Effect of organic materials on soil physio-chemical properties at Bayero University, Kano-Nigeria

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Abstract: Soil management using organic materials is one of the strategies of soil conservation and nutrients enhancement. This work evaluated the effect of organic materials (poultry manure and millet-chaff) on physio-chemical properties of soil at Agricultural Engineering Departmental farm, Bayero University, Kano-Nigeria. Three different points were randomly selected and the soil samples were collected at 0-20 cm, 20-40 cm and 40-60 cm depths making a total of nine samples. The physiochemical properties of the soil samples were determined in the laboratory and t-test was also conducted to analyse the effect of these organic materials on soil physiochemical properties before and after application. Based on the results obtained, it was discovered that some of the physiochemical properties were responsive to the organic materials. Moreover, the findings revealed that poultry manure and millet chaff improved some of the properties such as moisture content by 23.9% (from 13.4% to 16.6%) and 43.3% (from 13.4% to 19.2%) respectively. The soil was also found to be acidic with pH value of 6.13 and 6.33 after organic materials were applied. The salinity level of soil treated with millet chaff reduced by 53% (from 0.33 dS m^{-1} to 0.154 dS m^{-1}) while soil treated with poultry manure slightly reduced by 12.2% (from 0.33 ds m^{-1} to 0.29 ds m^{-1}). The organic matter, Nitrogen, Phosphorous and Potassium values of soil were increased by 79.3% and 26%, 23% and 23.2%, 45% and 30.4%, and 53.2% and 28.8% for the soil treated with poultry manure and millet chaff respectively. The result of t-test revealed that, there is significant difference in some of physiochemical properties of the soil after organic materials were applied. The findings revealed that organic materials used can be adopted as a substitute to inorganic fertilizer and based on this note, farmers are adviced to make the maximum utilization of organic materials rather than inorganic fertilizer which is expensive and sometimes detrimental to the soil and therefore to the yield of the crops.

Key Words: physio-chemical, organic materials, poultry manure, millet chaff

Citation: Sabo, A. A., M. S. Abubakar, M. D. Zakari, N. J. Shanono, A. N. Jibril, and U. K. Adamu. 2021. Effect of organic materials on soil physio-chemical properties at Bayero University, Kano-Nigeria. Agricultural Engineering International: CIGR Journal, 23(2): 52-59.

1 Introduction

Physio-chemical properties of the soils determine adaptability to cultivation and the level of biological activity that can be supported by the soil. Soil physical properties also largely determine the soil's water and air supplying capacity to plants. Many soil physical properties change with

Received date:2020-07-24 **Accepted date:**2021-03-02
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changes in land use system and its management practice such as intensity of cultivation, the instrument used and the nature of the land under cultivation, rendering the soil less permeable and more susceptible to runoff and erosion losses (Sánchez, 1977). Hence, physical properties of the soil are the key consideration for productive and sustainable agricultural production.

Soil chemical properties are the most important among the factors that determine the nutrient supplying power of the soil to the plants and microbes. The chemical reactions that occur in the soil affect processes leading to soil development and soil fertility build up. Minerals inherited from the soil parent materials overtime release chemical elements that undergo various changes and transformations within the soil.

Soil quality simply means the capacity of the soil to function within an ecosystem and land use boundaries, sustaining biological productivity, maintaining environmental quality and promoting plant, animal and human health (Doran and Jones, 1996). Good quality agricultural soil is not only producing better food and fiber, but also helping to establish natural ecosystems and enhancing air and water quality (Griffiths et al., 2010). Soil fertility changes and the nutrient balances are taken as key indicators of soil quality. Intensive agricultural production has caused a clear decline in soil fertility, and this fertility of the soil is a major concern for the long-term agricultural productivity and sustainability (Sarma et al., 2017). However, despite putting huge effort in feeding the global population, excessive use of mineral fertilizers is one of the main drivers behind the loss in soil fertility (Chen et al., 2014; Zhang et al., 2016). Bodirsky et al. (2014) proposed the use of organic materials, such as farmyard manure, poultry manure, straw or mixture of manure, millet chaff and compost, as alternatives for mineral fertilization.

Soil organic matter arises from the debris of green plants, animal residues and excreta that are deposited on the surface and mixed to a variable extent with the mineral component (White, 1997). Numerous previous studies have revealed that application of organic materials to agricultural soil can provide various benefits over mineral fertilization such as improved soil structure and enhancement in soil fertility (Thangarajan et al., 2013). Seufert et al. (2012) reported that the use of organic materials improved long-term maintenance of soil quality and particularly similar or even higher crop yields in certain cases when compared with the use of inorganic materials. Poultry manure and millet chaff are available and affordable organic materials in the study area. Therefore, this study focuses on the evaluation of the effect of the poultry and millet chaff on physiochemical properties of soil.

2 Materials and methods

2.1 Description of the study area

The study was conducted at Agricultural and Environmental Engineering Departmental Farm, Bayero University, Kano, which is located along Gwarzo road on Latitude 11° 58’38”N and Longitude 08° 20’80”E and an altitude of 454 m above sea level. The climatic condition of the area is characterized by annual average minimum and maximum temperatures of 20.5℃ and 33.9℃, maximum relative humidity of 82 and minimum relative humidity of 23 and an annual average rainfall of 890.40 mm, respectively (Muhammad, 2014; Shanono et al., 2014).

2.2 Sample collection and description of experimental treatments

The experiment was set up on 16th February, 2019 and the soil samples were collected on 18th February, 2019 before the application of the organic materials. The soil samples were collected using auger, core sampler (5 cm diameter), hammer, digger, hoe, shovel and steel ruler. Three different points were randomly selected and the soil samples were collected at 0 - 20 cm, 20 - 40 cm and 40 - 60 cm making a total of nine samples. Physical and chemical properties of soil samples were analyzed in the Agricultural and Environmental Engineering Departmental Laboratory.

A land of area of 6.0 m × 4.5 m was prepared into leveled basins of 2.0 m × 1.5 m. The treatments comprised of control and two different organic materials, and the treatments were leveled as A_0 = No organic material, A_1 = poultry manure and A_2 = millet chaff. The three treatments were replicated three times making a total of nine experimental runs. The average weight of poultry manure and millet chaff organic materials spread in each plot was 0.56 kg m^{-2} and 0.93 kg m^{-2} respectively. This amount was sufficiently enough to cover the plot area. Water was applied in the plots with materials in order to increase the rate of decomposition of the material in the plots. Soil samples were also taken on 19^{th} march, 2019 for physiochemical analyses from the plots with materials after two months of application with the belief that the materials were completely decomposed.

2.3 Determination of soil physical properties

Parameters on soil physical properties were determined, these are soil classification, soil texture, soil permeability, bulk density and moisture content of the soil.

2.3.1 Determination of soil classification

Particles size analyses were carried out whereby the percentage of sand, silt and clay were determined using Bouyoucos hydrometer method as described by Gee and Or (2002) using Equations 1- 4.

$$\%(Si+C)=\frac{CHR_1}{W_S}\times 100 \quad (1)$$

$$\%C=\frac{CHR_2}{W_S}\times 100 \quad (2)$$

$$\%Si=\%(Si+C)-\%C \quad (3)$$

$$\%S=100-\%(Si+C) \quad (4)$$

Where: S_i=the percentage of silt, C=the percentage of clay, S=the percentage of sand, CHR_1=first corrected hydrometer reading (g/cm3), CHR_2= second corrected hydrometer reading (g/cm3), W_s=weight of sample (g)

2.3.2 Determination of saturated hydraulic conductivity ($Ksat$)

Constant head permeameter was used to determine the saturated hydraulic conductivity of the soil using Equation 5 as described by Hussain and Nabi (2016).

$$K_{sat}=\frac{QL}{A}\Delta h \quad (5)$$

Where $Ksat$ = coefficient of permeability (cm s^{-1}), L = length of soil specimen (cm), A= cross-sectional of permeameter (cm^2), Q = V/t (cm^3 s^{-1}), V = volume of discharge (cm^3), t = average time for discharge (s^{-1}), Δh = hydraulic head difference across length (cm/s).

2.3.3 Determination of soil bulk density

Bulk density of the soil was determined using core sampler method (Grossman and Reinsch, 2002) as described in Equation 6.

$$\rho_b=\frac{M_S}{V_C} \quad (6)$$

Where ρ_b=bulk density (g cm^{-3}), M_S = mass of oven dried soil (g), and V_C = volume of core sampler (cm^3).

2.3.4 Determination of soil moisture content

The moisture content was determined by using gravimetric method as described by Michael and Ojha (2005) using Equation 7.

$$M_C=\frac{M_W-M_d}{M_d}\times 100 \quad (7)$$

where: M_c = moisture content (%), M_w = mass of wet soil (kg), and M_d = mass of dry soil (kg)

Other important soil parameters such as soil texture, available water in the soil, field capacity and wilting point of the soil were also determined using appropriate laboratory standard method.

2.4 Determination of soil chemical properties

Chemical properties of the experimental field soil were also determined in the laboratory and the parameters determined include: soil pH, electrical conductivity of the soil (E. C), organic matter content, available percentage of organic carbon (O. C), Nitrogen (N), phosphorous (P), potassium (K), sodium (Na), magnesium (Mg), calcium (Ca), cation exchange capacity (CEC), sodium adsorption ratio and exchangeable sodium percentage.

2.4.1 Determination of soil pH and electrical conductivity (EC)

Soil pH was determined using pH meter in the laboratory and soil salinity of the study area was also determined by obtaining electrical conductivity of the soil using saturation extraction method described by Udo et al. (2009).

2.4.2 Determination of organic matter content

Walkey Black wet oxidation method (Udo et al., 2009) was used to determine the percentage of organic matter content present in the soil as shown in Equations 8 and 9.

$$\%\ Organic\ Carbon = \frac{N(V_1 - V_2)}{W} \times 0.3f \tag{8}$$

$$\%\ Organic\ Matter = Organic\ Carbon \times 1.724 \tag{9}$$

Where; N= normality of ferrous sulphate solution (aq); V_1= ferrous ammonium sulphate required for the blank (mL); V_2 = ferrous ammonium sulphate required for the sample (mL); W= mass of sample (g); f = correction factor, 1.33.

2.4.3 Determination of sodium adsorption ratio and exchangeable sodium percentage

Sodium adsorption ratio and exchangeable sodium percentage was determined using Gapon equation as described in Equations 10 and 11 (Quirk, 2001; Sumner, 1993).

$$SAR = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}} \tag{10}$$

$$ESP = \left(\frac{Na}{CEC}\right) \times 100 \tag{11}$$

Where: SAR = sodium adsorption ratio;

Na, Ca and Mg = concentration of sodium, calcium and magnesium in the soil solution (cmol kg-1); ESP = exchangeable sodium percentage (%); CEC = cation exchange capacity (cmol kg^{-1}).

2.4.4 Determination of macro elements in the soil

The available nitrogen from the organic matter in the experimental field soil was determined using alkaline permanganate method (Subbaiah and Asija, 1956). Next to nitrogen, phosphorous is critical essential element in influencing plant growth and production. Olsen's method was employed in determining the available phosphorous in the soil. Photometer flame method was used to determine the available potassium and sodium presence in the soil. El Mahi et al. (1987) method was used in determining calcium and magnesium in the soil. Other chemical properties, such as CEC, were also determined using standard laboratory procedure.

2.5 Statistical analysis

A t-test was conducted to analyze the effect of the organic materials on physio-chemical properties of the experimental field soil before and after application.

3 Results and discussion

3.1 Soil of the experimental site before application of the organic materials

Tables 1 and 2 present mean results of some of physio-chemical properties of the soil before and after application of the poultry manure and millet chaff respectively. Before application of the organic materials, the soil was predominantly loam in texture with an average bulk density and moisture content of 1.5g cm^{-3} and 13.4% respectively. The respective hydraulic conductivity, field capacity (FC), wilting point (WP), and available water are given in the tables with their averages being 31.48 mm hr^{-1}, 22.2%, 8.03%, and 0.32% respectively. From the tables, the soil was found to be acidic with an average pH value of 6.4. The mean value of EC was found to be 0.33 dS m^{-1}. This indicated the salinity level is low in the experimental field (Udo et al., 2009), so injury to the plants is minimal. The available organic matter presence in soil was found to be 1.0%, and it was observed that, the percentage of the organic matter is decreased as the depth of the soil is in increasing. This may be due to most organic and biological activities that take place at the top soil which might enrich the organic matter at the top of the soil. Other chemical fertility of the soil was also determined in the laboratory by obtaining the amount of macro elements presence in the experimental field soil before the application of the organic materials. The macro elements include Nitrogen (N), Phosphorous (P), Potassium (K), Calcium (Ca), Magnesium (Mg), and Sodium (Na) with their respective mean values as 0.06%, 7.9 mg kg^{-1}, 0.35 cmol kg^{-1}, 2.8 cmol kg^{-1}, and 1.43 cmol kg^{-1} respectively.

Table 1 Mean results of physical and chemical properties of soil before and after application of poultry manure

Physical properties					Chemical properties				
Parameters	**Before**	**After**	**Pr**	**Remark**	**Parameters**	**Before**	**After**	**Pr**	**Remark**
Moisture Cont. (%)	13.4	19.20	0.02	*	Soil pH	6.40	6.33	0.23	ns
Bulk density (g cm^{-3})	1.5	1.56	0.074	ns	Organic matter (%)	1.00	1.26	0.001	*
Hydraulic Conductivity (mm hr^{-1})	31.48	17.94	0.02	*	E. C (dS m^{-1})	0.33	0.15	0.019	*
Avail. Water (%)	0.32	0.76	0.02	*	N (%)	0.06	0.07	0.004	*
FC (%)	22.2	26.7	0.03	*	O. C (%)	0.64	0.72	0.06	ns
WP (%)	8.03	16.7			P (mg kg^{-1})	7.90	10.30	0.004	*
Sand (%)	54.92	27.5			K (cmol kg^{-1})	0.35	0.45	0.06	*
Silt (%)	31.34				Ca (cmol kg^{-1})	2.80	3.03	0.008	ns
Clay (%)	13.74	25.71			Na (cmol kg^{-1})	0.21	0.26	0.02	*
Predominant texture	Sandy loam	Silt Loam			Mg (cmol kg^{-1})	1.43	1.60	0.19	ns
					CEC	4.97	5.43	0.003	*
					(cmol kg^{-1})	5.00	5.43	0.003	
					SAR (mg kg^{-1})	0.41	0.17		
					ESP (%)	4.20	4.80		

* =

*Significance, ns = not significant

Table 2 Mean results of physical and chemical properties of soil before and after application of millet chaff

Physical properties					Chemical properties				
Parameters	**Before**	**After**	**Pr**	**Remark**	**Parameters**	**Before**	**After**	**Pr**	**Remark**
Moisture Cont. (%)	13.4	16.60	0.03	*	Soil pH	6.40	6.13	0.02	ns
Bulk density (g cm^{-3})	1.5	1.53	1.00	ns	Organic matter (%)	1.00	1.79	0.001	*
Hydraulic Conductivity (mm hr^{-1})	31.48	24.28	0.01	*	E. C (dS m^{-1})	0.33	0.29	0.79	ns
Avail. Water (%)	0.32	0.61	0.02	*	N (%)	0.06	0.07	0.11	*
FC (%)	22.2	30.10	0.22	*	O. C (%)	0.64	0.90	0.004	*
WP (%)	8.03	16.93	0.36	*	P (mg kg^{-1})	7.90	11.50	0.00014	*
Sand (%)	54.92	35.46			K (cmol kg^{-1})	0.35	0.50	0.00025	*
Silt (%)	31.34	38.18			Ca (cmol kg^{-1})	2.80	3.50	0.037	*
Clay (%)	13.74	26.35			Na (cmol kg^{-1})	0.21	0.30	0.046	*
Predominant texture	Sandy loam	Loam			Mg (cmol kg^{-1})	1.43	1.83	0.0202	*
					CEC (cmol kg^{-1})	5.00	5.8	0.07	ns
					SAR (mg kg^{-1})	0.41	0.19		
					ESP (%)	4.20	5.2		

*Significance, ns = not significant

The mean values of organic carbon, cation exchange capacity (CEC), sodium adsorption ratio (SAR) and the exchangeable sodium percent of the soil were also determined to be 0.64%, 5 cmol kg^{-1}, 0.14 cmol kg^{-1} and 4.2% respectively. After application of the organic materials, the soil was found to change in texture. The soil treated with poultry manure changed from sandy loam to loam while soil treated with millet chaff changed from sandy-loam to silty-loam. The soil was found to have an average moisture content of 16.6% and 19.2% after application of poultry manure and millet chaff respectively. This means that poultry manure improved the moisture content by 23.9% (from 13.4% to 16.6%) while millet chaff is by 43.3% (from 13.4% to 19.2%).This is in consistent with finding by Ramakrishna et al. (2006) who found that application of organic materials to the soil increased the moisture content of the soil. The bulk densities of the soil after application of poultry manure and millet chaff were found to be 1.54 g cm^{-3} and 1.56 g cm^{-3} respectively. This indicated that bulk density was not responsive to the organic materials used compared with the initial bulk density which was found to be 1.5 g cm^{-3}.

The saturated hydraulic conductivity of the soil was found to decrease by 22.9% and 43% for poultry manure (from 31.48 mm hr^{-1} to 24.28 mm hr^{-1}) and millet chaff (from 31.48 mm hr^{-1} to 17.94 mm hr^{-1}) respectively. This could be attributed since water retention capacity of the soil increased and thereby the rate at which water passing through will be slow. The field capacity (FC) and wilting point (WP) of the soil treated with poultry manure were also found to increase from (22.2% dwb to 30.1% dwb) and (8.03% to 16.93%) respectively. While soil treated with millet chaff were increased from (22.2 dwb to 26.7% dwb) and (8.03% to 16.7%) respectively.

The soil was also found to be acidic with pH values of 6.13 and 6.33 after application of poultry manure and millet chaff materials respectively. The salinity level of soil treated with millet chaff reduced by 53% (from 0.33 dS m^{-1} to 0.15 dS m^{-1}) while that of soil treated with poultry manure slightly reduced by 12.2% (from 0.33 ds m^{-1} to 0.29 ds m^{-1}). This agreed with Kasim (2017) who found that the use of millet chaff as organic amendments is one of the strategies of reclaiming saline-sodic soil. Moreover, poultry manure increased soil organic matter (O.M: from 1.0% to 1.793%), organic carbon (O.C: from 0.64% to 0.901%), available nitrogen (N: 0.06% to 0.07%), phosphorous (P: from 7.9 mg kg^{-1} to 11.5 mg kg^{-1}), potassium (K: from 0.35 cmol kg^{-1} to 0.50 cmol kg^{-1}), calcium (Ca: from 2.8 cmol kg^{-1} to 3.5 cmol kg^{-1}), sodium (Na: from 0.21 cmol kg^{-1} to 0.3 cmol kg^{-1}) and magnesium (Mg: from 1.43 cmol kg^{-1} to 1.83 cmol kg^{-1}) by 79.3%, 40.7%, 23%, 45.5%, 53.2%, 25%, 42.85% and 28% respectively. This is in consistent with finding by Adeniyan and Ojeniyi (2005), who found that poultry manure and cow dung increased soil organic matter, available nitrogen (N), phosphorous (P), potassium (K), calcium (Ca) and magnesium (Mg), organic matter (O. M), organic carbon (O. C), available nitrogen (N), phosphorous (P), potassium (K), calcium (Ca), sodium (Na) and magnesium (Mg). On the other hand, millet chaff slightly increased the above elements by 26% (from 1.0 to 1.26), 13.4% (from 0.64 to 0.73), 23.2% (from 0.06 to 0.03), 30.4% (7.9 to 10.3), 28.8% (0.35 to 0.451), 8.2% (from 2.8 to 3.03), 26.5% (from 0.21 to 0.263) and 11.88% (1.43 to 1.6) respectively. The cation exchange capacity (CEC), sodium adsorption ratio (SAR) and exchangeable sodium percentage (ESP) were also increased by 16% (from 5.0 cmol kg^{-1} to 5.8 cmol kg^{-1}) and 8.6% (from 5.0 cmol kg^{-1} to 5.43 cmol kg^{-1}), 26.3% (from 0.14 cmol kg^{-1} to 0.19 cmol kg^{-1}) and 17.6% (from 0.14 cmol kg^{-1} to 0.17 cmol kg^{-1}) and 19% (from 4.2% to 5.2%) and 12.5% (from 4.2% to 4.8%) for poultry manure and the millet chaff respectively.

The results indicated some of the physiochemical properties determined were responsive to organic materials used (poultry manure and millet chaff). It was discovered that poultry manure revealed higher soil fertility than millet chaff. The high increase in the soil fertility obtained caused by poultry manure could be due to the chemical composition and rapid released of nutrients from poultry manure, while the slight increment obtained by millet chaff may be due to chemical constituents and incomplete decomposition of millet chaff after the application.

Moreover the tables also present the result of t-test which compared effect of organic materials used before and after application. The result revealed that there is significant difference in soil moisture content, hydraulic conductivity and available water of the soil and insignificant difference in bulk density and wilting point of the soil after application of both organic materials used for this experiment. Significant difference was also noticed in the field capacity of the soil after application of millet chaff while no significant difference was shown after application of poultry manure. For the chemical properties of the soil after application of the materials, significant difference was noticed on organic matter, organic carbon, phosphorous, calcium and sodium after application of both organic materials. There is also a significant difference in electrical conductivity, available nitrogen and CEC only in the soil treated with millet chaff and significant difference in soil pH and potassium only in the soil treated with poultry manure.

3 Conclusion

The study evaluated the effect of two different organic materials (poultry manure and millet chaff) on soil physiochemical properties at agricultural and environmental Engineering Departmental Farm, Bayero University, Kano. Based on the results obtained, significant differences were noticed on some of physiochemical properties of the experimental field soil after application of these organic materials. This indicated that organic materials used were responsive to physiochemical properties of the soil in the experimental site.

However, the findings revealed that poultry manure resulted in high improvement in fertility of the soil than that of millet chaff even though the millet chaff was not completely decomposes. It can be concluded that farmers are advised to make the maximum utilization of organic material rather than inorganic fertilizer which is expensive and sometimes detrimental to the soil and therefore to the yield of the plant.

Acknowledgments

Appreciation is extended to the Department of Agricultural and Environmental Engineering, Bayero University, Kano as well as the contributions of the anonymous reviewers who are also gratefully appreciated.

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