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ORIGINAL ARTICLE

Influence of Diameter Class and Field Conditions on Nutrient Cycling under *Toona ciliata* M. Roem Trees in North-Western Himalaya

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Abstract The aim of the present study is to report the variation in soil and plant nutrients, leaf litter deposition and microbial biomass, and their cycling under four different diameter classes and two field conditions of *Toona ciliata* trees growing under natural conditions in mid hills of Himachal Pradesh, India. Soil samples from two directions of each distance, i.e., 1 m from the tree trunk (E_1), half way to the crown radius (E_2), perimeter of the crown radius (E_3) and double the crown radius (E_4) in two different field conditions, i.e., cultivated field (C_1) and uncultivated field (C_2), were taken and mixed to form one composite sample. The collected soil samples were tested in the laboratory for different parameters through standard procedures. The results revealed that soil physico-chemical characteristics improved inside the tree canopy compared to outside. Bulk density and pH increased from the lowermost diameter class to the uppermost classes with successive increase in the diameter from 20 to 30 cm to >50 cm diameter at breast height (DBH) trees. Significantly higher nitrogen (480 kg ha^{-1}) and bulk density (1.18 g cm^{-3}) were recorded in cultivated fields. Soil organic carbon (2.30%) and soil carbon density (52.20 t ha^{-1}) showed significantly higher values in uncultivated bunds. Higher microbial biomass was recorded in the soil towards uncultivated bunds under the canopy of higher diameter class. The amount of nutrients (g m^{-2}) added to the soil due to the leaf litter accumulation were in the range of 29.9–45.5 (g m^{-2}) in carbon, 1.49–2.27 (g m^{-2}) in nitrogen, 0.061–0.092 (g m^{-2}) in phosphorus, 3.27–4.97 (g m^{-2}) in potassium, 3.27–4.97 (g m^{-2}) in calcium, 0.039–0.059 (g m^{-2}) in iron, 0.003–0.005 (g m^{-2}) in manganese and 0.001–0.002 (g m^{-2}) in copper. The study concludes that growing of this tree species in mid hill environmental conditions will make important contribution by improving the soil and nutrient conditions, and can be a source of fertility which would improve crop production and livelihood.

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1 Introduction

Trees are known to bring about changes in locality factors and other components of the ecosystem (Shukla 2009; Paletto and Chincarini 2012; de Foresta et al. 2013). Natural tree vegetation has the capacity to enhance soil organic matter due to organic matter inputs and to reduce carbon losses due to precipitation leaching and other disturbance factors (Guo and Gifford 2002; Don et al. 2011; Poeplau and Don 2013). The introduction of trees helps to check soil erosion and nutrient loss by leaching, and to gain microclimatic conditions which contributes to nitrogen fixation and increased biological activities by providing biomass (Schoeneberger 2009; Plieninger 2012). It is widely believed that agroforestry is the potential and successful major land management alternative for conserving soil as well as maintaining the soil fertility and productivity (Nair 1992; Nair 2012). Nutrient cycling is the most predominant and a key process in tree based ecosystems, as it maintains the availability of nutrients for vegetation growth (Xu et al. 2003). The concentration of CO_2 and other green house gases (GHGs) in the atmosphere has considerably increased over the last century and is set to raise further (Albrecht and Kandji 2003; Lorenz and Lal 2014; Jose and Bardhan 2012). In the era of climate change, increased population and large chunk of degraded lands, maintenance of multispecies and multistrata agroforestry practices are deemed worthwhile (Rajput et al. 2015, 2016; Goswami et al. 2016, 2017). Trees can increase the availability of nutrients through increased release of nutrients from soil organic matter (SOM) and recycled organic residues. Trees add organic matter to the soil system in various manners in the form of roots or litter fall or as root exudates in the rhizosphere (Fisher 1995; Bertin et al. 2003). Higher soil organic matter and organic forms of nutrients nearer the tree suggests that there could be increased mineralization and greater availability of plant nutrients under trees than in open areas during the cropping season (Rhoades 1995).

Toona ciliata M. Roem, a multipurpose tree species, dominates the agricultural landscapes of the sub-tropical and sub-temperate northwestern Himalayas (Divakar and Ratan 2017). Despite its wide distribution and numerous functions (timber, ship building, musical instrument fabrication, etc.), no study on the impact and contribution on nutrient cycling has been reported from the area. The present study, therefore, aimed to observe the impact of *Toona ciliata* trees on the soil enrichment potential, leaf biomass deposition and microbial biomass from the subtropical and moist temperate zone in mid hill conditions of Himachal Pradesh, India. To fulfil these objectives, the hypothesis tested was whether soil enrichment potential, leaf biomass deposition and microbial biomass vary with variation in tree diameter and field conditions.

2 Materials and Methods

2.1 Study Area

The present study was conducted in the farmer’s crop production fields in Darodeuriya area under Sirmour district of Himachal Pradesh, India. The study area is located between 30°50′47.7”N and 77°11′30.39″ E latitudes in northwest Himalaya at an elevation ranging between 1150 and 1200 m above sea level. The study area is representative of the range of conditions prevalent in mid hill zone of Himachal Pradesh and is a transitional zone between subtropical and moist temperate zone. The area, during the cropping season, experiences a wide range of temperatures with a mean minimum of 2.4 °C in December and a mean maximum of 32.6 °C in June. May and June are the hottest months and December and January the coldest ones. The area experiences a fair amount of frost but snowfall is rarely witnessed. Meteorological data of the study area are presented in Fig. 1.

2.2 Collection of Soil Samples

Nine soil samples from 0 to 20 cm layer of experimental field were collected for each treatment during months October–November of years 2014–15. Soil samples from two directions of each distance, i.e., at 1 m from the the tree trunk (E_1), at half way to the crown radius (E_2), at the perimeter of the crown radius (E_3) and at the double distance of the crown radius (E_4), in two different field conditions, i.e., cultivated field (C_1) and uncultivated field (C_2), were taken and mixed to form one composite sample. Collected soil samples were air dried, grinded, passed through 2 mm plastic sieve and stored in cloth bags for laboratory analysis. Three treatments/replications, i.e., diameter class, field condition and distance from the tree were studied using randomized block factorial design. The procedure by Gomez and Gomez (1984) was applied for data analysis using t test. Where ever the experimental effects exhibited significance at 5% level of probability, the critical difference was calculated.

2.3 Analysis of Soil Samples

The core tube method for undisturbed soil was used to determine the bulk density of soil. Particle density of soil was measured by Pycnometer. The soil pH was determined by soil: water ratio 1:2.5, using a pH meter (Jackson 1973). The electrical conductivity in

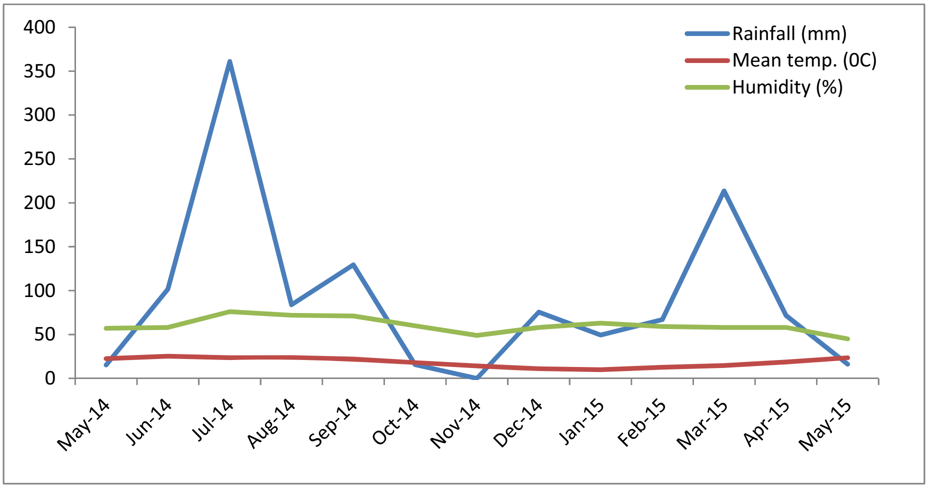

Fig. 1 Mean monthly meteorological data of the year 2014–2015

1:2.5 soil suspensions was measured by a Systronic conductivity meter and expressed as dS m^{-1}. Organic carbon was determined by the chromic acid titration method of Walkley and Black (1934). SOC density (Mg ha^{-1}) was calculated by multiplying percent organic carbon with bulk density and soil depth (Schlesinger 1986). Available nitrogen (%) was determined by the method of Subbiah and Asija (1956), available phosphorus by Olsen et al. (1954) method, available potassium (kg/ha) and exchangeable calcium by flame photometer method (Merwin and Peach 1951). The analysis of soil micronutrients (zinc, iron, copper and manganese) was carried out as per method suggested by Lindsay and Norvell (1978). Microbial biomass was determined by soil fumigation extraction method detailed by Vance et al. (1987).

2.4 Nutrient Categorisation

The classification of the nutrients into low, medium and high categories was done as per Bhandari and Tripathi (1979) for carbon, FAI (1977) for nitrogen, phosphorus and potassium, Tandon (1989) for calcium and Lindsay and Norvell (1978) for iron, manganese, zinc and copper.

2.5 Leaf Litter Biomass

Litter traps of size 1 m^2 were laid down under the tree canopies for collection of leaf litter. Leaf litter of *Toona ciliata* trees were collected at fortnightly interval between December–February by laying three 1 m^2 plots at different distances, i.e., 1 m from the tree trunk (E_1), half way to the crown radius (E_2), at the perimeter of the crown radius (E_3) and at the double distance of the crown radius (E_4), and for four different diameter classes, i.e., D_1 (20-30 cm), D_2 (30-40 cm), D_3 (40-50 cm) and D_4 (> 50 cm), and in two field conditions, i.e., cultivated (C_1) and uncultivated field (C_2). After collection and fresh weight observations, leaves were oven dried at temperature 65 °C for 48 h. The drying, grinding and storing of samples were carried out in accordance with the procedure described by Kenworthy (1964).

2.6 Estimation of Plant Nutrients

Total nitrogen in the leaves was estimated by micro Kjeldahl method, and carbon content in the leaf samples was determined by loss of ignition method, according to:

$$\text{Organic Matter } (\%) = \frac{\text{Sample weight (g)} - \text{Weight of ash (g)}}{\text{Weight of sample (g)}} \times 100$$

$$\text{Carbon content} = \text{Organic matter } (\%)\ /2$$

Phosphorus was estimated by vanado-molybdo-phosphoric acid method (Jackson 1973). Potassium and calcium in plant tissue were estimated on flame photometer (Jackson 1973). The determination of zinc, iron, copper and manganese were carried out on Atomic absorption spectrophotometer model 4141 by using 10 mL of 100 mL prepared sample, which was further diluted to 5 mL with distilled water. The macro and micronutrients of leaf were computed on dry weight basis and expressed as per cent and ppm, respectively (Table 1).

Table 1 Soil Physico-chemical characteristics in relation to tree diameter class, field condition and distance from the tree trunk

Treatments	Bulk density (g cm^{-3})	Particle density (g cm^{-3})	pH	EC (dS m^{-1})	Soil organic carbon (%)	Soil carbon density (t ha^{-1})
Effect of diameter classes (D)						
D_1 (20–30 cm)	1.170	2.170	7.170	0.160	2.210	51.710
D_2 (30–40 cm)	1.150	2.180	7.240	0.180	2.150	49.450
D_3 (40–50 cm)	1.170	2.220	7.400	0.230	2.360	55.220
D_4 (>50 cm)	1.189	2.200	7.550	0.190	2.150	50.740
$CD_{0.05}$(D)	0.025	0.036	0.061	0.036	NS	NS
Effect of field conditions (C)						
C_1 (cultivated field)	1.180	2.190	7.370	0.200	2.130	50.260
C_2 (uncultivated bunds)	1.150	2.000	7.380	0.180	2.300	52.900
$CD_{0.05}$(C)	NS	NS	NS	NS	0.160	NS
Effect of distance from the tree trunk (E)						
E_1 (1 m from tree trunk)	1.120	2.210	7.260	0.210	2.510	56.220
E_2 (half way to the crown radius)	1.150	2.200	7.330	0.200	2.290	52.670
E_3 (perimeter of crown radius)	1.180	2.180	7.330	0.190	2.150	50.740
E_4 (double the crown radius)	1.220	2.170	7.420	0.170	1.930	47.090
$CD_{0.05}$(E)	0.025	NS	0.061	NS	0.226	0.113

3 Results and Discussion

3.1 Physico-Chemical Characteristics of Soil

The soil physico-chemical characteristics under the *Toona ciliata* tree canopy were significantly influenced by the diameter class, except soil organic carbon, available phosphorus and zinc content. Bulk density and pH increased from the lowermost diameter class to uppermost ones with successive increase in the diameter from 20 to 30 cm to >50 cm diameter at breast height (DBH) trees. The increase in values of bulk density and pH may be due to the addition of high organic matter under large sized trees. Several studies, i.e., Goswami (2009), Devi (2011), Shah et al. (2013), carried out in different regions of Himachal Pradesh, India, have also reported the increase in pH value due to high organic matter production. Different tree species can differ significantly in their influence on soil properties (Augusto et al. 2002). As the trees grow older, more food needs to be produced through photosynthesis and is ultimately recycled back to soil through different cycles. The values of particle density and EC increased from D_1 to D_3 diameter trees and declined at D_4. Various soil characteristics, i.e., bulk density, pH, soil organic carbon and soil carbon density, were found influenced significantly with distance from the tree trunk. The values of bulk density, pH and EC showed an increasing trend from E_1 to E_4 and those of soil organic carbon (%) and soil organic carbon density showed a declining trend from E_1 to E_4**.** Singh and Hymavati (2012) reported slightly alkaline pH and increase in EC value under *Dalbergia sissoo* tree intercropped with *Zea mays.* The results of the present study are also supported by the studies of Berhe et al. (2013), Umar et al. (2013) and Casals et al. (2013). Higher organic carbon and soil carbon density were observed in the uncultivated bunds compared to cultivated ones. This can be ascribed to the relatively less disturbed soil and higher decomposing leaf litter in the uncultivated bunds, which might have lead to higher organic carbon and lower bulk density in the soil. Plant residue or litter increases of organic matter in soil have also been supported by Bowen et al. (1988). Several studies have focused on species interactions and subsequent growth in both natural communities and agroecosystems (Ewel and Bigelow 1996; Tilman 1999), where productivity is often found functional attribute of a species such as nitrogen fixation, canopy architecture and light availability (Ewel and Bigelow 1996).

3.2 Nutrients Status

Tree diameter classes influenced soil nutrients viz., nitrogen, potassium, calcium, iron, manganese and copper. The values reported for potassium, manganese and copper increased from D_1 to D_4. The maximum values of Nitrogen (486 kg ha^{-1}) and Calcium (1620.9 mg kg^{-1}) were in the soil under 40–50 cm diameter at breast height (DBH) class. The contents of Fe declined from 20.12 ppm in 20–30 cm to 7.28 ppm in 40–50 cm DBH class significantly and then increased to 10.79 ppm (Table 2). The effect of the field conditions on all the nutrients, except N, was insignificant. The N contents under uncultivated field bunds (455.70 kg ha^{-1}) were observed lower than the cultivated ones (480.07 kg ha^{-1}). Leaf litter provides an important link between productivity, biomass and ecosystem processes (Purahong et al. 2014; Uriarte et al. 2015). Litter production is an indicator of primary productivity and is important for nutrient cycling and export of nutrients and organic detritus to the ecosystem (Ashton et al. 1999; Mfilinge et al. 2005; Hossain and Fazlul-Hoque 2008). The contents of all the nutrients, except Ca, showed significant dependence on distance from the tree trunk. The nitrogen, phosphorus, potassium, manganese, zinc and copper contents in general declined significantly with successive increase in distance from E_1 to E_4 and for iron the trend was just reverse. Tree management practices can also significantly influence leaf litter decomposition rates and nutrient dynamics (Purahong et al. 2014).

Concentrations of nitrogen, phosphorus, potassium and calcium may increase or decrease with the alteration in canopy (Sollins et al. 1980; Lovett and Lindberg 1993). Improvement in the soil fertility below the trees of higher diameter classes can be attributed to the fact that the

Table 2 Nutrient status of soil in relation to tree diameter class, field condition and distance from the tree trunk

Treatments	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	Ca (mg kg^{-1})	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)
Effect of diameter classes (D)								
D_1 (20–30 cm)	447.40	30.82	347.08	616.15	20.12	9.14	2.95	2.39
D_2 (30–40 cm)	461.20	34.07	383.75	787.60	16.62	8.45	3.08	1.92
D_3 (40–50 cm)	486.30	42.20	575.65	1620.94	7.28	9.87	2.92	2.45
D_4 (>50 cm)	480.20	37.63	577.11	1073.85	10.79	11.02	2.82	3.04
$CD_{0.05}$ (D)	18.85	NS	149.19	239.06	2.43	1.412	NS	0.56
Effect of field conditions (C)								
C_1 (cultivated field)	480.07	38.89	455.41	1009.38	14.03	9.143	2.93	2.33
C_2 (uncultivated bunds)	455.70	33.46	486.63	1039.90	13.37	10.105	2.95	2.57
$CD_{0.05}$ (C)	13.33	NS	NS	NS	NS	NS	NS	NS
Effect of Distance from the tree trunk (E)								
E_1 (1 m from tree trunk)	504.85	46.85	597.31	1075.52	11.51	11.54	3.51	2.98
E_2 (half way to the crown radius)	472.18	38.36	496.91	1019.27	12.53	10.01	3.12	2.59
E_3 (perimeter of crown radius)	453.27	33.68	398.45	1003.65	14.34	9.09	2.74	2.29
E_4 (double the crown radius)	441.23	25.81	391.41	1000.10	16.42	7.83	2.39	1.92
$CD_{0.05}$ (E)	18.85	9.43	149.19	NS	2.43	1.52	0.25	0.56

bigger the tree, the higher is their leaf litter production and the more is the addition of nutrients to the soil. Yadav and Bisht (2014) reported a considerable nutrient addition due to leaf litter under Pecan nut tree. Higher contents of available nitrogen towards the cultivated field conditions can be owed to the fact that the farmers use external source of fertilizers in their fields to improve the productivity in addition to the supplemented nutrients added by the decomposition of the leaves. Aggarwal (1980) reported that soil under *Prosopis cineraria* has more soil organic matter, total N, P, K, available micronutrients (Zn, Mn, Cu and Fe) and slightly lower pH and EC than soil under open field conditions.

Among the interactions, only the influence of the cultivated conditions and diameter class was significant (Table 3). Maximum P content (40.81 kg ha^{-1}) in cultivated and (43.52 kg ha^{-1}) in uncultivated conditions was observed in 30–40 cm and 40–50 cm DBH, respectively. The values of K, Mn and Cu increased from D_1 to D_4. The maximum values of N (486 kg ha^{-1}) and Ca (1620.9 mg kg^{-1}) were in the soil under 40–50 cm DBH class (Table 4). The variation in P content under cultivated conditions was less than the reported values in uncultivated field conditions. Quality of the leaf litter and species specific conditions and age of the tree can affect the decomposition processes (Aponte et al. 2012) and soil parameters (Sariyildiz et al. 2015). Old stands have a high nitrogen stock and some years are needed to change the soil chemistry (Hagen-Thorn et al. 2004; Oostra et al. 2006).

A significant decline in the values of all the soil parameters with the increase in the distance from the tree trunk was observed except for bulk density, soil pH and the soil iron contents, which showed an increase with distance from the tree trunk. This can be ascribed to higher leaf litter accretion near the tree base than that at a distance far away from it. Githae et al. (2011) also reported higher soil nutrients under the canopy of *Acacia senegal* trees mainly due to higher leaf accumulation near the tree base. Sharma (2005) also reported that available N, P, K in soil was considerably higher under the tree canopy than that of bare field. According to Noumi et al. (2011), soils under trees had more OM, N, P than those in uncanopied sub-habitat. Aggarwal (1980) reported that the soil under *Prosopis cineraria* had more soil organic matter, total N, P, K, available micronutrients (Zn, Mn, Cu and Fe) and slightly lower pH and EC than the soil under open field conditions.

3.3 Soil Microbial Biomass (μg g^{-1})

Maximum microbial biomass (459.90 μg g^{-1}) was recorded under >50 cm diameter at breast height (DBH) class and minimum (390.65 μg g^{-1}) under 30–40 cm (Fig. 2). Statistically identical microbial biomass was recorded under the diameter class D_1 and D_3. Irrespective of diameter class and field conditions, microbial biomass decreased significantly with the increase in distance from the tree trunk (Fig. 3). Maximum value

Table 3 Interactions effect of tree diameter classes X field conditions (D X C) on phosphorus content of soil

	Diameter classes			
Phosphorus	D_1 (20–30 cm)	D_2 (30–40 cm)	D_3 (40–50 cm)	D_4 (>50 cm)
C_1 (cultivated field)	34.89	40.81	35.21	26.75
C_2 (uncultivated bunds)	26.75	23.51	43.52	40.05
$CD_{0.05}$	13.37			

Table 4 Interactions effect of tree diameter classes X Distance from trunk (D X E) of *Toona ciliata* tree on the Leaf Litter Biomass (g/m^2)

Diameter class	Distance from the Tree Trunk			
	E_1 (1 m from tree trunk)	E_2 (half way to the crown radius)	E_3 (perimeter of crown radius)	E_4 (double the crown radius)
D_1 (20–30 cm)	74.83	83.67	73.83	54.17
D_2 (30–40 cm)	87.50	87.50	55.00	43.33
D_3 (40–50 cm)	89.17	88.00	84.17	73.33
D_4 (>50 cm)	153.33	132.17	90.67	58.83
$CD_{0.05}$	9.25			

(574.05 μg g^{-1}) was recorded in the treatment situated at a distance of 1 m from the tree trunk (E_1), and was significantly higher than all the other treatments. Significantly lowest soil microbial biomass (272.90 μg g^{-1}) was recorded in treatment E_4. Among the field conditions, uncultivated bunds displayed significantly higher microbial biomass (434.96 μg g^{-1}) than cultivated field (409.73 μg g^{-1}) (Fig. 4). Chattopadhyay et al. (2012) also reported highest microbial biomass in forest and lowest in agriculture system. Compared with conventional practices, organic farming practices have been shown to promote higher microbial biomass (Lundquist et al. 1999; Petersen et al. 1997) and to alter microbial community composition (Bossio et al. 1998; Petersen et al. 1997).

Soil microbial biomass was significantly influenced by the diameter class and the distance from the tree trunk (Figs. 2, 3, and 4). Significantly higher microbial biomass was observed below the canopy of higher diameter class tree and declined with the increase in distance from the tree trunk. Nagarajan and Sundaramoorthy (2000) also reported that the canopy size of *Prosopis cineraria* significantly enhanced soil microbial C, N and P. Microbial biomass was reported higher in the uncultivated bunds as compared to the cultivated fields. This may be due to higher organic carbon content below the tree canopy as compared to the open condition. Bainard et al. (2013) also reported that intercropping system supports a more diverse soil microbial community compared to conventional agriculture system.

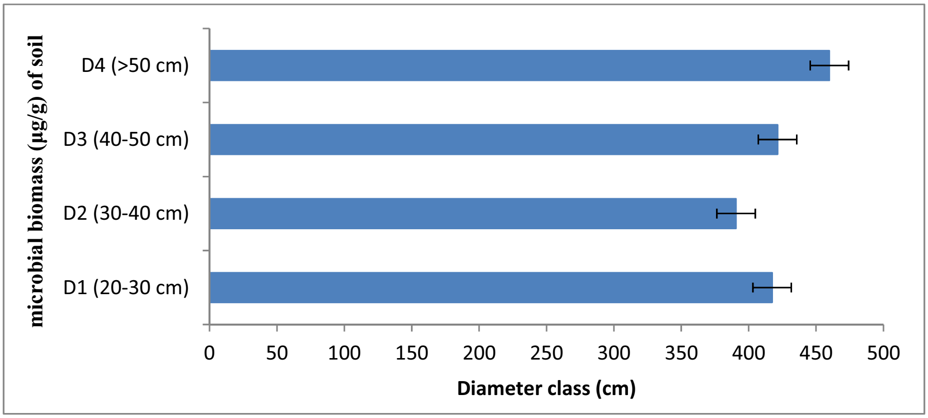

Fig. 2 Microbial biomass (μg g^{-1}) in relation to diameter class

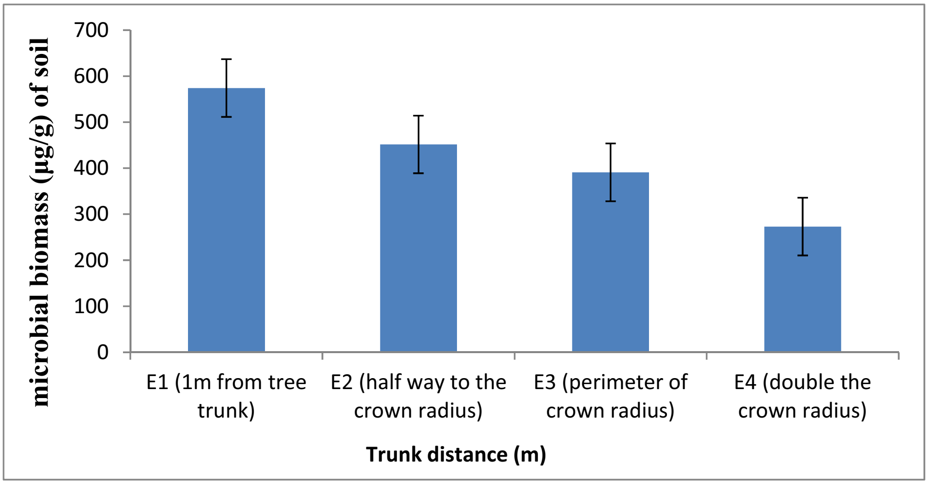

Fig. 3 Microbial biomass (μg g^{-1}) in relation to tree trunk distance

3.4 Leaf Litter Biomass (g m^{-2})

Significantly higher leaf litter biomass (108.75 g m^{-2}) was recorded under diameter class D_4, followed by D_2 (83.66 g m^{-2}), D_3 (78.33 g m^{-2}), and D_1 (71.62 g m^{-2}). On the average effect of distance from the tree trunk, maximum leaf litter biomass (101.21 g m^{-2}) was recorded in treatment $E_{1,}$ which remained statistically at par with treatment E_2 (97.83 g m^{-2}). Minimum leaf litter biomass (57.42 g m^{-2}) was recorded in treatment E_4, and was significantly lower than all the other treatments. The D_4 diameter class showed markedly higher leaf litter near the tree trunk than other diameter classes. The content of leaf litter under this diameter class declined consistently with increasing distance from the tree trunk. Litter production and subsequent decomposition are key processes in carbon and nutrient available for plant nutrition, and is affected by physico-chemical properties. Therefore, the litter decomposition and turnover of liable soil organic matter could be affected by differences in microclimatic conditions (Prescott 2002; Hattenschwiler and Vitousek 2000). The maximum leaf litter biomass

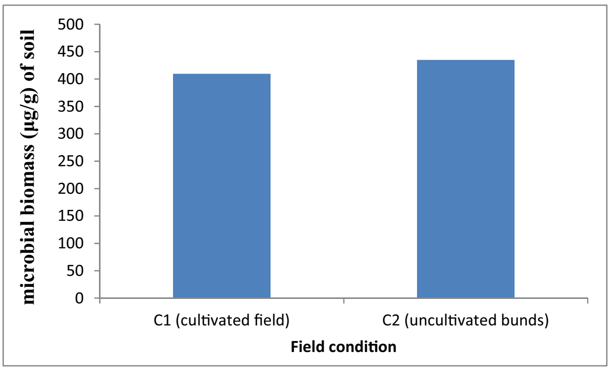

Fig. 4 Microbial biomass (μg g^{-1}) in relation to the field condition

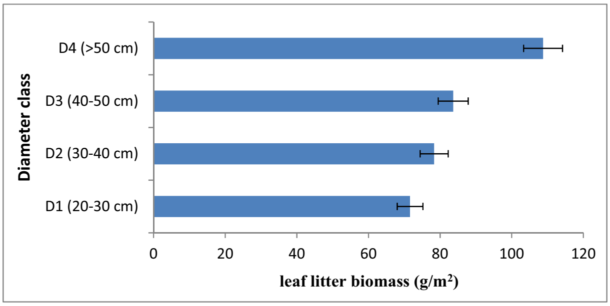

Fig. 5 Leaf litter biomass accumulation (g m^{-2}) vs diameter class

(153.33 g m^{-2}) was recorded in the treatment combination D_4E_1 and was higher than all other treatment combinations. Significantly minimum leaf litter biomass (43.33 g m^{-2}) was recorded in the treatment combination D_2E_4. Leaf litter biomass accumulation below the tree also varied with distance from the tree trunk and with the diameter class (Figs. 5, 6, and 7). But, the effect of the field condition was found to be non-significant. Significantly higher amount of the litter was added at a distance closer to the tree trunk and higher diameter class than located away from the the tree trunk and smaller diameter classes (Fig. 6). The effect of tree species diversity and composition on nutrient cycling might be better predictable by the litter mass and its nutrient content from litter decomposition rates (Prescott 2005).

3.5 Accretion of the Nutrients in the Soil by the Leaf Litter Accumulation

The per cent nutrients, i.e., carbon, nitrogen, phosphorus, potassium, calcium, iron, manganese, zinc and copper in the leaf litter of *Toona ciliata* were 42.15, 2.1, 0.0853, 0.077, 4.6, 0.0551, 0.0028, 0.0049 and 0.0017%, respectively (Table 5). The amount of the nutrients (g m^{-2}) added to the soil due the leaf litter accumulation in soils were in the range of 29.9–45.5 g m^{-2} C, 1.49–2.27 g m^{-2} N, 0.061–0.092 g m^{-2} P, 3.27–4.97 g m^{-2} K, 3.27–4.97 g m^{-2} Ca, 0.039–0.059 g m^{-2} Fe, 0.003–0.005 g m^{-2} Mn, and 0.001–0.002 g m^{-2} Cu. The amount of the nutrients available in the soil below the tree ranged from 49.75–55.22 t ha^{-1} carbon, 447.4–480.2 kg ha^{-1} nitrogen, 30.82–42.2 kg ha^{-1} phosphorus, 347.08–577.11 kg ha^{-1} potassium, 299.7–810.4 mg kg^{-1}

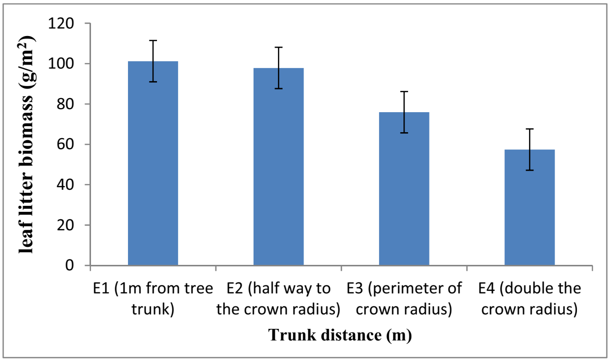

Fig. 6 Leaf litter biomass accumulation (g m^{-2}) vs tree trunk distance

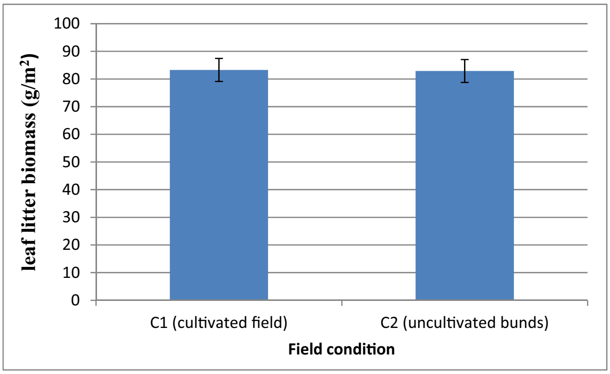

Fig. 7 Leaf litter biomass accumulation (g m^{-2}) vs field conditions

calcium, 7.28–20.12 ppm Fe, 8.45–11.02 ppm Mn, 2.82–3.08 ppm Zn and 1.92–3.04 ppm Cu (Table 5). The soil nutrients were then categorised into various soil fertility classes, and all the nutrients except nitrogen and zinc fell in 'High' category of soil fertility class. Tree species can also alter decomposition rates indirectly through effects on environmental conditions. Tree species can induce changes in soil fertility, microclimate, and faunal and microbial communities in the forest floor (Mitchell et al. 2007; Aponte et al. 2010), all of which influence the decomposition process (Hobbie 1996; Sariyildiz and Anderson 2003).

Extrapolation of input and decomposition rate can demonstrate the overriding importance of canopy litter in the recycling of N and P (Laiho and Prescott 1999). The rate of decomposition and nutrient mineralization can be increased or decreased by temperature, moisture and by the chemical and physical nature of the litter (Prescott 2002). Several studies (Edmonds 1980; Yavitt and Fahey 1986; Stohlgren 1988) have reported a positive relationship between initial concentrations of N or P and the rate of decay. Githae et al. (2011) also reported improvement in the soil fertility inside the tree canopy and a significant variation in the soil nutrients due to different amount of leaf litter deposition at different distances. The values of nutrients recorded in the present study in the leaves of *Toona ciliata* were similar to the studies carried out by Ares and Fownes (2000). The amount and composition of leaf litter produced can be affected by canopy, which largely determines the amount of nutrients to be recycled and the resulting nutrient availability (Prescott 2002).

Table 5 Accretion of nutrients in the soil through leaf litter in the present study

Nutrient	Leaf litter (%)	Nutrients added by the leaf litter (g m^{-2})	Nutrient status in soil	Remarks
Carbon	42.1500	29.9–45.5	49.75–55.22 (t ha^{-1})	High
Nitrogen	2.1000	1.49–2.27	447.4–480.2 (kg ha^{-1})	Medium
Phosphorous	0.0853	0.061–0.092	30.82–42.2 (kg ha^{-1})	High
Potassium	0.0770	0.055–0.083	347.08–577.11 (kg ha^{-1})	High
Calcium	4.6000	3.27–4.97	616.15–1620.94 (mg kg^{-1})	Sufficient
Iron	0.0551	0.039–0.059	7.28–20.12 (ppm)	High
Manganese	0.0028	0.002–0.003	8.45–11.02 (ppm)	High
Zinc	0.0049	0.003–0.005	2.82–3.08 (ppm)	Medium- high
Copper	0.0017	0.001–0.002	1.92–3.04 (ppm)	High

4 Conclusions

Significantly higher leaf litter biomass (g m^{-2}) was found to be accumulated under higher diameter classes and the leaf litter biomass displayed significantly decreasing trends with the increase in the distance from the tree trunk. Soil organic carbon percent and soil organic carbon density declined significantly with increase in the distance from the tree trunk. All the micronutrients, except Zn and P increased with increase in the diameter of *Toona ciliata* trees, which gives sufficient indication about the positive role of *Toona ciliata* trees in improving the fertility status of the soil under it. The level of most nutrients in the soil under the influence of naturally growing *Toona ciliata* M. Roem was in the category of medium to high. The treatments showing the higher leaf biomass deposition also showed the higher microbial biomass. The study thus concludes more and more trees shall be planted on the field bunds and boundaries for more nutrient production and healthy soil.

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