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Effect of mulch types on nutrient composition, maize (*Zea mays* L.) yield and soil properties of a tropical Alfisol in Southwestern Nigeria

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Abstract

Field investigations were carried out to evaluate the influence of shrub and herbaceous mulch types on soil properties and nutrient composition of maize (*Zea mays* L.) at the Teaching and Research Farm of the Federal University of Technology, Akure in the rainforest zone of southwestern Nigeria in 2013 and 2014 respectively. The shrub mulch; *Gliricidia sepium* and *Tithonia diversifolia*, herbaceous mulch; *Calopogonium mucunoides* and *Moringa oleifera* were applied at the rate of 5 t ha^{-1}. Application of NPK (20:10:10) fertilizer at the rate of 200 kg ha^{-1} was included as the standard treatment for the experiments. The treatments were laid out in randomized complete block design (RCBD) with three replication. The growth, agronomic parameters and nutritional quality of maize (*Zea mays* L.) were monitored and determined in both experiments. Results indicated that herbaceous mulch types and NPK fertilizer significantly ($P<0.05$) increased the number of leaves, plant height and leaf area when compared with the control in both years. Significant increases in yield parameters over the control were obtained for the NPK fertilizer treatment. In 2013 and 2014 cropping season NPK 20-10-10 treatment significantly produced the highest cob yield but was not significantly higher than the yield from *Gliricidia sepium* treatment in 2014. Soil organic carbon, total nitrogen (N), potassium (K), and exchangeable cations were positively stimulated by herbaceous mulches while residual phosphorus (P) was increased by NPK fertilizer treatment. Mulched treatments significantly increased crude protein, carbohydrate, nitrogen, phosphorus and ash content of maize grain in both years of cropping season thereby improving nutritional content of maize grain. Therefore, shrub and herbaceous mulch treatments applied at 5t/ha^{-1} could be applied alternatively in lieu of scarce and expensive inorganic fertilizer for improved maize yield, soil properties and nutrient composition.

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Introduction

Mulching is an effective method of manipulating crop growing environments in order to increase yield and improve product quality by controlling weed growth, reducing soil temperature, conserving soil moisture, reducing soil erosion, improving soil structure and enhancing organic matter content of the soil. Mulches are used for various reasons but water conservation and erosion control are the most important objective for its

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use in agriculture in dry regions. Other reasons for mulch use includes soil temperature modification, soil conservation, nutrient addition, improvement in soil structure, weed control and crop quality control. Mulching reduces deterioration of soil by way of preventing runoff and soil loss, minimizes weed infestation and checks water evaporation. Thus, it facilitates more retention of soil moisture and helps in control of temperature fluctuations, improves physical, chemical and biological properties of soil, as it adds nutrients to the soil and ultimately enhances the growth and yield of crops (Bhatt and Kheral, 2006; Anikwe et al., 2007; Sarkar and Singh, 2007; Glab and Kulig, 2008). Inyang (2005), revealed that mulch materials improved soil physicochemical properties, reduced soil temperature and evaporation, and increased the soil moisture content, thereby creating enabling soil microclimatic condition for crop growth.

Maize (*Zea mays* L.; family Poacea) ranks second to wheat in the world's cereal production. Wheat, rice and maize are the most important cereal crops in the world but maize is the most popular due to its high yields, ease of processing and digestion, and being cheaper than other cereals (Jaliya et al., 2008). Ayoola and Adeniyan (2006) reported that the use of inorganic fertilizers was not helpful under intensive agriculture because they were often associated with reduced yield, nutrient imbalance, leaching and pollution of groundwater (Sridhar and Adeoye, 2003). As the mineral fertilizer alone cannot meet the requirements of crops and cropping systems because of high cost and also environment related risks involved in its application and usage, integrated use of organics and inorganics is desired to attain the sustainability of a cropping system (Rao et al., 2002). Inorganic fertilizer use alone is inadequate to alleviate the physical and biological degradation of soil. The use of organic manure as fertilizer releases many important nutrients into the soil and also nourishes soil organisms, which in turn slowly and steadily make minerals available to plants (Erin, 2007). Soil amendment with manures, municipal biosolids, and other organic wastes has been found to improve the physical and chemical properties of soil (Barzegar et al., 2002; Mkhabelaa and Warmanb, 2005; Simon et al., 2013; Unagwu et al., 2013).

Moringa oleifera is one of the known promising exotic multipurpose tree species recommended for fuel wood, fodder, food, medicinal value and soil fertility improvement. *Moringa* is suggested as a viable supplement of dietary minerals. The pods and leaves of *Moringa* contain high amounts of Ca, Mg, K, Mn, P, Zn, Na, Cu and Fe (Aslam et al., 2005). The species has been reported to improve crop yield by improving soil fertility and providing semi-shade, useful in intercropping systems where intense direct sunlight can damage crops (Folkard and Sutherland, 1996). Early contact of *M. oleifera* leaf extracts with seeds of cereals enhanced germination of sorghum, length of maize radicals and hypocotyls of wheat. In the wake of skyrocketing global prices of inorganic fertilizers, land and water pollution associated with use of inorganic fertilizer and the contribution of inorganic fertilizer to climate change, there is a need to search for alternative sources of plant nutrients. *M. oleifera* is one such alternatives being investigated to ascertain their effects on growth and yields of crops. Sangakkara et al. (2005) reported that gliricidia leaves with a lower C:N ratio had a better impact on soil properties and crop growth. In the guinea savanna zone of Nigeria, Atayese and Liasu (2001) found that soil under *Tithonia* and siam weed had higher pH, porosity, moisture content, N, P, K, Na, Ca, mycorrhizal fungi spores and earthworm cast density and lower bulk density compared with bare soil. *Tithonia* has been found to produce high biomass and was reported as an effective biomass for mulching, increasing yield of rice and tomato (Liasu and Achakzai, 2007) and also an effective nutrient source for maize, beans and vegetables in Kenya, Malawi and Zimbabwe (Jama et al., 2000) and yam in Nigeria (Adeniyan et al., 2008). *Tithonia* is known to be rich in N, P and Ca (Taiwo and Makinde, 2005; Liasu and Achakzai, 2007), Olabode et al., (2007) reported that *Tithonia diversifolia* with its high nutrient status is a potential soil improver for enhanced productivity. The plant is recommended for use as a green manure or as a major component of compost manure. Dried *Tithonia* plants should also be preferably left to decompose on the field rather than burning them. Reducing fallow periods with sown leguminous plants such as *Calopogonium mucunoides* was also found to be a technically feasible, low-input method of improving soil nutrient levels for rice cropping in the Guinea and Sudan savannah regions of northern Ghana (Yiridoe et al., 2006).

Thus, the objectives of this study was to: (i) evaluate the effects of herbaceous mulch types, namely, *Moringa oleifera, Gliricidia sepium*, *Tithonia diversifolia*, *Callopogonium mucunoides*, and NPK 20:10:10 on soil health and fertility status, (ii) evaluate the effects of herbaceous mulch types and NPK 20:10:10 on growth and yield of maize; and (iii) assess potential increase in nutrient uptake and composition of maize as affected by mulching and chemical fertilization.

Material and Methods

Geology and vegetation of the study area

The study area (Akure), Ondo state Nigeria lies on latitude $7^0 17^1$North of the Equator and on longitude 15^0 14^1 east of the Greenwich meridian. It stands on an altitude of about 370 meters above the sea level. The study area also has hilly adjourning land which extends toward the bordering town of Ado-Ekiti (Ekiti state) and are studded with granite formations believed to be of volcanic origin spreading over an area of 99,287km^2. The study area falls into the pre-Cambrian exposed order granite belt, with formation dates back as far back as 600 to 3500 million years ago. Topographically, the site is generally flat and soil area generally falls into large quantity of red laterite and very little of mangrove swamp soil of humid tropical Equatorial area. Climatically, the study area has a tropical climate and belongs to the equatorial rain forest belts. The study area also has lots of adjourning creaks and lagoons, bordering the Atlantic Ocean, which are naturally separated one from another by mangrove swamps of raffia swamps. After this lies the well-drained rain forest region, which stretches to about two hundred kilometers inland.

Description of the experimental site

The experiment was conducted at the Crop Section of the Teaching and Research Farm of the Federal University of Technology Akure, Ondo State, Nigeria located at obanla within the University premises. The area lies within the tropical rainforest belt (7^0 17’N, 15^0 14’E). The rainfall pattern of Akure is bimodal with a wet season of about eight months occurring between April and October and with a brief dry spell which in most cases occur in the second half of August. The peak rainfall periods are June/July and September/October while the short dry season lasts from November to March. The mean daily temperature ranges from 27^0C to 37^0C throughout the duration of the study (Agro-climatological and Ecological Project, Ondo State Ministry of Agriculture).

Land preparation

The experimental field was mechanically cleared, ploughed and harrowed. The experimental layout was done and sectioned into blocks and plots.

Source of materials

Improved maize variety TZSR-Y-1 (streak resistant) was collected from the Ondo State Agricultural Development Project Seed Centre in Akure, Ondo state Nigeria.

Planting and cultural practices

The seeds of maize (*Zea mays* L.) were sown in an already prepared experimental field manually at 3 cm depth. Maize was sown at a spacing of 60 x 30 cm (55,555 plants/ha) with the total number of twenty-eight (28) maize plants per plot. Weed control was done manually by hand pulling and hoeing. Weeding was done three times throughout the cropping season. The first, second and third weeding were carried out at the 2nd, 6th and 9th weeks after planting. Weeds were not allowed to thrive before weeding was carried out in the experimental plots. Weeds uprooted were packed out of the experimental plots, so as not to interfere with the results of the experiment.

Field experiments

The experiments was laid out in a randomized complete block design (RCBD) and lasted for three months with each treatment replicated thrice. Each replicate consisted of six (6) treatments. Total land area measured 207 m^2 (23 m by 9 m) with 24 plots in all and each plot size measured 2 m by 2 m (4 m^2) with 1 m alley ways between plots and replicates. The first experiment was carried out between 2nd of September to 30th November, 2013 and the second experiment was carried out between 1st of May to 30th of July, 2014 at the same experimental site. Fresh prunnings of leaf and stems of shrubs (*Tithonia diversifolia* and *Gliricidia sepium*) and herbaceous mulch prunnings of (*Moringa oleifera* and *Calopogonium mucunoides*) were collected from the Agroforestry and tree crop unit at the teaching and research farm of the Federal University of Technology Akure. These fresh leaf and stem prunnings were chopped, weighed and tilled into the soil using traditional hoe at the rate of 5 t/ha^{-1} across designated treatment blocks and plots while NPK 20:10:10 was applied at the recommended rate of 200 kg ha^{-1} using the side placement method.

Data collection and sampling techniques

Data collection commenced a week after the application of treatments at 3 weeks after planting (WAP). Data on agronomic characteristics like plant height and number of leaves were collected fortnightly at the 3rd, 5th, 7th, 9th and 11th WAP and leaf area was taken at 8 WAP. Yield and yield components were also analyzed after harvesting. Plant height were measured with a meter rule and number of leaves by direct counting of the leaves. Leaf area was measured with leaf area metre. To determine dry matter yield the two middle rows from each plot at maturity were harvested after removing cobs, stacked for uniform drying, weighed and then converted to kg ha^{-1} using the following formula:

$$\text{Dry matter yield (kg ha}^{-1}) = \text{kg stover yield m}^{-2} \times 10{,}000 \text{ m}^2 \quad (1)$$

Shelling percentage was calculated using the following formula:

$$\text{Shelling percentage (\%)} = \frac{\text{Grain weight of four ears}}{\text{Total weight of four ears}} \times 100 \quad (2)$$

Grain Yield: For determining the grain yield, the two middle rows from each plot at maturity were harvested, husked, dried and threshed. Grain yield was calculated and converted to kg ha^{-1} using the following formula:

$$\text{Grain yield (kg ha}^{-1}) = \text{kg grain yield m}^{-2} \times 10{,}000 \text{ m}^2 \quad (3)$$

Biomass yield: At maturity, four central rows in each plot were harvested, dried to constant weight and weighed.

$$\text{Biomass yield (kg ha}^{-1}) = \frac{\text{Biomass yield per plot}}{\text{Plot area harvested}} \times 10{,}000 \text{ m} \quad (4)$$

Harvest Index: Harvest index was calculated using the following formula:

$$\text{Harvest index (\%)} = \frac{\text{Grain yield (kg ha}^{-1})}{\text{Biomass yield (kg ha}^{-1})} \times 100 \quad (5)$$

Soil sampling and physico-chemical analysis

The Soil at the experimental site is a clay loam alfisol classified as clayey skeletal oxic-paleustaif, five core samples were collected at random from each treatment plot with the aid of a soil auger at a depth of (0-15cm). The collected core samples were homogenized and a total of twenty four composite soil samples were collected from the trial sites for determination of chemical properties before planting and after harvest. The samples were air dried at room temperature, crushed and sieved through a 2mm mesh and subjected to particle size analysis using the Bouyoucos (1951) method. The soil pH was determined by using 1:2 of 10 g of soil to 20 ml distilled water ratio suspension. The suspension was stirred for 30 minutes and determined by glass electrodes pH meters which were standardized with a buffer of pH 7. Total nitrogen in the soil was analysed using Kjeldahl method, while available phosphorus was extracted using Olsen's extract and the P in the extract was determined via the use of spectrophotometer. The organic matter was determined using Walkley-Black (1934) wet Oxidation method. Potassium (K^+), Calcium (Ca^{2+}), Sodium (Na^+), and Magnesium (Mg^{2+}) were extracted by 1M Ammonium acetate (NH_4OAC), at pH 7 and the extracts were determined on a flame photometer while Calcium (Ca^{2+}) and Magnesium (Mg^{2+}) were determined by ethylene di-amine tetra acetic acid (EDTA) titration (AOAC, 1997).

Determination of Proximate composition of maize grain

Moisture content

The moisture content was estimated by drying triplicates 10g weight of the maize grain sample at 105oC for 24hr and then reweighing after cooling in a desiccator. The moisture content is expressed as percentage of the dry weight.

$$\text{Moisture content} = \frac{\text{Weight loss of sample}}{\text{Weight of the original sample}} \times 100 \quad (6)$$

(AOAC, 1997)

Ash Content

Two grams of grinded maize grain dried sample was weighed in to a dry porcelain dish and then heated in a muffle furnace at 6000C for 6 hours. It was cooled in desiccators and weighed. The percentage ash content was calculated thus:

$$\% \text{ Ash} = \frac{\text{Weight of ash}}{\text{Weight of sample}} \times 100 \qquad (7)$$

(AOAC, 1997)

Fat content

The fat content was determined using Soxhlet extraction method. The amount of oil produced was calculated and expressed as percentage of original sample.

$$\% \text{ Fat} = \frac{\text{Weight loss of sample (extracted fat)}}{\text{Weight of sample}} \qquad (8)$$

(AOAC, 1997)

Crude Protein

One gram of each grinded maize grain sample was weighed into a digestion flask. Ten grammes of potassium sulphate, 0.7g mercuric oxide and 20cm^3 concentrated sulphuric acid were added to the sample in the digestion flask. The flask was heated gently at an inclined angle after cooling 90ml of distilled water was added and mixed. A small piece of pumice was added to prevent bumping. 80ml of 2M sodium hydroxide solution was added while tilting the flask so that two layers are formed. The condenser unit was rapidly connected, heated and the distilled ammonia collected in 50ml boric acid / methyl red indicator. Fifty millilitres of the distillate was collected and titrated against 0.1M hydrochloric acid solution. The percentage nitrogen content percent was calculated thus:

$$\% \text{ N} = \frac{\text{(Volume of acid x Molarity of standard acid)}}{\text{Weight of sample (g)}} \times 0.014 \times 100 \qquad (9)$$

% Crude protein content = nitrogen content x 6.25 (AOAC, 1997) (10)

Total Carbohydrate

The total carbohydrate was determined by differential method. This was achieved by subtracting the total protein, fat, moisture and ash content from 100 thus:

% carbohydrate = (100 – (% moisture + % ash+ % fat + %protein + %fibre) (AOAC, 1997) (11)

Data analysis

The data obtained on the morphological characteristics, yield and yield components were analyzed statistically using the Analysis of Variance. Data were analyzed using SPSS 17th edition and the treatment means comparison done with the Tukey's HSD test.

Results and Discussion

Soil chemical properties as affected by mulch types

Table 1 shows the nutrient status and soil pH of the experimental site before the application of treatments. The pH of the soil was 5.77 and the values of OC, OM, N, P and K in the soil were 1.44 g kg^{-1}, 2.48 g kg^{-1}, 0.36 g kg^{-1}, 2.52 mg kg^{-1} and 0.67 cmol kg^{-1} respectively. The other exchangeable bases such as Na, Ca and Mg were 0.16 cmol kg^{-1}, 2.50 cmol kg^{-1} and 1.00 cmol kg^{-1} respectively. Soil particle fraction showed that the soil was a clay loam in texture indicating its low organic matter content and high percentage of clay. The soil was characterized by moderate acidity with pH value of 5.77. The fertility of the soil was low compared with established critical levels in a tropical alfisols. The organic matter content was low compared to the critical level of 20-30 g kg^{-1} reported by Enwezor et al. (1979). The soil was deficient in N compared with the critical values of 1.5 – 2.0 g kg^{-1} reported by Sobulo and Osiname (1981) while P was deficient based on the critical values of 10-16 mg kg^{-1} established by Adeoye and Agboola (1985). The K component of the soil was high compared to the critical levels of 0.16-0.25 cmol kg^{-1} indicated by Adeoye and Agboola (1985). The magnesium and calcium were sufficient compared with 0.2- 0.4 cmol kg^{-1} critical values of Adeoye and

Agboola, (1985) and 2.50 cmol kg^{-1} critical levels of Akinrinde and Obigbesan (2000) respectively. All the treatments utilized in this study were analyzed and found to contain N, P, K, Ca, Mg and a host of other mineral elements in appreciable amounts.

Table 1. Pre-Planting Physico-chemical properties of experimental site at a depth of (0-15cm)

Properties	**Values**
Physical properties (g kg^{-1})	
Sand	32.80
Silt	30.00
Clay	37.20
Textural class	Clay loam
Chemical properties	
pH in H_2O (1:1)	5.77
Organic carbon (g kg^{-1})	1.44
Organic matter (g kg^{-1})	2.48
Available P (mg kg^{-1})	2.52
Total N (g kg^{-1})	0.36
Exchangeable bases (cmol kg^{-1})	
Ca	2.50
Mg	1.00
K	0.67
Na	0.16

*Mean values of three replicates of soil sample are presented in the table

Table 2, shows that *Gliricidia sepium* has the highest content of N among the mulch materials, while *Calopogonium mucunoides* also had a relatively high N contents of 5.10%. However, *Tithonia diversifolia* had N content of 6.64% which was higher than that of *Calopogonium mucunoides,* the mechanism behind this high N content in *Tithonia diversifolia* when compared with *Calopogonium mucunoides* a known leguminous N fixer need to be studied. Other nutrient elements that were analyzed are P, K, Ca and Mg. NPK 20-10-10 fertilizer had the highest P content (9.65%) amongst the treatment, *Moringa oleifera* (7.30%) and *Gliricidia sepium* (2.29%) had the highest and lowest P content respectively amongst the mulch types. *Moringa oleifera* also contain higher Ca and Mg content (5.72 and 2.44 mg/kg) while *Tithonia diversifolia* (2.70mg/kg) contains the lowest Ca and *Calopogonium mucunoides* (1.28 mg/kg) the lowest Mg content. K content was highest in NPK fertilizer treatment (9.74%) and lowest in *Tithonia diversifolia* (2.41%) while *Moringa oleifera* had the highest K content (6.84%) amongst the mulch types. The effect of shrub and herbaceous mulch type's application on soil chemical properties after maize harvest are presented in Table 3. Significant increase with respect to soil pH after maize harvest was observed in all mulched treatments in comparison with the control and NPK standard rate. *Gliricidia sepium* and *Tithonia diversifolia* (5.69 and 5.67) mulched plots recorded higher soil pH levels over other mulched plots, control plot and NPK standard (Table 3).

Table 2. Chemical composition of shrub mulch and 20:10:10 NPK fertilizer

Elements	NPK	*Moringa oleifera*	*Gliricidia sepium*	*Tithonia diversifolia*	*Calopogonium mucunoides*
N (%)	18.25	4.55	7.18	6.64	5.10
P (%)	9.65	7.30	2.29	5.80	6.40
K (%)	9.74	6.84	3.65	2.41	4.52
Ca (mg/kg)	1.87	5.72	4.26	2.70	3.00
Mg (mg/kg)	1.21	2.44	1.50	1.58	1.28

The increase in soil pH might be due to the effect of the chopped herbaceous mulch and shrub which tend to improve on soil exchangeable bases while reducing exchangeable acidity thereby reducing soil acidity, similar results were also observed by Egbe et al. (2012). Soil organic carbon (SOC) of mulched plots was also increased significantly with *Calopogonium mucunoides* (1.99 g/kg) recording the highest SOC rate over all other treatments which includes the control and NPK treatment. The organic carbon accumulation in the herbaceous mulch treatment is a result of balance from subtraction by decomposition process and additions from synthesized humus from shrubs and herbaceous mulch. The incorporation of this mulch types improved the SOC better than the control and NPK standard rate. This can be attributed to the presence of more nutrients and organic carbon in the herbaceous mulch. The result of this study is similar to the findings of Tejeda et al. (2007) who reported that the application of leguminous residue had a positive effect on soil physical, chemical and biological properties and could be considered as a good alternative for improving low nutrient soils. With respect to soil nitrogen content, *Calopogonium mucunoides* and *Gliricidia sepium* mulched plot (0.76 g/kg) respectively recorded a significant increase over the control treatment (0.12 g/kg) and the NPK standard treatment (0.42 g/kg). A significant increase in soil available P was recorded in the *Moringa oleifera* mulch treatment (4.24 mg/kg) and the NPK standard treatment (5.06 mg/kg) when compared with other treatments. The benefit of using organic herbaceous mulch and shrubs is to release trapped atmospheric nitrogen and make it available as a biological source of nitrogen in a mulched plot for a following crop. These herbaceous mulch conserve soil moisture, increase soil organic matter and improves soil properties and microbial activity thereby supporting mineralization rate and release of nutrient such as N, P and K into the soil. This could be the rationale behind the increased nitrogen and potassium content in the shrubs and herbaceous mulch treated plots thereby contributing to better maize growth, biomass and yield in this mulch treatment over other mulch treatments. A significant increase in exchangeable bases was observed in the shrub and herbaceous mulched treatments. *Moringa oleifera* and *Calopogonium mucunoides* mulched plot reflected significant increase in soil Ca levels when compared with all other treatments (3.90 and 3.20 cmol/kg respectively), while *Gliricidia sepium* (0.80 cmol/kg) and *Calopogonium mucunoides* (1.40 cmol/kg) recorded significant increase in Mg levels. *C. mucunoides* and *Moringa oleifera* also significantly increased K levels (1.62 and 1.03 cmol/kg) respectively amongst the mulched treatments. All treatments significantly increased soil Na levels when compared to the un-mulched control treatment, however *Moringa oleifera* mulched plot recorded marginal higher Na values (0.16 cmol/kg) above other treatments. This probably had a stimulatory effect on the soil pH which influenced the reduction in exchangeable acidity of the soil and slightly raised the soil pH in all mulched treatments. The findings of this study revealed that exchangeable bases and soil fertility increased in herbaceous mulch and shrub treated plots corroborates earlier findings that leguminous shrubs are sources of utilizable N, P, K, Ca, Mg and organic matter (Awodun et al., 2007). This also confers liming characteristics to some herbaceous mulch and shrubs such as *Calopogonium mucunoides*, *Moringa oleifera*, *Gliricidia sepium* and *Tithonia diversifolia*. The soil is a very important medium for crop growth with significant bearing on physical, chemical and biological functions influencing plant productivity. Optimal application of organic mulch over a given field can influence soil properties such as, texture, organic matter, salinity, porosity, moisture content and subsoil characteristics which are critical factors that can influence crop yield.

Table 3. Soil chemical properties of treatments (0 – 15cm) after maize harvest in 2014

Treatments	pH (H_20)	OC (g/kg)	P (mg/kg)	N (g/kg)	Ca (cmol/kg)	Mg (cmol/kg)	K (cmol/kg)	Na (cmol/kg)
Control	5.32c	0.44d	1.28d	0.12d	1.10d	0.09d	0.24d	0.04b
NPK 20-10-10	5.15c	1.52c	5.06a	0.42c	1.90b	0.40c	0.59c	0.13a
M. oleifera	5.34abc	1.72b	4.24ab	0.60ab	3.90a	0.70b	1.03a	0.16a
G. sepium	5.69ab	1.53c	1.79c	0.76a	1.60b	0.80b	0.85b	0.12a
T. diversifolia	5.67ab	1.74b	3.71b	0.63ab	1.50c	0.70b	0.92b	0.13a
C. mucunoides	5.15c	1.99a	3.58b	0.76a	3.20a	1.40a	1.62a	0.13a

*Means followed by the same letter within each column are not significantly different (P=0.05) as indicated by Tukey's HSD test

Effects of the applications of mulches and NPK fertilizer on growth parameters of maize during the 2013 and 2014 cropping season

Tables 4 and 5 show the effects of herbaceous mulches and NPK fertilizer on number of leaves per maize plant at two weeks intervals over a period of 9 weeks after treatment applications in 2013 and 2014 cropping seasons. In both years, there were no significant differences in the numbers of leaves of maize at 3WAP. In both years all herbaceous mulch treatments and NPK fertilizer significantly increased the number of leaves produced when compared with the control at 5, 7 and 9 weeks after treatment application. There were variations in the number of leaves in their response to treatments. Significant increases in plant height over the control were obtained for all the treatments throughout the period of growth of maize with the NPK fertilizer consistently producing plants with the tallest height (Tables 6 and 7). It was also observed in both years that the number of leaves reduced in 11WAP as a result of shedding of leaves. In both years, all the mulches and NPK fertilizer significantly increased maize leaf area throughout the evaluation period when compared with the control (Tables 8 and 9). NPK manifested the highest leaf area throughout the evaluation period. The significant increases in leaf number, plant height and leaf area of maize obtained with the application of mulches throughout the evaluation period over the control suggests that they constitute an excellent source of mineral nutrients needed for plant growth. It was observed that NPK 20:10:10 fertilizer release of nutrient was quick as observed in the rapid physiological growth rate of maize plant on the experimental field immediately after inorganic fertilizer application. However, 21 days after shrub and herbaceous mulch application, the transient effect of the mulches on maize physiological growth became more pronounced than that of the inorganic fertilizer due to increasing rate of mineralization through the action of soil microbes. This agrees with the finding of Erin (2007), on the use of organic amendment as fertilizers, which releases many important nutrients into the soil and also nourishes soil organisms, which in turn slowly and steadily make minerals available to plants. The superior growth parameters and early tasseling in maize crop observed in this study and corroborated by earlier researcher (Uwah et al., 2011) could be attributed to the relatively available and fast release of nutrients inherent in the herbaceous mulch which promoted vigorous foliage, increased meristematic and intense physiological activities in plants which aided synthesis of more photo-assimilates.

Table 4. The effects of mulches and NPK on the number of leaves at different stages of growth of maize in 2013

	Number of leaves				
Treatments	3weeks	5weeks	7weeks	9weeks	11weeks
Control	5.00a	6.67a	8.00d	10.33ab	9.67bc
NPK (20:10:10)	5.33a	8.00a	10.00a	11.00a	10.67ab
M. oleifera	5.00a	7.00a	8.33cd	10.33ab	10.33ab
G. sepium	5.33a	7.00a	9.67ab	10.33a	10.33ab
T. diversifolia	5.00a	7.00a	9.33abc	10.00ab	10.00ab
C. mucunoides	5.00a	6.67a	9.33abc	11.00a	10.67ab

*Means followed by the same letter within each column are not significantly different (P=0.05) as indicated by Tukey's HSD test.

Table 5. The effects of mulches and NPK on the number of leaves at different stages of growth of maize in 2014

	Number of leaves				
Treatments	3weeks	5weeks	7weeks	9weeks	11weeks
Control	6.00ab	8.00b	9.33bc	11.33b	11.00c
NPK (20:10:10)	6.67a	9.00a	11.00a	13.67a	13.00a
M. oleifera	6.33a	8.00b	10.00b	11.67b	11.67bc
G. sepium	6.33a	8.00b	10.33ab	12.00b	11.67abc
T. diversifolia	6.67a	8.33ab	10.00b	11.67b	11.33bc
C. mucunoides	6.67a	8.67a	10.33ab	11.67b	2.67ab

*Means followed by the same letter within each column are not significantly different (P= 0.05) as indicated by Tukey's HSD Test

Table 6. The effects of mulches and NPK on plant height (cm) at different stages of growth of maize in 2013

	Plant height(cm)				
Treatments	3weeks	5weeks	7weeks	9weeks	11weeks
Control	33.56a	70.20b	84.71d	118.19d	121.04d
NPK (20:10:10)	31.59a	94.89a	145.22a	201.64a	205.99a
M. oleifera	30.19a	67.36b	87.92d	117.48d	121.99d
G. sepium	32.43a	74.07b	122.00b	163.75b	167.78b
T. diversifolia	30.58a	71.08b	112.02bc	147.85bc	153.58bc
C. mucunoides	30.74a	63.79b	104.52bcd	134.32cd	137.75cd

*Means followed by the same letter within each column are not significantly different (P=0.05) as indicated by Tukey's HSD Test.

Table 7. The effects of mulches and NPK on plant height (cm) at different stages of growth of maize in 2014

	Plant height(cm)				
Treatments	3weeks	5weeks	7weeks	9weeks	11weeks
Control	40.71a	71.67c	108.45e	160.71d	165.75e
NPK (20:10:10)	43.64a	106.85a	168.35a	239.81a	237.73a
M. oleifera	33.83a	86.52bc	130.31cd	168.13cd	175.18de
G. sepium	34.10a	90.42abc	135.65bcd	179.11cd	185.25cd
T. diversifolia	33.98a	91.27ab	121.55de	175.29cd	183.43cde
C. mucunoides	33.85a	84.68bc	119.67de	170.18cd	178.89de

*Means followed by the same letter within each column are not significantly different (P= 0.05) as indicated by Tukey's HSD Test

Table 8. The effects of mulches and NPK on leaf area (cm^2) at 8 WAP of maize in 2013

	Leaf area (cm^2)

Treatments	
Control	197.88e
NPK (20:10:10)	399.79a
M. oleifera	199.87e
G. sepium	360.74ab
T. diversifolia	222.35de
C. mucunoides	297.66bc

*Means followed by the same letter within each column are not significantly different (P= 0.05) as indicated by Tukey's HSD Test

Table 9. The effects of mulches and NPK on leaf area (cm²) at 8 WAP of maize in 2014

	Leaf area (cm²)
Treatments	
Control	372.44cd
NPK (20:10:10)	488.22a
M. oleifera	388.22cd
G. sepium	401.55c
T. diversifolia	436.44bc
C. mucunoides	438.15bc

*Means followed by the same letter within each column are not significantly different (P=0.05) as indicated by Tukey's HSD Test

Effects of mulches and NPK fertilizer on maize yield parameters at the end of the 2013 and 2014 cropping season

The trend in biomass yield as affected by treatments is similar in both years (Tables 10 and 11). The NPK fertilizer significantly increased biomass yield over the mulch treatments and control. The NPK and *Calopogonium mucunoides* gave the significantly highest biomass yield in the first year but NPK had the highest biomass yield in both years while control gave the lowest yield. Significant differences in grain yields were also observed among the treatments in both years (Tables 10 and 11).

Table 10. Effects of mulches and NPK fertilizer on maize yield parameters at the end of 2013 cropping season

Treatment	Dry matter (t ha^{-1})	Grain yield (t ha^{-1})	Biomass Yield (t ha^{-1})	Shelling percentage (%)	Harvest index (%)
Control	0.98d	0.63d	3.05c	70.31ab	20.66bc
NPK (20:10:10)	2.32a	2.19a	7.55a	72.10ab	29.01ab
M. oleifera	1.29cd	0.66d	3.11c	64.29b	21.22bc
G. sepium	1.90ab	1.41bc	4.22bc	70.36ab	34.41a
T. diversifolia	1.75ab	1.15c	4.91bc	68.95ab	23.42bc
C. mucunoides	2.15ab	1.72b	5.64ab	76.11a	30.50ab

*Means followed by the same letter within each column are not significantly different (P= 0.05) as indicated by Tukey's HSD Test.

Table 11. Effects of mulches and NPK fertilizer on maize yield parameters at the end of 2014 cropping season

Treatment	Dry matter (t ha^{-1})	Grain yield (t ha^{-1})	Biomass Yield (t ha^{-1})	Shelling percentage (%)	Harvest index (%)
Control	1.94d	1.23cd	4.98d	63.97c	24.65c
NPK (20:10:10)	3.18a	2.76a	9.12a	74.66a	30.26a
M. oleifera	2.16cd	1.60c	6.28c	67.00bc	25.64bc
G. sepium	2.79ab	2.22ab	7.89b	69.70b	28.14abc
T. diversifolia	2.66b	2.15b	7.52b	65.62c	28.59abc
C. mucunoides	2.35c	2.02bc	6.91c	71.89ab	29.18ab

*Means followed by the same letter within each column are not significantly different (P=0.05) as indicated by Tukey's HSD Test

NPK fertilizer gave significantly highest grain yield in the first year while the control had the lowest grain yields in both years. Furthermore, significant differences in dry matter yields among the treatments were also observed in both years of study. A comparison of the treatments indicated that the mulches and the NPK fertilizer resulted in significantly greater dry matter yields than the control; the NPK fertilizer gave significantly highest dry matter, followed by *Calopogonium mucunoides* and *Gliricidia sepium* mulches in the first and second years respectively (Tables 10 and 11). Higher shelling percentage were noted for the *Calopogonium mucunoides* mulch treatment and the NPK treatment in the first and second years respectively. These were however, not significantly different from some of the treatments in both cropping seasons. The *Moringa oleifera* and control recorded the lowest shelling percentage in 2013 and 2014, respectively but were also not significantly different from most of the treatments (Tables 10 and 11). Treatment effects exerted significant differences in harvest index in both years under study (Tables 10 and 11). *Gliricidia sepium* mulch and the NPK treatments recorded significantly greater harvest index in the first and second year respectively. The significant increases in yield parameters obtained with applications of the shrub and herbaceous mulch types over the control in this research can equally be ascribed to the steady and slow rate of nutrient release for plant uptake in the affected mulch-based plots. This is due to the adequate and regular supply of sufficient macro and micro nutrients needed for maize growth and yield. Pervaiz et al. (2009) observed that mulched treatments show significantly greater total uptake of N, P and K than corresponding un-mulched treatment. The slightly higher value recorded for *Gliridia sepium* may be ascribed to the fact that the treatment had high concentrations of N and P which after decomposition are released by mineralization for plant uptake. Egbe et al. (2012) reported that application of *Gliricidia sepium* leaf litter positively affected growth and yield of maize.

Effects of treatments on proximate and mineral composition of maize grain at the end of the 2013 and 2014 cropping season

There were significant differences in moisture contents of maize grains due to treatment effects in both years (Tables 12 and 13). The highest moisture content of maize grain was given by *Calopogonium mucunoides* and NPK in the first year while NPK had the highest moisture content in the second year (Tables 12 and 13). The results showed that different herbaceous and shrub mulch increased moisture content of maize grain as compared to the control. The high moisture content in grains obtained from *calopogonium mucunoides* mulch treatment and NPK fertilizer treatment might be due to the less evaporation of soil moisture (Rafiq et al., 2010) and weed density suppression. Thus, maximum moisture was utilized by the plant to increase grain moisture content and hence the yield (Ullah et al., 2010). Significant differences were found for ash contents amongst the treatments. The significantly highest ash content of maize grain was recorded by *Moringa oleifera* in both years (Tables 12 and 13). The significantly lowest ash content was given by *Gliricidia sepium* in the first year and Control in the second year (Tables 12 and 13). There were significant differences in fat content recorded amongst the treatments in both years (Tables 12 and13). The control treatment recorded the highest fat content in both years, which was not significantly different from *Calopogonium mucumoides* and *Moringa oleifera* in the first year. The lowest fat content was given by *Gliricidia sepium* in the first year and *Calopogonium mucunoides* in the second year (Tables 12 and 13). Crude fat is one of the most important components of maize grains; increase in fat content is essential for human health. Earlier studies by Farhad et al. (2009) reported mulching to be useful for the enhancement of maize grains quality. Significant differences in protein content occurred among the treatments in both years (Tables 12 and 13). Significantly the lowest protein content of maize grain was given by the control in both years while the highest protein content was given by *Gliricidia sepium* in the first year and *Moringa oleifera* in the second year (Tables 12 and 13). According to Rafiq et al. (2010), mulching helps in conserving moisture content as well as improve soil fertility which could in turn increase protein content of the grains. Boomsma et al. (2009) opined that availability of sufficient soil N and moisture for plants can lead to higher chlorophyll contents and photosynthetic activity which could produce grains with higher protein content. There were significant differences in crude fibre contents amongst the treatments in both years (Tables 12 and 13). Significantly the highest crude fibre of maize grain was recorded by NPK treatment in both years. The NPK treatment was not statistically better than that given by *Moringa oleifera* in both years. Significantly lowest crude fibre content was recorded by *Calopogonium mucunoides* in both years (Tables 12 and 13). Brunilda (2010), reported that the use of mulch could reduce fibre content of maize grains which could be beneficial for animal feed production and human health. Findings from the study indicate a significant CHO content in the *Tithonia diversifolia* mulch treatment when compared with other mulch treatments in the first year. Results from the second year indicate a statistical significant CHO content in the *Gliricidia sepium* mulch treatment and control treatment when compared with other mulch treatments (Tables 12 and 13). The increase or decrease in CHO content has implications on maize forage quality as there exist a positive relationship between CHO content and maize forage palatability and digestibility. An increase in the former causes an increase in the latter. This finding corroborates earlier report by Fonsca et al. (2000), who also reported the influence of higher CHO content on corn forage quality and palatability. There were significant differences observed in N contents recorded amongst the treatments in both years (Tables 12 and 13). Significantly, the highest N content of maize grain was given by *Gliricidia sepium* in both years while a significant lower N content of maize grain was given by control in both years. The N increase in maize grain from *Gliricidia sepium* mulched treatment is expected and can be ascribed to the high amount of utilizable N and organic matter content of the leguminous shrub *Gliricidia S.* due to its nitrogen fixing ability which are readily transferred, mineralized and absorbed by the maize plant after incorporation into the soil thereby increasing maize grain N content. Significant differences in P content occurred among the treatments in both years (Tables 12 and 13). *Tithonia diversifolia* and NPK treatments recorded significantly the highest P content in year one and two respectively. Values of proximate composition and mineral contents of maize grain were found to be significantly increased in the treatments involving application of mulches compared with the control. It is evident from the results obtained in this research that the values of the respective nutrient components obtained with the mulch-based treatments were generally comparable to those obtained from NPK and even better in some cases. Of all the treatments tested NPK significantly produced the highest grain yields in 2013 and 2014 cropping season while the mulch treatments improved soil organic carbon, soil nutrient status and nutrient composition of maize. The findings of this study has implication for resource poor farmers as it shows that soil fertility, maize yield and nutritional quality could be improved through the use of shrubs and herbaceous mulch with little or no recourse to inorganic fertilizer use.

Table 12. Effects of treatments on proximate and mineral composition of maize grain at the end of 2013 cropping season

Treatments	Moisture Content (%)	Ash (%)	Fat (%)	Crude Protein (%)	Crude fibre (%)	CHO (%)	N (%)	P (mg/100g)
NPK (20:10:10)	16.64a	1.48c	6.21b	5.74c	4.60a	58.40b	0.92b	5.09b
M. oleifera	13.85b	1.89a	6.74ab	7.71a	4.44a	55.43b	1.23a	3.74c
G. sepium	12.60b	1.09d	4.98c	8.26a	3.84b	60.21ab	1.32a	2.78d
T. diversifolia	12.76b	1.68b	5.96bc	5.77c	4.56a	69.26a	0.94b	6.35a
C. mucunoides	16.82a	1.61bc	6.78a	5.83c	2.95c	52.47c	0.93b	5.79a
Control	12.62b	1.89a	6.83a	5.00d	3.02c	61.09ab	0.52c	4.32bc

*Means followed by the same letter within each column are not significantly different (P=0.05) as indicated by Tukey's HSD Test.

Table 13. Effects of treatments on proximate and mineral composition of maize grain at the end of 2014 cropping season

Treatments	Moisture Content (%)	Ash (%)	Fat (%)	Crude Protein (%)	Crude fibre (%)	CHO (%)	N (%)	P (mg/100g)
NPK (20:10:10)	22.42a	1.31de	5.66c	5.38c	5.13a	65.76b	1.04b	5.84a
M. oleifera	17.54b	1.98a	6.28b	6.18a	4.74a	69.27b	1.33a	4.14a
G. sepium	13.16c	1.86ab	5.96bc	5.46c	4.22b	75.30a	1.54a	4.00a
T. diversifolia	15.74bc	1.59bc	5.45c	5.74b	4.38b	72.55ab	0.96b	4.24a
C. mucunoides	18.32b	1.86ab	5.32c	5.46c	3.59c	70.77b	1.08b	4.21a
Control	14.11c	1.27de	6.74a	4.32d	3.74c	76.56a	0.48c	2.95b

*Means followed by the same letter within each column are not significantly different (P=0.05) as indicated by Tukey's HSD Test

Conclusion

The results of this study showed the advantages of using mulches for the production of maize in terms of growth, yield and nutrient composition. The trend of events in plant growth and yield observed in this research implies that organic mulch use could compete favorably with inorganic fertilizer. Plant growth, soil properties and yield monitored in this research work show that *Gliricidia sepium, Tithonia diversifolia* and *Calopogonium mucunoides* applied at 5 t/ha^{-1} enhanced the nutrient composition and yield of maize. This suggest that the above materials are good source of sustainable and efficient organic amendment which could be recommended to small holder maize farmers for improving soil properties, optimum growth and yield of maize in the study area. The nutrient composition of maize as influenced by mulches used in this research is also capable of meeting the nutritional requirement of the people. Therefore, the use of shrubs and herbaceous mulches has further lend credence to the possibility of organic materials increasing the yield, nutritional content of maize and improvement of soil properties on a tropical alfisol.

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