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VARIED MULCH QUALITY EFFECTS ON SOIL MICROBES, GROWTH AND YIELD OF MAIZE (*ZEA MAYS* L.)IN AGROFORESTRY

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Abstract

Low cost and environmentally friendly land management system as alternative land-use system is an important management practice for sustaining soil fertility and crop productivity. Varied mulch quality effects on soil microbes, growth and yield of maize (*Zea mays* l.) in agroforestrywas studied.

Soil samples were collected from maize stands planted during the raining season at 30cm x 90cm (within and between rows) spacing with six treatments consisting of leaf mulches of 100 g *G. sepium*; 50 g *G. sepium* + 50 g *A. auriculiformis*; 40g *G. sepium* + 60g *A. auriculiformis*; 60g *G. sepium* + 40g *A. auriculiformis*; 100 g *A. auriculiformis* and control. These were replicated thrice in Completely Randomized Design (CRD). The soil samples were collected at four and eight weeks respectively after sowing to determine microbial population and diversity. It was found that the population of microorganisms was higher at 4WAA than 8WAA. 13 forms of bacteria and 11 forms of fungi were isolated at 4WAA; 3 forms of bacteria and 7 fungi were isolated at 8WAA. 3 bacterial and 7 fungi taxonomic groups were identical at 4WAA and 8WAA. However, 10 bacteria were exclusively found at 4WAA and 6fungi at 8WAA. *Aspergillusfumigatus*was the abundant fungal genera at 4WAA and 8WAA while *Staphylococcusaureus*, *Pseudomonasaeruginosa*and *Bacillussubtilis*were the abundant bacteria general at 4WAA.Matured and dried maize cobs were harvested; the grain yield was evaluated. Significantly higher grain yield was observed between control plot and plots with applied mulches, though there was no significant difference when yield from the varied quality mulched plots were compared. At 8WAS and 10WAS, there were significant($P \leq 0.05$)differences among treatments on height. Maize plants mulched with 40g *G. sepium* + 60g *A. auriculiformis*, control and 100 g *A. auriculiformis*had significantly ($P \leq 0.05$)bigger stem diameters,while others were not significant at 6WAS. Plant height, stem diameter,number of leaves and below ground biomass showed that 40g *G. sepium* + 60g *A. auriculiformis* had the best effectson soil microbial diversity, growth and yield of maize.

Keywords: Mulch quality,microbial population, maize, nutrientand agroforestry

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Introduction

Annual or perennial legumes have been recognized to be effective in soil fertility maintenance. Perennial legumes are preferred because of seasonal availability and limited nutrient input of annual legumes (Arlauskiene*et al.*, 2021). Organically certified, environmentally friendly, readily available and inexpensive materials are ideal to manage and replenish lost soil nutrients (Akintan, *et al.*, 2016). Mulches have been used for modification of agricultural lands, urban landscapes and forests (Chalker-Scott, 2007) since late 1930s. They are known to improve crop production by enhancing soil quality through soil moisture conservation, enhancing soil biological activities, and improving the chemical and physical properties of soil (Cooper, 1973;Hanada, 1991).

A great diversity of microorganisms affects plant growth and health(Boehm *et. al.*, 1993; Campbell and Greaves, 1990). The diversity and composition of these organisms in the rhizosphere can be affected by factors such as microbial interactions (Hedges and Messens, 1990), plant species, soil type (Hoitink and Boehm, 1999), soil management practices (Rovira*et al.*, 1990), and other environmental variables (Kennedy *et al.,* 2005).Management practices such as fertilization, crop rotation, application of organic amendments, and tillage may favor some microorganisms over others (Workneh and van Bruggen, 1994).

Soil microorganisms are the major organisms responsible for controlling the amount of nutrient cycling and for controlling the amount of nutrient available to plants (Hernot and Robertson 1994; Singh andRai 2004; Jain *et al,.* 2005). Soil microbes decompose plant and animal residues entering the soil and convert them into soil organic matter, which influences soil physical, chemical and biological properties thereby creating a complimentary medium for biological reactions and life support in the soil environment (Olson *et al.*, 2000).The plant species growing on the soil equally influence the population and species composition of the soil microorganisms (Hackl*et al.*, 2000).

Plant residues enter soil system as crop residues, tree leaf litter and prunings in agroforestry systems. These plant residues are sources of nutrients and organic matter when they decompose and could contribute to the maintenance of soil fertility (Zeng*et al.*,

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2010).Residue decomposition rates and nutrient release patterns are controlled by biotic and abiotic factors, the most important of which is residue quality (Silver and Miya, 2001; Mungai and Motavalli, 2006; Teklay*et al.*, 2007). Incorporating plant residues into agricultural soils can sustain organic carbon content, improve soil physical properties, enhance biological activities and increase nutrient availability (Hadas*et al*., 2004; Cayuela*et al*., 2009). Some studies have documented the effects of different soil and litter attributes and land use practices on the colonization and activity of soil fauna (Yang and Chen, 2009; Aquino *et al.*, 2008; Laossi*et al.*, 2008; Sileshi and Mafongoya, 2006; Reich *et al.*, 2005).

Although, the activity of soil organisms have been identified as a controlling factor for litter decomposition(Couteaux, *et al.,* 1995), the diversity of plant species on specific microbial activity should be considered as a mechanism by which the influence of climate and litter quality are realized. This study therefore investigated effects of varied mulch quality on soil microbes, growth and yield of maize (*Zea mays* L.) in an Agroforestry System.

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Materials and Methods

1. Study area:

The studyof effects of varied mulch quality on soil microbes, growth and yield of maize in an agroforestry Systemwas conducted at Teaching and Research Farm of the Federal University of Technology, Akure, Ondo State, Nigeria, during a raining season. Akure lies between latitude $7^0$18'32.64"N and $7^0$16'34.93"N and longitude $5^0$10'35.79"E and $5^0$7'38.97"E It's mean annual temperature of about 25^0C (minimum 19^0C and maximum 34^0C); relative humidity 84% and mean rainfall of 76mm were obtainable in the study area(Oyun *et al.*, 2006). The elevation is about 350m above sea level with gently undulating land form. The soil is classified as ferruginous tropical soil (alfisols) on crystalline rock of basement complex and belongs to the Egbeda series (Smyth and Montgomery, 1962).

2. Methodology:

A land area of 5m x 22m which was previously used for *Corchorusolitorius* (Jute mallow) cultivationwas cleared off existing weeds and demarcated into eighteen plots of 0.9m x 2.7m each with a buffer of 0.5m x 0.5m between plots. Oba Super 2 maize seeds(two seeds per hole) were sown on the field at a spacing of 30cm x 90cm (within and between rows) during the raining season with a total of 16 maize plants per plot. One week after sowing, the seedlings where thinned to one per stand. Fresh leaves from three years old *Gliricidiasepium* (Jacq.) Kunth ex Walp.and*Acaciaauriculiformis*A.Cunn. exBenth.trees were applied as treatment mulch. Treatment 1(100 g *G.sepium*), treatment 2 (50 g *G.sepium* + 50 g *A. auriculiformis*), treatment 3 (60g *G.sepium* + 40g *A. auriculiformis*), treatment 4 (40g*G.sepium* + 60g *A. auriculiformis*) and treatment 5 (100 g *A. auriculiformis*) attwo weeks of sowing while there was a control plot without mulch treatment in three replications.

3. Soil sampling and analysis

Grid soil sampling method was adopted for soil sample collection. Representative topsoil (0 – 15 cm) samples were collected, air dried, crushed in agate mortar and passed through a 2 mm sieve. Samples were used to determine the available nitrogen (N) content and measure pH.

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Additional samples were passed through a 0.149-mm mesh to estimate organic matter and total N contents. Soil organic matter (SOM) was measured using H_2SO_4–$K_2Cr_2O_7$ wet oxidation, followed by titration with $FeSO_4$ according with the Walkley–Black procedure (Nelson and Sommers, 1982); soil total nitrogen (STN) was determined using micro-Kjeldahl digestion, followed by colorimetric analysis (Nelson and Sommers, 1982, Nelson and Sommers, 1980). Soil pH was measured in a 1: 2.5 (m/v) soil: water ratio by using a pHS-3C pH/mV meter (Rex Ltd., Shanghai, China). Soil moisture was determined after the soil core samples were oven-dried at 105°C for8 h (Top and Ferre, 2002). Soil available nitrogen (SAN) was determined using the alkali-hydrolytic diffusion method (Page *et. al.,* 1983). Soil bulk density was measured from samples obtained using a volumetric steel ring (100 cm3) and calculated as the mass of oven-dried soil (105°C), divided by the core volume for each measurement depth.

4. Growth attributes, morphological characteristics and yield of maize

The following growth attributes (height, collar diameter and leaf number) were measured bi-weekly from four (4) to eight (8) weeks after germination. Maize heights (cm) were obtained by measuring from the soil level to the tip of the apical bud with the aid of ruler. Maize collar diameter (mm) was measured with a vernier caliper.Number of leaves per plant was also counted.The growth analysis of maize includesCrop Growth Rate (CGR), Relative Growth Rate (RGR) and Net Assimilation Rate (NAR)was evaluated at the site by assessing the biomass, land area and leaf area.Crop Growth Rate (gm^2 day^{-1}): dry matter accumulation rate per unit land area is referred to as crop growth rate, normally expressed as grams per square meter of land area per day {g (m of land area) - ^{2} Day – 1} (Gul*et al.,* 2013). It was determined using equation i: $Crop\ Growth\ Rate\ = \frac{W2 - W1}{SA\ (t2 - t1)}$ ..... Equation i

Where W_1 and W_2 are crop dry weights at two weeks and at ten weeks respectively.t_1 and t_2 are corresponding days and SA is the land area occupied by the plants sampled. Relative Growth Rate (gg^{-1} day^{-1}): Relative Growth Rate of a plant at any given time (t) is defined as the increase of plant material present per unit of time (Hoffmann and Poorter, 2002). It was determined using equation ii:

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$$Relative\ Growth\ Rate\ = \frac{LnW2 - LnW1}{t2 - t1}$$ …….. Equation ii

Where LnW_2 and LnW_1 are the natural logs of weights at time t_2(final time) and t_1(initial time.

Net Assimilation Rate (gm^2day^{-1}): dry matter accumulation per unit of leaf area is termed net assimilation rate (NAR) and is expressed as g (m of leaf area)$^{-2}$ day^{-1} (Gul*et. al.,* 2013). It was determined using equation iii:

$$Net\ assimilation\ rate\ = \frac{dw}{A\ x\ dt}$$ ----------Equation iii.

Where A is the leaf area, whiledw is the change in plant dry matter and dt is change in time.

2013)

5. Determination of soil microbial population and diversity

One gram (1g) of soil samples at 1 – 10cm depth were collected at 4WAA and 8WAA around the bottom of the plants andplaced in oven sterilized conical flasks, 20ml of distilled water was added, it was thoroughly shaken and allowed to stand for 20 minutes. Each suspension, one millilitre (1ml) was serially diluted in test tubes containing nine mills(9ml) of distilled water in test tube. One millilitre of solution was pipetted into a set of petri dishes and was overlaid with 20ml of Potato Dextrose Agar incorporated with 20ml streptomycin to eliminate bacteria. The plates were gently swirled to evenly mix up and allowed to gel. They were incubated for 18 – 24 hours and 72 hours at 25^0C in inverted position in two different incubators sterilized with potassium permanganate and formaldehyde for bacteria and fungi respectively.

Development of Colonies after incubation were counted using Gallenkamp colony counter. The colonies were sub-cultured to obtain pure isolates. The pure isolates of bacteria were aseptically transferred into nutrient agar and identified on the basis of classification schemes published in Bergey's Manual of Systematic Bacteriology (Krieg and Holt, 1984)while those of fungi were transferred on to potato dextrose agar slants and incubated (Rhode and Hartman, 1980).Morphological identification, physiological and biochemical tests for characterization of isolates were carried out using the method described by Cowan and Steel (1977).

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6. Statistical analysis

All data obtained in this study was analyzed using analysis of variance (ANOVA), while Least Significance Difference (LSD) was used for mean separation of various maize parameters according to method described by Williams and Abdi(2010).

Results and Discussion

Physico-chemical properties of the soil

Table 1 showed the physico-chemical properties of soil in the study area. The pH was found to be 6.8 indicating that the soil was near neutral and had moderate levels of residual nutrients with total nitrogen at 1.2g/kg, available P at 11.61mg/kg, organic carbon at 23.65g/kg and soil exchangeable acidity 0.15cmol/kg. The exchangeable bases were equally moderate and gave the following values, Ca (4.21cmol/kg), Mg (1.65cmol/kg), K (0.37cmol/kg) and Na (0.3cmol/kg).

Effects of varied mulch quality on maize height(cm) at 4, 6, 8 and 10 weeks after sowing (WAS)

Table 2 shows the effect of varying quality mulches on maize height at 4, 6, 8 and 10 weeks. Maize heights at 4WAS and 6WAS were not significantly ($P \leq 0.05$)different for all the applied treatments.8WAS, maize height (87cm) in control plot and treated plots with 40 g *G. sepium* + 60 g *A. auriculiformis* (135cm), 50 g *G. sepium* + 50 g *A. auriculiformis* (133cm), 60 g *G. sepium* + 40 g *A. auriculiformis* (119cm), 100 g *G. sepium* (108cm) and 100 g *A. auriculiformis* (101cm) mulches were significantly ($P \leq 0.05$)different. At 10WAS, maize height in plotstreated with 40 g *G. sepium* + 60 g *A. auriculiformis* (219cm), 50 g *G. sepium* + 50 g *A. auriculiformis* (204cm), 60 g *G. sepium* + 40 g *A. auriculiformis* (200cm), 100 g *G. sepium* (187cm), 100 g *A. auriculiformis* (177cm) and control (169cm) were significantly ($P \leq 0.05$)different. The trend of significance in maize height shows that 40 g *G. sepium* + 60 g *A. auriculiformis* had best height effect followed 50 g *G. sepium* + 50 g *A. auriculiformis*, 60 g

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G. sepium + 40 g *A. auriculiformis*, 100 g *G. sepium*, 100 g *A. auriculiformis* and control respectively

Effects of varied mulch quality on maize collar diameter (mm) at 4, 6, 8 and 10 weeks after sowing (WAS)

Table 3 shows the collardiameter (mm) of maize plants as affected by varied quality mulches. Maize plantsstem diameters were not significantly ($P \leq 0.05$)different at4, 8, and 10 weeks after sowingfor all the applied treatments. They responded significantly ($P \leq 0.05$) at 6WAS. Maize within plots treated with 40 g *G. sepium* + 60 g *A. auriculiformis* (14.02mm), 100 g *A. auriculiformis* (9.46mm) and control (9.20mm) had significantlydifferent stem diameters while 60 g *G. sepium* + 40 g *A. auriculiformis* (11.40mm), 50 g *G. sepium* + 50 g *A. auriculiformis*(11.61mm), and 100 g *G. sepium* (11.31mm) were not significant. The trend of significance in stem diameter shows that 40 g *G. sepium* + 60 g *A. auriculiformis*had the best effect on maize stem diameter.

Effects of varied mulch quality on maize leaf number at 4, 6, 8 and 10 weeks after sowing (WAS)

Tables 4 showed that leaf number of maize plants were significantly ($P \leq 0.05$) different at 4WAS, 6WAS, 8WAS and 10WAS. Maize treated with 40 g *G. sepium* + 60 g *A. auriculiformis* leaf mulch had higher number of leaves followed by 50 g *G. sepium* + 50 g *A. auriculiformis*. Next was 60 g *G. sepium* + 40 g *A. auriculiformis*, then 100 g *G. sepium*. Control plots had significantly($P \leq 0.05$) least number of leaves. The trend of maize number of leaves shows that plants treated with 40 g *G. sepium* + 60 g *A. auriculiformis* had significantly highest number of leaves.

Effects of varied mulch quality on maize morphological characteristics(crop growth rates, relative growth rate and net assimilation rate)

Table 5 showed that crop growth rates (CGR), relative growth rate (RGR) and net assimilation rate (NAR) were not significantly different ($P \leq 0.05$) between plots with applied mulches and control. The applied mulch significantly($P \leq 0.05$) affected the above and below ground biomass. Below ground biomass for maize within 40 g *G. sepium* + 60 g *A. auriculiformis*(0.56 g) plots were of higher dry matter while control plots (0.21g) were least.

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This was followed by 50 g *G. sepium* + 50 g *A. auriculiformis*(0.34g), then 60 g *G. sepium* + 40 g *A. auriculiformis*(0.32g) and 100 g *G. sepium*and 100 g *A. auriculiformis*(0.30g) respectively. The above ground biomass at 2 months was significant ($P \leq 0.05$) for maize within control plots (42.21g) and plots mulched with 40 g *G. sepium* + 60 g *A. auriculiformis* (68.35g) while other treated crops were not significant: 50 g *G. sepium* + 50 g *A. auriculiformis* (62.76g), 60 g *G. sepium* + 40 g *A. auriculiformis* (62.76g), 100 g *G. sepium*(45.96g) and 100*A. auriculiformis* (45.39g). The trend of significance in biomass shows that 40 g *G. sepium* + 60 g *A. auriculiformis* mulch had best effects on maize crop matter accumulation at above and below ground.

Effects of varied mulch quality on maize grain yield

Table 6 showed effect of varied mulch quality on maize grain yield at physiological maturity. The highest maize yield was obtained from plots mulched with 40 g *G. sepium* + 60 g *A. auriculiformis*(3436.29kg/ha) while maize plant without mulch (control) had the least yield (875.27kg/ha).50 g *G. sepium* + 50 g *A. auriculiformis* (3134.99kg/ha) was next to the highest yield, then by 60 g *G. sepium* + 40 g *A. auriculiformis* (3047.11kg/ha), next to it is 100 g *A. auriculiformis* (2683.05kg/ha) and 100 g *G. sepium*(2582.62kg/ha).

The difference in maize grain yield is significant ($P \leq 0.05$) between control plots and the plots with applied mulches, though there were no significant differences when grain yield from the varied quality mulched plots were compared.

Bacteria and fungi populations/identification in the soil of experimental plots

Table 7a, 7b and 7c showed microbial population in the soil around the mulched maize plants. At 4weeks after application (WAA), 100g *A. auriculiformis*had (7.4 X 10^7cfu/ml)bacteria population, 100g *G. sepium*(7.0 X 10^7cfu/ml), 50g *G. sepium*and 50g *A. auriculiformis*(6.5 X 10^7cfu/ml), 40g *G. sepium*and 60g *A. auriculiformis*(5.9 X 10^7cfu/ml); and 60g *G. sepium*and 40g *A. auriculiformis*(6.4 X 10^7cfu/ml). Soil sample without mulch (control) had the least (4.6 X 10^7cfu/ml) bacteria population. The highest fungi population at 4WAA was obtained in soil sample from 100g *G. sepium*(8.9 X 10^7cfu/ml),60 g *G. sepium* and 40g *A.*

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auriculiformis (8.6 X 10^7cfu/ml), 100g *A. auriculiformis*(7.7 X 10^7cfu/ml), 40 g *G. sepium* and 60g *A. auriculiformis* (7.6 X 10^7cfu/ml); and 50 g *G. sepium* and 50g *A. auriculiformis* (4.9 X 10^7cfu/ml). Soil sample without mulch(control) had the least (4.2 X 10^7cfu/ml) population.

At 8WAA, 100g *A. auriculiformis*had the highest bacteria population (95 X 10^3cfu/ml), 100g *G. sepium*(82 X 10^3cfu/ml), 50 g *G. sepium* and 50g *A. auriculiformis* (63 X 10^3cfu/ml), 60 g *G. sepium* and 40g *A. auriculiformis* (54 X 10^3cfu/ml) and 40 g *G. sepium* and 60g *A. auriculiformis*(40 X 10^3cfu/ml). Soil sample without mulch (control) had the least (25 X 10^3cfu/ml). The highest fungi population at 8WAA was obtained in soil sample from 100g *G. sepium*(104 X 10^3cfu/ml),100g *A. auriculiformis*(98 X 10^3cfu/ml), 60 g *G. sepium* and 40g *A. auriculiformis* (72 X 10^3cfu/ml), 50 g *G. sepium* and 50g *A. auriculiformis* (47 X 10^3cfu/ml) and 40 g *G. sepium* and 60g *A. auriculiformis* (41 X 10^3cfu/ml). Soil sample without mulch (control) had the least (28 X 10^3cfu/ml) population.

At 4WAA, 7 different types of bacteria and 5 fungi were identified in the soil around the plants in control plots, 10bacteria and 8 fungi in 50 g *G. sepium* and 50g *A. auriculiformis*, 9bacteria and 8 fungi in 40 g *G. sepium* and 60g *A. auriculiformis*, 12bacteria and 10 fungi in 60 g *G. sepium* and 40g *A. auriculiformis*, 12bacteria and 9 fungi in 100g *G. sepium*and 12bacteria and 8 fungi in 100 g *A. auriculiformis*. At 8WAA, 2bacteria and 3 fungi were identified in the soil around the plants in control plots, 3bacteria and 4 fungi in 50 g *G. sepium* and 50g *A. auriculiformis*, 3bacteria and 5 fungi in 40 g *G. sepium* and 60g *A. auriculiformis*, 3bacteria and 6 fungi in 60 g *G. sepium* and 40g *A. auriculiformis*, 3bacteria and 3 fungi in 100 g *G. sepium* and 3bacteria and 3 fungi in 100 g *A. auriculiformis*.

Altogether, 13 forms of bacteria and 11 forms of fungi were isolated at 4WAA; 3 forms of bacteria and 7 fungi were isolated at 8WAA. Three (3) bacterial and 7 fungi taxonomic groups were identical at 4WAA and 8WAA. However, 10 bacteria were exclusively found at 4WAA and 6 fungi at 8WAA. *Aspergillus* was the abundant fungal genera at 4WAA and 8WAA while *Staphylococcus*, *Pseudomonas* and *Bacillus* were the abundant bacteria general at 4WAA.

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Discussion

The significant differences recoded in 40g *G. sepium* and 60g *A. auriculiformis* mulched plants in this study could be as a result of mixing high and low quality organic materials that is *Gliricidia sepium* and *Acacia auriculiformis*respectively which in turn regulatedthe microclimate around the plants. This is supported by Akintan(2019) who postulated that there is no single organic material that releases N in perfect synchrony to plant demand, giving slow initial mineralization or immobilization followed by a large, rapid mineralization.

Increased in yield of maize with applied mulch 40g *G. sepium* and 60g *A. auriculiformis* mulched plants was in line with Cayuela*et al*.(2009) who reported that incorporating plant residues into agricultural soils can sustain organic carbon (C) content, improve soil physical properties, enhance biological activities, and increase nutrient availability. In the opinion of Sakala*et al*.(2000), mixing residues of trees and crops in tropical agroforestry systems,with different qualities can potentially be used to manipulate residue decomposition and regulate the timing of nutrient availability.

The increase in population of bacteria in various treatments over control could be regarded as destabilization of the soil ecological balance due to mulch application.Adesemoye*et al.,* (2002) and Abhanzioya*et al.,* (2016) noted increased population of bacteria and fungi in soil when organic cassava effluent was applied on maize farm. Population of bacteria and fungi decreased withtime as the quantity of litter decreased while some bacteria and fungi present at the beginning (4WAA) became extinct at the end (8WAA) of the study. Ogboghodo*et al.,* (2006) also reported that bacteria and fungi population increased with time as rates of cassava mill effluent increased while some bacteria that were present at the beginning of the study became extinct at the end of the study. Higher population of microbes around mulched crops(treatment plots) than crops in control plots may be attributed to favourable soil moisture and temperature; greater availability of nutrient as supported by other workers (Tangjang*et al.,* 2009).

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It was generally noted that in 4WAA, S*taphylococcus aureus, Bacillus substilis, Escherichia coli and Clostridium defficile*were dominant among other species. Tangjang*et al.,* (2009) noted that for a given community; only a few species are numerically predominant and may strongly affect the environmental conditions for the others. Increased inbacterial colonies in mulched plots could be due to increased organic carbon contents in the soil, which could be regarded as a major component of food supply for bacteria. Soil microbes are carbon limited; addition of organic carbon can increase microbial biomass (Shashidhar*et al.*, 2009). Variation in microbial load of different organic mulches could be due to theirdifferent chemical composition and decomposition rates (Kumar *et al.,* 2014). Asari*et al*., (2008) and Singh *et al*., (2011) also reported changes in composition of microbial communitiesdue to application of organic matter.

The highest population of microbes in sole *Gliricidia sepium* andsole *A. auriculiformis* mulched plots when compared to mixed quality litter could be attributed to the fact that decomposing of single litter is faster possibly because of similar properties and chemical composition. Zhang *et al.* (2022) noted that sole soybean decomposed faster when compared to mixed maize and pepper residue owing to different properties and chemical composition of the mixed residues. Higher microbes caused assimilation of soil nitrogen that affected their population growth and subsequently influence the amount of N availability which supported height, collar diameter, leaf number,maize grain yield and below ground biomass for growth performance of maize.Soil microbes are better competitorsfor nutrients than plants and that high C:N mulch can induce nutrient deficiencies in plants by stimulating microbial growth (Kaye and Hart, 1997; Hodge *et al*., 2000).

Population of fungal in any given environment is highly influence by vegetation formation. The rate of change in fungal population could be attributed to the type of vegetation (mulch) in a particular area (Entry and Emmingham, 1996), variation in physico-chemical characteristics of the soil and environmental complex of the locality (Bossio*et al.*, 2005).The higher counts of bacterial and fungal population at 4WAA could be attributed to type of plant materials and nutrient availability, while lower counts at 8WAA could due to poor nutrient availability in leaf litter. Tangjang*et al.*(2009) reported similar work on three arecanut-based

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traditional agroforestry systems in Kalitas and Nyishis. The growth performance of maize showed ratio of 40:60 of high quality/low quality legume mulch brings a great diversity of microorganisms in the rhizosphere which affected plant growth and health. This varied mulch in relation to microorganisms brought a synchrony of nutrient release to plant demand which affected the growth and yield of maize positively.

Conclusion and Recommendations

1. Conclusion

Evidently from this study, considerable amount of nitrogen can be added to the soil from leguminous leaves thereby partly replacing mineral fertilizer. The application of litter through biomass transfer to crop plant by resource poor farmers in the humid tropical environment can serve as low input systems for crop production.

2. Recommendation

Practically, it is recommended that the application of mixed low and high quality litter in alley cropping practice be effected. Farmers are encouraged to use varied quality (mixed) leaves mulch (40g high quality litter that is 32 compound leaves in case of *Gliricidia sepium*and 60g low quality litter that is 42 single leaves in case of *Acacia auriculiformis*) in agroforestry practice in order to benefit from the synergy of the different ecosystem functions from different tree species such as enhanced decomposition rate and nutrient release from low quality tree species. Generally, the level of agroforestry techniques adoption with the potential to increase crop productivity is still low among the practicing rural farmers in developing countries. Therefore, intensive efforts should be made by government agencies that are relevant in this aspect to further disseminate the technologies to the farmers and follow up to the stage of adoption. Finally, more research on residual effect of mixed mulches on soil is recommended.

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Appendix

Table 1: Physico-chemical of properties of the soil

Soil properties	**Value**
Particle size distribution (g/kg)	
Sand	740
Silt	168
Clay	92
Textural class	Sandy loam
pH (1: 1 H_20)	6.8
pH (1: 2 $CaCl_2$)	5.2
Exchangeable acidity(E.A., cmol/kg)	0.15
Organic carbon g/kg	23.65
Organic matter g/kg	41.26
Total nitrogen g/kg	1.2
Available phosphorus mg/kg	11.61
Exchangeable bases and ECEC (cmol/kg)	
Ca^{2+}	4.21
Mg^{2+}	1.65
K^{+}	0.37
Na^{+}	0.30
ECEC	6.68

K= potassium, Na= sodium, Ca=calcium, Mg= magnesium, ECEC = effective cation exchange capacity, EA=exchangeable acidity

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Table 2: Effects of varied mulch quality on maize height (cm) at 4, 6, 8 and 10 weeks after sowing (WAS)

	Height(cm)			
Treatment	4WAS	6WAS	8WAS	10WAS
Control (No mulch applied)	40a	45a	87f	169f
40 g/60 g (*G. sepium*/*A. auriculiformis*)	48a	53a	135a	219a
50g/50g (*G. sepium*/*A. auriculiformis*)	47a	52a	133b	204b
60g/40g (*G. sepium*/*A. auriculiformis*)	42a	48a	119c	200c
100g (*G. sepium*)	41a	47a	108d	187d
100g (*A. auriculiformis*)	40a	47a	101e	179e
SEM±	1.850	0.8117	5.1681	5.3761

WAS = Weeks After Sowing

Means with the same letter in a column are not significantly different($P \leq 0.05$)

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Table 3: Effects of varied mulch quality on maize collar diameter (mm) at 4, 6, 8 and 10 weeks after sowing (WAS)

	Stem diameter(mm)			
Treatment	4WAS	6WAS	8WAS	10WAS
Control (No mulch applied)	8.40a	9.20c	14.34a	16.49a
40 g/60 g (*G. sepium*/*A. auriculiformis*)	11.55a	14.02a	18.52a	21.23a
50g/50g (*G. sepium*/*A. auriculiformis*)	10.22a	11.61d	18.23a	20.75a
60g/40g (*G. sepium*/*A. auriculiformis*)	9.76a	11.40d	17.46a	20.59a
100g (*G. sepium*)	9.18a	11.31d	16.32a	18.21a
100g (*A. auriculiformis*)	8.83a	9.46b	14.42a	18.04a
SEM±	0.4421	0.5022	0.5721	0.4384

WAS = Weeks After Sowing

Means with the same letter in a column are not significantly different($P \leq 0.05$)

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Table 4: Effects of varied mulch quality on maize leaf number at 4, 6, 8 and 10 weeks after sowing (WAS)

	Number of leaves			
Treatment	4WAS	6WAS	8WAS	10WAS
Control (No mulch applied)	5f	6f	8f	10f
40 g/60 g (*G. sepium*/*A. auriculiformis*)	8a	8a	11a	13a
50g/50g (*G. sepium*/*A. auriculiformis*)	8b	8b	10b	12b
60g/40g (*G. sepium*/*A. auriculiformis*)	7c	8c	10c	12c
100g (*G. sepium*)	7d	7d	10d	12d
100g (*A. auriculiformis*)	6e	7e	9e	12e
SEM±	0.4773	0.3333	0.4216	0.4014

WAS = Weeks After Sowing

Means with the same letter in a column are not significantly different($P \leq 0.05$)

Table 5: Effects of varied mulch quality on maize morphological characteristics

Treatment	**Above ground Biomass (g)**	**Below ground Biomass (g)**	**Crop growth rate (CGR g/m²/day)**	**Relative growth rate (RGR g/g/day)**	**Net assimilation rate (NAR g/m²/day)**
Control (No mulch applied)	42.21c	0.21a	0.02a	0.18a	0.02a
40 g/60 g (*G. sepium*/*A. auriculiformis*)	68.85b	0.56c	0. 11a	0.22a	0. 14a
50g/50g (*G. sepium*/*A. auriculiformis*)	62.79a	0.34b	0.08a	0.21a	0. 09a
60g/40g (*G. sepium*/*A. auriculiformis*)	62.79a	0.32d	0.07a	0.19a	0.08a
100g (*G. sepium*)	45.96a	0.31e	0.04a	0.18a	0.05a
100g (*A. auriculiformis*)	45.39a	0.30f	0.02a	0.18a	0. 03a

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SEM±	4.6554	0.0477	0.0148	0.0072	0.0182

Means with the same letter in a column are not significantly different($P \leq 0.05$)

Table 6: Effects of varied mulch quality on maize grain yield

Means with the same letter in a column are not significantly different($P \leq 0.05$)

Treatment	Yield (kg/plot)	Yield(kg/ha)
Control (No mulch applied)	1.18	875.27b
40 g/60 g (*G. sepium*/*A. auriculiformis*)	4.64	3436.29a
50g/50g (*G. sepium*/*A. auriculiformis*)	4.23	3134.99a
60g/40g (*G. sepium*/*A. auriculiformis*)	4.11	3047.11a
100g (*G. sepium*)	3.49	2582.62a
100g (*A. auriculiformis*)	3.62	2683.05a
SEM±	3.865	372.5214

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Table 7a: Bacteria and Fungi populations in the experimental soil at 4th and 8th week of study

WAA = Weeks After Application

Treatment	4 Weeks After Application		8 Weeks After Applica
	Bacteria popn(cfu/ml)	Fungi (cfu/ml)	Bacteriapopn(cfu/ml)
Control (No mulch applied)	4.6×10^7	4.2×10^7	25×10^3
40 g/60 g (*G. sepium*/*A. auriculiformis*)	5.9×10^7	7.6×10^7	40×10^3
50g/50g (*G. sepium*/*A. auriculiformis*)	6.5×10^7	4.9×10^7	63×10^3
60g/40g (*G. sepium*/*A. auriculiformis*)	6.4×10^7	8.6×10^7	54×10^3
100g (*G. sepium*)	7.0×10^7	8.9×10^7	82×10^3
100g (*A. auriculiformis*)	7.4×10^7	7.7×10^7	95×10^3

Table 7b: Identified mulch decomposing microbes at 4 Weeks After Application

S/no	Isolate name	Control	50/50	40/60	60/40	100 Gliricidia	100 Acacia	Freq.	Type
1	*Staphylococcus Aureus*	+	+	+	+	+	+	6	Bact.
2	*Streptococcus faecalis*	+	+	+	+	+	+	6	Bact.
3	*Pseudomonas aeruginosa*	+	_	+	_	+	+	4	Bact.
4	*Pseudomonas putida*	_	+	+	+	_	-	3	Bact.
5	*Escherichia coli*	+	+	+	+	+	+	6	Bact.
6	*Serratia mercescens*	_	+	_	+	+	+	4	Bact.
7	*Clostridium*	+	+	+	+	+	+	6	Bact.

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	Defficile								
8	*Salmonella paratyphi*	_	+	_	+	+	+	4	Bact.
9	*Micrococcus halophilus*	_	+	+	+	+	+	5	Bact.
10	*Shigella Flexneri*	+	_	_	+	+	+	4	Bact.
11	*Klebsiellasp*	-	-	+	+	+	+	4	Bact.
12	*Bacillus subtilis*	+	+	+	+	+	+	6	Bact.
13	*Bacillus cereus*	-	+	-	+	+	+	4	Bact.
14	Mucor Hiemalis	+	+	+	+	+	+	6	Fungi
15	*Aspergillus fumigatus*	_	+	+	+	+	+	5	Fungi
16	*Aspergillus Niger*	+	_	_	+	+	-	3	Fungi
17	*Rhizopus Stolonifer*	_	_	+	+	+	+	4	Fungi
18	*Aspergillus flavus*	_	+	+	+	_	-	3	Fungi
19	*Fusariumoxysporum*	+	+	_	+	+	+	5	Fungi
20	*Fusariumsolani*	-	+	-	+	-	+	2	Fungi
21	*Penicilliumdigitatum*	-	+	+	-	+	-	3	Fungi

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22	*Penicilliumexpansum*	_	_	+	+	+	+	4	Fungi
23	*Geotrichumcandidum*	+	+	+	+	+	+	6	Fungi
24	*Alternariainfectoria*	+	+	+	+	+	+	6	Fungi

- and + indicate absence and presence respectively

50/50= 500 g *G. sepium* and 50g *A. auriculiformis*, 40/60=40 g *G. sepium* and 60g *A. auriculiformis,* 60/40=60 g *G. sepium* and 40g *A. auriculiformis* 100 Gliricidia=*G. sepium,* 100 Acacia=*A. auriculiformis*

Table 7c: Identified mulch decomposing microbes at 8 Weeks After Application

S/no	Isolate name	Control	50/50	40/60	60/40	100 Gliricidia	100 Acacia	Freq	Type
1	*Serratia Mercescens*	+	+	+	+	+	+	6	Bact.
2	*Micrococcus halophilus*	_	+	+	+	+	+	5	Bact.
3	*Bacillus subtilis*	+	+	+	+	+	+	6	Bact.
4	Mucor Mucedo	+	+	+	+	+	-	6	Fungi
5	*Rhizopus Nigricans*	+	+	-	+	-	+	4	Fungi
6	*Aspergillus Niger*	_	+	+	+	-	-	3	Fungi

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7	*Aspergillus Fumigatus*	-	-	-	-	+	-	1	Fungi
8	*Fusariumoxysporum*	-	-	+	+	+	-	3	Fungi
9	*Trichodermaviride*	+	-	+	+	+	+	5	Fungi
10	*Penicilliumnotateum*	_	+	+	+	-	+	4	Fungi

- and + indicate absence and presence respectively

50/50= 500 g *G. sepium* and 50g *A. auriculiformis*, 40/60=40 g *G. sepium* and 60g *A. auriculiformis,* 60/40=60 g *G. sepium* and 40g *A. auriculiformis* 100 Gliricidia=*G. sepium,* 100 Acacia=*A. auriculiformis*