Adamawa State University Journal of Scientific Research
ISSN: 2251-0702 (Paper)
Volume 5 Number 1, April, 2017
http//www.adsujsr.com

Effects of Saw Dust on the Hydraulic Characteristics of Compacted Clay Soils

T. Crowther[1], M.O. Isikwue[2], J.O. Awulu[2]
[1] *Department of Agricultural and Bio-Environmental Engineering, Adamawa State College of Agriculture, Ganye. Adamawa State, Nigeria*
[2] *Department of Agricultural and Environmental Engineering, Federal University of Agriculture, Makurdi. Benue State, Nigeria.*
Contact: *newtoncrowther@gmail.com; +234*

Abstract

A laboratory experiment was carried out to determine the effects of sawdust on the hydraulic characteristics of compacted clay soils. Three quantities of sawdust were incorporated into the clay soil as organic matter and then compacted at three moisture levels using four different compactive efforts. The three organic matter and moisture content levels were 4, 6, and 8%, and 20, 35, and 50% respectively. The four compaction levels were 0, 5, 10, and 15 proctor hammer blows. Soil properties determined were bulk density, penetration resistance, and hydraulic conductivity. Results showed that bulk density increased with increase in moisture content up to 35% and then decreased with further increase in moisture content at 50%. For 6 and 8% organic matter at all levels of hammer blows, the penetration resistance decreased with increasing moisture content levels. The hydraulic conductivity of the soil was found to increase with increase in organic content from 0 to 4% organic matter level; it decreased at 6%, but experienced a rapid increase at 8% organic matter level. This suggests that the addition of sawdust into clay soils could help in the reduction of compaction, which will lead to the improvement of its physical properties for plant growth.

Keywords: Compaction, Bulk Density, Penetration Resistance, Hydraulic Conductivity, Organic Matter

Introduction

The seedbed environment partly created by soil and plant management practices such as seedbed preparation, incorporation of fertilizer and residue, determine the relative success or failure of any crop production. Factors such as soil temperature, moisture, compaction, aeration and concentration of salt in the soil from applied fertilizers and residue can alter the soil conditions that influence the growth of crops. In particular, the compaction caused by machinery traffic can change the structure of the soil considerably.

Compaction is the densification of soil through the application of mechanical energy resulting in a reduction of pore spaces. The major effects of compaction are on soil density, soil strength and changes in water transmission, storage and evaporation properties of the soil. Soil compaction has negative effects on seed emergence (Montemayor, 1995; Radford *et al.*, 2000; 2001); yield and yield parameters of crops (Alakukku and Elonen 1995; Albas *et al*., 1994., Radford et *al*., 2001). Compaction has significant effects on soil physical, chemical and biological properties (Carman, 2002; Diaz-Zorita and Grosso, 2000; Lipiec and Stepniewski, 1995; Whalley *et al* 1995). The problem of soil compaction has increased for several reasons; earlier planting schedule, heavier equipments, and increased use of dual or floatation tires that encourage field operation on wetter soil are responsible for this problem. Wheel traffic from heavy farm equipment is also recognized as the major cause of soil compaction, although some compaction occurs from normal crop production practices (Wolkowski and Lowery, 2008). Soil compaction due to machinery traffic causes substantial losses at the farm level, but the extend of it depends on the tractor size used, machinery use intensity, weather conditions, and the type of crop grown (Lavoie *et al.*, 1991).

Organic materials (Crop residue) have low density and when incorporated into the soil or left on the soil surface could cushion the effect of external load and subsequently reduce the severity of compaction (Ohu *et al*., 2001). Gupta *et al*., (1987) stated that organic materials incorporated into the soil decompose over time to produce organic matter which can affect various soil physical properties like structure, hydraulic conductivity and aggregate stability. The authors further reported that soils with high levels of organic matter have better structure and resists compaction more than soils with lower organic matter levels. Organic matter affects both the chemical and physical properties of the soil and its overall health. Properties influenced by organic matter include: soil structure, moisture holding capacity, biodiversity, and activity of soil organism, (both those that are beneficial and harmful to crop production); and nutrient availability. It also influences the effect of chemical amendments, fertilizer, pesticides and herbicides (FAO, 2002). The amount of water retained in the topsoil is affected by the amount of organic matter content, the size, shape and arrangement of mineral particles (Gupta and Gupta, 2008). Generally, the more the amount of organic matter the soil contains, the more water it will be able to absorb depending on the soil texture and structure which are known to be modified by organic amendments (Osunbitan, *et al.,*1998, Ogedengbe and Akinwole, 2000; Ogedengbe and Fashina, 2001; Osunbitan and Adekalu, 2001; Bababe *et al.,* 2003, Gupta and Gupta, 2008).

The resistance of a soil to the penetration of a probing instrument is an index of soil compaction, moisture content, organic matter and the type of clay mineral (Baver *et al.,* 1972). Penetration resistance is an empirical, easy and cheap measurement technique of soil strength, widely used to assess soil compaction and the effect of soil management (O'sullivian et *al.*, 1987; Castrignano *et al.,* 2002). Compaction, moisture content and organic matter of the soil are the factors that usually affect penetration resistance of the soil. At higher moisture content, increasing organic matter level would result in increased penetration resistance for the soil, but the opposite is the case at lower organic matter level for the soil (Ohu *et al*., 1985).

Hydraulic conductivity and soil porosity are two most important properties regulating water movement and storage of air and water available to plants. Application of fresh composted crop and plant biomass is often recommended as a viable option to maintain good soil tilt compared with mineral fertilizer. Organic matter itself plays a dominant role in soil aggregation by increasing organic carbon (Tisdall and Oades, 1982), which increases the macro porosity and then improves water infiltration (Martens and Frankenbergers, 1992). Porosity and pore-size distribution determines the rate and movement of air and water in the soil (Boyles *et al.*, 1989). Organic matter interaction with soil particles form organo-mineral complexes, coupled with physical stress, improves soil aggregation (MacRae and Mehyugs, 1985). Macropores favour high infiltration rate, good tilt and adequate aeration for plant growth (Boyles *et al*., 1989). Organic matter increases the proportion of larger pores (Brady, 1974). These macropores are the dominant pathways of channel flow through the soil from surface ponding (Luxmoore, 1981). Farmers in the Benue-valley of Nigeria have a variety of organic materials which could be added to the soil to cushion the effect of compaction and add nutrients to the soil. However, the use of organic materials especially sawdust is limited because some are used as bedding materials in poultry farms. Another limitation is that the organic materials differ in their ability to provide nutrients to crops and enhance soil quality and these differences relate to rate of decomposition and nutrient release rate and pattern (Kumar and Goh, 2002). Although there are several organic materials available in the Benue-valley of Nigeria, sawdust is in abundance because it is generated during wood processing and may constitute environmental hazard if not appropriately handled. A way of handling and controlling the environmental hazard that can be caused by the abundant sawdust could be by incorporation into clay soil to enhance its workability (Crowther, 2016). This study was therefore designed to evaluate the effect of sawdust on the hydraulic characteristics of compacted clay soils.

Materials and Methods

The clay soil sample used for study was collected from the topsoil profile at 20cm depth. The sample was crushed to pass through a 2mm sieve after which they were air dried. Particle size analysis was performed using the hydrometer method following the procedure of Lambe (1951). The organic matter content of the soil was estimated from the carbon content of the sample using the method of Walkley and Black (1934). Sawdust was sieved through 2mm sieve and was added to the soil to raise its organic matter content from 2.14 to 4, 6, and 8%.

The initial moisture content of both the sieved soil and saw dust samples were determined using the oven-dry method. The liquid and plastic limits of the soil were also determined. The initial moisture content of the soil and that of sawdust were added to form the initial moisture content used in computing the rise in each level. The moisture content levels used for this study were 20, 35, and 50% based on the optimum moisture content for compacting the soil and on the consistency limit of the soil. The soil-organic matter mixtures were packed into polythene bags and kept air-tight to prevent moisture loss and maintain equilibrium before, during and after experiment. Compaction (number of blows) was performed using the Proctor hammer of which 0, 5, 10, and 15 blows were applied to the soil at every moisture content and organic matter level following the Standard Proctor Compaction Procedure (Lambe, 1951). The soil-organic matter-moisture content was compacted in a mold of 101.56 mm diameter by 105.29 mm height as measured with a digital Vanier Caliper. After compaction, the bulk density of the mixture was determined using the method demonstrated by (Lambe 1951). The penetration resistance of the soil in the mold was determined using the pocket penetrometer following the American Society of Agricultural Engineers (ASAE, 1982) standard procedure. The hydraulic conductivity of the soil mixtures was determined without compaction using the constant head permeameter.

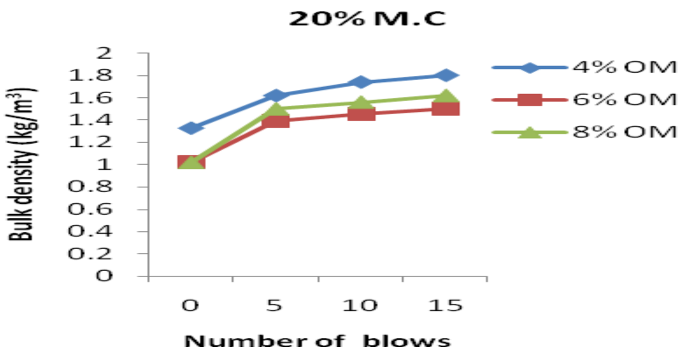
Results and Discussion

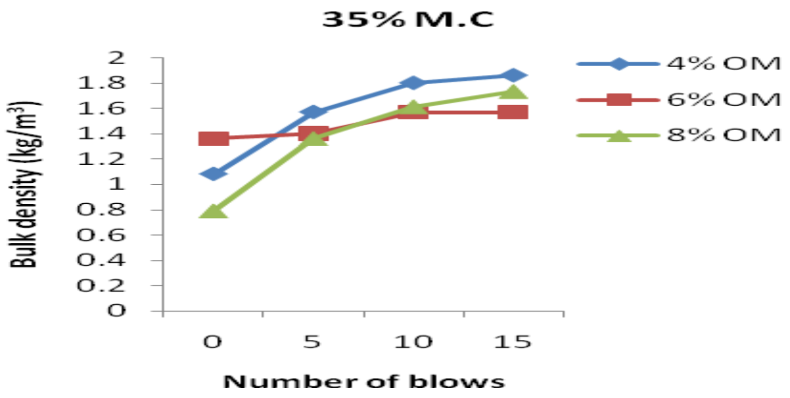
The result of particle size analysis was 18 % sand, 21 % silt and 61 % clay and it was classified as heavy clay. The organic matter content of the soil was found to be 2.14 %. The initial moisture content of the sieved soil sample was determined to be 4.12 % and that of sawdust was 2.51 %. The liquid and plastic limits of the soil as determined were 53.70% and 18.18% respectively.

Fig. 1 shows the effect of compaction on bulk density of the soil at different soil moisture content and organic matter levels. Bulk density increased with increase in moisture content up to 35% and then decreased with further increase in moisture content at 50%. This result was similar to that reported by Mamman *et al*., (2007). At various moisture level and compactive effort, the bulk density decreased with increase in organic matter level (4 – 6 %) and then increased at 8% organic matter level. The mean value of bulk density was highest at 15 blows, 4% organic matter and 35% moisture content. The 35% moisture content that recorded the highest value of soil bulk density could be regarded as the critical moisture content for compacting the soil-organic matter mixture. The ANOVA result indicates that number of blows, organic matter and moisture content as well as their interactions had significant effect ($p<0.05$) on the bulk density of the soil.

The effect of compaction on penetration resistance at different organic matter and moisture content levels is presented in Fig. 2. The result of ANOVA indicates that number of blows, organic matter and moisture content had significant effect ($p<0.05$) on the mean penetration resistance of the soil. The interactions of these factors also had significant effect ($p<0.05$) on the mean penetration resistance of the soil except for the interaction of moisture content and organic matter. This shows that penetration resistance increases with increase in compaction.

For 6 and 8% organic matter levels and at all levels of moisture content and hammer blows, the penetration resistance was decreasing with increase in moisture content levels. The decrease in penetration resistance at higher moisture level can be attributed to the fact that higher moisture in soils dislodges the bonding between soil particles. At 50% moisture content level and at all levels of hammer blows; increase in organic matter level causes an increase in penetration resistance. This may be attributed to the fact that at higher organic matter level saw dust must have absorbed the excess moisture and resist the penetration of a probing instrument. At 20% moisture content and most of the levels of compaction, penetration resistance increases with increase in organic matter level from 4 to 6% and then decreased at 8% organic matter level. At 35% moisture content level and all levels of compaction (hammer blows), penetration resistance decreased with increase in organic matter levels. Even though Ohu *et al;* (2001) reported that addition of organic matter could cushion the effect of compaction in the soil, it is now evident that the extent of alleviation will depend on the moisture content of compaction.





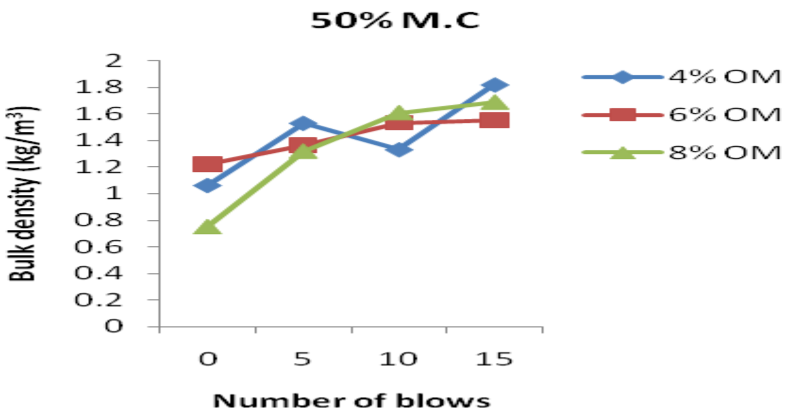
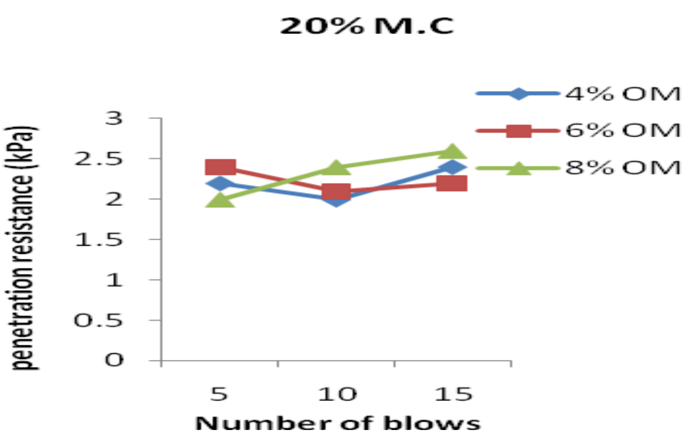


Figure 1: Effect of number of blows, organic matter (OM) and moisture content (MC) on bulk density (Kg/m^3) of sawdust



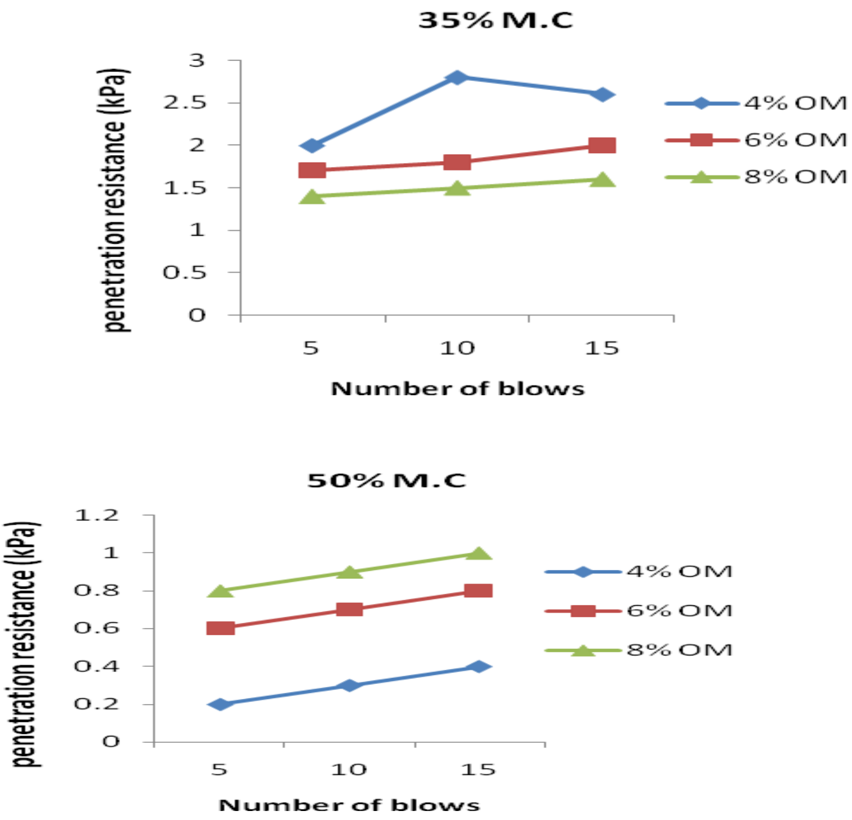


Figure 2: Effect of number of blows, organic matter (OM) and moisture content (MC) on penetration (kPa) of sawdust

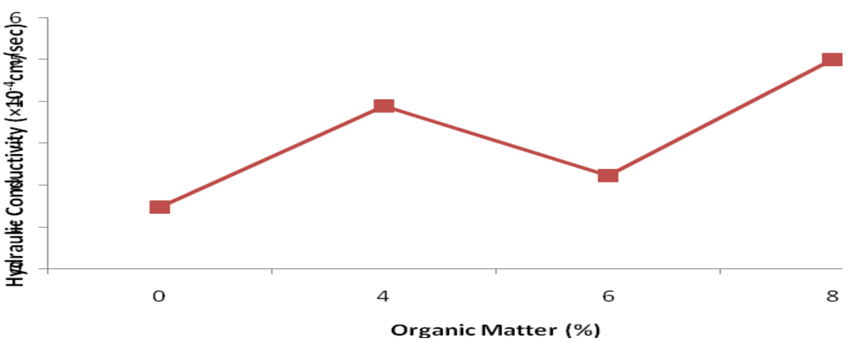


Figure 3: Characteristic Curve of the Hydraulic Conductivity of the soil

Fig 3.shows the effect of hydraulic conductivity of the soil at various levels of organic matter addition. The hydraulic conductivity increases with increase in organic matter content from 0 to 4%, it then decreases at 6% and then rapidly increased at 8%. As affirmed by Martens and Frankenberger (1992), organic matter itself plays a dominant role in soil aggregation by increasing organic carbon, which increases the macro porosity and then improves water infiltration.

Increasing or maintaining a high level of soil organic matter not only reduced bulk density and soil compaction, but can also help in increasing aggregate stability, reduce nutrient leaching, resistance to soil erosion, increase biological activities, reduction in soil carbon sequestration and also help to improve crop production that would lead to food security in Nigeria.

Amount of organic matter a soil contains will affect the soil's capability to be compacted. Generally, the higher the organic matter, the less the soil will compact. The soil aggregate will be coarse which will allow for better movement of moisture through larger pore spaces. Soil that has high organic matter content and thrives with soil organism is more resistant to compaction and can better recuperate from slight compaction. It appears that there is a great potential in managing the soil by the addition of organic matter as a means of alleviating the problems of soil compaction in improving the hydraulic characteristics of clay soils, however the extend of organic matter applied to the soil should be carefully taken into consideration. Whether the same result will apply to other soils need to be substantiated.

Conclusion

The result of ANOVA indicates that number of blows, organic matter and moisture content had significant effect ($p<0.05$) on the bulk density and mean penetration resistance of the soil. At all moisture content and hammer blows, 8% organic matter records the least value for bulk density and highest value for hydraulic conductivity even though penetration resistance depends on the level of moisture at compaction. Soil bulk density and penetration resistance has the highest values at 35% moisture content. This could be regarded as the critical moisture content of the soil. Further research using different organic materials to clay ratios before compaction and its effects on the hydraulic characteristics need to be investigated. This suggests that the addition of sawdust into clay soils could help in the reduction of compaction, which will lead to the improvement of its physical properties for plant growth.

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