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Fine Root Productivity of two Central Himalayan Forest Ecosystems

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Fine Root Productivity was studied in Oak and Chir Pine evergreen forests of Central Himalaya. The experiment was carried out in permanent plots in both the forest sites. The sampling was done at monthly intervals by digging 5 monoliths up to 30 cm soil depth to record root standing crop. The pits were filled by the same soil after extracting the fine roots and new root ingrowths were collected from pits at bi-monthly intervals to assess fine root productivity. The total root standing crop was 11320 Kg/ha and 12030 Kg/ha respectively in Chir pine and Oak forest sites. Annual Fine Root production was greater in Chir pine forests (1390 Kg/ha) than Oak forests (1091 Kg/ha). Lower biomass accumulation ratio and rapid mycorrhizal association in Chir pine favoured greater fine root productivity.

Key words: *Fine root, Root biomass, Central Himalaya, Oak forests, Pine forests, Fine root productivity.*

Introduction

Fine roots play significant role in the development of soil profile and substantial contribution tothe organic pool of the soil. Fine root biomass studies are important for understanding energy flow and nutrient cycling (Singh, 1983). Studies on root production have been partly hindered by the lack of simple and feasible techniques (Hamzah *et al.*, 1983). Fine root production is basically regulated by nutrient availability in the forest litter (Cuevas and Medina, 1988; Aerts *et al.*, 1992; Visalakshi, 1992). There are also reports that fine root productivity may be enhanced by rise in atmospheric CO_2 level (Curtis *et al.*, 1994), however root productivity is one of the most difficult parameters to measure. Preliminary studies indicate that greater fine root production also favourably affects mycorhizal biomass in the Central Himalayan Oaks (Rana *et al.*, 2000). This study is an attempt to meet the twin-object of assessing seasonal dynamics and production of fine roots by employing the in-growth technique in Oak (*Quercus floribunda*) and Chir pine (*Pinus roxburghii* Sarg.) forests of adjoining old land slide sites of Nainital town in Central Himalayan region.

Material and Methods

The study was conducted in two Central Himalayan evergreen forests (Oak and Chir pine forests) located, 10 km South west of Nainital town (29° 74′ N lat and 79° 29′ E long) at 1980 m and 1600 m elevations, respectively. The climate of the entire area is subtropical monsoonic, governed by south-west monsoon.

Sampling of Fine Roots

Fine root sampling was carried in three 0.25 ha permanent plots in each of the two forests from January 1991 to December 1991, regularly at monthly interval. Collections were facilitated by digging five monoliths (25 x 25 x 30 cm) up to 30 cm soil depth. The soil monoliths were transported to laboratory for extraction of the fine roots.

Sampling of New Ingrowths

For studies on root productivity, five soil monoliths (25 x 25 x 30 cm size) were removed from permanent plot in both forest sites. The fine roots were extracted from the soil and the root free soil was refilled into the pits in a way to maintain similar compactness (Kummerow *et al.*, 1990). It was assumed that new root ingrowths in the soil blocks represented root production. The ingrowths were consistently monitored at bimonthly intervals. Ingrowth pits were marked with bamboo sticks tied with plastic leaf at top at all the four corners of the soil block.

Root Mass Estimation

Fine roots were extracted from soil monoliths at different soil depths (i.e. 0-10, 10-20 and 20-30 cm) by hand sorting. The adhering soil particles were removed by washing in a fine jet of water. The live and dead fractions were hand separated depending on their degree of cohesion between cortex and periderm, colour and resilience. Live and dead roots were oven dried at 80°C to constant weight and the biomass and necromass were determined up to 4 decimal accuracy by digital balance. Roots recovered from in-growth cores were also processed similarly and oven-dried to constant weight.

Results and Discussion

Seasonality in Fine Root Standing Crop

Total root mass (TRM) : Seasonal changes in the fine root standing crop from January 1991 to December 1991 in Oak and Chir pine old land slide sites are presented in Table-1. In Chir pine site, the TRM cross 12 months ranged from 409 (January) to 1132 gm^{-2} (July). Initial estimates of TRM slightly increased during February and March and dropped in June. Thereafter, there was rapid rise peaking in August followed by a gradual decline during winter months.

In Oak site, the total root biomass ranged between 518 (May) and 1203 gm^{-2} (August). A considerable seasonal fluctuation occurred in TRM during 12 study periods. From January, the TRM gradually increased till March and indicated marked decline during summer. With the onset of rainy season, the TRM showed a spectacular rise till August (Peak TRM), and thereafter dropped during winter months.

Biomass and Necromass Fraction of Fine Roots

The live fine root biomass component (FRB) in Chir pine (up to 30 cm) ranged between 78 and 772 gm^{-2} during 12 study periods. Biomass fraction was highest in July and lowest in May (Table-1). FRB rapidly declined during April and May and thereafter increased till July. In Oak, FRB ranged between 386 and 848 gm^{-2} over annual cycle. Biomass fraction peaked in July and lowest fraction was recorded in May (See Table-1). Similar to Chir pine the trend with regard to increase and decline in FRB was also evident.

In Chir pine, the necromass (dead fraction of fine roots) ranged between 162 and 550 gm^{-2} (Table-1). Necromass was recorded highest in August and lowest in October. In Oak, necromass fluctuated from 105 (June) to 717 gm^{-2} (August). There was a sudden decrease during May and June. Thereafter, it increased till August and followed by a gradual decline during winter.

Fine Root Production

Fine root production levels (upto 30 cm soil) of Chir pine and Oak sites are presented in Table-2. The bi-monthly root production across both sites was between 3.2 (April) and 50 gm^{-2} (August). During the study period, root production sharply dropped from February to April and then increased gradually from June peaking in August. After August, the production declined up to December. The necromass fraction of newly produced roots was negligible and ranged from 0 to 0.95 gm^{-2}. The above trend was observed at both sites. The estimated bi-monthly fine root production ranged from 5 to 25 gm^{-2} and 3 to 44.9 gm^{-2} in Chir pine and Oak forests, respectively. The highest production was recorded in August and lowest in April in both the forests. The collection period of February, April and December recorded lower production.

The root standing crop (TRB) was 11320 kg ha^{-1} in Chir pine old landslide site and 12030 kg ha^{-1} in Oak site. These estimates lie within the reported range of values (9600-16100 kg ha^{-1}; Jenik 1969, and Klinge 1973) for various tropical forests. Higher fine root mass in present study is probably due to the greater moisture availability and optimum temperature for growth during rainy periods (June-October). During summer and winter months, root mass was recorded lowest in both the forests due to low soil moisture

Table-1
Standing crop of fine root biomass (gm^{-1}) in Chir pine and Oak forest

Month	Soil Depth (cms)	Chir pine Forest		Oak Forest	
		FRB	FRN	FRB	FRN
January	0-10	20.0	16.0	92.1	74.0
	10-20	22.0	85.0	145.0	74.2
	20-30	74.0	192.0	282.0	112.8
	Total	**116.0**	**293.0**	**519.1**	**261.0**
February	0-10	32.0	45.0	129.0	94.0
	10-20	26.0	125.0	212.0	102.0
	20-30	82.0	201.0	204.0	132.0
	Total	**140.0**	**371.0**	**545.0**	**328.0**
March	0-10	43.0	123.0	214.0	101.0
	10-20	51.0	142.0	194.0	123.0
	20-30	60.0	200.0	245.0	132.0
	Total	**154.0**	**464.0**	**653.0**	**356.0**
April	0-10	32.0	120.0	94.0	94.2
	10-20	26.0	139.0	184.0	67.7
	20-30	43.0	95.0	240.0	62.0
	Total	**101.0**	**354.0**	**510.0**	**223.9**
May	0-10	29.0	125.0	82.0	51.0
	10-20	19.0	132.0	110.0	42.0
	20-30	30.0	110.0	194.0	39.0
	Total	**70.0**	**367.0**	**386.0**	**132.0**
June	0-10	80.0	130.0	122.0	42.9
	10-20	125.0	140.0	154.0	30.0
	20-30	30.0	80.0	200.0	32.0
	Total	**235.0**	**350.0**	**476.0**	**104.9**
July	0-10	240.	145.0	242.0	225.0
	10-20	289.0	156.0	221.0	194.0
	20-30	243.0	59.0	185.0	120.0
	Total	**772.0**	**360.0**	**648.0**	**539.0**
August	0-10	155.0	140.0	152.0	212.0
	10-20	161.0	200.0	130.0	245.0
	20-30	159.0	210.0	204.0	260.0
	Total	**474.0**	**550.0**	**486.0**	**717.0**
September	0-10	50.0	210.0	121.0	145.0
	10-20	84.0	140.0	245.0	132.0
	20-30	80.0	190.0	202.0	201.0
	Total	**214.0**	**540.0**	**568.0**	**478.0**

Table-1 (Contd.)

Month	Soil Depth (cms)	Chir pine Forest		Oak Forest	
		FRB	FRN	FRB	FRN
October	0-10	45.0	19.0	104.0	120.0
	10-20	93.0	57.0	200.0	125.0
	20-30	85.0	91.0	292.0	178.0
	Total	**223.0**	**162.0**	**596.0**	**423.0**
November	0-10	28.0	16.0	100.0	88.0
	10-20	145.0	89.0	187.0	88.8
	20-30	395.0	144.0	241.0	138.9
	Total	**568.0**	**249.0**	**528.0**	**315.7**
December	0-10	30.0	17.0	105.0	82.0
	10-20	12.1	120.0	142.0	94.0
	20-30	80.0	329.0	292.0	145.6
	Total	**122.1**	**466.0**	**539.0**	**321.6**

FRB = Fine Root Biomass
FRN = Fine Root Necromass
TRM = Total Root Mass

coupled with extremes of higher and lower temperatures.

The total annual fine root production was 1091 (Oak) and 1390 kg ha^{-1} (Chir pine). Out estimates are comparable with the range of values (1170-2010 kg ha^{-1} yr^{-1}) reported for tropical forests by certain workers (Cuevas and Medina, 1988).

Fine root production varies with site quality and species composition (Fogel, 1983; Aerts *et al.*, 1992). The greater fine root biomass in Oak site compared to Chir pine may be attributed to a relatively low temperature, high soil moisture content and greater basal area. In addition, the higher elevation (1890 m) would also account for higher soil humidity which may favour the root growth in Oak forests. Moderate microclimate under closed canopy of Oak species is favourable for maximum fine root biomass and mycorrhizal development (Rana *et al.*, 2000). Genetic differences between Oak and Chir pine and their adaptability to different environmental conditions may probably govern the root productivity. Despite lower fine root standing crop, the greater fine root production in Chir pine forest during rainy season than that of Oak forest was recorded. Earlier ecological reports on Chir pine and Oak forests (Singh and Singh, 1987; Rana *et al.*, 1989) revealed that Chir pine indicates lower biomass accumulation ratio leading thereby to increased productivity. The frequent firewood collection, apart from grazing and browsing by cattle in oak forests also affects the fine root production. Yin (1989) stated that forest removal

Table-2
Fine root productivity of the investigated forests by in growth core method ($g/m^2/yr$)

Forest	Month						
	February	April	June	August	October	December	Total
Chir pine	6.8	5.0	24.0	50.0	42.2	11.0	139.0
Oak	8.0	3.2	14.7	44.9	25.3	13.0	109.1

would significantly influence fine root biomass production and mortality. Hence, both vegetation and physical environment are responsible for the control of fine root biomass (Persson, 1985). Furthermore, adequate soil moisture in rainy season favours rapid mycorrhizal association in Chir pine roots and also promotes adding new growth leading to increase in fine root production. However, detailed study on the forests of this region is required on the functional aspect of root ecology as fine roots contribute significantly to the net primary productivity and play important role in nutrient dynamics of the forest ecosystem.

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