Range Mgmt. & Agroforestry 37 (2) : 192-200, 2016
ISSN 0971-2070

Seasonal variation in biomass and nitrogen content of fine roots of bead tree (*Melia azedarach*) under different nutrient levels in an agroforestry system

Baljit Singh*, Parampardeep Singh and R. I. S. Gill
Punjab Agricultural University, Ludhiana-141004, India
*Corresponding author e-mail: singh-baljit@pau.edu
Received: 1st March, 2016 Accepted: 14th October, 2016

Abstract

The understanding of seasonal fine root distribution in agroforestry systems is important for assessing the root competition between tree and intercrop roots. Growth parameters of bead tree (*Melia azedarach* Linn.) were evaluated under different levels of N and P in an agroforestry system (pearl millet-wheat rotation under bead tree) in Punjab. Depth-wise (0-15, 15-30, 30-45 and 45-75 cm) distribution of fine root biomass (FRB), concentration and accumulation of N in the fine roots of bead trees were determined during four months (April, July, October and January) representing four seasons in the plantation in its 5th year of age under different nutrient levels. Leaf N concentration was also determined. The diameter at breast height (DBH) and height of 5 year old trees (in January 2010) were the highest (18.14 cm and 14.83 m, respectively) with the application of N and P @ $N_{40}P_{25}$, $N_{60}P_{37.5}$, $N_{80}P_{50}$, $N_{100}P_{62.5}$ and $N_{120}P_{75}$ kg ha^{-1} during 1st, 2nd, 3rd, 4th and 5th year, respectively. Significant variations (P<0.01) were observed for above parameters among soil depths, months and nutrient levels. Fine root biomass and N accumulation were significantly higher in July and October than April and January. These were lowest in unfertilized trees (31.1 g m^{-2} and 141 mg m^{-2}, respectively) and highest at the highest level of nutrient application (94.2 g m^{-2} and 1102 mg m^{-2}, respectively) in the soil profile (0-75 cm depth). More than 30% FRB and 37% N accumulation were restricted to 0-15 cm soil depth. Root and leaf N concentration were highest in April (0.96 and 1.10%, respectively) and lowest in January (0.67 and 0.94%, respectively). These also increased significantly (P<0.01) with the application of nutrients. The study signifies that the root competition for moisture and nutrients between tree and intercrop roots would be higher in summer crops than the winter crops.

Keywords: Fine root biomass, Growth parameters, N accumulation, Nutrient application

Abbreviations: DBH: Diameter at breast height; **FRB**: Fine root biomass; **GBH:** Girth at breast height

Introduction

Bead tree (*Melia azedarach* Linn.) commonly known as ‘dek’ is one of the main tree species being grown by farmers in northern India. It is suitable for growing on a variety of sites ranging from light to heavy soil texture and from normal to problematic sites (Anonymous, 2010). This species has fast growing and winter deciduous nature and narrow leaves; thus highly suitable for growing with agricultural crops. The timber of bead tree is preferred for making furniture, doors, windows, agricultural implements and packing cases in the market. It is used in cabinet making and in construction because of its resistance to termites. In different regions of the country, leaves of bead tree are lopped and fed to animals as highly nutritious fodder (Rashid and Sharma, 2012). The leaves of bead tree were found to contain 12.8 and 55.0% crude protein and neutral detergent fiber, respectively (Sultan *et al*., 2008). Indeed, based on chemical composition, relative preference and potential intake rates, the leaves of bead trees are fed to different types of livestock.

Roots are an important sink and source for nutrients in agroforestry systems. The competition between tree and crop roots in agroforestry systems can be reduced by understanding the root distribution of trees and crops in the soil profile. Trees have higher proportion of fine roots in the top soil which compete for resources with crop roots in agroforestry system (Singh, 1994; Dhyani and Tripathi, 2000). On the other hand, roots of trees enrich the soil with organic matter and nutrients by rapid turnover, intercept the leached nutrients from sub surface soil layers and recycle them to the surface (Allen *et al.,* 2004; Valverde-Barrantes *et al.,* 2007). Fine root biomass and productivity in various tree species is related to many factors such as tree spacing (Singh, 1994), soil depths

(Dhyani and Tripathi, 2000; Raizada *et al.*, 2013), ploughing depth (Newaj *et al.*, 2013), seasons in the year (Cavelier *et al*., 1999; Kern *et al.*, 2004), intercrops (Smith *et al.*, 1999), nutrient availability (Nadelhoffer *et al.*, 2002) and soil type (Kochsiek *et al.*, 2013). The nutrient concentration of fine roots determines the nutrient return potential of the roots. Nutrient concentration in fine roots may be higher than that in the tree foliage (Gordon and Jackson, 2000) and it is variable in various tree species under different depths (Valverde-Barrantes *et al.,* 2007).

Bead tree based system is an emerging agroforestry system in Punjab. The trees are grown on boundaries of agricultural fields or as block plantations without or with agricultural crops especially in the south-western region of the state. This species can play a significant role in crop diversification which is the need of the hour in the state. However, there is a lack of information on the influence of nutrients on growth of trees as well as biomass and nutrient dynamics of fine roots of bead tree which will be helpful in determining carbon and nutrient cycling from fine roots and evaluating the competition of tree roots with the roots of intercrops for nutrients and moisture. Therefore, the present study was conducted to evaluate growth of trees and seasonal variation in depth-wise distribution of fine root biomass, N concentration and accumulation in the fine roots of bead tree in response to different levels of nitrogen and phosphorus. Nitrogen concentration in leaves of bead tree was also determined to find out the standing state of nitrogen in trees during different seasons.

Materials and Methods

***Study site*:** The experiment was conducted at the research area of Department of Forestry and Natural Resources and Department of Soil Science, Punjab Agricultural University, Ludhiana during 2009-2010. The experimental site is located in Ludhiana district of Punjab at an elevation of 247 m above mean sea level and lies at 30.54^0 N latitude and 75.40^o E longitude. The experimental site received an annual rainfall of 837 mm, which was not evenly distributed and most of it (81%) was received during the rainy season (July to September).

***Experimental details*:** The experiment on bead tree based agroforestry system was established at a spacing of 5 m x 4 m (500 tree ha^{-1}) with a net plot size of 4 trees $plot^{-1}$ in randomized blocked design (RBD) with three replications in January 2005. The physico-chemical properties of surface soil (0-15 cm depth) were determined before initiation of the study by standard methods (Jackson, 1973). These were pH 8.1, EC 0.39 dS m^{-1}, OC 2.83 g kg^{-1}, available N 125 kg ha^{-1}, available P 11.5 kg ha^{-1}, available K 193 kg ha^{-1} and soil texture loamy sand. The bare rooted seedlings of bead tree were planted in January 2005 whereas the agricultural crops *i.e.* pearl millet (*Pennisetum glaucum* L.) and wheat (*Triticum aestivum* L.) were grown as intercrops in summer (*kharif*) and winter (*rabi*) season, respectively. Every year pearl millet was sown during first fortnight of July and harvested in end of September, whereas wheat was sown in first fortnight of November and harvested in end of April. The nutrients recommended to pearl millet and wheat was applied @ 100 kg ha^{-1} N and 125:62 kg ha^{-1} N: P_2O_5, respectively. Nitrogen and phosphorus were applied in the form of urea and diammonium phosphate, respectively. Pear millet was grown during first four years of tree age whereas wheat throughout the study period. Thus, there was no pearl millet as intercrop under the trees in the year (2009-10) of present study on root biomass and N dynamics.

There were ten nutrient levels which included nine selected combinations of N and P_2O_5 in addition to bead trees without any crop (uncropped treatment) (Table 1). In uncropped bead trees, no nutrients were applied whereas in the cropped (pearl millet-wheat rotation) trees, the experimental plots got the respective nine combinations of N and P in addition to the uniform dose of nutrients applied to intercrops (as mentioned above). The N levels for bead trees in 1st year varied from 0 to 120 g $tree^{-1}$ (60 kg ha^{-1}) whereas in 5th year, these varied from 0 to 280 g $tree^{-1}$ (140 kg ha^{-1}). The P levels varied from 0 to 50 g $tree^{-1}$ (25 kg ha^{-1}) in the 1st year and 0 to 150 g $tree^{-1}$ (75 kg ha^{-1}) in the 5th year (Table 1). The nutrients were applied in 1 m diameter ring around the tree during 1st year, 2 m diameter ring during 2nd year and 3 m wide strip (1.5 m on each side of tree row) during 3rd, 4th and 5th year of tree growth. The entire amount of P was applied in the month of May after harvesting of intercropped wheat whereas nitrogen was applied in 3 splits; 1st in May, 2nd in July and 3rd in September. The nutrients were applied during the growing period of trees every year because trees shed their leaves in winter season and thus their growth rate decreases in winters.

***Growth parameters of trees*:** Girth at breast height (GBH) was measured in centimetres with the help of measuring tape at 1.37 m above ground level**.** It was converted to diameter at breast height (DBH). Height of plants was measured in metres from ground level to tip of the main

Table 1. Applied levels of nutrients (N:P_2O_5, kg ha^{-1}) to bead trees during five years in an agroforestry system at Ludhiana

Treatment	1st year	2nd year	3rd year	4th year	5th year
T_1 (Uncropped)*	0:0	0:0	0:0	0:0	0:0
T_2	0:0	0:0	0:0	0:0	0:0
T_3	20:0	40:0	60:0	80:0	100:0
T_4	20:12.5	40:25	60:37.5	80:50	100:62.5
T_5	40:0	60:0	80:0	100:0	120:0
T_6	40:12.5	60:25	80:37.5	100:50	120:62.5
T_7	40:25	60:37.5	80:50	100:62.5	120:75
T_8	60:0	80:0	100:0	120:0	140:0
T_9	60:12.5	80:25	100:37.5	120:50	140:62.5
T_{10}	60:25	80:37.5	100:50	120:62.5	140:75

*Bead trees in this treatment had no intercrops and no application of nutrients. Only irrigation was applied

leading shoot of plants with Ravi's Multimeter. Crown diameter was taken in metres from two directions and their average was taken.

***Root sampling and determination of N*:** Fine roots (< 2 mm diameter) of bead trees were sampled in 5th year growth of trees during the four main seasons in the region *i.e.* during April 2009 (spring), July 2009 (summer/rainy), October 2009 (autumn) and January 2010 (winter). For excavation of roots, depth-wise (0-15, 15-30, 30-45 and 45-75 cm) soil cores were taken with a sharp edged steel augur of 12 cm diameter and 1 m length. The soil cores were taken around two trees in each plot at 50, 100, 150 and 200 cm distance on four perpendicular directions from the base of the tree stem. Each soil core was placed on a polythene sheet and roots were handpicked from the soil. The roots were distinguished into live and dead roots on the basis of appearance, texture, colour and friability. Live roots had characteristic appearance and colour, intact bark and were firm whereas the dead roots were dark and spongy. Only the live roots were collected as it was not possible to collect the dead and decomposing roots and the root fragments which were mixed as organic matter and not easily identifiable as roots. Diameter of the roots was measured and the fine roots (having < 2 mm diameter) were separated. Roots of the same depth from different horizontal directions around the tree base were pooled. Each sample was firstly washed with tap water and thereafter with distilled water to remove the adhering soil particles. The roots were oven dried at 65 ± 2°C till their constant weight and the dry fine root biomass was recorded. The dry fine root biomass (FRB) was expressed as g m^{-2}. The roots were ground and the concentration (%) and accumulation (mg m^{-2}) of N in the fine roots were determined. Nitrogen in the root samples was determined by Kjeldahl method (Jackson, 1973) and accumulation of N in the fine roots was calculated from FRB and N concentration of each sample.

***Leaf sampling*:** Leaves of bead trees were collected from lower branches of the plants during April 2009, July 2009, October 2009 and January 2010 (the trees have only a few leaves during January). Equal number of leaves were collected from lower, middle and upper parts of branches and pooled. These leaves were washed first with tap water, distilled water, dried under shade and placed in an oven at 65 ± 2°C for 48 hours. The dried samples were ground in a mill and preserved for chemical analysis. The N concentration of the leaves was also determined by Kjeldahl method.

***Statistical analysis*:** As the nutrient levels were applied in RBD, therefore the statistical analysis for tree growth parameters was conducted using analysis of variance (ANOVA) technique in RBD. To evaluate the influence of soil depths and seasons along with nutrient levels, analyses of fine root biomass and N accumulation in fine roots (0-75 cm soil depth), and leaf N concentration were conducted using ANOVA technique in split plot design

(SPD) taking four months in the main plots and ten nutrient levels in the sub plots (Panse and Sukhatme, 1985). Similarly, the effects of months and soil depths on fine root biomass, N concentration and N accumulation were determined in SPD taking four months in the main plots and four depths in the sub plots. The treatment means were separated by least significant difference (LSD) test at 5% level of significance ($P<0.05$). Correlation coefficients between different parameters were also calculated and tested at 1% level of significance ($P<0.01$).

Results and Discussion

***Growth parameters of trees and wheat yield*:** The DBH and height of bead trees increased significantly with the addition of fertilizers (Table 2). The DBH and height were the lowest in unfertilized plots (14.73 cm and 12.25 m, respectively) and they were highest (18.14 cm and 14.83 m, respectively) in T_7 i.e. with the addition of N and P @ $N_{40}P_{25}$, $N_{60}P_{37.5}$, $N_{80}P_{50}$, $N_{100}P_{62.5}$ and $N_{120}P_{75}$ kg ha^{-1} during 1st, 2nd, 3rd, 4th and 5th year, respectively. The differences amongst the various nutrient levels for crown diameter were not significant; however the highest crown diameter was obtained in T_9 (5.08 m). Henderson and Jose (2010) observed that 112 kg ha^{-1} year^{-1} nitrogen application increased the biomass of *Populus deltoides, Quercus pagoda* and *Platanus occidentalis* significantly. The grain yield of wheat in the 5th year was the lowest (2.28 t ha^{-1}) without nutrient application and it was highest in T_9 (2.67 t ha^{-1}), indicating additional yield of wheat at higher levels of applied nutrients.

***Fine root biomass*:** The fine root biomass (FRB) of bead trees averaged over nutrient levels (0-75 cm depth) increased significantly from April to October ($P<0.01$) and decreased in January (Table 3). It was lower in April and January than the other two months. The interaction effects revealed that the FRB in the month of April under various levels of nutrients was significantly lower ($P<0.01$) than the FRB of other months. The lowest FRB in April might be due to the initiation of growing season of the trees after the winter season from October to March. There was initiation of production of new leaves and roots in spring season during April after the winters. The growth of roots continued in July and October as a result of better availability of resources during these months, being rainy season. But the initiation of winters after October and peak winter season in January might have led to decreased root growth in January. In addition to low temperature in winters, leaf fall and pruning of the trees in December-January might have led to shedding and dying of fine roots. Similar observations were made by Dhyani and Tripathi (2000) in four tree species namely *Citrus reticulata*, *Alnus nepalensis, Prunus cerasoides* and *Paraserianthes falcataria* in northeast India. The fine root biomass in these trees gradually increased from

Table 2. Growth parameters of bead trees after 5 years of age and wheat grain yield in 5th year (2009-10) of tree growth at different nutrient levels

Nutrient levels	DBH (cm)	Height (m)	Crown diameter (m)	Wheat grain yield (t ha^{-1})
T_1 (Uncropped)	14.73	12.25	4.18	-
T_2	15.36	13.61	4.36	2.28
T_3	16.07	13.65	4.31	2.42
T_4	17.06	14.34	4.62	2.59
T_5	18.08	13.96	4.39	2.47
T_6	17.92	14.02	4.33	2.58
T_7	18.14	14.83	4.45	2.61
T_8	18.03	14.51	4.36	2.53
T_9	17.76	14.65	5.08	2.67
T_{10}	17.60	14.71	4.67	2.60
LSD ($P<0.05$)	1.98	1.20	NS	0.27

Table 3. Fine root biomass (0-75 cm depth) of bead trees under different nutrient levels

Nutrient levels	Fine root biomass ($g\ m^{-2}$)				
	April	**July**	**October**	**January**	**Mean**
T_1	26.8	31.1	35.1	31.4	31.1
T_2	39.7	42.2	44.9	35.7	40.6
T_3	40.5	49.2	59.9	40.2	47.4
T_4	42.4	57.7	57.1	42.2	49.8
T_5	53.7	56.9	65.4	50.9	56.7
T_6	40.2	63.2	75.9	53.7	58.2
T_7	46.3	70.9	85.4	55.2	64.4
T_8	55.5	73.2	85.0	72.2	71.5
T_9	58.8	90.3	112.0	77.6	84.7
T_{10}	59.9	113.4	104.7	98.8	94.2
Mean	46.4	64.8	72.5	55.8	
LSD (P<0.05)	Months (M): 2.05, Nutrient levels (NL): 2.01, M x NL: 4.03				

spring (pre-rainy) to autumn (post rainy) season and the maximum fine root biomass was in autumn and minimum during winters. Kern *et al.* (2004) observed that the fine root biomass of *Populus deltoides* was the highest in the growing season. The maximum root growth in a semi deciduous lowland forest in Panama occurred during the transitions from dry to wet and wet to dry season possibly as a response to moisture and nutrient pulses (Cavelier *et al.*, 1999). Thus understanding the root growth pattern during different seasons/months might help in assessing the root competition between various components of an agroforestry system. The competition between trees and intercrop roots for nutrients and moisture would be higher during July and October owing to their higher fine root biomass.

Average FRB across months was the lowest (31.1 $g\ m^{-2}$) in uncropped trees and increased significantly (P<0.01) with the application of nutrients. Average FRB was the highest at application of the highest level of N and P (94.2 $g\ m^{-2}$) *i.e.* in T_{10}. This indicated that the return of carbon and other nutrients were higher in T_{10} than other fertilizer treatments. The FRB was significantly lowest in uncropped trees in April (26.8 $g\ m^{-2}$) and significantly highest in T_9 in October (112 $g\ m^{-2}$). Application of N and P in the soil might have led to increased availability and absorption of these nutrients, thus increasing the FRB in fertilized treatments over the lower doses of N and P or unfertilized treatments. Nadelhoffer *et al.* (2002) observed that fine root production in control plots was 75 $g\ m^{-2}\ year^{-1}$ in wet sedge and 67 $g\ m^{-2}\ year^{-1}$ in moist tussock tundra whereas on the plots fertilized with N and P, this was 85 $g\ m^{-2}\ year^{-1}$ in wet sedge and 67 $g\ m^{-2}\ year^{-1}$ in moist tussock tundra indicating higher biomass on fertilized plots. Our study site had light soil texture (loamy sand) and low content of inherent available N and P in the soil. Thus the application of these nutrients on such site might have led to higher shoot biomass production and increased photosynthetic capacity leading to higher acquisition of carbon with excess carbon available to roots allowing root biomass to increase (Ostertag, 2001; Kern *et al.*, 2004).

Among the different depths, FRB was significantly highest in 0-15 cm and lowest in 45-75 cm depth (P<0.01) during all the months (Fig. 1a). Most of the FRB (30.8% in January to 39.6% in October) was restricted to the 0-15 cm soil layer (Fig. 1a). The higher FRB on the surface soil layer (>30%) coincides with more availability of nutrients, water and soil management on the top layer of soil (Cavelier *et al.*, 1999; Dhyani and Tripathi, 2000; Raizada *et al.,* 2013). Valverde-Barrantes *et al.* (2007) studied the fine root distributions and mass for six tree species of 16 years age and observed that under all the tree species, >60% of the total fine root mass to 1 m depth was located in the uppermost 15 cm of the soil. Due to higher FRB on surface layer, higher competition for nutrients and moisture is expected between tree and intercrop roots. At the same time, carbon and nutrient return through fine roots will also be higher in surface soil layer than the lower layers.

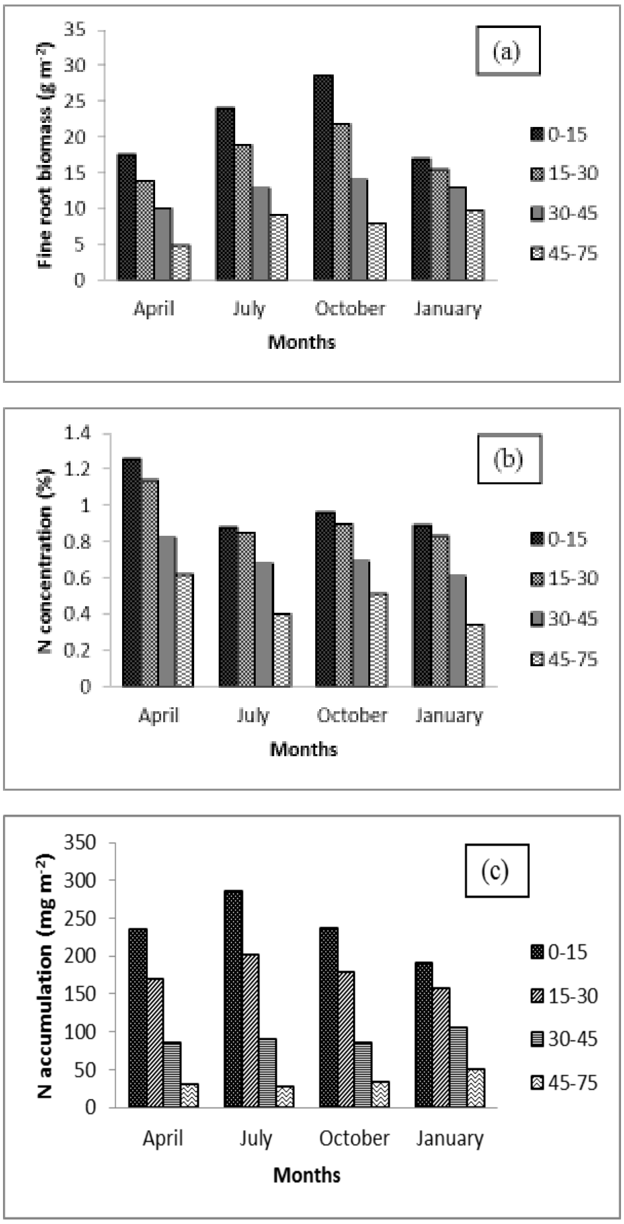

Fig 1. Fine root biomass (a) N concentration (b) and its accumulation (c) in fine roots of bead tree in different soil depths (cm) during various months

***N concentration of fine roots*:** Nitrogen concentration varied significantly (P<0.01) over different soil depths during various months (Fig. 1b). Concentration of N was the highest in April (1.26%) in surface soil depth (0-15 cm) and the lowest in January (0.34%) in 45-75 cm depth. Concentration of N averaged over depths was also significantly highest (P<0.01) in April (0.96%) and lowest in January (0.67%) (Fig.1b). The highest fine root N concentration in the surface soil depth (0-15 cm) might be attributed to more availability of nitrogen and its absorption by roots on the surface layer of soil (Fujimaki *et al.*, 2004; Valverde-Barrantes *et al.,* 2007). Appearance of new leaves in March-April (spring season) led to higher N concentration of fine roots. On the other hand, setting of winter season in October and further lowering of temperature might have led to decreased absorption of N from soil, thus decreasing N concentration of roots in winters. The pruning of tree branches in December-January and due to peak winters, there was shedding of fine roots and retranslocation of N prior to shedding which corresponded to the lowest N concentration in fine roots in January. Tripathi *et al.* (2009) observed the highest nutrient concentrations in summer followed by winter and rainy seasons in mature bamboo savanna soils in dry tropical region in India.

Nitrogen concentration of fine roots increased significantly with application of N and P. It increased from 0.44% without application of nutrients (T_1) to 1.05% with the application of maximum dose of N and P (T_{10}). Higher absorption of N at higher levels of nutrient application might have led to increased N concentration (Raison *et al.*, 1996). Absorption of nutrients would be more efficient on light textured than the heavy textured soils (Kochsiek *et al.*, 2013). Nadelhoffer *et al.* (2002) observed that fine root N and P concentrations increased with fertilization in wet sedge as well as moist tussock tundras.

***N accumulation by fine roots*:** Average fine root N accumulation (0-75 cm depth) over nutrient levels was highest (606 mg m^{-2}) in July and decreased significantly till January (P<0.01) (Table 4). The higher accumulation of N in fine roots in July and October might be due to higher fine root biomass as well as higher N concentration during these months. Nutrient accumulation is a function of root biomass and its concentration in the fine roots. Averaged over months, the N accumulation was the lowest (141 mg m^{-2}) without application of nutrients (T_1) and increased significantly (P<0.01) with the application of N and P. The N accumulation was lower in uncropped trees during all the months and higher in T_9 and T_{10} than the other levels. The application of N increased its accumulation in fine roots due to increased absorption of N by fine roots at higher levels. It also indicated that the return of N through decomposition of fine roots was the lowest in uncropped treatment and increased with fertilizer application. Nitrogen is the major constituent of organic materials; thus its accumulation was found to increase with N application in various tree based systems (Raison *et al.*, 1996; Valverde-Barrantes *et al.,* 2007). The interaction effects indicated that nitrogen accumulation

Table 4. Nitrogen accumulation (0-75 cm depth) in bead tree fine roots under different nutrient levels

Nutrient levels	**N accumulation ($mg\ m^{-2}$)**				
	April	July	October	January	Mean
T_1	166	156	116	125	141
T_2	342	188	176	241	237
T_3	247	361	262	340	302
T_4	317	357	365	396	359
T_5	420	427	471	552	467
T_6	498	587	458	497	510
T_7	521	718	580	573	598
T_8	741	827	692	785	761
T_9	885	1234	929	904	988
T_{10}	1062	1209	1327	810	1102
Mean	520	606	538	522	
LSD (P<0.05)	Months (M): 22, Nutrient levels (NL): 31, M x NL: 63				

in the fine roots varied significantly (P<0.01) under different depths during various months (Fig. 1c). It was highest in 0-15 cm and lowest in 45-75 cm depth during all the months. More than 37% of the total N was accumulated in the fine roots of 0-15 cm soil depth. Nitrogen accumulation in the fine roots of surface soil depth (0-15 cm) varied from 37.9% in January to 47.3% in July (Fig. 1c). Higher accumulation of N in the surface soil layer (>37%) was attributed to greater FRB and N concentration on surface soil layer than the lower layers (Fujimaki *et al.*, 2004; Valverde-Barrantes *et al.,* 2007).

***N concentration of tree leaves*:** Average leaf N concentration was highest in April (1.10%) and lowest in January (0.94%) (Table 5). Leaf N concentration in the month of April averaged over nutrient levels was significantly higher than the N concentration of other months (P<0.01). In April, the highest N concentration of leaves might be due to emergence of new leaves. The biomass was low during leaf initiation while the dilution effect of growth indicated that the nutrient concentration decreases as the biomass of any component increases (Lodhiyal and Singh, 1995). Therefore, leaf N concentration might have decreased in July as a result of growth and increase in biomass of leaves. However, on onset of winters in October, N concentration decreased due to initiation of senescence of leaves and retranslocation of N to wood prior to leaf shedding (Gordon and Jackson, 2000). In January N concentration continued to decrease probably due to higher N retranslocation from leaves before leaf shedding (Lodhiyal and Singh, 1995; Scherzer *et al.,* 1998).

Leaf N concentration averaged over months increased significantly (P<0.01) with the application of N and P. It was lower in uncropped trees during all the months and significantly highest in T_{10} (*P<0.01*). Nitrogen uptake by roots and its translocation to leaves have led to an increase in leaf N concentration with the application of nutrients. Magill *et al.* (1997) observed that foliar nitrogen concentration increased upto 25% in hardwood stands and 67% in the pines with the application of nitrogen.

***Relationship of root and leaf parameters*:** Fine root biomass during different months was significantly (P<0.01) related to root N accumulation (Table 6). The correlation coefficient (r) between these parameters varied from 0.915 in October to 0.993 in January. Similarly the root N concentration during various months was also significantly related to root N accumulation (r = 0.932-0.954) and leaf N concentration (r = 0.937-0.971). The significant positive correlation coefficients of fine root biomass and root N concentration with root N accumulation indicated higher N return in case of higher FRB. Significant coefficients between root N concentration and leaf N concentration also indicated more uptake of nitrogen at higher levels of N application.

Conclusion

The results on seasonal variation in the fine root biomass and N accumulation in bead tree fine roots indicated that these parameters were higher in July (summer/rainy

Table 5. Nitrogen concentration of bead tree leaves during different months under various nutrient levels

Nutrient levels	N concentration (%)				
	April	July	October	January	Mean
T_1	0.69	0.61	0.58	0.50	0.59
T_2	0.81	0.82	0.68	0.65	0.74
T_3	0.93	0.86	0.82	0.73	0.83
T_4	0.89	0.91	0.87	0.80	0.87
T_5	1.11	1.05	0.94	0.91	1.0
T_6	1.21	1.15	1.06	1.11	1.13
T_7	1.25	1.17	1.17	1.14	1.18
T_8	1.29	1.21	1.20	1.18	1.22
T_9	1.33	1.23	1.21	1.20	1.24
T_{10}	1.46	1.30	1.26	1.23	1.31
Mean	1.10	1.03	0.98	0.94	
LSD ($P<0.05$)	Months (M): 0.01, Nutrient levels (NL): 0.03, M x NL: 0.06				

Table 6. Pearson's correlation coefficients (r) between different root and leaf parameters (n=10)

Parameters	Months	Root N accumulation	Leaf N concentration
Fine root biomass	April	0.940*	-
	July	0.956*	-
	October	0.915*	-
	January	0.993*	-
Root N concentration	April	0.954*	0.953*
	July	0.936*	0.971*
	October	0.943*	0.970*
	January	0.932*	0.937*

*Significant at $P<0.01$

season) and October (autumn) than January (winter) and April (spring). The surface soil layer had higher FRB, N concentration and its accumulation in the fine roots. It signifies that the root competition for nutrients and moisture between the tree and intercrop roots will be higher in summer season crops (sown in June/July and harvested in September/October) than the winter crops (sown in November and harvested in April). Fine root biomass and N accumulation increased with application of nitrogen and phosphorus, indicating higher N return under higher nutrient levels. Application of N will lead to increase in uptake of N by plant as described by increasing leaf N concentration under higher levels of applied N.

References

Allen, S. C., S. Jose, P. K. R. Nair, B. J. Brecke, P. Nkedi-Kizza and C. L. Ramsey. 2004. Safety-net role of tree roots: evidence from a pecan (*Carya illinoensis* K. Koch)-cotton (*Gossypium hirsutum* L.) alley cropping system in the southern United States. *Forest Ecology and Management* 192: 395-407.

Anonymous. 2010. *Package of Practices for Forestry.* Punjab Agricultural University, Ludhiana. 26 pp.

Cavelier, J, S. J. Wright and J. Santamaria. 1999. Effects of irrigation on litterfall, fine root biomass and production in a semi deciduous lowland forest in Panama. *Plant and Soil* 211: 207-213.

Dhyani, S. K. and R. S. Tripathi. 2000. Biomass and production of fine and coarse roots of trees under agrisilvicultural practices in north-east India. *Agroforestry Systems* 50: 107-121.

Fujimaki, R., R. Tateno, M. Hirobe, N. Tokuchi and H. Takeda. 2004. Fine root mass in relation to soil N supply in cool temperate forest. *Ecological Research* 19: 559-562.

Gordon, W. S. and R. B. Jackson. 2000. Nutrient concentrations in fine roots. *Ecology* 81: 275-280.

Henderson, D. E. and S. Jose. 2010. Biomass production potential of three short rotation woody crop species under varying nitrogen and water availability. *Agroforestry Systems* 80: 259-273.

Jackson, M. L. 1973. *Soil Chemical Analysis*. Prentice Hall of India Pvt Ltd, New Delhi. 498 pp.

Kern, C. C., A. L. Friend, J. M. F. Johnson and M. D. Coleman. 2004. Fine root dynamics in a developing *Populus deltoides* plantation. *Tree Physiology* 24: 651-660.

Kochsiek, A, S. Tan and S. E. Russo. 2013. Fine root dynamics in relation to nutrients in oligotrophic Bornean rain forest soils. *Plant Ecology* 214: 869-882.

Lodhiyal, L. S. and R. P. Singh. 1995. Structure and function of an age series of poplar plantation in central Himalaya II. Nutrient dynamics. *Annals of Botany* 76: 201-210.

Magill, A.H., J. D. Aber, J. J. Hondricks, R. D. Bowden, J. M. Melillo and F. A. Stendler. 1997. Biochemical response of forest ecosystems to stimulated chronic nitrogen deposition. *Ecological Applications* 7: 402-415.

Nadelhoffer, K. J., L. Johnson, J. Laundre, A. E. Giblin and G.R. Shaver. 2002. Fine root production and nutrient content in wet and moist arctic tundras as influenced by chronic fertilization. *Plant and Soil* 242: 107-113.

Newaj, R., S. K. Dhyani, B. Alam, Ajit, R. Prasad, A. K. Handa, U. Kumar and S. Neekher. 2013. Long term effect of root management practices on rooting pattern in *Dalbergia sissoo* and grain yield of mustard under agrisilviculture system. *Range Management and Agroforestry* 34: 47-50.

Ostertag, R. 2001. Effects of nitrogen and phosphorus availability on fine root dynamics in Hawaiian montane forests. *Ecology* 82: 485-499.

Panse, V. G. and P. V. Sukhatme. 1985. *Statistical Methods for Agricultural Workers.* 4th edn. ICAR, New Delhi. 359 pp.

Raison, R. J., P. K. Khanna, M. J. Connel and R. A. Falkiner. 1996. Effects of water availability and fertilization on N cycling in a stand of *Pinus radiata*. *Forest Ecology and Management* 30: 31-33.

Raizada, A., J. Jayaprakash, A. C. Rathore and J. M. S. Tomar. 2013. Distribution of fine root biomass of fruit and forest tree species raised on old river bed lands in the north west Himalaya. *Tropical Ecology* 54: 251-261.

Rashid, A. and A. Sharma. 2012. Exploration of economically important fodder plants of district Rajouri – Jammu and Kashmir state. *International Journal of Life Science and Pharma Research* 2: 144-150.

Scherzer, A. J., J. Robbeck and R. F. J. Boerner. 1998. Foliar nitrogen dynamics and decomposition of yellow poplar and eastern white pine during four seasons of exposure to elevated ozone and carbon dioxide. *Forest Ecology and Management* 109: 355-366.

Singh, V. 1994. Root distribution in *Populus deltoides* "G-3" plantations in an arid region of north-western India. *Tropical Ecology* 35: 105-113.

Smith, D. M., N .A. Jackson, J. M. Roberts and C. K. Ong. 1999. Root distributions in a *Grevillea robusta*-maize agroforestry system in semi-arid Kenya. *Plant and Soil* 211: 191-205.

Sultan, J. I., I. U. Rahim, H. Nawaz, M. Yaqoob and I. Javed. 2008. Nutritional evaluation of fodder tree leaves of northern grasslands of Pakistan. *Pakistan Journal of Botany* 40: 2503-2512.

Tripathi, S. K., K. P. Singh and P. K. Singh. 2009. Temporal changes in spatial pattern of fine-root mass and nutrient concentrations in Indian bamboo savanna. *Applied Vegetation Science* 2: 229-238.

Valverde-Barrantes, O. J., J. W. Raich and A. E. Russell. 2007. Fine-root mass, growth and nitrogen content for six tropical tree species. *Plant and Soil* 290: 357-370.