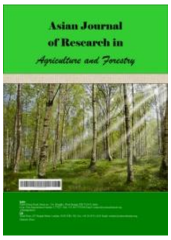

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Effects of Legumes Tree Leaf Mulch Placement and N-Mineralization on Maize Productivity in a Tropical Rainforest Area

O. J. Adeyekun [a], A. S. Akinbowale [b*], C. Arinzechi [c] and O. J. Akinbi [d]

[a] Department of Forestry, Ondo State Ministry of Natural Resources, Nigeria.
[b] Department of Forestry and Wood Technology, Federal University of Technology, P.M.B. 704, Akure, Nigeria.
[c] Department of Metallurgy and Environmental Engineering, Central South University, Changsa, Hunan, China.
[d] Forestry Research Institute of Nigeria, Ibadan, P.M.B. 5054, Nigeria.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Nutrient depletion in the rainforest area is a land use constraint that needs urgent attention. This study was carried out to investigate the effects of legumes tree leaf mulch placement and N-mineralization on maize productivity in a rain forest area. Three common indigenous nitrogen-fixing leguminous trees (*Albizia ferruginea, Albizia zygia* and *Spondias mombin*) were randomly selected around the experimental site. Fifty (50g) of freshly collected leaves from these species were bulked and weighed into 20cm x 25cm litter bags. Three litter bags were placed above-ground and three below-ground (5cm deep) at three replicates per treatment. Maize was planted at a spacing of 90cm x 30cm. Fresh samples of each mulch were applied in a ring form to the three selected plant per plot in above-ground and below-ground (5cm deep) pattern two weeks after planting. The results showed that *Albizia ferruginea* had the highest percentage nitrogen (5.49%) and *Spondias mombin* had the lowest (3.49%). The percentage calcium composition of *Albizia ferruginea* and *Albizia zygia* was the same order of magnitude (0.22%), while that of *Spondias mombin* was 0.16%. The decomposition rate of the samples was highest in *Spondias mombin* with the lowest

**Corresponding author: E-mail: akinloluakinbowale@gmail.com, akinbowaleas@futa.edu.ng;*

remaining weight of 2.92g and 3.16g in above and below ground litter bags respectively at week 10. *Albizia ferruginea* leaf had the highest nitrogen mineralization of 61.59% at above ground placement and *Spondias mombin* had the lowest of 52.18%. Nitrogen mineralization in the below ground placement was highest in *Spondias mombin* (67.32%) and lowest in *Albizia zygia* (40.39%). Generally, the above ground mulch placement decomposed faster than the below ground mulch placement at week 10. *Albizia zygia* was found to have outstanding performance on the height, girth and yield of maize. It is therefore recommended to poor resource farmers to allow *Albizia zygia* to thrive in and around their farms so that the leaves could be used as mulch for crop production.

Keywords: N-mineralization; legumes tree leaf mulch placement; rainforest; maize.

1. INTRODUCTION

Nutrient losses in tropical forests are compensated by small inputs from atmospheric deposition and through nitrogen fixation [1]. Fraterrigo et al. [2] reported that land-use practices can have effect on the distribution and supply of soil nutrients by directly altering soil properties and by influencing biological transformations in the rooting zone. A well-designed agroforestry system has potential to address problems of land degradation and declined in soil fertility. The aim of agroforestry in soil fertility initiative is to reverse the detrimental effects on agriculture that result in soil degradation and nutrient depletion by developing innovative soil and crop management practices that focus on soil fertility restoration and maintenance.

Provision of adequate supply of nutrients to crops has always been a leading objective of soil management. The practice of supplying deficient nutrients simply by adding fertilizers has given place to a new approach of integrated soil fertility management. This is directed at using low to moderate quantities of fertilizers in combination with biological methods of soil management. Myers et al*.* [3] observed that a farmer with limited cash flow cannot afford to change from a traditional system to one with high productivity through capital investment. Shifting cultivation, a sustainable traditional system of land cultivation, is increasingly becoming less efficient because of population growth and attendant land use pressures.

Current concerns about sustainability have also focused attention on the need to conserve nutrients and other resources as agriculture intensifies. The release of nutrients from decomposing organic input can be manipulated to coincide with period of nutrient demand by crops. A relationship exists between plant growth and up-take of nitrogen. Leguminous plants can serve as an important N source for crops in many parts of the tropics where fertilizer use is not economically feasible. In the tropics, mulching has been identified as an effective strategy of changing crop growing conditions to enhance yield and improve product quality by suppressing weed development, lowering soil temperature, conserving soil moisture, reducing soil erosion, improving soil structure, and increasing soil organic matter content [4]. Thus application of leaf mulch through agroforestry approach (e.g. alley cropping, tree fallow) with annual crops has the potential to improve soil fertility and productivity in the tropics.

Nutrient depletion in humid tropics is a land use constraint that needs urgent attention. Knowledge of the rate at which mulch decomposes and releases nutrients could help tropical farmers improve or maintain soil fertility [1]. Agroforestry technology therefore has potential to address the problems. Thus, this study investigated the process of nutrient replenishment through mulch application.

2. MATERIALS AND METHODS

2.1 Experimental Site

The experiment was carried out at the agroforestry site of the Teaching and Research Farm, Federal University of Technology Akure, Nigeria (latitude 7° 17′ N, longitude 5° 10′ E) with an annual mean rainfall and temperature of 1500 mm and 26°C respectively [5]. Relative humidity ranges between 85% and 100% during rainy season and less than 60% during harmattan period. The soils are classified as Ferruginous Tropical Soil (Aifisol) on crystalline rock of basement complex. The soil profile shows some medium to light textured materials near the surface, followed by sandy clay subsoil and a layer of sub angular quartz gravel below. The soil of the experimental site is impoverished, this was observed through the maize grown on the surrounding ploy.

2.2 Experimental Procedures

2.2.1 Sample preparation and analysis (macro nutrient composition)

The macro-elements (Magnesium, Potassium, Calcium and Phosphorus) were determined by ashing using a muffle furnace. One gram of each oven-dried sample was ashed at a temperature of 450^{o}C for 4 hours. It was cooled in a desiccator for one hour. Each of the samples was dissolved in 10 ml HCl and filtered. The filtrate was diluted to 100 ml.

Calcium and Magnesium were determined by EDTA titration, Potassium was determined using flame photometer, while Phosphorus was determined by spectro-photometer while Nitrogen was also determined by Micro- Kjeldahl acid digestion procedure [6].

2.3 Decomposition and Mineralization

Fifty (50 g) of freshly collected leaves from A*lbizia ferruginea, Albizia zygia* and *Spondias mombin* trees was bulked and weighed into litter bags of 20 cm x 25 cm made of polyvinyl material with mesh size of 2 mm which was large enough to prevent compression of the enclosed litter and allow free access to most group of micro-organisms was prepared. Three litter bags were placed above and below- ground (5 cm deep) at three replicates per treatment.

The litter bags (three replicates each) were retrieved from the field every two weeks. The bags were carefully lifted up at each harvesting period to reduce losses of particulate materials. The retrieved bags were carefully packed and transported to the laboratory. The experimental materials were then air dried for five days after which the weights were determined.

2.4 Effects of Added Mulch on Maize Growth

Three common indigenous nitrogen fixing leguminous trees were selected around the experimental site. These were *Albizia ferruginea, Albizia zygia* and *Spondias mombin*. The land was manually cleared and maize (*Zea mays*) was planted early July. The land was demarcated into plot of 3m x 3m and each ploy replicated three times giving a total of twelve plots. Maize was planted at a spacing of 90 cm x 30 cm. Fresh samples of each mulch were applied in a ring form to three selected plant per plot in above-ground and below-ground (5 cm deep) pattern two weeks after planting. The growth of the maize was measured at two weeks height interval by metre rule and girth by micro-metre screw gauge. At maturity, maize cobs were harvested and the grains removed from the husks and the weight per plot per treatment was determined in the laboratory by weighing.

2.5 Statistical Analysis

The means of plant nutrient contents were calculated. Analysis of Variance (ANOVA) was carried out to determine if there were significant differences among the treatment means, decomposition and N-mineralization rate of mulches [6]. Least significant difference (LSD) was used to identify the means that were significantly different from each other.

3. RESULTS

3.1 Macro-nutrients Composition of Selected Leaf Sample

The results of the laboratory analysis of leaf samples for Nitrogen, Calcium, Potassium and Phosphorus are shown in Table 1. Analysis of the micro-nutrients shows that *Albizia ferruginea* had the highest percentage nitrogen (5.49%) followed by *Albizia zygia* (5.41%) and *Spondias mombin* had the lowest percentage (3.49%). The percentage calcium composition of *Albizia ferruginea* and *Albizia zygia* was the same order of magnitude (0.20%), while that of Spondias mombin was 0.16%. Magnesium content was highest in *Albizia zygia* with 0.21% followed by *Albizia ferruginea* (0.17%) and lowest in *Spondias mombin* (0.14%). The highest percentage of phosphorus was obtained from *Albizia ferruginea* (0.22%), *Spondias mombin* had 0.12% and *Albizia zygia had* the lowest of 0.12%. Results of the Analysis of Variance (ANOVA) followed by the Fishers' Least Significant difference (LSD) test for comparing means of macro-nutrients composition of the leaf samples show a significant difference ($p \le 0.05$) in the means of nitrogen contents of the samples. However, there was no significant difference ($p \ge 0.05$) in the means of calcium contents of both *Albizia zygia* and *Albizia ferruginea*. The ash contents of *Albizia zygia* significantly differs from the other two samples.

3.2 Decomposition and Nitrogen Release Pattern of Selected Leaf Samples

The decomposition rate of leaf samples of the three leguminous species is presented in Table 2. Decomposition rate of the samples was highest in *Spondias mombin* with the lowest remaining weight of 2.92g and 3.16g in above and below ground litter bags respectively at week 10. The decomposition rate in the Albizia species was similar with residual undecomposed litter for both above and below-ground as 16.89g and 18.43g respectively. However, in *Albizia ferruginea*, it was 10.0g and 16.70g respectively. Generally, decomposition rate of the leaf samples at week 10 was higher in the above than below ground.

The results of percentage nitrogen released pattern of the three leguminous three species are presented in Table 3. Nitrogen released from leaf of *Albizia ferruginea* and *Spondias mombin* (33.43% and 28.27%) mulches above ground placement was higher at week 2 than that of *Albizia zygia* (24.84%). Also, the below-ground placed mulch of *Albizia ferruginea* (33.43%) and *Albizia zygia* (27.43%) had a higher rate of N-released compared to *Spondias mombin* (24.28%) at week 2. At week 10, *Albizia ferruginea* leaf (61.59%) had the highest nitrogen mineralization in the above ground placement, this was followed by *Albizia zygia* (55.94%) and lowest in *Spondias mombin* (52.18%). Nitrogen mineralization in the below ground placement was highest in *Spondias mombin* (67.32%), followed by *Albizia ferruginea* (61.59%) and lowest in *Albizia zygia* (40.39%).

Table 1. Percentage chemical composition of leaf samples of three leguminous species

Macro-nutrients	*Albizia zygia*	*Albizia ferruginea*	*Spondias mombin*
Nitrogen (%)	5.41[b]	5.49[a]	3.49[c]
Calcium (%)	0.20[a]	0.20[a]	0.16[b]
Magnesium (%)	0.21[a]	0.17[b]	0.14[c]
Potassium (%)	3.07[a]	2.05[c]	2.56[b]
Phosphorous (%)	0.12[c]	0.22[a]	0.12[b]
Ash (%)	1.60[b]	8.89[a]	8.90[a]

Means followed by the same alphabets on the same row are not significantly different at 0.05 level

Table 2. Decomposition rate of leaf samples of three leguminous species

Time (week)	*Albizia zygia*		*Albizia ferruginea*		*Spondias mombin*	
	AG(g)	BG(g)	AG(g)	BG(g)	AG(g)	BG(g)
2	30.86	26.84	32.7	31.43	17.05	19.00
4	28.49	25.88	28.91	31.4	16.64	14.36
6	26.11	21.67	26.95	23.07	6.00	9.27
8	18.30	21.07	25.15	20.91	4.80	7.45
10	16.89	18.43	10.08	16.70	2.92	3.16

AG- Above ground, BG- Below ground

**The mean value is the value of weight remaining. The initial weight subjected to decomposition experiment was 50g at week 0*

Table 3. Percentage nitrogen released pattern of three leguminous three species

Time (week)	*Albizia zygia*		*Albizia ferruginea*		*Spondias mombin*	
	AG(%)	BG(%)	AG(%)	BG(%)	AG(%)	BG(%)
2	24.84	27.43	33.43	33.43	28.27	24.28
4	62.62	66.31	46.23	59.03	32.25	16.31
6	63.72	68.9	33.43	35.99	20.3	24.28
8	58.53	68.9	56.47	53.91	44.21	56.16
10	55.94	40.39	61.59	61.59	52.18	67.32

AG- Above ground, BG- Below ground

Table 4. Effects of added tree mulch on maize growth (girth and height) and yield

Mulch/Treatment	Mean Height (cm)	Mean Girth (cm)	Mean grains weight (g)
Albizia zygia	132.5[a]	6.7[a]	72.7[a]
Albizia ferruginea	119.5[b]	6.1[b]	41.8[b]
Spondias mombin	105.7[c]	5.9[b]	40.2[b]
Control	93.7[c]	5.1[c]	32.5[b]

Means followed by the same alphabets on the same column are not significantly different at 0.05 level

3.3 Effects of Added Tree Mulch on Maize Growth (Girth and Height) and Yield

The results of the effects of added tree mulch on maize growth (girth height) and yield are presented in Table 4. The growth rate (total height and girth) of maize plant was measured. The weight of maize grains obtained per plot was used to represent the yield. The application of *Albizia zygia* mulch significantly increased height growth, girth and weight of maize grains. Mean heights of 132.5, 119.5, 105.7 and 93.7cm were recorded for *Albizia zygia, Albizia ferruginea, Spondias mombin* and the control respectively. *Albizia zygia* had the highest mean girth of 6.7cm and the lowest was recorded for the control (5.1cm). No significant effect was observed between plots with *Albizia ferruginea* and *Spondias mombin* on girth growth. Mean grains weight ranged from 32.5-72.7g. The lowest value of 32.5g was recorded for the control and highest value for *Albizia zygia* (72.7g).

4. DISCUSSION

4.1 Foliar Analysis for Macro-Nutrient Determination

Mulches of *Albizia zygia, Albizia ferruginea* and *Spondias mombin* were statistically different in their macro-nutrients compositions. The differences can be adduced to the differential effects on the growth and yield rate of the test crop. It can also be attributed to the differences in decomposition rate of the mulches [7].

4.2 Patterns of Mulch Decomposition and N-mineralization

The recycling of nutrients through breakdown of tree biomass, mostly litterfall or pruning, but also root that is added to the soil, is one of the essential acceptances of agroforestry. The quantity and nutrient content of the biomass introduced, as well as the rate at which it decomposes will obviously affect the extent of the advantages derived. Soil mulching using organic material is a method used to protect soil water while also assisting in maintaining a steady soil temperature inside the root system of crops [8].

The results of this study showed that *Spondias mombin* had a single-phase decomposition and nitrogen release pattern. Unlike the other mulches, which had an initial slow decomposition rate, which was followed by second phase of comparatively higher decomposition rate. Soil incorporated mulch is generally observed to decompose faster than surface-placed mulch[4]. Differences in decomposition rates may be due to narrow C:N ratio of the materials and this is attributed to factors such as polyphenols and lignin + polyphenol to N ratio [9] and also to the variation in the macro-nutrients composition of the materials. Sugihara et al. [10] hypothesized that during decay of plant residues, individual biochemical components are lost at a rate that is proportional to the amount of each component present. Using several decomposability indicators, differences in decomposition rate have been linked to substrate quality. The relative amounts of labile and recalcitrant materials, the nutritional content of tissue, the presence of inhibitory compounds, and the concentration of biochemical components such as lignin and cellulose are all factors employed in these indexes [9].

However, the absence of significant differences in the decomposition rate of *Spondias mombin, Albizia zygia* and *Albizia ferruginea* mulches placed-below and on the soil surface is therefore interesting. The probable reason for this is that the rapidity of decay of plant residues is not determined by a single factor. The litter bags could have created more humid condition for the mulch in the soil compared to the mulch on the surface[7]. There were more termites activities during the experiment, therefore the relatively large mesh size (5mm) of the litter bags used might have resulted in the loss of mulch through the activities of termites. Thus, the use of litter bags may change decomposition process.

The rate of N-release from *Albizia zygia* was highest during the first six weeks after application, when 60-70% of the mulch N was mineralized. Despite the differences in initial chemical compositions of the species, there was no difference between them in their N release characteristics. The reverse was the case in *Spondias mombin* mulch, there was slower rate of N-mineralization in the first six weeks after which there was a rapid release of nitrogen. In many forest species and in some legumes species, it has been recognized that nutrient rich leaf materials may be slow to release N and that this may be associated with lignin concentration. Vallis and Jones [11] observed that *D. intortum* was slow to release N. He reported that it might be attributed to the presence of polyphenols in the materials. This is plausible since polyphenols are reactive compounds that can form stable polymers with many forms of N [9]. Decomposition rate of *Spondias mombin* at the first six weeks was highest. However, mineralization was low unlike the other mulches where the rate of decomposition and N-mineralization was simultaneous.

4.3 Effects of Added Tree Mulch on Maize Growth (Girth and Height) and Yield

Mulch application had influence on soil properties giving rise to better root growth and yield of maize compared to no mulch treatment (control) due to increase soil water content resulting from reduced evaporation and increased infiltration. Generally, plant height was higher under mulch treatment than the unmulch, this might be due to moisture retention in the soil and decomposition of organic matter in the soil. According to Koller et al. [12], soil biota increase under mulched soil environment thereby improving nutrient cycling and organic matter build up over a period of several years.

The height growth of maize was influenced mostly by *Albizia zygia* mulch with mean height growth of (132.5 cm), followed by *Albizia ferruginea* (119.5 cm) and lowest was recorded in the control plot (93.7 cm). The girth growth of maize treated with *Albizia zygia* was more pronounced (6.7 cm) and it was lowest in the control plot (5.1 cm). The decomposition and N-mineralization rates would expect *Spondias mombin* to influence the growth and yield of maize than other mulches. However, reverse is the case in this study. This is because the mulch decomposed and the nutrient was locked up (humification) during the time maize needed the nutrients for growth and development. However, plots treated with *Albizia zygia* mulch were significantly influenced by the mulch application. Thus, after six (6) weeks, the nutrients were released into the soil (immobilization). Myers et al.[3], suggested that manipulation of mineralization rates through mixtures of plant residue with varying qualities could form the basis of practical management systems for efficient use of nutrients and for minimizing losses.

5. CONCLUSION AND RECOMMENDATIONS

The legumes tree leaf mulch (*Albizia ferruginea, Albizia zygia* and *Spondias mombin*) used in this study varied in their macro-nutrient compositions. Generally, above ground mulch placement decomposed faster than the below ground mulch placement. However, no significant difference was observed. The indigenous nitrogen fixing tree legumes were found to increase the growth and productivity of maize in the study area and hence, recommended for use as mulching material to supplement the use of high input resource such as inorganic fertilizer. Specifically, *Albizia zygia* was found to have outstanding performance on height, girth and total yield of maize. Poor resource farmers should allow the tree species to thrive in and around their farms so that the leaf could be used as mulch for crop production.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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