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Leaf-litter decomposition and nutrient release dynamics of some savanna agroforestry tree species: A model for soil improvement strategies

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ABSTRACT

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The application of leguminous agroforestry tree species using leafy biomass to improve soil fertility in the savanna alfisols is observed to be uncommon. Although, if applied, leguminous leafy biomass increases soil organic matter and improves its fertility potentials for crop productivity. This research investigated leaf-litter decomposition and nutrient release of some selected agroforestry tree species. Five species of agroforestry tree leafy biomass were selected (*Faidherbia albida, Leucaena leucocephala*, *Gliricidia sepium, Senna siamea*, *Albizia lebbeck*) and the effect of the biomass placement patterns of the litter bags in the soil was investigated; viz-a-viz surface placement (above-ground level) and embedded placement at 15cm depth (below-ground level) arranged as 5x2 factorial in Randomized Complete Block Design with four replicates. The data were analyzed using Analysis of Variance, while the means were separated using Duncan Multiple Range Test ($p \leq 0.05$). The soil results showed that the pH of the study area was near neutral (6.20) and loamy sand in nature.

The leafy biomass of all the agroforestry tree species tested were noted to release nutrients two weeks after decomposition. However, it was observed that the species of leafy biomass and placement patterns had significant influence on both weight loss and nutrient release. The rate of leaf-litter decomposition and nutrient release (mineralization) were significantly higher in biomass embedded in soil at 15cm depth (below-ground level) than the surface

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placement (above-ground level). The nutrients released in the form of nitrogen, phosphorus, potassium, calcium, magnesium, sodium and organic carbon from leafy biomass embedded in the soil reached more than 50% in the 14 days of biomass decomposition. *G. sepium* leafy biomass among other species decomposed and released nutrients more rapidly, both at embedded and surface placements. It is therefore recommended that *G. sepium* leafy biomass be used as an alternative organic based fertilizer to improve soil fertility for increased crop production in savanna alfisols.

Keywords: Leaf residues, decomposition, mineralization, soil fertility, alfisols

INTRODUCTION

In most tropical soils of the world, especially arid and semi-arid, are deficient in valuable nutrients like nitrogen (N), phosphorus (P) or both, and even soil organic carbon (Pandey et al 2006). In most cases, many of these soils are acidic, infertile and cannot support sustainable crop production without external inputs of inorganic fertilizers which are costly and often unavailable (Oyebamiji et al 2017). Leguminous tree can enhance soil fertility by adding N through N_2-fixation and recycling of nutrients through litter fall or pruning. The practice of agroforestry entails 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 into their individual components (Zeng et al 2009). The selection of appropriate tree species based on nutrient cycling is a vital issue in agroforestry practices (Daldoum et al 2010, Hasanuzzaman and Hossain 2014). Leafy biomass and its productivity are among the main factors that contribute to nutrient cycling in an ecosystem (Aerts and De Caluwe 1997). Leafy biomass of leguminous trees has been noted to help improve nutrient cycling in ecosystems (Muthuri et al 2005). There is always a need for current and future production of food, fodder and fuel wood, however, the continuous production of these needs has led to the depletion of soil fertility (Nair 1997). For sustainable and increasing production of food in a depleted soil, introduction of leguminous tree species that fix atmospheric N is to be encouraged. The leafy biomass is decomposed by soil organisms under the influence of soil physical and chemical properties, soil conditions and resources quality (biomass chemical composition) to release adequate nutrients to the soil for sustainable production (Theuerl et al 2010). An increased understanding of the decomposition of tree leafy biomass will complement the gap in the knowledge of nutrient cycling in agroforestry systems in semi-arid lands (Hui and Jackson 2008). Decomposition is the key process in the control of nutrient cycling and formation of soil organic matter (Oyebamiji et al 2018). The decomposition of tree leafy biomass is a major source of nutrients for the soil as leaves are broken down by insects and microbial decomposers in order to release free ions into the soil as a solution which is then made available to plants (Swift et al 1997). It is evident that leaves of trees that have high nitrogen content but low in lignin and polyphenols (eg, leaves of *Gliricidia sepium*) will decompose very quickly and release a large proportion of their N. Slow decomposition can be the result of several different characteristics, generally related to large amounts of reactive polyphenols or structural lignin and associated insoluble proanthocyanidins. The quality of an organic materials, which is being referred to, is its organic constituents and nutrient content (Cadisch and Giller 1997). Organic constituents are important in that the energy available to decompose organisms depends on the proportion of soluble carbon, cellulose, hemicellulose and lignin. Soluble carbon, which includes metabolic and storage carbon, is primarily responsible for promoting microbial growth and other activities (Smith 1994). Nutrients released therefore from the decomposed litters invariably improve the soil quality and fertility, and in turn, when made available to crops for their physiological and morphological growth, will promote food production ultimately for human benefit. The hypothesis of the study was that, there will be no significant effect of the placement pattern on the tree species leafy biomass. The objectives of the study investigated the mass of nutrients lost and the nutrients released during decomposition.

MATERIALS AND METHODS

The Study Area

The study area was located at the Main Campus of the Federal University Dutsin-Ma, Katsina State, Nigeria, which lies between Latitude 12º29'32"N and Longitude 7º49'63"E (Tukur and Kan 2013). The research was conducted during the rainy season, between June and September. The area receives an annual rainfall of 700mm, which is spread from May to September. The mean annual temperature ranges from 29-31ºC, the high temperature normally occurs in April/May and the lowest in December through February. The vegetation of the area is the Sudan savanna, sharing the characteristics and species of both the Guinea and Sahel savanna.

Experimental Design

The experiment was laid out as 5x2 factorial in a Randomized Complete Block Design (RCBD) with factor (1) as the leafy biomass of the five (5) species of nitrogen-fixing agroforestry tree (*Faidherbia albida, Leucaena leucocephala*, *Gliricidia sepium, Senna siamea*, *Albizia lebbeck*) and factor (2) as two (2) placement patterns; surface placement (above) and embedded placement at 15cm depth in the soil (below). Fifty (50) grams of freshly pruned leafy biomass of the selected agroforestry tree species were weighed into the litter bags measuring 35cmx37cm and placed on the surface (above) and embedded (below) at 15cm depth. Soil samples were randomly collected at various points with the use of a soil auger. The polythene tubes of 40cmx32cm dimension were filled to the brim with top soil. Observation was done on daily basis, while data were collected at 14 days (2 weeks) interval for 70 days (10 weeks). The nutrient release and weight loss parameters were measured and recorded.

Leaf biomass decomposition was determined using litter bags technique (Anderson and Ingram 1993). Fifty (50) grams of leafy biomass were weighed into 2mm mesh litter bags of 35cmx37cm size, and closed at both ends. Litter bags were placed in an area of land 60mx120m. Two hundred (200) litter bags were used; in which one hundred (100) litter bags were randomly placed on the surface of the soil (above-ground level) in four (4) replicates while the remaining one hundred

(100) litter bags were buried or embedded in the soil at 15cm depth (below-ground level) also in four (4) replicates. Twenty (20) litter bags each were randomly retrieved from the soil surface (above-ground level), and embedded (below-ground level) respectively at 14-day intervals. The litter bags were carefully removed, rinsed in clean running water to remove sand and other impurities apart from the biomass and taken to the laboratory where the bags were opened and the contents spread apart to remove attached clumps of soil and fine roots. The samples were oven dried at 75^0C to a constant weight to determine the final dry weight. Fresh leaf litter samples were collected and analyzed as the control.

The prediction of biomass decomposition was conducted using this equation $W_t=W_0\ e^{-kt}$ of Sulistiyanto et al (2005) that assumes the weight loss occurred exponentially:

$$W_t = W_0 e^{-kt}$$

Where, W_t = weight of biomass/litter after a period of observation (g); W_0 = initial biomass/litter weight (g); e = logarithm value; k = logarithm coefficient (constant) of decomposition rate; t = observation period (day).

Nutrient release was calculated using:

$$R(\%) = (W_0C_0 - W_tC_t) / W_0C_0 \times 100$$

Where:

W_t = weight of biomass/litter after a period of observation (g);
W_0 = initial biomass/litter weight (g);
e = logarithm value;
k = logarithm coefficient (constant) of decomposition rate;
t = observation period (day);
C_0 = initial nutrient concentration;
C_t = final nutrient concentration (Guo and Sims 1999).

Soil Preparation and Analysis

Soil samples were randomly collected from a depth of 0-30cm, air-dried, ground and were analyzed as described below. Soil pH was determined in 0.01M $CaCl_2$ by using a soil to solution ratio of 1:2.5 by means of a Philip analogue pH meter (Black 1965). The organic carbon content was determined by the wet oxidation method of Walkley-Black as described by Allison (1965). Total N was analyzed by Macro-Kjeldahl digestion, followed by distillation and titration (Brandstreet 1965, Anderson and Ingram 1993). The C:N ratio was computed as ratio of N to C. Available P was extracted by the Bray 1 method. The P concentration in the extract was determined colorimetrically by using the Spectronic 20 and absorption was read-off as described by Bray and Kurtz (1945) and modified by Murphy and Riley (1962). Exchangeable Na was extracted using ammonium acetate, while K was determined by flame photometer, and Ca and Mg by Atomic Absorption Spectrophotometer (AAS).

Data Analysis

All data were subjected to Analysis of Variance (ANOVA) using generalized linear models (GLM) procedure. The significant means were separated by the Duncan Multiple Range Test (DMRT) at five (5) percent level of significance (Duncan 1955). All statistical analyses were carried out using Statistical Analysis System (SAS) procedures and software (SAS 2003).

RESULTS

Soil Physical and Chemical Properties before the Experiment

The soil had particle sizes: 100g kg^{-1} sand, 100g kg^{-1} silt and 800g kg^{-1} clay belonging to the textural class loamy sandy. The soil had pH6.20 in water (H_2O), pH5.40 in salt ($CaCl_2$), 4.00g kg^{-1} organic carbon, 0.28g kg^{-1} total nitrogen and 2.10mg kg^{-1} available phosphorus. The soil also had exchangeable bases of 2.20mg kg^{-1} calcium, 0.47mg kg^{-1} magnesium, 0.25mg kg^{-1} potassium and 0.09mg kg^{-1} sodium (Table 1).

Table 1. Soil physical and chemical properties of the study area

Soil Properties	Values
Particle size (g kg^{-1})	
Sand	100
Silt	100
Clay	800
Textural class	Loamy sand
Chemical properties	
pH in water (H_2O) 1:2.5	6.20
pH in salt ($CaCl_2$) 1:2.5	5.40
Organic carbon (g kg^{-1})	4.00
Total nitrogen (g kg^{-1})	0.28
Available phosphorus (mg kg^{-1})	2.10
Exchangeable bases (Cmol kg^{-1})	
Ca	2.20
Mg	0.47
K	0.25
Na	0.09

K:Potassium; Ca:Calcium; Mg:Magnesium; Na:Sodium

Measurements of leaf biomass showed that *G. sepium* had a significantly higher nitrogen content (4.10g kg^{-1}) and *F. albida* had higher values (77.43, 21.51 and 15.00g kg^{-1}) of organic carbon, carbon to nitrogen ratio and polyphenol to nitrogen ratio respectively than other selected leafy biomass. However, *A. lebbeck* had significantly higher values (15.58, 64.92, 4.15 and 4.22g kg^{-1}) of lignin, lignin to polyphenol ratio, lignin to nitrogen ratio and lignin plus polyphenol to nitrogen ratio respectively compared to other types of biomass. Furthermore, *S. siamea* and *L. leucocephala* had significantly higher values (0.41g kg^{-1} and 20.00g kg^{-1}) of polyphenol and cellulose compared to other selected leafy biomass (Table 2).

Table 2. Mean chemical composition (g kg^{-1}) of the selected leafy biomass

Species/ chemical content	*Faidherbia albida*	*Leucaena leucocephala*	*Gliricidia sepium*	*Senna siamea*	*Albizia lebbeck*
Nitrogen	3.60^{b}	3.20^{c}	4.10^{a}	3.60^{b}	3.75^{b}
Carbon	77.43^{a}	50.73^{c}	48.04^{d}	58.75^{c}	74.76^{b}
C:N	21.51^{a}	15.85^{d}	11.72^{e}	16.32^{c}	19.94^{b}
Lignin	5.41^{e}	12.26^{b}	11.11^{c}	6.33^{d}	15.58^{a}
Polyphenol	0.24^{e}	0.32^{c}	0.37^{b}	0.41^{a}	0.29^{d}
L:PP	22.54^{d}	33.14^{c}	34.72^{b}	15.44^{e}	64.92^{a}
L:N	1.50^{e}	3.83^{b}	2.71^{c}	1.76^{d}	4.15^{a}
PP:N	15.00^{a}	8.65^{e}	12.81^{c}	8.78^{d}	15.63^{b}
(L+PP):N	1.57^{e}	3.95^{b}	2.79^{c}	1.87^{d}	4.22^{a}
Cellulose	12.16^{c}	20.00^{a}	6.17^{e}	6.33^{d}	17.00^{b}

C:N Carbon to Nitrogen ratio, L:PP Lignin to Polyphenol ratio, L:N Lignin to Nitrogen ratio, PP:N Polyphenol to Nitrogen ratio, (L+PP):N Lignin plus Polyphenol to Nitrogen ratio

Different letters as superscripts across the columns indicate significant difference ($p \leq 0.05$). Means followed by the same letters within the same column and treatments are not significantly different at 5% level of probability.

From the initial weight of 50g, there was generally a rapid loss of mass from the litter bags during the first 14 days of biomass placements by all the species of leafy biomass. However, *G. sepium* decomposed faster both at the surface (above-ground level) and embedded (below-ground level) compared to other leafy biomass under investigation with a mass loss of 41.76g (remaining 8.24g) at the below-ground level and 39.33g (remaining 10.67g) at the above-ground level respectively after 14 days of placement. At 28 days of biomass placement, *G. sepium* had lost 43.35g (remaining 6.65g) and 40.77g (remaining 9.23g) of its initial weight. The mass loss due to decomposition was slightly reduced from days 42 to 70 in almost all of the examined leafy biomass, even though, decomposition of the leafy biomass continued across all the days of the experiment (Figure 1).

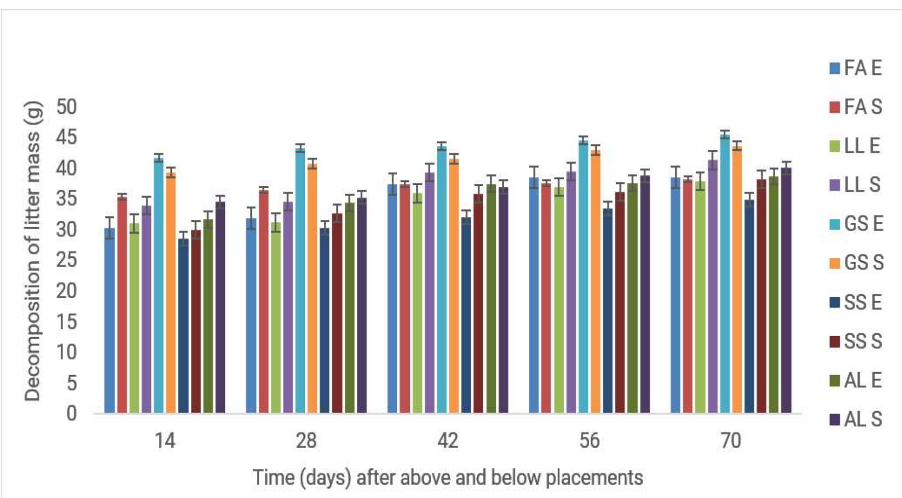

Figure 1. Loss of weight (g) of leafy biomass over a period of 70 days

FA: *Faidherbia albida,* LL: *Leucaena leucocephala*, GS: *Gliricidia sepium,* SS: *Senna siamea*, AL: *Albizia lebbeck;* E: Embedded placement, S: Surface placement

Consistently, at day 14 of biomass placement, *G. sepium* (embedded) had significantly higher values: 896.50g kg^{-1} (N), 881.40g kg^{-1} (OC), 873.80mg kg^{-1} (P), 773.20mg kg^{-1} (K), 823.20mg kg^{-1} (Ca), 793.20mg kg^{-1} (Mg) and 808.20mg kg^{-1} (Na) across all the examined nutrients. Meanwhile, *G. sepium* (surface placement) also had significantly higher values (797.90g kg^{-1}, 845.20g kg^{-1}, 887.40mg kg^{-1}, 707.40mg kg^{-1}, 757.40mg kg^{-1}, 727.40mg kg^{-1} and 742.40mg kg^{-1} N, OC, P, K, Ca, Mg, Na respectively), across all the examined nutrients. Moreover at day 28, *G. sepium* both at surface (above) (926.10g kg^{-1}, 837.30mg kg^{-1}, 737.30mg kg^{-1}, 787.30mg kg^{-1}, 757.30mg kg^{-1}, 772.30mg kg^{-1} and embedded (below) placement (942.90g kg^{-1}, 882.50mg kg^{-1}, 782.50mg kg^{-1}, 832.50mg kg^{-1}, 802.50mg kg^{-1}, 817.50mg kg^{-1}) had significantly higher values in nitrogen, phosphorus, potassium, calcium, magnesium and sodium respectively among other selected biomass. Comparison between *G. sepium* surface and embedded, shows that *G. sepium* embedded had a significantly higher value (911.60g kg^{-1}) than *G. sepium* surface placement in organic carbon. However, in relation to other biomass *G. sepium* both at the surface and embedded had higher significant effects compared to other selected biomass.

At 42 days, *G. sepium* embedded had significantly higher values (936.00g kg^{-1}, 960.30mg kg^{-1}, 904.80mg kg^{-1}, 804.80mg kg^{-1}, 854.80mg kg^{-1}, 824.80mg kg^{-1} and 839.80mg kg^{-1}) in organic carbon, phosphorus, potassium, calcium, magnesium and sodium compared to other selected biomass. Meanwhile, there was no significant effect between *G. sepium* both in the surface and embedded placements in nitrogen. Furthermore, *G. sepium* had significantly higher values (877.80g kg^{-1}, 859.90mg kg^{-1}, 759.90mg kg^{-1}, 509.90mg kg^{-1}, 779.90mg kg^{-1} and 794.90mg kg^{-1}) in organic carbon, phosphorus, potassium, calcium, magnesium and sodium respectively among other selected biomass.

At day 56, consistently *G. sepium* embedded placement was also observed to have significantly higher values (951.30g kg^{-1}, 928.80mg kg^{-1}, 828.80mg kg^{-1}, 878.80mg kg^{-1}, 848.80mg kg^{-1} and 863.80mg kg^{-1}) in organic carbon, phosphorus, potassium, calcium, magnesium and sodium respectively among other selected biomass. However, *A. lebbeck* embedded was noted to have a significantly higher value (986.90g kg^{-1}) in nitrogen. *G. sepium* surface placement was also noted to have consistently have significantly higher values (909.20g kg^{-1}, 968.50g kg^{-1}, 873.30mg kg^{-1}, 773.30mg kg^{-1}, 823.30mg kg^{-1}, 793.30mg kg^{-1} and 808.30mg kg^{-1}) across all the selected nutrient examined.

At day 70, among other leafy biomass under investigation, it was observed that *S. siamea* in surface placement had significantly lower values (897.80g kg^{-1} and 816.10mg kg^{-1}) in nitrogen and magnesium respectively. *A. lebbeck* in surface placement also experienced significantly lower value (837.90g kg^{-1}) in organic carbon. Furthermore, *L. leucocephala* also in the surface placement had significantly lower values (890.90mg kg^{-1}, 790.90mg kg^{-1}, 840.90mg kg^{-1} and 825.90mg kg^{-1}) in phosphorus, potassium, calcium and sodium respectively (Table 3).

Table 3. The nutrient content of decomposing leafy biomass at 14 days intervals

Days	Treatment	N (g kg^{-1})	OC (g kg^{-1})	P (mg kg^{-1})	K (mg kg^{-1})	Ca (mg kg^{-1})	Mg (mg kg^{-1})	Na (mg kg^{-1})
14	FA surface placement	675.50±0.07^{f}	619.60±0.08^{g}	644.80±0.89^{d}	544.80±0.89^{d}	594.80±0.89^{d}	564.80±0.89^{d}	579.80±0.89^{d}
	FA embedded placement	753.00±0.82^{cd}	787.80±0.74^{b}	721.10±1.09^{c}	621.10±1.09^{c}	671.10±1.09^{c}	641.10±1.09^{c}	656.10±1.09^{c}
	LL surface placement	678.70±2.08^{ef}	660.90±0.87^{f}	644.80±0.95^{d}	544.80±0.95^{d}	594.80±0.95^{d}	564.80±0.95^{d}	579.80±0.95^{d}
	LL embedded placement	728.30±0.95^{de}	723.00±1.39^{cd}	695.00±0.49^{c}	595.00±0.49^{c}	645.00±0.49^{c}	615.00±0.49^{c}	630.00±0.49^{c}
	GS surface placement	845.20±1.38^{b}	797.90±0.39^{b}	807.40±0.87^{b}	707.40±0.87^{b}	757.40±0.87^{b}	727.40±0.87^{b}	742.40±0.87^{b}
	GS embedded Placement	881.40±0.65^{a}	896.50±0.82^{a}	873.20±1.19^{a}	773.20±1.19^{a}	823.20±1.19^{a}	793.20±1.19^{a}	808.20±1.19^{a}
	SS surface placement	606.60±2.50^{g}	679.00±1.36^{ef}	643.70±3.26^{d}	543.70±3.26^{d}	593.70±3.26^{d}	563.70±3.26^{d}	578.70±3.26^{d}
	SS embedded placement	638.80±2.38^{fg}	706.00±1.67^{de}	629.60±1.64^{d}	529.60±1.64^{d}	579.60±1.64^{d}	549.60±1.64^{d}	564.60±1.64^{d}
	AL surface placement	740.10±2.91^{d}	672.80±0.31^{f}	706.00±0.62^{c}	606.00±0.62^{c}	656.00±0.62^{c}	626.00±0.62^{c}	641.00±0.62^{c}
	AL embedded placement	801.60±1.14^{bc}	746.50±1.07^{c}	736.80±1.28^{c}	636.80±1.28^{c}	686.80±1.28^{c}	656.80±1.28^{c}	671.80±1.28^{c}

Table 3. Continued

Days	Treatment	N (g kg^{-1})	OC (g kg^{-1})	P (mg kg^{-1})	K (mg kg^{-1})	Ca (mg kg^{-1})	Mg (mg kg^{-1})	Na (mg kg^{-1})
28	FA surface placement	760.40±0.16^{d}	710.70±0.01^{e}	679.80±0.75^{c}	579.70±0.75^{c}	629.80±0.75^{c}	599.80±0.75^{c}	614.80±0.75^{c}
	FA embedded placement	808.20±0.39^{c}	814.30±0.30^{bc}	744.10±0.47^{bc}	644.10±0.47^{bc}	694.10±0.47^{bc}	664.10±0.47^{bc}	679.10±0.47^{bc}
	LL surface placement	794.40±3.69^{cd}	738.60±4.69^{de}	728.70±5.26^{bc}	628.70±5.26^{bc}	678.70±5.26^{bc}	648.70±5.26^{bc}	663.70±5.26^{bc}
	LL embedded placement	819.00±0.45^{bc}	772.10±0.51^{cde}	708.70±1.08^{bc}	608.70±1.08^{bc}	658.70±1.08^{bc}	628.70±1.08^{bc}	643.70±1.08^{bc}
	GS surface placement	926.10±1.17^{a}	857.50±2.72^{ab}	837.30±2.93^{a}	737.30±2.93^{a}	787.30±2.93^{a}	757.30±2.93^{a}	772.30±2.93^{a}
	GS embedded placement	942.70±0.17^{a}	911.60±0.31^{a}	882.50±0.63^{a}	782.50±0.63^{a}	832.50±0.63^{a}	802.50±0.63^{a}	817.50±0.63^{a}
	SS surface placement	690.90±0.68^{e}	733.10±1.42^{de}	693.20±1.28^{bc}	593.20±1.28^{bc}	643.20±1.28^{bc}	613.20±1.28^{bc}	628.20±1.28^{bc}
	SS embedded placement	710.80±0.35^{e}	767.50±1.09^{cde}	705.10±1.56^{bc}	605.10±1.56^{bc}	655.10±1.56^{bc}	625.10±1.56^{bc}	640.10±1.56^{bc}
	AL surface placement	855.10±0.52^{b}	731.70±0.88^{de}	760.00±0.92^{b}	660.00±0.92^{b}	710.00±0.92^{b}	680.00±0.92^{b}	695.00±0.92^{b}
	AL embedded placement	850.80±0.97^{b}	779.40±1.42^{cd}	758.90±1.62^{b}	658.90±1.62^{b}	708.90±1.62^{b}	678.90±1.62^{b}	693.90±1.62^{b}

Table 3. Continued

Days	Treatment	N (g kg^{-1})	OC (g kg^{-1})	P (mg kg^{-1})	K (mg kg^{-1})	Ca (mg kg^{-1})	Mg (mg kg^{-1})	Na (mg kg^{-1})
42	FA surface placement	852.30±0.51^{d}	810.10±0.01^{bc}	787.90±0.79^{bc}	687.90±0.79^{bc}	737.90±0.79^{bc}	707.90±0.79^{bc}	722.90±0.79^{bc}
	FA embedded placement	838.60±0.33^{d}	839.70±3.33^{bc}	776.00±0.72^{c}	676.00±0.72^{c}	726.00±0.72^{c}	696.00±0.72^{c}	711.00±0.72^{c}
	LL surface placement	909.90±1.57^{c}	774.30±3.94^{c}	774.00±3.95^{c}	674.00±3.95^{c}	724.00±3.95^{c}	694.00±3.95^{c}	709.00±3.95^{c}
	LL embedded placement	942.80±1.51^{b}	870.80±3.37^{b}	809.60±4.88^{bc}	709.60±4.88^{bc}	759.60±4.88^{bc}	729.60±4.88^{bc}	744.60±4.88^{bc}
	GS surface placement	956.90±0.57^{a}	877.80±1.62^{ab}	859.90±1.43^{ab}	759.90±1.43^{ab}	809.90±1.43^{ab}	779.90±1.43^{ab}	794.90±1.43^{ab}
	SS surface placement	731.00±1.76^{f}	776.70±0.29^{c}	751.90±3.00^{c}	651.90±3.00^{c}	701.90±3.00^{c}	671.90±3.00^{c}	686.90±3.00^{c}
	SS embedded placement	774.50±0.31^{e}	828.20±0.29^{bc}	797.00±1.15^{bc}	697.00±1.15^{bc}	747.00±1.15^{bc}	717.00±1.15^{bc}	732.00±1.15^{bc}
	AL surface placement	912.60±0.15^{c}	799.90±0.31^{c}	821.40±0.81^{bc}	721.40±0.81^{bc}	771.40±0.81^{bc}	741.40±0.81^{bc}	756.40±0.81^{bc}
	AL embedded placement	922.20±0.49^{bc}	825.20±1.07^{bc}	790.80±1.37^{bc}	690.80±1.37^{bc}	740.80±1.37^{bc}	710.80±1.37^{bc}	725.80±1.37^{bc}

Table 3. Continued

Days	Treatment	N (g kg^{-1})	OC (g kg^{-1})	P (mg kg^{-1})	K (mg kg^{-1})	Ca (mg kg^{-1})	Mg (mg kg^{-1})	Na (mg kg^{-1})
56	FA surface placement	901.00±0.05^{e}	837.80±0.22^{cd}	812.00±0.47^{c}	712.00±0.47^{c}	762.00±0.47^{c}	732.00±0.47^{c}	747.00±0.47^{c}
	FA embedded placement	900.30±1.31^{e}	866.50±1.57^{bc}	797.80±2.35^{c}	697.80±2.35^{c}	747.80±2.35^{c}	717.80±2.35^{c}	732.80±2.35^{c}
	LL surface placement	951.60±0.34^{cd}	814.10±1.55^{d}	813.10±1.55^{c}	713.10±1.55^{c}	763.10±1.55^{c}	733.10±1.55^{c}	748.10±1.55^{c}
	LL embedded placement	941.10±1.16^{d}	876.70±2.97^{bc}	815.80±3.92^{c}	715.80±3.92^{c}	765.80±3.92^{c}	735.80±3.92^{c}	750.80±3.92^{c}
	GS surface placement	968.50±0.21^{abc}	909.20±0.84^{b}	873.30±0.96^{b}	773.30±0.96^{b}	823.30±0.96^{b}	793.30±0.96^{b}	808.30±0.96^{b}
	GS embedded placement	973.30±0.16^{ab}	951.30±0.36^{a}	928.80±0.67^{a}	828.80±0.67^{a}	878.80±0.67^{a}	848.80±0.67^{a}	863.80±0.67^{a}
	SS surface placement	848.70±0.43^{g}	822.40±0.67^{d}	799.90±0.74^{c}	699.80±0.74^{c}	749.80±0.74^{c}	719.80±0.74^{c}	734.80±0.74^{c}
	SS embedded placement	848.80±1.30^{f}	876.20±1.64^{bc}	801.70±2.05^{c}	701.70±2.05^{c}	751.70±2.05^{c}	721.70±2.05^{c}	736.70±2.05^{c}
	AL surface placement	953.70±0.25^{bcd}	813.80±1.09^{d}	928.50±0.34^{a}	828.50±0.34^{a}	878.50±0.34^{a}	848.50±0.34^{a}	863.50±0.34^{a}
	AL embedded placement	986.70±0.05^{a}	868.80±2.63^{bc}	837.70±0.59^{bc}	737.70±0.59^{bc}	787.70±0.59^{bc}	757.70±0.59^{bc}	772.70±0.59^{bc}

Table 3. Continued

Days	Treatment	N (g kg^{-1})	OC (g kg^{-1})	P (mg kg^{-1})	K (mg kg^{-1})	Ca (mg kg^{-1})	Mg (mg kg^{-1})	Na (mg kg^{-1})
70	FA surface placement	962.20±0.19^{c}	887.10±0.01^{cde}	938.50±0.20^{ab}	838.50±0.20^{ab}	888.50±0.20^{ab}	858.50±0.20^{ab}	873.50±0.20^{ab}
	FA embedded placement	961.20±0.85^{c}	908.20±1.20^{bcd}	904.90±1.67^{cd}	804.90±1.67^{cd}	854.90±1.67^{cd}	824.90±1.67^{cd}	839.90±1.67^{cd}
	LL surface placement	981.80±0.25^{a}	861.90±1.72^{de}	890.90±1.19^{d}	790.90±1.19^{d}	840.90±1.19^{d}	819.00±1.19^{d}	825.90±1.19^{d}
	LL embedded placement	979.80±0.36^{a}	914.90±3.65^{bcd}	947.50±0.95^{ab}	847.50±0.95^{ab}	897.50±0.95^{ab}	867.50±0.95^{ab}	882.50±0.95^{ab}
	GS surface placement	985.90±0.03^{a}	941.80±0.54^{ab}	959.20±0.33^{a}	859.20±0.33^{a}	909.20±0.33^{a}	879.20±0.33^{a}	894.20±0.33^{a}
	GS embedded placement	986.50±0.09^{a}	974.10±0.17^{a}	949.20±0.42^{ab}	849.20±0.42^{ab}	899.20±0.42^{ab}	869.20±0.42^{ab}	884.20±0.42^{ab}
	SS surface placement	897.80±0.23^{e}	873.20±1.33^{cde}	896.10±1.56^{d}	796.10±1.56^{d}	846.10±1.56^{d}	816.10±1.56^{d}	831.10±1.56^{d}
	SS embedded placement	927.10±0.76^{d}	923.00±1.07^{bc}	925.80±0.55^{bc}	825.80±0.55^{bc}	875.80±0.55^{bc}	845.80±0.55^{bc}	860.80±0.55^{bc}
	AL surface placement	973.10±0.10^{b}	837.90±2.46^{e}	947.80±0.80^{ab}	847.60±0.80^{ab}	897.80±0.80^{ab}	867.80±0.80^{ab}	882.80±0.80^{ab}
	AL embedded placement	989.60±0.09^{a}	890.20±0.74^{b-e}	954.10±0.70^{ab}	854.10±0.70^{ab}	904.10±0.70^{ab}	874.10±0.70^{ab}	889.10±0.70^{ab}

FA: *Faidherbia albida*, LL: *Leucaena leucocephala*, GS: *Gliricidia sepium*, SS: *Senna siamea*, AL: *Albizia lebbeck*

DISCUSSION

The soil was observed to have low total nitrogen and organic carbon. The soil belongs to the textural class loamy sand. The soil pH is slightly acidic near neutral. The distribution of soil exchangeable cations followed the order: Ca>Mg>K>Na. *G. sepium* among other leafy biomass investigated had the highest nitrogen content and lowest C-to-N (C:N) ratio. This aided its better performance in terms of rapid decomposition of its organic materials and early nutrient release. This agreed with the findings of Oladoye et al (2018) that the plant residues of higher quality in terms of chemical composition tend to decompose more rapidly with a net mineralization of nitrogen after incorporation into the soil. The decomposition of the leafy biomass had basically caused changes in the condition of the soil due to the influence of biological and abiotic factors. The decomposition of leguminous leafy biomass is important in the nutrient cycle due to the level of the cycled nutrients becoming readily available to plants for their use (Oyebamiji et al 2016).

The leaves that were high in N, low in lignin, and low in polyphenols (eg, those of *G. sepium* and *L. leucocephala*) decomposed quickly and released a large amount of their N. Well-lignified leaves (eg, *S. siamea*) decomposed slowly and caused immobilization of soil N for a long period of time (several weeks) before being released to the soil. The decomposition pattern of biomass of species with high N and polyphenol contents may be controlled by the protein-binding capacity of the polyphenols. However, decomposition will be very rapid when protein-binding capacity is low (eg, *G. sepium*), whereas decomposition was slow when protein-binding capacity was high (eg, *S. siamea*). Furthermore, species with low lignin and polyphenol contents may decompose slowly if large amounts of N are bound to condensed tannins as found in *F. albida*. The large variations in decomposition patterns of the biomass from several agroforestry tree species were based largely on the chemical quality parameters of the materials (ie, the leafy biomass) (Nair et al 1999).

High lignin and polyphenol contents of organic materials actually hamper the mineralization process due to their ability to bind proteins, thus determine the quality of organic materials to be decomposed by soil microbes (Hadanyanto et al 1997). However, De Costa and Atapattu (2001); Oyebamiji et al (2018) reported that weight loss of biomass or litters generally takes place in the first 14-28 days (2-4 weeks) of incorporation into the soil, since the physical and biological processes occurred faster during this time and most of the weight loss came from soluble fractions compared to lignocellulose fractions (Andren and Paustin 1987), because the soluble fractions of the biomass mostly contain simple organic compounds.

Weight loss of the biomass during the decomposition period is an indicator to estimate the rate of decomposition. It was clearly observed that the weight loss of the biomass was generally faster in the first 14 days across all the species examined. It was recorded that the leafy biomass of the agroforestry tree species had over 55 percent loss in weight during the first 14 days (two weeks) of incubation. However, there were differences among the species with the highest decomposition rate and nutrient release being observed in *G. sepium,* while, the lowest was observed in *S. siamea*. Generally, the weight lost was higher in embedded placements than on the surface. This could be a result of microbial activity that took place during the process of decomposition that was observed to be faster at below-ground level than in the above-ground level where microbial activities were minimal in comparison. The variation in the concentration and nature of the nutrients in the leafy biomass also affected the decomposition rate. This was similar to the observation of De Costa and Atapattu (2001) who noted that weight loss of biomass generally took place in the first 2-4 weeks of addition of the biomass into the soil irrespective of placement. The nutrient content in the remaining undecomposed litter generally increased with time (Oyebamiji et al 2017).

It was generally observed that *G. sepium* resulted in the highest nutrient release during decomposition at 14 days interval in the embedded (below-ground level) with nitrogen, organic carbon, phosphorus and exchangeable cations released across the period of investigation (14-70 days). This could be as a result of adequate distribution of rainfall and consistency in temperature and moisture dynamics that stimulate the activities of microbes and decomposers during the decomposition process, removal of unwanted plants that might use up the nutrients in the litter bags, and ultimately, the high chemical concentration quality of the organic materials (leafy biomass) that necessitated rapid decomposition and release of nutrients (Brown and Lemon 2008, Singh et al 2010, Lalitha et al 2010, Horneck et al 2011, Oladoye et al 2020).

CONCLUSION

This study establishes the fact that both the agroforestry tree species and the placement patterns had significant influence on the weight loss of the leafy biomass and their nutrient release. Generally, the embedded placement (below-ground level) decomposed and released nutrients faster than the surface placement (above-ground level). However, *G. sepium* leafy biomass among other examined species decomposed and released nutrients faster, both with embedded and surface placements. It is therefore recommended that *G. sepium* be used as an alternative organic based fertilizer to improve soil fertility and quality for improved crop production in savanna alfisols.

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