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Research Paper

Compaction Characteristics of Sandy Clay Loam Soil Under Different Tillage System

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Abstract—Concept of people about soil depends on their direct use of it. Agronomists call it a medium for crop production; engineers as a foundation of construction materials, environmentalist, a source of pollution and conservationists see it resources to preserve. Soil Tillage as a disturbance and manipulation process can be manual or mechanical using the tractor and its implements. The system chosen by farmers has a comparable influence on the properties of soil especially the compaction characteristics. Therefore, a research was carried out to find out the effects of tillage methods on compaction characteristics of agricultural soil where zero tillage, traditional tillage, mechanical tillage and fallowing have been practiced. It was observed that soil with traditional tillage had the highest mean value of penetration resistance (1677 kN/m^2) and moisture content (17%), while the highest mean value of bulk density (1.51 g/cm^3) was recorded in zero tillage. It was also recorded that soil depth had a linear relationship with penetration resistance as well as a polynomial relationship with the bulk density. All values of the penetration resistance and soil bulk density recorded are acceptable for root growth except the value recorded for traditional tillage. The observed values and relationships will serve as indicators of soil quality in the choice of tillage practices adopted by farmers as well as further research and experimentation.

Keywords— Bulk density, penetration resistance, moisture content, root growth, soil disturbance

1. Introduction

Soils support plants, and functions as sources of water and nutrients needed by plants. The physical form of the soil performs a large role in shaping the nature of biological and chemical reactions. The layering of soil affects water penetration, aeration, and rooting depth [1]. Many studies on soil development have revealed the differences in soil properties and other correcting productivities. Soil factors influencing compaction characteristics like penetration resistance are water content, soil bulk density and soil strength parameters [2].

Soil penetration resistance and soil bulk density as good indicators of soil compaction are known to be of high relevance in the use of farm machinery and draught animals with respect to their workability on the farm.

Today, soil tillage research is tending towards campaigning for conservation tillage as conventional tillage practices have been creating compaction problems on agricultural soil and tillage has been limited to the changes in soil condition for crop production [3]. In tillage process, undisturbed soil is cut, moved, impacted, inverted, squeezed and thrown in an effort to physically break the soil and bury weeds to physically destroy them by cutting [4], [5]. It was summarized that the objectives of soil tillage as development of a desirable soil structure for a good seedbed or root bed; control of weeds; facilitation of the placement of surface residues; minimization of soil erosion by water or wind; preparation of suitable land for irrigation practice; incorporation and mixing of fertilizer into the soil and destruction of insect peats as well as their eggs larvae and habitats.

The development of conservation tillage is a complex process with many variations. Excessive soil tillage is characterised with soil degradation processes like compaction, a decrease in soil stability and structure, and increase in soil erosion. One component of conservation tillage is its trend that is towards minimizing tillage activities to address the problems with soil degradation [6].

The use of farm machinery like tractors and a variety of tillage implements on agricultural soils for mechanical tillage in the tropics has been causing some form of degradation like compaction resulting to poor yields of crop. This concept made it necessary to study the influence of machinery usage on compaction characteristics of agricultural soils making tillage a reference farm operation.

1.1 Objectives of the Study

The objectives of this study was to determine the effects of tillage methods on compaction characteristics of agricultural soil.

2. Related Work

Soil compaction is caused by complete deterioration of the regime of the physiological profile of soil. From the view of crop production, compacted soil is characterized with low porosity, low water and air permeability, and an increased energy need for traction power in seedbed preparation [7]. Increase of soil degradation by compaction is largely due to the increased mass of agricultural machinery with its intensive use, even under unfavorable soil conditions [8].

It has been reported that soil compaction generally increased porosity with a decrease in amount of soil moisture available to plants and decreased water conductivity [9]. This influence usually results to an negative effect of compaction of surface soil on physical features of soil like increase in bulk density, decrease in total porosity and soil aeration, and a shift to smaller pore size [10], [11]. Intensive use of soil tillage equipment like the mouldboard ploughs, disc ploughs, disc harrows and tractors intensifies and accelerates compaction especially under wet conditions. This happens because compaction depends on the load pattern and stress applied as well as the soil inherent properties [12]. The effects of no tillage, rotary tillage and deep tillage in a tea garden on soil compaction, soil moisture, soil bulk density, growth and tea yield were studied via a field experiments. The results showed that deep tillage and rotary tillage could efficiently break the horizon layer and reduce soil-compaction [13]. The effects of primary, minimum, conventional and ridging tillage on penetration resistance, porosity and the yield respon se of Okra (Abelmoschus) were investigated for a growing season on a sandy loam soil. It was revealed that the highest penetration resistancewas recorded in the ploughed plot, whil e the lowest value was observed from the ridged plot [14]. It was reported that soil depth-bulk density relationship in a tilled soil was considered a polynomial relationship [5]. It was also reported by [15] that Zero Tillage had the highest value of penetration resistance.

3. Experimental Method

3.1 Experiment Site

The research was conducted at the research farm of Rufus Giwa Polytechnic, Owo, Nigeria (Lat7^0 15´N Long.5^0 35 ´E) and elevation of 210 m. Newly cultivated and fallowed portions of the site was selected for the experiment. The soil as analysed is sandy clay loam.

3.2 Experimentation

Soil samples were randomly collected in triplicates at varying depths between 0 and 42 cm in non-tilled, traditionally (manually) tilled, mechanically tilled and fallowed sandy clay loam soil. To determine the influence of machinery usage via soil tillage on compaction characteristics, soil samples and readings were collected from the tilled, non-tilled and fallowed portions of the selected experimentation site. The readings taken were analyzed for soil texture, penetration resistance, bulk density, moisture content and the chemical properties as presented in subsequent sections. This was repeated for each of the treatments.

3.3 Soil Measurement

Bulk Density and Moisture Content of the Soil

Soil samples were collected from seven depths varied at 0-6, 6-12, 12-18, 18-24, 24-30, 30-36 and 36-42 cm using a core sampler of 5.8cm diameter and 6cm height. The core sampler was driven into each depth to collect the samples. The collected soil was kept in an air tight polythene bag to avoid moisture loss and the sample was thereafter oven dried and weighed. The soil as oven dried was allowed to cool for one hour. The bulk density of the soil was determined using standard equation 1;
The soil moisture content was taken using a soil moisture meter (Lutron, PMS-714) at the soil depth of 6, 12, 18, 24 and 30 cm.

$$\text{Bulk Density} = \frac{Mass\ (g)}{Volume\ (cm^3)} \qquad (1)$$

Penetration Resistance

Soil penetration resistance was taken using a soil cone penetrometer (Electronic fill density tester, WG-IV) by continuous hand pushing of the cone tipped shank of the penetrometer into each depth (6 , 12, 18, 24, 30, 36 and 42 cm) and maximum reading taken at each depth and recorded. The penetration resistance was determined at the average of three (3) measurements for each experimental point.

Soil Texture

Soil samples were collected from seven locations of two (2) points each. Each point was 4m apart from each other. Soil from each spot (25 cm) diameter x 42 cm depth). The collected soil samples were air dried and analysed using the hydrometer method by measuring the proportion of various sized particles in a soil.

4. Results and Discussion

4.1 Tillage Methods and Compaction Characteristics

The relationship between soil tillage methods and soil compaction characteristics (Penetration Resistance and Bulk Density) as presented in Figure 1 showed that the traditional (manual) tillage method had the highest Penetration Resistance of 1677 kN/m^2 unlike the findings of a study by [16] in which Zero Tillage had the highest value of penetration resistance. The Same value of Penetration Resistance of 848.73 kN/m^2 was recorded for no-tilled and fallowed soils. Having the least value of Penetration Resistance of 762.36 kN/m^2 in mechanical tillage method shows the positive effect of tillage in compaction characteristics. This is in conformity with [13]. Contrary observation was recorded in the relationship between tillage methods and the bulk density. The highest value of bulk density was recorded in zero tillage. This is also similar to the study by [18]. All the values of soil bulk density (1.22 to 1.51 g/cm^3) recorded was within the acceptable values of bulk density for crop growth [19].

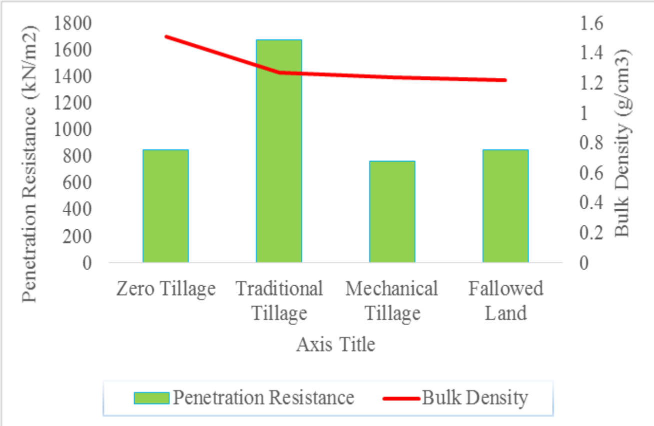

Figure 1: Tillage Methods versus Compaction Characteristics

4.2 Soil Depth and Compaction Characteristics

As presented in Figure 2, different relationships were recorded between soil depth versus penetration resistance and soil depth versus bulk density. A linear relationship in which the penetration resistance increased with an increase in soil depth was observed in soil depth-penetration resistance and the penetration resistance ranged from 197.16 to 1871.72 kN/m^2. This is in conformity with [20] that worked on soil compaction under varying rest periods and levels of mechanical disturbance in a rotational grazing system. For the bulk density-soil depth relationship, a polynomial relationship was recorded. The mean values of soil bulk density was not consistent with increase in soil depth. This is contrary to [21] that reported that soil bulk density increased with soil depth but similar to [5] that reported a polynomial trend for soil depth-bulk density relationship in a tilled soil. This variation was be due to differences in the nature of soil and agricultural practices.

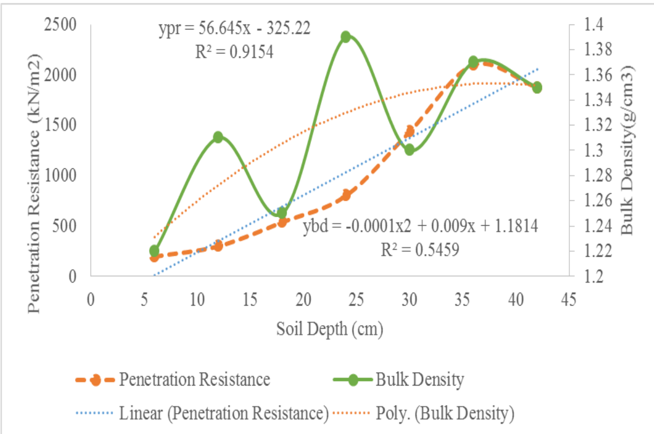

Figure 2: Soil Depth versus Compaction Characteristics

4.3 Tillage Methods and Soil Moisture Content

It was revealed as presented in Figure 3 that the highest value of soil moisture (17.3%) was recorded in the traditional (manual) tillage. The soil moisture recorded in the experiment varied between 12.97 and 17.3%. No significant difference was recorded in the moisture content of the soils in no-tilled and mechanically tilled soils as well as the fallowed agricultural soil. This is contrary to [22] that reported a good correlation between tillage and soil moisture conservation.

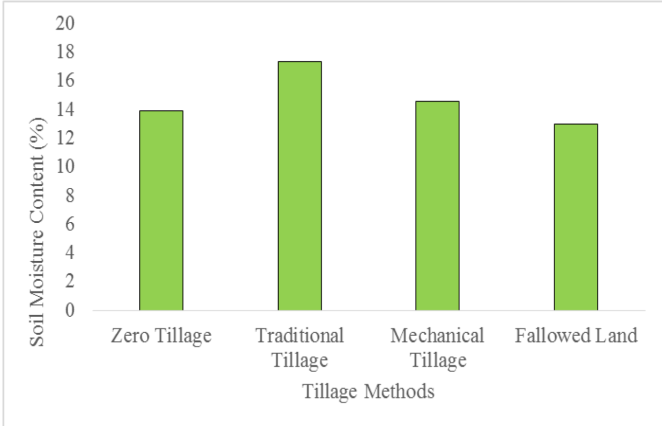

Figure 3: Tillage Methods versus Soil Moisture Content

4.4 Soil Texture

The textural class of the soil samples from the experimental locations is presented in Figure 4 and Table 1. The figure revealed as determined from the textural triangle after the laboratory analysis that all the soils in the experimental locations are sandy clay loam.

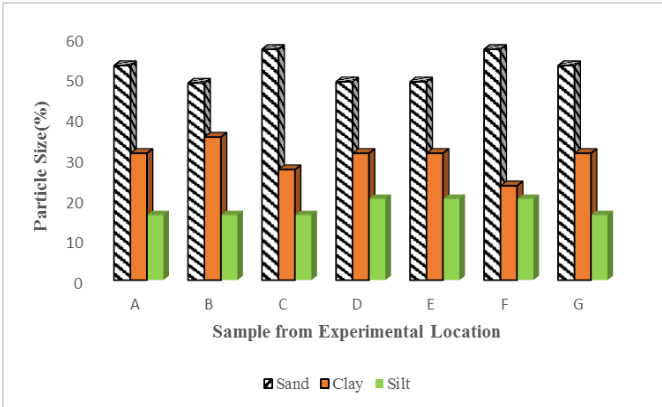

Figure 4: Textural Class of the Experimental Locations

Table 1: Textural Class of Experimental Soil

Soil sample	Particle size %			Textural Class
	Sand	**Clay**	**Silt**	
A	52.80	31.20	16.00	Sandy clay loam
B	48.50	35.20	16.00	Sandy clay loam
C	56.80	27.20	16.00	Sandy clay loam
D	48.80	31.20	20.00	Sandy clay loam
E	48.80	31.20	20.00	Sandy clay loam
F	56.80	23.20	20.00	Sandy clay loam
G	52.80	31.20	16.00	Sandy clay loam

5. Conclusions

Conclusively, farm machinery usage in the area of soil tillage has no adverse influence on agricultural soil in terms of Soil Penetration Resistance and Bulk Density which showed different relationships with tillage methods as well as with soil depth. Penetration Resistance and Bulk Density observed in this study are within the acceptable values for optimum root growth and Soil Penetration Resistance recorded for Zero Tillage and Fallowed soil are of the same values. This is an evidence that fallowing has an influence on soil strength.

Conflict of Interest
No conflict of Interest

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Authors' Contributions
Fasoyin, S. A. involved in protocol development, gaining ethical approval and field work.
Ale, M. O. researched literature, conceived the study, analyse the data and wrote the first draft of the manuscript
Abisuwa, T. A. participated in the field work and study conception. All authors reviewed and edited the manuscript and approved the final version of the manuscript.

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