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Effect of Trichoderma inoculated organic manure on water retention characteristics of two texturally contrasting soils in Nsukka, Southeastern, Nigeria.

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Abstract

The effect of Trichoderma inoculated organic manure on water retention characteristics of two texturally contrasting soils was investigated in the glasshouse of the Department of Soil Science, University of Nigeria, Nsukka. The study involved two texturally contrasting soils; sandy loam (SL) and loamy sand (LS) amended with poultry manure (PM) at three rates (10 t/ha, 20 t/ha, and 30 t/ha) and inoculated with Trichoderma at two rates (0 and 10 milliliters) per 4 kg of potting soil. The soil-poultry manure-Trichoderma mixture was watered to field capacity, tied in a black polythene bag, and incubated for 30, 60, and 90 days respectively. Soil samples were collected and analyzed to ascertain how the treatments influenced the soil water retention characteristics (SWRC) and plant available water capacity (PAWC) of the soils. The data obtained were analyzed using GEN STAT. Significant ($P<0.05$) effect of soil texture on PAWC and SWRC at 10 kPa, 33 kPa, and 1500 kPa at 30, 60, and 90 days of incubation were obtained. Generally, the results showed an increasing trend across the three incubation periods; 30 days < 60 days < 90 days. Similarly, the results showed that the different organic manure rates significantly ($p<0.05$) influenced PAWC and SWRCat 10 kPa, 33 kPa, and 1500 kPa at 30, 60, and 90 days of incubation. However, Trichoderma inoculation did not influence PAWC and SWRC of the soils significantly ($P<0.05$) at 10 kPa, 33 kPa, and 1500 kPa after 30, 60, and 90 days of incubation. The study concluded that soil texture and the amount of organic manure influenced PAWC and SWRC especially at 10 kPa, and 33 kPa but to a lesser extent at1500 kPa.

Keywords: incubation; glasshouse; soil water retention; inoculation; plant available water

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1.0 Introduction

Sustainable agricultural productivity in the derived savanna is constrained by soil moisture stress due to changing rainfall patterns and associated soil moisture loss. There is no doubt that soil and water are among the key resources that determine to a great extent the existence and survival of man. Achieving high growth and yield of crops requires optimal nutrients and soil water management as primary factors in the root zone (El-Kholy *et al.,* 2000). The huge dependence of most soil functions on soil water retention signifies their important influence on agricultural productivity and other environmental processes. Therefore, to enhance the long-term supply of ecosystem services, sustainable agricultural productivity, and improve the livelihood of the populace that is dependent on soil and water, there is a need to investigate soil management systems that help the soil to retain water.

In soils, various soil and external attributes influenced the retention capacity and availability of water. For instance, the inherent capacity of soil to retain water mostly depends on specific soil parameters such as; soil texture, soil structure, and soil organic matter (SOM) content(BIO Intelligence Service, 2014). Along with other soil parameters e.g. soil organic matter and texture, soil structure is a key function to manipulate the movement and retention of water in the soil. However, sustaining a good structure by maintaining stable aggregates lies in the organic matter budget of the soil (Metin *et al.,* 2017). The beneficial effects of SOM on soil structure culminates in enhancement in soil water retention and hydraulic conductivity, delays runoff, and reduces erosion. Organic matter increases soil water retention by increasing the number of micropores and macropores in the soil either by "gluing" soil particles together or by creating favorable living conditions for soil organisms. Certain types of soil organic matter can hold up to 20 times its weight in water (Reicosky, 2005). According to Hudson (1994), the available water holding capacity of the soil increases by 3.7% for each 1% increase in soil organic matter. Researchers have also reported an increase in the water retention capacity of soils at field capacity and the wilting point following organic manure addition (da Costa et al., 2013). However, this effect may be largely dependent on the soil texture, the rate of wastes used, the period after wastes application, waste type, and processing method (da Costa *et al.,* 2013). Nath (2014) found a strong positive correlation between water holding capacity and total organic matter and clay contents, but also a strong negative correlation between water holding capacity and sand content.

Soil constitutes the main reservoir of microorganisms, as well as the greatest source of biological diversity. Most fertile soils have a proportion of capillary to non-capillary pores in well-balanced conditions (50:50) and contain a large quantity of various animal, bacterial and other species organisms. Soil's natural soaking ability is affected by its biodiversity given by the presence of a sufficient number of bacterial and other species of organisms in soil (Zemánek, 2011). One of the most abundant groups of organisms in the soil is fungi. *Trichoderma spp* is a fungal genus found in many ecosystems. *Trichoderma spp* are mainly asexual fungi that are present in all types of agricultural soils and decaying wood. The fungus is also a decomposer of cellulosic waste materials and thus is expected to aid the decomposition of organic manures that build soil structure and improve soil water retention. Moreover, as revealed by research in recent decades, some Trichoderma strains can interact directly with roots, increasing plant growth potential, disease resistance, and tolerance to abiotic stresses (Rosa *et al.*, 2012). Shukla (2012) found that *Trichoderma harzianum* significantly increased the ability of rice plants to tolerate drought stress and increase rice water-holding capacity. In other studies (Doni *et al.,* 2014; Thakur *et al*., 2010), reduced transpiration rates and increased water use efficiency were reported for Trichoderma treated rice plants.

Despite these benefits, little or no research has been done to evaluate the effect of this important soil microbe on water retention characteristics of soils. The main objective of this study was to evaluate the effects of Trichoderma inoculated organic manure on the water retention characteristics of two texturally contrasting soils. The specific objectives of this work are to; (i) evaluate water retention characteristics of two texturally contrasting soils (ii) determine the effect of organic manure on water retention characteristics of two texturally contrasting soils and (iii) determine the effect of Trichoderma inoculation on water retention characteristics of two texturally contrasting soils.

2.0 Materials and methods

2.1 Description of the study area

The study was carried out in the glasshouse belonging to the University of Nigeria Teaching and Research Farm in Nsukka, Southeastern Nigeria. Nsukka is located in Enugu State situated in the northern part of southeastern Nigeria and lies between latitude 06°51'N and longitude 07°24'E with an elevation of 447.2 m above sea level. This area is characterized as a derived savannah in the humid tropical climate with two seasons; the wet and dry seasons. The rainy season starts from April to October while the dry season begins from November to March. The rainfall is bimodally distributed with peaks in July and September. There is usually a short break (August Break) in the month of August. The average annual rainfall amount is about 1600 mm and 85% of this takes place within the rainy season. The rainy season is usually a period of high humidity, generally low temperatures, and low evapotranspiration. The average minimum and maximum temperatures are about 22°C and 30°C respectively. The relative humidity rarely falls below 60% (Asadu, 2002). The soils of the area have a high percentage of sand and granular structure at the top and the topsoil is characterized by rapid to very rapid permeability (Obi and Asiegbu, 1980). The soil is a Ultisol that belongs to the Nkpologu series (Nwadialo, 1989). The soil is very deep, dark-reddish brown at the top layer and reddish in the subsoil. It is coarse to medium sandy loam, acid in reaction, and low in nutrient status. Its clay mineralogy is composed mainly of kaolinite and quartz.

2.2 Procurement of soil and poultry manure

Two soils of different textural classes were collected from Ekwegbe in Igbo-Etiti and the University of Nigeria Teaching and Research Farm in Nsukka. The two soils were taken to the laboratory for particle size distribution using the hydrometer method as described by Gee and Or (2002) to determine their textural classes (Table 1). The result showed that the textural classes of the soils were loamy sand (LS) and sandy loam (SL). The loamy sand had the highest sand content (864 g kg^{-1}) but lower silt content of 33 g kg^{-1}compared to sand and silt contents of 564 g $kg^{-1}$and 333 g kg^{-1}respectively for the sandy loam. The result showed that the clay content of the two soils was low and similar to a value of 103 g kg^{-1}.

Poultry manure was obtained from the poultry farm of the Department of Animal Science, University of Nigeria Nsukka.

Table 1: Particle size distribution of the experimental soils

Soils	Coarse sand (g/kg)	Fine sand (g/kg)	Total sand (g/kg)	Silt (g/kg)	Clay (g/kg)	Textural class
Nsukka	267	329	864	33	103	Loamy sand
Ekwegbe	119	445	564	333	103	Sandy loam

2.3 Experimental Procedure.

The study involved three factors; soil texture (sandy loam, loamy sand), Trichoderma inoculation rate (0 and 10 millimeters), and rates or levels of poultry manure applications (10 tha^{-1}, 20 tha^{-1}, 30 tha^{-1}). The soils and poultry manure used for the study were air-dried, crushed, and passed through a 2 mm sieve. Thereafter, 4kg of the soils were weighed into three sets of thirty-six (36) pots given a total of one hundred and eight (108) pots. The soil was mixed with 10 tha^{-1}, 20 $tha^{-1}$and 30 tha^{-1} respectively of poultry manure (PM). Eighteen of these pots were inoculated with Trichoderma using a 10 ml syringe while 18 of the remaining pots were left without Trichoderma inoculation. The soil-Trichoderma-organic manure mixture in the pots was watered to field capacity and incubated with airtight black polythene bags. The experiment was a 2x2x3 factorial in a completely randomized design (CRD) with three replications giving a total of thirty-six experimental units. The incubation experiment lasted for 30 days, 60 days, and 90 days resulting in three sets of thirty-six experimental units and a total of 108 experimental units in all.

2.4 Soil sampling

At the end of each incubation period, soil samples were collected from the pots, carefully labeled, and processed for laboratory analysis.

2.5 Determination of Soil water retention characteristics

The soil water retention characteristics (SWRC) at 10 kPa (0.3 bar), 33 kPa (1 bar), and1500 kPa (15 bar) were determined on soil samples using the 08.03 pressure plate membrane apparatu**s or** sandbox method (Eijkelkamp Agrisearch Equipment, Giesbeek, The Netherlands) in three replicates. The sand/kaolin box method is a standard method for measuring the pF curves, also called soil water retention curves, in a large soil moisture range from saturation (0 kPa or pF 0) to a dry state corresponding to an applied pressure of near 1500 kPa or pF 4.2. For the measurements, the core cylinders with a diameter of 3.5 cm and a height of 5 cm were placed on two sheets of nylon cloth and two sheets of cellophane, which have been saturated with tap water, by avoiding any air inclusion. We assumed equilibration when water drainage through the outlet had ceased usually lasting at least 4 days. Plant available water (PAWC) was calculated as the difference between water retention at 10 kPa i.e. field capacity (FC) and water retention at 1500 kPa i.e. permanent wilting point (PWP) according to Romano and Santini (2002).

PAWC = FC - PWP

2.6 Statistical Analysis

Data generated from the experiment were subjected to analysis of variance (ANOVA) appropriate for a factorial experiment in a completely randomized design (CRD) using Genstat Discovery Software, Edition 4. Means for the main effects of soil texture, poultry manure, and Trichoderma inoculation on soil water retention characteristics and plant available water capacity were compared for significant differences using the Fischer's least significant difference (F-LSD) procedure as described by Obi (2002). Differences were accepted at $P \leq 0.05$.

3.0 Results

3.1 Effect of soil texture, poultry manure rate, and Trichoderma inoculation soil water retention characteristics (SWRC)and plant available water capacity (PAWC)at 30, 60, and 90 days of incubation.

Results in Table 2 showed a significant ($P < 0.05$) effect of soil texture on soil water retention characteristics (SWRC) and plant available water capacity (PAWC) at 30, 60, and 90 days of incubation. The result showed that water retention at 10 kPa, 33 kPa, and 1500 kPa was highest in sandy loam soil but lowest in loamy sand soil at 30, 60, and 90 days of incubation. Similarly, the result showed that PAWC was highest in sandy loam soil whereas loamy

Table 2: Main effect of soil textural type on soil water retention characteristics (SWRC) and plant available water capacity (PAWC) at30, 60, and 90 days of incubation.

Soil texture	10 kPa	33 kPa	1500 kPa	PAWC
		30 DAYS OF INCUBATION		
LS	18.06	13.07	13.33	4.73
SL	20.55	15.53	13.76	6.79
$LSD_{0.05}$	**1.56**	**1.48**	**1.8**	**1.33**
		60 DAYS OF INCUBATION		
LS	17.62	14.08	12.73	4.89
SL	19.66	16.97	13.02	6.64
$LSD_{0.05}$	**1.76**	**1.77**	**2.51**	**1.08**
		90 DAYS OF INCUBATION		
LS	16.69	14.23	12.12	4.57
SL	19.80	17.74	13.53	6.27
$LSD_{0.05}$	**2.81**	**2.12**	**1.89**	**1.22**

LS = loamy sand, SL= sandy loam.

sand soil consistently showed lower values of PAWC at 30, 60, and 90 days of incubation.

Table 3 showed the effect of Trichoderma inoculation on soil water retention characteristics SWRC) and plant available water capacity (PAWC) at 30, 60, and 90 days of incubation. The results showed a non-significant (P<0.05) effect of Trichoderma inoculation on SWRC at 10 kPa, 33 kPa, and 1500 kPa and PAWC at 30, 60, and 90 days of incubation.

Table 3: Main effect of Trichoderma inoculation on soil water retention characteristics (SWRC) and plant available water capacity (PAWC) at 30, 60, and 90 days of incubation.

Trichoderma	10 kPa	33 kPa	1500 kPa	PAWC
30 DAYS OF INCUBATION				
Inoculation	13.69	9.98	6.89	6.80
No-inoculation	13.92	10.63	7.20	6.72
$LSD_{0.05}$	NS	NS	NS	NS
60 DAYS OF INCUBATION				
Inoculation	13.41	10.08	7.58	5.83
No-inoculation	13.86	10.97	8.17	5.69
$LSD_{0.05}$	NS	NS	NS	NS
90 DAYS OF INCUBATION				
Inoculation	13.83	11.35	8.63	5.20
No-inoculation	12.67	9.62	7.01	5.66
$LSD_{0.05}$	NS	NS	NS	NS

Table 4 showed the main effect of organic manure application rates on soil water retention characteristics (SWRC)and plant available water capacity (PAWC)at 30, 60, and 90 days of incubation. The result showed a significant (P<0.05) effect of poultry manure (PM) application rate on SWRC at 10 kPa, 33 kPa, and 1500 kPa. Generally, SWRC increased with the increasing rate of poultry manure (PM) application (Table 4).

Table 4: Main effect of poultry manure application rate on soil water retention characteristics (SWRC) and plant available water capacity (PAWC) at 30, 60, and 90 days of incubation

PM	10 kPa	33 kPa	1500 kPa	PAWC
30 DAYS OF INCUBATION				
10t ha^{-1}	13.37	11.98	7.22	6.15
20t ha^{-1}	15.38	12.51	7.85	7.53
30t ha^{-1}	17.66	14.42	8.07	9.59
$LSD_{0.05}$	**1.8**	**1.69**	**0.75**	**1.74**
60 DAYS OF INCUBATION				
10t ha^{-1}	12.52	9.93	6.39	6.13
20t ha^{-1}	14.82	11.80	8.27	6.55
30t ha^{-1}	16.58	13.85	9.47	7.11
$LSD_{0.05}$	**1.51**	**1.23**	**0.55**	NS
90 DAYS OF INCUBATION				
10t ha^{-1}	12.15	9.57	6.55	5.60
20t ha^{-1}	13.81	10.14	7.01	6.80
30t ha^{-1}	14.79	11.75	8.90	6.89
$LSD_{0.05}$	**1.21**	**1.2**	**0.45**	NS

Note: PM = poultry manure

It was only at 30 days of incubation that the result showed a significant ($p<0.05$) effect of PM rate on PAWC.

3.2 Interaction effect of soil texture and Trichoderma inoculation on soil water retention characteristics (SWRC) and plant available water capacity (PAWC) at 30, 60, and 90 days of incubation.

Table 5 showed the interaction effect of soil textural type and Trichoderma inoculation status on SWRC and PAWC at 30, 60, and 90 days of incubation. The results showed that the interaction of soil textural type with or without Trichoderma has no significant ($p<0.05$) effect on SWRC throughout the incubation periods. However, the interaction of soil textural type and Trichoderma inoculation had a significant ($p<0.05$) effect on PAWC at 30 days of incubation only.

Table 5: Interaction effect of soil textural type and Trichoderma inoculation on soil water retention characteristics (SWRC) and plant available water capacity (PAWC) at 30, 60, and 90 days of incubation

Soil texture	Trichoderma	10 kPa	33 kPa	1500 kPa	PAWC
		30 DAYS OF INCUBATION			
LS	Inoculation	18.33	16.16	13.00	5.33
	No-inoculation	17.79	14.98	12.67	5.12
SL	Inoculation	19.06	16.80	13.78	5.28
	No-inoculation	20.05	18.27	13.74	6.31
$LSD_{0.05}$		**NS**	**NS**	**NS**	**0.51**
		60 DAYS OF INCUBATION			
LS	Inoculation	18.08	15.07	12.19	5.89
	No-inoculation	17.16	13.09	12.27	4.89
SL	Inoculation	18.75	16.09	12.96	5.79
	No-inoculation	19.56	17.85	13.08	6.48
$LSD_{0.05}$		**NS**	**NS**	**NS**	**NS**
		90 DAYS OF INCUBATION			
LS	Inoculation	16.10	14.38	11.90	4.20
	No-inoculation	15.28	12.09	10.34	4.94
SL	Inoculation	17.56	15.32	12.36	5.20
	No-inoculation	18.07	16.16	12.69	5.38
$LSD_{0.05}$		**NS**	**NS**	**NS**	**NS**

LS: loamy sand, SL: sandy loam

Table 6 showed the interaction effect of soil textural type and poultry manure rate on SWRC and PAWC at 30, 60, and 90 days of incubation. At 30 days of incubation, the interaction of soil texture and poultry manure significantly ($p<0.05$) affected SWRC at 10 kPa, 33 kPa, and PAWC. The highest SWRC for both soil textural types was obtained with a 30 t ha^{-1}poultry manure application rate. At 60 days of incubation, the result showed a non-significant ($p<0.05$) soil texture-poultry manure interaction effect on SWRC. At 90 days of incubation, SWRC was significantly ($p<0.05$) influenced by the interaction of soil textural type and poultry manure at 10 kPa only. The highest SWRC for both soil textural types was obtained with 30t ha^{-1} of poultry manure application rate while the lowest SWRC for both soil textural types was obtained with 10t ha^{-1} of poultry manure application rate.

Table 6: Interaction effect of soil textural type and poultry manure application rate on water retention characteristics and plant available water capacity (PAWC)at different tension after 30, 60, and 90 days of incubation

Soil type	PM Rate	10 kPa	33 kPa	1500 kPa	PAWC
		30 DAYS OF INCUBATION			
LS	10t ha^{-1}	15.75	11.52	8.41	7.34
	20t ha^{-1}	15.94	11.67	9.18	6.76
	30t ha^{-1}	16.48	12.53	9.41	7.07
SL	10t ha^{-1}	17.99	15.43	10.02	7.97
	20t ha^{-1}	18.83	15.86	10.52	8.31
	30t ha^{-1}	19.83	16.31	10.73	9.10
LSD$_{0.05}$		**2.09**	**1.96**	**NS**	**1.22**
		60 DAYS OF INCUBATION			
LS	10t ha^{-1}	15.05	11.71	8.65	6.40
	20t/ha	15.11	11.95	8.93	6.18
	30t/ha	15.69	12.59	9.36	6.33
SL	10t/ha	15.98	12.15	9.13	6.85
	20t/ha	16.52	13.66	10.06	6.46
	30t/ha	17.46	14.11	10.34	7.12
LSD$_{0.05}$		**NS**	**NS**	**NS**	**NS**
		90 DAYS OF INCUBATION			
LS	10t/ha	14.96	10.40	8.38	6.58
	20t/ha	15.01	10.89	8.49	6.52
	30t/ha	15.21	11.81	9.07	6.14
SL	10t/ha	15.34	11.75	9.03	6.31
	20t/ha	15.72	12.39	9.52	6.20
	30t/ha	16.38	13.39	10.33	6.05
LSD$_{0.05}$		**1.81**	**NS**	**NS**	**NS**

LS=loamy sand, SL=sandy loam, PM = poultry manure

Table 7 showed the interaction effect of Trichoderma inoculation and poultry manure application rate on soil water retention characteristics (SWRC) and plant available water capacity (PAWC) at 30, 60, and 90 days of incubation. At 30 days of incubation, a significant ($p<0.05$) interaction effect of Trichoderma inoculation and poultry manure application rates on SWRC at 33 kPa and 1500 kPa, and PAWC was observed. 10 t ha^{-1}of poultry manure with or without Trichoderma inoculation gave the highest SWRC at 33 kPa. At 1500 kPa, 10 t ha^{-1} of poultry manure gave the highest water retention with Trichoderma inoculation while 20 t ha^{-1} of poultry manure gave the highest water retention without Trichoderma inoculation. Similarly, PAWC was highest at 10 t ha^{-1} of poultry manure application with Trichoderma inoculation and 30 t ha^{-1} of poultry manure application rate without Trichoderma inoculation. At 60 days of incubation, a significant ($p<0.05$) interaction effect of Trichoderma inoculation and poultry manure on PAWC and SWRC at 10, 33, and 1500 kPa was observed. The highest SWRC across all tensions was obtained at 30 t ha^{-1} of poultry manure application with Trichoderma inoculation while the highest SWRC across all tensions was obtained at 20 t ha^{-1}of poultry manure application without Trichoderma inoculation. However, the result showed that 20 t ha^{-1} of poultry manure with Trichoderma inoculation and 30 t ha^{-1}of poultry manure without Trichoderma inoculation gave the highest PAWC. Similarly, at 90 days of incubation, a significant ($p<0.05$) interaction effect of Trichoderma inoculation and poultry manure on SWRC at 10 and 1500 kPa and PAWC was observed. The result showed that the application of 30 t ha^{-1}of poultry manure with and without Trichoderma inoculation respectively gave the highest SWRC values at 10, 33, and 1500 kPa. Also, the result showed that 20 t ha^{-1} of poultry manure application with Trichoderma inoculation and 30 t ha^{-1} without Trichoderma inoculation gave the highest PAWC.

Table 7: Interaction effect of Trichoderma inoculation and poultry manure application rate on soil water retention characteristics (SWRC) and plant available water (PAWC) at 30, 60, and 90 days of incubation

Trichoderma	PM Rate	10 kPa	33 kPa	1500 kPa	PAWC
		30 DAYS OF INCUBATION			
Inoculation	10t/ha	11.92	8.49	5.56	6.36
	20t/ha	12.35	9.49	6.37	5.98
	30t/ha	12.81	9.96	6.73	6.08
No-inoculation	10t/ha	13.82	10.46	5.87	7.95
	20t/ha	13.42	10.54	6.33	7.09
	30t/ha	14.50	11.88	6.41	8.09
$LSD_{0.05}$		**NS**	**1.33**	**0.52**	**1.03**
		60 DAYS OF INCUBATION			
Inoculation	10t/ha	10.26	9.85	6.78	3.48
	20t/ha	11.68	10.26	6.58	5.10
	30t/ha	12.31	11.14	7.38	4.93
No-inoculation	10t/ha	11.78	10.01	7.00	4.78
	20t/ha	12.95	11.35	7.96	4.99
	30t/ha	14.85	12.56	8.57	6.28
$LSD_{0.05}$		**1.02**	**1.09**	**1.05**	**1.12**
		90 DAYS OF INCUBATION			
Inoculation	10t/ha	10.82	9.09	6.21	4.61
	20t/ha	11.23	9.20	6.81	4.42
	30t/ha	11.44	9.75	6.87	4.57
No-inoculation	10t/ha	11.47	10.06	6.90	4.57
	20t/ha	13.72	11.07	7.21	6.51
	30t/ha	14.38	11.75	7.93	6.45
$LSD_{0.05}$		**0.74**	**NS**	**0.46**	**0.99**

PM = poultry manure

4.0 Discussion

The results showed a significant ($P<0.05$) effect of soil texture on water retention characteristics and plant available water capacity (PAWC) of the soils investigated at 30, 60, and 90 days of incubation. This could be attributed to the differences in texture; the proportion of the particles of sand, silt, and clay contents of the soils. Da Costa *et al.* (2013) also reported significant differences in soil moisture retention and availability for soils of different textures. The consistently higher soil water retention characteristics (SWRC) at 10 kPa, 33 kPa, and 1500 kPa and PAWC obtained in sandy loam soils compared to the loamy sand soil could be attributed to the fact that soil texture determines the pore size distribution in the soil to a great extent and consequently, plant available water (O'Geen;2013). According to O'Green (2013), coarse-textured soils have the lowest PAWC because they contain large pores with limited ability to retain water while loamy textured soils have the highest PAWC because they contain a wide range of pores that favors high water retention. This assertion of O'Green (2013) is consistent with the result presented in this study. Moskal *et al.* (2001) also reported significantly higher values of water retention at 10 kPa (0.01 MPa) and 1500 kPa (1.5 MPa) respectively for sandy loam soils compared to loamy sand and sand. From the result of this study, the higher content of silt and lower sand content of sandy loam soil compared to the loamy sand soil may have accounted for the differences observed in their SWRC and PAWC. According to Davis and Wilson (2005), silt and clay have high water retention capacity or ability than sand. Similarly, this result showed a significant ($P<0.05$) effect of poultry manure application on soil water retention characteristics and plant available water capacity. The result corroborates the findings of Obi and Ebo (1995) who reported significant improvement in water retention at low tensions between 0.1 and 0·33 bar as well as available water capacity following organic manure application. Similarly, Cercioglu *et al*. (2014) reported that the addition of organic wastes such as chicken manure resulted in a significant increase in field capacity (FC), wilting point (WP), and available water content (AWC) of soils when compared to the control. According to Rawls *et al*. (2003), organic matter promotes an increase in water retention, regardless of the soil texture. Da Costa *et al*. (2013) also admitted that the cause of the greater water retention may be associated with the high OM content observed in the soils. Kukal *et al*. (2012) also reported significant improvement in the water holding capacity and retention even at high suction following the application of the organic amendment. According to Kukal *et al*. (2012), the improvement may be attributed to the restricted movement of water from subsurface to surface causing reduced evaporation. Generally, the results of this study showed that SWRC tends to increase with an increase in the amount of poultry manure applied irrespective of soil texture. This result corroborates the findings of other researchers (e.g. Wall and Heiskanen,2003; Saxton and Rawls, 2006; Singer *et al*., 2006; Margulies, 2012) who reported a positive correlation between increasing organic matter content with improvement in the capacity of soils to store water, and in particular plant available water irrespective of the texture considered. The increase in water retention characteristics of the soils with an increase in the amount of poultry manure applied could also be attributed to the high-water adsorption capacity of poultry manure as organic material. According to Blanco-Canqui and Lal (2007), decomposed organic materials possess a greater specific surface area and thus adsorb more water than inorganic soil particles. Bhogal *et al.*(2009) also reported that the organic carbon input from organic manure increased plant available water capacity from 14.3 to 28.9%. However, such an increase in PAWC with an increase in poultry manure application and consequently SOM favors coarse-textured soils than fine-textured soils, and soils low in initial organic matter content (BIOIS, 2014). The non-significant effect of Trichoderma inoculation on PAWC and SWRC at 10 kPa, 33 kPa, and 1500 kPa may be attributed to the low quantity or concentration of Trichoderma used in this study.

5.0 Summary and Conclusions

The study investigated the effect of microbial inoculated organic manure on soil water retention characteristics (SWRC) and plant available water capacity (PAWC) of two texturally contrasting soils in southeastern Nigeria. The study involved two texturally contrasting soils mixed with poultry manure at 10 tha^{-1}, 20 t $ha^{-1}$and 30 t $ha^{-1}$with or without Trichoderma inoculation, and thereafter incubated for 30, 60, and 90 days respectively. The results showed a significant effect of soil texture and the rate of poultry manure application on SWRC at 10 kPa, 33 kPa, and 1500 kPa, and PAWC of the soils at 30, 60, and 90 days of incubation. Similarly, the results showed that SWRC and PAWC increased with the increasing rate of poultry manure application irrespective of the texture. However, the study showed that Trichoderma inoculation did not make any significant contribution to SWRC and PAWC of the soils. However, its association with plant roots may enhance root water uptake. The study concluded that the texture of the soil and the quantity of organic manure applied influenced the SWRC and PAWC. Further studies focusing on increasing the quantity of Trichoderma inoculation and the mechanism of enhancing root water uptake is therefore recommended.

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