Comparative Study of Leaf Litter Decomposition of Two Exotic Tree Species In Afaka Kaduna State, Savanna Ecological Zone, Nigeria

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Abstract: There is high demand for nutrients by exotic tree species due to their rapid growth rate. The decomposition of leaf litters of two plant species, *Tectona grandis* and *Eucalyptus camaldulensis* were investigated using litterbag study. Soil and leaf litters were collected from six sampling sites in each plantation designated as El - E6 for *E. camaldulensis* and Tl - T6 for *T. grandis* respectively. The collected samples were analyzed for their chemical properties using standard methods at day 1, 30 and 60 during the experimental period. Results showed that the decomposition rate in *E. camaldulensis* ranged from 0.00271 to 0.00571 while in *T. grandis*, decomposition rates ranged from 0.00824 to 0.01527. There was a general decrease in both foliar mass and chemical compositions while soil chemical and microbiological parameters increased, indicating nutrient release into the soil. Decomposition rates was higher in *T. grandis* than *E. camaldulensis* with ranges of 0.00824 - 0.01527 day"[1] and 0.00271 - 0.00571 day" 'respectively, possibly due to the hard texture and waxy coating of *E. camaldulensis.* Significant difference was observed in their decomposition rates with a F-Value of 0.001. due to the difference in their s~il chemical properties. Carbon (IV) oxide evolution was highest on day 30 in both species. Analysis of variance revealed that soil carbon, carbon (IV) oxide evolution, pH, potassium and magnesium were significantly different between the sampling sites of each plantation. It is concluded from this study that site conditions determine to a large extent, the decomposition rate of leaf litter samples.

Keywords: Decomposition, leaf litters, soil. rate, microbiological, chemical

Introduction

The maintenance and sustenance of forest ecosystem is dependent on decomposition of organic matter since the nutrients released are measures of the net productivity of agro-ecosystems. This maintenance also depends on soil chemical and microbiological properties (Beare *et al*, 1992). Many studies carried out have confirmed that leaf litter decomposition is crucial in understanding nutrient dynamics in tree species plantation (Berg *et al*, 2010; Berg, 2000; Bockheim *et al*, 1991, Bernhard-Reversat, 1988). Perry *et al* (2008) also reported that leaf litter decomposition is a biogeochemical process that influences the rates of carbon and nutrient cycling in forest ecosystems. According to Robertson and Paul (1999), leaf tissues account for 70% of above-ground litter fall in forests. This is because, the recycling of nutrients is an energy source for soil organisms (Charley and Richards, 1983; Berg and McClaugherty, 2008).The process of leaf litter fall, litter decomposition and its mineralization are critical in maintaining a dynamic forestry/agriculture ecosystem. The availability of nutrients and their plant uptake depends upon the reabsorption and retranslocation of the nutrients before leaf fall and subsequently on decomposition and mineralization of the organic matter. Swift *et al* (1979) opined that the rates of litter decomposition are determined by the litterchemistry, qualitative and quantitative composition of the microbial community and their physical environment. The litter chemistry and quality do not only include the concentration and availability of nutrients, but also chemicals such as tannins which affect the activity of heterotrophs.

The decomposition of leaf litter and return of nutrients into the soil is an important source of inorganic ions for plant uptake. Release and immobilization of nutrients proceeds through time in different ways according to their concentration and activities of living organisms. Many models of decomposition of litters such as the quality of the litter (Singh *et al*, 1999), biotic and abiotic factors (Mary and Sankaran, 1991; Bardgett, 2005; Deka, 1982) are factors that influence the rate of decomposition and release of nutrients.

There is high demand for nutrients due to the rapid growth rate of trees in plantations (Mary and Sankaran, 1991).Rapid growth of forest plants implies that nutrients are removed from the soil fast and immobilized in the above-ground biomass of the exotic plant species. Nutrient removal may result in a decline of the soil fertility if replenishment with inorganic fertilizer or manure is inadequate. A decline in soil fertility implies a decline in the quality of soil which includes decrease in the level of soil carbon, pH, cation exchange capacity, total nitrogen and plant nutrients. Consequently, nutrient uptake, decomposition and return through litter fall in forest plantations have gained importance in recent research (Hartemink 2003; Demel, 2000; Davidson, 1989).

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Exotic plant species such as *Eucalyptus camaldulensis* and *T. grandis* have the characteristics of fast growth rate and thereby take up nutrient at a fast rate from the soil, leading to a reduced soil fertility. There is need therefore for a rapid decomposition of litters from these exotics to balance rapid nutrient depletion from the soil and avert soil degradation. Studies on litter decomposition in forest ecosystems have been carried out in some parts of the world especially in the temperate zones(Anderson and Flanagan, 1989; Fogel and Cromack, 1977; Meentemeyer, 1978; Bockheim, 1991). There is a little or no information on the litter decomposition of exotic tree species grown in plantations in savanna ecosystem, despite their abundance where they are used as shelterbelt and in soil reclamation.

The aim of this study was to investigate leaf litter decomposition under *Tectona grandis* and *Eucalyptus camaldulensis* plantations in Afaka, Kaduna State, Nigeria;

Materials and Methods

Study site

This study was conducted in two plantations in Afaka, Kaduna State, Nigeria. The coordinates of the study area are defined by latitude 10° 36' 21.28" N and longitude 7 ° 18' 57.17" E. A mean annual rainfall of about 1200 mm is usually recorded in the rainy season and the mean annual temperature is about 24.5°C (Nwaedozie *et al.*, 2013).

Leaf litter and Soil sample collection

Leaves from the two tree plantation species were selected for this study: *Eucalyptus camaldulensis* (Eucalyptus) and *Tectona grandis* (Teak). Soil samples as well as leaf litter samples were collected randomly from six sampling sites in each plantation using a table of random number. All leaves were air-dried to constant moisture content before the beginning of the decomposition assay. Litterbag method was employed (Bocock *et al,*1960). Three litterbags were used for one sampling site; in all, eighteen litterbags were used for each plant species. Chemical analysis of leaf litters and soils were carried out at National Geosciences Research Laboratory (NGRL), Kaduna.

Soil analysis

Standard methods of soil analysis were used to determine the chemical properties of the soil. Organic carbon was determined by Walkley and Black method (Walkley and Black, 1934). Available nitrogen was estimated by Kjeldhal method (Subbiah and Asija, 1956). The content of P, K, Ca and Mg was analyzed in a solution after samples were digested in a mixture of K_2SO_4 + $CuSO_4$ + $FeSO_4$ in the ratio of 10: 0.5: 1 (Henway and Heidal, 1952; Black, 1965; Olsen *et al.*, 1954). Soil pH was determined in a 1:2.5 (w/v) soil/water extract, with a glass electrode pH meter (Rigobelo and Nahas, 2004). The analysis were done on day 1, 30 and 60, of the decomposition study.

Decomposition assay

The leaf litter decomposition study was carried out using the mesh bag technique described by Mary and Sankaran (1991).Ten grams (10 g) of air-dried leaf litter of each species as well as its corresponding soil from a sampling site were transferred separately in nylon mesh bags- (mesh size 2 mm) and the openings closed firmly by stitching. A total of 18 litter bags was used for each species. The soil and its litter samples obtained from a particular sampling site were triplicated to facilitate their analyses in terms of mass loss, quantification of carbon (IV) oxide evolved, chemical. The litter and soil was watered with 20 ml of distilled water periodically to maintain 60-70% water holding capacity. Control sets contained soils without leaf litters.

Respiration rate was determined by measuring and quantifying the evolving$CO_2$from the decomposing litter following the method described by Qingkui *et al* (2008). Glass vials containing 10 ml of 0.5MSodium hydroxide (NaOH) to trap the evolved CO_2 were put each litter bag. After 3 days of introducing the NaOH, the glass vial was removed and the CO_2 trapped in NaOH was determined titrimetrically. The residual alkali was titrated against 0.1 M HCl using phenolphthalein as indicator and CO_2 evolution from litters then calculated. The difference between the values for soil with the litters and litter-free soil gave the CO_2 evolution from the enclosed litter. The amount of CO_2evolved was converted into µg CO_2 g^{-1} oven dry litter day^{-1}. The determination of CO_2evolution was carried out at day 1, 30 and 60.

Percentage litter mass was also determined after day 1, 30 and 60and the rate of decomposition constant, k (day^{-1}) of leaf litter was estimated from these data by using negative exponential decomposition model proposed by Olson (1963).

Statistical Analysis

Decomposition rate (k) of leaf litter was estimated using the decay model (Olson, 1963).

$M_t = M_0 e^{-kt}$

Where 'M_0' is the initial mass of litter, 'M_t' is the mass of litter remaining after time t, 'e' is exponential logarithm, 't'is the time (day) and *k*is the decomposition rate (day^{-1}).T-test was used to determine any significant difference between the decomposition rate of *E. camaldulensis and T. grandis.* Significant difference in the evolution of Carbon (IV) oxide at day 1, 30 and 60, was determined using One-way Analysis of Variance. Difference in the soil chemical and microbiological parameters of each sampling sites were evaluated using one-way analysis of variance. A Post-test, Tukey's Honestly Significant Difference Test, was used for pair wise comparison of the parameters in the sampling sites. Correlation analysis was carried out on

the soil chemical and microbiological parameters. A comparison of the soil chemical and microbiological parameters between the *E. camaldulensis and T. grandis* plantations, was analyzed using T-test. The expected P-Value for all the analysis is 0.05.

Results

Mass loss (%) and Decomposition rates of the leaf litters

Among *E. camaldulensis* leaf litter samples, mass loss was highest in E4, with decomposition rate of 0.00571 and lowest in E6, with decomposition rate of 0.00271 (Table 1). There was a general sharp decline in the mass of the leaf litter during the course of decomposition in both species. (Fig. 1 and 2). Mass loss was highest in T6 sample and lowest in T4 sample of *T. grandis* with decomposition rates for T6 and T4 as 0.01527 and 0.00824 respectively (Table 1).

T-test revealed that the decomposition rate of *E. Camaldulensis* and *T. Grandis* differs significantly. The P-Value was 0.001 which is less than the expected value, 0.05 (Table 1).

Carbon (IV) oxide evolution from the decomposing leaf litter samples

The Carbon (IV) oxide evolution varied among the litter samples. Throughout the decomposition, E4 released the highest quantity of CO_2 in comparison with other samples of *E. camaldulensis* leaf litter samples. There was also variation in the Carbon (IV) oxide evolution among the litter samples of *T. grandis*. T2 evolved the highest quantity of CO_2relative to other *T. grandis* litter samples while T4 evolved the least amount of CO_2 (Table 2).

Analysis of variance revealed that the quantity of CO_2evolved in different days of decomposition, was significantly different among *E. camaldulensis* leaf litter samples, *T. grandis* leaf litter samples and the control. The P-Values on day 1, 30 and 60 were 0.003, 0.001 and 0.0002 respectively (Table 2).SampleE3 &E4 and E4 & E5 differed significantly in the amount of CO_2evolved (Table 5). There was no correlation between CO_2 and other soil chemical and microbiological parameters under *E. camaldulensis* plantation (Table 8).

Sample T2 differed significantly from all other litter samples in their amount CO_2 evolution (Table 6). As presented in table 9, the amount of CO_2 evolved correlated negatively with calcium (r = -0.7866).

pH

The pH of the samples were generally less acidic. The highest pH was in E5 on day 1 while the lowest was in E1 on day 60 (Table 3). ANOVA showed that the pH of soil samples in all the six sampling sites were not significantly different from each other (Table 5). The pH correlated positively with carbon, with r value of 0.764 while a negative correlation between pH and magnesium was observed, with r value of -0.799 (Table 8).

Also, the pH of *T. grandis* litter samples were generally less acidic. The highest pH (6.7) was in T6 on day 60 and the lowest was recorded in T3 on day 30, with pH of 4.2 (Table 4). There was no significant difference in the pH of the soil samples from the six sampling sites (Table 6). pH correlated negatively with nitrogen (r = -0.815) while a positive correlation was observed between pH and magnesium, with r value of 0.7333 (Table 9).

Carbon

There was a general increase in soil carbon and decrease in the carbon content of all the leaf litter samples of *E. camaldulensis*, indicating that carbon nutrients were release to the soil (Table 3). There was a significant difference in the soil carbon of all the samples, with a P-Value of 0.016 (Table 5). Tukey's Honestly Significant difference Test revealed that the soil carbon of E1 and E2 was significantly different from each other (Table 5).

There was also a general increase in soil carbon and decrease in the carbon content of all the leaf litter samples of *T. grandis* (Table 4). According to Tukey's Honestly Significant difference Test, the soil carbon of T2 and T3 was significantly different from each other (Table 6).

Nitrogen

Nitrogen declined in the leaf litter and increased in the soil (Table 3 and 4). In all the six sampling sites, nitrogen content of the soil differed significantly, with a P-Value of 0.002. Tukey's test showed that nitrogen content of E5 differed from other samples. Similarly, E1 and E3 differed from each other (Table 5). Nitrogen showed no correlation with other soil chemical and microbiological parameters (Table 8). T2 and T3 did not follow the general trend of increase in soil nitrogen, it rather decreased (Table 4). In all the six sampling sites of *T. grandis* plantation, nitrogen content of the soil differed significantly, with a P-Value of 0.0052. Tukey's test showed that nitrogen content of T1 and T2 differed significantly from each other (Table 6). Table 9 reveals that there was a negative correlation between soil nitrogen and phosphorus (r = -0.3899).

Phosphorus

Table 3 and 4 show that soil phosphorus increased in all sites except in sample E5 where it had a constant value of 1.91 mg/g on day 30 and day 60. The phosphorus content of the leaf litter decreased during decomposition except sample E3 and E6 which had constant values of 0.21 mg/g and 0.31 mg/g respectively on day 30 and 60. ANOVA revealed that there was significant difference in soil phosphorus for all the sites, with a P-Value of 0.003. E6 differed significantly from all other samples according to Tukey's test (Table 5). There was no correlation

between phosphorus and other soil chemical and microbiological parameters. (Table 8).

The phosphorus content of the leaf litter samples of *T. grandis* decreased during decomposition except in sample T4, which had a constant value of 0.20 mg/g on day 30 and 60. ANOVA revealed that there was no significant difference in the soil phosphorus of all the *Tectona grandis* samples, with a P-Value of 0.54 (Table 6).

Potassium

In *E. camaldulensis* samples, potassium decreased steadily in the leaf litter of all the samples but increased in the soil (Table 3). Constant value (1.91 mg/g) of Phosphorus was recorded in E5 on day 30 and 60. ANOVA shows that soil phosphorus levels of the samples are not significantly different, with a P-Value of 0.082 (Table 5). Potassium correlated negatively with calcium, with r value of -0.864 (Table 8).

This pattern was replicated in the samples from *T. grandis* plantation as potassium also decreased steadily in the leaf litter from all the samples but increased in the soil except in T4 (Table 4). ANOVA reveals that soil phosphorus levels in the samples were not significantly different, with a P-Value of 0.138. Also, Potassium had no correlation with any of the soil chemical and microbiological parameters (Table 9).

Calcium

Statistical comparison of the soil chemical and microbiological parameters under *E. camaldulensis* and *T. grandis* plantations

As presented in table 7, carbon (IV) oxide evolution, pH, carbon, potassium and magnesium differed significantly between the two plantations under study. However, Nitrogen, phosphorus and calcium did not differ significantly from each other.

Table 3 reveals that there was decrease in the calcium level of the leaf litter samples and a general increase in soil calcium level. Calcium content of soil carbon was not significantly different in all the samples, with P-Value 0.374 (Table 5). Calcium did not correlate with any of the soil chemical and microbiological parameters (Table 8).

Leaf litter samples of T5 and T6 had constant values of 10.01 and 12.00 mg/g respectively on day 30 and 60. There was a general increase in soil calcium level except in sample T2 (Table 4). Calcium content of soil carbon was not significantly different in all the samples, with P-Value 0.222 (Table 6).

Magnesium

The level of magnesium declined in both *E. Camaldulensis* and *T. grandis*leaf litter samples but increased sharply in the soil during decomposition (Table 3 and 4). In *E. camaldulensis*, Analysis of variance revealed that the magnesium content of the soil in all the samples are not significantly different, with a P-Value of 0.131 (Table 5). Analysis of variance of magnesium in *T. grandis* revealed that the magnesium content in all the soil from all the samples were also not significantly different, with a P-Value of 0.669 (Table 6).

No correlation was observed between magnesium and other soil chemical and microbiological parameters (Table 8 and 9).

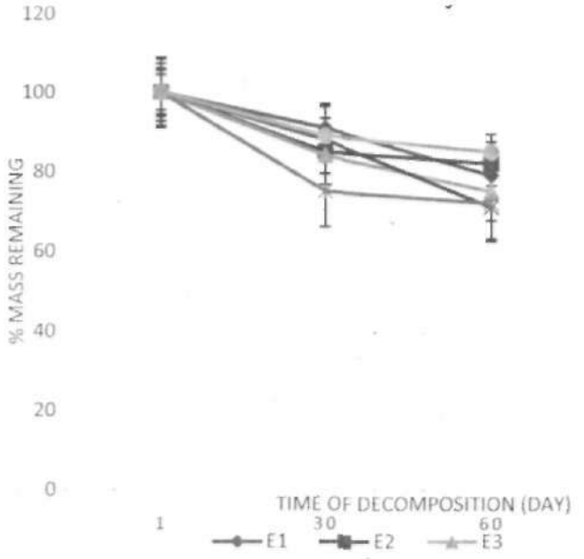

Fig. 1: Percentage mass of *E. camaldulensis* leaf litter remaining after different periods of decomposition.

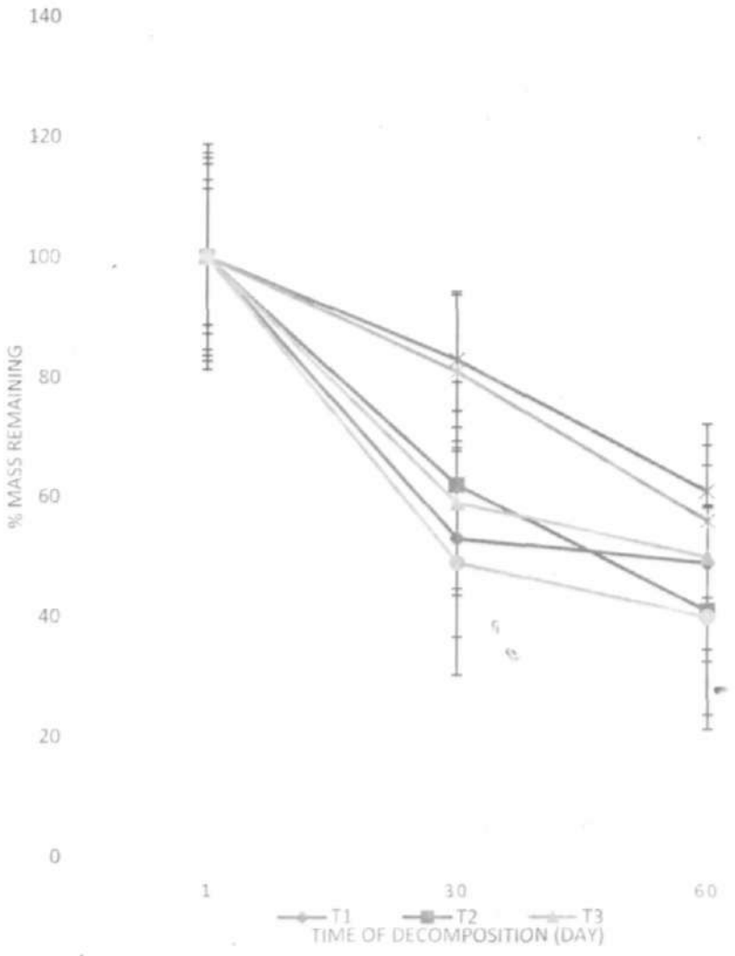

Fig. 2: Percentage mass of *T. grandis* leaf litter remaining after different periods of decomposition.

Table 1: A comparison of decomposition rates of leaf litter samples of *E. camaldulensis* and *T. grandis*

	Decomposition rates, k (day^{-1})	
Samples	*E. camaldulensis*	*T. grandis*
1	0.00393	0.01189
2	0.00331	0.01486
3	0.00479	0.01155
4	0.00571	0.00824
5	0.00548	0.00966
6	0.00271	0.01527
T-Value = 6.14, P-Value = 0.001		

Table 2: Carbon (IV) oxide evolution (µg/g/day) from the decomposing leaf litter samples

Samples	Day 1			Day 30			Day 60		
	Control	*E. camaldulensis*	*T. grandis*	Control	*E. camaldulensis*	*T. grandis*	Control	*E. camaldulensis*	*T. grandis*
1	110.0	320.0	180.0	113.8	413.3	200.0	114.4	498.0	156.7
2	125.0	390.5	540.5	109.5	422.0	581.3	144.0	471.1	516.5
3	92.0	380.7	140.4	129.0	455.5	212.5	115.0	312.4	273.3
4	186.0	500.0	139.0	189.7	572.2	187.7	132.6	554.4	266.6
5	150.0	250.9	240.0	199.5	302.4	242.0	194.0	305.5	260.8
6	90.0	400.0	250.6	100.0	440.5	312.2	98.0	442.0	319.5
	F-Value = 8.91, P-Value = 0.003			F-Value = 12.23, P-Value = 0.001			F-Value = 15.62, P-Value = 0.0002		

Table 3: The chemical properties of soil and leaf litters during the decomposition of *E. camaldulensis* litter samples

Sample	Time (Day)	pH	C (mg g^{-1})		N (mg g^{-1})		P (mg g^{-1})		K (mg g^{-1})		Ca (mg g^{-1})		Mg (mg g^{-1})	
			Leaf	Soil	Leaf	Soil	Leaf	Soil	Leaf	Soil	Leaf	Soil	Leaf	Soil
1	1	6.5	555.12	401.00	23.67	19.21	0.32	1.45	0.82	0.61	16.78	6.82	0.64	0.26
	30	4.6	520.00	422.11	19.89	22.00	0.29	1.92	0.80	0.87	15.34	9.94	0.44	1.24
	60	4.5	452.45	422.18	19.00	22.50	0.21	2.20	0.75	0.88	15.11	10.01	0.21	1.25
2	1	7.1	512.87	518.00	22.75	13.43	0.41	1.23	0.76	0.32	14.17	11.48	0.52	0.30
	30	5.9	501.35	542.34	20.56	16.90	0.28	1.47	0.61	0.50	13.98	18.00	0.41	0.71
	60	5.0	330.33	578.42	17.67	19.64	0.25	1.48	0.52	0.55	11.00	8.85	0.13	0.64
3	1	6.8	499.97	437.12	25.90	11.34	0.30	1.43	0.85	0.64	15.69	10.20	0.55	0.21
	30	5.2	487.53	444.50	19.98	12.92	0.21	1.45	0.81	0.71	15.63	10.86	0.48	0.34

	60	6.0	422.76	449.60	18.85	15.93	0.21	1.60	0.63	0.52	13.00	11.02	0.32	0.45
4	1	5.8	539.40	459.77	20.86	15.64	0.38	0.82	0.80	0.43	13.34	5.29	0.61	0.56
	30	5.6	504.17	490.35	17.64	18.79	0.35	1.87	0.63	1.00	12.02	11.23	0.44	0.60
	60	6.3	500.78	490.80	15.00	19.00	0.30	1.90	0.61	1.20	10.54	10.05	0.25	0.71
5	1	7.4	532.86	501.22	21.83	23.40	0.43	1.64	0.77	0.91	14.14	8.56	0.52	0.19
	30	7.0	472.00	532.90	18.56	26.00	0.37	1.91	0.65	0.94	13.02	10.67	0.46	0.35
	60	4.7	434.33	541.79	18.01	26.89	0.29	1.91	0.45	0.94	11.09	10.80	0.45	0.45
6	1	5.6	560.05	419.00	23.46	10.01	0.39	0.36	0.72	0.57	10.13	12.13	0.51	0.62
	30	6.1	525.42	522.78	20.05	17.45	0.31	0.60	0.55	0.70	10.00	12.20	0.39	0.65
	60	6.8	520.15	604.45	19.91	17.50	0.31	0.62	0.46	0.73	8.16	11.05	0.21	0.67

Table 4: The chemical properties of soil and leaf litter during the decomposition of *T. grandis* leaf litter samples

Sample	Time (Day)	pH	C (mg g^{-1})		N (mg g^{-1})		P (mg g^{-1})		K (mg g^{-1})		Ca (mg g^{-1})		Mg (mg g^{-1})	
			Leaf	Soil	Leaf	Soil	Leaf	Soil	Leaf	Soil	Leaf	Soil	Leaf	Soil
1	1	4.6	500.40	381.07	20.45	17.67	0.28	1.25	0.72	0.91	13.14	11.18	0.54	0.31
	30	5.0	467.65	402.81	19.76	19.54	0.22	1.42	0.66	1.83	11.67	11.62	0.30	0.32
	60	5.8	433.33	441.11	17.19	20.20	0.21	1.50	0.54	1.54	11.50	15.60	0.30	0.54
2	1	6.1	489.34	433.20	15.96	15.00	0.43	1.21	0.68	0.82	16.54	10.65	0.55	0.26
	30	5.3	412.12	440.00	15.00	15.01	0.36	1.56	0.53	0.94	14.67	10.87	0.29	0.30
	60	5.4	336.34	448.50	14.67	14.93	0.28	1.84	0.43	1.67	14.53	9.94	0.13	0.46
3	1	4.8	523.07	389.11	19.76	17.78	0.34	1.34	0.87	0.62	13.85	12.00	0.41	0.18
	30	4.2	423.74	413.78	18.04	17.90	0.31	1.65	0.77	0.67	11.00	12.87	0.32	0.20
	60	5.4	400.45	415.12	18.00	15.72	0.25	2.30	0.71	1.34	10.54	14.42	0.27	0.61
4	1	5.7	474.08	376.76	19.00	13.42	0.29	1.19	0.65	0.92	12.03	10.60	0.39	0.36
	30	5.9	458.59	381.00	17.75	16.00	0.20	1.21	0.54	0.99	9.76	12.11	0.31	0.38
	60	6.2	336.65	400.07	17.05	18.33	0.20	1.95	0.44	0.56	9.70	11.92	0.23	0.47
5	1	4.4	435.00	412.56	18.95	19.64	0.25	1.29	0.88	1.03	10.43	11.43	0.25	0.25
	30	4.3	403.33	418.90	18.56	21.11	0.20	1.36	0.62	1.72	10.01	11.98	0.19	0.26
	60	4.9	375.50	460.19	16.65	20.84	0.18	1.34	0.61	1.75	10.01	12.45	0.16	0.26

6	1	4.8	413.97	363.00	21.26	14.72	0.32	1.14	0.73	0.56	13.71	9.94	0.43	0.37
	30	4.5	387.05	382.59	20.00	17.82	0.26	1.32	0.60	0.92	12.00	10.60	0.41	0.42
	60	6.7	350.00	392.60	18.85	17.56	0.22	1.52	0.59	0.88	12.00	12.80	0.36	0.42

Table 5: Soil chemical properties under *E. camaldulensis* plantation

Sample	$C0_2$	pH	C	N	P	K	Ca	Mg
1	410.4	5.3	415.10^{a}	21.24^{a}	1.86^{a}	0.79	8.92	0.92
2	427.9	6.0	546.25^{a}	16.66^{b}	1.39^{b}	0.46	12.78	0.55
3	382.9^{a}	6.0	443.74	13.40^{ac}	1.49^{c}	0.62	10.69	0.33
4	542.2^{ab}	5.9	480.31	17.81^{d}	1.53^{d}	0.88	8.86	0.62
5	286.3^{b}	6.4	525.30	25.43^{bcde}	1.82^{e}	0.93	10.01	0.33
6	427.5	6.2	515.41	14.99^{e}	0.53^{abcde}	0.61	11.80	0.65

Values on the same column that have the same letter in the superscript are significantly different at 0.05 level using Tukey's Honestly Significant Difference Test

Table 6: Soil chemical properties under *T. grandis* plantation

Values on the same column that have the same letter in the superscript are significantly different at 0.05 level using Tukey's Honestly Significant Difference Test

Sample	$C0_2$	pH	C	N	P	K	Ca	Mg
1	178.9^{a}	5.1	408.33	19.14^{a}	1.39	1.43	12.80	0.39
2	546.1^{abcde}	5.6	440.57^{ab}	14.98^{ab}	1.53	1.14	10.48	0.34
3	208.7^{b}	4.8	406.00^{a}	17.13	1.76	0.87	13.09	0.33
4	197.8^{c}	5.9	385.94	15.91^{c}	1.45	0.82	11.54	0.40
5	247.6^{d}	4.5	430.55	20.53^{b}	1.33	1.50	11.95	0.25
6	294.1^{e}	5.3	379.39^{b}	16.70^{c}	1.32	0.78	11.11	0.40

Table 7: Comparison of the soil chemical and microbiological parameters under *E. camaldulensis* and *T. grandis* plantations

Parameters	T-Value	P-Value	
CO_2	3.08	0.007	*
pH	2.64	0.013	*
C	5.14	0.0001	*
N	0.69	0.496	Ns
P	0.206	0.838	Ns
K	3.2	0.003	*
Ca	1.9	0.066	Ns
Mg	3.46	0.003	*

Table 8: Correlation of soil chemical properties under *E. camaldulensis* plantation

	CO_2	pH	C	N	P	K	Ca
pH	-0.383						
C	-0.140	0.764**					
N	-0.494	0.021	0.077				
P	-0.267	-0.372	-0.386	0.634			
K	-0.115	-0.012	-0.266	0.726	0.530		
Ca	-0.152	0.457	0.676	-0.470	-0.603	-0.864*	
Mg	0.480	-0.799**	-0.412	0.048	-0.044	0.012	-0.289

***P < 0.05, **P < 0.01**

Table 9: Correlation of soil chemical properties under *T. grandis* plantation

	CO_2	pH	C	N	P	K	Ca
pH	0.317						
C	0.575	-0.329					
N	-0.555	-0.815*	0.184				
P	0.065	-0.035	0.149	-0.389**			
K	-0.004	-0.531	0.690	0.740	-0.357		
Ca	-0.786**	-0.586	-0.138	0.574	0.369	0.212	
Mg	-0.135	0.733**	-0.723	-0.534	-0.084	-0.566	-0.121

***P < 0.05, **P < 0.01**

Discussion

Leaf litter decomposition is determined by exogenous and endogenous variables such as environmental conditions, chemical compositions of the litter and site conditions (Suberkropp and Chauvet, 1995). Soil microbiological characteristics, soil chemical properties and litter chemistry have been considered as important factors controlling the decomposition rate of leaf litters (Singh *et al*., 1999; Sundarapandian and Swamy, 1999; Ribeiro *et al*., 2002; Tateno *et al*., 2007). Leaf litter samples of *E. camaldulensis* and *T. grandis* collected from different sampling sites under Eucalyptus and Tectona plantations respectively, had different decomposition rates which suggest that soil chemical and microbiological characteristics of each sampling site were not the same. Differences in these chemical and microbiological characteristics represent the important factors which determined their decomposition rate. Swift *et al*., (1979); Sundarapandian and Swamy, (1999); Tripathi *et al* (2006) and Tateno *et al*., (2007) have submitted that the difference in the quantifiable chemical compositions of the leaf litters are good indicator of the decomposition rate This result agrees with the findings of Pandey *et al*. (2007) who reported that decomposition rate of Quercus leaf litter samples differed in different sampling sites under Quercus plantation. He attributed this to differences in the site conditions. Ozalp *et al* (2007) reported that water tupelo leaves on the Big and Little Bull Creeks side decomposed faster than on the Pee Dee River side probably due to the environmental factors such as nutrient availability and soil chemical properties.

Difference in decomposition rate among *E camaldulensis* leaf litter samples and *T. grandis* samples may also be attributed to the difference in site fertility. Some studies have shown that leaf litter decomposes faster on more nutrient-rich stands (Swift *et al*., 1979).

Variations in the decomposition rate of leaf litter samples of each plant species under the same environmental conditions as reported in this study can be attributed to the differences in soil carbon, carbon (IV) oxide evolution, nitrogen and phosphorus. Changes in the soil chemical properties of the litter samples during decomposition was due to the mineralization and changes in microbial population during the period of decomposition (Norden, 1994; Chen *et al*., 2011).

According to Melillo *et al* (1989), the result of this investigation which reveals that the mass loss of litter occurred exponentially with time (Fig. 2 and 3), can be described by a two phase model: an initial phase of constant mass loss and a phase of very slow loss. In all the samples, the pattern of remnant mass over time suggests that, at sixty days of decay, leaves remained at Phase I of Melillo *et al* (1989). A sharp decline in mass of leaf litters during the early stages of decomposition can be due to the initial high metabolization of soluble chemical components and also due to a favourable environmental conditions for decomposition (Singh, 1969; Anderson, 1973; Williams and Gray, 1974). These soluble metabolizable components which control the initial mass loss rates include soluble carbohydrates, phenolics, and tannins (Berg and Tamm, 1991).The degradation of complex molecules into more simple compounds, as sugar, amino acids as well as lignocellulose material (La Caro and Rudd 1985) could have inhibited the rapid mass loss at the later stage of the decomposition. Machado (1995) also had a similar results and reported that the decomposition rate of leaves of some native trees in a secondary semi-deciduous forest at southeast Brazil, decreases with increasing decomposition time.

The result shows that the decomposition rates of *T. grandis* leaf litter samples were faster in comparison with that of *E. camaldulensis* leaf litter samples (Fig. 2 and 3). The decomposition rate was also observed to be significantly different between the two plant species (Table 3). This may be due to their different soil chemical and microbiological parameters. Swift *et al* (1979) opined that the decomposition process is regulated by three of variables: (i) the characteristics of the microbial community (ii) Litter chemistry and quality and (iii) the chemical properties of the soil. The decomposition rates of all materials are governed by these variables though their relative importance can vary from site to site. Some researches carried out have shown that in general, the rate of decomposition of Eucalyptus leaves is slower than that

of many broad leave species (Hatch, 1955; McColl, 1966; Mary and Sankaran, 1991). From the findings of Soni (1985), the decomposition rate of leaf litter of *Eucalyptus spp* was slower than that of *Tectona spp* and *Butea monosperma* (Lamk) Taub at Jabalpur. The slow rate of leaf litter decomposition of *E. camaldulensis* relative to *T. grandis* was explained by Lorenz *et al* (2000) who reported that tannins reduces digestibility and palatability of plants and reduce microbial activity, hence slows down the decomposition of *Eucalyptus camaldulensis leaf litters*. Also, De Moral and Muller (1969) reported that the slow rate of decomposition of *Eucalyptus* leaf litter isdue to the presence of polyphenols like ellagic, chlorogenic and gallic acids and volatile terpenes in their leaves. The presence of polyphenols in leaves is known to reduce decomposition rates of litters by inhibiting the microbial enzyme activity (Benoit and Starkey, 1968, Williams and Gray, 1974). Moreover, the physical properties of *Eucalyptus* leaves such as hard texture and waxy coating on the surface, are also known to influence decomposition rate (Swift *et al*,. 1979; Ramakrishnan, 1985).

The difference in carbon (IV) evolution in all the samples of both plant suggests that varied nutrient availability and site conditions affect microbial activities. Carbon (IV) oxide evolution was highest on day 60 of decomposition in all the samples because of intense microbial activities during decomposition. This finding agrees with Rejmankova and Sirova (2007) who reported that microbial activities are high at the later stage of decomposition when litters have high nutrient availability. This variation in microbial activity between litters may be attributed to the differences in physical and chemical characteristics of the litters, which are known to affect decomposition rates (Swift *et al.*, 1979).

The decreased organiccarbon content of the litter and its increase in soil organic carbon is due to leaf litter decomposition since decomposition will release organic carbon into the soil. Similar findings for *Tectona spp and Eucalyptus spp* have also been reported by Prasad *et al*(1991) and Flaig (1984).This result is in conformity with the findings of various researchers (Hosur and Desog, 1995; Manhas *et al.*, 1997; Duttaand Dhiman, 2001).

The decrease innitrogen concentration of the leaf litter with the advancement of decomposition can be attributed to higher demand for nitrogen during the intense microbial activity. This finding is corroboratedby the findings of Kumar and Deepu (1992), who also observed an increasein soil nitrogen and a decrease in litter nitrogen during decomposition of leaf litter of *Casuarina, Acacia* and *Leucaena*. As stated by Debnath and Hajra (1972), the decrease in leaf litter nitrogen may also be due to the adverse climatic conditions and rapid immobilization of nitrogen by microorganisms. Decomposition of litter is known to provide a stable supply of carbon and energy for microorganisms and cause an increase in the microbial biomass pool, thereby increasing soil respiration rate which in turn enhances nitrogenavailability in the soil (Surekha *et al.*, 2004).

Cozzo (1976) reported that phosphorus is released through different patterns, depending on its initial concentration and site conditions. In the present study, higher available phosphorus content was observed before the experiment in litter samples of both plant species. A significant decline in available phosphorus was recorded towards end of the experiment. This initial higher amount of available phosphorus concentration of decomposing litter may be attributed to biological translocation from deeper soil layers (McBrayer and Cromaek, 1980). The decrease in phosphorus concentration towards the end of the experiment can be ascribed to high rate of litter decomposition in the course of decomposition (Arunanchalam *et al.*, 1998). Lal *et al* (2000) clearly explained that the increase in available soil phosphorus content could be attributed to the production of organic acids during decomposition, thereby increasing the availability of phosphorusin soils.

Potassium, magnesium and calcium are among the most mobile nutrients in the litters of *Eucalyptus spp and Tectona spp* (Attiwill 1968, O'Connell and Grove 1996).Decrease in the level of potassium content of the leaf litter and its increase in the soil during decomposition may not be ascribed to the activities of microbes due to its non-correlation with total viable bacteria and fungi. Potassium is not strongly bound in organic structures, unlike nitrogen and sulphur, as reported by Hosur and Desog (1995), hence, microbial action is not critical for potassiumrelease as it is for the mineralization of organic bound elements. This could be one of the reasons that accounted for lower immobilization as indicated by the large release to the available pool (Chaminade, 1955).

The initial increase in calcium concentration in the decomposing litter could be attributed to slower rate of decomposition. The noticeable decrease in calcium concentration of leaf litter and an increase in soil calcium concentration, is inconformity with the results of Thomas (1969). The lower calcium content in the soil before litter decomposition can be attributed to low microbial activities in soil (Surekha *et al.*, 2004).

A decline in magnesium level of the leaf litter samples during decomposition is due to the fact that it is necessary requirement and component of enzymes of litter decomposing microbes (Swift *et al.*, 1979). This resultsare in agreement with the findings of Sivakumar (1992). Moreover, the significant increase in soil magnesium during decomposition may be due to biological mobilization of magnesium into the soil (Staff and Berg,1982).

Conclusion

The decomposition rates of *E. camaldulensis* and *T. grandis* leaf litter samples in different sampling

sites were different, which is due to variation in their soil chemical properties. The rate of decomposition of *E. camaldulensis* leaf litter was slower than that of *T. grandis* leaf litter. The decomposition of leaf litter is accompanied with the evolution of CO_2 which is an indication of exhaustion of carbon compounds in the litter. It is concluded that site condition is a major determinant of the decomposition rate of leaf litter of *E. camaldulensis and T. grandis* samples.

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