Effects of Some Tillage Parameters on Soil Cone Index Using Disc and Mouldboard Ploughs.

Y. Abubakar[1], and Hussaini, M. S.[1]

1.Department of Agricultural and Bio-Environmental Engineering,
Federal Polytechnic, P.M.B. 35, Mubi, Adamawa State,
Nigeria.(yahayaabubakar70@gmail.com)

Abstracts

A study was conducted on the effects of soil moisture content implement speed and tillage depth on soil cone index using disc and mouldboard ploughs on loamy sand soils. Analysis of variance and Duncan's multiple range tests shows that, moisture content, implement speed and tillage depth have significant effects on soil cone index. Further analysis revealed that, at 1.94m/s (7Km/h) implement speed, the soil physical properties (cone index) reduced to minimum considerably and usually maintain a constant value which equals the values recorded at implements speed of 2.5m/s (9Km/h) and 2.78m/s (10Km/h) . This shows that, the physical properties of soil required for good soil tillage could be achieved at implement speed of 7km/h.

Keywords; *Soil Cone Index, Tillage Depth, Soil Moisture and Implement Speed*

1.0 Introduction

Conventional tillage practices modify soil structure by changing its physical properties such as soil bulk density, soil penetration resistance and soil moisture content.

Tillage, the physical modification of soil, is performed using various methods. This is usually accomplished through the use of manual hoe, tractorized and animal drawn implements. The main purposes include tilt formation, weed control, enhancement of soil aeration, drainage and incorporation of residues and fertilizers. Root and crop growth is facilitated. Also seepage and storage of water are enhanced. Tillage also controls disease and pest infestation.

The aim of soil tillage in crop production is to produce soil conditions and environment favourable to crop growth by changing the soil bulk density, soil aggregate, size distribution and other characteristics of soil, (Johnson and Buchele, 1967).

It is a process of modifying soil properties by pulverization, cutting, inversion or movement of the soil resulting in improved soil condition for optimal crop growth and yield, (Grisso et al, 1996). It is a major event in the process of crop production, which consumes nearly 30 – 35 percent of the total energy requirements, (Manian et al, 2000).

Tillage, when done at the correct soil moisture, allows the soil to fracture along the existing soil structural planes. The soil moisture should be such that soil aggregates will separate easily when worked, without the smearing or destroying the aggregates, which would occur if the soil is too wet. Tillage, and the subsequent residue management effects, will have a profound effect on soil processes and properties that directly impact crop production. Examples of these processes and properties are soil structure, water infiltration and movement in the soil, bulk density, aeration, soil warming, biological activity, and residue and organic matter relationships.

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

Tillage tools and implements are used to produce those favourable soil conditions. Tillage is a major management problem in agronomic practices. The study will help provide classified data for agricultural soils within the study area and to determine an optimum soil penetration resistance for workable moisture content of the soil.

The specific draught for agricultural tools and implements varies widely under different conditions, being affected by such factors as the soil type and condition, ploughing speed, plough type, shape and friction characteristics of the soil engaging surfaces, share sharpness, and shape, depth of ploughing, width of furrow slice, type of attachments, and adjustment of the tool attachments. A great deal of work has been done in evaluating these various factors and investigating possible means of reducing draught. Mathematical methods and models have been developed for predicting draught (Reece, 1965; Stanford, 1979).

Apart from the working width, forward speed is a factor that allows increased rates of operational performance. A very wide range of speed is possible with a tractor and implements are designed to perform best within a particular range of speeds.

The availability of data on soil penetration resistance is important in selecting suitable tillage implements for a particular farming situation. Farm managers and consultants use data of soil physical properties in specific soil types to determine the matching implement and size of tractor required. Therefore, predictions of soil cone index are important for tractor selection and implement matching.

The study of soil physical properties in tillage operation which relates other tillage parameters such as soil moisture content, tool speed, depth of work disc and tilt angle, type of tool etc provide information for machinery design parameters. It will also improve machinery and implements utilization, within the Savannah agro-ecological zone of Nigeria

The aim of this work is to determine the effects of implement speed variations, depth of tillage and moisture content on soil cone index using disc and mouldboard ploughs and achieve a recommend practical ways of reducing the tractor speed and hence the power requirement for the implements.

2.0 MATERIALS AND METHODS

The study was conducted at the demonstration farm of the Department of Agricultural and Environmental Engineering, Modibbo Adama University of Technology, Yola during the year 2016. Soil particle size distribution analysis showed the soil to be loamy sand (Sand - 76%, Silt – 15% and clay – 9%). At the period of this experiment, the field looks like fadama area, and lies on a gentle slope.

The equipment consist of a conventional tractor, disc and mouldboard ploughs, an oven drier for analyzing moisture content of soil and weighing balance.

Experimental Design

The test was carried out using a disc and mouldboard ploughs. For tillage operations, the treatments include; moisture content (M) of the soil (before and after rainfall) at two (2) levels, implement speed (S) five (5) levels, depth of ploughing (D) two 2 levels and three replications for each test. The four variables were combined in a factorial split-plot design with three blocks.

Split-plot design is generally suitable for factorial experimental with three or more factors (Gomez and Gomez, 1984). The moisture levels were designated as M_1 and M_2, and where M_2 corresponds to normal moisture content for ploughing (20hr after rainfall), and M_1 was drier than M_2 (six days after rainfall). Implement speed levels were 3, 5, 7, 9, and 10km/hr since average speed of ploughing is about 7km/hr (Ahanekun *et al*, 2003).

Soil properties were determined before and after tillage treatments. The physical field layout was achieved by using Pegs and colour tags, field measuring tapes and lines to mark out the sub plot and the strips.

Determination of Soil Properties

In order to define the initial soil conditions, soil samples were collected from each treatment to determine the soil parameters. Soil properties measured include: soil moisture content, penetration resistance and bulk density.

Determination of Soil Moisture Content

The soil moisture content was determined gravimetrically. Soil sample for each treatment was taken before and after tillage operations, and placed in an air tight container (tin). The sample was immediately taken to the laboratory and weighed with an accurate weight balance and then placed for an oven drying at a temperature of 110^0C for 24 hours as in Gwarzo, (1990).

The loss of weight in drying divided by the original weight of individual soil sample multiplied by one hundred percent (100%) as shown in the equation below determines the moisture percentages of the soil samples on dry basis

Specific Growth Rate (SGR)

$$Mc = \frac{Wo - Wd}{Wd} \times 100 \quad \text{(James,1988)} \qquad (1)$$

where;

Mc = Moisture content of the soil (%db)

Wo = Weight of moist soil (g)

Wd=Weight of dry soil (g)

The results of the soil moisture content before and after tillage were presented in appendix 6 and the average values of the results for each treatments was presented on appendix 4, showing data for before and after tillage respectively.

Determination of Soil Penetration Resistance (Cone Index)

The cone index of each treatment was determined using the hand held penetrometer with model number; (WF24950) calibrated in Kg/cm^2 before and after tillage. The cone depth profile for each sub-plot was taken up to a maximum depth of the instrument (5cm) as stated in the instructions manual, depending on the hardness or penetration resistance of the soil.

Determination of Machine Parameter

Mersey Ferguson 375 and John Deere tractors were used to perform the experiments. The machine parameters determined was the tractor speed.

Determination of Tractor Speed

Five treatments of the tractor speeds chosen were 3, 5, 7, 9, and 10 km/hr corresponding to S_1, S_2, S_3, S_4 and S_5 respectively. Before the actual experiments starts, the various revolutions per minute of the engine read off from the speedometer that corresponds to the chosen tractor forward speeds were determined. This is to ensure that the tractor attains such speeds before measurement at joint up pulls was taken under each soil moisture regime.

Data Collection and Analysis

Data was collected as described under research methodology. The average values of the results obtained were presented on Table 1. This result was subjected to Analysis of variance ANOVA to evaluate the significance of each treatment in a split –plot design with a factorial treatment design of 2×2×2×5. This was to determine the effect of soil moisture, tool speed, depth of cut, and combine effect of moisture content, tool speed, tillage depth on the soil bulk density after tillage.

Comparison of means was performed with Duncan's Multiple Range Tests to determine the significance of each treatment on soil bulk density at $P< 0.05\%$.

However, results for bulk density were illustrated graphically to show the influence of moisture content, forward speed and depth of cut on bulk density of the soil using disc and mouldboard ploughs in figures 1 and 2.

RESULTS AND DISCUSSIONS

Table 1 shows the average values for bulk density, cone index and moisture contents of the soil on each treatment plot after tillage.

Effects of speed and moisture content and tillage depth on Cone index

The average results in Table 1 shows that, implement speed has a significant effect on penetration resistance (cone index). The value of cone index decreases from 1.2kg/cm^2 to1.1kg/cm^2 and to 0.2kg/cm^2 for implement speed of 3km/hr (0.83 m/s), 5km/hr (1.34 m/s) and 10km/hr (2.79 m/s) respectively.

Table 2 shows the analysis of variance (ANOVA) Table for the effect of speed and moisture content on penetration resistance of the soil. The effect of whole block on cone index was significant. The

Table 1: Average soil properties after tillage

Implement	Speed	Moisture (%)	Content	Cone Index	(Kg/m^3)	Bulk Density	(Kg/cm^2)
		Depth I (15cm)	Depth II (19cm)	Depth I (15cm)	Depth II (19cm)	Depth I (15cm)	Depth II (19cm)
Disc plough 6.58%	0.83	6.63	6.73	1.2	1.16	1.120	1.169
	1.39	6.9	6.7	1.1	1.2	1.099	1.158
	1.94	6.5	6.67	0.8	0.5	1.075	1.120
	2.50	6.33	6.6	0.2	0.46	1.059	1.066
	2.79	6.63	6.47	0.2	0.4	1.033	1.066
Mould board plough 6.58%	0.83	6.9	6.47	1.1	1.1	1.119	0.831
	1.39	6.5	6.33	0.6	0.7	1.117	1.135
	1.94	76.	6.67	0.3	0.3	1.114	1.132
	2.50	56.	6.56.	60.	0.2	1.090	1.128
	2.79	376	3	20.	60.	1.080	1.124
Disc plough 10.47%	0.83	10.2	10.3	1.2	1.16	1.169	1.197
	1.39	10.1	310.	1.1	0.6	1.148	1.157
	1.94	710.	410.	026	02	1.119	1.140
	2.50	4310	4310	0.26	0.2	1.111	1.114
	2.79	.171	.171	020	0.2	1.111	1.085
Mould Board plough 10.47%	0.83	10.2	10.27	1.1	1.1	1.166	1.195
	1.39	710.	10.47	0.6	0.6	1.151	1.173
	1.94	4710	10.31	0.2	0.2	1.129	1.150
	2.50	.310.	0.47	0.2	0.2	1.126	1.144
	2.79	4710	10.3	0.2	0.2	1.093	1.138

Table shows that, the effects of moisture content (M), tillage implements (I), and tillage depth (D) were not significant at $P < 0.05$ and 0.01, but forward speed (S) was significant at $P < 0.05$ and 0.01. Interactions of moisture content and tillage implements (M×I), moisture content tillage

depth (M×D), and tillage depth and implement type (D×I) were significant at 0.05% and 0.01% significant level. Also, the combine interactions of moisture content, implement type and tillage depth (M×I×D) were significant on cone index at $P < 0.05$ and 0.01 levels

Table 2: Analysis of variance in Split-plot Design for Cone index

SV	DF	SM	MS	F	Computed F 1%	5%
Replication	2	0.265	0.1325	1.713^{ns}	375	6.51
Main-plot factor	7	0.05	0.00734	0.092345^{ns}	277	4.28
Moisture (M)	1	0.3005	30.3003	3.88235^{ns}	460	8.86
Implement (I)	1	-0.962	--0.962-	-12.437^{ns}-	460	8.86
Depth (D)	1	-0.3712	0.3712	4.79897^{ns}	460	8.86
M x I	1	35.4523	35.4523	458.336**	460	8.86
M x D	1	35.4523	35.4523	458.336**	460	8.86
D x I	1	35.0323	35.0323	452.906**	460	8.86
M x I x D	1	3.9453	3.9453	38.785**	460	8.86
Error a	14	1.0829	0.07735			
Subplot factor (S)	4	15.73	3.9325	39.8834**	148	3.56
Main x Subplot Factor	39	17.6463	0.45247	45.8895**	154	1.84
S x M	4	14.165	3.54125	359.153**	148	3.56
S x I	4	15.456	3.864	319.886**	148	3.56
S x D	4	166.985	41.74625	4233.90**	148	3.56
S x M x I x D	4	17.233	4.308	436.94**	148	3.56
Error b	80	0.7887	0.00986			
Total	119	18.7				

M = Moisture content, **I** = Implement, **D** = depth of tillage, **S** = Speed of operation, **DF** = Degree of freedom, **SS** = Sum of square, **MS** = Mean square, **F** = Freedom, ** = Highly significant and **ns** = not significant

The Table also analyses the sub-plot as in split-plot design. Implement forward speed (S) was the main factor in sub-plot. It shows that, the effect of speed (S) and the interaction between main plot and sub-plot were significant (P< 0.05 and 0.01). Interactions between speed and moisture content (M×S), speed and implement type (S×I) speed and depth of tillage (S×D) and the combine interactions of speed, moisture content, implement type and tillage depth (S×M×I×D) were significant on cone index at P<0.05 and 0.01.

Table 3; The Duncan's Multiples range test for implement draught, moisture content, cone index and bulk density.

S/NO	Treatment	Cone index	Bulk Density
1	$S_1M_1 I_1 D_1$	1.167 ab	1.1203 hijklmn
2	$S_1 M_1 I_1 D_2$	1.133 ab	1.16 bc
3	$S_1 M_1 I_2 D_1$	1.167 ab	1.124 ghijkl
4	$S_1 M_1 I_2 D_2$	1.133 ab	1.135 efghijk
5	$S_1 M_2 I_1 D_1$	1.233 a	1.169 bc
6	$S_1 M_2 I_1 D_2$	1.167 ab	1.196 a
7	$S_1 M_2 I_2 D_1$	1.100 ab	1.167 bcd
8	$S_1 M_2 I_2 D_2$	1.067 ab	1.195 a
9	$S_2 M_1 I_1 D_1$	1.067 ab	1.0667 ab
10	$S_2 M_1 I_1 D_2$	0.73 c	0.733 ab

11	$S_2 M_1 I_2 D_1$	1.00 b	1.1203 hijklmn
12	$S_2 M_1 I_2 D_2$	0.66 c	1.132 fghijk
13	$S_2 M_2 I_1 D_1$	1.067 ab	1.148 cdefg
14	$S_2 M_2 I_1 D_2$	0.6c d	1.157 bcde
15	$S_2 M_2 I_2 D_1$	0.633 c	1.167 bcd
16	$S_2 M_2 I_2 D_2$	0.6c d	1.174 b
17	$S_3 M_1 I_1 D_1$	0.767 c	1.073 qrs
18	$S_3 M_1 I_1 D_2$	0.367 efg	1.135 efghijk
19	$S_3 M_1 I_2 D_1$	0.433 de	1.188 ijklmno
20	$S_3 M_1 I_2 D_2$	0.3ef g	1.128 fghijkl
21	$S_3 M_2 I_1 D_1$	0.267 efg	1.119 hijklmn
22	$S_3 M_2 I_1 D_2$	0.2f g	1.14 efghi
23	$S_3 M_2 I_2 D_1$	0.233 fg	1.129 fghijkl
24	$S_3 M_2 I_2 D_2$	0.2f g	1.1497 cdef
25	$S_4 M_1 I_1 D_1$	0.23f g	1.0513 st
26	$S_4 M_1 I_1 D_2$	0.2f g	1.066 rs
27	$S_4 M_1 I_2 D_1$	0.4 ef	1.097 nop
28	$S_4 M_1 I_2 D_2$	0.267 efg	1.124 ghijklmn
39	$S_4 M_2 I_1 D_1$	0.267 efg	1.1113 klmno
30	$S_4 M_2 I_1 D_2$	0.2f g	1.114 jklmno
31	$S_4 M_2 I_2 D_1$	0.2f g	1.126 fghijkl
32	$S_4 M_2 I_2 D_2$	0.267 rfg	1.114d efgh
33	$S_5 M_1 I_1 D_1$	0.2f g	1.0343 t
34	$S_5 M_1 I_1 D_2$	0.167 g	1.066 rs
35	$S_5 M_1 I_2 D_1$	0.367 efg	1.105 lmnop
36	$S_5 M_1 I_2 D_2$	0.267 efg	1.1123 klmnop
37	$S_5 M_2 I_1 D_1$	0.2f g	1.1107 klmno
38	$S_5 M_2 I_1 D_2$	0.2f g	1.085 pqr
39	$S_5 M_2 I_2 D_1$	0.2 gh	1.093 opq
40	$S_5 M_2 I_2 D_2$	0.2 fg	1.138 efghij

a, b, c, ……. z; Indicates the significance levels of each treatment at (P< 0.05) and treatments with the same letter are not significantly different. Also, S = speed, M = moisture content, I = implement and D = depth of tillage, while the subscript 1 – 5 indicates the level of each factor in the treatment.

Comparison test with Duncan's Multiple Range Tests (DMRT) table 4.3 above column three (3) shows that, the effects of implement speed (S), moisture content (M), implement type (I) and tillage depth (D) were significant on cone index at P<0.05. The highest value of penetration resistance was indicated by letter "**a**" with lower moisture level (M_1) 6.58% db using disc plough operating at a lower speed of 0.83m/s (3Km/h) and tillage depth (D_1) of 15cm as the treatment. This may be due low speed of the implement and hence produced poor soil loosening. The (DMRT) shows that, cone index decreases in alphabetic order. The lowest value of penetration resistance was indicated by letter "**g**" with moisture level (M_1) using disc plough (I_1) operating at speed of 5km/hr (S_5) at tillage depth (D_2) 19cm as the treatment. The low value of penetration resistance on this treatment may be due to the high implement speed at depth (D_2) of 19cm and produces excess soil loosening. This indicated that, cone index decreases with increase in speed of implement. Treatments with the same letters are significantly not different at P<0.05.

Figures 1 and 2 illustrated the influence of implement speed, tillage depth and moisture content on penetration resistance (cone index) for treatment plots when disc and mouldboard ploughs were used respectively, at moisture regime of 6.58% db. At tillage depth of 15cm, the cone index of disc plough Figure1 decreases with increase in speed of implement and reaches the lowest constant value of 0.2kg/cm^2 for implement speeds of 9km/hr (2.5m/s) and 10km/hr (2.79m/s) respectively and at 19cm depth of tillage, the value continue to drop to 4kg/cm^2 at speed of 10km/hr (2.79m/s). Figure 2 illustrated that, the cone index of treatment plots tilled with mouldboard plough. At tillage depth of 15cm, the value of cone index decreases with increase in implement speed. The lowest value of penetration resistance was recorded at implement operating speed of 10km/hr (2.79m/s) and at tillage depth of 19cm. The value of cone index decreases with increase in speed of implement and maintained a constant value of 0.26kg/cm^2 for implement speeds of 9km/hr (2.5m/s) and 10km/hr (2.79m/s) respectively. The figures above shows that, disc and mouldboard ploughs at an average moisture level of 6.58% db(M_1) and tillage depth of 15cm and 19cm, cone index decreases with increase in speed of implement and maintained a constant value at 9km/hr and 10km/hr for disc plough and from 7km to 10km for mouldboard plough.

Figures 3 and 4 illustrated the influence of implement speed (S), tillage depth (D) and moisture content (M) on cone index for disc and mouldboard ploughs respectively, at an

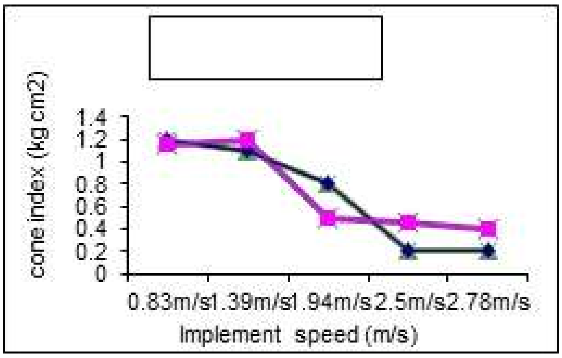

Figure 1.

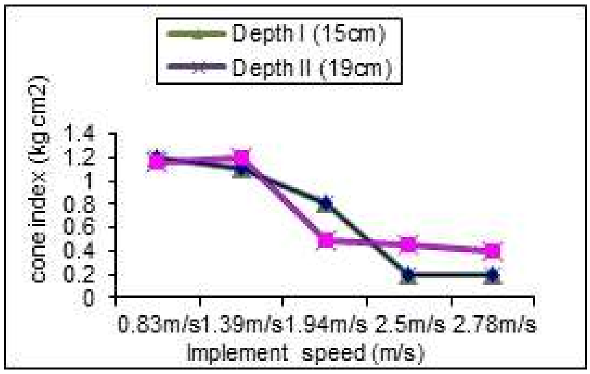

Figure 2.

In Figure 3, Cone index decreases for every increase in speed of implement while using disc plough at 15cm tillage depth. When tillage depth was increased to 19cm using the same implement, cone index decreases with increase in operational speed for implement speeds of 3km, 5km and 7km/hr and maintained a constant value of cone index for implement speeds of 7km, 9km and 10km/hr. This indicated that, at10.47% db; 19cm tillage depth and implement speed 7km/hr, of the lowest value of penetration resistance was achieved. Figure 4 shows that, mouldboard plough at 15cm and 19cm tillage depth, cone index decreases from 1.1kg/cm^2 to 0.6kg/cm^2 for implement speeds of 3km/hr and 5km/hr respectively and maintained a constant value of 0.2kg/cm^2 for the speeds of 7km/hr, 9km/hr and 10km/hr for the two tillage depths. However, at 10.47% db, a constant value of cone index was maintained at

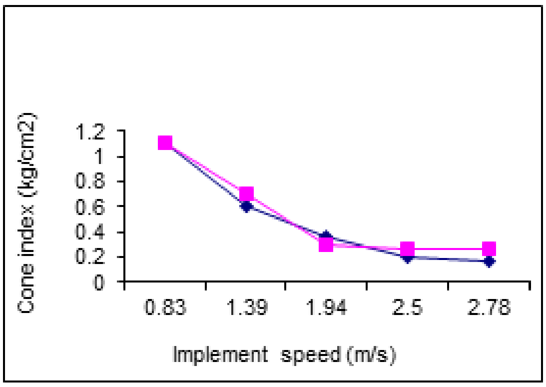

Figure 3.

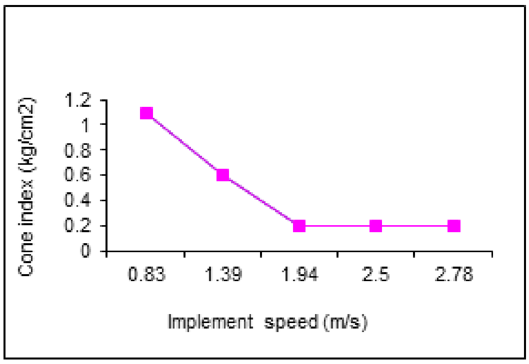

Figure 4

Figures 3 and 4 illustrated the influence of implement speed and tillage depth on cone index using disc and mouldboard plough respectively at moisture content of 10.47% db.

7km/hr, 9km/hr and 10km/hr. This indicated that at 10.47% db, an optimum soil loosening can be achieved with an implement speed of 7km/hr (1.94m/s) and hence, a lesser draught and power requirement.

Conclusion

Field investigation was carried out on the effects of soil moisture content, implement speed and tillage depth on soil bulk density using disc and mouldboard ploughs on loamy sand soils at the Modibbo Adama University of Technology, Yola, Agricultural engineering research farm. The variables were combined in a factorial split-plot design with three blocks. Soil properties (moisture content and bulk density) were determined before and after tillage on each treatment. Soil disturbance were measured during the tests.

Analysis of variance, Duncan's multiple range tests and graphical figures shows that, moisture content, implement speed and tillage depth have significant effects on bulk density of the soil. The analysis further revealed that, at 1.94m/s (7Km/h) implement speed, the physical properties of the soil (bulk density) reduced to minimum considerably and usually maintain a constant value which equals the values recorded at implements speed of 2.5m/s (9Km/h) and 2.78m/s (10Km/h) . This shows that, the physical properties of soil required for good soil tillage could be achieved at implement speed of 7km/h

Recommendations

In case of further studies on the soil under consideration, the use of three (3) moisture level may reveal additional information on draught and power requirement of the soil.

REFERENCES

Ahanekun, I.E.,; Onwualu, A.P.; James, D. and Ani, A.O. (2003). Effect of Soil Moisture and Tools Speed on Draught and Power Requirement of Disc Plough; Proceedings of the 4th International Conference and 25th Annual General Meeting of the Nigerian Institute of Agricultural Engineers

Blake, S.R. and Hartge, K.H. (1986). Bulk Density Core Method, In Method of Soil Analysis Part I Physical and Mineralogical Properties. Klute, A. (eds) Agronomy Monograph 9, American Society of Argon Madison, Wisconsin PP.363 – 366

Gomez, K. A. and Gomez A.A. (1984) Statistical Procedures for Agricultural Researches, 2nd Edition, John Wiley and Sons. Inc., New York

Grisso, R.D, Yasin M and Kocher, M.F. (1996). Tillage Implements Force Operating in Salty Clay Loam. Trans of the ASAE 39(6): 1977-1982.

Gwarzo, M.A.S. (1990). Capacitive Performance Study and Optimisation of Power and Machinery on a Large Scale Farm. Ph.D Thesis Department of Agricultural Engineering Ahmadu Bello University, Zaria.

James, L.G. (1988). Principles of Farm Irrigation System Design. New York John Willey Krieger Publishing Company.

Johnson, C.E. and Buchele, W.F. (1967). Energy in Clod-Size Reduction of Vibratory Tillage. Trans. of the ASAE, 12(3): 371-374

Manian, R. Kathirvel, k. and Rao, V. R. (2000): Influence of Operating and Disc Parameters on Performance of Disc Tools. AMA Vol. 31 (2): 19-2

Reece, A. R. 1965. The Fundamental Equation of Earth –Moving Mechanics. Earth Moving Machinery Symposium.

Institution of Mechanical Engineers London. Vol. 179, 3F, pp 8- 14: In Gill and Vanden Berg.(1968).

Stanford, J.V. (1979). Force Prediction Models for Brittle and Flow Failure of Soil by Draught Tillage Tools. *Journal of Agricultural Engineering Research*. Vol. 29, 51 – 60.