrease of forest cover and increase in human population and industries have resulted in further increasing the gap between demand and supply of forest resources with the consequent increase in pressure on remaining forests. It has also resulted in serious ecological imbalance and increased environmental degradation. To partially cope with this situation, options are taken to plant fast-growing exotics such as *Pinus* species in the hills and *Eucalyptus* species and *Populus* species in the plains.

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The determination of plantation biomass is a major and difficult task which has received little attention in India. The task becomes compounded if biomass is to be measured and analysed in its proper context as a part of primary production (Lieth 1973, Lieth & Whittaker 1975).

The estimation of NPP (= net primary productivity, the dry organic matter synthesised per unit area at a time or a rate of dry organic matter production) is therefore, of necessity, a long term project. Apart from a few studies in Kumaun Himalaya, the biomass and NPP of exotic plantations in India have received little attention (Lodhiyal 1990, Bargali & Singh 1991, 1995, Bargali *et al.* 1992). A study is presented here with particular reference to the increase in biomass in relation to changes in NPP in the *Pinus patula* plantations of Kumaun Himalaya.

Materials and methods

Study site

The study sites were located between 28°43' 45" - 30°20' 12" N and 78° 44' 30" - 80° 18' 45" E at an altitude of 1850 m at Ranikhet (Kalka) in the Kumaun hills. Figures 1 shows the monthly rainfall and temperature. The site received 1313 mm annual rainfall (average of 1981-1990), of which 76% occurred in the rainy season (July to September). Mean daily temperature varied from 7.8 °C to 21.1°C (Source: State Forest Department of U.P.). Snowfall occurs in winter.

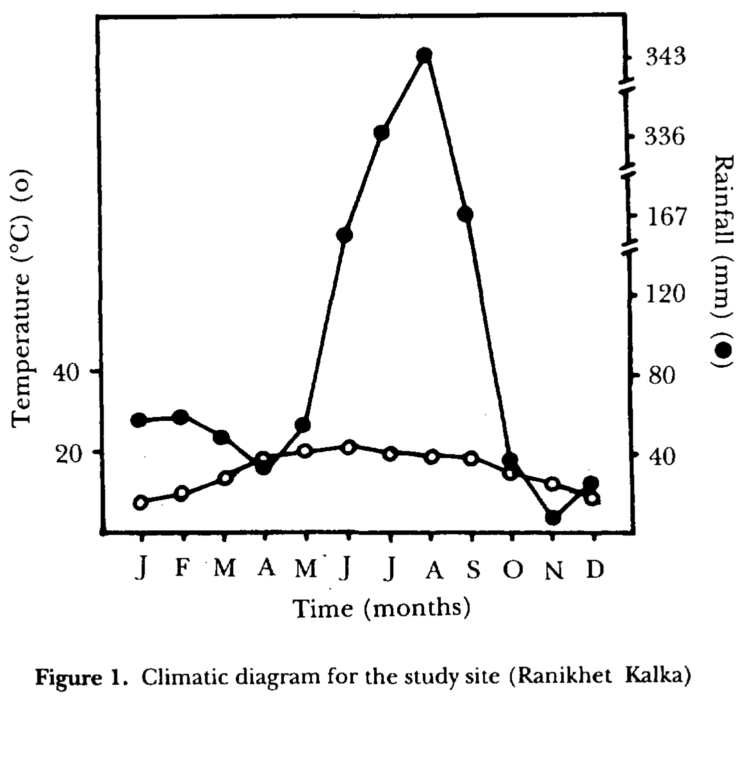

Figure 1. Climatic diagram for the study site (Ranikhet Kalka)

The soil is residual, shallow and sandy. Water holding capacity ranged from 53.2 to 58.1% and pH is acidic (6.0 - 6.3). The land form of the study area was a hill slope. Rocks exposed at the sites were grey to greyish-green garnetiferous mica schist and granitic gneisses.

The original vegetation that was replaced by *Pinus patula* plantations was a mixed banj oak forest. The common species were *Quercus leucotrichophora, Rhododendron arboreum, Aesculus indica, Pyrus pashia, Myrica esculentia,* etc. The natural vegetation was destroyed by the local people and the State Forest Department has put these areas under plantation.

Three plantations of *Pinus patula* of ages 15, 18 and 21 years were chosen as the study sites. They were near to each other and had similar conditions at initial establishment.

Methods

All the three plantations had 2500 trees ha^{-1} which had been planted at 2 × 2 m spacing from one-year-old seedlings grown in the nursery. Shrub and herb vegetations were sampled in ten 2 × 2 m and 1 × 1 m random quadrats respectively. Trees in a randomly selected sample plot of 0.25 ha were measured for dbh. The tree diameter size ranged between 10 and 30 cm. The four dbh classes designated to represent tree size in each plantation were 10-15, 15.1-20, 20.1-25 and 25.1-30 cm. Three individuals from each dbh class were harvested from each plantation. Each tree was felled into the space between adjoining individuals. The roots were then dug out up to 1 m depth and 1 m radius from the base of each tree. The above-ground parts were separated into bole, branches, twigs (third and higher order branches), foliage and cones. The root system was categorised into stump, lateral and fine roots. The fine roots (5 mm diameter) were estimated by digging out three 25 × 25 cm monoliths before exposing the stump and lateral roots. The fresh weights of all components were determined in the field. Pre-weighed composite samples from upper, middle and lower strata (about 500 g fresh weight) of each tree component were brought to the laboratory and dried to constant weight at 60 °C. Multiplication by appropriate factors yielded the weights of the different components. Regression analyses were made to relate the dry weight of each component to mean diameter at breast height.

Three individuals of average size for each shrub species were harvested and then roots were recovered up to 50 cm depth. The harvested shrub material was separated into foliage, stems and roots. The biomass of the herb layer was determined when it was at its peak during September-October. The harvested material was separated into above-ground and below-ground components, Fresh and dry weights were determined for each shrub and herb component.

The estimate of mean biomass (by component) for each diameter class was multiplied by the density of trees in that diameter class and stand biomass was calculated by summing up the biomass values across diameter classes. Average biomass of each shrub species was multiplied by its respective density (individuals

ha^{-1}) in the stand. The sum of biomass of trees, shrubs and herbs yielded the total standing biomass of the vegetation on the site.

Data for forest floor material were collected from six 50 × 50 cm randomly placed quadrats once in each season, i.e. rainy, winter and summer. All the live and dead herbaceous shoots in each quadrat were first harvested at ground level. The materials left on the forest floor were then collected carefully, avoiding contamination with soil as much as possible and categorised into: (A) fresh leaf litter, (B) partially decomposed litter, (C) wood (including cones), and (D) miscellaneous litter (consisting of material other than the above). The collected materials were brought to the laboratory, separated by category and oven-dried weights were determined.

The litter input was measured by placing six litter traps randomly on the forest floor in each plantation. Each trap was 50 × 50 cm with 15 cm high wooden sides. The litter was collected at monthly intervals during the study period and separated into needles and woody parts. The samples were weighed after oven drying at 60 °C to constant weight.

Twenty-four individuals in each plantation and in different diameter classes were marked in September 1989 and remeasured for increase in diameter in September 1990. Using the allometric equations, the biomass of different components of trees were calculated using the dbh measurements for 1989 (B_1) and 1990 (B_2). The net change in biomass ($\Delta B = B_2 - B_1$) yielded the current annual increment in biomass accumulation. The sum of the ΔB values for different components yielded net biomass accretion in the trees. Annual leaf fall was added to the foliage biomass accumulation to represent annual leaf production. Wood and bark litter values were added to the biomass accumulation in twigs. The death of main roots is rare in actively growing trees but considerable mortality occurs in fine roots and was considered as 1/5 of leaf litterfall.

The current annual increment in the stem diameters of ten average-sized individuals of shrubs was recorded in September 1990. Increase in biomass of these shrub species was calculated using the regression equations and this was added to the foliage biomass (assuming 100% turnover of leaves in 1 year) to obtain net annual production. The average production of a species when multiplied by its density yielded the total production of that species. Summing up net production values of all species, the total shrub production for a site was obtained.

The biomass (above-ground and below-ground) of herbs on all sites was determined during their peak growth in September 1989. This value was assumed equal to net herb production. The sum of net production values of trees, shrub and herb layers yielded the total net primary production of the plantation site.

The turnover rate (K) of the litter was calculated following Jenny *et al.* (1949) and Olson (1963) as $K = A/A + F$, where A = annual increment in litter (= annual litterfall) and F = biomass of litter at steady state. Turnover time (t, years) is the reciprocal of turnover rate (k, y^{-1}) and is expressed as $t = 1/k$. In the present study F value was the standing crop of partially + more decomposed litter.

Results and discussion

Biomass

The regression parameters for allometric equations developed in the present study are given in Table 1. The biomass of each component and of the total tree was significantly related to the respective dbh.

Table 1. Relationships between the biomass of tree components (Y, kg dry weight $tree^{-1}$) and diameter at breast height (x, m). The equation used was Y=a+bx, n = 12.

Component		Plantation age (y) 15	18	21
Bole	a	- 4.733	0.544	0.010
	b	1.192	1.195	1.126
	r^2	0.998	0.998	0.998
Branch	a	0.019	0.172	- 0.099
	b	0.286	0.278	0.289
	r^2	0.996	0.998	0.998
Twig	a	- 0.078	0.761	- 0.008
	b	0.238	0.198	0.233
	r^2	0.998	0.784	0.998
Foliage	a	- 1.120	0.365	0.063
	b	0.295	0.215	0.214
	r^2	0.982	0.950	0.996
Cone	a	0.023	- 0.104	- 0.108
	b	0.141	0.152	0.153
	r^2	0.998	0.996	0.998
Stump root	a	- 0.053	0.005	- 0.845
	b	0.227	0.225	0.258
	r^2	0.996	0.994	0.990
Lateral root	a	- 0.225	0.048	- 0.035
	b	0.122	0.110	0.114
	r^2	0.982	0.950	0.998
Fine root	a	- 0.201	- 0.211	- 0.031
	b	0.096	0.093	0.112
	r^2	0.982	0.925	0.925

All equations are significant at $p < 0.01$.

The total tree biomass was increased from about 107 t ha^{-1} in the 15-y-old to 126 t ha^{-1} in the 18-y-old and 149 t ha^{-1} in the 21-y-old plantations (Table 2). Bole contributed 41 to 48% to the total biomass, branches 11.3 to 12.7%, twigs 9 to 10.4%, foliage 8.5 to 10.4%, cones 5.8 to 6.0%, and roots 16.4 to 19.5%.

Table 2. Biomass of different components (t ha^{-1} ± s.e.) in different aged plantations of *Pinus patula*

Component	Plantation age (y)		
	15	18	21
Tree			
Bole	44.80 ± 3.6	60.54 ± 6.2	71.34 ± 6.9
Branch	13.63 ± 1.2	14.20 ± 1.6	16.70 ± 1.6
Twig	11.11 ± 0.6	11.71 ± 1.0	13.65 ± 0.9
Foliage	11.20 ± 0.7	11.56 ± 1.2	12.71 ± 1.6
Cone	6.47 ± 0.6	7.27 ± 0.8	8.79 ± 1.6
Stump root	10.65 ± 2.7	11.16 ± 2.2	13.12 ± 2.3
Lateral root	5.23 ± 0.8	5.57 ± 0.7	6.60 ± 0.9
Fine root	4.02 ± 0.9	4.08 ± 0.8	6.49 ± 1.0
Total	107.11 ± 10.4	126.09 ± 11.6	149.40 ± 12.9
Shrub			
Stem	0.10 ± 0.008	0.12 ± 0.009	0.16 ± 0.008
Foliage	0.03 ± 0.002	0.03 ± 0.002	0.06 ± 0.004
Root	0.02 ± 0.002	0.02 ± 0.002	0.03 ± 0.002
Total	0.15 ± 0.009	0.17 ± 0.012	0.25 ± 0.017
Herb			
Above-ground	1.36 ± 0.2	1.32 ± 0.2	1.37 ± 0.3
Below-ground	0.30 ± 0.03	0.28 ± 0.03	0.28 ± 0.04
Total	1.66 ± 0.21	1.60 ± 0.16	1.65 ± 0.20
Total vegetation	108.92	127.86	151.30

Analysis of variance showed significant ($p < 0.01$) variation in total tree biomass and its components among the different aged plantations. Hence, the boles accounted for the greatest proportion of the total biomass. The proportion of foliage (10.3-12.8%) to the above-ground biomass was greater than those (4.5-9.3%) reported for some coniferous forests (Chaturvedi & Singh 1987). Bargali *et al* (1992) suggested that the proportion of foliage biomass decreases with the increase in plantation age.

The root biomass (19.9-26.2 t ha^{-1}) was lower than that in *Pinus radiata* forest (33 t ha^{-1}, Will 1966) oak pine forest (36 t ha^{-1}, Whittaker & Woodwell 1969) and chir pine forest (34 - 38 t ha^{-1}, Rana *et al.* 1988a).

The shrubs and herbs contributed 0.13-0.17% and 1.1-1.5% to the total vegetation respectively.

Forest floor biomass

The seasonal mean total forest floor biomass (including herbaceous litter) increased from 6.9 t ha^{-1} in the 15-y-old to 8.9 t ha^{-1} in the 24-y-old plantation (Table 3). The accumulated forest floor biomass in the present study was markedly lower than those reported for temperate pine stands (e.g. 167.7 t ha^{-1}, Jenny *et al.* 1949; 20-24 t ha^{-1}, Hutnik 1964; 12.7-110 t ha^{-1}, Ovington 1965). The present value lies in the range reported for other Himalayan subtropical and tropical forests (Singh &

Singh 1987). This is due to the fact that these plantations are situated in a montane subtropical belt where temperatures are never too low to inhibit faunal and microbial activity (Upadhyay & Singh 1985a), but not as high as in the tropics. The system represents an intermediate situation between temperate and tropical conditions (Pandey & Singh 1981a, b).

The turnover rate was 52-54% and turnover time 1.85-1.92 y (Table 4). Upadhyay and Singh (1985 b), on the basis of litter bag studies, found that the annual weight loss of *Pinus roxburghii* needles was 51%. Chaturvedi and Singh (1987) have reported 48% annual replacement of *P. roxburghii* needles.

Table 3. Forest floor biomass (t ha^{-1}, averaged across season). (Values in parentheses are percentages of the total).

Forest floor category	Age of plantation (y)		
	15	18	21
Fresh leaf litter	1.7(24.6)	2.0(25.6)	2.3(26.1)
Partially + more decomposed litter	2.3(33.3)	2.6(33.3)	3.0(32.9)
Wood litter	0.7(10.1)	0.8(10.2)	1.0(11.4)
Miscellaneous litter	1.1(15.9)	1.3(16.7)	1.3(14.8)
Herbaceous live	1.0(14.5)	1.0(12.8)	1.1(12.5)
Herbaceous dead	0.1(1.4)	0.1(1.3)	0.2(2.3)
Total	6.9	7.8	8.9

Table 4. Turnover rate (k, y^{-1}) and turnover time (t, y) for litter

	Age of plantation (y)		
	15	18	21
Turnover rate (k)	0.54	0.52	0.52
Turnover time (t)	1.85	1.92	1.92

Litterfall

The total annual litterfall ranged from 2.01 to 3.00 t ha^{-1} in the 15- and the 21-y-old plantations respectively (Table 5). Needles accounted for 49 - 57% and woody litter 43 - 51%. These values are similar to those reported for natural chir pine (*Pinus roxburghii*) forests of Central Himalaya (Chaturvedi & Singh 1987, Rana *et al.* 1988a)

Table 5. Annual litterfall (t ha^{-1}) on different aged plantations

Age of plantation (y)	Needle	Woody	Total
15	0.99 ± 0.091	1.02 ± 0.089	2.01
18	1.29 ± 0.098	1.19 ± 0.096	2.48
21	1.70 ± 0.108	1.30 ± 0.109	3.00

Table 6. Net primary productivity (NPP) of different components (t ha^{-1} y^{-1}) in different aged plantations of *Pinus patula*. (Values in parentheses are the percentage contributions).

Component	Plantation age (y)		
	15	18	21
Tree			
Bole	3.58(34.3)	4.21(38.1)	4.53(38.4)
Branch	0.86(8.2)	0.67(6.1)	0.40(3.4)
Twig	1.48(14.2)	1.48(13.4)	1.67(14.1)
Foliage	1.90(18.2)	2.04(18.5)	2.49(21.1)
Cone	1.02(9.8)	0.91(8.2)	0.57(4.8)
Stump root	0.68(6.5)	0.78(7.0)	0.96(8.1)
Lateral root	0.37(3.6)	0.38(3.4)	0.42(3.6)
Pine root	0.53(5.1)	0.58(5.2)	0.76(6.4)
Total	10.42	11.05	11.80
Shrub			
Stem	0.4(66.7)	0.05(71.4)	0.04(50.0)
Foliage	0.01(16.6)	0.01(14.3)	0.02(25.0)
Root	0.01(16.6)	0.01(14.3)	0.02(25.0)
Total	0.06	0.07	0.08
Herb			
Above-ground	1.36(81.9)	1.32(82.5)	1.37(83.0)
Below-ground	0.30(18.1)	0.28(17.5)	0.28(17.0)
Total	1.66	1.60	1.65
Total vegetation	12.14	12.72	13.53

Net primary productivity (NPP)

The reliability estimates of production for a site depends mainly on the accuracy in the determinations of the annual biomass increment of trees. By using the same vernier calliper at exactly the same locations on the tree, systematic errors in successive measurements of dbh of marked trees were reduced in the present work.

The total net primary production of the components and of total vegetation increased with age, ranging from 12.14 t ha^{-1} y^{1} in the 15-y-old plantation to 13.53 t ha^{-1} y^{1} in the 21-y-old plantation (Table 6). Our values of total net production fall nearer to the range of 18.5 - 24.5 t ha^{-1} y^{1} for Central Himalayan chir pine forests (Singh & Singh 1987). Whittaker and Woodwell (1971) have also reported net production value of 13 t ha^{-1} y^{1} for temperate forests.

Shrub net production in the present study accounted for 0.5 - 0.6% of the total forest net production. Rana *et al.* (1988 a,b) have reported 1.06% for chir pine and 6.2% for chir pine-mixed broadleaf forest of Central Himalaya. Above-ground herbaceous net production falls in the range of values (1.4 - 2.2 t ha^{-1} y^{1}) reported by Chaturvedi and Singh (1987) for chir pine forest. Considerably greater values (1.7- 2.0 t ha^{-1} y^{-1}) were found for oak forests of this region (Rawat & Singh 1988).

In the present study the net production was 8.9 - 11.1% of the total biomass, similar to that of chir pine (10.1%) reported by Rana *et al.* (1988 a) and higher than that of chir pine-mixed broad leaf forests (6.7%) of this region (Rana *et al.* 1988 b).

Biomass accumulation ratio

Biomass accumulation ratio (biomass/net production) has been used to characterise the production conditions in forest communities. It expresses the quantity of biomass retained per unit of net production. The ratio is largely governed by stand age. In natural forests the differences in biomass accumulation ratio are mainly due to varied conditions of the size and rate of wood increment, as affected by environmental conditions and the age of trees. The ratios for tree layer (10.3, 11.4 and 12.7) are lower than those reported for uneven-aged natural chir pine (12.1, Rana *et al.* 1988 b). The present values are also lower than those in the range of 20 - 50 reported by Whittaker (1966) for intermediate and mature forests.

Conclusion

The net primary production values of the 15- to 21-y-old *P. patula* plantations do not exceed those of uneven-aged natural forests of *Pinus roxburghii* (18.5 - 24.5 t ha^{-1} y^{1}) and oak (16 - 21 t ha^{-1} y^{1}) of the region as the study areas were very close to these natural forests. Better quality of soil and wood, greater protective attributes and richer wildlife seem to be the additional advantages of natural oak forests. However, the soil conditions of these pine plantations are similar to those of the natural chir pine forests of the surrounding. In comparison, the NPP values of other exotic plantations in the plain area of the region (Tarai belt with average 280 m elevation), i.e. 8-y-old *Eucalyptus tereticornis* (23.4 t ha^{-1} y^{1}) and 8-y-old *Populus deltoides* (25 t ha^{-1} y^{1}), are higher than that of *P. patula*. Thus, though approaching the NPP level reported for other different communities elsewhere (see Lieth & Whittaker 1975), the *P. patula* plantations in the region studied are not especially highly productive.

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