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To Assess the Impact of Disc Plough Weight and Draught on Physical Properties of Sandy Loamy Soil

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Abstract: *Field experiments were conducted to assess the impact of disc plough weight and draught on physical properties of sandy loamy soil at the National Center of Agricultural Mechanization (NCAM), Ilorin, Nigeria. The soil physical properties indicators were moisture content, bulk density, porosity, shear strength and cone index as well as depth and width of cut were examined in sampled soil accordance with the APHA (2005) standards. The tillage treatment in the study was conventional tillage by two passes operation for disc plough. The required soil physical properties were measured at various depth ranges from 0 cm to 21cm at 7cm intervals and analyzed. Results showed that the average value of the soil physical properties at various depths before and after tillage operations indicated that Moisture content (10.16 ±0.1, 12.13 ±0.1), Bulk density (1.53 ± 0.1, 1.46 ±0.1), Porosity (35.55 ±0.03, 36.89 ±0.05), Cone index (0.75 ±0.41, 0.32 ± 0.01) and Shear strength (0.10 ±0.01, 0.02 ± 0.01) respectively. There were significant differences (p 0.05) between values obtained at before (non-tillage) and after tillage operation. Result indicated that tillage operation had significant impact on soil physical properties, exhibited better moisture conservation, higher soil porosity, reduced the soil strength properties, more farm power and speed requirement. The study proved that the shear strength and resistance to penetration are more reliable indices for assessing soil tilth than the bulk density under tillage operation and the depth and width of cut increased with weight of the implement.*

Keywords*: Disc plough, Implement weight, Non-Tillage, Soil physical properties, Tillage Operation, Draught*

I. Introduction

Soil is versatile material which can be used for different purposes. It is in this respect that various professional bodies gave it definition to suit their professions. To a farmer, soil is the substance that supports plant life and act as reservoirs for the water and nutrients needed by plants, whereas to the geologist it is an ambiguous term meaning the mantle from which it was derived. To civil engineer the term soil is defined as any unconsolidated material composed of discrete solid particles with gases or liquid between. To the Agricultural engineer the term soil is viewed as not a foundation and construction material but as an important resource for crop and livestock production, hence the soil water management and the physical properties are very important in the scientific management of soil to achieve optima in the crop and livestock production (Omole,1991).Soil fertility depends most of their physical, chemical, and mineralogical properties from the initial materials or parent materials from which they developed. Tillage represents the most costly single item in the budget of a farmer and is one of management practices that are important to the soil quality enhancement. Tillage defined as mechanical manipulation of soil which is used to maintain, modify or promote changes in soil structure in an effort to produce more desirable soil environment for plant growth (Kumar et-al., 2011; Ojha and Michael, 2011 and Jain, 2009).Tillage is a management input that affects soil physical characteristics cited by (Katsvairo et al., 2002). Soil properties affected by tillage are as follow: crop residue cover, soil test measurement, nutrient availability, structure and aggregate stability, water relationships, temperature and strength. Soil physical and chemical properties are important for favourable conditions for crop growth and maintaining soil quality (Rachman et al., 2003).The suitability of a soil for sustaining plant growth and biological activity is a function of physical and chemical properties (Mulumba and Lai, 2008). Soil tillage consists of breaking the compact surfaces of earth to a certain depth and to loosen the soil mass for better aeration and water infiltration, root growth, weed control, soil erosion and moisture control and hence improve crop yields. Three things are involved in soil tillage which includes: The power source, the soil and the implement (Olantunji, 2007;.Jain,2009) reported that a certain amount of tillage is required on most soils to promote growth of plants and the progress of a country parallel the development of the tillage tools used in the cultivation of its soil. The effect of tillage on the soil depend on the shape of the implement, the number of passes, the speed and timing of tillage, type and moisture of the soil. Ojha and Michael (2011) reported that about 20 percent of the total energy required for crop production is utilized in tillage operation. Kumar, et-al. (2011) and Jain, 2009) highlighted the preference of Disc plough as primary tillage in following conditions:

(i) Clayey and sticky soils where mould board plough does not scour well
(ii) Soil having hard pan or plough sole below regular ploughing depth.
(iii) Dry and hard land which is difficult to penetrate with mould board plough.
(iv) Stony and stumpy soils which are likely to cause damage to mould board plough
(v) Extremely loose soil, where the mould board plough will not turn soil
(vi) High speed ploughing
(vii) Soil cover and with long trashes

Tillage processes on the soil physical properties can be imparted either positively or negatively depending on the management method and also concluded that temporal variability of soil physical properties can be even greater than spatial variability in agriculturally managed soil (Rashidi, M and Keshavarzpour, F. 2007; Strudley et al., 2000; Alletto and Coquet, 2009). The positively impact of tillage on the soil physical properties lead to soil aeration, infiltration and water holding capacity enhancement and reduced penetration resistance which resulted to good tilth, nutrient uptake, crop growth and increase crop yield. The object of this study was to assess the impact of the disc plough weight and draught on sandy loam soil.

II. Materials And Methods

2.1 The Study Area.

The project research was carried out at National Center for Agricultural Mechanization (NCAM), Ilorin, The soil of the site is sandy loamy soil, which is 370m above the sea level and lies on longitude $40^{0.}30'$ East and latitude $8^{0}.26'$ North with mean annual rainfall and air temperature of 1000mm and 30^{0}C respectively. Nigeria. 50x20m plot of land was used for the experiment

2.2 Description Of The Equipment

Two 75 HP Diesel Tractor (Massey Fergunson) with 15.5 – 38.0mm diameter rear tyres and 7.5 – 20 0 mm front tyres with operated speed of 8km/hr. The Baldan AF mounted disc plough consists of three plane concave discs with a spacing of 550mm, the disc diameter 64.5mm, the working depth of the disc ranged from 150 – 300mm and working Width 900mm as presented in Fig.1. The implement was powered through its 3 points hitch by a 75HP Massey Fergunson diesel tractor.

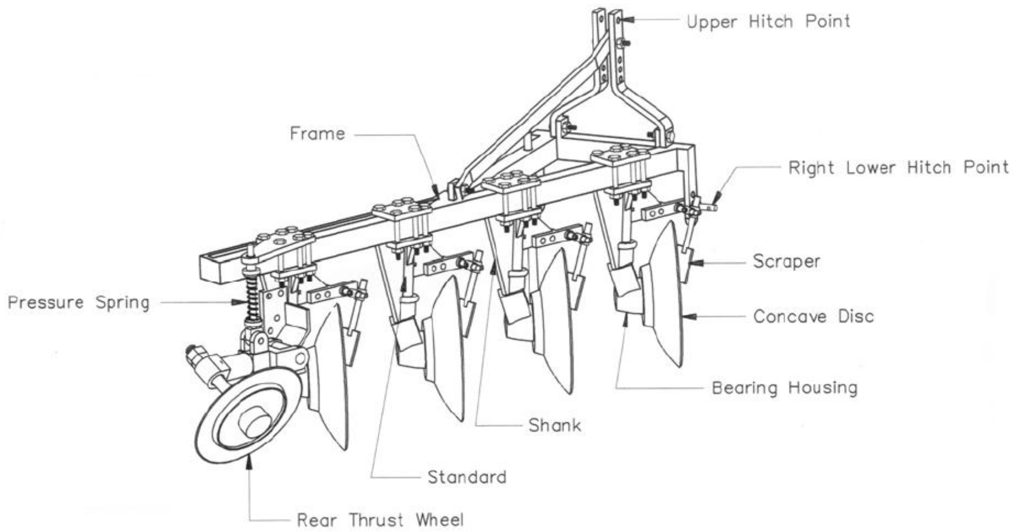

Figure 1 – Disc plough and its component (ASAE 1999)

2.3 Parameter Measurements

2.3.1 Soil Moisture Content (%)

Three soil samples were randomly taken with soil auger at various depths and intervals of 0 -7, 7 – 14 and 14 – 21cm soil layers before and after ploughing operations. Soil samples were weighed, oven dried at 105^{0}C for 24 hrs and weighed again to determine the gravimetric moisture content. The result is presented in Table 1.

$$\text{Moisture Content (Dry basis)} = \frac{\text{Weight of moist soil} - \text{Weight of dry soil}}{\text{Weight of moist soil}} \times 100 \quad (1)$$

2.3.2 Soil Bulk density (g/cm^3)

Soil bulk density was determined accordance to APHA, (2005). Three soil samples were randomly taken with soil auger at various depths and intervals of 0 -7, 7 – 14 and 14 – 21cm soil layers before and after ploughing operations Soil bulk density was determined using the volume of the core sampler after gravimetric moisture determination with the application of the equation below. Three cone samplers labeled A, B and C was used to collect the soil samples at various depths. The samplers was weigh empty, and then weighed with the soil. The sample was later placed in an oven at a high temperature of about 105°C for 24 hours and cool in a desiccator. The bulk density was then be determined by the formula. The result is presented in Table 2.

$$\text{Bulk density of soil} = \frac{\text{Mass of oven dry soil}}{\text{Volume of core}} \ (\text{g/cm}^3)$$

2.3.3 Porosity (%)

Soil bulk density was determined accordance to APHA, (2015). Three soil samples were randomly taken with soil auger at various depths and intervals of 0 -7, 7 – 14 and 14 – 21cm soil layers before and after ploughing operations. Porosity was measured using the core sampler and mathematically expressed as the percentage ratio of the total pore volume by the bulk soil volume. The result is presented in Table 3.

Porosity = Total pore volume / Bulk soil volume

2. 3.4 Soil Cone Index (N/Cm^2)

Soil cone index was determined accordance to ASABE (2006). Three soil samples were randomly taken with soil auger at various depths and intervals of 0 -7, 7 – 14 and 14 – 21cm soil layers before and after ploughing operations. The core penetrometer of cone diameter 20.27mm and cone base area of 320mm^2 was pushed into the soil by hand at speed of 2cm/s. The result is presented in Table 3.4

2. 3. 5 Soil Shear Strength (N/Cm^2)

The soil shear strength was measured to determine the level of soil compaction. Three soil samples were randomly taken with soil auger at various depths and intervals of 0 -7, 7 – 14 and 14 – 21cm soil layers before and after ploughing operations. The Hand Held-Field Shear Vane was pushed into the soil at various depths to determine the soil shear strength. The result was presented in Table 3.

2.3.6 Draft Force

Dilon Dynamometer connected to a data logger in the tractor cab was used to measure the draft force of the tillage implement. The dynamometer was attached to the front of the tractor on which the implement was mounted as presented in Fig.2. The draft and specific draught obtained when the auxiliary tractor was pulling tractor B in a neutral gear at average moisture content of 12.13% within the measured distance of 25m at various speeds when the disc plough without and with engage was presented in Table 6.

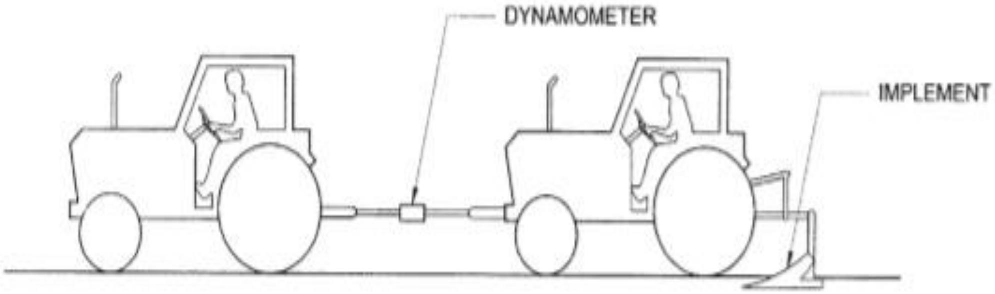

FIGURE 2: Auxiliary tractor pulling the implement in an operating position

2.3.7 Tillage Depth And Width (Cm)

Four weight of the implement was used to determine the depth and width of cut. The first weight is the initial weight of the implement which is approximately 401kg. The approximate weight of the implement was obtained from the manufacturer manual of the disc plough. After the initial weight of the implement have been recorded, an iron block of 29kg, 52kg and 79kg were used to obtain the second, third and fourth weight respectively. At the commencement of the tillage operations and after tillage operations, the tillage depth and width of cut at various weight of the implement were measured using steel tape by inserted down into the tilled soil until a hard pan was encountered for tillage depth while steel tape was inserted from the furrow wall to the tilled area in case of width cut. The results were presented in Table 7.

2.4 Data Analysis

Descriptive statistics was performed on data .Means were compared with Duncan's multiple range test. The statistical inferences were made at 0.05 (5%) level of significance.

III. Results And Discussion

3.1 Impact Of Disc Plough On Soil Moisture Content.

Soil moisture is the source of water for plant use in particular in rainfed agriculture (Mweso, 2003). Soil moisture is highly critical in ensuring good and uniform seed germination and seedling emergence (Arsyid et al., 2009). The average soil moisture content is presented in Table1.The average soil moisture content after ploughing recorded higher soil moisture content than before ploughing (non-tillage) based on the depth of penetration of the sampler. It was also observed that in each sample taken both before and after ploughing that at depth of 14 – 21cm, the moisture content of each sample become higher, which can be concluded that the more the depth of penetration of the core sampler in the experimental plot, the higher the percentage of the moisture content. There were significant differences ($p \leq 0.05$) between values of soil moisture content before and after ploughing operation. The differences may be attributed to the fact that disturbance and pulverizing caused by tillage operation produced finer and loose soil structure which tend to conserve more moisture (Rashidi and Krshavarzpour, 2007).

Table 3.1: The average soil moisture content before and after ploughing operation at various soil depths

Depth (cm)	Mean before Ploughing (%)	Mean after Ploughing (%)
0 – 7	$9.69^{a} \pm 1.03$	$11.88^{b} \pm 1.02$
7 – 14	$10.35^{a} \pm 0.06$	$12.08^{b} \pm 0.44$
14 – 21	$10.43^{a} \pm 0.57$	$12.42^{b} \pm 0.06$

Results presented are means values of each ± standard deviation. The means values with different superscript are significantly different ($p \leq 0.05$) while those with the same superscript are not significantly different ($p \geq 0.05$) as assessed by Duncan's Multiple Range Test (vertical comparison only)

3.2 Impact Of Disc Plough On Soil Bulk Density

The average soil bulk density is presented in Table 2. The result indicated that average bulk density before ploughing (non-tillage) operation is higher than that of after ploughing operation, based on the depth of penetration of the sampler. The bulk density was also found to be increased with the depth.There were not significantly differences ($p \geq 0.05$) between values of bulk density before and after ploughing operation. The bulk density of a soil gives an indication of the soil's strength and thus resistance to tillage implements or plants as they penetrate the soil. This study supported the observation made by Tebriigge and Durring (1999) that bulk density increased under no-till in relation to conventional tillage.

Table 2**:** The average soil bulk density before and after ploughing operation at various soil depths

Depth (cm)	Mean before Ploughing (g/cm^3)	Mean after Ploughing (g/cm^3)
0 – 7	$1.43\ ^{a} \pm 0.23$	$1.33^{a} \pm 0.03$
7 – 14	$1.55^{a} \pm 0.14$	$1.46^{a} \pm 0.06$
14 – 21	$1.60^{a} \pm 0.81$	$1.58^{a} \pm 0.02$

Results presented are means values of each ± standard deviation. The means values with different superscript are significantly different ($p \leq 0.05$) while those with the same superscript are not significantly different ($p \geq 0.05$) as assessed by Duncan's Multiple Range Test. (vertical comparison only)

3.3 Impact Of Disc Plough On Soil Porosity.

Soil porosity and organic matter content play a critical role in the biological productivity and hydrology of agricultural soils. Pores influence the infiltration, storage, and drainage of water, the movement and distribution of gases, and the ease of penetration of soil by growing roots (Franzluebbers, 2002). The average soil porosity at given soil layers is presented in Table 3. The result indicated that average porosity before ploughing (non-tillage) operation is lower than that of after ploughing operation, based on the depth of penetration of the sampler. The porosity was also found to be decreased with the depth. There were significantly differences ($p \geq 0.05$) between values of bulk density before and after ploughing operation. Porosity generally decreased with soil depth due to the natural increase in packing density with depth due to soil weight and lower moisture content as dry season sets in.

Table 3: The average soil porosity (%) before and after ploughing operation at varioussoil depths

Depth (cm)	Mean before Ploughing (%)	Mean after Ploughing (%)
0 – 7	$36.06^{a} \pm 0.03$	$37.88^{b} \pm 0.02$
7 – 14	$35.55^{a} \pm 0.03$	$36.68^{b} \pm 0.44$
14 – 21	$35.03^{a} \pm 0.02$	$36.12^{ab} \pm 0.06$

Results presented are means values of each ± standard deviation. The means values with different superscript are significantly different ($p \leq 0.05$) while those with the same superscript are not significantly different ($p \geq 0.05$) as assessed by Duncan's Multiple Range Test (vertical comparison only)

Impact of Disc Plough on Shear strength and Soil Cone index Penetrometer resistance measurements of soil can be used to assess the need for tillage operations, which help maintain effective plant rooting and facilitate good water and nutrient uptake (Veenstra et al., 2006). The average cone and index soil shear strength are presented in Table 4 and Table 5 respectively. Both soil shear strength and cone index increased with depth significantly before ploughing (non-tillage) while the result of the cone index and shear strength within the soil regions 0-7, 7-14 and 14-21cm after ploughing operation are low and also similar to each other dues to the fact that the soil has being plough and pulverize which lead to less in the resistance to penetration in the soil. The high shear strength values observed before till may be ascribed to the lower moisture content. The results for both cone index and shear strength shown that penetration resistance decreased with increase in soil moisture content and vice versa. There were significantly differences ($p \leq 0.05$) between values of cone index as well as shear strength before and after ploughing operation.

Table 4: The average cone index (N/cm^2) before and after ploughing operation at various soil depths

Depth (cm)	Mean before Ploughing (N/cm^2)	Mean after Ploughing (Ncm^2)
0 – 7	$0.56^b \pm 0.14$	$0.30^a \pm 0.01$
7 – 14	$0.79^b \pm 0.21$	$0.32^a \pm 0.01$
14 – 21	$0.91^b \pm 0.80$	$0.32^a \pm 0.01$

Results presented are means values of each ± standard deviation. The means values with different superscript are significantly different ($p \leq 0.05$) while those with the same superscript are not significantly different ($p \geq 0.05$) as assessed by Duncan's Multiple Range Test (vertical comparison only)

Table 5: The average soil shear strength (N/cm^2) before and after ploughing operation at various soil depths

Depth (cm)	Mean before Ploughing (N/cm^2)	Mean after Ploughing (N/cm^2)
0 – 7	$0.03^c \pm 0.01$	0.001a ±0.001
7 – 14	$0.12^b \pm 0.01$	0.002a± 0.000
14 – 21	$0.13^b \pm 0.01$	0.003a ± 0.001

Results presented are means values of each ± standard deviation. The means values with different superscript are significantly different ($p \leq 0.05$) while those with the same superscript are not significantly different ($p \geq 0.05$) as assessed by Duncan's Multiple Range Test (vertical comparison only)

3.4: Impact Of Weight Of Disc Plough On Depth And Width Of Cut.

The average soil depth and width of cut is presented in Table 6. The result indicated that increase in the weight of the implement at constant ploughing speed, showed an appreciable changes in the depth and width of cut. This study was agreed with the findings of Olatunji (2007) that increases the weight of implement lead to increase in depth and width of cut at the same soil moisture content and speed. There was no significant difference ($p \leq 0.05$) among the depth of cut as well as width of cut at various weights

Table 6: The average depth and width of cut at various weight of implement

Weight of Implement (kg)	Depth of cut (mm)	Width of cut (mm)
401	$11.30^a \pm 0.40$	$1.63^b \pm 0.02$
430	$11.40^a \pm 0.10$	$1.68^b \pm 0.02$
453	$11.50^a \pm 0.20$	$1.70^b \pm 0.02$
480	$11.56^a \pm 0.20$	$1.73^b \pm 0.03$

Results presented are means values of each ± standard deviation. The means values with different superscript are significantly different ($p \leq 0.05$) while those with the same superscript are not significantly different ($p \geq 0.05$) as assessed by Duncan's Multiple Range Test (vertical comparison only)

3.6: The Effect Of Speed On Draft And Specific Draught At Constant Soil Moisture Content

The change in draft and specific draught with respect to speed and constant soil moisture content when disc plough is engaged and without engaged is presented in Table 7. The results shown that both the draft and specific draught for disc ploughing with engage and without engage increases with speed at constant moisture content. There were significant differences ($p \geq 0.05$) between draft as well as draught with engage and without engage at various speed at constant moisture content.

Table 7: The Draft and Specific Draught for Disc Plough Without and With Engage at various Speed and constant Moisture content (12.13%)

	Without Engage		With Engage	
Speed (cm)	Draft (KN)	Specific Draught (KN/cm^2)	Draft (KN)	Specific Draught (KN/cm^2)
0.83	$3.19^a \pm 0.1$	$19.90^e \pm 0.1$	$3.65^b \pm 0.1$	$22.80^f \pm 0.2$
1.39	$3.27^a \pm 0.1$	$20.40^e \pm 0.1$	$5.45^c \pm 0.2$	$34.10^g \pm 0.5$
1.94	$5.20^c \pm 0.2$	$31.50^g \pm 0.2$	$7.34^e \pm 0.2$	$45.90^h \pm 0.5$
2.50	$6.38^d \pm 0.2$	$34.10^g \pm 0.3$	$7.45^e \pm 0.3$	$46.60^h \pm 0.6$

Results presented are means values of each ± standard deviation. The means values with different superscript are significantly different ($p \leq 0.05$) while those with the same superscript are not significantly different ($p \geq 0.05$) as assessed by Duncan's Multiple Range Test (vertical comparison only)

IV. Conclusion

This study had shown a data base that can be used for the prediction of the impact of tillage on soil physical properties. The results from the study indicate that:
*Tillage operations significantly affected soil penetration resistance, dry bulk density, moisture content and porosity
* Tillage operation on the soil exhibited better moisture conservation and higher soil porosity.
* Tillage operation reduced the soil strength properties but the more farm power and speed required
* The shear strength and resistance to penetration are more reliable indices for assessing soil tilth than the bulk density under tillage operation
* The depth and width of cut increased with weight of the implement.

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