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Research Article

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Effect of Compaction, Moisture Content and Cow Dung on Saturated Hydraulic Conductivity and Penetration Resistance of a Sandy Loam Soils of Maiduguri

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Abstract Hydraulic conductivity is one of the soil properties that determine the flow of water under hydraulic gradient. Laboratory experiment was conducted using soil samples collected from University of Maiduguri Teaching and Research farm to investigate the effect of compaction, moisture content and rate so organic matter incorporation on saturated hydraulic conductivity of a sandy loam soils. The organic matter used is cow dung at vary ingrates (2%, 4% and 6%) moisture content also were raised to 2%, 4% and 6% for compaction. The samples were subjected to four level so compaction (0, 5, 10 and 15 blows using proctor hammer). Thirty six (36) treatments were obtained and laid in a CRD. Penetration resistance was determined using penetrometer and saturated hydraulic conductivity was determined using falling head penetrometer method after compaction. The result of the study indicated that there is a great potential for using organic matter to alleviate the problem of soil compaction, more importantly, the use of cow dung which shows a significant effect on compaction with a maximum saturated hydraulic conductivity (1.8x10-3cm/s). Therefore, the use of cow dung at varying rates can amelio rate the effect of compaction on saturated hydraulic conductivity and penetration resistance.
Keywords Saturated Hydraulic Conductivity, Compaction, Penetration Resistance Organic Matter

Introduction

Knowledge of variability of soil physical properties can assist in defining the best strategies for a sustainable soil management through the provision of vital information for estimating soil susceptibility to erosion; hydrological modelling and efficient planning of irrigation projects [1]. Soil properties such as texture and structure strongly influence water movement within the soil. Saturated hydraulic conductivity depends strongly on soil texture and structure and therefore can vary widely in space [2]. Soil hydraulic conductivity is a measure of soil's ability to transmit water. It is influenced by some soil physical properties and chemical properties and is needed for the study of infiltration, drainage, irrigation and solute movement. Also, it is a key parameter for monitoring of soil and water management [3]. Knowledge of the rate of water permeability through soil types is essential for determining the type of plants to be grown, plant spacing, yield, managing soil – water systems and erosion control. Compacted soils will have less pore volume resulting in lower hydraulic conductivity especially in clayey soils [4].

Hydraulic conductivity is affected by compaction, organic matter, bulk density, texture, porosity and water content of the soil. Soil compaction is the physical consolidation of the soil by an applied force that destroys the structure, reduces the porosity, limits water and air infiltration, increases resistance to root penetration and often results in a reduced crop yield [5]. Soil compaction therefore, has great effect on saturated hydraulic conductivity because almost all the soil properties are affected by it. The more compacted the soil, the greater will be the bulk density of the soil. The higher the level of organic matte incorporated into the soil, the lesser the compaction effect and the higher the hydraulic conductivity of the soil.

Soil organic matter is a key component of any ecological system. It has been recognized for a long time that organic matter serves as a granulating agent in soils. Baver (1935) observed that the percentage of aggregate larger than 0.05mm and carbon content of soils are positively correlated [6]. Ohu (also reported that organic matter incorporation considerably reduces the effect of compaction. Compaction affects hydraulic conductivity of the soil through its influence on the pore size distribution, shape and structure of the soil [7]. Soil compaction occurs when the soil particles are pressed together reducing pore space from macro pores to micro. Heavily compacted soils therefore have few large pores and reduced rates of both water infiltration and drainage from compacted layers. This occurs because large pores are the most effective in moving water through soil when it is saturated. In addition the exchange of gases slows down in compacted soils causing an increase in the likelihood of aeration related problems. Compacted soils also mean that the root must exert a greater force to penetrate the compacted layer. Soil penetration resistance increases with increase in compaction level [8]. The resistance of the soil to penetration of a probing instrument is an integrated index of soil compaction, moisture content, texture and the type of clay minerals.

This study is therefore carried out to determine the effect of types and rates of organic matter incorporation on compaction and also determine the effect of compaction on saturated hydraulic conductivity and penetration resistance.

Materials and Methods

Experimental Site

The soil for the study was collected at the University of Maiduguri Teaching and Research Farm. The site is located in the north eastern part of Nigeria between longitudes 13°05´´E and latitudes 11° 50´´N and an elevation of 354m above sea level. The study area has a tropical climate characterized by low and erratic distribution of rainfall. The mean annual rainfall is about 625mm and means annual temperature is between 27 – 32°C [9]. The steady state infiltration varies from 72mm – 220mm/hr with average of 135mm/hr [10]. Soil of the study area has a sandy loam textures and has been classified as typic ustipsamment according to USDA system of classification [2].

Sample Collection and Preparation

Twenty five (25) kilograms of composite soil sample was collected from 0 – 15cm depth at the Faculty of Agriculture Teaching and Research Farm and was brought to the hydraulic laboratory of Agricultural Engineering Department. The soil samples were air – dried, large clods were gently crushed to pass through a 2mm sieve so as to remove unwanted materials larger than 2mm. The soil samples was treated (mixed) with cow dung at varying rates (2%, 4% and 6%) after finely ground and pass through 2mm sieve and was moistened with predetermined water at different moisture levels (2%, 4% and 6%) to bring them to critical moisture content for compaction. The samples were then packed into air – tight polythene bags to avoid moisture loss and to obtain a homogenous mixture of the samples. Each sample was subjected to four levels of compaction using 0, 5, 10 and 15 blows of standard proctor hammer in cylindrical cores of 10cm in diameter and 11. 5cm height in accordance with the standard proctor compaction procedure [11]. The above hammer blows correspond to static equivalent pressure of 66.7kPa, 177kPa, 298kPa and 389kPa respectively as obtained from Ohu [8]. Compacted cores were covered with nylon fastened with rubber ban to avoid moisture loss and left for 24 hours by setting them in a basin of water to be saturated by capillary rise in the laboratory.

Penetration Resistance

Penetration resistance was determined from penetrometer reading corresponding to the various compaction levels for the sample. Penetration resistance on each of the treatment was determined using proctor penetrometer. In each treatment, penetrometer readings were taken at different locations. The penetrometer has a base needle of 0.9cm in diameter. The penetration resistance for each of the treatment was calculated from the equation below:

$$PR = \frac{F}{A}$$

Where PR = penetration resistance
F = force (Pa)
A = area (cm)

Saturated Hydraulic Conductivity Determination

Saturated hydraulic conductivity was determined for all 36 treatments used in the laboratory; the compacted samples were saturated by capillary rise by setting them in a basin of water. After 24 hours the samples were transferred to permeameter cell fitted with rubber ban, sealed at both ends to prevent leakage of water and air bubbles. Sample is then filled to a falling head permeameter cell while still in water. Water was flushed through each sample several times so as to ensure that only minimal amount of air bubbles were present in the sample before measurements were taken. Different head levels were maintained in each samples and allowed to drop to new levels within 120 seconds (2 minutes). Two readings were taken for each sample.

This procedure was repeated on each of the treatments and hydraulic conductivity was calculated according to Darcy's equation below:

$$K = \frac{2.3aL}{At} \log\left(\frac{h_1}{h_2}\right)$$

Where: K = saturated hydraulic conductivity (cms^{-1})

a = cross – sectional area of the stand pipe (cm^2)

L = length of the soil sample (cm)

t = time taken for the head to fall from H_1 to H_2 (s)

A = cross – sectional area of the sample (cm^2)

h_1 and h_2 = hydraulic heads at time t_1 and t_2 respectively

Organic Matter Determination: The organic matter content of the soil was determined using Walkey and Black Method [13].

Water Content Determination: Water content of the soil at the time of sampling was determined in the laboratory by the gravimetric method [14].

Results and Discussion

The result of the effect of cow dung, moisture content and compaction levels on saturated hydraulic conductivity and penetration resistance are presented in table 1 below. The results indicated that cow dung rate have a significant difference at $p < 0.05$ for saturated hydraulic conductivity with the highest value of (1.94×10^{-3} cm/s) at 2% and lowest value of (1.64×10^{-3}cm/s) at 6%. Penetration resistance also shows significance difference at ($p<0.05$) with the highest value of (10.42kPa) at 2%. These results is not in agreement with that reported by Ohu (1985) that the increase in organic matter increases infiltration rate and reduces penetration resistance and effect of compaction is also reduce. This error may be contributed by poor mixture of cow dung and soil.

Moisture content on the hand shows no significant difference at 4% and 6% but is significant at 2% with the highest value of (2.18×10^{-3} cm/s) and the lowest value of (1.60×10^{-3} cm/s) at 4%. But penetration resistance shows no significant difference at 2% and 4% but is significant at 6% with the highest value of (13.42kPa) and lowest value of (12.16kPa) at 2%, all at ($p<0.05$). This result agrees with that reported by Ohu (1985) which says that excess water concentration leads to water logging [2].

Table 1: Effect of cow dung, moisture content and compaction levels on saturated hydraulic conductivity and penetration resistance

Treatments	K_{sat} (cms^{-1})	Penetration Resistance (Kpa)
Cow dung (%)		
2	1.94×10^{-3a}	10.42^{c}
4	1.82×10^{-3b}	13.44^{b}
6	1.64×10^{-3c}	14.29^{a}
SE(±)	1.846×10^{-5}	
LSD (0.05)	3.722×10^{-5}	
Moisture content (%)		
2	2.18×10^{-3a}	12.17b
4	1.60×10^{-3b}	12.51^{b}
6	161×10^{-3b}	13.42^{a}
SE(±)	1.846×10^{-5}	
LSD (0.05)	3.748×10^{-5}	
Compaction level		
0	$2.63 X 10^{-a}$	0.00^{d}
5	1.86×10^{-3b}	13.44^{c}
10	1.34×10^{-3c}	17.50^{b}
15	1.36×10^{-3c}	19.93^{a}
SE(±)	2.127×10^{-5}	
LSD(0.05)	4.318×10^{-5}	
CD x MC	***	***
CD x CL	***	***
MC x CL	***	NS
CD x MC X CL	***	NS

Compaction level indicated that there is significant difference for saturated hydraulic conductivity at ($p<0.05$). the highest value of saturated hydraulic conductivity (2.63x10-3) was obtained at 2blows and the lowest value of $1.34x10^{-3}$ cm/s at 10 blows. Penetration resistance also shows significant difference at ($p<0.05$). the highest value of penetration resistance (19.93kPa) was obtained at 15 blows and the lowest value of (0.000kPa) at 0 blows. This result is in agreement with that reported by Ohu (1989) which observed that the higher the level of compaction, the lower the saturated hydraulic conductivity and the higher the penetration resistance [7].

The result of the effect of cow dung and moisture content interaction on saturated hydraulic conductivity and penetration resistance is shown in Table 2. The statistical result indicated that cow dung and moisture content have significant ($p<0.05$) effect on saturated hydraulic conductivity ($2.29x10^{-3}$ cm/s) was found at 2% cow dung and 2% moisture content and the lowest value ($1.33x10^{-3}$ cm/s) was found at 6% cow dung and 4% moisture content. Cow dung rate and moisture content also showed significant effect on penetration resistance at ($p<0.005$).The maximum value of penetration resistance (14.37kpa) was found at 6% cow dung and 4% moisture content and the lowest value (9.25kPa) at 2% cow dung and 2% moisture content. These results are in agreement with those reported by Ohu (1985), who reported that the higher the organic matter content, the higher the hydraulic conductivity and the lower the penetration resistance of the soil [8].

Table 2: Interaction effect of Cow dung and Moisture Content on K_{sat} and Penetration Resistance

CD (%)	MC (%)	Ksat (cms-1)	Penetration Resistance (kPa)
2	2	$2.29x10^{-3a}$	9.25^{e}
2	4	$1.81x10^{-3c}$	10.00^{d}
2	6	$1.7x10^{-3d}$	12.00^{c}
4	2	$2.10x10^{-3b}$	12.87^{b}
4	4	$1.67x10^{-3d}$	13.33^{b}
4	6	$1.70x10^{-3d}$	14.14^{a}
6	2	$1.16x10^{-3b}$	14.37^{a}
6	4	$1.33x10^{-3f}$	14.37^{a}
6	6	$1.42x10^{-3e}$	14.12^{a}
SE (±)		$3.327x10^{-5}$	0.3833
LSD (0.05)		$6.75x10^{-5}$	0.7782

The result of the effect of cow dung and compaction interaction on saturated hydraulic conductivity and penetration resistance are presented in Figure 1 and 2. The result indicated that the effect of cow dung and compaction level significantly affect saturated hydraulic conductivity at ($P<0.05$). The highest value of saturated hydraulic conductivity ($3.00x10^{-3}$ cm/s) was found at 4% cow dung rate and 0 blows and the lowest value ($1.00x10^{-3}$ cm/s) at 4% cow dung rate and 15 blows compaction level. This result is also in line with that reported by Ohu (1985) that the higher the number of blows, the lower the saturated hydraulic conductivity. Penetration resistance on the hand was significantly affected at ($p<0.05$). The highest value of penetration resistance (20.85kPa) was found at 6% cow dung rate and 15 blows compaction level and the lowest value ($-1.39x10^{-16}$ kPa) at 4% cow dung and 0 blow compaction level. The result also is in line with the one reported by Ohu (1985) [8].

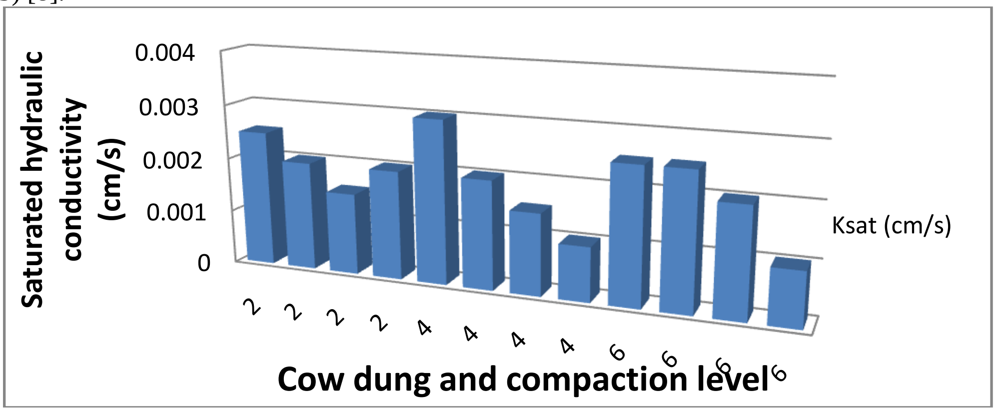

Figure 1: Interaction effect of cow dung and compaction level on Ksat

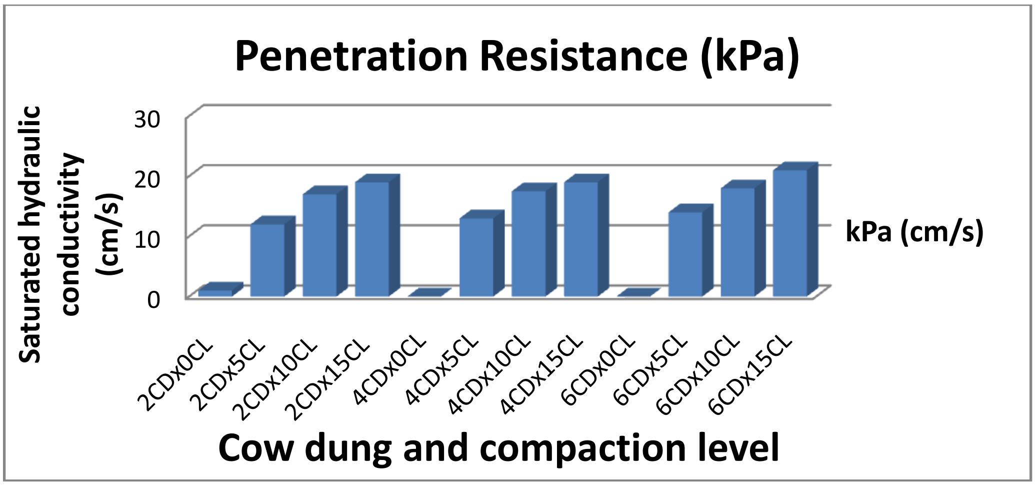

Figure 2: Interaction effect of cow dung and compaction level on Penetration Resistance

Conclusion

From the foregone study, it can be concluded that, the combine effect of 2% cow dung, 2% moisture content and 15 blows compaction level had the highest value of saturated hydraulic conductivity ($4.83x10^{-3}$ cm/s) and the lowest value ($6.58x10^{-4}$ cm/s) was obtained at 2% cow dung, 6% moisture content and 15 blows compaction level. The penetration resistance also reaches maximum (21.57kPa) at 4% cow dung, 6% moisture content and 15 blows compaction level and the minimum ($-5.47x10^{-3}$ kPa) at 4% cow dung, 6, Moisture content and 0 blow compaction level.

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