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Influence of green manure from spear grass on selected soil physical properties and maize growth in southern Guinea Savanna of Nigeria

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Abstract

A field experiment was conducted in 2019 to determine the sole and combined effects of green manure from spear grass and NPK 15:15:15 fertilizer on selected soil physical properties and performance of maize (*Zea mays* L.). The treatments consisted of spear grass applied at, 5.0, 10.0 t ha^{-1}, NPK 15:15:15 at 120 kg Nha^{-1}, 2.5 t ha^{-1} + 60 kg N ha^{-1}NPK and control (no amendment). The six treatments were arranged in a Randomized Complete Block Design with three replications. Green manure combined with NPK significantly reduced bulk density and increased total porosity compared to the control and sole NPK. Volumetric moisture content was significantly higher on 5 t ha^{-1}, 10 t ha^{-1} and 2.5 t ha^{-1} + 60 kg N ha^{-1}NPK compared to the control and NPK. Corresponding values of saturated hydraulic conductivity under 5 t ha^{-1}, 10 t ha^{-1} and 2.5 t ha^{-1} + 60 kg Nha^{-1}NPK were higher than the control and NPK although statistically similar. Sole application of NPK gave significantly tallest plant, widest stem, highest number of leaves and largest leaf area compared with the control and other treatments. However, the order of growth parameter under the treatments were NPK>2.5 t ha^{-1} + 60 kg N ha^{-1}NPK >5 t ha^{-1} >10 t ha^{-1} >control. Soil physical condition was improved under sole application of organic amendment and combined application than sole NPK. Therefore, organic amendment from locally sourced materials applied either sole or combined can be used to improve soil physical condition and crop production.

KEYWORDS: Spear grass, Green manure, NPK, Physical properties, maize growth
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1.0 Introduction

One of the major draw backs of sustainable crop production in Nigeria is the inherent low soil fertility and unfavourable soil physical properties such as bulk density (Adekiya and Ojeniyi (2002). Continuous cropping and injudicious use of inorganic fertilizer are liable to change soil properties due to imbalanced fertilization have been recognized as one of the important factor that limits crop productivity. Bush fallow which had been an efficient, balanced and sustainable system for soil productivity and fertility restoration in the past is presently unsustainable due to high population pressure and other human activities which have resulted in reduced fallow period (Steiner 1991). The use of inorganic fertilizer has not been helpful under intensive agriculture because it is often associated with reduced crop yield, soil acidity and nutrient imbalance (Obi and Ebo, 1995; Ojeniyi, 2000; Ayoola and Adeniyan, 2008). Moreover, chemical fertilizers are expensive for the resource poor farmers and not readily available when required.

Several studies have shown that essential plant nutrients are below recommended levels in most Nigerian arable lands (Molindo, 2009; Jamala *et al.,* 2012; Ojeniyi *et al.,* 2012). This perennial problem contributes immensely to factors that militate against food production. In fact, many reports have associated drastic decreases in maize yields with depleted soil nutrients (Ayoola, 2011; Zafar *et al.,* 2011). The use of inorganic fertilizers has thus become a common practice as these agrochemicals help in improving soil fertility considerably. However, subsistence farmers do not have access to these products due to economic constraints. Similarly, the long-term consequences associated with disproportionate usages of synthetic fertilizers are sometimes catastrophic.

Organic fertilizers have proved to be a good solution to replenishing poor soils as they have been widely reported to increase soil organic matter, enhance physical properties and are environment friendly (Efthimiadou *et al.,* 2010; Ibrahim and Fadni, 2013). A wide array of organic materials such as animal manure, green manures, legume cover crops, and crop residues have been in use over the years and have been found to enhance crop yields and nutritional values compared to synthetic fertilizers. However, organic manures from both plant and animal sources are not without shortcomings as they are not always readily available, and may require the extra cost and labour while acquiring them and are often needed in enormous quantities to produce noticeable effects (Ayoola, 2011).

A better approach to soil fertility management consists of using balanced proportions of organic and inorganic fertilizers. The integrated use of organic and inorganic fertilizers improves crop growth and yield by enhancing several growth parameters including leaf area index, plant height, and grain yield of maize among others (Efthimiadou *et al.* 2009; Zerihun et al. 2013). Further studies have demonstrated that a combination of inorganic and organic fertilizers in the right amounts and proportions gives better results compared to when they are solely used (Ojeniyi *et al.,* 2013). It has been reported that green manures when used in combination with inorganic fertilizers enhance crop and soil productivity (Kumar *et al.,* 2000; Islam and Munda, 2012). The yields of important crops such as maize, cowpea, cassava and tomatoes and the soil on which these plants were grown have been found to be significantly improved under combined use of organic-mineral fertilizers (Taura and Fatima, 2008; Achieng *et al.,* 2010; Ibrahim and Fadni, 2013).

Furthermore, a lot of plant-based organic fertilizers have been reported to be beneficial to farmers. *Tithonia diversifolia* and a common invasive weed in Africa and Nigeria in particular (Akobundu and Agyakwa, 1998) and its biomass is rich in essential nutrients (Jama *et al.,* 2000; Olabode *et al.,* 2007). It has been used to increase the growth and yield of crops (Ilori *et al.,* 2010; Ademiluyi, 2012). However, spear grass [*Imperata cylindrica* (L.) Raueschel] has been known to be one of the dominant and serious weed of intensive agriculture which can cause severe yield loss due to its competitive nature (Chikoye *et al*., 2000). Despite its negative effects on crop, the grass among others has many uses such as mulching, thatching, animal feeds, rhizomes for soil erosion control, medicine for curing diseases (Lepetu, 2011). Aside these uses, Oyeyiola *et al*. (2017) in an incubation studies reported that the liming potential of Imperata was 15% higher than chemical fertilizer.

Maize (*Zea mays L*.) is a tropical crop largely grown in various parts of Nigeria and is one of the most widely consumed food and a basic raw material for feed mill and beverage industries. In order to sustainable production of maize for continuous food supply, there is a need for soil fertility strategy that is cheap, ecofriendly and affordable by the peasant farmers. Since Imperata is widely available and can be used as green manure instead of slash and burn. Therefore, this study was to determine the effects of green manure from Imperata either sole or combined with chemical fertilizer on soil physical properties and performance of maize.

2.0 Materials and methods

2.1 Site description and treatments

Field experiments were conducted at the Teaching and Research Farms, Ladoke Akintola University of Technology (LAUTECH), Ogbomoso, Oyo State, Nigeria during 2018 and 2019 cropping seasons. Ladoke Akintola University of Technology lies between latitude $8^0$10'15" N and longitude of $4^0$11' 48" E located in the southern guinea savanna ecological zone of Nigeria. The rainfall pattern was bimodal with peaks in July and September (Table 1). The total annual rainfall in the location was about 1400 mm with mean air temperature range of 38°C to 28°C and mean relative humidity of 74%. The soil at the experimental site belonged to Alfisol as classified by USDA taxonomy (Soil Survey Staff, 2006). It was a moderately well drained, ferruginous soil with a sandy loam texture.

The field experiment consisted of spear grass (*Imperata cylindrica*) green manure with sole application at the rate of 5 tonha^{-1}, 10 tonha^{-1}, 2.5 tonha^{-1} combined with 60 N kg ha^{-1} of NPK 15-15-15, NPK 15-15-15 at 120 N kg ha^{-1} and a control with no green manure or fertilizer. The five treatments were laid out in a randomised complete block design with three replications. Each replicates comprised 5 plots, each of which measured 3 x 3 m^2. Blocks were separated by 2 m while plots were 1 m apart.

2.2 Application of green manure and sowing of maize

Land preparation was done by ploughing twice after which the site was laid out to the required plot size of 3 m x 3 m. Spear grass used as green manure was harvested from the Teaching and Research Farm of the University. The spear grass was chopped into small sizes and incorporated into the soil at the required rates with the use of hoe. The plots were left for two weeks before sowing maize seeds to allow for decomposition of the green manure.

Sowing of maize variety (Oba super 6) seeds obtained from the International Institute of Tropical Agriculture (IITA) Ibadan were sown on July 5, 2019. Three seeds were planted per hole at inter-row spacing of 0.75 m and 0.25 m intra-row spacing using cutlass. At 2 weeks after sowing (WAS), thinning of maize plants to 1 plant per stand as done which was followed by weeding of the plots manually using hoe. Application of NPK 15-15-15 fertilizer was done simultaneously at 2 WAS by ring method to both plots receiving 120 kg ha^{-1} and 60 kg ha^{-1}. Collection of data started 2 weeks after sowing, and consecutively at 2-week interval after the first collection. Growth parameters measured were plant height using metre rule, stem girth (by the use of vernier calliper) and leaf area was measured according to Singh and Saxena (1975) using the formula; L * B * 0.75. Where L= Leaf length and B= Leaf breadth (broadest part).

2.3 Soil sampling and analyses

Soil samples were taken at a depth of 0- 0.15 m randomly from the site prior to the start of the experiment at different points and bulked to make a composite sample. The soils were air dried and sieved through 2 mm sieve and taken to the laboratory for particle size distribution and chemical analyses. Particle size analysis was done by hydrometer method (Gee and Or, 2002). Soil pH was determined with the pH meter using glass electrode in a soil: water ratio of 1:1. Organic carbon was determined by the Walkley-Black procedure described by (Nelson and Sommers, 1986). Available phosphorus was determined using Bray II method (Bray and Kurtz, 1945) while Total nitrogen was determined by Macro-Kjeldahl method (Bremner, 1965). Exchangeable cations were extracted with 1 N ammonium acetate.

2.4 Soil physical properties

Soil undisturbed samples were collected to determine physical properties of the soil with the aid of cylindrical core (0.5 m wide and 0.5 m height) from the field at 2,4, 6, 8, 10 and 12 WAS at 2 week intervals to determine bulk density, total porosity, and gravimetric moisture content as follows;

Bulk density was determined according to Grossman and Reinsch, (2002) method and calculated using the formula:

$$\text{Bulk density} = \frac{\text{soil mass oven dried}(g/cm^3)}{\text{volme of core}}$$

Volume of soil sample = volume of core = $\pi r^2 h$

r = inner radius of the core, h= height of the core (cm)

Total porosity of the soil was calculated from the values of bulk density (Db) and particle density (Dp) of 2.65 Mgm^{-3}) using the following equation:

$$Tp = \left(1 - \frac{Db}{Dp}\right) \times 100$$

Where, Tp = Total porosity
Db=Bulk density Dp= Particle density assumed (2.65 Mgm^{-3})
Volumetric moisture was calculated using the formula;

$$VMC = GMC * \frac{BD}{Dw}$$

Where VMC- Volumetric moisture content; BD- Bulk density and Dw- Density of water
Soil bulk density was determined by the core method (Grossman and Reinsch, 2002) Total porosity values were derived from bulk density data using the formula:

$$Total\ porosity = \frac{BD}{PD} * 100$$

Saturated hydraulic conductivity (Ksat) was determined by the method of Klute and Dirksen (2004).

$$Ksat = Ql/(l + L)At$$

Where: Ksat= saturated hydraulic conductivity
Q - quantity of water at constant flow
L -length of the soil core
l - height of water above the soil
A - cross sectional area of the core (cm^2); πr^2
t = time interval (hour)

2.5 Data Analysis
Data collected were subjected to analysis of variance (ANOVA) using SAS (SAS Institute Inc., 2002). Means were compared using the least significant difference (LSD) at $P = 0.05$.

3.0 Results

3.1 Initial physical and chemical properties of the soil
The particle size distribution and selected chemical properties of the soil are presented in Table 1. The particle size distribution indicates that the texture of the soil was loamy sand. Soil pH was slightly acidic, organic carbon, available phosphorus and total nitrogen were generally low according to the critical levels of 3% OM, 0.2% N, 10.0 mg kg^{-1} available P, 0.16 – 0.20 cmol kg^{-1} exchangeable K, 2.0 cmol kg^{-1} exchangeable Ca and 0.40 cmol kg^{-1} exchangeable Mg recommended for crop production in ecological zones of Nigeria (Akinrinde and Obigbesan, 2000).
Effect of green manure and NPK fertilizer on soil physical properties

3.2 Bulk density
Data on the effect of green manure and NPK fertilizer on soil bulk density are presented in Table 3. Green manure and NPK treatments had similar effects on soil bulk density at 4, 6, 8 and 10 WAS. However, at 12 WAS, bulk density of soil was significantly reduced by the combined application of green manure with NPK fertilizer (GM+NPK) compared to the control and NPK. However, 5 $tonha^{-1}$ and 10 $tonha^{-1}$ of green manure were not different from the control, NPK and GM+ NPK.

Table 1: Meteorological data of the study area

	June 2019	July 2019	Aug. 2019	Sept. 2019	Oct. 2019
Rainfall (mm)	253.00	228.26	152.22	416.74	436.16
Rel. humidity (%)	87.53	90.78	88.02	88.95	89.13
Max. temperature (^oC)	29.73	28.09	27.73	28.98	26.89
Min. temperature (^oC)	23.19	21.81	20.86	21.96	21.65

Table 2: Chemical and Physical properties of soil used for the experiment

Parameter	Value
pH (H_2O)	7.40
Phosphorus (mg kg^{-1})	19.49
Total N (g kg^{-1})	0.067
Organic carbon (g kg^{-1})	0.78
Potassium (cmol kg^{-1})	0.11
Sodium (cmol kg^{-1})	0.03
Calcium (cmol kg^{-1})	4.43
Magnesium(cmol kg^{-1})	0.23
Exchangeable acidity (cmol kg^{-1})	0.00
ECEC	4.80
Sand (g/kg)	800.00
Silt (g/kg)	80.0
Clay (g/kg)	120.00
Textural class	Loamy sand

3.3 Total porosity
Total porosity as affected by green manure and NPK treatments are shown in Table 4. Green manure and NPK had similar effects on total porosity from 4 to 10 WAS. However, at 12 WAS, GM+NPK had significantly higher total porosity relative to the control and NPK. There was no significant difference in total porosity between 5 ton ha^{-1} and 10 ton ha^{-1} of green manure.

Volumetric moisture content
The effects of green manure and NPK on volumetric moisture content (VMC) in soil are presented in Table 5. Green manure and NPK had no significant effect on VMC at 4 WAS and 10 WAS. Conversely at 6 WAS, 5 ton ha^{-1} of green manure had significantly higher VMC compared to the control, while VMC on NPK was not different from the control, 10 $tonha^{-1}$ and GM+NPK. Similarly, at 8 WAS, 5 ton ha^{-1} of green manure increased VMC than the control and NPK treatment, while 10 ton ha^{-1} of green manure and GM+ NPK were similar to the control and NPK. Relative to the control, VMC was significantly higher on GM+NPK, 5 $tonha^{-1}$ and 10 ton ha^{-1} of green manure applied at 12 WAS. There was no significant difference in volumetric moisture content between green manure applied at 5 $tonha^{-1}$ and 10 ton ha^{-1} and GM+NPK.

Table 3: Effects of green manure from spear grass on soil bulk density (Mg m-3)

Treatment	**4**	**6**	**8**	**10**	**12**
			Weeks after sowing		
Control (No green manure)	1.48	1.49	1.59	1.57	1.62
NPK 15-15-15	1.51	1.55	1.60	1.55	1.56
5 $tonha^{-1}$ of green manure	1.49	1.52	1.44	1.56	1.50
10 $tonha^{-1}$ of green manure	1.49	1.42	1.49	1.46	1.49
2.5 $tonha^{-1}$ of green manure + 1/2 NPK	1.41	1.35	1.37	1.49	1.40
LSD(0.0	0.19^{ns}	0.20^{ns}	0.22	0.19^{ns}	0.15

Saturated hydraulic conductivity

The application of green manure either sole or combined had no significant effect on saturated hydraulic conductivity (Ksat) throughout the sampling period (Table 5). However, Ksat increased with application of GM+NPK, 5 ton ha^{-1} and 10 ton ha^{-1} respectively by 38%, 34% and 30% compared with the control.

Table 4: Effects of green manure from spear grass on total porosity (m3m-3) of soil

Treatment	**4**	**6**	**8**	**10**	**12**
			Weeks after sowing		
Control (No green manure)	0.44	0.44	0.46	0.44	0.39
NPK 15-15-15	0.43	0.42	0.40	0.42	0.41
5 $tonha^{-1}$ of green manure	0.44	0.43	0.46	0.41	0.43
10 $tonha^{-1}$ of green manure	0.44	0.46	0.44	0.45	0.44
2.5 $tonha^{-1}$ of green manure + 1/2 NPK	0.47	0.49	0.48	0.41	0.47
LSD (0.05)	0.07^{ns}	0.08^{ns}	0.09^{ns}	0.08^{ns}	0.06

Effect of green manure and NPK fertilizer on maize growth

Plant height: The data on the result of green manure and NPK are presented in Fig. 1. Maize plants were taller on NPK and green manure compared with the control throughout the sampling period. At 2WAS, NPK significantly recorded taller plants than green manure applied at 5 ton ha^{-1}, 10 ton ha^{-1} and GM + 1/2NPK. However, at 4 to 10 WAS, plant height from 5 ton ha^{-1}, 10 ton ha^{-1} and GM + 1/2NPK were significantly different from NPK while green manure of 5 ton ha^{-1} was similar to10 ton ha^{-1} from their effects on maize plant height. The GM+1/2NPK treatment had significantly taller plants than green manure applied at the rate of 5 and 10 ton ha^{-1}.

Table 5: Effects of green manure from spear grass on volumetric moisture content

Treatment	**4**	**6**	**8**	**10**	**12**
			Weeks after sowing		
Control (No green manure)	0.48	0.48	0.42	0.55	0.43
NPK 15-15-15	0.52	0.50	0.62	0.57	0.41
5 $tonha^{-1}$ of green manure	0.60	0.78	0.84	0.63	0.58
10 $tonha^{-1}$ of green manure	0.52	0.47	0.54	0.57	0.52
2.5 $tonha^{-1}$ of green manure + 1/2 NPK	0.51	0.61	0.69	0.65	0.57
LSD(0.05)	0.118^{ns}	0.12	0.17	0.16^{ns}	0.09

Table 6: Effects of green manure from spear grass on saturated hydraulic conductivity ($cmhr^{-1}$) of soil

Treatment	4	6	8	10	12
			Weeks after sowing		
Control (No green manure)	25.00	27.67	19.25	18.76	44.58
NPK 15-15-15	16.73	27.73	19.20	20.59	46.68
5 $tonha^{-1}$ of green manure	34.17	37.75	23.98	23.70	59.61
10 $tonha^{-1}$ of green manure	36.88	25.80	18.60	16.63	57.89
2.5 $tonha^{-1}$ of green manure + 1/2 NPK	35.51	32.20	20.88	20.16	61.53
LSD(0.05)	34.51^{ns}	16.34^{ns}	8.07^{ns}	7.66^{ns}	30.57^{ns}

Stem girth: Maize stem girth were significantly affected by green manure and NPK compared to the control throughout the sampling period (Fig. 2). Green manure applied at 5 $tonha^{-1}$ recorded the thinnest plant girth compared with NPK while no difference was observed between10 tonha-1 and GM + NPK. At 4WAS, NPK fertilizer produced the thickest plant than green manure at sole application and combined application.GM+ 1/2NPK recorded thicker plant than 5 ton ha^{-1} and 10 ton ha^{-1} of green manure.

Leaf area: Data on the effect of green manure and NPK are presented in Fig. 3. At 2WAS, all treatment applied had no significant influence on leaf area of maize compared with the control. However, among the treatments, NPK recorded larger plant area than 5 ton ha^{-1} and 10 ton ha^{-1} of green manure and GM + 1/2NPK. All treatments had significant differences on leaf area of maize when compared with the control with NPK recording the largest leaves. Similar trends were observed at 6 to 12 WAS; whereby NPK consistently produced significantly larger area than the control and other treatments.

4.0 Discussion

The incorporation of green manure had no significant influence on bulk density of the soil. However, it was observed that plots treated with green manure incorporation had higher bulk density initially but eventually had reduced bulk densities compared to the control plots subsequently. This could be attributed to increase in soil organic matter resulting from the decomposing green manures by micro-organisms. The presence of the green manures is expected to have increased activities of beneficial soil fauna in organic matter decomposition which led to enhancement of soil porosity and reduction in soil bulk density. Several authors reported lower soil bulk density due to incorporation of green manure (Biswas and Mukherjee, 1991; Mandal *et al*., 2003; Herrera- Arreola *et al*., 2007).

Similarly, to bulk density, the incorporation of green manure did not significantly influence the total porosity of the soil until 12 WAS when the total porosity of plots with incorporated green manure increased. The decomposition of organic matters has been earlier reported to lead to improvement in the physical properties of soils with greater water retention and transmission capacities (Goldhamer *et al*., 1994; Islam and Weil, 2000; Min *et al.,* 2003). Similarly, Chikowo *et al.* (2004) reported that incorporation of woody legumes into the soil reduces bulk density and increases soil granulation and porosity.

Furthermore, the incorporation of green manure did not initially influence the volumetric and gravimetric moisture content as well as the hydraulic saturation of the field. This might have followed from the slow decomposition of the spear grass used as the green manure. This means that there will be a range of pore size in soils under different levels of green manures incorporation and organic fertilizer use. Those in turn are related to pore size distribution and continuity. This has been identified to be very important for the air and water balance of soil since water retention critically depends upon pore size distribution (Aon *et al.,* 2001)

The application of green manuring significantly influenced the growth of maize plants in terms of height, stem diameter, number of leaves and leaf area. This signifies that the nutrient status of the evaluated organic fertilizer and green manure varies and thus the observed growth differences. Many studies have shown that either green manure alone or combined with organic fertilizer can stimulate the growth, yield and nutrient uptake of crops (Yang *et al.,* 2015, Bai *et al.,* 2015 and Zhang *et al.,* 2016). Under the present investigation, the use of NPK alone resulted in the highest values of the growth parameters, although these were mostly not significantly different from the obtained values when NPK was combined with green manure. This indicates that with green manure incorporation, a reduction in organic fertilizer input could still maintain soil N availability to sustain maize growth. This finding agrees with those of other studies using either legume or non-legume green manures (Yang *et al.,* 2015, and Zhang *et al.,* 2016).

Conclusion

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