Octa Journal of Environmental Research
International Peer-Reviewed Journal
Oct. Jour. Env. Res. Vol. 1(3): 177-186 ***July–Sept.,2013***
Available online http://www.sciencebeingjournal.com ISSN 2321-3655
Research Article

Octa Journal of Environmental Research
(Oct. Jour. Env. Res.) ISSN: 2321-3655
Journal Homepage: http://www.sciencebeingjournal.com

DECOMPOSITION AND MACRONUTRIENTS RELEASE OF ROOTS OF *MILLETTIA THONNINGII* PLACED AT THREE SOIL DEPTHS IN THE TROPICS

Egbe E.A.[ab], Nwoboshi L.C.[c], Ladipo D[db]
a. Department of Botany and Plant Physiology, University of Buea, Box 63 Buea, Cameroon
b.. International Institute of Tropical Agriculture, (IITA) PMB3112 Ibadan, Nigeria
c.. Department of Forest Resources Management, University of Ibadan, Nigeria
d. Director, CENRAD PMB 5052 Jericho Ibadan, Nigeria
Corresponding author`s E-mail: egbe1@yahoo.com
Received: 20th June, 2013 Revised: 27th August 2013 Accepted: 15th Sept. 2013

Abstract: Decomposition of *Millettia thonningii* (Schumach and Thonn) Bak fine roots (≤2 mm) and coarse roots (2-5 mm) was conducted at IITA Ibadan, south-western Nigeria. The study investigated the effect of soil depths, root size and chemical composition of the roots on decomposition, mineralization and immobilization of nutrients. The roots were put in 2 mm mesh-bags and buried at three soil depths; 1.5, 15, and 30 cm and evaluated for 210 days. Decomposition of fine and coarse roots was significantly ($p<0.05$) greater at 15 cm soil depth than at the 1.5 cm and 30 cm soil depths. The decomposition constant at 1.5, 15 and 30 cm for fine roots were, $1* 10^{-2}$, $1.3*10^{-2}$ and $1.2*10^{-2}$ respectively while those of coarse roots were $9*10^{-3}$, $1.2 * 10^{-2}$ and $9 * 10^{-3}$ respectively. The nutrient released was greatest at the 15 cm soil depth than the other soil depths for both root sizes. Potassium was the most and easily released element while calcium was immobilized in the coarse roots. The nutrient release patterns of fine roots at 1.5, 15 and 30 cm was as follows: potassium (K)>phosphorus (P)>nitrogen (N)>magnesium (Mg)>calcium (Ca), K>P>N>Mg>Ca, and K>P>N=Mg>Ca respectively. The nutrient release patterns of coarse roots at 1.5, 15 and 30 cm soil depths were: K>Mg>N>P>Ca, K>N>Mg>P>Ca and K>N>Mg>P>Ca respectively. The results therefore indicate that soil depth and root sizes have major influence on decomposition and mineralization of nutrients though polyphenol concentrations, C: N and L: N ratios also influenced these biological processes.
Keywords: Mineralization, Immobilization, Decomposition Constant, Nutrient Release Constant Rate, Half-life and Lignin: Nitrogen Ratio

INTRODUCTION

Root residues of crops and trees contribute significantly to nutrient dynamics and carbon turnover in agricultural and forest ecosystems. Plant roots also provide pathways for the movement of carbon and energy from the canopies to the soil. Therefore root production and turnover directly impact the biogeochemical cycles of carbon and nutrients in terrestrial ecosystems (McGroddy et al., 2004; Majdi et al 2005; Espeleta and Clark 2007). The decomposition of these residues might influence the growth of succeeding crops. In some areas in the tropics where traditional cropping methods are still practiced, farmers usually allow a few trees and shrubs to remain on their farm while others are cut. Although these practices generally improve on the organic and nutrient content of the soil, the implications of these practices in the context of ecosystem functioning are little understood (Nwoboshi,

1982; Kang et al., 1984;Urquiaga et al., 1998;Hua et al., 2002). Root decomposition is influenced by complex factors that include the litter quality and edaphic factors such as temperature, moisture, nutrients, soil microflora and macrofauna changes (Brussaard et al., 1992; Gijsman et al., 1997; Dilustro et al, 2001). Apart from climatic factors such as temperature and rainfall, litter decomposition and nutrient releases also depend on lignin, nitrogen, carbon-phosphorous-, carbon-nitrogen ratios and polyphenol concentrations (Müller et al, 1988; Palm and Sanchez, 1990; Gijsman et al., 1997; Urquiaga et al. 1998; Yavitt et al; 2011).

Yang et al. (2000), Smith et al. (1998) and Berg (1984) have indicated that loss of litter to decomposition may depend on intrinsic factors such as total non-structural carbohydrate (TNC), N, P, K, Ca, Mg, S, lignin and C: N ratios. Day (1995) also observed that N, P, K, carbon (cellulose) and microsites do influence the rate of decomposition. For roots and pine needles, P, S and N control the first phase of initial decay, and lignin concentration is important in the later phase of decomposition (Berg and Ågren 1984; Gijsman et al., 1997; Urquiaga et al., 1998). Calcium concentration and C/N ratio have greater effects on root decay while mean rainfall, temperature and evapotranspiration have low influence (Whendee and Miya, 2001). Palm and Sanchez (1990, 1991) observed that plant material with concentrations of polyphenol and lignin may have little N-mineralization if the concentration is above the critical value of 15-25g/kg N and ascertained that net mineralization was dependent on lignin to polyphenol ratio rather than lignin to nitrogen or C: N ratios.

However nitrogen concentration in organic material has to be above a critical level (15-25g/kg N) before net mineralization will occur (Stevenson, 1986). The drivers of decomposition thus vary with .species and across biomes, necessitating species-specific studies in the relevant ecological region (Powers et al., 2009). Earlier studies have elucidated the root size variation and distribution with soil depth (Egbe, 1997). This study investigates how the effect of root size, soil depths, and chemical composition of the roots affects root decomposition and nutrient release pattern in a leguminous tree species, *Millettiathonningii*(Schum. &Thonn.)Bak. This would give baseline information on the nutrient input into the soil by the roots of this species in tropical terrestrial ecosystems.

MATERIAL AND METHODS

The experiment was carried out at IITA main station in Ibadan (7^{o} 30'N; 3^{o} 45'Eand altitude of 224 m) South western Nigeria. This site has a mean annual rainfall of 1360 mm and the rainfall starts in late March and ends in early November. Rainfall also has a short period of break in mid-August and it is approximately seven days. The peak period of rainfall is from late May to early August and from September to mid-October. The mean annual temperature is 28.5^{oC} and the relative humidity is 67-85% and the soil type is an Alfisol.

Decomposition of fine (≤2 mm) and coarse (2-5 mm) roots of *Millettiathonningii* were studied in the field for 210 days using the buried bag method. Roots of *M. thonningii* were collected from 15 plants that were greater than 11 years old. Root segments with diameter ≤2 mm and 2-5 mm were collected and air-dried for 6 weeks. Initial samples were collected for reference analyses. Twenty-five grams each of fine and coarse roots were then weighed and placed separately into 2 mm mesh bags (15 x 15 x 2.5 cm). These bags were buried flat in small pits (400 cm^2) at depths of 1.5, 15 and 30 cm. The experimental layout was a randomised complete block design with three replications. A total of 270 decomposition bags were used; that is, 45 bags for each soil depth and root diameter. The experiment had five collection periods namely 30, 90, 120, 180 and 210 days. For each collection period, nine decomposition bags were collected for each treatment and the roots were cleaned with a fine brush to remove soil particles. The roots were oven dried at 60°C for 72 hours and weighed with a sensitive balance (Mettler Toledo AG 204, accuracy ± 0.1 mg; Mettler Toledo Products, Switzerland).

The weighed samples were bulked with respect to root size and soil depth. Sub-samples were taken from each bulked sample, milled and analysed for macronutrients (N, P, K, Mg and Ca) percentage organic carbon, cellulose, polyphenols and lignin concentration. Organic carbon was determined by the method described by Walkley and Black (1934). The total nitrogen was determined by micro-kjeldahl method (Bremner, 1965), Exchangeable Ca, Mg, and K were extracted using the Melhlich-3 method (Melhlich, 1984) and determined by atomic absorption spectrophotometry. Available P was extracted by Bray-1 procedure and analysed using the molybdate blue method described by Murphy and Riley (1962). Lignin and cellulose was determined by acid detergent fibre (ADF) method (Clancy and Wilson, 1966; Van Soest and Wine, 1968). Total polyphenols was determined according to Allen et al. (1974).

The decomposition rate and nutrient release pattern from the roots was calculated based on the empirical equation on decomposition constant K. (Jensen, 1984).

$$Y_{(t)} = Y_{(0)}e^{-kt}$$

Where $Y_{(0)}$= original amount of root litter
$Y_{(t)}$= residual of root after a period t
e = the base of the natural logarithm (e =2.718)
k = decomposition constant

$$t_{1/2} = \frac{0.693}{k}$$

Where $t_{1/2}$ = half-life
The data collected were subjected to analysis of variance using Minitab version 16 and significant mean difference were separated by Duncan multiple range test (DMRT) at $\alpha = 0.05$.

RESULTS AND DISCUSSION

Fine and coarse root decomposition

Figure 1 shows the effect of root size and soil depth on the decomposition. Fine roots decomposed significantly ($p<0.05$) faster than coarse roots at various soil depth. The decomposition constant of fine roots ranged from $1*10^{-2}$ to $1.3*10^{-2}$/day. Coarse roots had decomposition constant range of $9*10^{-3}$ to $1.2*10^{-2}$/day. The half-life of fine roots placed at 1.5, 15 and 30 cm soil depths were 69, 53 and 57 days respectively.The rapid weight loss in decomposition of the roots within the first 30 days was probably due to leaching of soluble compounds (Saito, 1957) as a result of decomposition of readily available carbon (Urquiaga et al., 1998). The coarse roots had a half-life of 77, 57 and 77 days at 1.5, 15 and 30 cm soil depths respectively. Fine roots decomposed relatively faster than coarse roots and this may be as a result of low polyphenol and lignin concentrations, low C: N and L: N ratios and higher nitrogen concentration than that of coarse roots. This result is similar to that observed on different litter types, and in different species (Palm and Müller et al., 1988; Sanchez, 1990;Gijsman et al*.,* 1997;Gijsman et al*.,* 1997;Urquiaga et al., 1998;). The polyphenol concentration was higher in the coarse roots of the species, and this can be associated to the transport of secondary plant products to older tissues.

Haynes (1986) suggested that lignin and polyphenol reduce N-mineralization rate because lignin degraded to phenolic compounds and those with other polyphenols already present combine with plant protein and amino acids to form humic polymers that resist decay. Considering the effect of soil depths, it was noted that the decomposition rate of fine roots at 15 cm soil depth was significantly ($p<0.05$) less than that at the 1.5 cm soil depth. However, the decomposition rate of coarse roots at the 15 cm soil depth was significantly higher ($p<0.05$) than that at the 1.5 and 30 cm soil depths. The decomposition of fine roots with respect to soil depths had the following order; 15 > 30 >1.5 cm while that of the coarse roots was, 15 > 1.5 =30 cm.The decomposition of both fine and coarse roots was generally higher at the 15 cm depth than 1.5 and 30 cm soil depths. Reasons for this difference may

be associated with the types of decomposing micro-organisms and macroorganismsin the soil (1.5 cm) and those at 15 and 30 cm soil depths which need further investigation (Urquiaga et al., 1998; Leff et al., 2011). However in the dry period, it observed that there were more termites at 15 cm soil depth followed by 30 cm and least at 1.5 cm soil depth.

The rapid decomposition of both fine roots and coarse roots at 15 cm might thus be associated with the higher microbial (Leff et al., 2011) and meso-fauna populations at this soil depth than at the 1.5 or 30 cm depths. Gupta and Singh (1981) reported that decaying maize roots at 10 cm depth consistently supported large populations of meso-fauna and showed a greater rate of decay than those placed at 5 cm soil depth. Powers et al. (2009) in a study across 14 tropical countries also found higher decomposition rates in treatments with mesofauna, as opposed to those from which it was excluded. Berg (1984) however reported that large roots of Scots pine decomposed slower than small or medium roots.

Chemical composition and nutrient released/immobilized of fine and coarse roots

It was observed that fine roots had a higher percentage of organic carbon, cellulose, and macronutrients while coarse roots had higher calcium, lignin, and polyphenol concentrations than fine roots (Table 1). This may be related to the ages of these plant parts as more lignin and polyphenols increase as the plant get older. The carbon: nitrogen (C: N) and lignin: nitrogen (L: N) ratios of coarse roots were higher (20.3 and 10.7 respectively) than those of fine roots (13.9 and 5.4 respectively).The nutrient remaining/immobilized in the decomposition of fine rootsis illustrated in Table 2. After 210 days of root decomposition, the release of N, Ca and K was highest at the 15 cm soil depth and these were significantly different at P=0.05 than those at the 30 cm soil depth. These nutrients released were not significantly different ($p>0.05$) from those released at the 1.5 cm soil depth. Calcium was immobilized at the 30 cm soil depth.

The nutrient release constant of fine roots had the following ranges, N=$-3 * 10^{-3}$ and $-5 * 10^{-3}$, P= $-5 * 10^{-3}$ and $-7 * 10^{-3}$, Ca= $-3 * 10^{-3}$ and $+3 * 10^{-3}$, Mg= $-3 * 10^{-3}$ and $-4 * 10^{-3}$ and K= $-7 * 10^{-3}$ and $-12 * 10^{-3}$. The nutrient release pattern of the fine roots at 1.5, 15 and 30 cm were of the following order; K>P>N>Mg>Ca, K>P>N>Mg>Ca, and K>P>N=Mg>Ca respectively.Calcium was immobilized in the coarse roots at all the soil depths while in fine roots it was immobilized only at 30 cm depth. The immobilization of Ca may be associated with the relatively stable nature of the element in decomposing organic matter and often its concentration increases as the organic matrix in which it is embedded decays (Abboti and Crossley, 1982). Calcium released from the fine roots at soil depth 1.5 cm and 15 cm was above 100% as there was immobilization of this nutrient in the coarse roots. Unlike Ca, potassium had the highest release from both fine and coarse roots. This is due to the highly mobile nature of K and the fact that it is more easily leached from plant material. Microbes can also take-up released K or it can leached to lower soil depths. The K released from fine roots at the three soil depths was 95% more than that released by coarse roots. This was due to the fast decay rate of the fine roots. Nitrogen is also a mobile element and fine roots released more nitrogen than coarse roots by 100%, 64%, and 7% at soil depths of 1.5, 15 and 30 cm respectively. This is probably as a result of lower lignin concentration in the fine roots when compared to those of coarse roots (Vanlauweet al., 1996).

Nutrient remaining/immobilized in coarse roots is shown in Table 3. Nutrient release was highest at 15 cm for all the nutrients except Calcium, which was immobilized at all the soil depths. Phosphorus was also immobilized at 30 cm soil depth. The nutrient release constant of coarse root was as follows: N= $-1.1 * 10^{-3}$ and $5 * 10^{-3}$; P= $+0.6 * 10^{-3}$ and $1.4 * 10^{-3}$; Ca= $+1.3 * 10^{-3}$ and $+2.8 * 10^{-3}$; Mg= $-1.2 * 10^{-3}$ and $-4.9 * 10^{-3}$ and K= $-3.4 * 10^{-3}$ and $-8.9 * 10^{-3}$. The decrease in N concentration

compared to the initial value is indicative of low formation of stable complexes with lignin to resist release of nitrogen and this is consistent with findings of Mcgroddy et al. (2004).

However more nitrogen was released at the 15 cm soil depth might be due to the favourable conditions of the meso-fauna and other microbes which are important in the decomposition processes (Gonzalez and Seastedt, 2001). The amount of phosphorus released from fine root was more than 100% compared with that released by coarse roots at all the soil depths. This may be related to phosphorus fixation with Ca, as Ca concentration was higher in coarse roots than in fine roots. It has also been reported that the concentration of phosphorus in litter is important in regulating the rate of decomposition (Gijsman et al., 1997; McGroddy et al., 2004). The formation of phosphorus complexes with calcium and other elements in the decomposing material reduces phosphorus availability to the decomposing microbes and might results in a reduced rate of decomposition (Gijsman et al., 1997). For nutrient poor soils, phosphorus would be immobilized, and decomposition would represent a net uptake and nutrient retention mechanism (Mcgroddy et al., 2004). Magnesium released from fine roots was highest only at soil depth 1.5 cm than soil 15 and 30cm soil depths. The possible reason of this result might be the formation of complexes with other elements in the decomposing materials and the soil. Magnesium released from coarse roots at soil depths 15 and 30 cm was about 14% and 38% more than that released by fine roots.

The nutrient release pattern of coarse roots at 1.5, 15 and 30 cm soil depths was as follows: K>Mg>N>P>Ca; K>N>Mg>P>Ca; and K>N>Mg>P>Ca respectively.The fast mineralization rate at 15 cm soil depth is associated with the rate of substrate decomposition, and it may be favoured by both micro and macro-fauna (Leff et al., 2011; Powers et al., 2009) especially during the dry period. Singh and Shekhar(1989) observed the release of N, P, and K during decomposition of maize roots to be 1.5 times greater at a 12.5 cm depth than at 5 cm. On the other hand, Iversen et al. (2008) did not find a significant difference in N and C turnover within the top 30 cm of soil, indicating that the rates of decomposition within the soil profile may be driven by other factors. The result indicates that more organic matter and nutrients are added to the soil during root death at 15 cm soil depth or the topsoil than at greater soil depths, and this is significant for fertility of the plough layer in these soils.

Table 1. Initial chemical properties of fine (<2mm) and coarse roots (2-5mm) of *M. thonningii*

Root properties	%C	%N	%P	%Ca	% Mg	% K	% Lignin	% Polyphenol	% cellulose	C:N ratio	L:N ratio
Fine roots	40.16	2.88	0.08	1.69	0.39	1.36	15.56	0.85	30.31	13.97	5.40
Coarse roots	39.62	1.95	0.06	1.79	0.37	1.20	20.82	1.20	25.10	20.32	10.70

Table 2. Effect of soil depths on the rate of nutrient released/immobilized in decomposition of fine roots of *Millettia thonningii.*

Percentage nutrient remaining/immobilized on sampling date (Days)								
Nutrients	Soil depth	0	30	90	120	180	210	Kc x 10^{-3}/day
N	1.5	100^{a}	92.73^{b}	77.86^{a}	77.12^{a}	91.14^{a}	38.38^{a}	-5.0^{a}
	15	100^{a}	77.12^{a}	80.81^{b}	74.17^{a}	89.29^{a}	35.42^{a}	-5.0^{a}
	30	100^{a}	92.98^{b}	85.23^{c}	76.06^{a}	84.87^{a}	57.19^{b}	-3.0^{b}
P	1.5	100^{a}	100.00^{a}	76.47^{c}	58.82^{a}	47.06^{a}	29.41^{a}	-6.0^{a}
	15	100^{a}	88.23^{a}	58.82^{b}	47.06^{a}	35.29^{a}	23.52^{a}	-7.0^{a}
	30	100^{a}	82.35^{a}	35.29^{a}	52.94^{a}	35.29^{a}	35.29^{b}	-5.0^{a}

Ca	1.5	100[a]	93.79[a]	112.79[a]	92.24[a]	94.96[a]	57.75[a]	-3.0[a]
	15	100[a]	84.88[a]	90.31[a]	77.91[a]	67.83[b]	50.39[a]	-3.0[a]
	30	100[a]	93.41[a]	106.98[a]	91.47[a]	87.21[a]	106.59[b]	+0.3[b]
Mg	1.5	100[a]	115.90[b]	100.00[c]	77.27[b]	65.91[a]	63.64[b]	-3.0[a]
	15	100[a]	65.91[a]	59.09[a]	56.81[a]	54.55[a]	40.91[a]	-4.0[a]
	30	100[a]	106.81[b]	72.73[b]	81.82[b]	65.91[a]	63.64[b]	-3.0[a]
K	1.5	100[a]	33.37[b]	11.37[a]	9.20[a]	10.19[a]	9.41[a]	-11.0[a]
	15	100[a]	30.58[b]	36.86[b]	13.33[a]	10.59[a]	7.84[a]	-12.0[a]
	30	100[a]	23.53[a]	45.49[c]	48.63[b]	54.51[b]	23.92[b]	-7.0[b]

For each nutrient element, values within a column with the same letter(s) are not significantly different at α = 0.05.
Kc = Nutrient release constant
-ve = Release of nutrient element. +ve=Nutrient immobilization

Table 3. The effect of soil depths on nutrient released/immobilized in the decomposition of coarse roots of *Millettia thonningii*

	Percentage nutrient remaining/immobilized on sampling date (Days)							
Nutrients	Soil depth	0	30	90	120	180	210	Kc x 10^{-3}/day
N	1.5	100[a]	96.18[c]	86.46[b]	81.25[b]	78.47[c]	78.82[c]	-1.1[b]
	15	100[a]	76.74[a]	76.74[a]	71.53[a]	66.67[b]	57.98[a]	-5.1[a]
	30	100[a]	82.98[b]	75.69[a]	68.06[a]	60.42[a]	61.46[b]	-4.8[a]
P	1.5	100[a]	125.00[b]	87.50[a]	75.00[a]	75.00[a]	87.50[b]	-0.6[b]
	15	100[a]	75.00[a]	100.00[b]	75.00[a]	125.00[c]	75.00[a]	-1.4[a]
	30	100[a]	150.00[b]	100.00[b]	125.00[b]	112.50[bc]	112.50[c]	+0.6[c]
Ca	1.5	100[a]	178.69[a]	182.84[ab]	185.79[c]	198.82[a]	181.08[b]	+2.8[a]
	15	100[a]	149.70[a]	139.64[a]	131.95[a]	105.92[c]	139.64[a]	+1.6[b]
	30	100[a]	175.74[a]	164.49[b]	148.52[b]	168.64[a]	130.18[a]	+1.3[c]
Mg	1.5	100[a]	117.95[b]	84.62[b]	97.43[c]	89.74[b]	76.92[c]	-1.2[b]
	15	100[a]	56.41[a]	79.49[a]	74.36[b]	89.74[b]	35.89[a]	-4.9[a]
	30	100[a]	115.38[b]	82.21[b]	61.54[a]	69.23[a]	46.15[ab]	-3.7[a]
K	1.5	100[a]	28.68[a]	22.06	19.85[a]	21.32[a]	18.38[a]	-8.1[a]
	15	100[a]	47.06[b]	66.12c	54.41[b]	86.76[c]	15.44[a]	-8.9[a]
	30	100[a]	69.12[c]	43.38b	50.74[b]	65.44[b]	49.26[b]	-3.4[b]

For each nutrient element, values within a column with the same letter (s) are not significantly different at α = 0.05.
Kc = Nutrient release constant
-ve = Release of nutrient element. +ve = Nutrient immobilization

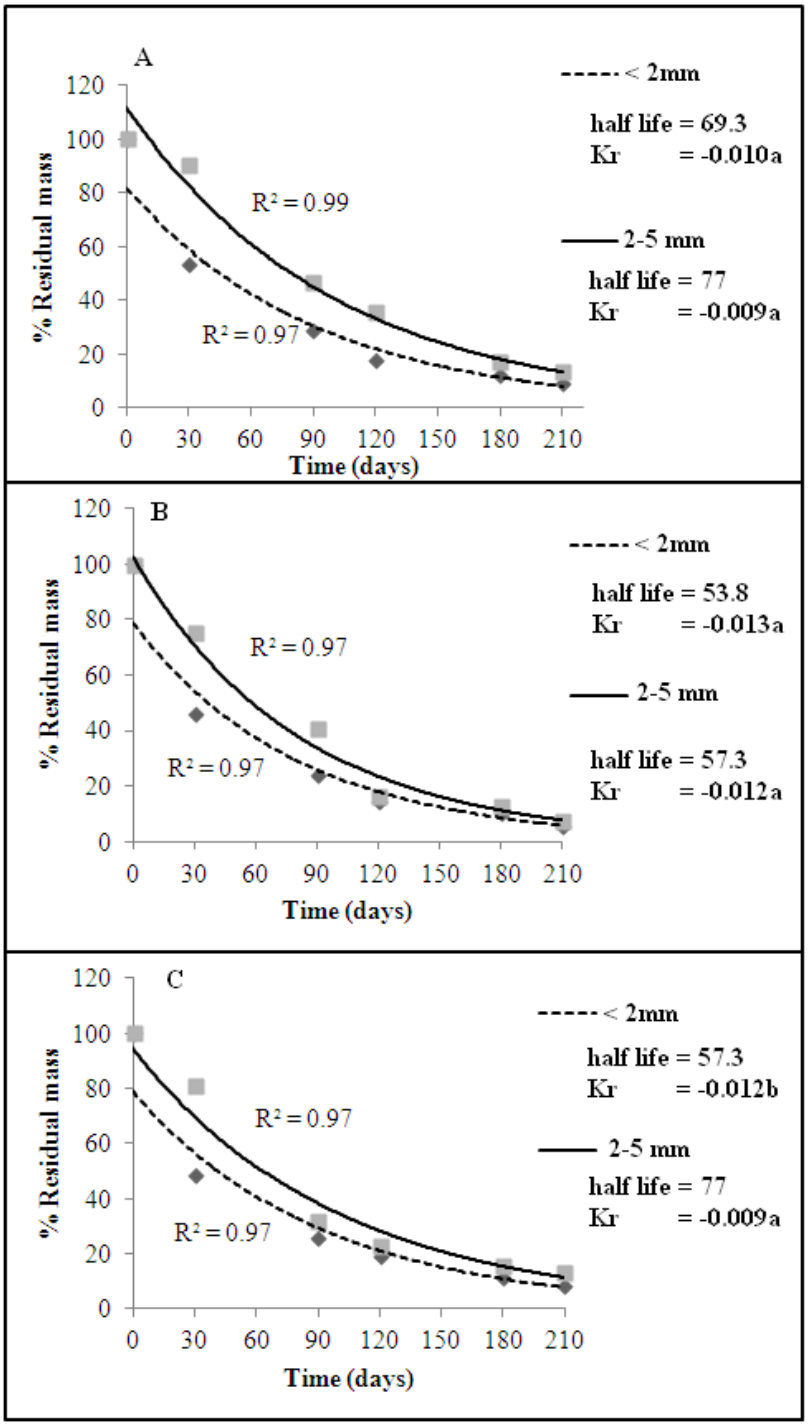

Figure 1.The effects of root sizes and soil depth on the rate of root decomposition. A= rate of decomposition at 1.5 cm, B = rate of decomposition at 15 cm, C = rate of decomposition at 30 cm; Kr = decomposition constant, Kr values with the same letter within each figure are not significantly different at α = 0.05

CONCLUSION

The seasonal regrowth and death of roots of the species and especially fine roots would improve soil fertility and the channels left by dead roots also improves the physical properties of the soil. The 15 cm soil depth favoured rapid decomposition of both fine and coarse roots, possibly due to

high meso-fauna, micro flora and fauna. Roots contribute immensely to the soil organic matter pool and their chemical properties have an influence on the rate of decomposition. The retention or incorporation of *Millettia thonningii* root materials into agro-ecology would improve on soil organic carbon sink and sustainable land use.

Acknowledgements: The research was funded by the International Institute of Tropical Agriculture and International Centre for Research in Agroforestry. The Authors thank Dr. B.T. Kang for his useful comments during this research.

REFERENCES

Abboti D.T and CrossleyJr D. A (1982); Wood litter decomposition following clear-cutting. Ecol 63(1): 35-42.

Allen S. E, Grimshaw H. M., Parkinson P. A and Quarmby C (1974); Chemical Analysis of Ecological Materials. New York: Willey.

Berg B and Ågren G. I (1984); Decomposition of needle litter and its organic chemical components: theory and field experiment. Long-term decomposition in Scot pine forest III. Can. J. Bot. 62:2880-2890

Berg B. (1984); Decomposition of roots litter and some factors regulating the process: long-term root litter decomposition in a Scots pine forest. Soil Biol. Biogeochem. 16:609-617.

Bremner J. M (1965); Total nitrogen. In: Methods of Soil Analysis. Black C. A (ed). Agron.American Soc. Agron.Madison Wisconsin pp1141-1171.

Brussaard L, Swift M. J and van der Heide J. (1992); Biological activity as a component of sustainable soil fertility in tropical cropping systems.Proc. Symposium on Sustainability and Use of Resources in Developing countries. Gottingen, Germany. 24-25 October 1991.

Clancey M. J and Wilson R. K (1966); Development and application of a new chemical method for predicting the digestibility and intake of herbage samples.Proc.10th Int. Grassland Congress.pp445-453.

Day F. P (1995); Environmental influences on belowground decomposition on a coastal barrier island determined by cotton strip assay. Pedobiolog 39:289-303.

Dilustro J. J., Day F. P and Drake B. G (2001); Effect of elevated atmospheric CO_2 on root decomposition in a scrub oak ecosystem. Global Change Biol. 7:581-589.

Egbe E. A (1997); Potentials of two indigenous multipurpose tree species for agroforestry systems in some humid lowland areas of Nigeria and Cameroon.Ph.D Thesis, University of Ibadan, Nigeria.

Espeleta J.F and Clark D.A (2007); Multi-scale variation in fine root biomass in a tropical rain forest: a seven-year study. EcolMonogr 77: 377-404

Gijsman A. J., Alarcon H. F and Thomas R. J (1997); Root decomposition in tropical grasses and legumes, as affected by soil texture and season. Soil Biol. Biochem. 29: 1443-1450.

Gonzalez G, and Seastedt T.R (2001); Soil fauna and plant litter decomposition in tropical and subalpine forests. Ecol82(4): 955–964.

Gupta S. R and Singh J. S (1981);The effect of plant species, weather variables and chemical composition of plant materials on decomposition in tropical grassland. Plant and Soil 59: 99-117.

Haynes R. J (1986);The decomposition process: Mineralization and immobilization humus formation and degradation. In: Mineral Nitrogen in the Plant-Soil System. Editor R J. Haynes. Pp 52-176. Orlando: Academic Press.

Hua C., Harmon M. E., Sexton J and Fasth B (2002); Fine root decomposition and nitrogen dynamics in coniferous forest of the Pacific Northwest USA. Can. J. For. Res. 32(2) 320 - 331

Iversen C. M., Ladford J andNorby R. J (2008); CO_2 enrichment increase carbon and nitrogen input from fine roots in decicuous forest. NewPhytol.179: 837–847.

Jensen B. H. (1984); A simple method for calculating decomposition and accumulation of "young" soil organic matter. Plant and Soil 76, 297-304.

Kang B. T., Wilson, G. F and Lawson, T. L. (1984); Alley Cropping, a Stable Alternative to Shifting Cultivation. Ibadan: IITA.

Leff J.W., Diana, R.,Nemergut, D.R., Grandy, A. S., O'Neil,l S. P., Wickings, K., Townsend, A. R and Cleveland C. C. (2011); The Effects of Soil Bacterial Community Structure on Decomposition in a Tropical Rain Forest. Ecosyst. DOI: 10.1007/s10021-011-9510-2.

Majdi H., Pregitzer, K., Moren, A. S., Nylund, J. E and Agren, G.I (2005); Measuring fine turnover in forest ecosystems. Plant and Soil 276:1-6

Mehlich M (1984). Mehlich 3 soil test extractant: Modification of the détermination of the Mehlich 2 extractant. Comm in Soil Sci & Plant Analy 15: 1409-1416.

McGroddy M. E., Whendee L., Silver W. L andde Oliveira Jr. R. C (2004);The Effect of Phosphorus Availability on Decomposition Dynamics in a Seasonal LowlandAmazonian Forest.Ecosyst 7:172-179.

Müller M., Sundman M.V., Soininvaara O andMerilainen A (1988); Effect of chemical composition on the release of nitrogen from agriculture plant materials decomposing in soils under field conditions. Biol. Fertil. Soils. 6: 78-83.

Murphy, J, and Riley, J.P. (1962). A modified single solution method for determination of phosphate in natural waters. Analy Chimica Acta 27:31-36.

Nwoboshi L. C (1982); Tropical Sivilculture.Principles and Techniques. University Ibadan 333p

Palm C. A and Sanchez P.A (1990). Decomposition and nutrient release pattern of leaves of three tropical legumes. Biotrop 22(4): 330-338.

Palm C. A and Sanchez P.A (1991); Nitrogen release from the leaves of some tropical legumes as affected by their lignin and polyphenolic contents. Soil Biol. Biochem. 23(1): 83-88.

Powers J. S., Montgomery R. A., Adair E. C., Brearley F. Q., DeWalt S. J., Castanho C. T., Chave J., Deinert E., Ganzhorn J. U., Gilbert M. E., González-Iturbe J. A., Bunyavejchewin S., Grau H. R., Harms K. E., Hiremath A., Iriarte-Vivar S., Manzane E., de Oliveira A. A., Poorter L, Ramanamanjato J., Salk C., Varela A,, Weiblen G. D andLerdau M. T (2009); Decomposition in tropical forests: a pan-tropical study of the effects of litter type, litter placement and mesofaunal exclusion across a precipitation gradient. J. Ecol. 29:801-811.

Saito T (1957); Changes in beech litter under microbiological decomposition.Ecol. Rev. 14: 209-216.

Singh K. P and Chandra S (1989); Weight loss in relation to environment factors during decomposition of maize and wheat roots in a seasonally dry tropical region. Soil Biol. Biochem. 21(1): 73-80.

Smith C. K., Gholz H. L and De AssisOliveira F (1998); Fine litter chemistry early-staged decay, and nitrogen dynamics under plantation and primary forest I lowland Amazonia. Soil Biol. Biochem. 30: 2159-2169

Stevenson F. J (1986); Cycle of Soil Carbon, Nitrogen, Phosphorus, Sulphur and Micronutrients. New York: John Wiley and Sons.

Urquiaga S., Cadisch G., Alves B. J. R., Boddey R. M and Giller K. E (1998); Influence of decomposition of roots of tropical forage species on the availability of soil nitrogen. Soil Biol. Biochem. 30: 2099-2106.

Van Soest P. J and Wine R. H (1968); Determination of lignin and cellulose in acid-detergent fibre with permanganate. J. Assoc. Off. Agric. Chem. 51, 391- 398.

Vanlauwe B., NwokeO. C., Sanginga N and Merckx R (1996); Impact of residue quality on C and N mineralization of leaf and root residues of three agroforestry species. Plant and Soil 183:221-231.

Walkley A and Black L. A (1934); An examination of the Detjareff method for determining soil organic matter and a proposed modification to the chromic acid titration method. Soil Sci. 37: 29-38

Whendee L. S andMiya R. K (2001); Global patterns in roots decomposition: Comparison of climate and litter quality effect. Oecol 129 (3): 407-419.

Yang Y. S., Guang-Shui C., Jianfen G and Peng L (2000); Decomposition dynamics of fine roots in mixed forest of *Cunninghamialanceolata* and *Tsoongiodendronodorum* in mid-subtropics. Ann. For. Sci. 61:65-72

Yavitt J. B., Harms K. E., Garcia M. N., Mirabello M. J and Wright S. J (2011); Soil fertility and fine root dynamics in response to 4 years of nutrients (N, P, K) fertilization in a lowland tropical moist forest, Panama. Austral Ecol 36: 433-445

CONFLICT OF INTEREST : Nothing