



INTERACTION EFFECT OF SOIL AMENDMENTS AND TILLAGE PRACTICES ON SOIL PROPERTIES

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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 interaction effect of soil amendments and tillage practices 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 management practices 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.

Keywords: Soil amendments, tillage, soil properties, soil sample, treatments

INTRODUCTION

Soil is a basic resource in crop production, its ability to sustain economic yield of crops is determined largely by its properties and management level. Soil conservation is necessary to promote sustainable crop production, because soil is the major medium for plant growth. Soil component include mineral matters, organic matters, air and water. These soil components are vital to crop production. The components are not readily renewable after depletion. Soil resources of the world are finite, non-renewable, unequally distributed in different eco-regions and fragile to drastic

perturbations (Lal, 1995; Akinrinola, 2018). For the purpose of food production on large scale, the maintenance of soil organic matter is necessary. Crop residues are about five percent of soil component (Akinrinola, 2018). An essential strategy for the large scale food production is the maintenance of soil organic matter. In essence, management of soil and water conservation are vital agricultural practices require to meet the demand for food production in Nigeria and other tropical countries.

Use of fertilizers to sustain soil on most tropical soils is necessary due to their low nutrient status. The use of



chemical fertilizers to sustain soil on a long term basis has not been very effective. It usually leads to a decline in soil organic matter content, soil acidification and soil physical degradation, which consequently leads to increased soil erosion (Doran et al., 1996; Olasupo et al., 2018). Inorganic fertilizers are usually not available and are rather expensive for the smallholder farmers. Organic manures are used as an alternative for inorganic fertilizers. They release nutrients rather slowly and steadily over a longer period and also improve the soil fertility status by activating the soil microbial biomass (Olasupo et al., 2018).

Soil tillage is one of the fundamental agro-technical operations in agriculture because of its influence on soil properties (physical, chemical and biological), environment and crop growth. Since intensive soil tillage strongly influence soil the soil properties, it is important to apply appropriate tillage practices that avoid the degradation of soil structure, maintain crop yield as well as ecosystem stability (Lal, 1995; Adelabu et al., 2018). No-till and strip till practices reserve most of the organic residues on undisturbed surface whereas conventional tillage incorporates residues into soil thereby increases soil-residue contact, favouring rapid decomposition of soil organic matter through oxidation and the rate of carbon mineralization (Curtin et al., 2012; Adelabu et al., 2018). Conservation tillage involves the practice that minimizes the disruption of the soil structure, significantly save the time with seedbed preparation, increased soil organic matter and reduces operation costs.

Application of soil amendments (organic and inorganic fertilizers) combined with tillage practices is known to be effective in reducing soil erosion, maintaining soil fertility and conserving soil water. It will be quite interesting therefore to study the interactive effects of soil amendments and soil tillage for soil sustainability. The objective of the study was to determine the interaction effects of soil amendments and tillage practices on soil properties in Makurdi, Nigeria.

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 drain.

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 m²) 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 formula: BS = Total 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/m³ 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/m³ and 1.6 Mg/m³ for clay and sandy soils respectively, and higher bulk density above 1.6 Mg/m³ 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 ₂ O)	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 and Tillage Practices on Soil Properties

The main effect of soil amendments and tillage practices on soil properties is presented in Tables 2 and 3. Higher values of nutrients were observed in 2019 than 2018 cropping season. Ridge tillage x 10 t/ha poultry manure treatment combination gave the highest soil nutrient values followed by surface hoeing x 10 t/ha poultry manure, zero tillage x 10 t/ha poultry manure, ridge tillage x 15 t/ha moringa, surface hoeing x 15 t/ha moringa, zero tillage x 15 t/ha moringa, ridge tillage x 120 kg/ha SSP, surface hoeing x 120 kg/ha SSP, zero tillage x 120 kg/ha SSP, ridge tillage x control, surface hoeing x control and zero tillage x control. All control plots had lower values of nutrients. Integrated use of soil amendments and tillage practices were beneficial in improving the physical properties of soil. Decreased in bulk density and high porosity were noted in all the treatment combinations compared to the result obtained at the beginning of the experiment (Table 1). The value of BD at the beginning of the experiment was 1.4 Mg/m³ but reduced to 1.38 - 1.25 Mg/m³ in 2018 and 1.39 - 1.23 Mg/m³ in 2019 cropping season. Lower values of soil bulk density 1.25 – 1.23 Mg/m³ and higher porosity 53.6 – 52.8 % were obtained under ridge tillage x 10 t/ha poultry manure in 2018 and 2019. Bulk densities of the soil were low in ridge tillage as compared to surface hoeing and zero tillage. These results are in agreement those of Materechera and Mloza (1997), who concluded that a distinct hard and compacted layer had developed below

the ridges (25 cm depth) in both conventional tillage and minimum tillage. Soil on ridges had consistently lower bulk density and hydraulic conductivity than surface tillage and zero tillage. These results are also in agreement with those of Gordon *et al.* (1993; Khurshid *et al.*, 2006), who reported that ridged plots contained a greater amount of moisture in the soil profile and thereby reducing bulk density than minimum tillage and zero tillage. Other reports also indicated that, as compared to control and zero tillage plots, interaction of soil amendments with ridge tillage and surface hoeing have greater porosity (Suwadjo and Abujamin, 1983); increased water holding capacity (Unger and Wiese, 1979; Unger and Jones, 1981; Edwards *et al.*, 2000), higher infiltration rate (Bonsu, 1983), increased amount of percolation, less runoff and water erosion (Suwadjo and Abujamin, 1983) and less evaporation (Unger and Jones, 1981).

Interaction effect of soil amendments and tillage treatment combinations on soil chemical properties improved soil pH, organic matter (O.M) content, nitrogen (N), phosphorus (P), exchangeable bases (EB), exchangeable acidity, CEC, base saturation and electrical conductivity relative to the control plots (Tables 2 and 3). Application of poultry manure had greater influence on soil properties compared to moringa and SSP over the control. Similar results were reported by Adeyemo *et al.* (2019) which stated that highest soil organic matter was recorded when 10 t/ha of poultry manure was applied and was significantly higher ($P < 0.05$) at every period of determination from other organic treatments. The results of poor values of soil properties under the control plots and zero tillage plots suggested that soil organic matter is greatly affected by soil erosion and is related with productivity. Depletion of soil organic matter by erosion is accompanied by the removal of plant nutrients, deterioration of soil structure, and diminishing soil workability (Mandal *et al.*, 2012; Lal and Mishra, 2015). Depletion of soil organic matter and erosion are spirally cyclic since a decrease in organic



matter increase the susceptibility of soil to erosion, thereby increasing the rate of depletion of soil organic carbon (Pierce and Lal, 1994; Mandal *et al.*, 2012).

From the results it could be observed that little or no nutrients were added to control plots in 2019 compared to 2018 cropping season due to non-applications of soil amendments. The depletion of soil nutrients in the control plots could be as a result of plant uptake and erosion without replacement. Higher values of phosphorus (P) and potassium were obtained at 120 t/ha SSP treated plots in 2019 cropping season compared to other treatment combinations. The higher values of phosphorus were as a result of application of SSP fertilizer which contains more phosphorus contents than poultry and moringa manures.

Generally, the value of soil nutrients in the control plots were lower compared to plots treated with soil amendments. Higher nutrients values were observed in ridge tillage x 10 t/ha poultry manure treatment combination in the both cropping seasons.

CONCLUSION

Soil amendments and tillage practices significantly affected soil properties. The study has shown that the study site had 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. Interaction between soil amendments and tillage practices 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 ridge tillage x 10 t/ha poultry manure followed by ridge tillage x 15 t/ha moringa and ridge tillage x 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.



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 ₂ O)			(Mg/kg)			(Cmol/kg)			(%)	(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	7.2	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	5.6	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



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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