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Influence of Poultry Manure on Aggregate Stability and Infiltration Rates of a Disturbed Sandy Loam Soil

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Abstract
An evaluation of soil aggregate stability and infiltration rate is significant in the assessment of soil management practice. The objective of this study was to evaluate the influence of poultry manure on aggregate stability and infiltration rate on a disturbed sandy loam soil of Bauchi. Poultry manure was applied at 0, 10, 15, 20, and 25 Mg/ha at three replications in a completely random design. Four weeks after, aggregate stability and infiltration rates were determined by wet sieving method and double ring infiltrometer respectively. Treatment levels showed an increase in aggregate stability of the soil by mean weight diameter (MWD) indices from 0.337mm (control) to 0.473 – 0.934mm (for 10 – 25Mg/ha treatments).Infiltration rates also showed a significant increase as the manure was added from 1.3mm/min for the control plot, to 2.7 – 3mm/min for 10 – 25 Mg/ha treatment levels respectively. The results also indicates that application of poultry manure did significantly ($P < 0.05$) affects aggregate stability and infiltration as determined by ANOVA. It was then concluded that poultry manure was effective in increasing soil aggregate stability and infiltration rates, but decreasing bulk density from 1.35g/cm^3 for control plot to 1.33 – 1.25 g/cm^3 for 10 – 25M g/ha treatment levels in the tillage zones.
Keywords: – Aggregate stability, Poultry manure, Infiltration rates, Treatment levels, Sandy Loam and Bulk density.

INTRODUCTION

Restoring the native vegetation is the most effective way to regenerate soil health. Under these conditions, vegetation cover in areas having degraded soil may be better sustained if the soil is amended with an external source of organic matter (Paloma, et al., 2016). The addition of organic material to soils also increases infiltration rates and reduces erosion rates (Paloma, et al., 2016).Soil organic matter is important in maintaining soil structural stability, aiding the infiltration of air and water, promoting water retention and reducing erosion (Li, et al., 2007).

Soil aggregate stability is one of the main factors controlling topsoil crushability and erodibility.The most important soil properties influencing structural stability are texture and organic matter content (Le Bissonmais, 1996). Intensive agricultural production is known to cause a decline in soil organic matter content, that leads to the alteration of soil structural stability. The addition of exogenous organic matter generally results in the improvement in the soil organic matter content and soil stability (Metzger, et al., 1987).The effects observed on aggregate stability vary with the characteristic of both exogenous organic matter content and the soil. Organic matter increases aggregate stability by enhancement of aggregate hydrophobicity and the inter – particle cohesion. Hydrophobic compound diminish the rate of aggregate wetting, while microbial activity influences both aggregate properties (Lynch and Bragg, 1985).

Aggregate analysis is often used in experiments where various tillage methods are applied and then evaluated by examining the resulting stable aggregates. Because of their direct relation to cohesive force, aggregate size and stability are important to understanding soil erosion and surface sealing. Analysis of dry aggregates may be used to estimate possible wind erosion effects, while wet analysis may be more appropriate to evaluate or predict erosion due to rainfall impact and runoff. The stability of wet aggregates can be related to surface seal development and field infiltration, as water stable fraction may restrict water entry from the surface seals (Loch, 1994).Aggregate analysis may aid us to understand most aspect of soil water behavior, including runoff, infiltration and redistribution as well as soil aeration and root growth. Increasingly, aggregate properties are being used in models that predict soil hydraulic properties, including water retention and unsaturated hydraulic conductivity (Kosugi and Hopmans, 1998).

Poultry manure contains nutrient elements that can support crop production and enhance the physical and chemical properties of the soil. It increases the moisture holding capacity of the soil and improves lateral water movement and decrease general doughtiness of sandy soil (Amanullah, et. al., 2010). Ravikumar and Krishamoorthy, (1983), observed that poultry manure application at 10 t/ha improves the physical properties of soil. Soil physical properties such as bulk density, water holding capacity and percent water stable aggregation were noted to be favorably influenced by poultry waste addition to soil. Mbagwu, (1992) reported that poultry manure significantly decrease bulk density and increase total macro porosity, infiltration capacity and available water capacity.

Most soils are vulnerable to compaction, crusting and erosion because of their low organic matter status and unstable aggregates (Mosaddeghi, et. al., 2009). The objectives of this study is to determine the influence of different level of poultry manure application on aggregate stability and infiltration rates on a disturbed sandy loam soil in Bauchi state, northeastern Nigeria

Materials and Methods

Field site description and manure

The field experiment was conducted at the research and teaching farm of the Agricultural and Bioresource Engineering Department, ATBU, Bauchi (10o 16 56.1 N, 9o 47 54.1 E), located within Sahel/Sudan vegetation zone of Nigeria. The mean maximum temperature ranges between 20 – 29.3o, while the mean relative humidity and rainfall are between 80 – 90% and 950 -1000mm respectively. The soil type is sandy loam.

The poultry manure was collected from smallholder poultry (layer and broiler) farmers within Bauchi metropolitan area. The poultry manure has a high content of litter, which resulted from accumulation of poultry dropping getting mixed up with the litter (sawdust, rice husk wood shavings and straws).

Experimental Procedure

The experimental design was a randomized complete block (RCB) design with three replication (blocks) and five manure treatment level (application rate). The treatment levels include; control – No manure, 10Mg/ha, 15Mg/ha, 20Mg/ha and 25Mg/ha respectively. All the experimental plots were tilled using a hand hoe. After the application of the poultry manure to each plot according to the treatment level, it was then irrigated and allowed to achieve compaction for a period of 30 days.

Soil Sampling

Soil samples for aggregate stability were obtained after the 30 day elapsed in February, 2016. A 5Kg composite air – dry sample (three subs – sample per plot) were taken from the top 20cm of the soil for mean weight diameter (MWD) determination.

Aggregate Stability Test

Water stable aggregate stability was measured using Yoder wet sieving machine, and sieves used had diameters of 4, 2.1, 0.5, 0.25 and 0.053mm. For each field sample triple analysis was undertaken on 100g sub – samples. The sub – samples were spread on the top most sieve of the nest and were oscillated vertically in distilled water for 10minutes. The fractions remaining on the sieve was oven dried at 105ºC for 24 hours, weighed and corrected for sand to obtain the proportion of the true soil aggregates. The mean size of aggregate denoted d_1 to d_5 retained by each sieve was computed and the MWD of the soil samples was then computed according to Nyamangara et al., (2001) as

$$MWD = \sum_{i=1}^{5} di\ Wi \quad (1)$$

Where, MWD is Mean weight diameter (mm), di is diameter of the ith size fraction and Wi is proportion of the total weight sample occurring in the ith fraction.

Field Infiltration Measurements

The experimental plots was divided into three strips at an equal interval and marked. The infiltration test was carried out at the marked points. Infiltration measurement was conducted using a double ring infiltrometer. The infiltrometer was driven into the soil to a depth of 10cm and a measuring tape was fixed inside the inner cylinder from were readings were taken. Readings were taken at intervals to determine the amount of was water infiltrated during the time intervals with an average infiltration head of 5cm sustained. The infiltration rate was then computed as;

$$Ir = I/t \quad (2)$$

Where, Ir is infiltration rate (mm/min), I is infiltration (mm) and t is time (minute)

Statistical Analysis

The statistical analysis used in this study was descriptive statistics and analysis of variance (ANOVA) in accordance with SPSS software to determine the effect of poultry manure on soil aggregate stability and infiltration rate. Mean separation using least significant difference (LSD) at $P \leq 0.05$ was conducted to indicate significant F – value.

Results and Discussion

Aggregate stability

The soil aggregate stability index (MWD) was observed to be sensitive to change in soil organic (poultry manure) matter content. The MWD for the aggregate of the control plot of 0.337mm was significantly increased as the level of manure application rate increases from 10 – 25Mg/ha to 0.473 – 0.934mm (Table 1). These results indicates an improvement in the structural stability of the sandy loam soil, which correspond to Martens and Frankenberger, (1992) report, which observed a 22% of increase in aggregate stability with the application of 25Mg/ha of poultry manure on an irrigated Arlington soil. Similarly, Metzger, et al.,(1987) states that addition of exogenous organic matter generally results in the improvement in soil organic matter content and soil stability. The bulk density of the soil was observed to decrease as poultry manure was amended with the soil with 1.35g/cm3 for the control plot to 1.33 – 1.25g/cm3 for treatment of 10 – 25Mg/ha (Table 1). Mbagwu, (1992) reports that poultry manure significantly decreased the bulk density and increased total and macro porosity, infiltration capacity and available water capacity. Also, Agbede et, al., (2008) states that poultry manure significantly reduces soil bulk density and temperature and increase total porosity and moisture content in Nigerian soils. In determining the relationship between poultry manure and aggregate stability of sandy loam soil, Table 2 indicates that the application of poultry manure at different treatment levels has significant ($P \leq 0.05$) effect on aggregate stability of the soil. However, Elwell, (1986) reported that a strong relationship exist between soil organic carbon (C) and water stable aggregates (MWD).

Table 1. Means of Bulk density, Mean Weight Diameter and Infiltration Rates.

Treatment Level	Bulk Density	MWD	Infiltration Rate
Mg/ha	g/cm^3	mm	mm/min.
0	1.35	0.337	1.30
10	1.33	0.473	2.70
15	1.31	0.639	3.00
20	1.28	0.672	2.70
25	1.25	0.934	2.50

Table 2. ANOVA on Effect of Poultry Manure on Aggregate Stability.

Source of Variation	SS	df	MS	F	Sig.
Between Groups	0.609	4	.152	1.522E5	.000
Within Groups	0.000	10	.000		
Total	0.609	14			

Infiltration rate

Table 3 shows the results of infiltration rates for the sandy loam soil at various levels of poultry manure treatments. It was observed that the infiltration of water into the soil increased significantly as poultry manure was amended with the soil. The mean infiltration rate for the control plot of 1.3mm/min increases to 2.7 – 3.0 mm/min for the treatment levels. The result was clearly illustrated in figure 1. Martens and Frankenberger, (1992) reported an increase in infiltration rates, resulting from applications of organic materials, while the application of animal manure to the surface 130mm of soil was effective in increasing water infiltration as were the rooting system of cover crops. Ravikumar and Krishamoorthy, (1983) reported that soil physical properties such as bulk density, water holding capacity and water stable aggregation were noted to be favorably influenced by poultry waste addition to the soil. Similarly, Mbagwu (1992) reports that poultry manure increase infiltration capacity and available water capacity. Table 4 indicates that poultry manure application to soil has a significant ($P \leq 0.05$) influence on the soil infiltration. Martens and Frankenberger (1992) in their study showed that infiltration rates were increased more by decreased bulk density in the tillage zone and influenced less by increased aggregate stability.

Table 3 ANOVA on Effect of Poultry Manure on Infiltration Rate.

Source of Variation	SS	df	MS	F	Sig.
Between Groups	5.256	4	1.314	6.317	.008
Within Groups	2.080	10	.208		
Total	7.336	14			

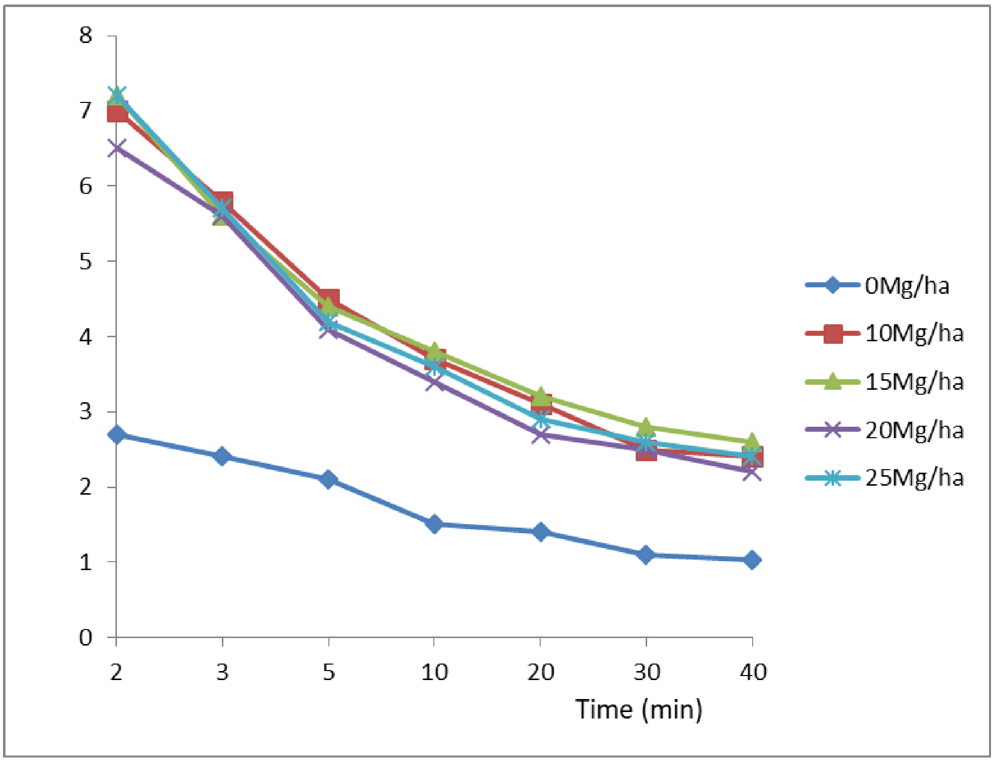

Fig. 1: Infiltration Rates Curves of the Sandy loam Soil under Different Manure Applications.

Conclusions

In this study, poultry manure improved the aggregate stability and infiltration rates of the disturbed sandy loam soil as indicated from the results obtained. Poultry manure can effectively be used to enhance physical fertility of soils with low organic matter. Hence, from the study, it can be conclusively stated that application of poultry manure at different levels of treatment restores soil structure by increasing its size aggregates and infiltration, as well decreasing bulk density. However, the application of poultry manure shows significant positive influence on soil physical properties (i.e. aggregate stability, infiltration rate and bulk density).

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