Original Research Article

Effect of organic production of maize on soil microbial population and activities on alfisol in Abeokuta, Southwestern Nigeria

Abstract

The study investigated the effect of organic production of maize on soil microbial population and activities. In this study, different fertilizers such as compost, neem fertilizer, poultry manure, green manure, NPK, organo-mineral fertilizer, were applied to the soil for maize production and soil samples were collected and taken to the laboratory for analysis. The effect of the different fertilizers on growth of maize was determined. The soil samples were analyzed for microbial biomass nitrogen, carbon and phosphorus; total viable count and total fungi count; phosphorus mineralization and organic matter level. Results of the analysis showed that compost and NPK gave significantly higher numbers of leaves, plant height and leaf area than other fertilizers. Poultry manure and organo-mineral fertilizer gave significantly higher microbial biomass carbon and nitrogen relative to other fertilizers but organo-mineral fertilizer gave significantly higher microbial biomass phosphorus. Neem fertilizer gave a significantly higher viable count while NPK gave a significantly higher total fungi count compared to other fertilizers. Organo-mineral fertilizer gave significantly higher inorganic phosphorus and organic matter production shortly after application (3 WAP) whereas neem fertilizer gave higher levels at 6 WAP. Conclusively, the use of composts should be encouraged in the organic production of maize to enhance yield and improve the soil quality.

Keywords: chemical fertilizer, maize, microbial population, neem, organo-mineral, poultry manure

Introduction

One of the important concerns in the effort to improve crop production in Nigeria is the maintenance of soil fertility and productivity (Akinbola, 2012). In the past, cultural methods like shifting cultivation and bush fallowing were practiced by the farmers especially the peasant farmers to maintain and improve the soil fertility and productivity. However, due to demographic and economic changes, the attendant shortcoming of the fallow period has led to rapid decline in soil fertility and productivity (Adetunji, 1997). Consequently, land is no longer able to support economic yield of crops without the addition of nutrients in form of fertilizers. However, many studies (Agboola, 1980; Agboola and Omueti, 1982; *Nottidge et al*., 2005) have shown that continuous use of inorganic fertilizers alone may lead to soil chemical degradation, which may be detrimental to the health of the ecosystem. Furthermore, fertilizers prices have been increasing in recent years and the procurement and distribution network has been largely insufficient. Consequently, fertilizers are getting out of reach of farmers.

Study (Agboola and Akinnifesi, 1991) has indicated that the key to soil maintenance in Nigeria is the improvement of soil organic matter. This is valid because our soils are generally low in organic matter, low in Cation Exchange Capacity, loose in structure and do not hold water and nutrient to any appreciable extent (Agboola and Akinnifesi, 1991). These are properties which could be improved by the addition of organic matter. Organic matter acts as store house of nutrients like Nitrogen, Phosphorus, Sulphur etc. it improves infiltration, stabilizes soil structure, improves soil tilt, releases carbon dioxide and provides energy for micro organisms. This has heightened the interest of agronomists and soil scientists in the use of organic manure as nutrient source for our soils. Soil organic matter also affects crop growth and yield, either directly by supplying nutrients or indirectly by modifying the soil physical properties, thereby improving the root environment, thus stimulating plant growth (Avnimelech, 1986; Cabrera *et al*., 1998; Liebig and Doran, 1999). Bauer and Black (1994) indicated that the highest total aerial dry matter and grain yields were associated with the highest organic matter contents of the soils. In addition, crop production based on the use of organic manures rather than chemical fertilizers is assumed to be a more sustainable type of agriculture (Yayock and Awoniyi, 1974; Fabiyi and Ogunfowora, 1992; Obire and Akinde, 2004; 2005; 2006).

Therefore, in recent years the application of organic fertilizer has received great attention from environmentalists, agriculturists and consumers alike. The nutrients released after the biological breakdown of the soil organic matter supply the nutrients essential for plant growth in organic farming. In general, the mineralization rate of soil organic matter is slow (Fernandez *et al*., 2006; Li *et al*., 2005). Therefore, to establish and maintain soil organic matter content to a certain level through the initial application of a large quantity and the continuous application of compost are important in organic farming (Amujoyegbe *et al*., 2007; Adeleye *et al*., 2010) and enhance the soil microbial activities which enhance nutrient supply (Udoh *et al*., 2005). However, climate and soil significantly affect the accumulation and storage of organic matter in the soil because of the interactions of temperature and moisture on plant productivity and the ability of the soil mineral components to retain organic matter. Soil is known to be composed of four major components namely: mineral materials (45%), water (25%), air (25%) and organic matter (5%) (Harry and Nyle, 1996). These components exist in intimately mixed condition and interaction between these components may not permit ideal condition for plant growth. Among the four components, organic matter is of utmost importance in cultivated soils (Adigun and Babalola, 2016). This could be largely attributed to the functions it performs in improving soil fertility. Under intensive farming, most soils exhibit rapid depletion of organic matter (Agboola and Sobulo, 1981). It is interesting to know that all the functions of organic matter depend on decomposition and its eventual mineralization which is done by soil organisms. This project therefore, aims at using organic fertilizers to produce maize and to determine their effects on soil microbial population and activities.

Materials and Methods

Location of the site: The site that was used for this project is located behind the male hostel (Umar Kabir Hall), beside the College of Plant Science farm in Federal University of Agriculture, Abeokuta, Ogun State, Southwestern Nigeria. The site has a mean annual rainfall of 1113.1mm. The rainfall has the characteristics bimodal distribution with peak in July and September and a break in August.

Field layout: The field was prepared through minimum tillage. A total land area of 26 m x 37 m (962 m^2) was used and this was divided into 28 plots of 5 m x 4 m (20 m^2) each. Six plots were applied with fertilizers and one plot used as control. All these were replicated four times.

Treatments: The fertilizer used for the project were compost obtained by composting Mexican sunflower (*Tithonia diversifolia* and poultry dung), poultry dung, neem fertilizer, organo-mineral fertilizer, NPK and green manure (fresh *Tithonia diversifolia*). The organic fertilizers were worked thoroughly into the soil well before planting, green manure was incorporated, but NPK fertilizer was applied two weeks after planting.

Experimental design: The experimental design used was Randomized Complete Block Design (RCBD).

Planting: Maize was planted two weeks after the application of organic fertilizer using a spacing of 75 cm x 50 cm.

Data collection: The agronomic parameters collected weekly include: Plant height (cm), Leaf area (cm^2) and Number of leaves

Physical and chemical analysis of soil sample: The laboratory analyses that were carried out on the soils at the beginning and at the end of the experiments were: Particle size analysis using the hydrometer method described by Gee and Bander (1986), pH was determined in a 1:1 soil to water using a pH meter with glass electrode (Thomas, 1996), Total N was determined by macro Kjedhal digestion technique by Bremner (1996), Organic carbon was also determined by wet oxidation method of Walkley and Black which was modified by Nelson and Sommers (1996). Available P was extracted using Bray 1 method (IITA, 1997) and determined colorimetrically using the method of Murphy and Riley (1962). Exchangeable acidity was determined by titrimetry (IITA, 1997). CEC was determined by summation of total exchangeable bases and total acidity (Braize, 1998) while Exchangeable bases were extracted with one normal ammonium acetate buffer at pH 7.0. Na^+ and K^+ in the extract were determined by flame photometry while Ca^{2+} and Mg^{2+} were determined using AAS (IITA, 1997).

Microbial biomass determination

Microbial biomass C = (Extracted C_{t1} – Extracted C_{t0}) x 2.64

Microbial biomass N = (Extracted N_{t1} – Extracted N_{t0}) x 1.46

Microbial biomass P = (Extracted P_{t1} – Extracted P_{t0}) x 2.5

Statistical analysis: Data was analyzed using Analysis of Variance (ANOVA) to test for differences among samples and Duncan Multiple Range Test (DMRT) for mean separation.

Results

Initial Soil Sample Analysis

Table 1 shows the routine analysis carried out on the soil used. The soil is loamy sand, neutral in reaction, low in organic carbon, nitrogen, phosphorus with moderate level of Cation Exchange Capacity.

Table 1. **Physical and chemical properties of experimental soil (0-20 cm)**

Parameters	**Values**
Sand %	86.4
Clay %	10.0
sSlt %	3.6
Textural class	Loamy sand
pH	7.1
Organic carbon %	1.3 %
Organic matter %	2.24 %
Exchangeable acidity (cmolkg^{-1})	5.9
Exchangeable bases (Mg, Ca, K, Na)	
Magnesium (cmolkg^{-1})	0.80
Calcium (cmolkg^{-1})	3.25
Potassium (cmolkg^{-1})	0.22
Sodium (cmolkg^{-1})	0.21
CEC (cmolkg^{-1})	10.38
Total Nitrogen, %	0.09
Available Phosphorus (mgkg^{-1})	7.78

Table 2 shows the microbial parameters of the initial soil sample which indicates that the soil had microbial biomass Carbon of 14 mg kg^{-1}, microbial biomass Nitrogen of 0.31 mg kg^{-1}, microbial biomass Phosphorus of 17.15 mg kg^{-1}. It also had a total viable count of 26.2 x 10^5 cfug^{-1} and total fungal count of 0.75 x 10^5 cfug^{-1}.

Table 2. **Microbial parameters of initial soil sample**

Parameters	**Values**
Micro biomass carbon (mgkg^{-1})	14
Micro biomass nitrogen (mgkg^{-1})	0.13
Micro biomass phosphorus (mgkg^{-1})	17.15
Total viable count (cfug^{-1})	26.2 x 10^5
Total fungal count (cfug^{-1})	0.75 x 10^5

Effect of different types of fertilizers on number of leaves of maize

Table 3 shows that at 3 WAP, green manure and control gave significantly lower number of leaves compared to other fertilizer ($p<0.05$). At 4 WAP, NPK, compost and poultry manure gave a significantly higher number of leaves than control but was similar to neem fertilizer, organo-mineral fertilizer and green manure. At 5 WAP, NPK fertilizer gave significantly higher number of leaves than neem fertilizer, green manure and control, it was followed by neem fertilizer which gave higher number of leaves than green manure and control, while green manure had significantly higher number of leaves than control ($p<0.05$). At 6 WAP, compost gave significantly higher number of leaves than any other fertilizers except NPK which was followed by organo-mineral fertilizer, the next was poultry manure which had a significantly higher number of leaves than control. Control gave significantly lower number of leaves than some of the treatments ($p<0.05$) but similar to neem fertilizer and green manure.

Table 3. **Effect of different types of fertilizers on number of leaves of maize.**

Fertilizers	**3WAP**	**4WAP**	**5WAP**	**6WAP**
Green manure	8.6^{b}	10.9^{ab}	11.5^{c}	12.0^{cd}
Organo-mineral fertilizer	10.6^{a}	12.1^{ab}	12.9^{ab}	12.7^{b}
Neem fertilizer	10.2^{a}	11.2^{ab}	12.3^{b}	12.0^{cd}
Poultry manure	11.2^{a}	12.5^{a}	12.6^{abc}	12.3^{c}
Compost	11.3^{a}	12.6^{a}	13.3^{ab}	13.7^{a}
NPK	11.6^{a}	12.4^{a}	13.5^{a}	13.3^{ab}
Control	8.3^{b}	9.5^{b}	10.8^{d}	11.3^{d}

Means with different superscript on the same column differ significantly ($p<0.05$)

Effect of different types of fertilizers on plant height of maize.

Table 4 shows that at 3 WAP, NPK gave significantly higher plant height compared to organo-mineral, green manure and control while it was followed by organo-mineral fertilizer. Control and green manure gave a significantly lower plant height than other treatment ($p<0.05$). At 4 WAP, NPK, compost and poultry manure gave significantly higher plant height than any other fertilizer, this was followed by organo-mineral fertilizer and neem fertilizer. Control and green manure gave significantly lower plant height than other treatments ($p<0.05$). At 5 WAP, NPK, compost and poultry manure gave a significantly higher plant height than control ($p<0.05$) and had a similar plant height with other fertilizers. At 6 WAP, compost and NPK gave a significantly higher plant height than neem fertilizer, green manure and control ($p<0.05$) but similar to other fertilizers.

Table 4. **Effect of different types of fertilizers on plant height of maize.**

Fertilizers	**3WAP**	**4WAP**	**5WAP**	**6WAP**
Green manure	39.9^{c}	59.6^{c}	127.5^{ab}	198.7^{b}
Organo-mineral fertilizer	52.3^{b}	81.4^{b}	137.9^{ab}	226.7^{ab}
Neem fertilizer	54.7^{ab}	80.6^{b}	131.6^{ab}	210.9^{b}
Poultry manure	58.8^{ab}	101.6^{a}	157.3^{a}	235.9^{ab}
Compost	61.8^{ab}	112.2^{a}	170.8^{a}	261.6^{a}
NPK	66.4^{a}	102.5^{a}	164.4^{a}	262.1^{a}
Control	34.8^{c}	51.9^{c}	89.9^{b}	198.3^{b}

Means with different superscript on the same column differ significantly ($p<0.05$).

Effect of different types of fertilizers on Leaf Area of maize

Table 5 shows that at 3 WAP, NPK gave a significantly higher leaf area than any other treatments except poultry manure and compost, this was followed by organo-mineral fertilizer, followed by neem fertilizers. Control gave a significantly lower leaf area than the treatments ($p<0.05$) but similar to green manure. At 4 WAP, green manure and control gave significantly lower leaf area than other fertilizers ($p<0.05$) with the exception of neem fertilizer. At 5 WAP, NPK gave significantly higher leaf area than some other fertilizers although it was similar to compost and poultry manure, followed by organo-mineral and neem fertilizers. Control and green manure gave significant lower leaf area than other treatments ($p<0.05$). At 6 WAP, compost gave significantly higher leaf area compared to other fertilizers but similar to NPK, followed by organo- mineral fertilizers which was significantly higher than control, neem and green manure ($p<0.05$).

Table 5. **Effect of different types of fertilizers on leaf area of maize.**

Fertilizers	**3WAP**	**4WAP**	**5WAP**	**6WAP**
Green manure	251.8^{cd}	376.8^{b}	411.2^{c}	694.1^{c}
Organo-mineral fertilizer	402.8^{b}	605.5^{a}	567.2^{b}	764.6^{b}
Neem fertilizer	376.6^{c}	527.2^{ab}	563.8^{b}	663.0^{c}
Poultry manure	479.9^{abc}	657.4^{a}	622.7^{ab}	775.7^{bc}
Compost	496.7^{ab}	704.9^{a}	644.9^{ab}	928.0^{a}
NPK	547.5^{a}	663.5^{a}	689.2^{a}	833.8^{ab}
Control	193.6^{d}	337.4^{b}	452.9^{c}	678.3^{c}

Means with different superscript on the same column differ significantly ($p<0.05$)

Effect of different fertilizers on activities and population of soil micro-organisms

Table 6 shows that plots treated with organo-mineral fertilizer had a significantly higher microbial biomass phosphorus compared to other treatments, this was followed by NPK which was similar to green manure, followed by control which was higher than compost, neem fertilizer and poultry manure, followed by neem fertilizer while poultry manure gave a significantly lower microbial biomass phosphorus than other treatments ($p<0.05$) with the exception of compost.

Plots treated with poultry manure gave a significantly higher microbial biomass carbon than any other fertilizers and control. It was followed by NPK which was similar to control, followed by compost, followed by green manure. Organo-mineral fertilizer gave a significantly lower microbial biomass carbon compared to other treatment ($p<0.05$) with the exception of neem fertilizer. Plots treated with poultry manure, control, NPK and compost gave significantly higher microbial biomass nitrogen compared to the other fertilizers and control, it was followed by green manure. Neem fertilizer and organo-mineral fertilizer gave a significantly lower microbial nitrogen compared to other fertilizer ($p<0.05$). Neem fertilizers gave significantly higher total viable count than poultry manure but similar to all other treatments ($p<0.05$). NPK gave a significantly higher total fungal count than other treatments but comparable to neem fertilizer and control, followed by poultry manure, green manure follows. Organo-mineral and compost gave significantly lower total fungal count than other treatments ($p<0.05$).

Table 6. **Activities and population of microorganisms as affected by different fertilizers in maize production.**

Fertilizers	**Microbial BiomassP (mg kg^{-1})**	**Microbial BiomassC (mg kg^{-1})**	**Microbial BiomassN (mg kg^{-1})**	**TotalViable Count (cfug^{-1})**	**TotalFungi Count (cfug^{-1})**
Compost	9.78^{de}	10.21^{c}	1.11^{a}	$18.4x10^{5ab}$	$0.4x10^{5d}$
Green manure	10.40^{bc}	10.03^{d}	0.58^{b}	$18.2x10^{5ab}$	$0.5x10^{5c}$

NPK	10.79^{b}	10.56^{b}	1.06^{a}	$16.65x10^{5ab}$	$0.7x10^{5a}$
Neem fertilizer	10.08^{d}	9.55^{de}	0.09^{c}	$19.6x10^{5a}$	$0.65x10^{5ab}$
Organo-mineral	11.33^{a}	9.29^{c}	0.09^{c}	$19.15x10^{5ab}$	$0.4x10^{5d}$
Poultry manure	9.39^{c}	10.93^{a}	1.25^{a}	$15.7x10^{5b}$	$0.55x10^{5b}$
Control	10.63^{c}	10.18^{bc}	1.03^{a}	$18.55x10^{5ab}$	$0.6x10^{5abc}$

Means with different superscript on the same column differ significantly ($p<0.05$)

Effect of different fertilizers on soil organic and inorganic phosphorus

Table 7 shows that at 3 WAP, control plot gave significantly lower organic phosphorus than neem fertilizer, organo-mineral fertilizer and poultry manure but was comparable with NPK, green manure and compost. Also, plots treated with organo-mineral fertilizer had significantly higher inorganic phosphorus than control but was similar to other treatment ($p<0.05$). At 6WAP, plots treated with neem and organo-mineral fertilizer gave significantly higher organic phosphorus than green manure and control but comparable to other treatments, this was followed by green manure while control plots had a significantly lower organic phosphorus than the other treatments ($p<0.05$) with the exception of poultry manure. Also, plots treated with neem fertilizer had significantly higher inorganic phosphorus than other fertilizers but was comparable to organo-mineral fertilizer and NPK, followed by compost while control gave significantly lower inorganic phosphorus than other treatments ($p<0.05$) but comparable to green manure and poultry manure.

Table 7. **Percent organic and inorganic phosphorus as affected by different fertilizer in maize production.**

Fertilizers	**OrganicP 3WAP**	**InorganicP 3WAP**	**OrganicP 6WAP**	**InorganicP 6WAP**
Compost	0.52^{ab}	0.20^{ab}	0.42^{ab}	0.22^{b}
Green manure	0.47^{ab}	0.19^{ab}	0.38^{b}	0.18^{bc}
NPK	0.47^{ab}	0.19^{ab}	0.42^{ab}	0.23^{ab}
Neem fertilizer	0.59^{a}	0.24^{ab}	0.50^{a}	0.25^{a}
Organo-mineral	0.59^{a}	0.26^{a}	0.51^{a}	0.23^{ab}
Poultry manure	0.58^{a}	0.22^{ab}	0.34^{bc}	0.18^{bc}
Control	0.38^{b}	0.18^{b}	0.24^{c}	0.15^{c}

Means with different superscript on the same column differ significantly ($p<0.05$)

Effect of different fertilizers on organic matter production

Table 8 shows that at 3 WAP, plots treated with organo-mineral fertilizer had a significantly higher organic matter than poultry manure but comparable to other types of fertilizer and control ($p<0.05$). At 6 WAP, plots treated with neem fertilizer had significantly higher organic matter compared to other fertilizer but comparable to green manure, followed by control, followed by compost while poultry manure gave a significantly lower organic matter compared to other treatments and control but was comparable to organo-mineral fertilizer ($p<0.05$).

Table 8. **Soil organic carbon and organic matter as affected by different fertilizers in maize production**

Fertilizers	Organic Carbon 3WAP	Organic Matter 3WAP	Organic Carbon 6WAP	Organic Matter 6WAP
Compost	2.02^{ab}	3.48^{ab}	1.60^{c}	2.76^{c}
Green manure	1.92^{ab}	3.31^{ab}	1.97^{abc}	3.4^{abc}
NPK	2.04^{ab}	3.52^{ab}	1.85^{b}	3.19^{bc}
Neem fertilizer	1.89^{ab}	3.26^{ab}	2.25^{a}	3.88^{a}
Organo-mineral	2.38^{a}	4.1^{a}	1.81^{bcd}	3.12^{bcd}
Poultry manure	1.69^{b}	2.91^{b}	1.49^{d}	2.57^{d}
Control	2.17^{ab}	3.74^{ab}	2.14^{ab}	3.69^{b}

Means with different superscript on the same column differ significantly ($p<0.05$)

Discussion

NPK fertilizer and compost had the highest effect on the number of leaves, plant height and leave area of maize. This was due to the fact that the nutrients in NPK fertilizer are easily released for plant uptake. Previous studies have also shown that composted organic materials enhanced fertilizer use efficiency, by releasing nutrients slowly and thus reducing the losses, particularly nitrogen (Paul and Clark, 1996; Muneshwar *et al*., 2001; Nevens and Reheul, 2003; Golap *et al*., 2004; Felipo *et al*., 2004; Ahmad *et al*., 2006; Amujoyegbe *et al*., 2007; Polat *et al*., 2009; Ewuzie, 2009; Adeleye *et al*., 2010; Bamaiyi *et al*., 2011; Mbah *et al*., 2011; Babalola and Adigun, 2013). Also, compost which was a combination of *Tithonia diversifolia* and poultry manure had undergone decomposition hence; it gave a faster released of nutrients. Control and green manure had the lowest effect on number of leaves, plant height and leaf area of maize, this is due to the fact that, no nutrient is applied in control hence; the nutrients in the soil were inadequate to meet plant needs. Green manure which was fresh *Tithonia diversifolia*, takes a longer time for it to decompose slowing down the release of nutrients and hence having little or no effect on plants during its early growth stage. This is in consonance with Adediran *et al.* (1999) who reported that nutrients in organic fertilizer are not immediately available to plants, although, this slow release feature can be advantageous.

The microbial biomass phosphorus was higher in plots treated with organo-mineral fertilizer and NPK; this is because nutrients in inorganic fertilizer are easily released to the soil rendering them available for microbial assimilation. Since addition of organic fertilizer increases mobilization of phosphorus and microbial activities in soil, it might also be a contributing factor in improving nutrition, as well as root system (Bahl and Torr, 2002; Salako, 2008). Similar studies by other workers have shown that the composted organic materials enhanced fertilizer use efficiency by releasing it slowly and thus, reducing its losses (Muneshwar *et al*., 2001; Nevens and Reheul, 2003; Asghar *et al*., 2006; Zahir *et al*., 2007a, b). Also, organic phosphorus was least in control plots because no nutrient was added and the mineralization of phosphorus to inorganic phosphorus was least in control as well.

Conclusion

The study shows that plots treated with compost and NPK gave significantly higher number of leaves, plant height and leaf area than other fertilizers. While plots treated with poultry manure and organo-mineral fertilizer had significantly higher microbial biomass carbon and nitrogen relative to other fertilizers but plots treated with organo-mineral had significantly higher in microbial biomass phosphorus. Furthermore, plots treated with neem fertilizer had higher microbial viable count while NPK had higher fungi count than other fertilizer and control. Plots treated with organo-mineral fertilizer had higher phosphorus mineralization and organic matter production shortly after application (3 WAP) whereas neem fertilizer gave higher levels at 6 WAP. Therefore, the use of value added organic fertilizer to get higher yield is therefore wise than sole application of either huge amount, low quality, raw organic material or adequate amount of chemical fertilizer. The use of organic manure ensures stability of soil structure improve soil organic matter status, nutrients availability and high crop yield.

Recommendation

Since compost was observed to be efficient in most of the parameters investigated, it is therefore recommended that enhanced compost should be used as soil amendment in organic production of maize. Furthermore, it is recommended that this type of research should be done for other crops since the crops may differ in their response to enhanced organic fertilizers.

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