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Water Characteristics of Soils under Different Rates of Poultry Manure in an Ultisol of Southeastern Nigeria

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ABSTRACT

The effect of different rates of poultry manure application on water characteristics of Oforola soils was studied. The different poultry manure rates were 0, 10, 20, and 30 t/ha, while the soil properties studied were particle size distribution, bulk density, porosity, organic matter, saturated hydraulic conductivity, volumetric water content, volumetric infiltration rate, sorptivity and water repellence index. Data were subjected to multiple correlation ($p = 0.05$ and $p = 0.01$) and analysis of variance ($p = 0.05$) using RCBD. The results show that the particle size distribution and water repellence index did not differ significantly among the different treatment rates. Soil porosity and organic matter were observed to increase with increasing treatment rate but were not significantly influenced by the different treatment rates. Bulk density was significantly influenced in the 30 t/ha treated plot. Both the saturated hydraulic conductivity and volumetric water content were significantly influenced in the 20 and 30 t/ha treated plots, while both volumetric infiltration rate and sorptivity were significantly influenced in all the treated plots. The result of the correlation analysis showed that the treatments had positive influence ($p = 0.01$) on porosity ($r = 0.982$), organic matter ($r = 0.967$) and volumetric water content ($r = 0.976$) but negatively influenced ($p = 0.01$) bulk density ($r = -0.982$), saturated hydraulic conductivity ($r = -0.989$), volumetric infiltration rate ($r = -0.990$) and sorptivity ($r = -0.994$). Also, the treatments correlated positively but non-significantly with water repellence index (r value), which correlated negatively and significantly with the percent clay content (r value). Based on the findings, a further study is recommended to establish a standard and beneficial poultry manure rate that would enhance soil water characteristics for sustainable productivity. o improve the soil constraints to maintain and sustain the productivity of the soils.

1.0. Introduction

Soil water status affects soil properties either directly by its influence on soil weathering and profile development or indirectly on a short term basis by influencing soil factors such as soil strength, friability and permeability to water and solutes and gases. Unfortunately, most interest in soil water is centered on its content and availability with little or no regards to its interrelations with other soil properties and environmental factors (Enyioko et al., 2012). The maintenance of water and nutrients at optimal level within root zone is a primary factor to achieve high growth and yield quality of crops (Doerr et al., 2000).

In sub-saharan Africa, soil moisture is the most limiting factor of crop yield in rain-fed agriculture. Many researchers have reported that addition of organic manure significantly influenced soil water characteristics such as infiltration rate, hydraulic conductivity and sorptivity (Wanas, 2002; Onweremadu and Anikwe, 2007; Orfánus et al., 2008; Diana et al., 2008; Mubarak et al, 2009; Enyioko et al., 2012). In Oforola, rain-fed agriculture is predominant, where ultisol of Oforola is often acidic, containing low activity clay, weakly structured, porous and generally low in nutrient composition (Ufot, 2012). Currently, the soil is subjected to continuous cropping with application of inorganic fertilizers only, thereby leading to degradation as a result of decline in organic matter contents of the soils (Okoye, 2005). The weak structure, compaction, crusting, low water retention which are attributes of ultisols can be tackled by supplying organic manure to help build up organic matter content of the soil (Lal, 1986; Anikwe, 2000).

Wanas (2002) reported that addition of organic manure to soil increased the retention and availability of soil moisture as well as the cohesive force among the soil particles but reduced the velocity of downward water movement, restricted the deep percolation and leaching out of soil nutrients. The use of poultry manure has been encouraged due to its potential to modify soil conditions by improving its water holding capacity, aeration, drainage, friability and its ability to provide energy for microbial activities (Goladi and Agbenin, 1997). The improvement of the chemical and hydro-physical properties of soil is as a result of the addition of organic matter obtainable from application of poultry manure. The importance of organic matter of soil in relation to soil moisture can be observed in the improvement of soil porosity, infiltration rate and soil water retention (Wanas, 2002). Pagliai et al. (1987) reported that organic manure can act as water absorbent materials that can increase soil water retention and improve soil structure. Wanas and Omran, (2006) reported that use of poultry manure led to beneficial effect on hydro -physical properties of studied soils such as bulk density, pore size distribution, aggregate stability, soil water retention, hydraulic conductivity and infiltration rate.

However, there are little or no data on effect of poultry manure which is easily available for use, on the hydro-physical properties of ultisols of Oforola. Hence, the objective of this study was to evaluate the relationships between the water characteristics of ultisols and different rates of poultry manure application.

2.0. Materials and Methods

2.1. Study Area

The research was carried out in the Research and Demonstration Farm of the Federal College of Land Resources Technology, Oforola in Owerri West Local Government Area of Imo State. The area lies between latitude 50 14I and 60 31I North, and longitude 70 34I and 60 151 East (Uwakwe, 2012).

Oforola lies within the low land, humid tropical ecosystem of South Eastern Nigeria. The annual rainfall in Oforola ranges from 1,500 – 2,500 mm. The minimum and maximum temperature ranges from 200C to 310C respectively, which creates an annual relative humidity of 90 mm during the rainy season and 75 mm during the dry season (Uwakwe, 2012).

According to Ufot, (2012), Oforola is dominated by typic paleusult characterized by low activity clays, low nutrient reserves, low moisture retention, nutrient imbalance, high acidity, high Al toxicity, high tendency to crust, compact and erode and generally porous, weakly structured, but well drained in such a way that runoff water disperses 30 minutes after a typical rainfall storm.

The vegetation of the area is controlled by geologic factors of topography, relief and lithology as well as other anthropogenic factors (Ufot, 2012). The vegetation ranges from light rainforest to derived savannah. The area supports extensive man-made vegetation communities where oil palm trees predominate. Human activities such as bush burning, agriculture and construction works have greatly modified the natural vegetation in the area and contributed to the erosion problem that is prominent (Uwakwe, 2012).

2.2. Field Layout and Operations

The experimental field was cleared and laid out in a Randomized Complete Block Design (RCBD) with four treatments and replicated four times (4 x 4 replications). The poultry manure procured from the College Poultry Farm was applied as surface manure and incubated for two weeks before planting of maize was done. The treatment matrix included four blocks of 0 t/ha, 10 t/ha, 20 t/ha and 30 t/ha of the poultry manure applied in each replication. Composite soil sample was collected from the experimental field to determine the initial properties of the studied soil before the beginning of the experiment and at the end of the experiment. Both core and auger samples were collected from each plots, labeled and sent to the laboratory for analysis.

2.3. Soil Parameters Analyzed.

The soil samples were analyzed for the following parameters: Particle Size Distribution was determined using Bouyoucos hydrometer method as described by Gee and Or, (2002). Soil organic matter content was calculated by multiplying Van Bemmelen's factor of 1.724 by organic carbon determined by modified Walkley-Black dichromate digestion method as described by Nelson and Sommers (1996). Volumetric moisture content at 150cm suction (cm^3/cm^3) was determined with a Büchner funnel using suction head method as described by Ouyang et al. (2013). Total porosity was determined using numerical method as outlined by Redding and Devito (2006). Saturated hydraulic conductivity was determined using the constant head method and calculated using Darcy's equation as outlined by Reynolds et al, (2002).A 6 inches double ring infiltrometer was used in the field to determine volumetric infiltration rate (cm^3/s) as described by Kirkham (2005) using the formula:

$V/t = \pi r^2 h/t$ …………(1)

Where: v is the volume of water that infiltrated the soil in cm^3, π is a unit-less constant of value 3.143, r is the radius of the infiltrometer inner ring in cm, h is the recorded depth of infiltrated water in cm and t is the given time in s.

Sorptivity was determined from cumulative infiltration rate as a function of the square root of time as described by Hallett et al. (2004) using the formula:

$$I = S\sqrt{t} \quad \ldots\ldots\ldots\ldots(2)$$

Where: I is the cumulative infiltration rate in cm/s, S is sorptivity in cms-1/2 and t is time in s.

Water repellence was determined as a ratio of soil organic matter and clay content as described by De Bano (2000).

2.4. Statistical Analysis

Data generated were subjected to multiple correlation analyses of variance for Randomized Complete Block Design using Genstat Discovery (2011) Edition 4. Mean separation was done using Duncan's New Multiple Range Test (DNMRT) at 5% level of probability.

3.0. Result and Discussion

The result of the selected hydro-physical properties of the studied soil before land clearing and application of poultry manure are presented in Table 1. From the results, the field is predominantly sandy with sand content of 828.0 gkg-1, silt content of 20.0 gkg-1 and clay content of 152.0 gkg-1. Bulk density was observed to be 1.31 g/cm3. Porosity (50.57%) was observed to be relatively high due to the sandy nature of the field. This agrees with the findings of Enyioko et al, (2017) that sandy soil encourages porosity. The observed organic matter content was 27.30 gkg-1 indicating the soils had high per cent organic matter (> 20.0 gkg-1). 0.0123 cm/s, 0.156 cm/s-1/2, 0.293 cm3/s, 0.153 cm3/cm3and 0.180 were observed for hydraulic conductivity, sorptivity, volumetric infiltration rate, volumetric water content at 150 cm suction and water repellence index respectively.

Table 1: Result of selected hydro-physical properties of the soil before treatment

soil properties	Value
Sand (gkg^{-1})	828.0
Silt (gkg^{-1})	20.0
Clay (gkg^{-1})	152.0
Texture	Sandy loam
Bulk density (g/cm^3)	1.31
Porosity (%)	50.57
Organic matter (gkg^{-1})	27.30
Hydraulic conductivity, ksat (cm/s)	0.0123
Sorptivity ($cm/s^{1/2}$)	0.156
Volumertic infiltration rate (cm^3/s)	0.293
Volumetric moisture content at 150cm suction (cm^3/cm^3)	0.153
Water repellence index	0.180

3.1. Comparison of Selected Hydro-Physical Properties of Soils Applied with Different Rates of Poultry Manure

The results of analysis on the effect of different rates of poultry manure application on selected hydro-physical properties of soils are presented in Table 2. Sand dominated the other fractions in the particle size analysis. The result showed sand had means of 833.0, 803.0, 793.0 and 823.0 gkg-1 among the different rates of poultry manure (0, 10, 20 and 30 /ha respectively). However, sand did not differ significantly (p = 0.05) among the treatment rates. Onweremadu et al. (2011) noted that the sandy nature was a reflection of the coastal plain sand parent materials from which the soils were formed.

The silt was generally low, which could be as a result of high weatherability. This agrees with the findings of Ahn (1993), that the silt content of the soil is dependent on weatherability rate. The silt had percent mean values of 40.0, 40.0, 60.0 and 40.0 gkg-1 for 0, 10, 20 and 30 t/ha treated plots respectively. There was no significant difference (p = 0.05) in silt content among the treatments.

Clay particles recorded means of 127.0, 157.0, 147.0 and 137.0 gkg-1 for 0, 10, 20 and 30 t/ha treated plots respectively. Clay content showed no significant difference (p = 0.05) among the applied treatment rates. This implies that the treatments applied at different rates had no effect on clay percent of the soil under study. Therefore confirming the findings of Agbede et al. (2008), that poultry manure has no effect clay content of soils.

Bulk density had mean values of 1.31, 1.27, 1.17 and 1.06 g/cm3 for 0, 10, 20 and 30 t/ha treated plots respectively, which were lower than the critical limits for root restriction (1.75-1.85 g/cm3), according to Soil Survey Staff, (1996). This shows that bulk density reduced with increasing treatment rates, which is in line with findings of Agbede et al. (2008), that poultry manure reduced the bulk density of soils. However, bulk density was significantly affected (p = 0.05) only in the 30 t/ha poultry manure treated plots. This implies that poultry manure rate < 30 t/ha has no effect on the bulk density of the studied soil.

Porosity values were relatively high, but insignificant at p = 0.05 for all treatments (50.66, 52.26, 55.76 and 60.00% for 0, 10, 20 and 30 t/ha respectively). High porosity could be as a result of low bulk density, hence, agreeing with the relationship between porosity and bulk density according to Ewulo et al. (2008). However, as the treatment rates increased from 0 to 30 t/ha poultry manure application rate, the porosity also increased from 50.66 to 60.00%. This shows that poultry manure improves porosity of soils, which agrees with Wanas and Omran, (2006), who reported that use of poultry manure led to beneficial effect on hydro-physical properties of studied soils such as bulk density and pore size distribution (porosity).

Organic matter values of the treated soils increased in the order of 4.10%>, 4.03%>, 3.61%>, 3.43% for applied rates of 30 t/ha, 20 t/ha, 10 t/ha and 0 t/ha of poultry manure respectively. However, organic matter showed no significant treatment effect at p = 0.05 among the applied treatment rates. This insignificant difference may be attributed to the rate of decomposition of the poultry manure, as suggested by Enyioko et al. (2017), that attributed insignificant treatment effect of straw mulch on organic matter to the rate of decomposition of the straw mulch.

The saturated hydraulic conductivity of the treated soils reduced with increasing treatment application rates in the order of 0.0122 cm/s>, 0.0118 cm/s>, 0.0109 cm/s>, 0.0101 cm/s for 0 t/ha, 10 t/ha, 20 t/ha and 30 t/ha respectively. This indicates that poultry manure reduced the saturated hydraulic conductivity of the studied soils, agreeing with Wanas and Omran, (2006), that reported that use of poultry manure led to beneficial effect on hydraulic conductivity and infiltration rate. However, result revealed that poultry manure had significant influence (p = 0.05) on the saturated hydraulic conductivity of the 20 and 30 t/ha treated plots.

The volumetric water content at 150 cm suction was observed to increase with increasing treatment level. The order of increase was in the trend 0.152 cm3/cm3 <, 0.158 cm3/cm3<, 1.72 cm3/cm3<, 1.91 cm3/cm3 for 0 t/ha, 10 t/ha, 20 t/ha and 30 t/ha treated plots respectively. This result agrees with Ewulo et al. (2008),that reported that moisture content increased as the level of poultry manure application increased. However, result indicated that poultry manure significantly increased (p = 0.05) the volumetric water content of the 20 and 30 t/ha treated plots.

The volumetric infiltration rate shows the volume per time of water infiltration into the soil. The volumetric infiltration rate of the treated soils reduced with increasing treatment rates in the order 0.296 cm3/s>, 0.286 cm3/s>, 0.265 cm3/s>, 0.246 cm3/s for 0, 10, 20 and 30 t/ha applied treatment rates respectively. This reduction in volumetric infiltration rate may be attributed to the improvement in soil organic matter by poultry manure application. The volumetric infiltration rate differed significantly at p = 0.05 among all the treatment rates, implying that poultry manure significantly reduced the volumetric infiltration rate of the soils, therefore agreeing with findings of Jiao et al. (2006) that manure reduces the rate of water that enters the soil.

The sorptivity shows the ability of soil to absorb water. The sorptivity values of the treated soils reduced in the order 0.157 cm/s½>, 0.151 cm/s½>, 0.141 cm/s½>, 0.131 cm/s½ for 0, 10, 20 and 30 t/ha treated plots respectively. The sorptivity showed significant treatment effect (p = 0.05) among all the treated plots. Implying that sorptivity of the soil was significantly reduced by addition of poultry manure. This agrees with the conclusion by Hallett et al. (2004), that poultry manure reduced the ability of soil to absorb water.

Water repellence according to Hallet et al. (2007) shows the ability of soil to repel water. The water repellence index value for plots 0, 10, 20 and 30 t/ha was 0.251, 0.178, 0.248 and 0.269 respectively. The water repellence index was observed to be relatively low (<1) and insignificant at p = 0.05 for all the treatments. The low water repellence index could be as a result of the clay content of the soil.

Table 2: Mean Comparison of Selected Hydro-Physical Properties of Soils Applied with Different Rates of Poultry Manure

Treatment (t/ha)	**0**	**10**	**20**	**30**
Sand (gkg^{-1})	833.0^{a}	803.0^{a}	793.0^{a}	823.0^{a}
Silt (gkg^{-1})	40.0^{a}	40.0^{a}	60.0^{a}	40.0^{a}
Clay (gkg^{-1})	127.0^{a}	157.0^{a}	147.0^{a}	137.0^{a}
Bulk density (g/cm^3)	1.31^{a}	1.27^{a}	1.17^{ab}	1.06^{b}
Porosity (%)	50.66^{a}	52.26^{a}	55.76^{a}	60.00^{a}
Organic matter (gkg^{-1})	34.3^{a}	36.1^{a}	40.3^{a}	41.0^{a}
Hydraulic conductivity, Ksat (cm/s)	0.0122^{a}	0.0118^{a}	0.0109^{b}	0.0101^{c}
Volumetric moisture content at 150cm suction (cm^3/cm^3)	0.152^{c}	0.158^{c}	0.172^{b}	0.191^{a}
Volumertic infiltration rate (cm^3/s)	0.296^{a}	0.286^{b}	0.265^{c}	0.246^{d}
Sorptivity ($cm/s^{1/2}$)	0.157^{a}	0.151^{b}	0.141^{c}	0.131^{d}
Water repellence index	0.251^{a}	0.178^{a}	0.248^{a}	0.269^{a}

Mean values followed by same letter(s) within the same row are not significantly difference at 5% probability level (DNMRT)

3.2. Correlation Matrix of Selected Hydro-Physical Properties of Soil applied with Four Different rates of Poultry Manure

The results of the correlation matrix of selected hydro-physical properties of soils applied with the four different rates of poultry manure are presented in Table 3. The results indicated that the saturated hydraulic conductivity, volumetric infiltration rate and sorptivity were positively influenced (p = 0.01) by bulk density (r = 0.998, r = 0.998 and r = 0.997 respectively) and negatively influenced (p = 0.01) by the treatment (r = -0.989, r = -0.990 and r = -0.994 respectively), porosity (r = -0.997, r = -0.997 and r = -0.997 respectively) and organic matter (r = -0.964, r = -0.964 and r = -0.962 respectively). While the volumetric water content was positively influenced (p = 0.01) by the treatment (r = 0.976), porosity (r = 0.999) and organic matter (r = 0.928). But was negatively influenced (p = 0.01) by bulk density (r = -0.999). The water repellency index on the other hand was observed to be only negatively influenced (p = 0.05) by percent clay content (r = -0.773). These results further agree with findings of Wanas and Omran, (2006). Ewulo et al. (2008), Jiao et al. (2006) and Hallet et al. (2004) which noted that poultry manure can increase the amount of water contained in soils and reduce water absorption and movement into or through soils. The results also confirms the assumption earlier stat-

Table 3: Correlation matrix of selected hydro-physical properties of soils applied with different levels of poultry manure

Correlating Properties	Correlation Coefficient
Treatment vs Sand	-0.283
Treatment vs Silt	0.258
Treatment vs Clay	0.200
Treatment vs Porosity	0.982**
Treatment vs Organic matter	0.967
Treatment vs Bulk Density	-0.982**
Treatment vs Hydraulic conductivity	-0.989**
Treatment vs Volumetric water content	0.976**
Treatment vs Volumetric infiltration rate	-0.990**
Treatment vs Sorptivity	-0.994**
Treatment vs Repellency	0.399

Table 4: Correlation matrix between porosity and hydro-physical properties

Correlating Properties	Correlation Coefficient
Porosity vs Sand	-0.108
Porosity vs Silt	0.175
Porosity vs Clay	0.018
Porosity vs Organic matter	0.940**
Porosity vs Bulk Density	-0.999**
Porosity vs Hydraulic conductivity	-0.997**
Porosity vs Volumetric water content	0.999**
Porosity vs Volumetric infiltration rate	-0.997**
Porosity vs Sorptivity	-0.997
Porosity vs Repellency	0.539

Table 5: Correlation between Org matter and hydo-physical properties

Correlating Properties	Correlation Coefficient
Organic matter vs Sand	-0.400
Organic matter vs Silt	0.488
Organic matter vs Clay	0.187
Organic matter vs Bulk Density	-0.945**
Organic matter vs Hydraulic conductivity	-0.964**
Organic matter vs Volumetric water content	0.928**
Organic matter vs Volumetric infiltration rate	-0.964**
Organic matter vs Sorptivity	-0.962**
Organic matter vs Repellency	0.465

Table 6:

Correlating Properties	Correlation Coefficient
Bulk density vs Sand	0.114
Bulk density vs Silt	-0.194
Bulk density vs Clay	-0.012
Bulk density vs Hydraulic conductivity	0.998**
Bulk density vs Volumetric water content	-0.999**
Bulk density vs Volumetric infiltration rate	0.998**
Bulk density vs Sorptivity	0.997**
Bulk density vs Repellency	-0.550

Table 7:

Correlating Properties	Correlation Coefficient
Hydraulic conductivity vs Sand	0.178
Hydraulic conductivity vs Silt	-0.248
Hydraulic conductivity vs Clay	-0.055
Hydraulic conductivity vs Volumetric water content	-0.994**
Hydraulic conductivity vs Volumetric infiltration rate	0.999**
Hydraulic conductivity vs Sorptivity	0.999**
Hydraulic conductivity vs Repellency	-0.529

Table 8:

Correlating Properties	Correlation Coefficient
Volumetric water content vs Sand	-0.240
Volumetric water content vs Silt	0.144
Volumetric water content vs Clay	-0.008
Volumetric water content vs Volumetric infiltration rate	-0.994**
Volumetric water content vs Sorptivity	-0.993**
Volumetric water content vs Repellency	0.550

Table 9:

Correlating Properties	Correlation Coefficient
Volumetric infiltration rate vs Sand	0.180
Volumetric infiltration rate vs Silt	-0.247
Volumetric infiltration rate vs Clay	-0.064
Volumetric infiltration rate vs Sorptivity	0.999**
Volumetric infiltration rate vs Repellency	-0.521

Table 10:

Correlating Properties	Correlation Coefficient
Sorptivity vs Sand	0.192
Sorptivity vs Silt	-0.233
Sorptivity vs Clay	-0.090
Sorptivity vs Repellency	-0.493

Table 11:

Correlating Properties	Correlation Coefficient
Repellency vs Sand	0.442
Repellency vs Silt	0.191
Repellency vs Clay	-0.773*
Repellency vs Sand	0.442

** = correlation is significant at the 0.01 level, * = correlation is significant at the 0.05 level

ed, that water repellence is influenced by the percent clay content of the soil.

4.0. Conclusion.

The study was carried out to investigate the effect of different rates of poultry manure on water characteristics of Oforola soils. The result of analysis showed that the field was predominantly sandy with mean values of 83.30%, 80.30%, 79.30% and 82.30% for 0, 10, 20 and 30 t/ha respectively. The percent sand, silt and clay all recorded a non-significant difference ($p = 0.05$) among the different rates of poultry manure applied. The soil porosity and organic matter content increased with increase in poultry manure application rate, as well as the volumetric water content which increased significantly ($p = 0.05$) among the 20 and 30 t/ha poultry manure treated plots. Poultry manure significantly reduced ($p = 0.05$) bulk density in the 30 t/ha treated plots and saturated hydraulic conductivity in both the 20 and 30 t/ha treated plots, but significantly reduced ($p = 0.05$) volumetric infiltration rate and sorptivity in all the treated plots. Water repellence was not influenced by the different treatment rates. The result of the correlation reveals that the treatments had positive influence ($p = 0.01$) on porosity ($r = 0.982$), organic matter ($r = 0.967$) and volumetric water content ($r = 0.976$) but negatively influenced ($p = 0.01$) bulk density ($r = -0.982$), saturated hydraulic conductivity ($r = -0.989$), volumetric infiltration rate ($r = -0.990$) and sorptivity ($r = -0.994$). However, water repellence was not influenced ($p = 0.01$) by the treatments but was negatively influenced ($p = 0.05$) by percent clay content of the soil. The result therefore reveals that the selected hydro-physical properties of the soil were generally influenced by the different rates of the poultry manure applied except the water repellence index which was influenced by the percent clay content of the soil.

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