

FINE ROOT BIOMASS, FOREST FLOOR AND NUTRIENT STATUS OF SOIL IN AN AGE SERIES OF TEAK PLANTATION IN DRY TROPICS

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ABSTRACT

The present study was conducted in an age series of teak plantation in tropical environment at Barnawapara Wildlife Sanctuary, Chhattisgarh during the year 2011-2012. Total fine root biomass in the present study was between 4.80 t ha⁻¹ and 9.81 t ha⁻¹ and showed the decrease trends of fine root biomass with the age of the teak plantation. The forest floor biomass increased with the age of the teak plantation and the total forest floor biomass in the present study was between 2.19 t ha⁻¹ and 2.66 t ha⁻¹. Total nitrogen observed under soil in age series of teak plantation ranged from 0.083 to 0.143% for surface soil (0-10 cm) and 0.064 to 0.091% for lower layer soil (10-20 cm). Total carbon was ranged from 1.124 to 1.736% for surface soil sample and 0.703 to 1.312% for lower layer soil sample. The concentration of available phosphorus (0-20 cm) under the 19 years old teak plantation and 33 years old teak plantation varied from 8.55 to 12.04 kg ha⁻¹ and 13.74 to 12.06 kg ha⁻¹, respectively. The availability of phosphorus in the soil of 23 years old teak plantation was found to be higher as 11.88 to 15.72 kg ha⁻¹ than the other plantations. Whereas, it was recorded minimum in the 19 years old teak plantation. The result of available potassium for the soil were 314.07 to 335.48 kg ha⁻¹, 382.21 to 266.47 kg ha⁻¹ and 292.95 to 249.54 kg ha⁻¹ under 19 years old teak plantation, 23 years old teak plantation and 33 years old teak plantation, respectively. The value of C, N and P% are higher in moderate age (23 years) plantation in comparison to value of K%, which found higher in the old age plantation (33 years).

INTRODUCTION

Fine roots are physiologically the most active parts of the root system. They are chiefly responsible for water and nutrient uptake, usually in a symbiotic union with mycorrhizal fungi, and have a much shorter lifespan than coarser roots (Wells and Eissenstat, 2001). Although fine root biomass contributes relatively little to total tree biomass (usually < 5%), fine roots are major contributors to C litter inputs to the soil because of their rapid turnover (Norby and Jackson, 2000). Root productivity is one of the most difficult ecosystem parameters to measure and studies on root production have been partly hindered by the lack of simple and feasible techniques. Alterations in root system architecture may occur without a change in total root biomass. Morphological plasticity of fine roots has been proposed as a mechanism by which plants respond to variation in soil nutrient supply (Hodge, 2004). Root length density, root surface area, root tip and branching density are all considered to reflect stand absorptive potential (Eissenstat *et al.*, 2000; Craine, 2006). There are relatively few data on how root biomass and root morphology change in relation to forest stand age (Helmisaari and Hallbacken, 1999; Makkonen and Helmisaari, 2001; Claus and George, 2005), reflecting the difficulty of obtaining root biomass data and of comparing results obtained by different methods. A recent study showed that understory roots may contribute significantly to the forest soil C budget (Bakker *et al.*, 2006). Furthermore, there have been few attempts to quantify the contribution of fine roots of understory vegetation to total C litter inputs in forest soils. Rapid fine-root turnover in fertile

ecosystems may lead to higher root production even though fine-root biomass decreases with increasing fertility (Nadelhoffer, 2000; Burton *et al.*, 2000). It has been predicted that fast-growing species in high-fertility ecosystems will show high levels of morphological plasticity.

Quantification of biomass is essential for stipulating the status and flux of biological materials for understanding the dynamics of the ecosystem (Anderson, 1970). Different age gradation of plantation or stand may affect the biomass of vegetation, forest floor littermass, litter fall and net primary productivity (Bargali *et al.*, 1992; Lodhiyal *et al.*, 1995). Teak ranks 3rd among tropical hardwood species in terms of plantation area established worldwide, covering 2.25 million ha (Krishnapillay, 2000). In context of ecosystem functioning, the study of root biomass did not carried out until the 1970s. Some scientist made attempts to understand roots as a part of the entire forest ecosystem in last 2-3 decades. Still, there was no any research work have to being done in accordance of age series in the Chhattisgarh state. Therefore, the present work is carried out for filling the knowledge gap regarding fine root, forest floor biomass and soil nutrient parameters in teak plantation.

MATERIALS AND METHODS

The study was conducted in Barnawapara wildlife sanctuary situated in North corner of Raipur district. The study area is located between 21°20' 0" to 21°25'47" North latitudes and 82°21' 17" to 82°26' 27" East longitudes. The general topography of area is undulating due to formation of rockout

crop. The area adjoining Nawapara forest village has a number of hillocks scattered all over the area. Dry deciduous forest, grasslands, agriculture lands and human habitations surrounds the study area. The climate of study area is dry humid tropical. The average annual rainfall in the study area ranges from 1200-1350mm. It gradually decreases from south east direction to North West direction. The mean annual maximum and minimum temperatures of study area are 33.1°C and 20.5°C, respectively. Soils of Barnawapara area are grouped in to three classes viz., Inceptisols, Alfisols and Vertisols. Different types of forest vegetation occur in the study area. Northern and Eastern part are covered with luxuriant forests, whereas teak plantations occupy a major area in southern part. In western part, large area is covered by degraded and mixed forest and also with bamboo brakes occasionally found as patches (Champion and Seth, 1968).

The fine root biomass was calculated by taking 5 monoliths (15cm × 15cm × 15cm) on each site. The fine roots were separated by wet-sieving (Bohm, 1979). Proportions of live and dead fine roots were estimated following Persson (1982). Estimation of forest floor biomass was done by using 50 cm × 50 cm randomly placed quadrats, and then categorized into different component following Pandey and Singh (1981a).

Soil samples were collected from to 0-10cm and 10-20cm soil depth on each site and were analyzed for carbon, nitrogen, phosphorus, potassium. Organic carbon and nitrogen concentration were estimated using CHNOS Auto Analyser. Available phosphorus was determined using spectrophotometer following Jackson (1958). Available potassium was determined using flame photometer following Jackson (1958). For collection of data quadrats were selected under stratified random sampling design. Data on the biomass and soil was analyzed in one way analysis of variance. The significant difference between treatment means for all parameters were tested at $P < 0.05$ using least significant difference (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Fine root biomass

The total fine root biomass in the present study was between 4.80 t ha⁻¹ and 9.81 t ha⁻¹ (Table 1). The fine root biomass value was highest on 19 years old teak plantation (9.81 t ha⁻¹) followed by 23 years old teak plantation (7.75 t ha⁻¹) and lowest on 33 years old teak plantation (4.80 t ha⁻¹). The fine root biomass decreases with age of the teak plantation. Analysis of variance indicated that the variations in fine root biomass due to age of plantation (site) were non-significantly different at 5% level of significance. Evidently root mass estimates varied greatly with respect to sampling depth and diameter class under consideration besides the forest types and their locations across the tropics. Fine root production also varies succinctly with site quality and species composition (Aerts *et al.*, 1992; Fogel, 1983; Persson, 1982; Shaver and Billings, 1975). Our finding that fine root biomass was highest in the young stand for all root fractions agrees with the results of Makkonen and Helmisaari (2001), who found the largest fine root biomass in the pole stage stand of a Scots pine chronosequence. Higher root biomass in the young stand, which is in agreement with a similar finding described for young lodgepole pine, where the belowground biomass increased with tree density (Litton *et al.*, 2003). However, although individual older trees have finer root biomass than younger trees, because tree density decreases with the stand age, fine root biomass for the whole stand decreases with age. Also, Claus and George (2005) documented a clear effect of stand age on standing fine root biomass with highest values in young adult stands in forest chronosequences of European beech, Norway spruce and Turkey oak. In India, Lodhiyal *et al.* (1995) observed the fine roots biomass as 1.2 t ha⁻¹ for 5 years age plantation, 1.2 t ha⁻¹ for 6 years age plantation, 1.1 t ha⁻¹ for 7 years age plantations and 1.0 t ha⁻¹ for 8 years age plantations, similar trend were also observed in present study which revealed that the fine root biomass was remain higher in young plantation than the

Table 1: Fine root biomass (t/ha) in an age series of teak plantation at Barnawapara Wildlife Sanctuary

Plantation	Fine Root Biomass		Thickness > 5mm		Total
	Thickness < 5mm		Live	Dead	
19 Years Teak Plantation	2.67	4.28	2.86	-	9.81
23 Years Teak Plantation	1.55	2.22	3.98	-	7.75
33 Years Teak Plantation	1.28	2.49	0.98	0.05	4.80

Table 2: Forest floor biomass (t/ha) in various components in an age series of teak plantation at Barnawapara Wildlife Sanctuary

Forest Floor Biomass	19 Years Teak Plantation	23 Years Teak Plantation	33 Years Teak Plantation
Fresh leaf litter	0.90	1.35	0.87
Decayed litter	0.62	0.45	0.61
Wood litter	0.67	0.51	1.18
Total	2.19	2.31	2.66

Table 3: Chemical properties of soil in an age series of teak plantation at Barnawapara Wildlife Sanctuary

Chemical Properties of Soil	19 Years Teak Plantation		23 Years Teak Plantation		33 Years Teak Plantation	
	0-10	10-20	0-10	10-20	0-10	10-20
Total N %	0.104	0.064	0.143	0.091	0.083	0.079
Total C %	1.129	0.703	1.736	1.312	1.124	1.084
Available P (kg/ha)	8.55	12.04	11.88	15.72	13.74	12.06
Available K (kg/ha)	314.07	335.48	382.21	266.47	292.95	249.54

mature ones. Fine root biomass in present study was found to be higher than the findings made by Kumar *et al.* (2011). Vanninen and Makela (1999) observed that the fine root biomass of pine stand differing in age was the lower than the present findings in different age series of the plantations. Yin *et al.* (1989) stated that forest removal 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). Differences in fine root biomass estimates among studies may be a result of several factors, including local site conditions and sampling depth (Cronan, 2003). The study revealed that growth and accumulation of fine roots varied greatly with respect to species composition, tree density and basal area, season and soil characteristics.

Forest floor biomass

Total forest floor biomass in the present study was between 2.19 t ha⁻¹ and 2.66 t ha⁻¹. It was found highest (Table 2) on 33 years old teak plantation (2.66 t ha⁻¹) followed by 23 years old teak plantation (2.31 t ha⁻¹) and lowest on 19 years old teak plantation (2.19 t ha⁻¹). In 19 years old teak plantation the distribution of biomass in the different components was 0.90 t ha⁻¹ in fresh leaf litter, 0.67 t ha⁻¹ in wood litter and 0.62 t ha⁻¹ in decayed litter. The fresh leaf litter, wood litter and decayed litter constituted 41.10, 30.59 and 28.31%, respectively of the total forest floor biomass. The 23 years old teak plantation revealed the distribution of biomass in the different components was 1.35 t ha⁻¹ in fresh leaf litter, 0.51 t ha⁻¹ in wood litter and 0.45 t ha⁻¹ in decayed litter. The fresh leaf litter, wood litter and decayed litter constituted about 58.44, 22.08 and 19.48%, respectively of the total forest floor biomass. The distribution of biomass in the 33 years old teak plantation different components was 0.87 t ha⁻¹ in fresh leaf litter, 1.18 t ha⁻¹ in wood litter and 0.61 t ha⁻¹ in decayed litter. The fresh leaf litter, wood litter and decayed litter constituted 32.71, 44.36 and 22.93%, respectively of the total forest floor biomass. The forest floor biomass increased with the age of the teak plantation. Analysis of variance indicated that the variation in forest floor litter biomass due to age of plantation (site) was non-significantly different at 5% level of significance. Bargali *et al.* (1992) and Lodhiyal *et al.* (1995) found the increasing trend in forest floor litter mass of eucalyptus and poplar plantations respectively in Central Himalaya. Present estimates of forest floor biomass were also supported by Kumar *et al.* (2011). The total forest floor biomass was 4.04 t ha⁻¹ for 5 years age plantation, 4.92 t ha⁻¹ for 10 years age plantation and 5.1 t ha⁻¹ for 15 years age plantation in the study of Kumar *et al.* (2011).

Soil properties in age series of teak plantation

The chemical properties of soil across the age of plantation sites viz., 19 years old teak plantation, 23 years old teak plantation and 33 years old teak plantation is given in Table 3. Analysis of variance indicated the variation in total nitrogen and total carbon among the different age of plantation was significantly varied at 5% level of significance. Available phosphorus and available potassium were not significantly different at 5% level of significance. Total nitrogen observed under soil in age series of teak plantation ranged from 0.083 to 0.143% for surface soil (0-10 cm) and 0.064 to 0.091% for

lower layer soil (10-20cm). Among the plantations, the 23 years old teak plantation contained maximum nitrogen content at both the soil depth as compare to the other plantations. Total carbon observed under soil in age series of teak plantation were ranged from 1.124 to 1.736% for surface soil sample (0-10cm) and 0.703 to 1.312% for lower layer soil sample (10-20 cm). Among the plantations, the 23 years old teak plantation contained maximum carbon content at both the soil depth as compare to the other plantations. The concentration of available phosphorus (0-20 cm) under the 19 years old teak plantation and 33 years old teak plantation varied from 8.55 to 12.04 kg ha⁻¹ and 13.74 to 12.06 kg ha⁻¹, respectively. The availability of phosphorus (0-20 cm) in the soil of 23 years old teak plantation was found to be higher as 11.88 to 15.72 kg ha⁻¹ than the other plantations. Whereas, it was recorded minimum in the 19 years old teak plantation. The result of available potassium for the soil (0-20 cm) were 314.07 to 335.48 kg ha⁻¹, 382.21 to 266.47 kg ha⁻¹ and 292.95 to 249.54 kg ha⁻¹ under 19 years old teak plantation, 23 years old teak plantation and 33 years old teak plantation, respectively. In all the study sites the potassium content was low in 33 years old teak plantation while it was higher under the soil of 23 years old teak plantation.

In general, most microbial activity occurs in the upper soil layers (0-20 cm) as soil at this depth is more nutritious and porous. Soil organic C of lower soil layer is lower than upper soil layer. The result of this study is consistent with the research done by Janmahasatien and Phopinit (2001). The dynamics and properties of litter are important not only for investigations of C dynamics but also for those of mineral nutrient dynamics in forest ecosystem because the return of nutrients through litter is an important pathway for nutrient transfer between plants and soil (George and Buvanewaran, 2001). Burke (1989) suggested that nutrient dynamics are closely linked to seasonal variation in temperature and moisture. Moreover, the higher values of mineral N, inorganic P and soil physical properties close to trees could be attributed to higher amount of organic matter inputs through litter fall, root mortality and herbaceous biomass. Singh *et al.* (2000) reported that temporal variation in soil organic carbon, increased soil organic carbon and coincided with the periods of litter production. Singh and Singh (2002) have reported the soil nutrients were significantly higher in the plantation area compared with the non-planted control plot. Kumar *et al.* (2010) have reported organic carbon between 2.23-2.81%, while concentration of nitrogen from 0.16-0.21% and that of phosphorus from 0.021-0.03 % in all three sites, which is compared with the present findings. Tangsinmankong *et al.* (2007) studied the carbon stocks in soil of mixed deciduous forest and teak plantation. Results revealed that soil organic carbon from all sites decreased generally with the increasing depth from the surface soil to the lower layer soil. Similar observations were observed the present study. Contrary to this they also showed the highest carbon stocks in soils of 6 years old teak plantation followed by the 24 and 15 years old teak plantations and mixed deciduous forest i.e., 157.03, 105.67, 78.78 and 70.96 t C ha⁻¹ respectively. The dissimilarity of soil organic carbon may be due to forest fire, forest management and topography. Takahashi *et al.* (2009) studied the soil respiration in different ages of teak plantations in Thailand. They concluded that

carbon dynamics in the soil under teak plantations were determined by the soil moisture regime, which is controlled by seasonal rainfall pattern and annual rainfall. Soil respiration in teak plantations had no clear difference between different stand ages. Chauhan *et al.* (2010) reported the soil organic carbon in natural forest as 2.2% and 1.5% in plantation forest whereas the available phosphorus was 10.7 kg ha⁻¹ and 8.4 kg ha⁻¹ for both natural and plantation forest. They reported the value of N as 209.2 kg ha⁻¹ for natural forest and 170 kg ha⁻¹ for plantation forest whereas the available K was 331 kg ha⁻¹ for natural forest and 294.5 kg ha⁻¹ for plantation forest. The values were found within the range for the present findings.

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