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Decomposition and Nutrients Release Pattern of Leaves, Stems / Vines and Roots of Selected Leguminous and Non-Leguminous Plant Species

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Abstract. Decomposition and nutrients release pattern of leaves, stems/vines and roots of leguminous plants (*Pueraria phaseoloides* and *Centrosema brasilianum*) and non-leguminous plants (*Chromolaena odorata* and *Panicum maximum*) were examined for a period of 98 days. The decomposition rate declined in the order *P. maximum* > *C. odorata* > *P. phaseoloides* > *C. brasilianum*. On the 98th day, between 63% and 71% of stems/vines only had decomposed. The % mass of the remaining materials were in the order of *C. odorata* > *P. phaseoloides* > *C. brasilianum* > *P. maximum* and the decomposition rate was in the reverse order. The mass loss and decomposition rates of the parts of the plant species followed the initial N concentrations of the residues in the order of leaves > roots > stems/vines. The initial N contents in plant residues varied from 0.42 to 3.19 g/kg and P from 0.03 to 0.27 g/kg. The pattern of N remaining in the stems/vines of the species at 98 days after placements (DAP) was in the order *P. phaseoloides* (49%) > *C. odorata* (42%) > *C. brasilianum* (41%) > *P. maximum* (36%). The chemical composition of the residues shows that the leaves are richer in N and P than the roots and least in stems/vines in the order *C. odorata* > *C. brasilianum* > *P. phaseoloides* > *P. maximum*. A direct relationship was observed between the initial N contents of the residues and initial polyphenol contents ($r = 0.72$, $p < 0.01$), but no relationships with the P content of the residues. The data reported in this study shows that the decomposition patterns of above and below - ground residues of leguminous and non-leguminous plant species could have positive effect on nutrients requirement of crops.

Keywords: nutrients release, plant decomposition, non-leguminous, *Pueraria phaseoloides*, *Centrosema brasilianum*, *Chromolaena odorata*, *Panicum maximum*

Introduction

In agroforestry systems, plant residues enter the soil system as crop residues and tree leaf litter and pruning residues. These plant residues are sources of nutrients and organic matter when they decompose and could contribute to the maintenance of soil fertility. The use of plant residues to improve crop production has become a major focus of soil fertility management in the tropics (Tian, 1998). Thus, bio-availability of nutrients is a function of nutrients supply and nutrients limitation, which in turn depend on differences in the rate of decomposition, mineralization and other processes (Swift *et al*., 1979). Residue management for nutrients recycling involves synchronizing nutrients release with crop demands. This could be achieved by manipulating the nutrients release pattern of the residues through appropriate timing and placement of organic input to meet crop use (Myers *et al*., 1994). For instance, incorporating plant residues into agricultural soils can sustain organic carbon (C) content, improve soil physical properties, enhance biological activities, and increase nutrient availability (Zeng *et al*., 2010; Cayuela *et al*., 2009; Hadas *et al*., 2004).

Residue decomposition rates and nutrient release patterns are controlled by both biotic and abiotic factors, the most important of which is residue quality (Zeng *et al*., 2010; Teklay *et al*., 2007; Mungai and Motavalli, 2006; Silver and Miya, 2001). The initial concentrations of nitrogen (N), phosphorus (P), polyphenol and lignin,

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*Author for correspondence; E-mail: abuaisha2k3@yahoo.com and the ratios of C/N, lignin/N and polyphenol/N are generally recognized as the main litter quality variables controlling rates of decomposition (Zeng *et al*., 2010; Liu *et al*., 2007; Teklay *et al*., 2007; Raiesi, 2006; Silver and Miya, 2001; Mafongoya *et al*., 2000). The immobilization of nutrients during decomposition often results in reduction of soil nutrients availability and also lowers nutrients losses (Gómez Rey *et al*., 2008).

Understanding the regulatory mechanism of decomposition and nutrients release of below and above ground organic input is necessary for the prediction of mass loss and nutrients release pattern in agro-ecosystem. Since agroforestry systems contain a mixture of plant species such as trees and crops that have different growth forms and residue qualities, their mixed residues therefore, may not decompose in a similar pattern to their individual components. Because of management practices such as on-site retention of straw and tillage, residues of trees and crops usually become mixed and decompose simultaneously within the same soil volume. Interactive effects of residue mixtures on decomposition may occur when residues of component species with contrasting residue quality are mixed (Zeng *et al*., 2010; Hoorens *et al*., 2002). For example, in tropical agroforestry systems, mixing residues of trees and crops with different qualities can potentially be used to manipulate residue decomposition and regulate the timing of nutrients availability (Zeng *et al*., 2010; Sakala *et al*., 2000). Decomposition of organic matter in the soil is intrinsically heterogeneous, because a number of compounds of different characteristics and qualities are present in the original material and are produced during the decay process (Berg *et al*., 1982).

The decomposition process depends on a range of agro-ecological factors such as temperature, precipitation, soil moisture, available nutrients and biological activity of the soil. The nutrients released from decomposing residues are important stage of nutrient cycle in terrestrial ecosystem that influences primary productivity. Plant nutrients are released from litter by both, the physical leaching and break down of structural organic components by soil organisms. Elements are retained to different extent in decomposing litters by microbial immobilization. Therefore, the dynamics of a single element depends on its status as a limiting or non-limiting nutrient for microbial growth (Swift *et al*., 1979; Parnas, 1975; Gosz *et al*., 1973). Elements in limiting concentration are retained in the litter up to certain critical concentration and then released at the same rate as the organic matter decreased (Berg and Staaf, 1981). Nutrients release is determined by leaf weight loss and change in nutrients concentration in the decomposing leaves (Tian, 1998). Risasi *et al*. (1998) reported that N release pattern of decomposing roots is the same as dry-matter loss. As a part of study on regeneration of degraded soil by plant biomass under tropical climates, this study reports the decomposition and nutrients release pattern of leaves, stems/vines and roots of selected leguminous and non-leguminous plants.

Materials and Methods

Site location and plant materials. The decomposition study was carried out between July and November, at West Bank (WB) III block of International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. Residues of *Pueraria phaseoloides* and *Centrosema brasilianum* were used as leguminous plant while *Chromolaena odorata* and *Panicum maximum* were used as non-leguminous plants. The experiment was conducted on an on-going long term fallow management trial. Natural bush crop fallow (NF) and *Pueraria phaseoloides* crop fallow (PF) cycles with a year of cropping followed by a year fallow were used. The plots were under maize/cassava crop when trial was conducted.

Preparation of plant materials. Leaves, stems/vines and roots of matured plants of the plant species used were collected and air dried in the screen house prior to application. The stems/vines were cut into 10 cm size for easy placement in the litterbags. Sub samples were taken and oven dried at 65 °C for 48 h for dry matter determination. The dried samples were ground, sieved with 0.85 mm diameter sieve and analyzed for their chemical composition.

Experimental procedure. The site was laid out in a split plot arrangement in a randomized complete block design with four replications. The main plot size was 6 × 9 m, while the subplots were 6 × 4 m, totaling 24 subplots (Table 1). Forty five gram of dry matter per hectar or 5 tons of dry matter per hectare, (i.e. root, stem/vine and leaves of these plants) were placed as mulch material in 5 mm mesh size litterbags measuring 30 × 30 cm. Litterbags containing shoot residues (leaves, stem/vine) were surface placed while those with root were buried at 5 cm depth in an established maize (*Zea mays* L.) – cassava (*Manihot esculenta* Crantz) trial on NF and PF plots. Leguminous residues were placed on the plot under PF while non-leguminous residues were placed on the plot under NF prior to cropping. A total

Table 1. Layout of the experimental site

Main plot/sub plot					
Centrosema and *Pueraria*			*Chromolaena* and *Panicum*		
Root	Vines	Leaves	Roots	Stems	Leaves
:C:	:P:	:P:	:Pa:	:Ch:	:Pa:
Px xC	C: :P	Cx xP:	Chx xPa	Pa: :Ch	Chx xPa
:P:	xCx	:C:	:Ch:	xPax	:Ch:
C: :P	P: :C	P: :C	Pa: :Ch	Ch: :Pa	Pa: :Ch
xCx	:P:	xPx	xPax	:Ch:	xPax
P: :C	Cx xP	C: :P	Ch: :Pa	Pax xCh	Ch: :Pa
:P:	:C:	:C:	:Ch:	:Pa:	:Ch:

P = *Pueraria*; C = *Centrosema*; Ch = *Chromolaena*; Pa = *Panicum*; : = Maize stand; x = Cassava stand.

of 240 litterbags were used and each replicate had 30 litterbags, so that each treatment could be sampled five times. Forty eight litterbags were retrieved randomly at 0, 5, 12, 21, 42 and 98 days after placement. The residues in the litterbags were collected for dry matter determination and chemical composition analysis.

Soil analysis. The soil pH was determined using soil distilled water ratio of 1:2. Total organic carbon (C) was determined by wet combustion. Total nitrogen (N) was analyzed by micro Kjeldahl digestion followed by distillation titration (Tian *et al*., 2007). Available phosphorus (P) in the soil was measured using the Oslen method as modified by Okalebo *et al*. (1993). Exchangeable cations were extracted from soil by 1N ammonium acetate (NH_4OAc). Total calcium (Ca) and magnesium (Mg) were by nitroperchloric digestion and measured by atomic absorption spectrophotometer (EMBRAPA, 1999) and determined using atomic absorption spectroscopy (AAS) while potassium (K) was determined by flame photometer. The microbial C and N of the soil was measured by the fumigation-extraction method of Amato and Ladd (1988) as modified by Joergensen and Brooks (1990). Ash free dry weight was determined by ashing the plant samples in a muffle furnace at 550 °C for 3 h.

Plant analysis. Total N, Ca and Mg and K were determined as explained above. P was determined colorimetrically by the molybdate blue method in an auto-analyzer (Zeng *et al*., 2010). Lignin, cellulose and hemi-cellulose content were determined by the acid detergent fibre method (Van Soest and Wine, 1968).

Data analysis. ***The decomposition rate constant (k)***. The decomposition rate constant (k) was estimated using the Wieder and Lang (1982) first order single exponential equation:

$$L_R/L_I = e^{-kt} \quad \ldots\ldots\ldots\ldots (1)$$

where, L_R is the weight of litter at a given time, L_I is the initial litter weight at t = 0, t is the time interval of sampling, k is the decomposition rate constant.

Nutrients released rate. Nutrients released over time by the organic matter were calculated using the formula by Giashuddin *et al*. (1993) with the following equation:

$$\%N_R = 100 - \%w \quad \ldots\ldots\ldots\ldots (2)$$

where, N_R is the nutrients released, w is the original nutrients content remaining. The original nutrients were determined using equation:

$$\%N_O = \frac{\%w_t \times \%w}{\%w_0} \quad \ldots\ldots\ldots\ldots (3)$$

where, N_O is the original nutrients, w_0 and w_t are remaining nutrients after time 0 and time t, respectively.

Decomposition and nutrients release patterns. Ash free weight of the remaining plant materials and decomposition rate constants were subjected to ANOVA, to determine difference in decomposition and nutrients release patterns of different parts of the studied leguminous and non-leguminous plant species. Earthworms number was normalized by $\log_{10}(x + 1)$ transformation and fresh earthworm weight was transformed by square root before ANOVA (Tian *et al*., 2000). The biomass ninhydrin-N (B_{NRN}), biomass C (B_c), and biomass N (B_N) were estimated according to the following relations (Joergensen and Brooks, 1990; Amato and Ladd, 1988; Shen *et al*., 1984):

$$B_{NRN} = NRN_f - NRN_n \quad \ldots\ldots\ldots\ldots (4)$$

where, NRN_f is the ninhydrin-N extracted from fumigated soil, NRN_n is the ninhydrin-N extracted from unfumigated soil:

$$B_c = 21 \times B_{NRN} \ldots\ldots (5)$$

$$B_N = 3.1 \times B_{NRN} \ldots\ldots (6)$$

Results and Discussion

Soil properties of the study area. The soil properties of the studied area are presented in Table 2. The pH ranged from slightly acidic to neutral (6.2 - 7.0). Organic C and total N contents were moderate. Available P was low, exchangeable K, Ca, and Mg were also low for both PF and NF plots. The textural class of the NF plot ranged from loamy sand in the upper 0 - 5 cm to sandy soil at 5 - 15 cm depth. The PF plot on the other hand had loamy and sand texture at both soil depths.

Table 3 shows the effect of residue parts on soil chemical properties of the site after the decomposition study. The leaves, vines and roots of leguminous plant species were of the same effect on the soil chemical properties. For the non-leguminous plant species, *C. odorata* leaf, stem and root did not affect the soil pH, available P and exchangeable K differently. The effect of the parts of the species on the soil organic C, total N and exchangeable Mg were in the order of leaves > roots > stems, while the exchangeable Ca followed the order roots > leaves > stems. There was no difference in the influence of the leaves and roots on the soil properties. *P. maximum* leaves, stem and root did not affect the soil chemical properties.

Chemical composition of the residue. Chemical compositions of the residues are shown in Table 4. The N and P were found in higher contents in the leaves than roots and least in stems/vines. The N was in the order of *C. odorata* > *C. brasilianum* > *P. phaseoloides* > *P. maximum*. In *P. phaseoloides*, *C. odorata* and *C. brasilianum* P content of the plant parts was in the order of leaves > roots > stems/vines unlike *P. maximum* where it was in the order of leave > stem > root. Exchangeable K and Ca in *P. phaseoloides* were higher in the root and least in the leaves. For *C. odorata*, exchangeable K was highest in root and least in stem, while Ca content was highest in the leaves and least in stems. In *P. maximum* exchangeable K and Ca were in the order of leaf > root > stem. The Mg content was highest in leaves and least in vines of leguminous residues while it was in the order of stems > leaves > roots in the non-leguminous residues.

The polyphenol content of the leguminous species was in the order of leaves > roots > vines and in the non-leguminous species it was in the order of leaves > stems > roots. A direct relationships was observed between the initial N contents of the residues and initial polyphenol contents ($r = 0.72$, $p < 0.01$), but no relationships with the P content of the residues.

The lignin was higher in the stems/vines and least in the leaves for all the species except in *P. maximum* where the least concentration was in the root. The cellulose content followed similar content as the polyphenol content for all plant parts. Correlation analysis showed that the initial cellulose contents of these residues were negatively correlated with initial N and P content of the materials ($r = -0.85$, $p < 0.01$ for N and $r = -0.69$, $p < 0.05$ for P), respectively. Hemicellulose was highest in *P. phaseoloides* leaves but least in the vine, however, the root of *C. brasilianum*, has higher concentration of hemicellulose while the

Table 2. Soil properties of the studied area before the study

Properties	Natural fallow	*Pueraria* fallow	Natural fallow	*Pueraria* fallow
	(0 – 5 cm)		(5 – 15 cm)	
pH (H_2O) (1:2)	6.9	6.7	7.0	6.2
Organic carbon (g/kg)	16.4	15.4	8.2	6.8
Nitrogen (g/kg)	1.6	1.5	0.9	0.7
Average phosphorus	6.2	6.2	2.9	2.1
Potassium [cmol (+)/kg]	0.5	0.3	0.3	0.4
Calcium [cmol (+)/kg]	5.4	3.8	3.7	3.0
Magnesium [cmol (+)/kg]	1.1	0.8	0.7	0.6
Sand (g/kg)	829.6	790.5	880.3	853.6
Silt (g/kg)	107.4	152.9	62.0	82.4
Clay (g/kg)	63.0	56.6	57.8	63.1
Texture	Loamy sand	Loamy sand	Sand	Loamy sand

Table 3. Soil properties of the studied area after the study

Properties	*Pueraria*			*Centrosema*			*Chromolaena*			*Panicum*		
	Leaf	Vine	Root	Leaf	Vine	Root	Leaf	Stem	Root	Leaf	Stem	Root
pH(H_2O) (1:2)	6.1	6.1	6.1	6.1	6.0	6.3	6.3	6.4	6.5	6.5	6.5	6.5
Organic carbon (g/kg)	5.3	6.8	5.3	5.9	5.6	5.3	8.8	5.8	8.5	8.0	6.7	6.5
Nitrogen (g/kg)	0.5	0.6	0.4	0.6	0.5	0.4	0.9	0.5	0.9	2.9	0.8	0.8
Average phosphorus (mg/kg)	2.5	2.0	1.9	2.1	1.9	0.6	2.7	2.6	3.4	2.5	1.8	2.1
Potassium [cmol (+)/kg]	0.9	0.5	0.5	0.4	0.4	0.5	0.7	0.7	0.6	1.1	0.7	0.6
Calcium [cmol (+)/kg]	2.3	2.8	2.4	3.2	2.6	3.2	4.7	3.3	5.1	4.3	3.6	3.6
Magnesium [cmol (+)/kg]	0.3	0.4	0.4	0.6	0.4	0.5	0.9	0.5	0.8	0.7	0.7	0.5

Table 4. Soil properties (chemical composition) of the studied area after the study

Properties (%)	*Pueraria*			*Centrosema*			*Chromolaena*			*Panicum*		
	Leaf	Vine	Root	Leaf	Vine	Root	Leaf	Stem	Root	Leaf	Stem	Root
Nitrogen	2.90	0.93	1.17	3.17	0.96	1.17	3.19	0.50	0.88	1.31	0.42	0.60
Phosphorus	0.15	0.06	0.11	0.27	0.11	0.13	0.20	0.03	0.06	0.10	0.09	0.05
Potassium	2.28	4.85	6.29	2.42	3.35	1.64	1.57	0.39	3.53	2.15	1.28	1.50
Calcium	0.27	0.31	0.40	0.40	0.30	0.34	0.41	0.06	0.24	0.13	0.04	0.07
~~Magnesium~~	~~0.26~~	~~0.11~~	~~0.16~~	~~0.28~~	~~0.22~~	~~0.26~~	~~0.45~~	~~0.83~~	~~0.40~~	~~0.36~~	~~0.76~~	~~0.33~~
Lignin	9.72	11.22	11.14	6.36	14.92	12.58	7.46	12.18	11.64	4.60	10.66	2.16
Polyphenol	1.39	0.45	0.58	1.61	0.53	0.56	2.90	1.63	1.15	0.91	0.45	0.38
Cellulose	26.48	45.74	43.08	28.08	44.80	41.68	12.06	52.56	40.44	35.62	46.82	32.86
Hemicellulose	20.74	14.72	16.18	9.47	10.66	14.12	7.44	11.04	10.38	22.90	18.78	17.56

least concentration was found in the vine. In the non-leguminous residues, *C. odorata* had highest concentration of hemicellulose in the stems and the least concentration in the leaves. *P. maximum* had highest concentration in the leaves while its root had the least concentration.

Residue decomposition. The residue remaining over time (undecomposed materials) expressed as percentage of the initial amount applied are shown in Fig. 1. There were no significant differences among the species ($p < 0.05$) tested at any sampling period. At 42 days after placement (DAP), the quantities of undecomposed leaves of the leguminous species were similar but different from that of non-leguminous plant species. *C. brasilianum* had the highest amount of undecomposed material (53%), followed by *P. phaseoloides* (49%) *C. odorata* (37%) and *P. maximum* (35%). At 98 DAP, *C. odorata* leaves had decomposed completely. The decomposition rate declined in the order of *P. maximum* > *C. odorata* > *P. phaseoloides* > *C. brasilianum*. The decomposition of stems/vines was not significantly different for all the plant species throughout the sampling period ($p > 0.05$). At 98 DAP, between 63% and 71% of stems/vines only had decomposed. The % mass of the remaining material were in the order of *C. odorata* > *P. phaseoloides* > *C. brasilianum* > *P. maximum* and the decomposition rate is in the reverse order.

The dry matter loss of *P. maximum* root was rapid within the first 12 DAP, compared with other species. It then followed a similar trend as that of *C. odorata* and *C. brasilianum* roots from 21 DAP through 98 DAP. *C. odorata* and *C. brasilianum* roots had steady decomposition rate from 42 through 98 DAP. *P. maximum* had the least decomposition rate and this is clearly shown from 42 DAP. At 98 DAP, 43% of *P. maximum* roots remained whereas in *P. phaseoloides*, *C. brasilianum* and *C. odorata*. 20%, 15% and 13% of the root materials, respectively remained. The decomposition constant rate of the root residues were in the order of *C. odorata* > *C. brasilianum* > *P. phaseoloides* > *P. maximum*.

Nitrogen release pattern. The N mineralization pattern of leguminous and non-leguminous plant species were not significantly different ($p < 0.05$) particularly for the leaves over incubation period (Fig. 2). The leaves of the residue showed rapid N mineralization within the first 12 DAP and afterwards a steady mineralization through 98 days of study (Fig. 2). The N release pattern of the leaves was relatively higher than the total mass loss for most of the corresponding dates except for *P. maximum* leaf at 98 DAP.

The stems/vines of *P. phaseoloides* and *C. odorata* showed initial N immobilization at 12 DAP then followed by increasing net N mineralization throughout the decomposition period. On the other hand, *C. brasilianum* and *P. maximum* showed a steady net N mineralization throughout the study period. The pattern of N remaining in the stems/vines of the species at 98 DAP were in the order *P. phaseoloides* (49%) > *C. odorata* (42%) > *C. brasilianum* (41%) > *P. maximum* (36%).

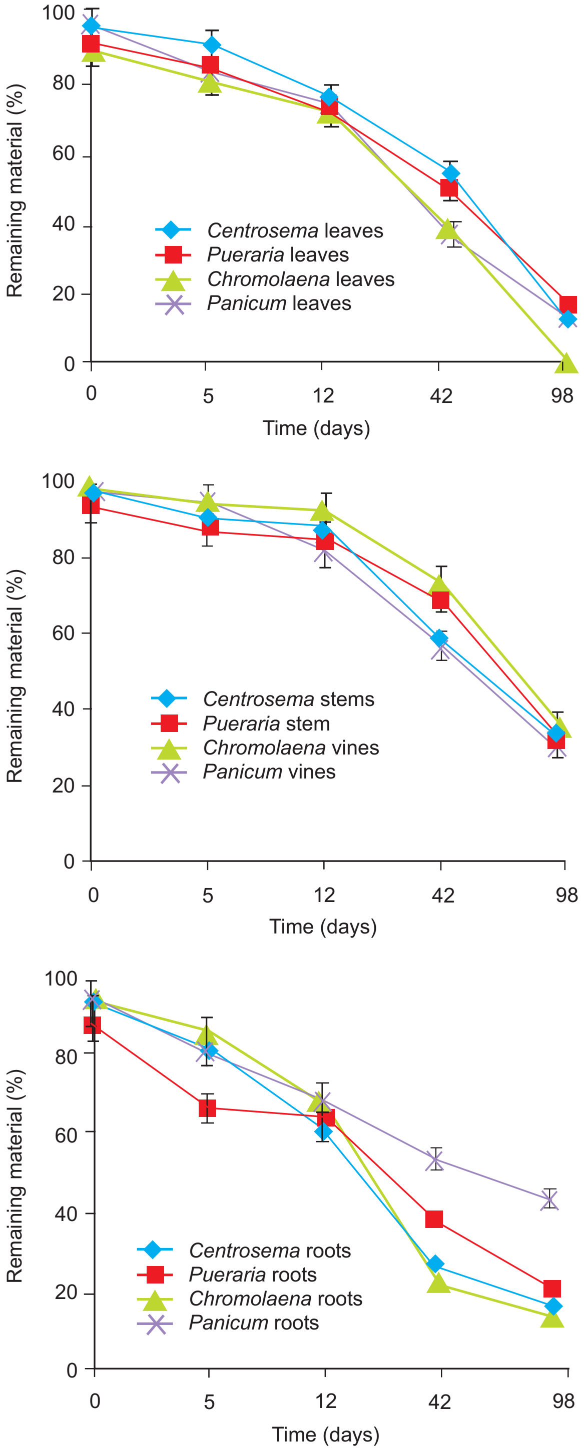

Fig. 1. Dry matter loss in shoots and roots of leguminous and non-leguminous plant species.

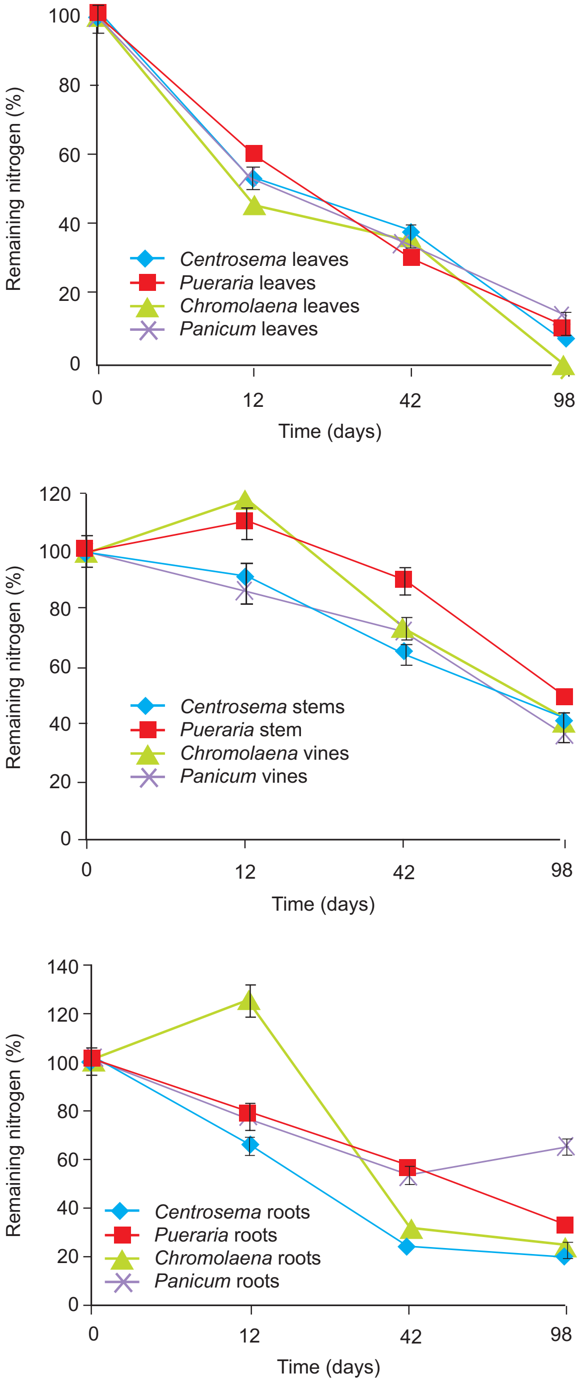

Fig. 2. Nitrogen release pattern in shoots and roots of leguminous and non-leguminous plant species.

The N release pattern of the legume roots decreased over time unlike non-leguminous roots. *C. brasilianum* root showed initial N immobilizations at 12 DAP and then mineralization afterwards. *C. brasilianum* root released the highest concentration of its N between 12th and 42nd days of the study. *P. maximum* root showed an inverse pattern of N release compared with *C. brasilianum* root. An initial rate of net mineralization was observed up till 42 DAP while immobilization was observed at 98 DAP. The effect of initial cellulose contents of the residues was positively and highly correlated with N release patterns ($r = 0.77$, $p < 0.01$), but initial N and P contents of the residues were inversely related with N mineralization rates ($r = -0.78$ N and -0.78 P, $p < 0.01$) (Table 5).

Phosphorus release pattern. Phosphorus release patterns of different species were significantly different ($p < 0.05$). The pattern of P remaining in the leaves was similar to that of dry matter loss. The percentage P remaining decreases gradually throughout the decomposition period. Unlike N, less P were released within the first 12 days of the study (Fig. 3).

For the stem/vines, P release was more rapid in *C. brasilianum* and *P. maximum* between 12 DAP through 42 DAP. At 42 DAP, 66% P and 72% P of *C. brasilianum* and *P. maximum* had been released respectively. At the end of the study (98 days) significantly higher P remained in the *C. odorata* than other plant species. The P remaining were in the order; *C. odorata* (50%) > *P. phaseoloides* (27%) > *C. brasilianum* (19%) > *P. maximum* (13%).

P release pattern of root residues of non-leguminous species was different from that of leguminous species. P immobilization was observed at 12 DAP for *C. odorata* and at 98 DAP for *P. maximum*. For the leguminous species, a rapid P mineralization (56%) was observed in *P. phaseoloides* root between the first 12 days of decomposition and a gradual mineralization afterwards. Unlike *P. phaseoloides*, *C. brasilianum* root showed an initial slow P mineralization (17%) within the first 12 DAP, then gave rapid net P mineralization of 68% at 42 DAP and followed with gradual release of P through 98 DAP (Fig. 3). The initial P contents of the residues have a weak inverse relationship with the P mineralization rates (Table 5).

Soil microbial biomass. There were significant differences ($p < 0.05$) between the plant species and the parts in their effects on microbial biomass C and N (Fig. 4). Biomass C and N followed the same pattern for all the treatments since one is a direct measure of the other (Beloso *et al.*, 1993). The inherent microbial C and N of the experimental site before the study was higher than what was observed at 12 DAP. The

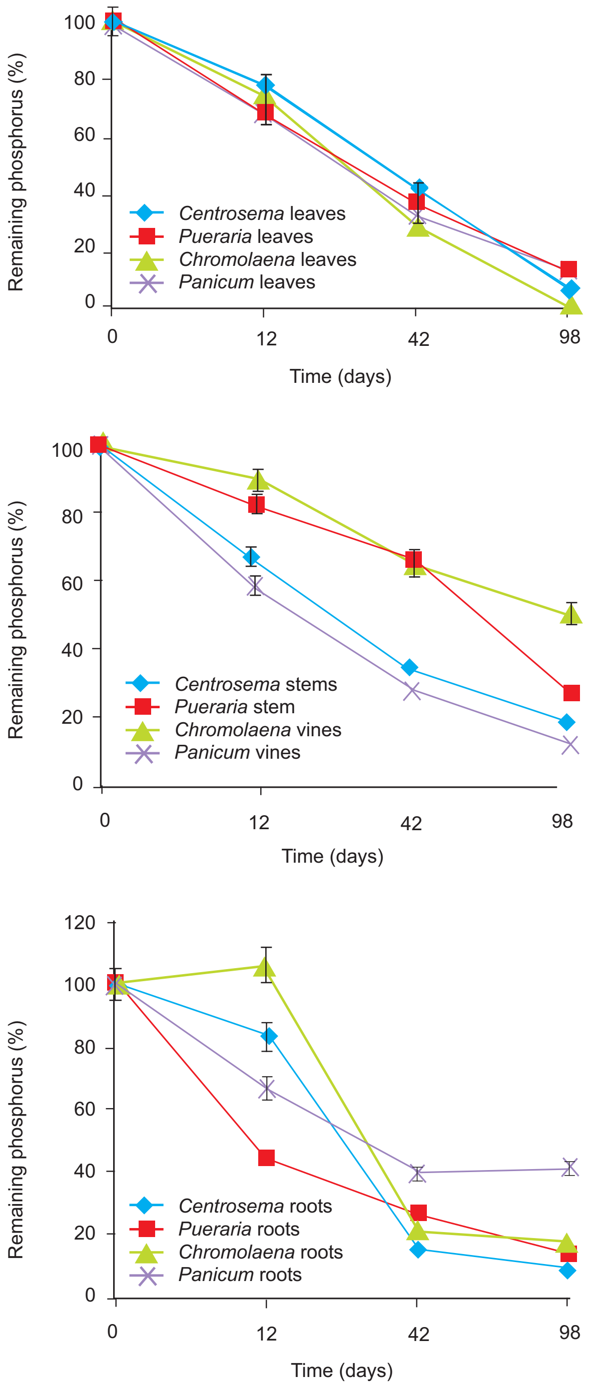

Fig. 3. Phosphorus release pattern in shoots and roots of leguminous and non-leguminous plant species.

Table 5. Inter correlation (r) among decomposition rate constant (k), residue qualities, nutrient remaining and soil microbial biomass

	Decomposition constant	Nitrogen	Phosphorus	Polyphenol	Cellulose	N-Remaining	P-Remaining	Bio C
Decomposition constant	-	-	-	-	-	-	-	-
Nitrogen	0.01 (ns)	-	-	-	-	-	-	-
Phosphorus	0.03 (ns)	0.89**	-	-	-	-	-	-
Polyphenol	0.03 (ns)	0.72**	0.52 (ns)	-	-	-	-	-
Cellulose	-0.15 (ns)	-0.85**	-0.69*	-0.68*	-	-	-	-
N- Remaining	-0.4 (ns)	-0.78**	-0.78**	-0.50 (ns)	0.77**	-	-	-
P- Remaining	-0.39 (ns)	-0.36 ns)	-0.53 (ns)	-0.01 (ns)	0.41(ns)	0.65*	-	-
Bio C	-0.43 (ns)	0.38 (ns)	0.30 (ns)	0.67*	-0.32 (ns)	-0.19 (ns)	0.12 (ns)	-
Bio N	-0.43 (ns)	0.38 (ns)	0.30 (ns)	0.67*	-0.32 (ns)	-0.19 (ns)	0.12 (ns)	1.00**

** = significant at 1%; * = significant at 5%; ns = not significant at 1%.

maximum effects of residue input on the microbial biomass C and N were observed at 42 DAP for all the parts. The reduction in biomass C and N at 98 DAP followed the decrease in dry matter loss of the residues.

Generally, soil microbial biomass C and N were higher for the leaves and least for roots except for *C. odorata* stem, which gave the overall highest biomass C and N at 42 DAP. For leaves *P. phaseoloides* had the least biomass C and N across the sampling dates. At 42 DAP the biomass C and N were in the order *P. maximum* (385 mg C/kg and 57 mg N/kg) > *C. odorata* (352 mg C/kg and 52 mg N/kg) > *C. brasilianum* (343 mg C/kg and 51 mg N/kg) > *P. phaseoloides* (270 mg C/kg and 40 mg N/kg). But at 98 DAP the influence of the plant species on biomass C and N were in the order *C. odorata* > *P. maximum* > *C. brasilianum* > *P. phaseoloides*.

For the stems/vines of the species, *P. phaseoloides* also gave the least biomass C and N at 12th and 42 DAP while the least was recorded for *C. brasilianum* at 98 DAP. At 42 DAP, the residues influenced on biomass C and N are in the order *C. odorata* (430 mg C/kg and 63 mg N/kg) > *P. maximum* (387 mg C/kg and 57 mg N/kg) > *C. brasilianum* (297 mg C/kg and 44 mg N/kg) > *P. phaseoloides* (272 mg C/kg and 40 mg N/kg). At 98 DAP *C. odorata* stem still gave the highest population of the soil biomass followed by *P. phaseoloides* vine with no distinctive difference between those given by *C. brasilianum* and *P. maximum* species.

For the roots at 12 DAP, non-leguminous species supported higher soil biomass C and N than the leguminous species with no distinctive difference between each pair of the two classes. At 42 DAP, the residue affected biomass C and N in the order of *P. phaseoloides* (239 mg C/kg and 35 mg N/kg) > *C. odorata* (221 mg C kg and 33 mg N/kg) > *P. maximum* (182 mg C/kg and 27 mg N/kg) > *C. brasilianum* (137 mg C/kg and 20 mg N/kg). At 98 DAP *P. maximum* root gave slightly higher microbial biomass C and N than other three plant species, though with no distinctive difference. Correlation analysis showed that the initial polyphenol contents of the residues had a direct relationship with soil microbial biomass C and N ($r = 0.67$, $p < 0.05$).

The ability of plant residues to decompose and release nutrients is a quality of the plant. For most of the plant species, leaves which are richer in quality than roots and stems/vines built the highest soil nutrients. The implication is that the plant part with highest quality and fastest decomposition rates encouraged higher organic matter build up. This is in agreement with the report that soil organic matter contents and relative proportion of different organic matter fractions, which have different roles in nutrients cycling and in determining soil structure, depend on the amount and quality of organic matter input (Mafongoya *et al*., 2000; 1998).

The mass loss and decomposition rates of the parts of the plant species followed the initial N concentrations of the residues in the order of leaves > roots > stems/vines, which is in agreement with earlier observations of Koenig and Cochran (1994); Rienertsen *et al*. (1994) and Douglas *et al*. (1980). *C. odorata* leaves that had the highest N content showed the most rapid mass loss while *P. maximum* that had the least N content had the least mass loss at 98 DAP.

The leguminous plant species on the other hand were intermediate based on their initial N concentrations.

Strong correlation between residue N concentration and C mineralization suggested that initial N concentration of residues was the main factor controlling decomposition and nutrient release (Zeng *et al*., 2010; Teklay *et al*., 2007; Raiesi, 2006; Mafongoya *et al*., 2000). The initial concentrations of N, lignin, polyphenol, cellulose and hemicellulose, also belong to some of the chemical factors that influence decomposition rates (Mafongoya *et al*., 2000; Palm, 1995; Constantinides and Fownes, 1994; Smith, 1994; Tian *et al*., 1993).

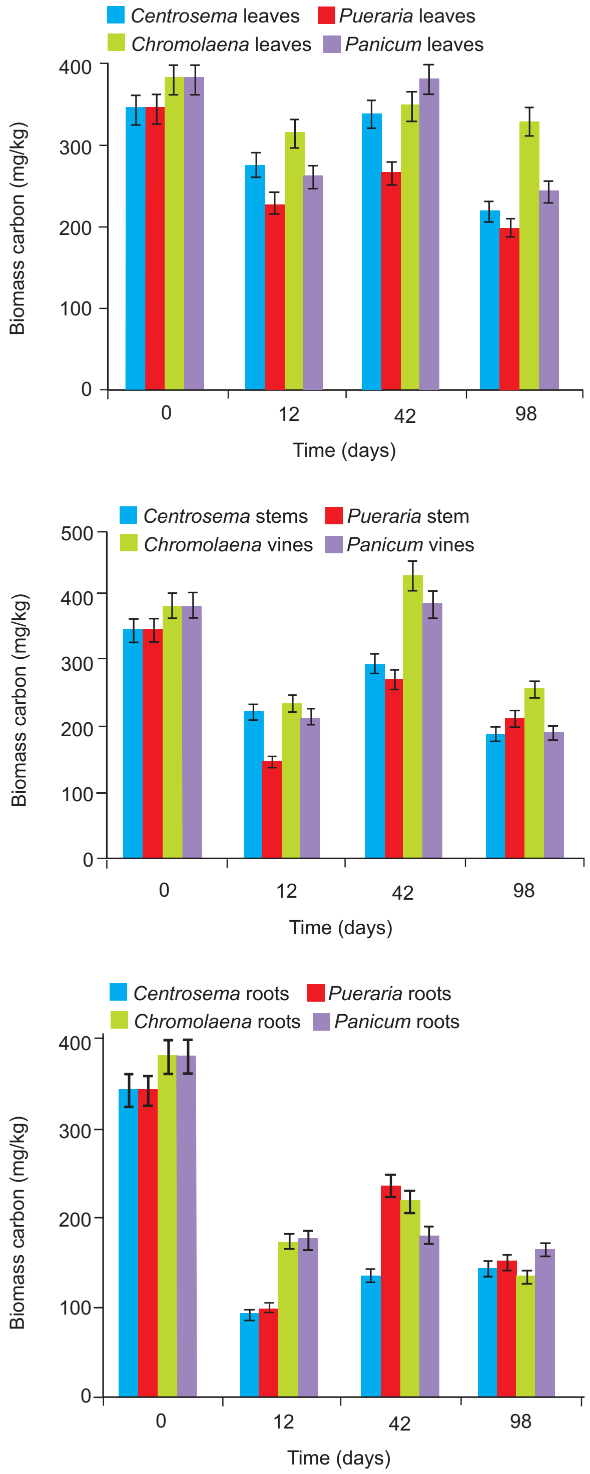

Fig. 4. Microbial biomass C under shoots and roots of leguminous and non-leguminous plant species.

Due to increased plant productivity, trees can also enhance soil fertility by increasing organic matter input through leaf and root decays (Jose *et al*., 2000). Therefore, legume crops have an advantage over other crops during species selections in temperate agroforestry systems. The lignin content of species determines the mass loss rates of the residues. For non-leguminous species the leaves, stems and roots decomposed in the order of their lignin contents. *C. odorata* root which had higher lignin decomposed faster than the *P. maximum* due to its higher N content. The least decomposition rate constant of *P. maximum* root was due to higher cellulolytic materials in the tissue or some other factors. The lignin content of *P. phaseoloides* leaf and vine was the factor that caused the slow decomposition rate. However, the lower lignin content of the root assisted its faster decomposition rates. For *C. brasilianum* the lignin content also followed the trend in the mass loss and decomposition rates of the parts.

In spite of the higher polyphenol content of *C. odorata* leaf over the leguminous species, it decomposed faster than the corresponding parts in the legumes, this was due to the higher N, low lignin, cellulose and hemicellulose contents in their parts (Hirobe *et al*., 2005). Although the polyphenol content of the *P. maximum* leaf was higher than in the stem or root, faster dry matter loss observed in this study was attributed to the higher N and relatively low lignin content of the leaf (Tian *et al*., 2007).

The higher the cellulose contents of the plant species, lower the decomposition rate except for the *P. maximum* in which reverse trend was observed. It was so for the *P. maximum* due to the relatively low lignin contents. The slower decomposition rates observed in the stem/vine compared with leaves and roots of these residues could be attributed to their higher cellulolytic content of the material (Koenig and Cochran, 1994; Rienertsen *et al*., 1994).

The P release pattern is similar to N release pattern in the leaves of the residues except that there was no initial leaching of P as was the case of N. The lower P mineralization rates observed in the residues could be due to low initial P content in these residues (Gijsman *et al*., 1997). No P immobilization was observed in the stems/vines but was noticed for roots at 12 DAP in *C. odorata* and at 98 DAP in *P. maximum*. This observation is due to the amount of soluble C compounds or little soluble P in the residues (Mafongoya *et al*., 1998; Aber and Melillo, 1991) or due to grazing action of fauna on microbial tissues (Tian, 1998; Couteaux and Bottner, 1994). Total P seemed to be a good predictor of rate of residue decomposition. The importance of P in decomposition had also been observed in other studies (Jin *et al*., 2008; Liu *et al*., 2007; Aerts and De Caluwe, 1997).

Application of different plant residues raised the soil microbial biomass C and N level that was significant between the plant species. This is a reflection of the increased number of microorganism under the residue (Goyal *et al*., 1993; Perucci, 1992). The initial decrease in the level of biomass C and N recorded at 12 DAP was attributed to degradation of the most biodegradable C fraction of organic materials by microorganisms (Beloso *et al*., 1993).

Conclusion

The quality of the residues used in this study has effect on their decomposition and nutrient release patterns. The decomposition and nutrient release pattern of the root closely followed that of leaf especially in *Chromolaena*, which was not different from those of legume roots. The roots and leaves had higher effects on the chemical properties of the soil than stems/vines, thus roots may serve as a valuable source of nutrients. The N release pattern which is correlated with initial cellulose of the residue suggested that cellulose is a predictive factor in N mineralization of leguminous and non-leguminous plant. Similarly, the polyphenolic content of the residue also enhances the microbial biomass. The data report in this study showed that the decomposition patterns of above and below - ground residues of leguminous and non-leguminous plant species could have positive effect on nutrients requirement of crops. Management techniques that combine different residue parts could be used to manipulate decomposition and nutrients release of organic residues to optimize short and long-term nutrients release patterns to meet crop nutrients requirements.

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