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Research Paper

Decomposition Rates of Plant Residues and Nutrient Dynamics under Field Conditions in a Humid Tropical Environment

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In a field incubation experiment to determine the rate of plant residues and nutrient dynamics in a humid tropical environment using litterbags, the decomposition of and nutrient release from Dovewood, Elephant grass, Velvet bean, Guinea grass, Water hyacinth and wood shavings were monitored for 56 days. Litterbags were buried 10 cm in soil and were retrieved every 14 days and oven-dried at 60°C for 48 h for dry and organic matter determinations. Thereafter, litterbag contents were prepared and stored for the determination of nitrogen (N) and phosphorus (P) contents. Decomposition was highest in bags of water hyacinth (k = 0.4464) and lowest in wood shavings (k = 0.0668). The percentage of soil amendments remaining after 56 days of decomposition were 48% for Dovewood, 38% for Elephant grass, 34% for Velvet bean, 29% for Guinea grass, 0% for water hycinth and 85% in Wood shavings. Decomposition rate did not affects N and P release patterns, however nitrogen release from Dovewood was Highest (k = 0.2570) and wood shavings had the Lowest (k = 0.1170). Guinea grass had the highest P release (K = 0.3751) whereas wood shavings and Velvet grass had the lowest P release (k = 0.1630).The chemical composition of plant residues was responsible for the differences in decomposition rates and nutrient release. The use of Dovewood and Guinea grass therefore were recommended as nitrogen and phosphorus sources respectively.

Keywords: Decomposition rates, plant residues, nutrient dynamics, soil organic matter

INTRODUCTION

The use of locally and easily available organic materials as soil amendments has become a research priority in low external input agricultural systems. To determine the amounts and frequencies of application of soil amendments, knowledge of their decay rate and nutrient release patterns is needed. Continuous cropping in the humid forest of the Niger Delta can deplete the fertility of the fragile ultisols causing low crop yields (Gbaraneh *and* Nwonuala, 2011). High salt concentration in the soil is a serious problem in vast otherwise productive agricultural lands in Nigeria (Opuwaribo and Odu, 1978). The decomposition and nutrient release within a given environment is controlled by many factors including the chemical composition of organic amendments, placement and nature of soil organisms (Swift *et al.,* 1979). For research in applied soil biology, the synchronization of nutrient release from organic material and the plant nutrient uptake are a topic of great interest in cases where burning is replaced by biomass mulching, (Addiscott *et al*., 1991; Myers *et al*., 1994). Furthermore, the existence and extent of plant-microbe competition for inorganic and organic N and P resources need to be elucidated (Kaye and Hart, 1997). Following slash-and-mulch fall short of those after burning, this is ascribed to a lack of nutrients (Denich *et al*., 2004). In order to project more efficient agricultural systems, there should be a clear understanding of the determinants of nutrient supply, especially those that condition nutrient release from plant residues (Seneviratne, 2000). Organic resources play an essential role in soil fertility management in the tropics by their short- term effects on nutrient supply and longer-term contribution to soil organic matter (SOM) formation (Palm *et al*., 2001). Tian, (1992) reported that the initial chemical properties of crop residues such as N polyphenol, and lignin concentration in crop residues have considerable influence on the decomposition and nutrient release rates. This knowledge is needed to more efficiently, manage manure and plant residues for cropping in the humid tropics. To project more efficient agricultural systems, there should be a clear understanding of the determinants of nutrient supply, especially those that condition nutrient release from plant residues (Seneviratne, 2000). Organic resources play an essential role in soil fertility management in the tropics by their short-term effects on nutrient supply and longer-term contribution to soil organic matter (SOM) formation (Palm *et al*., 2001). The decomposition rate and the amount of nutrient release from organic matter (OM), particularly from leguminous trees, determine the short-term benefits of tree residues for crop nutrition (Handayanto *et al*., 1997). The main objective of this study was to determine the decomposition rates of plant residues under field conditions in a humid tropical environment. The specific objective were to (i) examine the chemical properties and nutrient supply potential of selected soil amendments, (ii) determine the decomposition rates of the residues in soil and (iii) evaluate their nutrient release patterns.

MATERIALS AND METHODS

Site description

Field incubation experiments were carried out at the Rivers State University of Science and Technology Teaching and Research Farm in Port Harcourt (04' 48° N, 006' 58° E, 23 m asl).The annual rainfall averages 4018 mm (FAO, 1985), with a mean monthly temperature of 27°C, and relative humidity of 70-84%. The area has bimodal rainfall pattern, the main growing season is from April to August and minor growing season is from August to October and dry season December to April.

Experimental detail

Litter bags measuring 20 x 20 cm, with mesh size of 2 mm were filled with 25 g of oven dried (60°C) biomass of Dovewood, water hyacinth wood shavings, Guinea grass, Elephant grass and Velvet bean. These were chopped to about 3cm long prior to drying. Litter bags filled with the biomass were buried 10cm below the soil surface in a plantain orchard 1m apart. Each treatment was replicated 3 times making a total number of 72 litter bags. Triplicate litter bags were retrieved every 14 days, for dry matter (DM) determination. The experiment began in April and ended in June 2015. On each retrieval date, the soil on the litter bag was leaned and the biomass was opened and transferred into a pan for air drying. The experimental design was Completely Randomized Design (CRD) with split plot arrangement of treatments.

Soil analysis

For soil sampling, ten subsamples were randomly collected (employing a coordinate point sampling technique) at 0–15 cm depth from a 2 x 2 m^2 area in the center of the plot, and composited and were analyzed for pH, particle size, organic carbon, total nitrogen, available phosphorus, calcium, sodium, magnesium and potassium. Soil pH was determined by electrometric pH method (Bates, 1954), particle size was determined by hydrometer method (Bouyoucos, 1951), exchangeable potassium, was determined by flame photometry method (Doll and Lucas, 1973), total nitrogen was analyzed by Kjeldahl digestion and distillation method (Bremher and Mulvaney, 1982). Organic carbon was analyzed by Walkley-Black wet oxidation method. Available phosphorus was determined by Bray and Kurtz method (Bray and Kurtz, 1945), sodium and magnesium were determined by EDTA titration method (Tel and Rao 1982).

Analytical methods for plant residue (organic amendments)

The plant residues Dovewood, Elephant grass, Velvet bean, Guinea grass and were oven dried at 60°C for two hours and transferred into the desiccator to cool. 0.2 g of the oven-dried plant residues were poured directly into a 100 ml conical flask and covered to avoid dust and loss of materials. 6 ml of plant extracting solution was added, covered, and allowed to stand overnight. The sample mixture was gently heated gradually at a temperature of 30°C for 2 h on the hot plate then 3 ml of H_2SO_4 was added and heated vigorously until the sample was digested (wet-acid digestion method). With the digest, phosphorus (P) was determined by Vanado-molybdo-Yellow method and nitrogen (N) by Kjeldahl method.

Statistical analysis

The nonlinear regression (NLIN) procedure of SAS (SAS institute, 1987) was used to determine daily decay constant (k) of organic amendments using the single exponential model $Yt = Pe^{-kt}$,where Yt is the fraction of the original amendment material remaining after time t: P

Table 1. The initial soil physical and chemical properties of the experimental site (N=X).

Soil particle size gkg^{-1}			Texture	Soil Chemical properties gkg^{-1}					Exchangeable cations Cmol kg^{-1}			
Sand	Silt	caly		pH	OC	OM	TN	Av. P $mgkg^{-1}$	Ca	Mg	K	Na
780	920	122	LS	5.30	8.80	15.10	3.0	13.33	17.3	1.93	0.11	0.34

Table 2: Initial chemical properties of plant residues

Amendment materials	C	N	P	C/N Ratio
Dovewood	10.11	0.31	0.20	32.61
Elephant grass	8.09	0.35	0.25	23.11
Velvet bean	10.11	0.49	0.16	20.63
Guinea grass	5.67	0.34	0.20	16.68
Water hyacinth	3.12	0.14	0.61	22.28
Wood shavings	99.00	0.21	0.48	471.43
SE±	15.301	0.065	0.083	

Table 3. Daily decay rate constants (k) of plant residues

Amendment material	Daily decay constant (k)
Dovewood	*0.*2336
Elephant grass	0.2845
Velvet bean	0.2967
Guniea grass	0.3163
Water hyacinth	0.4464
Wood shavings	0.0668
SE±	0.05046

= relative pool size: k = daily decay constant and t = time of decomposition in days. Decomposition rates and nutrients released were subjected to analysis of variance (ANOVA) for a Completely Randomized Design (CRD) and means were compared using standard error (SE±) (Tables 1 and 2).

RESULTS AND DISCUSSION

Residue decomposition

The trend and magnitude of the decomposition rate constant (day^{-1}) showed a rapid decrease in residues dry matter from Water hycinth, Guniea grass, Velvet bean, Elephant grass, Dovewood and Wood shavings (Figure 1). Wood shavings decomposed very slowly and after 28 days of the experiment, only 22% of the original dry matter was lost. Thereafter, the rate of decomposition slowed considerably to the point that 85% of the initial residue remained at 56 days after placement. The slow rate of decomposition of wood shavings suggests that it can provide adequate soil surface protection when used as mulch. Thirty eight percent of the original dry matter of Dovewood was lost after 28 days of the experiment and the rate of decomposition slowed considerably to a point that 48% of the initial residue remained at 56 days after placement. For Elephant grass, the rapid loss of dry matter occurred 28 days after placement and resulted in the loss of 62% of the original dry weight. Similarly, only 34% and 29% of the initial dry weight for Velvet bean and *Guniea grass* remained at 56 days after placement (Figure 1) which implies a rapid decomposition rate. Water hycinth decomposed at the fastest rate compared to the other residues. In the first 42 days of placement 71% of the residues were decomposed. Water hycinth as reported in Sanni *et al.,* (2013), has 29.9% organic carbon, 2.19% nitrogen, 0.59% phosphorus and 4.85% potassium in wet weight. This result agreed with Tian, (1992), Vanlauwe *et al.* (1996), and Mohammed *et al.* (2013). These nutrients are essential for plant growth and development. At 14 and 24 days after placement, the residues of Dovewood, was observed to be dusty and smoky. Residues of herbaceous legumes are known to decompose rapidly because of their high N contents, low concentrations of lignin and low C:N ratios (Ikpe *et al.,* 1997, the placement of litter bags 15cm below soil surface likely enhanced the rate of decomposition compared to surface application(Ikpe *et al*., 1997. The high decay constant of water hycinth obtained in this experiment (Table 3) suggests that water hycinth with high N content may have low residue effect in the supply

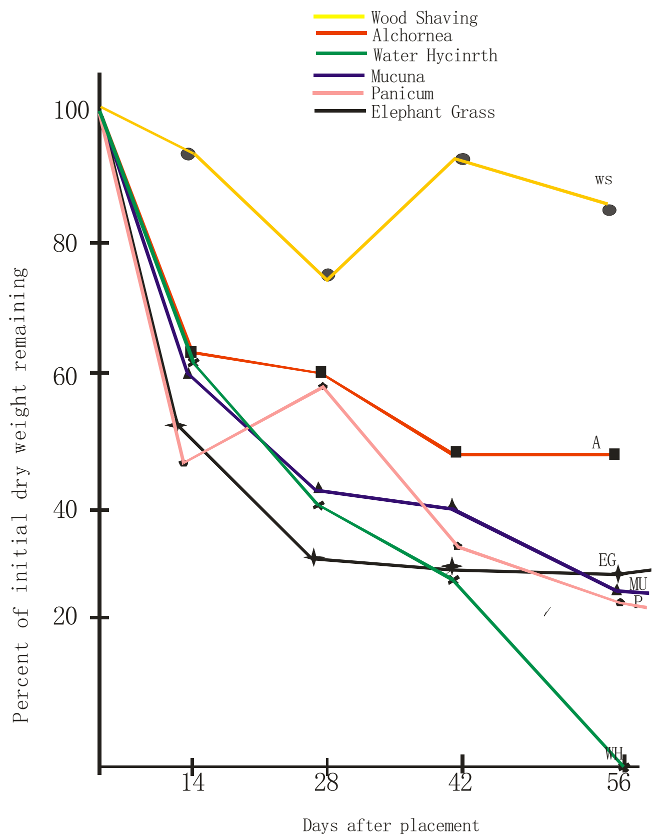

Figure 1. Effects of biomass on their rate of decomposition

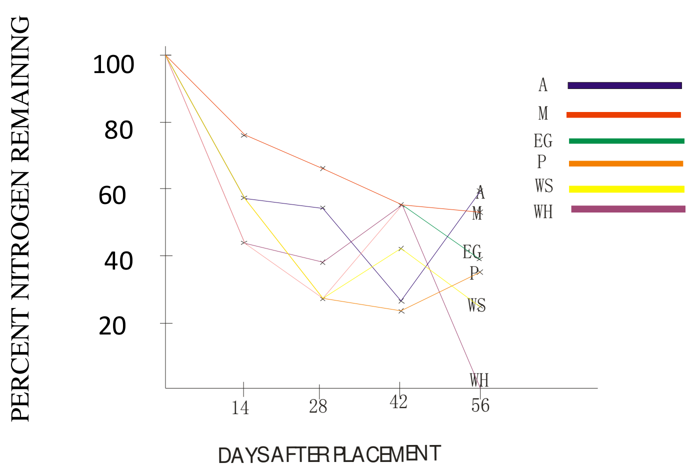

Figure 2. Nitrogen release from selected plant residues

of nutrients to subsequent food crops. However it is not clear whether it was completely mineralized or converted, in part, into soils organic matter (SOM). Some components quickly disappear while others are less susceptible to microbial enzymes and persist. The water –soluble fraction contains the least resistant plant

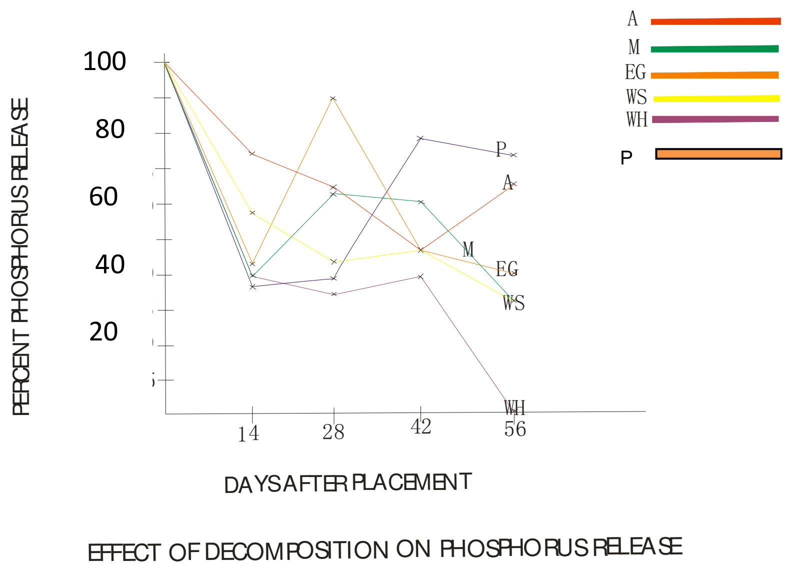

Figure 3. Phosphorus released from selected plantresidues

Table 4. Nutrients Release Constant (k) after 56days of decomposition.

Amendment materials	N	P
Dovewood	0.2570	0.3380
Elephant grass	0.1632	0.2002
Velvet bean	0.2560	0.1632
Guniea grass	0.2330	0.3751
Water hyacinth	nd	nd
Wood shavings	0.1174	0.1630
SE±	0.04121	0.05540

nd = not determined.

components and is first to be metabolized. As a result, in where tissues in which 20 to 30 percent of the dry matter is water- soluble, decomposition proceeds rapidly, Cellulose and hemicelluloses, on the other hand, disappear not as quickly as the water-soluble substances, but their persistence usually is not too great. The lignins are highly resistant and consequently become relatively more abundant in the residual, decaying organic matter (Mulongoy and Akonbundu, 1993).

Chemical properties of soil amendments

The chemical properties of soil amendments (Table 2) indicated that Velvet bean had the highest and water hycinth the lowest N content while the phosphorus content was highest in water hycinth and lowest in Velvet bean dry matter. The release of nutrients (Table 4) from the soil amendments differed considerably. Nitrogen release from Dovewood and Velvet bean was faster than from other soil amendments and wood shavings had the slowest release (Figure 2). Velvet bean and Dovewood had the highest P and wood shavings and Velvet bean had the lowest P release to the soil (Figure 3). This result also agreed with Tian, (1992), Vanlauwe *et al.,* (1996), Mohammed *et al.,* (2013) and José *et al*, (2008).

Conclusion

After determining the decomposition rates of six soil amendment materials, water hyacinth, Guniea grass Elephant grass and Velvet bean, could be classified as high quality amendments while Dovewood and wood shavings are of low quality due to their slow decomposition. This slow decomposition would make

Dovewood and wood shavings suitable as mulch for cassava, yam, and for all other perennial crop. Based on our findings, plant residues, especially water hyacinth, Guniea grass, Velvet bean and Elephant grass are recommended as mulch for arable crops whereas wood shavings and Dovewood should be used for perennial crops in the humid tropics.

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