DECOMPOSITION AND NUTRIENT RELEASE PATTERNS OF LEAF MULCHES OF *Leucaena leucocephala, Gliricidia sepium* AND *Cassia spectabilis* IN THE HUMID ZONE OF GHANA

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ABSTRACT

The rate of decomposition and nutrient release of leaf mulches of Leucaena leucocephala, Gliricidia sepium and Cassia spectabilis were investigated under field conditions using wooden square frames over a period of 70 days.

Decomposition rates followed the order Leucaena leucocephala> Gliricidia sepium> Cassia spectabilis with half life values of 18 days, 35 days and 69 days respectively.

Nutrient release ranked as follows: K>Mg>N>P>C>Ca for Leucaena leucocephala, K>Mg>P>N=Ca>C for Gliricidia sepium and K>Mg>P>N>Ca=C for Cassia spectabilis. The nutrient and lignin levels of the material played key roles in determining decomposition and nutrient release patterns.

Significant soil nutrient enrichment occurred under decomposing leaf mulches within 0-30 cm layer depth.

Key words: *Leaf mulch, Chemical characteristic, Decomposition rates, Nutrient release patterns, Soil enrichment.*

INTRODUCTION

Alley Cropping is an agroforestry technology that offers great potential for developing a more productive low-input and sustainable food production system in the humid tropics including West Africa. In alley cropping, arable crops are grown between hedgerows of planted woody trees or shrubs that are preferably nitrogen fixing (13). One of the basic principles of this technology is the periodic pruning of the hedgerows to reduce shading and competition with the associated crops. Prunings from the trees and shrubs are added to the soil as green manure or applied as mulch to improve on the physical, chemical and biological properties of the soil (15). There are many tree species for alley cropping (16). However, the potential of the prunings from these tree species to improve soil physical and chemical conditions differ greatly and depend largely on its nutrient content and rate of decomposition. Therefore, studies on the nutrient content and rates of decomposition of hedgerow species will be useful in the choice and selection of species to be included in alley cropping development.

The rate of decomposition of plant material is mainly influenced by the prevailing temperature and rainfall (24), lignin content (18), polyphenolic content (20), nitrogen content(21), carbon/nitrogen ratio (3) and lignin/nitrogen ratio (27). Therefore, the chemical composition of decomposing material determines the quality of the material as a food and substrate for decomposers. Material of high quality decompose and release nutrients rapidly whiles that of low quality decompose slowly (28).

The purpose of this study was to determine the rate of decomposition and also nutrient release patterns from leaf mulches of *Leuceana leucocephala, Gliricidia sepium* and *Cassia spectabilis*. The three tree species were selected for this study because *Leuceana leucocephala* and *Gliricidia sepium* are widely used in alley cropping while *Cassia spectabilis* though exotic has performed well in AFNETA multipurpose tree screening and evaluation trials under local conditions.

MATERIALS AND METHODS

Location of study:

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The study was conducted at the Institute of Renewable Natural Resources research farm at the University of Science and Technology in Kumasi (01° 36' W, 06° 43'W and 287m elevation). The study site is situated in the forest belt and has a humid tropical lowland climate with mean annual rainfall of 1298mm and temperature ranges from an average minimum of 22°C to an average maximum of 31.3°C. The soil is of the Asuansi series which belongs to the Bomso/ Nta-Ofin Association (26). The soil taxonomy at the family level is Oxic Halplustalf (31).

The Experimental Set-Up

The experiment was conducted in an open area without shade and free of weeds and other leaf materials. The experimental design was a completely randomised design with three replications. Three tree species namely; *Leucaena leucocephala*, *Gliricidia sepium* and *Cassia spectabilis* comprised the treatments. Decomposition of the leaf mulches were studied using wooden square frames that measured 30cm x 30cm, and 10cm high. Twenty frames were used for each species. A mixture of young and mature leaves were collected from several trees of each species which were of the same age. Fresh leaves of each species weighing the equivalent of 100g dry weight were spread out uniformly in wooden frames.

Soil and Mulch Sampling

At the start of the experiment, representative soil samples were collected at 0-15cm and 15-30cm depths from 10 spots located randomly on the experimental site, bulked for each depth and air dried. Sub-samples were later analysed to determine initial soil physical and chemical properties of the site. During the decomposition studies, soil samples from the 0-15cm and 15-30cm layers were collected from three randomly selected wooden frames on each sampling date. The soil were bulked for each depth and species, allowed to dry and ground in a mortar to pass a 2mm sieve. Sub-samples were later analysed for C, N, P, K, Ca and Mg to determine nutrient build up in the soil resulting from decomposition of mulch materials.

Sub-samples of mulch materials of the tests tree species were oven-dried at 70°C for twenty-four hours, ground in a Willey Mill, stored and later analysed to determine initial contents (day 0) of C, N, P, K, Ca, Mg and Lignin. Then, on each sampling day, (14, 28, 42, 56 and 70 days after initiating the experiment) three wooden frames of each species were randomly selected and their mulch content put in sampling bags. Adhering soil particles were removed and the samples oven-dried at 70°C for twenty-four hours and then weighed. For each species, two samples weighing close to the average oven-dry weight per sampling date were ground in a Willey Mill and later analysed to determine the concentration of C, N, P, K, Ca and Mg for studying the mineralization of the mulch materials.

Laboratory Analyses:

Mulch Samples

Percent lignin was determined using the acid detergent fibre method (10). Organic carbon was determined by Walkley-Black method and Nitrogen by micro Kjeldahl method. Phosphorus and Potassium were determined using the Vanado-molybdophosphoric acid yellow colour method (11). Calcium and Magnesium were determined by the ethylene-diamine tetra-acetic acid (EDTA) method (23).

Soil Samples

Particle-size distribution was determined by the hydrometer method (4). Soil pH was potentiometrically measured in the supernatant suspension of 1:1 soil-water mixture using 25 grams of soil sample. Organic Carbon was determined by Walkley-Black method and total nitrogen by micro Kjeldahl method. Available Phosphorus and Potassium were determined using Bray No. 1 extracting solution. Phosphorus was measured calorimetrically by spectrophotometer and Potassium measured by flame photometer (5). Exchangeable Calcium and Magnesium were analysed using the extraction technique and titrating against 0.02N versenate (22). Exchangeable acidity was determined by the KCl method (11). Total exchangeable bases were analysed by the method of Bray and Willhite (6). Cation exchange capacity (CEC) was determined by the summation method and Base saturation obtained by relating exchangeable bases to cation exchange capacity using the formula:

$$\text{Base Saturation} = \frac{\text{Total Exchangeable Bases}}{\text{Cation Exchange Capacity}} \times 100 \quad \text{...Eqn 1}$$

RESULTS AND DISCUSSION

Chemical Characteristics of Leaf Mulch:

The chemical properties of leaf mulch of the tree species varied considerably and are compared in table 1. Carbon and Nitrogen levels were high in *Leuceana leucocephala* and low in *Giricidia sepium*. Phosphorus level was high in *Gliricidia sepium* and low in *Leuceana leucocephala*. However, Potassium, Calcium and Magnesium levels were high in *Gliricidia sepium* and low in *Cassia spectabilis*. Lignin and lignin/nitrogen ratio were high in *Cassia spectabilis* and low in *Leuceana leucocephala*.

The nutrient levels reported in this study compares favourably with levels reported by previous authors (8, 30) with the exception of Phosphorus. The high Phosphorus level in the leaves reported in this study is difficult to explain since in general the percent phosphorous in leaf is known to range between 0.2 and 0.3 (34). Differences in nutrient uptake by the species is probably the major factor contributing to variation in leaf chemical characteristics.

Pattern of Weight Loss and Decomposition

The rate of weight loss in leaf mulches of the tree species followed the order *Leuceana leucocephala*> *Gliricidia sepium*> *Cassia spectabilis* (fig 1). The half-life values or time for 50% of leaf material to decompose were 18 days for *Leuceana leucocephala*, 35 days for *Gliricidia sepium* and 69 days for *Cassia spectabilis*.

The chemical characteristics of the leaf mulch of the three tree species (table 1) could have contributed to the different rates of decomposition more than the climatic factors, which do not change so much within a year and within a site in the tropics (17). The high decomposition rate of *Leuceana leucocephala* (fig 1) probably is the result of high carbon levels (46.2%), high nitrogen levels (3.85%), low levels of lignin (5.6%) and lignin/nitrogen ratios (1.45). Bahaguna et al. (2) and Yamoah et al. (33) have reported that materials with high nitrogen content decompose faster and the rate of decomposition is inversely proportional to lignin/nitrogen ratio (27).

Gliricidia sepium leaf mulch had significantly low lignin (7.6%), carbon (41.24%) and nitrogen (3.36%) levels than *Cassia spectabilis* and decomposed faster. This could be attributed to the high levels of lignin (8.7%) and lignin/nitrogen ratio (2.43) of *Cassia spectabilis*. Lignin is resistant to decomposition and plant materials with high lignin content decompose more slowly than material which were low in lignin

(2). The dominant influence it exerts over decomposition rates could result from its ability to serve as a surrogate for many physical and chemical properties which regulate litter decomposition and hence retards the overall decomposition process (32).

Nutrients Release Rates

The release of nutrients from the leaf mulches expressed as nutrient release constants (K) differed significantly (table 2). Potassium was released at a faster rate than all the other nutrients as evidenced by the high nutrient release constant (K). Apart from carbon and nitrogen, the release of nutrients were faster in *Glircidia sepium*. *Cassia spectabilis* exhibited the lowest nutrient release rate. The ranking of nutrients release in decomposing leaves of the tree species are as follows: K>Mg>N>P>C>Ca for *Leuceana leucocephala*, K>Mg>P>N=Ca>C for *Gliricidia septum* and K>Mg>P>N=Ca>C for *Cassia spectabilis*.

Nutrient mineralization is known to be strongly affected by the chemical composition of leaves (19) and there appears to be a relationship between initial nutrient levels and nutrient release in this study. Species with high nitrogen levels but low lignin levels released nutrients at a faster rate than species low in nitrogen but high lignin levels. For example, *Leuceana leucocephala* leaves had high levels of carbon and nitrogen and released these nutrients at a faster rate. *Gliricidia sepium* leaves had low carbon and nitrogen levels than *Cassia spectabilis* but released the nutrients at a faster rate because mineralization was lowered by the presence of high concentration of lignin in leaf material of *Cassia spectabilis* (25). The release of phosphorus, potassium, calcium and magnesium from the leaves followed the order *Glircidia sepium*>*Leuceana leucocephala*>*Cassia spectabilis* and probably demonstrates the importance of substrate quality in nutrient mineralization. *Glircidia sepium* with the highest levels of the nutrient, released nutrient at a faster rate.

The slow release of calcium in this study has been observed both in the tropics and temperate zone (1). This is generally attributed to accumulation of calcium oxalate in the fungi that colonize decomposing leaf material (9). The low mineralization of calcium could also be due to its presence in the form of calcium pectate in the middle lamellae of the cell wall and the storage of calcium in the form of calcium oxalate crystals (7). While the rapid mineralization of potassium from the leaves support claims that leaching is the primary process influencing its release (29). Potassium is usually present as a free moving cation in the cell fluid, and is actively involved in the synthesis of amino acids and proteins. During the disintegration of cell membrane, it is easily washed out of the leaf material (12).

Nutrient Changes in Soil

The initial soil properties in the 0-15cm and 15-30cm layers of the study site are presented in table 3. In both layers, the texture is loamy sand and the soil is highly acidic. Generally organic matter, C, N, P, K, Ca and Mg levels, CEC and base saturation within 0-15cm depth were higher than within 15-30 cm depth of the profile.

Significant soil enrichment ($p<0.05$) in C, N, P, K, Ca and Mg were recorded after the decomposition studies within both 0-15cm and 15-30cm profile depths. Within 0-15cm layer, increased soil organic carbon, available phosphorus and exchangeable magnesium contents were recorded under decomposing leaves of *Leuceana leucocephala*. Percent change in soil total nitrogen, total potassium and exchangeable calcium were higher under decomposing leaves of *Gliricidia sepium*. In terms of ranking, the general order of changes in soil chemical properties were N>K>Mg>Ca>C>P for *Leuceana leucocephala* and *Gliricidia sepium* and N>K>Mg>C>Ca>P for *Cassia spectabilis* (table 4). Within 15-30cm depth the improvement to soil nutrient elements under decomposing leaves were high in *Leuceana leucocephala* followed by *Gliricidia sepium* and then *Cassia spectabilis*. For each of the species, the general ranking of changes in soil chemical properties were as follows: N>K>Mg>Ca>P>C (table 5).

Species differences in changes in soil nutrient levels recorded under the decomposing leaves could be due to differences in nutrient uptake, litter quality and decomposition rates. Nutrient additions to soil from decomposing leaf mulch of *Leuceana leucocephala, Gliricidia sepium* and *Cassia spectabilis* support and confirm the potential of these prunings when applied either as green manure or mulch in agroforestry to improve soil physical and chemical properties. Kang et al. (14) observed increases in soil organic matter and nutrient status on soils with continuous addition of prunings than those receiving no prunings.

CONCLUSIONS

Based on the results, these conclusions can be drawn. The rate of decomposition of leaf mulch was faster in *Leuceana leucocephala* followed by *Gliricidia sepium* and *Cassia spectabilis*. The rate of decomposition was influenced largely by the quality of the leaf material.

Nutrient mineralization in leaf mulches were influenced by their nutrient and lignin contents. Species with high C, N, P, K, Ca and Mg content, released nutrients at a faster rate than species high in lignin and low in nutrient content.

Decomposition of the leaf mulches led to significant increases in the nutrient content of the soil within 0-15cm profile depths. These nutrient additions to the soil from decomposing leaves supports and confirms the potential of prunings when applied either as green manure or mulch in agroforestry to improve soil fertility.

The management implications from these conclusions in agroforestry are that, for long-term water and soil conservation, leaf mulch of *Cassia spectabilis* could be considered because of its persistancy. However, leaf mulches of *Leuceana leucocephala* and *Gliricidia sepium* could be used in agroforestry technologies to improve the fertility of the soil because of their rapid release of nutrients. Where long-term water conservation and rapid nutrient release are desired, then mixtures of slow and fast decomposing mulches could be used.

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Table 1: Initial chemical characteristics of leaves of *Leucaena leucocephala, Gliricidia sepium* and *Cassia spectabilis*

Chemical Characteristics	Species			LSD (0.05)	C.V. (%)
	Leucaena leucocephala	*Gliricidia sepium*	*Cassia spectabilis*		
Carbon %	46.20	41.24	43.69	1.07	1.48
Nitrogen %	3.85	3.36	3.58	0.07	1.20
Phosphorus %	0.32	0.45	0.34	0.02	3.06
Potassium %	1.56	2.87	1.40	0.19	5.51
Calcium %	1.32	1.40	1.12	0.02	1.10
Magnesium %	0.36	0.44	0.29	0.0	1.59
Lignin %	5.6	7.6	8.7	0.40	3.0
Lignin/Nitrogen	1.45	2.26	2.43	0.13	3.02
Carbon/Nitrogen	12.0	12.3	12.2	0.20	13.4

Table 2: Nutrient Release Constants (K) for leaf mulch of *Leucaena leucocephala Gliricidia sepium* and *Cassia spectabilis*

Nutrient	Species			LSD (0.05)	C.V. (%)
	Leucaena leucocephala	*Gliricidia sepium*	*Cassia spectabilis*		
Carbon	0.015	0.010	0.007	0.002	9.38
Nitrogen	0.020	0.015	0.009	0.003	12.0
Phosphorus	0.018	0.020	0.010	0.005	20.0
Potassium	0.042	0.045	0.018	0.0034	5.95
Calcium	0.009	0.015	0.007	0.0038	22.35
Magnesium	0.029	0.030	0.017	0.0046	11.11

TABLE 3: Soil Physical and Chemical Properties of the study site[1]

Characteristics		Depth of Profile	
		0-15cm	15-30cm
Organic matter	(%)	1.32 (0.03)	0.62 (0.02)
Carbon	(%)	0.66 (0.02)	0.30 (0.07)
Nitrogen	(%)	0.07 (0.03)	0.03 (0.02)
Phosphorus	(ppm)	1.65 (0.04)	0.25 (0.04)
Potassium	(ppm)	36.50 (0.52)	20.0 (2.40)
Calcium	(Meq/100g)	1.10 (0.40)	0.30 (0.02)
Magnesium	(Meq/100g)	0.70 (0.30)	0.21 (0.40)
Cation Exchange Capacity	(Meq/100g)	2.74 (0.14)	1.21 (0.03)
Base Saturation	(%)	69.0 (1.58)	50.0 (1.73)
pH(H_2O)		4.85 (0.03)	44.95 (0.04)

[1] Standard Deviation of means are given in parentheses

TABLE 4: Percent changes in soil Chemical Properties under decomposing leaf mulches at 0-15cm depth of profile[1]

Soil Chemical Property	Species			LSD (0.05)	C.V. (%)
	Leucaena leucocephala	*Gliricidia sepium*	*Cassia spectabilis*		
Organic Carbon	31.8	28.8	22.7	1.01	2.22
Total Nitrogen	114.3	157.0	85.7	0.55	0.28
Available Phosphorus	10.9	5.5	4.2	0.35	3.07
Total Potassium	74.2	90.6	64.8	0.46	0.37
Exchangeable Calcium	36.4	39.0	24.8	0.28	0.50
Exchangeable Magnesium	61.4	48.6	31.4	0.33	0.42

1 Percent changes in soil = c/a x 100 where "a" is initial soil nutrient level, "b" is soil nutrient level at day 70 and change is c= b-a.

Table 5. Percent change in Soil Chemical Properties under decomposing leaf mulches at 15-30cm depth of profile[1].

Soil Chemical Property	Species			LSD (0.05)	C.V. (%)
	Leucaena leucocephala	*Gliricidia sepium*	*Cassia spectabilis*		
Organic Carbon	20.0	-13.3	12.7	0.25	1.00
Total Nitrogen	133.3	103.0	76.7	0.16	0.10
Available Phosphorus	28.0	20.0	18.0	0.65	2.26
Total Potassium	97.7	94.5	68.0	11.64	7.93
Exchangeable Calcium	46.3	43.7	38.6	0.54	0.78
Exchangeable Magnesium	80.95	66.7	42.9	0.38	0.36

1 Percent changes in soil = c/a x 100 where "a" is initial soil nutrient level, "b" is soil nutrient level at day 70 and change is c=b-a.

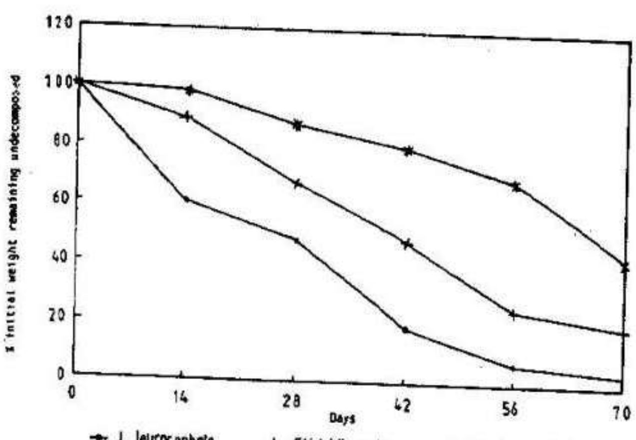

Fig.1 Percentage of initial weight remaining with time in decomposing leaves of Leucaena leucocephala, Gliricidia sepium, and Cassia spectabilis.