EFFECTS OF DIFFERENT SOIL TILLAGE CHARACTERISTICS ON THE GROWTH AND YIELD OF MAIZE (Zea Mays L.) IN SAMARU ZARIA, NIGERIA

Kawuyo*[1], U.A., M.L. Suleiman[2] and D.D. Yusuf[2]

* Corresponding author, kawuyo2011@gmail.com

1: Department of Agricultural and Environmental Resoures Engineering, University of Maiduguri, Nigeria.

2: Agricultural Engineering Department/ IAR, Ahmadu Bello Univerity, Zaria, Nigeria.

Abstract

The study was conducted to evaluate the performances of different animal drawn implements on the upland soils of Samaru, Zaria for three years (2008 – 2010). Two white Fulani bulls were used to pull mouldboard ridger and mould board plough implements at different depths and speed of operation. A 2 x 3 x 3 factorial experimental design was arranged in a Randomized Complete Block Design. The experimental design comprised of eighteen treatments replicated three times. Results show that grain yield, treatments T_8 ($I_1S_3d_2$) and T_{15} ($I_2S_2d_3$) resulted in the highest grain yield (4.71 t/ha and 4.89 t/ha) for the mouldboard ridger and mould board plough respectively. It was also found that, plant height varied with the implement used and depth of tillage considered, and the plant height increased with increase in tillage depth. The analysis of variance showed that tillage depth significantly affected the maize grain yield.

Keywords: *animal drawn implements, tillage methods, growth and yield, maize*

1.0 Introduction

Agriculture is the dominant economic activity in terms of employment and linkages with the rest of the economy in the world. Roughly 75% of Nigeria's land is arable, of which only about 40% is cultivated (NEEDS, 2004). Agriculture in most developing countries including Nigeria is predominantly at subsistence level dominated by small holder farmers (Umar, 1994). Thus these farmers cannot meet their food and fibre requirements which is due to their land size and increasing population. This increase in population in the world that is followed by higher food demands make mechanisation of agriculture almost compulsary. Maize (Zea Mays L.) is the third most important cereal crop after wheat and rice, as it contributes a major portion of staple food for world's rising population. It has greater nutritional value as it contains about 72% starch, 10% protein, 4.8% oil, 8.5% fiber, 3% sugar and 17% ash (Saif *et al.,* 2003). They further reported that, due to higher yield potential, short growing period, high value for food, forage and feed for livestock, poultry and a cheaper source of raw material for agro-based industries, maize is increasingly gaining an important position in the cropping system. The production of maize can be improved and enhanced using better inputs, proper production technology and appropriate tillage methods. Important factors like soil tillage and appropriate fertilizer application can improve soil physical properties and enhance maize yields. Leghari *et al* (2015) reported that selection of an appropriate tillage method can enhance grains production by about 25 percent.

Tillage practice modifies the soil structure by changing its physical properties such as moisture content, bulk density, and penetration resistance. Changes in the soil physical properties affect the seedling emergence, plant population density, root distribution and crop yield (Khan *et al.,* 2001). Among the crop production factors, tillage contributes up to 20% (Khurshid *et al.,* 2006). The nurturing objective is one of developing a desirable soil structure that promotes seed germination, plant emergence, and root growth (Hunt, 1995). The soil can be tilled using the availabe and affordable source of power. This can either be tractor or animal with the appropriate implement to achive the desired objective. Starkey (1986) reported that in much of sub-Saharan Africa, systematic attempts to introduce animal traction began between 1905 and 1945. Animal traction, in Nigeria dates as far back as 1920's in Daura, Katsina state, used in accomplishing variety of farm operations mainly upland and in particular ridging and transportation of farm produce (Suleiman, 2000). The first animal-drawn implement introduced in Nigeria was a wooden plough (Gwani, 1990), but from 1934, these implements were replaced by the popular Ransome EMCOT ridgers (Chaundhury and Musa, 1984). A number of researchers (Kaul, 1989; Husseini, 1998; Starkey, 1992; and Musa, 1989) have reported on the introduction and adoption level of animal draught technology in Nigeria in particular, and Africa in general. They all agreed that it is an appropriate, affordable and sustainable technology. Draught animal power can be economically and environmentally sustained and hence can go a long way towards increasing the productivity of labour, improve timeliness of field operations to exploit the short cropping sessions, and relieve the farmer from the drudgery of performing field tasks (Suleiman, 2000). Draught animals are being used all over the world to reduce drudgery and to intensify agricultural production. Small-scale farming is the most widely practiced type of agricultural production in most Sub-Saharan countries and about 80 % of the farmers in developing countries use human or animal power in the production of their food and income needs (Gebresenbet *et al.,* 1997). Before the introduction of tractors in the era of oil boom, animal power has had a long history in Nigerian agriculture (Gbadamosi and Magaji, 2004). Up to 84 million draught animals are used for crop production and transportation purposes in India (Cartman, 1994). With 60 % of farmers having less than 4 ha, tractor ownership is not economically viable, leaving draught animal power as the only alternative (Dave, 1999). Haque *et al.,* (2000) reported that apart from the ridgers, no other animal-drawn implement is used for crop production in Adamawa state of Nigeria. The animal-drawn mouldboard plough is widely used for primary tillage in the developing countries of Africa (Loukanov *et al.* 2005). Due to the contributions of animal traction to the production of different crops, this work, therefore, aimed to evaluate the effect of different animal-drawn implements on the growth and yield of maize in Zaria, Nigeria.

2.0 Materials and Methods

2.1 The study area

The field study was conducted on sandy loam soil at Samaru - Zaria (11^o 11′ N, 07^o 38′E and 685 m above sea level). Samaru is located in the Northern Guinea savanna zone of Nigeria with an average annual rainfall of 1,100 mm and is spread between May and October (Yusuf, 2003). Field experiments and laboratory works were conducted between June and October 2008, 2009 and 2010 cropping seasons.

2.2 Treatment and experimantal design

The study consisted of two animal - drawn tillage implements (T_1, mouldboard ridger and T_2, mouldboard plough), three different soil operating depths (d_1, 5 -10 cm, d_2, 11 -15 cm and d_3, 16 - 20 cm) as the range for palnting depth of different crops in the study area, and three operating speeds (S_1, 0.69 m/s, S_2, 0.97 m/s and S_3, 1.25 m/s) commonly used in literature. The combination of the implements, speed and depth resulted into eighteen treaments as presented below.

$T_1 = I_1S_1d_1$	$T_2 = I_1S_1d_2$	$T_3 = I_1S_1d_3$	$T_4 = I_1S_2d_1$	$T_5 = I_1S_2d_2$	$T_6 = I_1S_2d_3$
$T_7 = I_1S_3d_1$	$T_8 = I_1S_3d_2$	$T_9 = I_1S_3d_3$	$T_{10} = I_2S_1d_1$	$T_{11} = I_2S_1d_2$	$T_{12} = I_2S_1d_3$
$T_{13} = I_2S_2d_1$	$T_{14} = I_2S_2d_2$	$T_{15} = I_2S_2d_3$	$T_{16} = I_2S_3d_1$	$T_{17} = I_2S_3d_2$	$T_{18} = I_2S_3d_3$

Where: I_1 = Animal – drawn Emcot ridger

I_2 = Animal – drawn mouldboard plough

S_1 = Speed of 0.69 ms^{-1}

S_2 = Speed of 0.97 ms^{-1}

S_3 = Speed of 1.25 ms^{-1}

d_1 = Operating depth of 5 – 10 cm

d_2 = Operating depth 0f 11 – 15 cm

d_3 = Operating depth of 16 – 20 cm.

The treatments were randomly assigned in 2 x 3 x 3 factorial experiment arranged in a randomized complete block design in three replications. Each plot size was 5 m wide x 10 m long. The area of land used for the study was 0.36 ha.

2.3 Field experimentantion

Field experiments were conducted using two white Fulani bulls to operate the implements. This is because of their ease of control and response to verbal command. The implements considered in this study were animal-drawn mouldboard plough and ridger. This is because they are the most commonly used in the study area. Also same harnessing system was used throughout the study. The measuring devices used included spring type dynamometer, stopwatches, measuring tape, soil penetrometer, and electronic weighing balance. Common methods of agronomic practices (planting, fertilizer application, weeding and harvesting), data collection and analysis were applied to all the experimental treatments and maize crop (Sammaz – 12) variety which is commonly used by farmers in the study area was used as the test crop.

2.4 Data collection

Soil samples of the top soil (0 – 15 and 15 – 30 cm) were obtained from the experimental field by the use of auger, core samplers, cutting blade and nylon bags for the laboratory determination of percentage organic matter, particle size analysis, bulk density and soil moisture content. Growth parameters considered in the study include plant height, leaf area index and 1,000

- kernel weight. The seedlings emerged 6 – 8 days after planting on all the treatments. The plant height was measured using a meter rule from soil surface to the tip of the last leaf. Three plants randomly selected from each treatment and the mean value of plant height was recorded. Plant heights were measured as from 3 weeks after planting and followed in two weeks interval up to 9 weeks after planting. Leaf Area (LA), was used to determind the leaf area index, of individual leave area was estimated using equation 1 (Saxena and Singh, 1965 as reported by Yusuf, 2001).

$$LA = 0.75 \times Length \times Breath \quad (1)$$

The Leaf Area Index (LAI) was calculated using equation 2 (Watson, 1952, also reported by Yusuf (2001).

$$LAI = \frac{Total\ LA}{Total\ land\ area} \quad (2)$$

The 1,000 - kernel weight was determined by counting 100 seeds of the grain after harvest. Grain yield was determined after harvesting the crop by hand at the grain moisture content of about 15% db. The harvested maize grain was shelled manually and the grain for each plot was weighed to estimate the grain yield for that plot.

2.5 Data analysis

The field and laboratory data collected were analyzed statistically by Analysis of Variance (ANOVA) technique as reported by Gomez and Gomez, (1984). The standard error of each mean was calculated and presented in form of figures and/or tables.

3.0 Results and Discussions

3.1 Soil Condition

The physical properties and organic matter content of the soil samples are presented in Table 1. From the USDA triangle, the soil can be classified as sandy loam. The soil constituents consist of high sand fraction (62.8-67.8 %). This result confirms the observation of Yusuf (2001). The soil profile indicates moderate percentage of organic matter content. The soil organic matter decreased with increase in depth of soil profile as shown in Table 1. Tsimba et al. (1999) reported similar observation. The 0 – 15 cm depth of soil profile recorded values between 1.18 to 1.43% of the organic matter content while the corresponding value in 15 – 30 cm depth was 0.92 to 1.26%. This showed that the level of soil organic matter is moderate.

Table 1: Mean values of some soil physical properties of the experimental site (2008, 2009 and 2010)

Depth of soil profile[a] (cm)	Sand (%)	Silt (%)	Clay (%)	Organic Matter (%)	Soil classification[b]
2008					
0 – 15	62.8	20.2	17.2	1.18	Sandy loam
15 – 30	67.8	17.5	14.7	0.92	Sandy loam
2009					
0 – 15	65.3	17.5	17.2	1.26	Sandy loam
15 – 30	64.1	18.7	17.2	1.09	Sandy loam
2010					
0 – 15	64.0	18.3	17.3	1.43	Sandy loam
15 – 30	65.9	17.9	16.2	1.26	Sandy loam

[a] = Each value is a mean of three measurements
[b] = USDA, triangle in: Dunn *et al.,* (1980)

3.2 Crop Growth Parameters

3.2.1 Leaf Area Index

Table 2: Mean values of Leaf Area Index at 9 WAP

Treatment	Year		
	2008	2009	2010
T_1	912.89	1333.96	1357.04
T_2	1062.26	1663.81	1428.27
T_3	1186.56	1470.97	1570.43
T_4	765.52	1174.97	1416.96
T_5	835.50	1310.81	1482.77
T_6	1002.21	1502.12	1498.70
T_7	583.27	1468.29	1427.16
T_8	1001.47	1551.87	1517.27
T_9	744.98	1644.74	1443.01
T_{10}	712.72	1457.30	1092.49
T_{11}	952.82	1289.92	1336.27
T_{12}	1062.82	1324.06	1473.71
T_{13}	883.27	1091.81	1662.56
T_{14}	1085.39	1271.90	1724.15
T_{15}	1241.15	1221.61	1879.61
T_{16}	1147.87	1205.24	1686.49
T_{17}	791.79	1685.77	1893.40
T_{18}	1393.91	1237.75	1848.89

The mean values of the Leaf Area Index (LAI) for the different years under study is presented in Table 2. LAI was significantly affected ($P \leq 0.01$) by the tillage depth investigated in this study for the combined three years considered. LAI increased from 3 Weeks After Planting (WAP) to the peak value at 9 WAP. The increase in depth of tillage resulted to increased in LAI (Table 2). Similar result was reported by Yusuf (2001) and Rahman, et al. (2004). Mould board plough operating at depth d_3 (16 - 20 cm) representing treatment T_{18} showed superiority in the LAI values throughout the study years (2008 – 2010) over other tillage treatments. The implement type and tillage depth significantly ($P \leq 0.01$) affected the LAI. The interaction between implement and depth, speed and depth showed significant effect ($P \leq 0.01$) on LAI in the study years. It was also observed that, the interaction of implement, speed and depth was significant ($P \leq 0.05$) in 2008 and 2009 but not in 2010.

3.2.2 Plant Height

The effects of tillage treatment on plant height varied from year to year throughout the study period as shown in Table 3. Maize plant heights varied with the implement used and the depth of tillage considered in the study. Increased in tillage depth for both implements resulted in increased plant height. Tilling with the mould board plough at depth d_3 (16 – 20 cm) in 2009 field study produced the highest maize plant height when compared with other treatments. At 9 WAP, treatment T18 gave the highest mean value of plant height. A similar result on tillage treatment was obtained by Olofintoye (1989) who conducted a study on the effects of tillage and weed control methods on weed growth and performance of rice in the same area of study. This shows that, the deeper the soil is tilled, there is more tendency for higher root growth whic will extract more nutrients required for crop growth.

Statistical Analysis of variance for the study period showed that the implement, speed and depth of tillage significantly affected ($P \leq 0.01$) the plant height at 9 WAP. Also the interaction of implement, speed and the tillage depth significantly affected ($P \leq 0.01$) the maize plant height. Same observation was reported by Yusuf (2001) who said that, tillage treatments significantly affected ($P \leq 0.01$) the plant height of maize. Rahman *et al.;* (2004) also reported similar results on a sandy loam soil in Mymensingh, Bangladesh.

Table 3: Combined analysis of variance for plant height for the 3 – year period at 9 WAP

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	Calculated F
Replication	2	21.834362	10.917181	0.98
Year (Y)	2	4014.782016	2007.391008	180.07**
Implement (I)	1	621.477099	621.477099	55.75**
Speed (S)	2	220.143374	110.071687	9.87**
Tillage depth (d)	2	2602.421276	1301.210638	116.72**
I x Y	2	3572.435926	1786.217963	160.23**
d x Y	4	553.040905	138.260226	12.40**
S x Y	4	1850.734239	462.683560	41.50**
I x S	2	526.842634	263.421317	23.63**
I x d	2	693.784239	346.892119	31.12**
S x d	4	2797.754609	699.438652	62.74**
I x S x d	4	4807.059053	1201.764763	107.80**
I x S x Y	4	131.049465	32.762366	2.94^{ns}
I x d x Y	4	349.067984	87.266996	7.83**
S x d x Y	8	1977.740000	247.217500	22.18**
I x S x d x Y	8	2492.014897	311.501862	27.94**
Error	106	1181.673790	11.147870	
Total	161	28413.85586		

** = significant at 0.01 probability level; ^{ns} = not significantly different

Table 4: Means and Standard Deviation of Crop Assessment Parameters as Affected by Different Tillage Treatments in the 3 – year study (2008 – 2010)

Treatments	Crop assessment parameters[a]									
	Plant height[b] (cm)			1000-Kernel weight[c] (g)			Maize grain yield[c] (t/ha)			Average yield (t/ha)
	2008	2009	2010	2008	2009	2010	2008	2009	2010	
T_1	132.43±6.21	150.47±2.01	116.06±1.90	166.93±9.25	160.30±5.90	164.91±1.05	4.00±5.76	4.48±1.12	3.71±4.00	4.06
T_2	132.00±8.40	134.31±1.60	119.10±1.64	182.95±14.57	177.00±5.18	164.74±1.83	2.82±13.01	3.17±2.35	3.10±3.02	3.03
T_3	144.67±2.85	147.11±1.54	120.17±2.07	166.37±16.20	172.94±1.78	174.22±1.22	4.48±0.83	4.60±3.09	4.32±4.84	4.47
T_4	119.77±3.38	131.29±0.54	119.04±1.47	148.23±6.04	170.02±0.85	168.86±1.32	3.38±12.41	3.87±2.43	3.77±2.41	3.67
T_5	129.56±4.25	138.29±1.01	124.29±2.16	156.07±13.99	146.95±0.67	171.28±1.68	3.29±11.67	3.76±2.24	3.87±1.94	3.64
T_6	153.39±0.37	153.08±0.52	129.26±1.40	156.12±14.64	196.53±2.17	183.37±1.89	4.42±4.34	4.77±4.62	4.68±1.73	4.62
T_7	132.29±1.80	144.50±1.80	127.28±3.68	134.33±3.59	147.73±1.74	155.10±1.15	1.56±8.28	2.01±2.21	2.11±3.37	1.89
T_8	134.94±0.73	143.28±0.62	127.43±1.04	200.54±3.96	192.21±0.76	180.44±1.02	4.61±1.16	4.97±0.71	4.61±7.42	4.71
T_9	105.78±0.78	132.04±1.13	131.82±1.35	141.95±6.80	141.31±0.71	173.18±1.89	2.81±5.37	2.97±1.17	3.90±0.92	3.23
T_{10}	96.49±7.19	132.86±0.81	127.94±0.37	148.25±7.62	185.96±1.08	161.11±1.30	2.54±10.55	2.71±0.99	2.74±1.81	2.66

T_{11}	143.76±0.71	152.93±0.75	132.83±1.13	140.86±9.15	171.80±1.10	182.54±0.50	4.53±3.51	4.90±2.18	4.64±1.77	4.69
T_{12}	131.86±5.90	134.59±0.75	138.47±2.10	157.26±11.14	186.21±1.36	169.04±1.05	2.71±10.90	2.91±2.21	3.23±2.08	2.95
T_{13}	113.88±5.95	127.81±1.53	135.49±1.87	122.97±7.15	166.84±2.76	164.06±0.76	2.71±7.77	2.80±3.09	2.98±4.98	2.83
T_{14}	137.08±3.20	146.04±0.69	142.36±1.32	158.52±15.46	149.30±0.60	171.84±1.89	3.33±12.16	3.72±1.56	3.59±3.48	3.55
T_{15}	142.98±2.24	142.88±0.31	144.88±1.82	169.64±6.47	171.91±1.81	188.20±0.83	4.55±3.35	5.03±1.41	4.90±1.71	4.89
T_{16}	133.09±6.75	147.06±0.41	142.97±1.16	138.74±7.23	186.41±0.96	180.83±1.74	4.19±13.98	4.89±5.74	4.38±2.43	4.49
T_{17}	102.24±6.09	127.33±0.97	147.20±1.22	169.70±7.95	190.51±0.70	170.63±0.87	3.11±5.67	3.51±1.12	3.48±2.04	3.37
T_{18}	143.81±12.43	154.89±0.78	155.70±0.92	162.89±11.04	176.65±0.47	173.20±1.03	3.19±4.27	3.60±1.15	3.54±1.75	3.44
$\bar{x}$	129.45	141.15	132.35	156.80	171.70	172.09	3.46	3.82	3.75	3.67
SD	15.82	9.03	11.10	18.41	16.88	8.58	0.88	0.93	0.75	0.84
CV (%)	12.218	6.396	8.385	11.740	9.832	4.985	25.394	24.396	20.043	22.876

3.2.3 1000-kernel Weight

The 1000-kernel weight for the 3 years of study (2008 to 2010) is presented in Table 4 From the Table, the mouldboard ridger, treatment T8 ($I_1S_3d_2$) had higher 1000-kernel weight than other treatments. Also for the mould board plough, treatment T15 ($I_2S_3d_2$) had the corresponding higher value. This may probably be due to good soil tilt which leads to small soil aggregates of the seed beds. Analysis of variance showed that, the depth of tillage and the interaction of implement, speed and tillage depth significantly affected ($P \leq 0.01$) the 1000-kernel weight for the years of study. The combined analysis of variance of 1000-kernel weight over the period of study also showed significant effect ($P \leq 0.01$) of the implement, speed and depth of tillage interaction on 1000-kernel weight.

3.3.4 Maize Grain Yield

The results for tillage treatments on maize grain yield are presented in Table 3. Increased in depth of tillage resulted to increase of maize grain yield as shown in Table 3. For the mouldboard ridger, treatment T8 ($I_1S_3d_2$) resulted in the highest average grain yield (4.71 t/ha) for the 3 – year study and the least treatment in terms of average maize grain yield is T7 (1.89 t/ha). For the mould board plough, the highest average maize grain yield was obtained in treatment T15 ($I_2S_2d_3$) as 4.89 t/ha and the least was in treatment T10 with average value of 2.66 t/ha for the 3 – year study. This may be because of the good seed and seedling environment created by the tillage treatment which enhanced crop growth and improved maize grain yield. Gomez (2011) also reported that ploughing depth significantly influenced maize grain yield.

The combined analysis of variance showed that, maize grain yield was significantly ($P \leq 0.01$) affected by the speed of operation and depth of tillage in the period under study. The results further showed that there was significant ($P \leq 0.05$) effect of the maize grain yield on the implements considered. The implement, speed and tillage depth interaction also significantly ($P \leq 0.01$) affected the maize grain yield.

4.0 Conclusion

From the results of this study, the following conclusions are drawn. Plant height varied with the implement used and depth of tillage considered, and that plant height increased with increase in tillage depth. The highest mean grain yield obtained was 4.71 t/ha for mouldboard ridgerat speed of 1.25 m/s and 11 - 15 cm depth of operation, and 4.89 t/ha for the mould board plough at the speed of 0.97 m/s and 16 20 cm depth. Finally, operating implement deeper resulted to higher maize grain yields.

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