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Effect of Moisture at Tillage on Bulk Density and Soil Strength

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ABSTRACT

This study was aimed at investigating the changes in bulk density and soil strength in response to soil moisture contents at tillage and to manage the soil in relation to soil conservation. The experimental units were ploughed at different moisture content ranging from 19% MCI to 13% MC4 except control plots which were sprayed with systematic herbicide. The soil ranged between sandy loams to loamy sand in the profile. The experiment was carried out at Obafemi Awolowo University Teaching and Research Farm (OAUT & R.F), Ile-Ife in 2011. The experimental field was 0.6ha and was laid out in a modified randomized complete block design RCBD. For the first cropping session, cone index was significantly lowest for MC2 treatment 1.35kg/cm^2 followed by MC3 treatment 1.32kg/cm^2 at 0-5 cm soil depth, no tillage which had the highest value 1.84kg/cm^2. At 5-10cm soil depth, MC3 had significantly lowest cone index 1.57 kg/cm^2 also no significant difference was also recorded for the bulk densities of the two seasons considered. However, there was a significant difference among the treatments for initial bulk density considered. MC3 had the highest bulk density value 1.48a glcm^3 followed by MC1, 1.44ab glcm^3 and MC4 1.43ab glcm^3, the least value was recorded for MC2, 1.32b glcm^3.

Keywords: Moisture Content, Tillage, Bulk Density, Soil Strength, Soil Type.

Introduction

Conventional tillage causes problem on dusty, fine sandy soils, particularly when dry; on very heavy sticky soils and on a structure less soils, especially those with high sodium content (Morgan 1998). Crop production activities are essentially seasonal. There is therefore an appropriate time to carry out every single operation on the farm beyond which the effectiveness of the operation or crop performance is adversely affected. In order to achieve the objectives of agricultural mechanization, a preliminary definition of agricultural mechanization in each country is required, which takes into consideration its socio-economic conditions, the development targets to be achieved and the optimal mechanization level to be used in order to ensure a certain labour productivity that will be able to face the timeline is requirement and reduce production costs (Igbeka, 2000). The influence of tillage implements on soil physical properties is significant (Boydas and Turgut, 2007). Buschiazzo *et al.,* (1998) reported that the soil physical properties, affected by soil tillage treatments, could influence the yield level of grown crops. Soil moisture content (SMC) is a very important parameter for cutting and milling the soil. With low soil moisture content, the cohesion force between particles of soil is very strong and a lot of energy is needed during tillage. With the higher soil moisture content, tillage equipment cannot effectively be used in the field (Hojat and Kaveh, 2009). Baurer and Kucera (1978) concluded that inconsistencies in relative grain yield differences among tillage treatments over a period of years were, in part, associated with inconsistent differences in soil properties produced by given tillage treatments from one year to another. Inconsistencies were concluded to be likely associated with the presence of soil water at the time of tillage and climatic conditions-primary water supply, water distribution and temperature. Ojeniyi and Dexter (1979) indicated that there is an optimum water content where tillage produces a maximum number of small soil particles and a minimum number of large voids. They also indicated that greatest total macro porosity was produced in the range of water content 12.6 to 18.3 percent on an Urrbrae loam soil (17% clay, 32% silt and 51% sand). The practices of no tillage and minimum tillage reduce erosion rates under maize (Bonsu and Obeng, 1979) and those achieved by multiple cropping but generally not to the levels obtained with surface mulching. No tillage was found to have reduced annual soil loss under maize with two corps per year near Ibadan, Nigeria to 0.007kg/m^3 compared with 0.56 kg/m^2 for hoe and cutlass, 0.83kg/m^2 with mould board plough and 0.91kg/m^2 for a mould board plough followed by harrowing (Osuji *et al.,* 1980).

Soil tillage, in general, is one of the fundamental field operations in agriculture because of its influence on soil properties, environment, and crop production (Hojat and Kaveh, 2009). Tillage methods affect soil physical properties and, thus, have a direct influence on the replenishment and depletion of soil water storage and crop performance. Tillage method is one of the most influential technical factors on the outcome of a crop, since it changes both the physical properties and moisture content of the soil (Thompson & Taylor, 1982; Varco et al., 1989; Ahadiyat & Ranamukhaarach, 2007). Certain tillage management practices could improve some soil physical properties and soil fertility as well as increase the conservation of soil moisture (Abu-Hammad & Battikhi, 1995).

Increase in soil water content and crop resistance to drought are due to loose soil, increase soil small openings, increase pervious water content and decrease surface rain run-off (Zongqing *et al.,* 1995). Ehlers, (1980) concluded that tillage may change soil bulk density, shoot and root growth and water uptake pattern of a crop. Mcfarland *et al.,* (1990) concluded that long term effects of tillage practices on soil physical properties may depend on the associated cropping sequence and more research on interactive effect was required.

Soils response to external load depends on soil moisture content (w). There is an optimum range of w at which the soil is most compatible. In general, the ρ_b changes nonlinearly in relation to change in w. Beginning with low moisture content increase in w serves to render the soil more plastic and workable and facilitate the compaction process (Hogentogler, 1936; Olson, 1962). The dry bulk density increases with an increase in w, and the maximum ρ_b is obtained at an optimum w, beyond which ρ_b drops with further increase in w. The magnitude of the peak ρ_b at a given w depends on soil texture and the load applied.

Soil strength is the resistance that has to be overcome to obtain a known soil deformation. It refers to the capacity of a soil to resist, withstand, or endure an applied stress (σ) without experiencing failure (e.g. rupture, fragmentation, or flow) (Lal *et al.*, 2004). It is soil's resistance that must be overcome to cause physical deformation ($\in$) of a soil mass. It implies that maximal stress which may be induced in soil without causing it to fail. In agriculture, soil strength has applications to root growth, seedling emergence, aggregate stability, erodibility and erosion, compaction and compatibility and draft requirements for plowing. Soil strength is an important soil physical property, with numerous applications to agronomy and engineering. Important agronomic applications are those related to impacts of crusting and compaction on plant growth and agronomic yield. Relevant engineering applications are related to trafficability, draft power required to till the soil for alleviating soil compaction, and soil as a foundation for hydraulic and civil structures (e.g. dams, roads, buildings). Tillage induced soil compaction is becoming a growing ecological concern because of the steady growth in the weight of machineries used in Agriculture. This problem is exacerbated by carrying out tillage operations under unfavorable moisture conditions. In Nigeria, no conscious effort has been made to evaluate the appropriate soil moisture conditions for the tillage of benchmark agricultural soils. This study was expected to establish the optimum range of moisture contents for the cultivation.

Materials and Methods

The Study Area

The field experiment was carried out at the Obafemi Awolowo University Teaching and Research Farm (O.A.U.T. & R.F.), Ile-Ife in 2011. The co-ordinates of the location range from latitude 7° 33.308 'N to 7° 33.267 'N and longitude 4° 33.466 'E to 4 ° 33.446 'E. It is located in the rain forest ecosystem in the Southwestern region of Nigeria with a mean annual rainfall of about 1,400 mm which is bimodal distributed with peaks in June and September. Average daily radiation is 19.2 MJ m^{-2} d^{-1} while average monthly value for humidity, maximum temperature, minimum temperature, sunshine hour, potential evapotranspiration (PET), wind speed were respectively 73.8 %, 30.7 ^{0}C, 27 ^{0}C, 6.6 hour, 4.36 mmd^{-1} and 114.6 km d^{-1}. The soils at the experimental site were derived from coarse grained granite and gneisses and classified as Iwo series (Smyth and Montgomery, 1962) and as Alfisol (Okusami and Oyediran, 1985). The soil is well drained with the surface texture varying from sandy loam to loamy sand.

The experimental field was 0.6 ha and was laid out in a modified randomized complete block design (RCBD), all the control treatments were arranged in the block to avoid disturbance. The treatment units were ploughed at different moisture contents ranging from 13 % (MC4,) to 19 % (MC1) except control plots which were not tilled but sprayed with glyphosate herbicide.

The experimental field had four replicates with twenty plots. Each plot was 10 m by 10 m with 5 m inter row spacing. The treatments (moisture contents) which were determined with the use of time domain reflectometry were: MC1 (Average moisture content of 19 %), MC2 (Average moisture content of 16 %), MC3 (Average moisture content of 14 %), MC4 (Average moisture content of 13 %) and the zero tillage (control) plot.

A dynamic cone penetrometer (UK DCP 2.2) with 20 mm cone diameter and 60 degree angle was used to measure the soil strength. Soil samples were collected at random within each plot using the core sampler (71.284 cm^3 volume) at 0-15cm soil depth. Samples collected using the core sampler was used for bulk density determination.

Data were analyzed using analysis of variance (ANOVA) while the means were separated with the use of Duncan Multiple Range Test to determine the effect of moisture content at tillage on bulk density and soil strength.

Results and Discussion

The analysis of variance showed that for all the treatments MC1 to MC4 first bulk density taken for the first cropping season did not vary significantly with soil moisture contents at tillage ($P \leq 0.05$) ,Table 1.1

Table 1.1: Effect of Moisture Contents at Tillage on the Bulk Density of 0-5 cm Soil Layer

Bulk Density (g/cm^3)				
Treatments	**First Season**		**Second Season**	
	Db1	**Db2**	**Db3**	**Db4**
C	1.45a	1.45a	1.22a	1.36a
MC1	1.52a	1.56a	1.36a	1.30a
MC2	1.48a	1.47a	1.16a	1.34a
MC3	1.59a	1.55a	1.37a	1.35a
MC4	1.56a	1.40a	1.30a	1.39a
Mean	1.52	1.49	1.28	1.35

Means along the same column followed by the same alphabets are not significantly different at $P \leq 0.05$ according to Duncan's multiple range tests.

The mean bulk density was 1.52 g/cm^3. Mean value of bulk density for C, MC1, MC2, MC3, MC4 were 1.45, 1.52, 1.48, 1.59, 1.56 g/cm^3 respectively. There were no significant differences in the bulk density values for the second reading taken in the first cropping season.

For the second cropping season, the analysis of variance showed that neither the first bulk density values nor the second bulk density value were significant. The mean for the first bulk density values in the second cropping season were 1.22, 1.36, 1.16, 1.37, 1.30, g/cm^3 for C, MC1, MC2, MC3, MC4 respectively (Table 1.1) Bulk density values for the second cropping season were relatively lower when compared with the first cropping season. This might be due to the repeated pulverizing action especially in the conventional tillage. The results are in agreement with those of Anazodo *et al., (*1991). Control and MC2 maintained relatively lower bulk density values while MC3 had relatively higher bulk density in the two cropping seasons. The initial soil bulk density for the two cropping seasons is shown in Table 1.2.

Table 1.2: Effect of Moisture Contents at Tillage on Bulk Density at Initial and Maturity of the Maize Crop

Treatments	Initial	Maturity (g/cm^3)
C	1.33b	1.40a
MC1	1.44ab	1.43a
MC2	1.32b	1.40a
MC3	1.48a	1.45a
MC4	1.43ab	1.39a

Means along the same column followed by the same alphabets are not significantly different at $P \leq 0.05$ according to Duncan's multiple range tests.

There was a significant difference among the treatments considered. MC3 had the highest bulk density 1.48 g/cm3 followed by MC1, 1.44 g/cm3 and MC4, 1.43 g/cm3.The least value was recorded for MC2, 1.32 g/cm3. The order of increase in bulk density was MC3 > MC1 > MC4 > C > MC2. There was no significant difference in the bulk density at maize maturity, (Table 1.2). Soil bulk density was generally lower at maize maturity compared with the initial bulk density except for MC2 and MC1 treatments where there was slight increase.

The soil resistance to cone penetrometer (cone index) was used as a measure of soil strength in this study. Fig. 1.1 shows soil cone index at depths as influenced by tillage treatments.

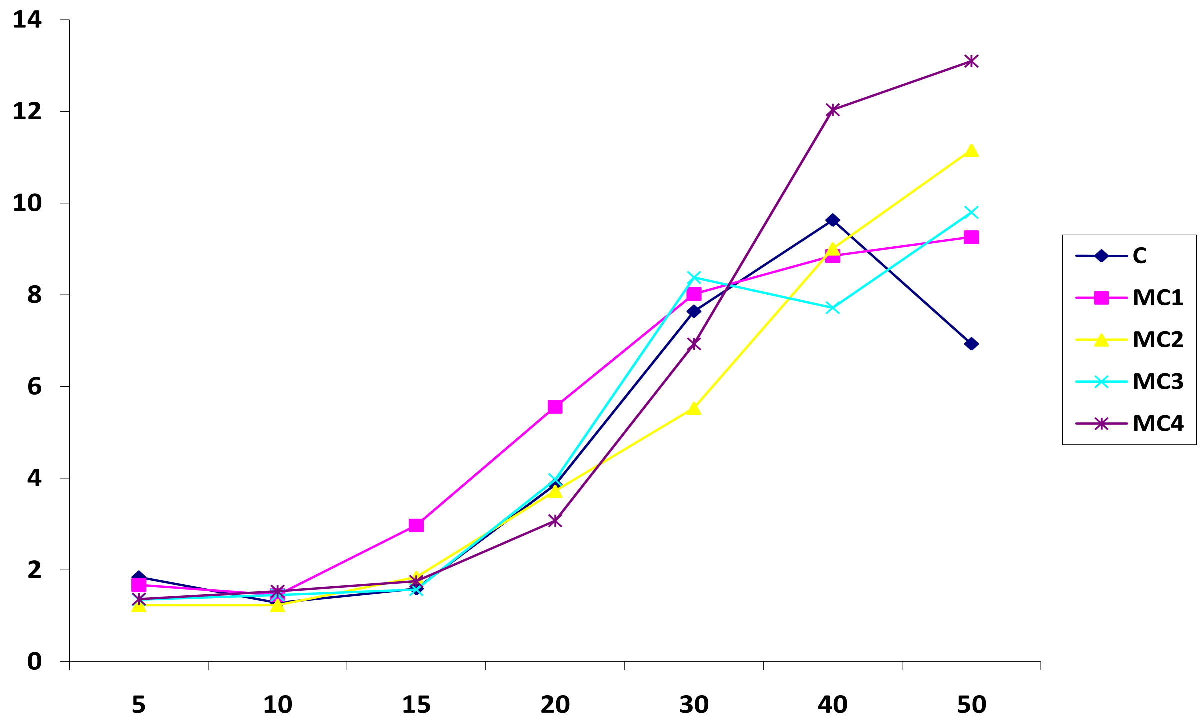

Figure 1.1: Effect of Moisture Contents at Tillage on Soil Cone Index

There was a significant difference ($p \leq 0.05$) at 5, 15 and 40 cm soil depth. The control experimental plot, i.e. plot without tillage had the highest cone index value of 1.84 Kg/cm^2 at 0-5 cm soil depth compared to others that were tilled (disc + harrow). The MC3 and MC2 with 1.35 and 1.23 kg/cm^2 respectively had the least value. The order of increase in soil penetrometer resistance was C > MC1 > MC4 > MC3 >MC2. The highest penetrometer resistance with control experimental plot can be attributed to no soil manipulation. This reduced the evaporation rate and run off following rainfall and subsequently, the soil was able to resist force more than other treatments at this soil depth (Anazodo *et al.,* 1991). At a depth of 5-10 cm, there was no significant difference in the soil resistance to cone penetrometer. Although MC4 with the value of 1.53 kg /cm^2 was the highest, it is not significantly from control experimental plot (C) 1.28 kg/cm^2 that had the least value. There was a significant difference at the soil depth of 10-15 cm with MC1 having the highest value of 2.97 kg/cm^2 while the least was recorded for MC3 1.57 kg/cm^2. The order of soil penetrometer resistance was MC1 > MC2 > MC4 > C> MC3.The higher values of soil strength recorded for conventional tillage system when compared with zero tillage system at this soil depth might be due to soil compaction as a result of heavy machinery continuously used in the former (Ojeniyi and Dexter, 1979). There is no significant variation in the penetrometer resistance from the 15 to 40 cm soil depth. Between 40 and 50 cm soil depth, control experimental plot had the least resistance to penetration value of 6.93 kg cm^{-2} while MC4 with the value 13.10 kg/cm^2 was the highest. The implication of this is possible mechanical impedance to root development and proliferation under MC4 when compared to other treatments in line with observation of Barber, 1971; Adepetu and Sagay, 1981.

Conclusion

The mean bulk density value at 4 weeks for 14 % and 16 % moisture contents were 1.59 and 1.48 g/cm^2 respectively while the second mean bulk density value taken at 8 weeks for 14 % and 16 % moisture contents were 1.55 and 1.47 g/cm^3 which were lower in value. Lower bulk density and cone index value in 14 % and 16 % moisture content attribute make these treatments to have least mechanical impedance to root development and proliferation which can favor performance of growth crop when compared to other treatments. Soil bulk density was generally lower than the first cropping season for all the treatments considered. This may be due to repeated pulverization action during tillage operations. No tillage had the least bulk density value of 1.22 g/cm^3 followed by the plots tilled at 16 % moisture content which had a mean value of 1.48 g/$cm^{3.}$ It showed that tillage at lower moisture content can improve soil properties so as to sustain crop growth, development and yield. It can thus be suggested that tilling at moisture content that ranges between 14 and 16 % or 3 to 6 days after rainfall has a comparatively higher advantage in soil physical properties management in relation to soil conservation.

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