# PRODUCTION AND DECOMPOSITION OF FINE ROOTS IN CENTRAL HIMALAYAN FOREST SPECIES

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**USMAN, S. 2002. Production and decomposition of fine roots in central Himalayan forest species.** The present paper investigates the decomposition and production rate of fine roots in broad-leaved and needle-leaved forests of central Himalayas. Fine root growth was measured using the ingrowth core method and decomposition of three root litter classes for both tree species was estimated using the litterbag technique. Fine root production decreased with increase in soil depth and it was inversely proportional to soil bulk density. The maximum fine root production occurred during the rainy season followed by summer and winter. The rate of fine root decomposition was maximum in the rainy reason and decreased with increased root diameter. The percentage contribution of live root across the months varied from 58 to 75%. During the sampling period, dead root biomass peaked in August and declined abruptly during winter while live root biomass peaked in September and October.

Key words: *Quercus leucotrichophora* - *Pinus roxburghii* - fine root production - decomposition - live root - dead root

**USMAN, S. 2002. Pengeluaran dan pereputan akar halus spesies hutan di tengah Himalaya.** Artikel ini menyelidik tentang kadar pereputan dan pengeluaran akar halus di hutan daun lebar dan hutan daun jejarum di tengah Himalaya. Pertumbuhan akar halus disukat menggunakan kaedah penokokan kor. Pereputan tiga kelas sarap akar bagi kedua-dua spesies pokok dianggar menggunakan teknik beg sarap. Pengeluaran akar halus berkurangan dengan bertambahnya kedalaman tanah dan berkadar songsang dengan kepadatan pukal tanah. Pengeluaran maksimum akar tanah berlaku pada musim hujan diikuti musim panas dan sejuk. Kadar pereputan akar halus adalah maksimum pada musim hujan dan berkurangan dengan bertambahnya diameter akar. Peratusan akar hidup di sepanjang tahun berubah-ubah daripada 58 hingga 75%. Dalam tempoh pensampelan, biojisim akar mati memuncak pada bulan Ogos dan menurun dengan mendadak pada musim sejuk manakala biojisim akar hidup memuncak pada bulan September dan Oktober.

## Introduction

A central issue in ecosystem structure and functioning is the dynamics of the organic matter component, namely, energy flow and nutrient cycling (Bourliere & Hadley 1970). Pomeroy (1970) argued that the flux of materials is essential for the continuity and stability of living system. Fine root production is an important component of both dry matter and nutrient cycling in forest ecosystem (Singh & Singh 1981, McClaugherty *et al.* 1985, Vogt *et al.*, 1986 ). The greatest proportion of the root system of many forests is located in the upper soil horizon (Vogt *et al.* 1983, Coleman *et al.* 1988). The roots near the soil surface undergo more rapid changes than the deep roots (Hendrick & Pregitzer 1992).

Decomposition processes, where essential mineral elements in plant biomass are made available for further plant growth, are important parts of the nutrient cycle. Litter and humus contain organic materials capable of binding nutrients. Consequently the rate of nutrient release is generally governed by the decomposition rate of litter and humus. The decomposition of plant litter is one of the most crucial processes in the biochemical cycle of forest ecosystem (De Cantanzaro & Kimmins 1985). It is regulated by soil organisms, environmental conditions and the chemical nature of the litter. In many studies litter N content or C:N ratio has been shown to be of critical importance in the process of decay (e.g. Witkamp 1966, Berg & Staff 1980). Extensive information on decomposition from above-ground litter and on factors controlling these processes in different forest ecosystems of the world has been compiled by Singh and Gupta (1977), Upadhyay and Singh (1985) and Bargali (1996). However, studies on fine root (< 2 mm), which contribute 20 to 80% of the total annual carbon stock in soil, are limited (McClaugherty *et al.* 1982). This study was designed to compare fine root production and decomposition pattern (having different root diameter classes) of two dominant tree species, viz. *Quercus leucotrichophora* and *Pinus roxburghii.*

## Materials and methods

The present study was carried out in the central Himalayan predominant evergreen forests of *Q. leucotrichophora* and *P. roxburghii* in Kumaon Himalaya. At lower elevations the slopes are covered with the subtropical *P. roxburghii* while at higher elevations one or two species of *Quercus* dominates with conifer.

The study site of *Q. leucotrichophora* is located at Kailakhan (Nainital), 2 km away from Nainital (29° 24' N, 79° 28' E) at 2150 m elevation and for *P. roxburghii* it was approximately 5 km from Nainital (29° 27' N, 79° 23' E, 1600 m elevation).

Total above-ground and below-ground vegetation are greater in oak forest than in chir pine forest (Usman 1993). Both forests have similar tree density but the total basal area of banj oak (*Q. leucotrichophora*) forest is greater than that of chir pine forest because of larger (greater diameter) trees in oak.

The rocks present in the *Q. leucotrichophora* forest are commonly black carbonaceous and pyritous locally oxidised to ash grey colour with characteristic oxidation rings on parting planes. In the pine forest quartzite consists of variegated purple brown, fawn grey and white quartarnite and sublitarcenite interbedded with purple ferrugious and less commonly olive green shales.

The soil was sandy clay in texture and acidic in nature. The pH ranged from 5.8 to 6.8 and the water holding capacity (WHC) varied from 30 to 51%. The organic carbon and total nitrogen contents in the soil were 2.5 to 3.0% and 0.21 to 0.26% respectively (Table 1).

**Table 1** Comparative account of physico-chemical properties of soil in banj oak and chir pine forests

| Parameters | Banj oak forest | Chir pine forest |
|---|---|---|
| Bulk density (g $cm^{-3}$) | 0.89 | 0.98 |
| Texture (%) | | |
| Sand | 56.1 | 61.9 |
| Silt | 25.0 | 20.4 |
| Clay | 18.6 | 17.6 |
| pH | 6.4 | 5.8 |
| Total N (%) | 0.26 | 0.21 |
| Organic C (%) | 3.06 | 2.54 |
| C/N ratio | 11.77 | 12.10 |
| Available P (%) | 0.016 | 0.008 |
| Total K (%) | 0.10 | 0.06 |
| Water holding capacity (%) | 51.3 | 30.4 |
| Soil moisture (%) | 43.1 | 34.6 |

For determination of soil moisture content, 1000 g of soil was dried in an oven at 80 °C till constant weight. Then the dry weight of soil sample was measured and moisture percentage was determined on dry weight basis as:

$$\text{moisture content} = \frac{\text{fresh weight - dry weight}}{\text{dry weight}} \times 100$$

Fine roots are generally defined as non-woody small diameter roots and mycorrhizae. Upper values for fine roots diameter vary among published studies but generally range from < 1 to ≤ 5 mm. Definitions of fine roots vary among studies because fine root morphology and size vary among species and even within species and across sites. For fine root production, roots up to 1 mm diameter were taken from *Q. leucotrichophora* and *P. roxburghii* forest sites. The soil samples were collected along the transects in oak and pine forest ecosystems. Sampling was carried out up to 60-cm soil depth and samples were taken from 0–20, 20–40 and 40–60 cm soil depths with the help of soil cores. Soil cores have been accepted as a suitable mean of sampling of fine roots (Fogel 1985). The samples were removed using a long steel corer with an internal diameter of 8.5 cm, with sharp and hardened cutting edge. A total of 81 cores were sampled, i.e. 27 cores for each soil depth (0–20, 20–40 and 40–60 cm).

In the new ingrowth process the fine roots were extracted from the soil and the root free soil was then returned to their original position in the pits, trying to maintain as far as possible the original compactness. It was assumed that any ingrowth of new roots in the soil blocks represents fine root production (Usman *et al.* 1999).

Fine roots were excavated and collected from *Q. leucotrichophora* and *P. roxburghii* (dbh 31.8–51.8 cm) forests in December 1990. Fine roots were separated from the other organic matter by hand (all sample handling was done wearing gloves). Most of the dead fine roots were discarded but the separated roots invariably included some dead roots. The fine root samples were categorised into three different classes on the basis of their diameter, namely, small roots having diameter up to 1 mm, medium roots 1–2 mm diameter and large roots having 2–3 mm diameter. The litter bag technique was used to quantify the rate of decomposition following Upadhayay & Singh (1989) and Usman (1993). Nylon litter bags of 10 × 10 cm size containing 5 g air-dried root samples were placed on the forest floor at a depth of 10 cm at random locations for one year. A total of 360 litter bags were placed at both the forest sites, 60 each for small, medium and large roots. Five bags were collected from each forest site every month. Immediately after collection, the litter bags were placed in individual polythene bags and transported to the laboratory. The residual materials were carefully separated from the bags and were carefully cleaned and brushed free of adhering soil and other debris. The material was dried at 60 °C to constant weight.

## Results

### *Root decomposition*

The weight loss for the two litter species during decomposition is shown in Figure 1. Analysis of variance indicated significant differences in weight loss due to main effect of litter species and root diameter. In addition, two way interaction of site × diameter ($p < 0.01$), diameter × month ($p < 0.01$) and site × month ($p < 0.01$) was also significant.

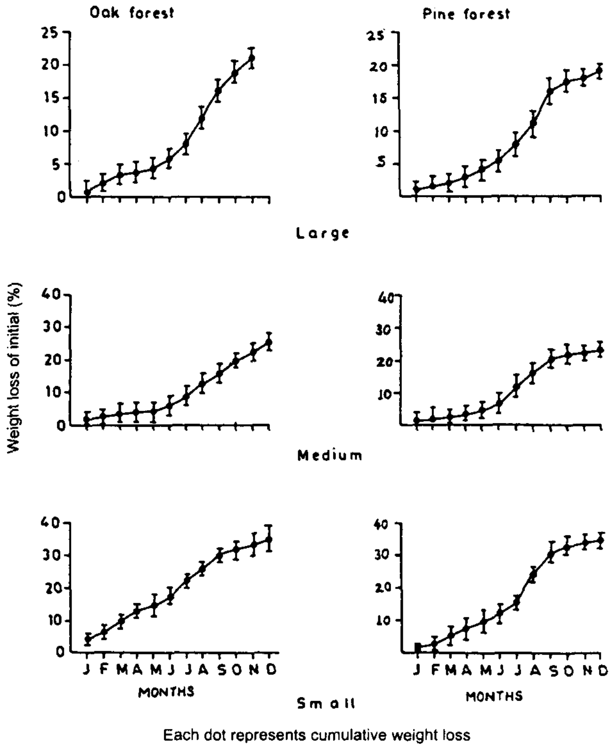


**Figure 1** Monthly per cent cumulative weight loss of small, medium and large root diameter classes at oak and pine forest sites

To assess the temporal pattern of weight loss the weight percentage remaining was regressed against the time elapsed. A negative relationship was observed between weight percentage remaining and time.

Banj oak forest:

$y = a + bx$

$y = 221 - 172\,x$ ($r^2 = -0.99$, $p < 0.01$) (small root)

$y = 237 - 206\,x$ ($r^2 = -0.99$, $p < 0.01$) (medium root)

$y = 222 - 204\,x$ ($r^2 = -0.99$, $p < 0.01$) (large root)

Chir pine forest

$y = a + bx$

$y = 196 - 149\,x$ ($r^2 = -99$, $p < 0.01$) (small roots)

$y = 193 - 177\,x$ ($r^2 = -98$, $p < 0.01$) (medium roots)

$y = 198 - 205\,x$ ($r^2 = -98$, $p < 0.01$) (large roots)

where

$x$ = days elapsed and

$y$ = weight percentage remaining.

The fine root litter of oak forest decomposed slightly faster than that of pine forest site. The rate of decomposition decreased significantly with increase in root size. A negative relationship was obtained according to the following equations.

Oak forest $y = 9.27 - 0.187\,x$ ($r = -0.89$, $p < 0.01$)

Pine forest $y = 6.25 - 0.124\,x$ ($r = -0.97$, $p < 0.01$)

where

$x$ = rate of decomposition (%) and

$y$ = root size (mm).

After one annual cycle at the *Q. leucotrichophora* forest site the rate of root decomposition was 35.0, 25.0 and 22.6%, and in the *P. roxburghii* forest site 35.0, 23.8 and 19.02%, for 0–1, 1–2, and 2–3 mm root diameter classes respectively. At both the forest sites the maximum weight loss occurred for 0–1 mm root diameter followed by 1–2 and 2–3 mm diameters (Figure 1).

### *Root production*

Marked seasonal variations in live fine root production and dead fine root production were observed in both forests. Fine root production represents a varying proportion of the total accumulated organic matter of the forest stands. At both forest sites, the ratio of live to dead root mass differed significantly between the months. The chir pine forest always showed proportionally more dead roots (32%) than banj oak forest (29%).

Annual live fine root production was 3629 kg ha$^{-1}$y$^{1}$ in banj oak forest and 2508 kg ha$^{-1}$y$^{1}$ in chir pine forest. Fine root necromass (dead root) production was 1527 kg ha$^{-1}$y$^{1}$ and 1197 kg ha$^{-1}$y$^{1}$ in banj oak and chir pine forests respectively (Figure 2). The bulk of the total below-ground fine root production (live + dead) was distributed in the 0–20 cm layer (63% in the oak forest and 53% in the pine forest). At both forest sites the upper 40 cm soil depth showed 91% of the total below-ground biomass.

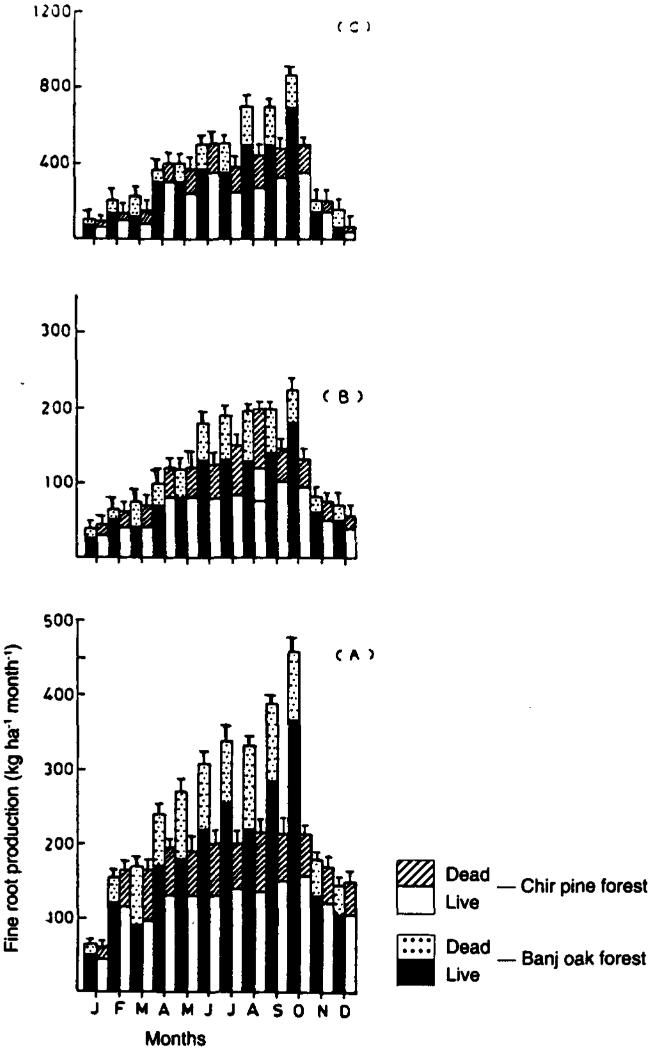


**Figure 2** Live and dead fine root production in an oak and pine forest at 0–20 (A), 20–40 (B) and 40–60 (C) cm soil depths

## Discussion

In our study, the root litter of the oak forest site decomposed slightly faster than the pine root litter. The rates of root decomposition (% per day) in the present study, 0.083% for oak and 0.071% for pine, are slower than corresponding above-ground tissues (0.253 % for oak leaves and 0.127 % for pine needles, Upadhyay *et al.* 1989).

Singh *et al.* (1990) showed that abundance of decomposing microbes depends partly on the native litter through its influence on the soil properties. They also stated that the annual cycle was minimum at the pine forest. In addition the resistant pine leaf litter showed lower populations of bacteria, actinomycetes and microarthropods (Upadhyay & Singh 1985) compared to oak leaf litter. The poor microflora at the pine site was due to the resistant nature of the surrounding leaf litter of native plant species which restricted the decomposition. In contrast oak forest litter was rich in microbes due to abundant plant species which promoted the decomposition, whereas, at the pine forest, monoculture stand with low biodiversity was less favourable for the microbes. The poor physico-chemical properties of the soil were also responsible for the slow decomposition rate in the chir pine forest. In the chir pine forest the pore space in the soil was less than that of oak forest site; this was reflected in the higher bulk density. Soil physical conditions may influence the tropic structure of the soil. Biological communities enhance the rate of decomposition and mineralisation (Bargali *et al.* 1993). Exponential regression analysis showed positive correlation between soil moisture and net weight loss per month (small, medium and large root diameter classes) (Figure 3). In pine forest all root diameter classes showed significant differences of weight loss with increasing soil moisture. However, in oak forest only small roots showed significant difference with soil moisture.

In general, most microbial activity occurred in the upper soil layers (0–20 cm soil depth) which were more nutritious and porous, whereas in lower depths soil compaction reduced the pore spaces available for microbial activity. Our data showed that in both forests about 80% of the root tips were in the upper 20 cm of soil. It thus appeared that the upper soil horizons permitted a higher concentration of fine root tips, which decreased with increasing depth as nutrient availability deceased. The nutrients that are released from the litter are not leached down to the soil profile but are transferred directly to the surface of the roots, which are growing intermingled with decaying matter (Went & Stark 1968). This might be one of the reasons for greater fine root production measured in the 0–20 cm soil layer in this study.

Root biomass was inversely proportional to the soil density. When bulk density increases, soil strength increases and aeration decreases leading to adverse effects on root growth (Nambiar and Sands 1992).

The fine root production in this study, 5.3 t $ha^{-1} y^{1}$ at the oak forest and 3.7 t $ha^{-1} y^{1}$ at the pine forest, lies within the range of 1.4 to 11.5 t $ha^{-1} y^{1}$ reported for various temperate forests (Keyes & Grier 1981, Adhikari 1992). Broad-leaved or oak forest is more productive in fine roots than coniferous forest (Satoo 1970, 1971).

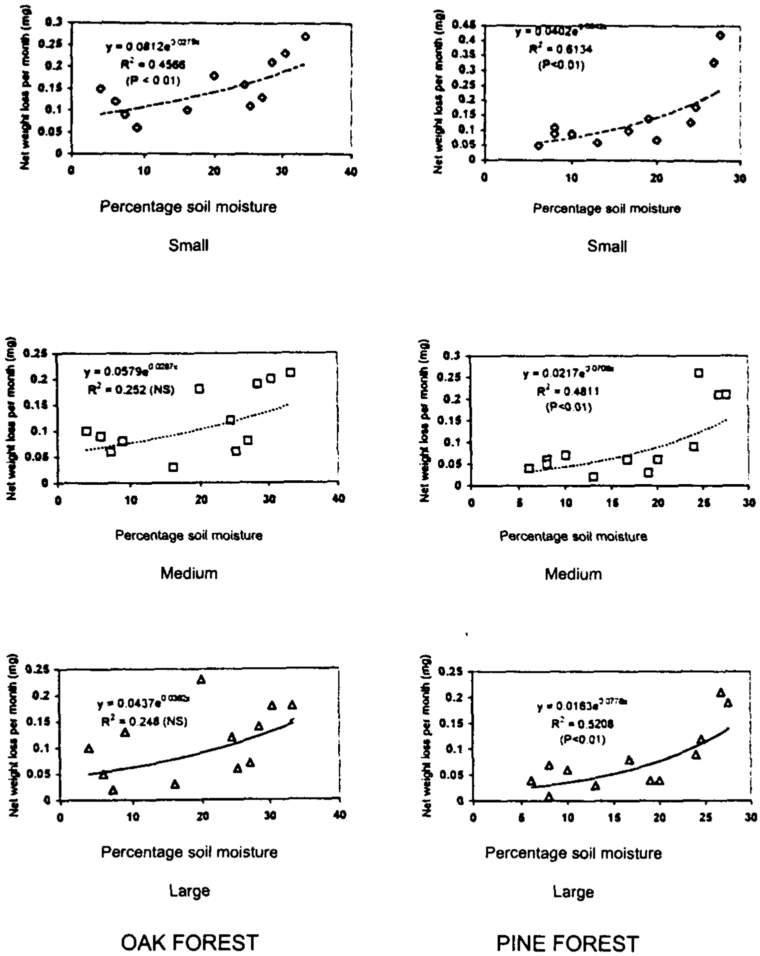


**Figure 3** A experimental regression between percentage soil moisture and net weight loss per month in small, medium and large root diameter classes at oak and pine forest sites

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