

EFFECT OF COMPACTION, RICE HUSK/SAW DUST AND MOISTURE CONTENT ON BULK DENSITY AND PENETRATION RESISTANCE OF CLAY SOILS (VERTISOLS)

Crowther, T. *, Hussaini, I.D., Tsunda, P.M. and Ijantiku, J.

Department of Agricultural and Bio-Environmental Engineering. Adamawa State College of Agriculture, P.M.B. 2088.Ganye. Adamawa State, Nigeria

*Corresponding email: newtoncrowther@gmail.com

ABSTRACT

Two organic materials (rice husk, saw dust) at three different levels of treatment were separately incorporated into clay soil and then compacted at three moisture content levels using four compactive efforts. The three organic matter and moisture content levels were 4%, 6%, and 8% and 20%, 35%, and 50%(w/w) respectively. The four levels compaction were 0, 5, 10 and 15 blows (0, 175, 350, and 404 kPa) proctor hammer blows. Soil properties determined were; soil bulk density and penetration resistance. Hydraulic conductivity was determined without compacting the soil. The result indicated that compaction, organic matter and moisture content as well as their interactions had significant effect ($p < 0.05$) on bulk density and penetration resistance of the soil. It was generally observed that, with increasing organic matter content and level of soil compaction, bulk density decreased. The mean bulk densities were however highest at 15 blows, 4% organic matter and 35% moisture content for both rice husk and sawdust. Penetration resistance value attained maximum value at 15 blows, 8% organic matter at 35% moisture content for rice husk, while that of sawdust was maximum at 15 blows, 4 % organic matter and 35% moisture content. The overall best performance was observed with sawdust that had the least value for bulk density, penetration resistance and its hydraulic conductivity seems to double that of rice husk.

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

1 INTRODUCTION

The ever-increasing need of food for the millions of human beings on earth have encouraged producers to mechanize farm operations. The use of heavy equipment and repeated passes on agricultural fields lead to soil compaction. Compaction is the densification of soils through the application of mechanical energy resulting in a reduction of pore spaces. Soil compaction has a negative effect on seed emergence, yield and yield parameters of crops [1]. Soil compaction has significant effects on soil physical, chemical and biological properties [2] Organic materials have low density and when incorporated into the soil or left on the soil surface could cushion the effect of compaction. [3] States 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. Organic matter amendments help prevent and loosen surface compaction by promoting biological activity and by raising the soil organic matter levels. Soils with higher levels of organic matter resist compaction more effectively [4]. The higher organic matter content was speculated to have improved the structure of the soil and the humid effect of organic matter might have supplied more nutrients to the crop, which resulted into higher yields. Farmers in the semi-arid region of Nigeria have a variety of organic materials which could

be added to the soil to cushion the effects of compaction and add nutrient to the soil. However, the use of organic materials especially crop residues is limited because some are used to feed livestock. 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 rates of decomposition and nutrient release rate and pattern [5]. Heavy machine with axle loads that exceed 10 tones increase the risk of compaction extending into the subsoil, compacting soils to a depth that cannot be removed by conventional tillage [6]. Soil strength is a measure of the ability of a soil to resist deformation from an applied force. Strength increases as soil particles become more tightly pressed together. Many researchers have reported major increases in soil strength because of excessive soil compaction. As soil strength increases, the plant root must exert greater force to penetrate the soil. In some cases, the roots are unable to penetrate excessively compacted soil and grow laterally. 'Pancake' root development is a classic example of root growth occurring under compacted conditions. As roots grow down through the soil and encounter restrictive layer, they spread horizontally and are unable to fully use moisture and nutrients below this layer, which often limits plant growth [6]. Soil compaction affects nutrient uptake. Nitrogen is affected in a number of ways by compaction. Poorer internal drainage of soil will cause more denitrification losses and less mineralization of organic nitrogen; nitrate losses by leaching will decrease; loss of organic nitrogen (in organic matter) and surface applied nitrogen fertilizer may increase; and diffusion of nitrate and ammonium to the plant root will be slower in compacted soil than wet, but faster in those that are dry [7]. Organic matter not only binds the soil but also lightens and expands the soil making it possible to have high porosity. Plants roots promote the granulation by their decaying in the soil and by the disruptive action of their root as they move through soil. The role of organic matter is very important, its high content in the soil influences physical properties, a good value of cation exchange capacity (CEC), reduce the mobility of nutrients in the soil solution, preventing the loss of useful substances by means of the action of enzymes, avoid the pollution of water table, improves soil porosity, help the chemical stabilization of structure, reduce the process of soil erosion and molecules, the microorganisms and enzymatic activity. The amount of water retained in the top soil is affected by the amount of organic content, the size, shape and arrangement of mineral particles [8]. Mechanical resistance and poor aeration may restrict root growth, which especially affects the uptake of nutrients [9]. Organic matters affect both the chemical and physical properties of the soil and its overall health. Properties influenced by organic matter include: soil structure; moisture holding capacity; diversity; and activity of soil organism, both those that are beneficial and harmful to crop production; and nutrient availability. It also influences the effects of chemical amendments, fertilizer, pesticides and herbicides [10]. Organic matter influences the physical conditions of soil in several ways. Plant residues that cover the soil surface protect the soil from sealing and crusting by rain drop impact, thereby enhancing rainwater infiltration and reducing runoff. Surface infiltration depends on a number of factors including aggregation and stability, pore continuity and stability, the existence of cracks, and the surface condition. Increased organic matter contributes indirectly to soil porosity (via increased soil faunal activity). Fresh organic matter stimulates the activity of macrofauna such as earthworm, which create burrows lined with the glue- like secretion from their bodies and intermittently filled with cast material [11]. The consequence of increased water infiltration combined with a higher organic matter content is increased soil storage of water. Organic matter contributes to the stability of soil aggregates and pores through the bonding or adhesion properties of organic materials such as bacterial waste products, organic gels, fungal hyphae and worm secretion and casts. Moreover, organic matter intimately mixed with mineral soil materials has a considerable influence in increasing moisture holding capacity, especially in the topsoil, where the organic matter content is greater, more water can be stored [11]. Organic material (Crop residues) has low density and when incorporated into the soil or left on the surface could cushion the effect of external load and will subsequently reduce the severity of compaction [3]. 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 [12]. Addition of organic matter to soil results in decrease in penetration resistance [13]. 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 [12]. Hydraulic conductivity and soil porosity

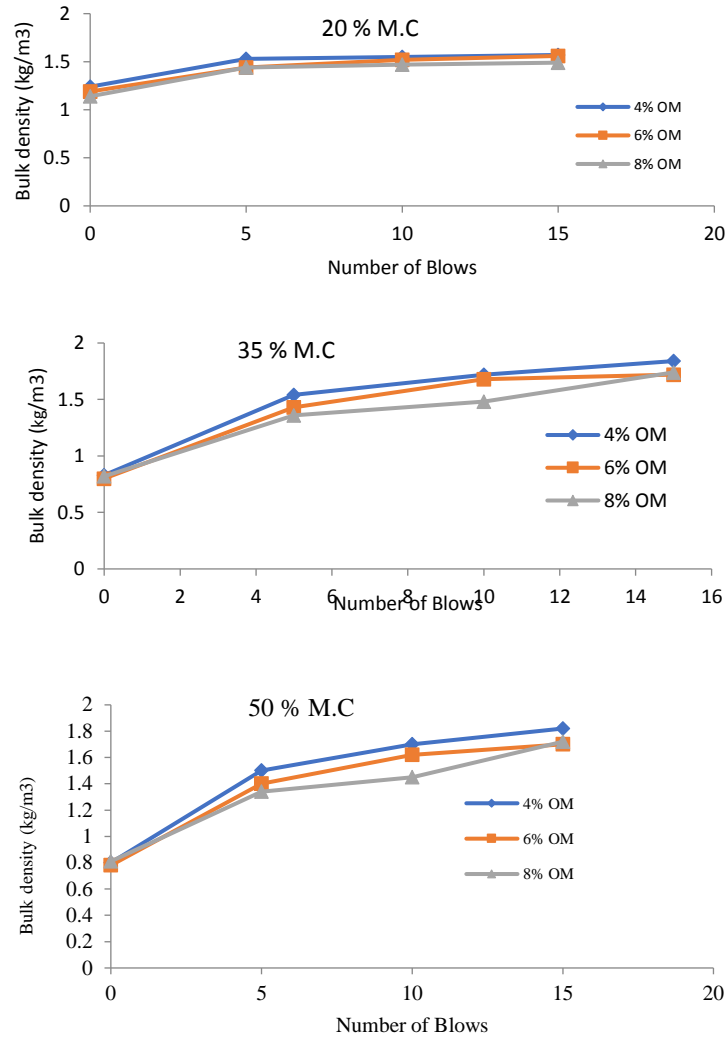
are two most important properties regulating water movement and storage of air and water available to plants. Application of fresh composted crop and plant biomass is often recommended as a viable option to maintain good soil tilt compared with mineral fertilizer. Organic matter itself plays a dominant role in soil aggregation by increasing organic carbon, which increases the macro porosity and then improves water infiltration [13]. Porosity and pore-size distribution determines the rate and movement of air and water in the soil [14]. Organic matter interaction with soil particles formed organo-mineral complexes, coupled with physical stress, improves soil aggregation [15]. Macropore favours the high infiltration rate, good tilt and adequate aeration for plant growth [14]. Which are of paramount importance in a research work like this one.

2 METHODOLOGY

The soil used for this study was clay soil. It was collected from the top 20cm of the soil profile. The sample was grounded to pass through a 2mm sieve after which it was dried. Particle size analysis was performed using the hydrometer method following the procedure of [15]. The organic matter content of the soil was estimated from the carbon content of the sample using the method of [16]. Rice husk/Saw dust was sieved through 2mm sieve and was added to the soil to raise its organic matter content. The initial moisture content of both the sieved soil and Rice husk/Saw dust was 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 Rice husk/Saw dust 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 [15]. The soil-organic matter-moisture content was compacted in a mold of 101.56mm diameter by 105.29mm height as measured with a digital vanier caliper. After compaction, the bulk density of the mixture was determined using the method of [15]. The penetration resistance of the soil in the mold was determined using the pocket penetrometer following [17] standard procedure. The hydraulic conductivity of the soil mixtures was determined without compaction using the constant head permeameter.

3 RESULTS AND DISCUSSION

The particle size analysis shows that the soil contains 18% sand, 21% silt and 61% clay. The Textural Class was classified as heavy clay. The organic matter content was found to be 2.14%. The initial moisture content of the soil sample was determined to be 4.12% and that of rice husk and saw dust were 7.41 and 2.51% respectively. The Liquid limit and Plastic limit were 53.70 and 18.18% respectively. From Figure 1, it was generally observed that, with increasing organic matter content of the soil at any level of compaction, the bulk density was decreasing. The 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.



Figures 1. Show the Effects of Number of Blows, Organic Matter and Moisture Content on Bulk Density for Rice Husk

It was observed that, with increase in organic matter content of the soil at any level of compaction, the bulk density decreased. Thus, the maximum bulk density obtained at any level compaction level was found to decrease with higher organic matter incorporation in the clay soil. Since the bulk density of soil particle (2.65kg/m^3) is greater than that of organic matter (1.40kg/m^3), then the decrease in bulk density should be expected as reported [18]. This is because addition of organic matter to the soil makes them resistance to compaction. This may also result from the dilution of soil matrix with less dense material as reported [19]. The resulting effect of high resistance to compaction and dilution will be a decrease in bulk density value. The 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 lowest values of bulk density (0.78 kg/m^3) were recorded at zero blows, 6% organic matter level, and 50% moisture content for rice husk, while it is 0.75 kg/m^3 at zero blows, 8% organic matter and 50% moisture content for saw dust. This suggests that incorporation of organic matter into clay soils could reduce the effect of compaction, which invariably improved its workability. Generally, it was observed that the bulk density increases with increase in moisture content from 20% to 35% and then decreases at 50%. This means that there is optimum moisture content at which to achieve maximum compaction, and this is achieved at the critical

moisture content of 35%. From Figures 2, 3 and 4, it was observed that for soil mixed with saw dust (6 to 8% organic matter), penetration resistance decreased with increase in moisture content, while that of rice husk (6 to 8% organic matter), the penetration resistance increases with increase in moisture level to 35% and then decreases at 50% moisture level. 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. Considering 5 and 10 blows; penetration resistance decreased with increase in percentage organic content from 4% to 8%. But for 15 blows, the penetration resistance increased with increase in percentage organic matter. Furthermore, considering the effect of moisture content, it is obvious that penetration resistance increased from 20% to 35% and drastically decreased with further increase in moisture content to 50%. Even though [3] 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.

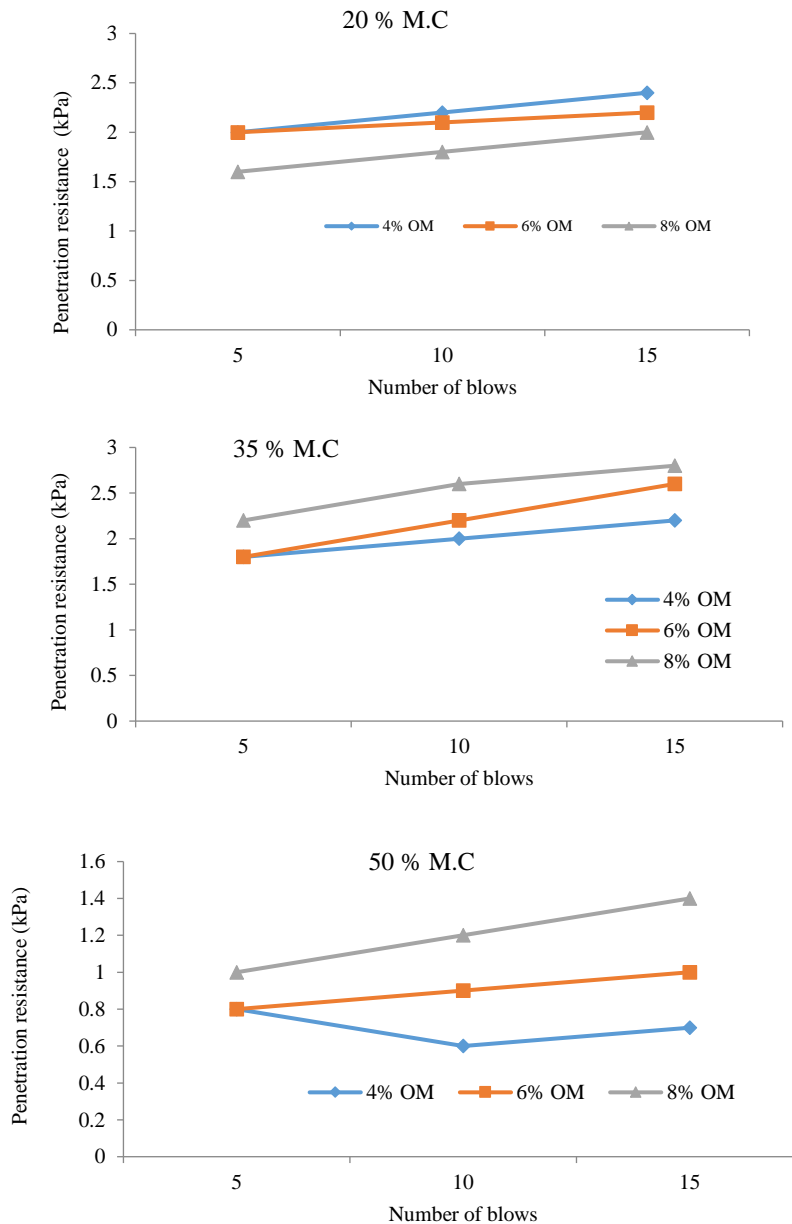


Figure 2. Effects of Number of Blows, Organic Matter and Moisture Content on Penetration Resistance of Rice Husk

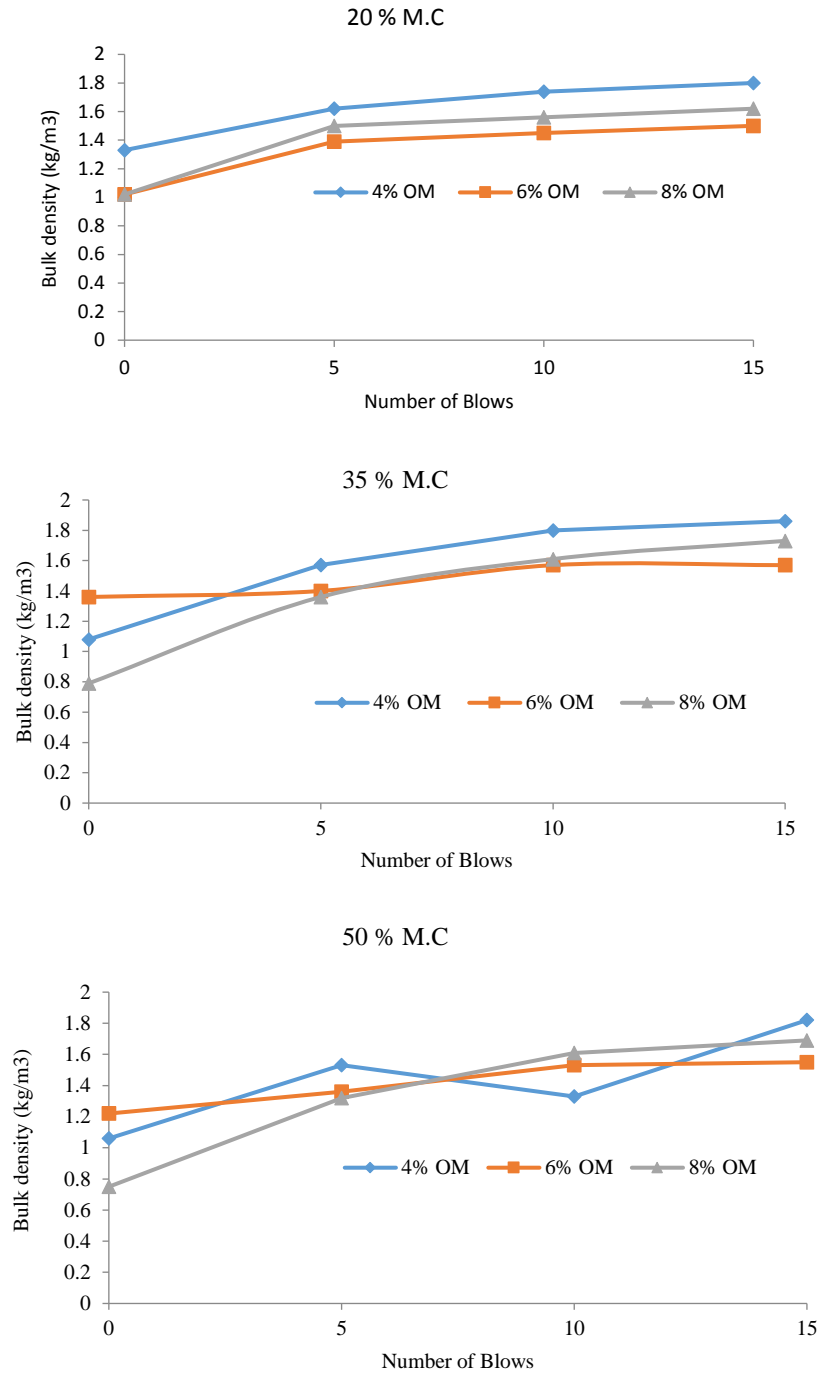


Figure 3. Effects of Number of Blows, Organic Matter and Moisture Content on Bulk Density for Saw Dust

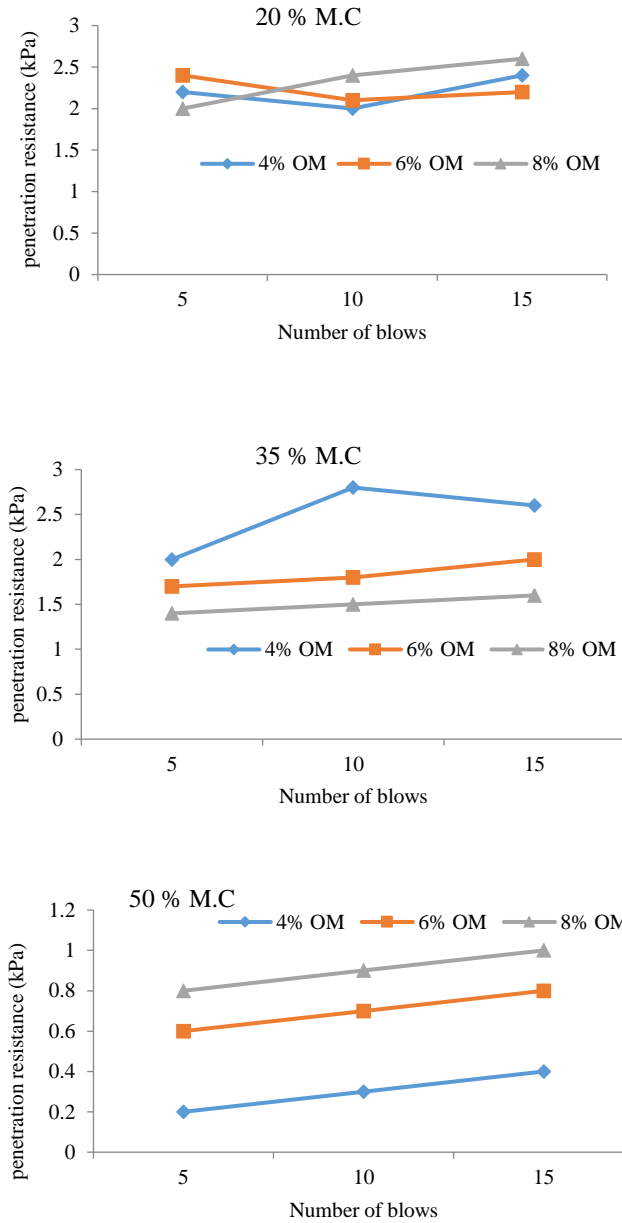


Figure 4. Effects of Number of Blows, Organic Matter and Moisture Content on Penetration Resistance for Saw Dust

From Figure 5, the hydraulic conductivity of the soil was measured at different percentage of the two organic matters; rice husk and saw dust. the characteristic curve of the hydraulic conductivity of the soil is irregular in its pattern. The hydraulic conductivity of the soil was found to increase with increase in organic content from 0% to 4%, it decreased at 6%, but experience a rapid increase at 8%. This is applicable to the two organic matters. The increase in hydraulic conductivity at higher organic matter content in the soil presumably resulted from increased in total porosity. The value of hydraulic conductivity for saw dust at 4 and 6% organic matter level seems to double that of rice husk of the same level. These may be attributed to variance in their particle size composition. Rice husk has smaller particle size and therefore mixed well with the clay particles, while saw dust seem to have more bulk materials and therefore contribute more pore spaces for the passage of air and water as reported by [14, 18].

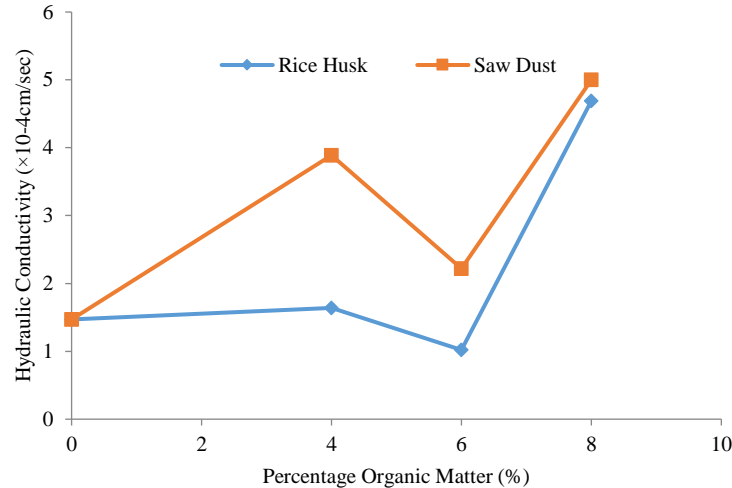


Figure 5. The Hydraulic Conductivity of the Soil at various Organic Matter Levels

4 CONCLUSIONS

The result of the study indicates that number of blows, organic matter and moisture content had significant effect on the bulk density and mean penetration resistance of the soil. The maximum density obtained at any level of compaction was decreased with higher organic matter incorporation in the clay. The hydraulic conductivity increases with increased organic matter content from 0 to 4% organic matter level, it decreased at 6%, but rapidly increase at 8% organic matter. Further research in the incorporation of other organic matter to clay soil before compaction and its effects on the hydraulic characteristics is however suggested.

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