Mycorrhizal biomass in Central Himalayan oaks: Method and estimates

In Central and Western Himalayas, at elevation ranging from 1000 m to the timber line (appprox. 3600 m), oak species (*Quercus* spp.) form the climax vegetation[1,2]. In Central Himalaya (along Garwal and Kumaun, a tract contiguous with Nepal), about 4297 km^2 of land is covered with oak forests[3]. These broadleaf forests are considered to provide the most effective water and soil conservation[4]. Certain studies have documented the role of mycorrhizae in plant nutrition, successful afforestation and reclamation programmes for improvement of environment and optimizing production[5–9]. There are some reports on biomass of Central Himalayan oak[10–12]; however, lack of information on mycorrhizal biomass prompted this study.

The study on mycorrhizal biomass was conducted in four central Himalayan oak forests during 1991. The oak forests were on four sites: two sites at Kilbury, one dominated by *Q. floribunda* and the other *Q. lanuginosa*; one site at Naina peak dominated by *Q. semecarpifolia*; and one site at Kailakhan dominated by *Q. leucotrichophora*. All sites were within 5 km of Nainital (29°24′N lat., 70°28′E long.). The elevations are: *Q. leucotrichophora* site 1950 m, *Q. floribunda* site 2140 m, *Q. lanuginosasite* 2200 m and *Q. semecarpifolia* site 2550 m. The climate is monsoon-temperate. Each year is divisible into three seasons: rainy (June–September); winter (November–February); and summer (April–May). Annual average rainfall is 2488 mm and mean monthly temperature ranges from 6 (January) to 20.5° (June). Soil is sandy loam in texture and slightly acidic in nature (pH 6.0–6.4) with water-holding capacity between 55 and 65% and soil organic carbon between 0.85 (*Q. semecarpifolia* forest) and 2.04% (*Q. leucotrichophora* forest). Total N in soil is from 0.09 to 20% (*Q. semecarpifolia* vs *Q. leucotrichophora*).

Vegetative analysis in the oak forest was done by using twenty randomly distributed 10 × 10 m quadrats. Lateral root biomass for different oak species was estimated by using the already developed regression equations[11,13]. In our study it was reasonable to consider those roots as lateral roots (> 5 mm dia in size) supporting ectomycorrhizae. Normally lateral roots are non-ectomycorrhizal but support ectomycorrhizal formation on subsidiary rootlets, including fine roots, which are swollen and are of various colours. Our past studies[11,14] revealed oak root biomass ranging from 83 to 243 t ha^{-1}, of which lateral and fine roots accounted for about 12 to 15%. Using an augar (5 cm dia and 30 cm length), five core samples (up to 30 cm soil depth) were collected underneath five trees from each of the cbh classes (i.e. 40–60, 60–80, 80–100, etc.) of oak species. Samples were collected during the months of July and August. Ginwal[15] studied seasonal variation on the occurrence of mycorrhizae in Himalayan oaks and reported peak activity during July and August (rainy season). Sampling was

Table 1. Tree density, basal area and lateral root biomass across cbh classes in four Central Himalayan oak forests

Cbh class (cm)	Mean cbh (cm)	Tree density (tree ha^{-1})	Total basal area (m^2 ha^{-1})	Lateral root biomass (kg ha^{-1})
Q. leucotrichophora				
40–60	51.5	80	1.69	1418.40
60–80	66.0	40	0.02	868.34
80–100	96.4	70	5.18	2049.87
100–120	113.2	200	20.40	6666.14
120–140	–	–	–	–
140–160	154.0	10	1.89	428.38
Total		400	29.18	11431.06
Q. floribunda				
40–60	–	–	–	–
60–80	74.5	112	4.95	1729.76
80–100	87.5	100	6.08	1813.56
100–120	–	–	–	–
120–140	133.6	150	21.32	4147.22
140–160	143.2	53	8.65	1572.04
Total		415	41.00	9262.58
Q. lanuginosa				
40–60	45.8	50	0.83	215.84
60–80	67.0	100	3.57	630.59
80–100	94.5	70	4.98	619.48
100–120	–	–	–	–
120–140	131.8	40	5.53	469.83
140–160	152.0	138	25.38	1970.80
Total		398	40.29	3933.54
Q. semecarpifolia				
40–60	46.5	80	1.38	352.31
60–80	64.7	150	5.00	908.83
80–100	82.5	120	6.50	932.87
100–120	–	–	–	–
120–140	–	–	–	–
140–160	–	–	–	–
Total		350	12.88	2194.01

Table 2. Regression equation (ln $Y = a + b$ ln x) for tree cbh classes and micorrhizal dry weight

	Live mycorrhiza				Dead mycorrhiza			
Cbh class (cm)	*a*	*b*	*r*	Syx	*a*	*b*	*r*	Syx
Q. leucotrichophora								
40–60	–0.3106	0.8735	0.902	0.0446	–00.7988	0.5794	0.967	0.0162
60–80	–4.6240	1.8738	0.968	0.0203	–13.4140	3.7923	0.951	0.0510
80–100	–1.3311	1.0331	0.890	0.0168	–17.4692	4.3333	0.968	0.0354
100–120	–5.6665	1.8461	0.985	0.0117	–39.3921	8.7692	0.972	0.0761
120–140	–	–	–	–	–	–	–	–
140–160	–27.4495	6.0532	0.987	0.0174	–59.5542	12.1978	0.965	0.0580
Q. floribunda								
40–60	–	–	–	–	–	–	–	–
60–80	–17.4057	4.600	0.951	0.0335	–47.1940	11.3267	0.956	0.0776
80–100	–9.0440	2.4675	0.968	0.0102	–22.9926	5.5349	0.904	0.0442
100–120	–	–	–	–	–	–	–	–
120–140	–4.3011	1.3093	0.989	0.0035	–81.3468	16.9588	0.968	0.0792
140–160	–41.0008	8.7419	0.975	0.0620	–105.0578	21.5508	0.981	0.1624
Q. lanuginosa								
40–60	–7.9478	2.2125	0.930	0.0426	–14.5699	3.9857	0.860	0.1155
60–80	–11.5372	2.8345	0.948	0.0357	–5.9923	1.5839	0.965	0.0162
80–100	–35.7187	7.9958	0.988	0.0268	–14.1874	3.2569	0.990	0.0162
100–120	–	–	–	–	–	–	–	–
120–140	–13.5928	2.9832	0.934	0.0322	–14.4525	3.1471	0.970	0.0217
140–160	–30.5746	6.2874	0.878	0.0610	–19.3562	4.0410	0.931	0.0282
Q. semecarpifolia								
40–60	–12.1481	3.3779	0.959	0.0417	–21.8225	5.8321	0.943	0.0858
60–80	–6.7167	1.8043	0.933	0.0258	–18.4101	4.5875	0.968	0.0446
80–100	–15.7915	3.8620	0.925	0.0306	–16.7771	3.9640	0.878	0.0415
100–120	–	–	–	–	–	–	–	–
120–140	–	–	–	–	–	–	–	–
140–160	–	–	–	–	–	–	–	–

Table 3. Mycorrhizal biomass (kg ha^{-1}) across cbh classes in four Central Himalayan oak forests

Cbh class (cm)	*Q. leucotrichophora*	*Q. floribunda*	*Q. lanuginosa*	*Q. semecarpifolia*
Live mycorrhiza				
40–60	1.83	–	0.08	0.18
60–80	1.01	1.26	0.15	0.34
80–100	2.07	0.73	0.13	0.42
100–120	4.28	–	–	–
120–140	–	1.23	0.10	–
140–160	0.21	0.58	0.38	–
Total	9.40	3.80	0.84	0.94
Dead mycorrhiza				
40–60	0.35	–	0.10	0.14
60–80	0.48	0.57	0.19	0.31
80–100	0.72	0.58	0.13	0.24
100–120	1.60	–	–	–
120–140	–	0.79	0.10	–
140–160	0.07	0.36	0.35	–
Total	3.22	2.30	0.87	0.69

done within 1 m radius around a tree, as lateral roots formed a complex network in this zone. Ginwal[15] has reported the detailed monthly estimates for mycorrhizae, but in this paper we have reported only the peak mycorrhizal biomass. Following Thaper and Rehill[9], each core sample was divided into six sub-samples at 5 cm soil depth (i.e. 0–5, 10–15, 15–20, 20–25 and 25–30 cm). Thirty sub-samples were thus studied for each of the selected trees in a cbh class. Collected soil samples (carrying root material) were brought to the laboratory in polyethylene bags for further process. Soil mixed in water was shaken well in a 15 ml flask and the content poured into a sieve to trap short roots. The latter were thoroughly washed in tap water. Live and dead short roots were identified with the help of a magnifying glass. The dead short roots were always black and shrivelled, while live roots were swollen and variously coloured, including black. After mycorrhizal count was done, samples were oven-dried at 60°C to constant weight. Mycorrhizal dry weight was estimated up to 30 cm soil depth on volume basis (100 × 100 × 30 cm) for each of the cbh classes of oak species under present investigation. Data were subjected to regression analysis. Regression equation for each oak species was in the form of $\ln Y = a + b \ln x$, where Y is mycorrhizal dry weight (g), a is intercept, b is slope or regression coefficient, and x is tree chb (cm). Using the regression equation, mycorrhizal dry weight was obtained for different cbh classes. Totalling across different cbh classes yielded stand mycorrhizal biomass.

Table 1 gives tree density, basal area and lateral root biomass for four Central Himalayan oaks. Tree density ranged from 350 tree ha^{-1} (*Q. semecarpifolia*) to 415 tree ha^{-1} (*Q. floribunda*). Total basal area of *Q. floribunda* was higher (41 $m^2 ha^{-1}$) than other oak forests. There was decrease in mycorrhizal number and dry weight with increasing soil depth in the present study. Relationship between mean tree cbh and mycorrhizal dry weight for oak species is indicated in Table 2. High positive correlation ($r = +0.86$ to 0.99; $P < 0.01$) with low error of estimate was recorded for each species.

Table 3 gives mycorrhizal biomass in oak forests under study. Live mycorrhizal biomass ranged from 0.84 (*Q. lanuginosa)* to 9.4 kg ha^{-1} (*Q. leucotrichophora)*. Dead mycorrhizal biomass was between 0.69 (*Q. semecarpifolia)* and 3.22 kg ha^{-1} (*Q. leucotrichophora*). Lateral root biomass of oak species was positively correlated ($r = 0.90$; $P < 0.01$) with total mycorrhizal biomass in the present study. Individually, live and dead mycorrhizal biomass also indicated similar correlation with lateral root biomass. *Q. leucotrichophora* had greater mycorrhizal biomass than other oak species. No reports are available to compare similar forests studied elsewhere. It assumes greater root:shoot ratio in *Q. leucotrichophora* than in other species[10,14]. Secondly, the better soil nutrient status in *Q. leucotrichophora* forest than in other forests may be the probable reason for relatively high mycorrhizal biomass. According to Ginwal[15], significantly higher mycorrhizal mass in *Q. leucotrichophora* is due to more mycorrhizal mass per unit root. Mycorrhizal density was also reported to be more in *Q. leucotrichophora* forest than the other tree species. The mycorrhizal density (mycorrhizal tips/m^2) in different oak forests ranged from 5124 (*Q. lanuginosa*) to 9064 (*Q. leucotrichophora*).

The four oak species occur at different altitudes. This may be the reason for variation in the occurrence of mycorrhizae in different forests. *Q. leucotrichophora*, being at the lower elevations usually with closed canopy, remains under moderate microclimate favourable for mycorrhiza and maximum fine root production in tree. Moreover, moisture retention capacity of soil of this forest is maximum and supports maximum activity of microbes[16]. Another important factor which cannot be avoided is the variation in the genotype of the host[17]. Genetic differences between different species of *Quercus* and their adaptability to different environmental conditions may probably govern the ectomycorrhizal occurrence in their respective forests. Because of the variation in host receptivity in different species of oak and variation in ineffective potential in mycorrhizal fungi at different altitudes and environmental conditions, it was possible that species of oak differed in mycorrhizae richness. As regard dead mycorrhizal component[7], the rate of destruction of mycorrhizae is more in poor-quality sites than quality sites. Thaper and Rehill[9] also made a similar observation.

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