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

Abstract

Nutrient depletion in the rainforest area is a land use constraint that need urgent attention. This study was carried out to investigate the effects of legume tree leaf mulch placemenet 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 was 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 percentage (3.493%). The percentage calcium composition of *Albizia ferruginea* and *Albizia zygia* was the same order of magnitude (0.216%), while that of *Spondias mombin* was 0.157%. 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. *Albizia ferruginea* leaf (61.59%) had the highest nitrogen mineralization at above ground placement and *Spondias mombin* had the lowest (52.18%). Nitrogen mineralization in the below ground placement was highest in *Spondias mombin* (67.32%) and lowest in *Albizia zygia* (40.39%). The study concluded that below ground mulch placement decomposed faster than than the above ground mulch placement in the selected leguminous leaf samples. *Albizia zygia* was found to have outstanding performance on 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 leaf could be used as mulch for crop production

Keywords: N- Mineralization, Leaf Mulch Placement, Rainforest

Introduction

Natural forest ecosystems are generally perceived as nutritionally stable in the sense that losses of nutrients are minimal. Losses that do occur are compensated for by small inputs from atmospheric deposition or, in the case of nitrogen from fixation. Human-induced disturbance of these systems generally upsets this dynamic equilibrium. Nutrients are loss through the conversion of forest and forest land to other land-use type . Losses of nutrients such as Potassium and Magnesium are frequent (Myers et *al*., 1994). Modern land management systems have not had much impact in many tropical countries because of the socioeconomic conditions prevalent in these areas. 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 *a*l (1994) 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 the crop. A relationship exists between plant growth and up-take of N. 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 (Egbe et *al*., 2012). 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 need urgent attention. Knowledge of the rate at which mulch decomposes and releases nutrients could help tropical farmers improve or maintain soil fertility (Lu et *al*.,2015). Agroforestry technology therefore has potential to address the problems. Therefore, this study investigated the process of nutrient replenishment through mulch application.

MATERIALS AND METHOD

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 (Adesuyi et *al*., 2018). Relative humidity ranges between 85% and 100% during rainy season and less than 60% during harmattan period. The soils of the study area 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.

Experimental procedures

Sample preparation and Analysis (macro nutrient composition)

Th macro-elements (Magnesium, Potassium, Calcium and Phosphorus) were determined by ashing using 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 sample was now dissolved in 10ml HCl and filtered. The filtrate was diluted to 100ml. However, Calcium and Magnesium were determined by EDTA tiltration, Potassium was determined by using flame photometer, while Phosphorus was determined by spectro-photometer. Nitrogen was determined by Micro- Kjeldahl acid digestion procedure.

Decomposition and Mineralization

Fifty (50g) of freshly collected leaves from A*lbizia ferruginea, Albizia zygia* and *Spondias mombin* was bulked and weighed into litter bags of 20cm x 25cm made of polyvinyl material with mesh size of 2mm 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-ground and three below- ground (5cm deep) at three replicates per treatment.

The litter bags (three replicates each) were retrieved from the field every two weeks for a total of 12 weeks. The bags were carefully lifted up at each harvesting period to reduce losses of particulate materials. Soil and debris adhering to the mulch were removed with brush. The retrieved bags were securely packed and transported to the laboratory. The experimental materials were then air dried for five days after which the weights were determined.

Effects of added mulch on maize growth

Three common indigenous nitrogen fixing leguminous trees were selected around the experimental site. These are *Albizia ferruginea, Albizia zygia* and *Spondias mombin*. The land was manually cleared and maize (Zea mays) 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 90cm x 30cm. Fresh samples of each mulch were applied in a ring form to three selected plant per plot in above-ground and below-ground (5cm 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.

Statistical Analysis

Analysis of Variance (ANOVA) was carried out to determine if there is significant differences among the treatment means .Least significant difference (LSD) was used to identify the means that were significantly different from each other. Analysis of Variance (ANOVA) was also carried out to determine if significance differences among the treatment plots; time of decomposition and nitrogen mineralization and their effects on maize growth and yield. Also differences in decomposition and N-mineralization are of mulches were determined by the same analytical tool.

RESULTS

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. The analysis of the micro-nutrients shows that *Albizia ferruginea* had the highest percentage nitrogen (5.49%) followed by *Albizia zygia* (5.414%) and *Spondias mombin* had the lowest percentage (3.493%). The percentage calcium composition of *Albizia ferruginea* and *Albizia zygia* was the same order of magnitude (0.216%), while that of Spondias mombin was 0.157%. Magnesium content was highest in *Albizia zygia* with 0.216% followed by *Albizia ferruginea* (0.168%) and lowest in *Spondias mombim* (0.144%) respectively. The highest value of phosphorus was obtained from *Albizia ferruginea* (0.22%), *Spondias mombin* had 0.196% and the lowest from *Albizia zygia* (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 leaf samples show that there was significant differences ($p \leq 0.05$) in the means of nitrogen contents of the samples. There was no significant difference ($p \geq 0.05$) in the means of calcium contents of both *Albizia zygia* and *Albizia ferruginea* .In addition, there were also significant differences in the means of magnesium, potassium and phosphorus contents of the leaf samples. Ash contents of *Albizia zygia* significantly differs from that of the other two samples

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

Macro-nutrients	*Albizia zygia*	*Albizia ferruginea*	*Spondias mombin*
Nitrogen (%)	5.41[b]	5.492[a]	3.493[c]
Calcium (%)	0.2[a]	0.2[a]	0.157[b]
Magnesium (%)	0.21[a]	0.168[b]	0.144[c]
Potassium (%)	3.07[a]	2.05[b]	2.564[c]
Phosphorous (%)	0.12[c]	0.227[a]	0.196[b]
Ash (%)	1.6[b]	8.89[a]	8.9[a]

Decomposition and nitrogen release pattern of selected leaf samples.

The decomposition rate of leaf samples of 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). However, in *Albizia ferruginea*, it was 10.08g and 16.70g respectively. Generally, decomposition rate was higher in below ground than above ground in all the leaf samples.

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
4	28.49	25.88	28.91	31.4	16.64	14.36
6	26.11	21.67	26.95	23.07	6	9.27
8	18.3	21.07	25.15	20.91	4.8	7.45
10	16.89	18.43	10.08	16.7	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*

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 in 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-release compared to *Spondias mombin* (24.28%) at week 2. At week 10, *Albizia ferruginea* leaf (61.59%) had the highest nitrogen mineralization at 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 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

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

Effects of added tree mulch on maize growth(girth height) and yield are presented in table 4. The growth rate of maize plant (total height and girth) were measured. The weight of maize grains obtained per plot was used to represent the yield. The table shows that the application of *Albizia zygia* mulch significantly increase height growth,girth and weight of maize of maize grains. However, no significant effect was observed between plots with *Albizia ferruginea* and *Spondias mombin* on girth growth. Maize growth (girth and height) and yield was lowest in the untreated (control) plots.

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

Mulch/Treatment	Mean Height(cm)	Mean Girth(cm)	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

DISCUSSION

Foliar analysis for macro-nutrient determination

The mulches of *Albizia zygia, Albizia ferruginea* and *Spondias mombin* are statistically different in their macro-nutrients compositions. The differences in the mulch macro-nutrient composition 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 (Awal & Khan, 2000).

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 one means of protecting soil water while also assisting in maintaining a steady soil temperature inside the root system of crops (Samaila et al., 2011).

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. No significant difference was detected between the rate of decomposition of the mulches on the surface and below the surface. Soil incorporated mulch is generally observed to decompose faster than surface-placed mulch (Egbe et *al*., 2012). The absence of significant differences between decomposition rate of *Spondias mombin, Albizia zygia* and *Albizia ferruginea* mulches placed-below and on the soil surface therefore is interesting. 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. However, the differences in decomposition and N-mineralization rates may also 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 (Gentile et *al.*, 2009) and also to the variation in the macro-nutrients composition of the materials. Sugihara et al. (2012) 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. According to Swift et *al.,(*1979), differences in rate of decomposition have been related to substrate quality using various indices of decomposability. Factors used in these indices include the relative amounts of labile and recalcitrant materials, the nutrients content of tissue, the presence of inhibitory substances and concentration of biochemical components such as lignin and cellulose.

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 is 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 (1973) observed that *D.intortum* was slow to release N. He suggested that this was related 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 (Gentile et al. 2009). Decomposition rate of *Spondias mombin* at the first six weeks was highest. However, mineralization was low unlike the other mulches which the rate of decomposition and N-mineralization was simultaneous.

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

Mulch application has influence on soil properties giving rise to significantly better root growth and yield of maize compared to no mulch treatment(control) due to increase soil water content resulting from reduce evaporation and increase infiltration. Generally, plant height was highest under mulch treatment compared to 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*. (2013) 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 (132.494cm), followed by *Spondias mombin* (119.5cm) and *Albizia ferruginea* (105.7cm) and lowest was recorded in the control plot (93.7cm). The girth growth of maize treated with *Albizia zygia* was more pronounced (6.7cm) and it was lowest in the control plots (5.1cm). 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 was more significantly influenced by the mulch application. Thus, after 6 weeks the nutrients are release into the soil (immobilization). Myers et *a*l (1994) 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.

Conclusion and Recommendations

The study shows that the legume tree leaf mulch (*Albizia ferruginea , Albizia zygia and Spondias mombin*) varied in their macro-nutrient compositions. It was also observed that below ground mulch placement decomposed faster than than the above ground mulch placement in the selected leguminous leaf samples. The indigenous nitrogen fixing tree legumes were found to increase the growth and productivity of maize in the study area and hence it is 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. It is therefore recommended to poor resource farmers to allow *Albizia zygia* to thrive in and around their farms so that the leaf could be used as mulch for crop production.

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