Effect of Organic and Inorganic Amendments on Soil Properties in Makurdi, Benue State, Nigeria

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Abstract
Field experiments were carried out at the Teaching and Research Farm of the University of Agriculture, Makurdi, (Latitude 7°46' – 7°50'N and Longitude 8°36' – 8°40'E) during the 2018 and 2019 cropping seasons to assess the effect of organic and inorganic amendments on soil properties in Makurdi, Benue State, Nigeria. Twelve treatments were used, these include zero tillage x control, zero tillage x 15 t/ha moringa, zero tillage x 10 t/ha poultry dropping, zero tillage x 120 kg/ha SSP, ridge tillage x control, ridge tillage x 15 t/ha moringa, ridge tillage x 10 t/ha poultry dropping, ridge tillage x 120 kg/ha SSP, surface hoeing x control, surface hoeing x 15 t/ha moringa, surface hoeing x 10 t/ha poultry dropping and surface hoeing x 120 kg/ha SSP. Soil sample collections for physical and chemical properties of the soils of the study site were determined at the beginning and end of the experiment. The mechanical analysis of the study site indicated sandy loam texture with low values of soil nutrients, organic matter (7.3 g/kg) and soil pH (6.5) before the application of treatments. The effect of soil amendments on soil properties obtained after harvest shows improved soil properties such as pH, O.M, N, P, exchangeable bases EA CEC, BS, EC and porosity relative to the low values of nutrients obtained from the control plots. Higher values of soil properties were obtained under ridge tillage x 10 t/ha poultry manure followed by ridge tillage x 15 t/ha moringa and other treatment combinations compared to control plots.

Key Words: *Soil properties, organic, inorganic, amendments, treatments*

INTRODUCTION

Good soil management is a key to sustainable farming practices. Generally, there is close link between good and profitable farming; improving/maintaining soil fertility and good environmental management. It is clear that good soil management can drastically reduce the value of land for agriculture and lead to environmental problems which invariably results into soil degradation and this is termed unsustainable use of land. Sustainable land management has been defined as the use of appropriate soil management practices that enables land users to maximize the economic and social benefits from the land while maintaining or enhancing the ecological support functions of the land resources.

The application of organic manure has consistently increased yields of horticultural crops such as garden egg (Solanum melongena), pepper (Capsicum annum L.) and tomatoes (Lycopersicon esculentus). Aliyu (2000) obtained highest yields of pepper with 5t Farmyard manure (FYM) + 5t of poultry manure + 50 kgN/ha or 10t of FYM + 5t of poultry manure. Barreto and Dynia (1988) quoting Hollanda (1982) reported that 42 t/ha of cow manure was economically beneficial to cowpea. The problematic aspect of these high rates of organic manure recommendations is the unavailability of such enormous amounts. Peasant farmers operating at subsistence level or slightly above subsistence cannot generate these quantities of OM even for their small plots of less than one hectare. Rather than recommending rates that are not feasible, the emphasis should be the complimentary role of OM in soil health and fertility maintenance, instead of total reliance on OM as source of nutrients. Moreover, apart from unavailability of these high amounts recommended, the quality is also very low due to inadequate storage and handling.

A fertile soil contains adequate amounts of the essential nutrient in the right proportion, free from toxic substances and well drained to favour effective aeration and sufficient water supply, favours the growth and yield of plants. In the wake of increasing global prices of inorganic fertilizer, land and water pollution arising from use of inorganic fertilizer and the contribution of inorganic fertilizer to climate change and destruction of soil properties there is a need to find alternative soil and crop improvement materials. Study on the use of moringa and poultry manure for agricultural purposes to enhance biochemical content of soil has not been widely evaluated in Benue State, Nigeria, hence the need to evaluate impact of organic and inorganic amendments on soil properties.

MATERIALS AND METHODS

Experimental Site

The experiment was carried out at the Teaching and Research Farm of the University of Agriculture, Makurdi, in the Southern Guinea Savanna zone of Nigeria. The experimental area is characterized by warm tropical climate with distinct wet and dry seasons. The wet season starts from April to October with an annual rainfall of about 1137 mm although the amount and duration vary annually.

The soils are underlain with Makurdi sandstone and are moderately deep to deep. The soils are coarse textured; especially in the surface horizons, with variable texture in the surface layers. The soils are well drained to moderately well drained.

Experimental Treatments and Design

Total plot size of 17 m x 66 m was used. The experiment was a factorial experiment in randomized complete block design (RCBD), with three tillage methods (zero tillage, ridge tillage and surface hoeing) and four soil amendments (control, 15 t/ha moringa, 10 t/ha poultry dropping and 120 kg/ha SSP) replicated three times. Tillage treatments constituted the main plots with amendments in the sub-plots, resulting in Total of Twelve (12) treatment combinations of experimental plots of 5 m x 5 m (25 m^2) with 0.5m alley between them.
The treatment combinations were zero tillage x control, zero tillage x 15 t/ha moringa, zero tillage x 10 t/ha poultry dropping, zero tillage x 120 kg/ha SSP, ridge tillage x control, ridge tillage x 15 t/ha moringa, ridge tillage x 10 t/ha poultry dropping, ridge tillage x 120 kg/ha

SSP, surface hoeing x control, surface hoeing x 15 t/ha moringa, surface hoeing x 10 t/ha poultry dropping and surface hoeing x 120 kg/ha SSP.

Soil Sampling

Three composite auger samples that represent the soils of the study site were collected at the upper, middle and lower position of the plots at the beginning and end of the experiments from the top 0 – 30 cm depth in each plot based on the treatment combinations. Three (3) samples collected from each plot were bulked, air-dried and ground to pass through a 2 mm sieve before taken for analysis at the NICANSOL laboratory of the University of Agriculture, Makurdi. Undisturbed core samples were also taken from 0 – 15 cm depth and used to determine dry bulk density, total porosity and hydraulic conductivity.

Laboratory Analyses

The relative proportion of the soil separates was determined by hydrometer method of Bouyoucos (1951) (Udo *et al*., 2009). Bulk density (BD) was obtained by core method (Obi, 2000). Total porosity was obtained from bulk density value and assumed particle density of 2.65 Mg m^{-3} (Obi, 2000). Hydraulic conductivity was determined by permeability method (Obi, 2000). The glass electrode method was used to determine the soil pH (Udo *et al*., 2009). Organic carbon (OC) content of the soil samples were determined by the chromic acid oxidation procedure of Walkley – Black (Udo *et al*., 2009). Electrical conductivities (EC) of the soil samples were measured with electric conductivity meter in a paste of 1:5 soil/water (Udo *et al*., 2009). Cation exchange capacity (CEC) of the soils was determined by Summation (TEB + EA) method (Udo *et al*., 2009). Extractable bases were determined using the ammonium acetate extract. Sodium and potassium were determined using the flame photometer. Calcium and magnesium were determined using atomic absorption spectrophotometer (AAS) (Udo *et al*., 2009). Total nitrogen was determined using the standard Macro-Kjeldahl method (Udo *et al*., 2009). Bray – I method was used to determine the available phosphorus. Exchangeable acidity (EA) was extracted using the titrimetric method (Udo *et al*., 2009). Exchangeable base (EB) was obtained by summation of the values of bases [EB = $\sum$ (K, Na, Mg, Ca)].

The base saturation (BS) value of the soils was calculated in percentages using the formular: BS = Toal exchangeable bases / CEC x 100

RESULTS AND DISCUSSION

Soil Properties of the Study Site

The soil properties of the study site at the start of the experiment as presented in Table 1 represent a typical tropical soil which has been continuously and intensively cultivated. The textural composition of the soil indicated sandy loam texture at the depth of 0 – 30 cm. Sand is the dominant fraction followed by silt and clay. The soil is coarse (with sand fraction of 750 g/kg), and, therefore, likely to be prone to erosion and leaching with continuous cultivation. Loss of organic matter is expected to be high due to crop utilization and rapid mineralization without replacement. The soil has little silt and clay fraction of 150 and 100 g/kg, respectively which may be susceptible to erosion. Similar results were obtained by Morgan (1995) who concluded that soils with a restricted clay fraction, between 90 and 300 g/kg are most susceptible to erosion.

The bulk density value was 1.4 Mg/m^3 in the surface horizon which could be suitable to crops. This result is in agreement with that of Donahue *et al*., 1990; Landon, 1991; Maniyunda and Malgwi, 2011 who suggested that plants perform best in bulk densities within 1.4 Mg/m^3 and

1.6 Mg/m^3 for clay and sandy soils respectively, and higher bulk density above 1.6 Mg/m^3 tends to inhibit root growth. This could be due to soil's resistance to root penetration, poor aeration, slow movement of nutrients and water and buildup of toxic gases and root exudates as explained by Obi (2000). Conversely, the total porosity was 47 %, the bulk density and total pore space values of the soil were rated as moderate and were considered to favour good aeration, root penetration and free water movement in the soil. However, with continuous cultivation without proper management practices, the agricultural land use may exert some influence on bulk density and total pore spaces of the soil. Hydraulic conductivity of the soil was high (63.1 Ksat) which indicate that the soil has high rate of water infiltration as the flow of water into the porous medium was as high as 63 Ksat. The soil with these kinds of characteristics may be drought prone as pointed out by Hillel (1980).

The soil pH in water showed that the soil was slightly acidic (6.5) at the start of the experiment. This may be due to the leaching of appreciable quantities of exchangeable base-forming cations (Ca, Mg, K and Na) from the surface layers of the soil and high buffering capacity. Soil pH is the most important factor influencing crop performance. It influences the rate of organic matter decomposition, microbial activities, forms and extent of nutrient availability and nutrient uptake by plants. The soil pH of the study site is moderate for agriculture as it is within the normal range (5 – 8.5) for most arable crops.

The soil was characteristically low in nutrients including N, P and K. The major limiting factor for crop production in the tropics is the deficiency of soil nutrient resulting from land degradation which affects the growth, nutrient content, and uptake by the plant. Low levels of Nitrogen, Phosphorus, Potassium and organic matter were observed in the soil used for the experiment which substantiates the claims of Ogboehi *et al*. (2017) that reported most of Nigerian soils to be deficient in Nitrogen potassium, potassium and even organic matter. Lombin, (1987), Odunze *et al*. (1991), Chiezey and Odunze (2009) observed that soils of the savanna are inherently low in fertility. Low levels of organic matter content, total nitrogen and available phosphorus contents of the soil may be as a result of rapid rate of organic matter decomposition and moisture availability as well as burning of residue after harvest in addition to intensive and continuous cultivation without proper management practices which must have brought about decline in soil nutrient composition.

The exchangeable bases were generally moderate to low. Calcium and magnesium were the dominant cation. Potassium and Sodium were low in concentration. This might be attributed to intensive cropping of the soil and crop removal without replacement resulting in chemical deterioration as reported elsewhere by Maniyunda and Malgwi (2011).

The CEC was low (6.2 Cmol/kg) which is less than 12 Cmol/kg and is considered minimum value of fertile soil (Maniyunda and Malgwi, 2011). Low CEC of the soil implies that with continuous cultivation without proper management practices, the soil may undergo rapid physical and chemical degradation (Maniyunda and Malgwi, 2011). Exchangeable acidity was rated moderate (1.2 Cmol/kg). Base saturation of the study site is generally high (80.6 %). Base saturation values greater than 50 % indicate fertile soil while values less than 50 % indicate low fertility (FAO - UNESCO, 1998). Therefore, the soil in the study site could be considered fertile. The electrical conductivity was low (0.1 ds/m). It shows that the soil is non-saline.

Table 1. Physical and Chemical Properties of the Soil of the Study Site at the Start of the Experiment (2018)

Soil properties	Values
Sand (g/kg)	750
Silt (g/kg)	150
Clay (g/kg)	100
Textural class	Sandy Loam
pH (H_2O)	6.5
Organic Carbon (g/kg)	4.2
Organic Matter (g/kg)	7.3
Nitrogen (g/kg)	0.9
Phosphorus (mg/kg)	2.3
Potassium (Cmol/kg)	0.2
Sodium (Cmol/kg)	0.1
Magnesium (Cmol/kg)	2.2
Calcium (Cmol/kg)	2.5
Total Exchangeable Bases (Cmol/kg)	5.0
Exchangeable Acidity (Cmol/kg)	1.2
Cation Exchange Capacity (Cmol/kg)	6.2
Base Saturation (%)	80.6
Electrical Conductivity (ds/m)	0.1
Bulk Density (Mg/m^3)	1.4
Porosity (%)	47.1
Hydraulic Conductivity (Ksat)	63.1

Effect of Soil Amendments on Soil Properties

The main effect of soil amendments on soil properties is presented in Tables 2 and 3. Higher values of nutrients were observed in 2019 than 2018 cropping season. Higher nutrient values were obtained at 10 t/ha poultry manure amendments followed by 15 t/ha moringa, 120 kg/ha SSP fertilizer and control plots. All control plots had lower values of soil nutrients.

The effect of application of soil amendments on soil properties showed high improvement on soil properties in the two cropping seasons. Higher values of nutrients were observed in 2019 than 2018 cropping season due to increase in soil nutrients as a result of reapplication of soil amendments in the second year trial. Higher nutrient values were obtained at 10 t/ha poultry manure amendments in all the plots, followed by 15 t/ha moringa, 120 kg/ha SSP fertilizer and control plots. All control plots had lower values of nutrients.

Agricultural wastes (organic amendments) such as poultry and moringa manure have been proposed by many researchers to be good method, environmental friendly, and cost effective for improving physical and chemical status of degraded soils. Poultry manure is an exceptional source of organic fertilizer which contains high percentage of nitrogen, phosphorus, potassium and other important nutrients readily available for plant uptake as compared to other organic sources (Mohamed *et al*. 2010). The poultry litter used was a mixture of the substrate, usually wood chips or rice straw, with bird droppings, feathers, and leftover food. Its composition could vary with the quantity and quality of substrate used. Generally, poultry litter contents is around 24 to 40 g/kg N, 20 to 35 g/kg of P_2O_5, 18 to 35 g/kg of K_2O, and 65 to 90 g/kg of dry matter (Garg and Bahla, 2008). Due to its composition and availability at low cost in the rural communities, this residue can be used by farmers in the fertilization of crops (Ojeniyi *et al*., 2013). It improves the physical characteristics and conditions of the soil and improves the nutrient uptake and crop productivity (Mbah and

Nneji, 2011). The addition of organic amendments such as poultry manure and moringa extract improves soil properties by improving organic matter contents of the soil, which has a stimulatory effect on the structure and aggregate stability, thereby improving the aeration, buffering of soil reaction, water holding capacity, cation exchange capacity, and microbial activities, total porosity, and hydraulic conductivity of soils.

Higher soil properties were obtained from moringa treated plots after poultry manure. Many researchers reported the importance of moringa as one of the important sources of soil organic manure. It contains high quantities of nitrogen, phosphorus and potassium and other nutrients. Application of moringa leaf extract at 30% concentration significantly increased the organic carbon and organic matter content of the soil (Ogbuehi and Agbim, 2018). The cation exchange capacity was also significantly increased with 30% moringa leaf extract application. The application of moringa leaf extract generally improved physical and chemical properties of soil especially at 30% level of concentration. This finding confirms the findings of Anyaegbu (2014) who reported that application of Moringa extract increased the availability of micro and macro nutrients in the soil for plant uptake.

CONCLUSION

The study has shown that the study site has sandy loam texture with low values of soil nutrients, organic matter (7.3 g/kg) and soil pH (6.5) before the application of treatments. Soil amendments improved soil properties (soil pH, O.M., N, P, exchangeable bases, EA, CEC, BS, EC, porosity and reduce bulk density). Higher values of soil properties were obtained under 10 t/ha poultry manure followed by 15 t/ha moringa and 120 kg/ha SSP treatment combinations compared to control plots.

It is, therefore, recommended that 10 t/ha poultry manure on ridge tillage follow by 15 t/ha moringa application could be viable tools for sustainable soil management practices in Makurdi under rainfall condition. However, the quality of manure must be taken into consideration as the nutrient supplying power depends on the conditions under which the manure was stored.

Table 2: Interaction Effect of Soil Amendments and Tillage on Soil Properties (2018)

Treatments	Sand	Silt	Clay	O.C	OM	N	PH	P	Na	K	Ca	Mg	TEB	EA	CEC	BS	EC	BD	Porosity	HC
	(g/kg)						(H_2O)	(Mg/kg)	(Cmol/kg)						(Ksat)	(%)	(ds/m)	(Mg/m^3)		(%)
1. Zero tillage x control	750	150	100	4.9	8.5	0.9	6.8	2.5	0.2	0.31	2.7	2.2	5.4	1.2	6.6	81.8	0.21	1.38	47.9	54.9
2. Zero tillage x moringa (15 t/ha)	790	110	100	5.8	10.0	2.1	72	2.7	0.26	0.38	2.9	2.6	6.12	1.3	7.4	82.8	0.24	1.30	50.9	50.1
3. Zero tillage x Poultry dropping (10 t/ha)	750	150	100	7.3	12.5	4.3	7.4	4.3	0.30	0.41	3.4	2.9	7.01	1.0	8.01	87.5	0.27	1.27	52.1	47.2
4. Zero tillage x SSP (120 kg/ha)	690	190	120	5.1	8.8	1.1	6.9	4.2	0.23	0.37	2.7	2.5	5.8	1.6	6.8	85.3	0.27	1.35	49.1	52.0
5. Ridge tillage x control	730	150	120	5.1	8.8	0.9	7.1	2.7	0.14	0.36	2.8	2.3	5.3	1.1	6.4	82.8	0.22	1.34	49.4	43.6
6. Ridge tillage x moringa (15t/ha)	790	110	100	5.8	10.0	2.2	7.3	2.9	0.42	0.40	3.1	2.9	6.6	1.2	7.8	84.6	0.23	1.27	52.1	39.4
7. Ridge tillage x poultry dropping (10 t/ha)	790	110	100	7.6	13.1	4.6	7.6	4.5	0.28	0.43	3.6	3.2	7.5	1.1	8.6	87.2	0.30	1.25	52.8	35.5
8. Ridge tillage x SSP (120 kg/ha)	750	150	100	56	9.7	2.1	7.5	4.3	0.24	0.38	3.0	2.7	6.3	1.0	7.3	86.3	0.25	1.30	50.9	40.7
9. Surface hoeing x control	650	190	160	5.1	8.8	1.2	7.2	2.8	0.2	0.38	3.0	2.5	6.1	1.3	7.4	82.4	0.24	1.28	51.7	50.4
10. Surface hoeing x moringa (15 t/ha)	750	130	120	5.3	9.2	2.5	6.9	2.9	0.23	0.4	3.1	2.9	6.6	1.2	7.8	84.4	0.23	1.28	51.7	48.1
11. Surface hoeing x poultry dropping (10 t/ha)	750	130	120	7.5	12.9	4.5	7.3	4.6	0.29	0.42	3.5	3.1	7.3	1.0	8.3	87.9	0.29	1.27	52.1	44.3
12. Surface hoeing x SSP (120 kg/ha)	790	110	100	5.3	9.2	2.1	7.4	4.7	0.21	0.39	3.1	2.9	6.6	1.2	7.8	84.6	0.27	1.30	50.9	49.1

Table 3: Interaction Effect of Soil Amendments and Tillage on Soil Properties (2019)

Treatments	Sand	Silt	Clag	O.C	Om	N	PH	P	Na	K	Ca	Mg	TEB	EA	CEC	BS	EC	BD	Porosity	HC
							(g/kg)					(H2O)	(Mg/kg)							(Cmol/kg)
(%) (ds/m)	(Mg/m^3)	(%)		(Ksat)																
1. Zero tillage x control	750	130	120	4.8	8.3	1.1	6.9	2.4	0.21	0.3	2.5	2.2	5.2	1.1	6.3	82.5	0.22	1.39	47.6	57.8
2. Zero tillage x moringa (15 t/ha)	750	130	120	6.9	11.9	2.2	6.9	2.7	0.23	0.39	3.0	2.7	6.4	1.3	7.7	83.1	0.24	1.30	50.9	51.0
3. Zero tillage x Poultry dropping (10 t/ha)	750	130	120	7.4	13.8	4.5	7.4	4.3	0.35	0.47	3.7	3.2	7.7	1.2	8.9	86.5	0.29	1.30	50.9	47.4
4. Zero tillage x SSP (120 kg/ha)	690	190	120	5.7	9.9	1.3	6.9	4.5	0.25	0.38	2.8	2.5	5.9	1.1	7.0	84.3	0.30	1.35	49.1	53.1
5. Ridge tillage x control	750	130	120	5.9	10.2	1.7	7.5	2.8	0.27	0.41	3.3	2.8	6.8	1.2	8.0	85.0	0.25	1.33	49.8	43.3
6. Ridge tillage x moringa (15 t/ha)	790	110	100	7.4	12.8	.1	6.8	3.6	0.34	0.51	3.9	3.6	8.4	1.3	9.7	86.6	0.27	1.27	52.1	38.7
7. Ridge tillage x poultry dropping (10 t/ha)	690	190	120	8.9	15.4	5.3	6.9	4.6	0.37	0.59	5.1	4.3	10.4	1.3	11.7	88.9	0.38	1.23	53.6	35.1
8. Ridge tillage x SSP (120 kg/ha)	750	130	120	6.0	10.4	2.9	7.4	5.1	0.37	0.63	3.6	3.2	7.7	1.1	8.8	87.5	0.25	1.30	50.9	40.2
9. Surface hoeing x control	740	140	120	5.5	9.5	1.3	7.3	2.9	0.25	0.39	3.1	2.6	6.3	1.2	7.5	84.0	0.25	1.35	49.1	48.5
10. Surface hoeing x moringa (15 t/ha)	790	110	100	7.3	12.6	2.7	6.9	30.1	0.28	0.47	3.5	3.2	7.5	1.2	8.7	86.2	0.24	1.28	51.7	47.3

11. Surface hoeing x poultry dropping (10 t/ha)	780	120	100	8.1	14.0	48.8	7.2	4.6	0.33	0.53	4.3	3.8	9.0	1.1	10.1	89.1	0.32	1.25	52.8	40.3
12. Surface hoeing x SSP (120 kg/ha)	750	130	120	5.9	10.2	2.4	6.9	4.9	0.25	0.48	3.3	3.0	7.0	1.2	8.2	85.4	0.31	1.33	49.8	41.2

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