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Effect of Primary Tillage Implements on Soil Physical Properties under Maize Production

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ABSTRACT: *Effect of four primary tillage implements on soil transient physical properties were evaluated on clay soil. The objective of the study was to evaluate the effect of the tillage implements on the transient physical properties. The experiment was laid out in randomized complete block design (RCBD) with three replications. Four tillage implements used were the local plow (Maresha), ripper maresha, mofer attached ARDU mouldboard plough and AIRIC mouldboard. Statistical analysis was made using SAS computer package. Analysis of Variance (ANOVA) was used to evaluate the significance level of effects on each of the parameters considered in study. The investigation made clearly indicated that all tillage implements statistically significant in creating the favourable soil conditions when compared with no tillage (i.e. lowest soil penetration resistance, lowest dry bulk density, highest soil moisture content, highest infiltration rate and highest total porosity). The no tillage treatment resulted in or produced the most unfavourable soil conditions (i.e. highest soil penetration resistance, highest dry bulk density, lowest soil moisture content, low infiltration rate and lowest total porosity). The highest soil moisture contents were observed under ARDU and AIRIC plough treatments after 60 days of planting.*

Keywords: *maize, primary tillage implements, tillage, transient soil physical properties*

I. INTRODUCTION

Maize (Zea mays L.) is the most important grain crop in Ethiopia and is produced throughout the country under diverse environments. Successful maize production depends on the correct application of production inputs that will sustain the environment as well as agricultural production. These inputs are, plant population, soil tillage, fertilisation, weed, insect and disease control, harvesting, marketing and financial resources. In Ethiopia, maize grows from moisture stress areas to high rainfall areas and from lowlands to the highlands. It is one of the important cereal crops grown in the country. Therefore, considering its importance in terms of wide adaptation, total production and productivity, maize is one of the high priority crops to feed the increasing population of the country.

Tillage is defined as a set of operations performed on the soil to prepare a seedbed, control weeds and improve soil physical conditions for enhancing the establishment, growth and yield of crops, as well as conserving soil moisture [1]. In Ethiopia, the land preparation is characterized by the use of backward traditional farm implements.

These include simple hand tools and animal drawn implements such as *Maresha*, which are used by peasant farmers for seedbed preparation, weeding and cultivation purpose (Mengesha and Zelalem, 1997) as cited by [2]. The traditional farm implements used by the peasants are considered to be among the main factors that retarded the agricultural productivity in the country. These traditional farm implements need to be used four to eight times, depending on soil type and moisture content, on a single plot of land, to create a suitable seedbed, which is usually obtained in the expense of time and energy, and damage of vital soil physical properties leading to soil compaction or densification. These implements usually result in hand to mouth and non-market oriented production. Tillage tools and practices are indigenous and chosen by the farmers themselves based on their resources and requirements. However, these indigenous tools and practices pose constraints such as inefficiencies, drudgery and poor quality of work, which results in low yields. Promoting and upholding productivity of farmers beyond subsistent level is closely related to the use of improved farm implements and tools (mechanization of agriculture) to till and cultivate land.

II. MATERIALS AND METHODS

2.1. Description of the Study Area

The experiment was conducted in Omo Nada Woreda of Jimma Zone which is located between latitudes of $7^0$38' and $8^0$45'N, and longitudes of $36^0$00' and $37^0$15'E [3]. The Woreda has an elevation ranging from 1000 to 3340 meter above sea level (masl). The mean annual rainfall is 1131.08 mm with bimodal rainy seasons. The average maximum and minimum temperature are 27.60^0C and 13.00^0C respectively, and the average relative humidity is 70.00%.

2.2. Experimental Design

The experiment was conducted during the months from June to September in the year 2014 G.C. The experiment was a randomized complete block; four tillage implements: ARDU plough (Fig. 1), AIRIC plough (Fig. 2), Local maresha (Fig. 3) and Ripper maresha (Fig. 4) were used to effect tillage operation. Each test had three replications each. Three untilled plots were used as control. Each plot size was 4 m by 10 m (40 m^2) with a buffer zone of 4 m between plots (Fig. 5). Tillage operations were carried out using a pair of oxen by trained person for each type of implements. The second tillage operations were done after 15^{th} days of first pass or operation. These treatments (tillage implements) were applied on clay and Maize was used as test crop and sown after preparing the experimental plot using the implements stated above.

Figure 1. ARDU mouldboard plough

Figure 2. EIRIC mouldboard plough

Figure 3. local maresha

Figure 4. ripper maresha

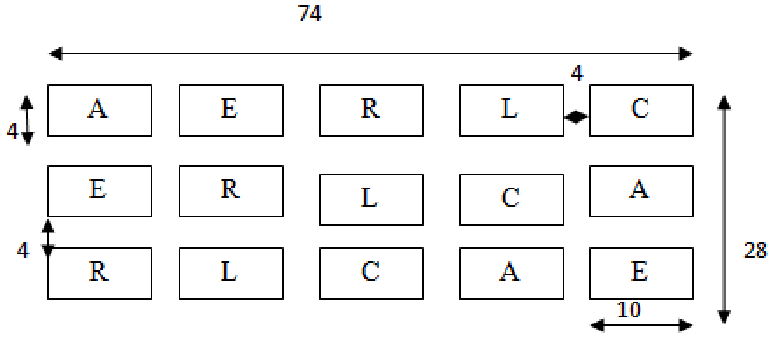

Figure 5. Layout of experimental plots (A-ARDU plough, E-AIRIC plough, R- Ripper maresha, L-local maresha and C-control plots; all dimensions are in meter).

2.3. Statistical analysis

All data collected were properly organized and subjected to rigors statistical analysis, analysis of variance (ANOVA) using statistical analysis software (SAS). The least significant difference (LSDs) at 5% probability was used to check whether there existed significant differences among the induced soil physical properties using different tillage implements.

III. EFFECT OF TILLAGE IMPLEMENTS ON SOIL PHYSICAL PROPERTIES

3.1. Rainfall Amount and Distribution during the Season

Jimma and the surrounding areas is high rainfall recipient, and the study was affected during the rainy season, discussion with providing bird's eye view of rainfall pattern will be misleading and confusing since two of the parameters against which the tillage implements were evaluated, soil moisture content and infiltration were affected by rainfall.

Seasonal rainfall pattern obtained from the Jimma Meteorological Station showed bimodal distribution. The monthly rainfall during the cropping season (June to September) of 2014 in the study area as recorded at Jimma Meteorological Station is shown in Fig. 6. The months, May to September, cover the main growing season in the study area. It can be seen from Fig. 6 that the maximum total rainfall was recorded in the months of August and May.

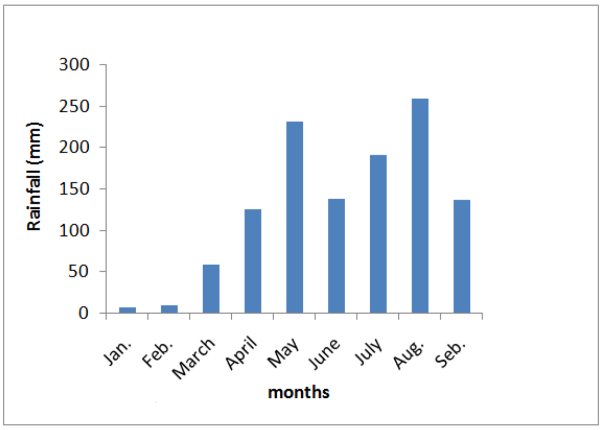

Figure 6. Monthly total rainfall distribution in 2014

3.2. Effect of tillage implements on dry bulk density

Increase in dry bulk density was observed during the growing period as time progressed; this is due to the natural consolidation of the soils as indicated [4] who reported that increase in bulk density in the arable layer takes place with time because of natural settlement (Table 1). The soil dry bulk density of all treatments was increasing throughout the growing season due to natural settlement of soil by different rate which agrees with the result of [5]. The mean dry bulk densities of the soil treated with ARDU, AIRIC. RIPPER and LOCAL maresha were not statistically different 15, 30, 75 days after the application of the treatment or after planting

Table 1. Effect of tillage implements on soil bulk density on days after planting

Mean bulk density (g/cm^2)								
Treatments &soil types	Days after planting							
	15	30	45	60	75	90	105	120
Clay soil								
A	1.14^b	1.15^b	1.17^b	1.18^b	1.19^b	1.21^c	1.23^c	1.24^c
E	1.15^b	1.16^b	1.17^b	1.19^b	1.20^b	1.22^c	1.24^{bc}	1.26^{bc}
R	1.15^b	1.17^b	1.18^b	1.20^{ab}	1.22^b	1.23^{bc}	1.24^{bc}	1.25^c
L	1.16^b	1.17^b	1.18^b	1.19^b	1.22^b	1.24^{bc}	1.25^{ab}	1.26^{bc}
C	1.19^a	1.20^a	1.21^a	1.23^a	1.26^a	1.26^a	1.27^a	1.27^a

Means within the columns for the treatments in the same soil types followed by the same letter are not significantly different at P≤0.05.

3.3. Effect of tillage implements on total porosity

As can be seen from table 2, the total porosity of all soil types decreased after planting**.** This is because of the natural settlement of soil and the increased dry bulk density as time went on. Hence the total porosity and dry bulk density has the inverse relationship.

Table 2. Effect of tillage implements on durability of porosity

Mean total porosity (%)								
Treatments &soil types	Days after planting							
	15	30	45	60	75	90	105	120
Clay soil								
A	56.72^a	56.47^a	55.97^a	55.59^a	54.97^a	54.21^a	53.58^a	52.95^a
E	56.47^a	55.97^a	55.72^a	55.09^a	54.46^a	53.96^{ab}	53.20^{ab}	52.57^{ab}
R	56.35^a	55.84^a	55.34^{ab}	54.84^{ab}	54.08^a	54.59^a	53.20^{ab}	52.70^a
L	56.22^a	55.72^a	55.47^a	54.97^a	53.83^a	52.95^{ab}	52.70^{bc}	52.07^{bc}
C	54.97^b	54.46^b	54.46^b	53.33^b	52.45^b	52.32^b	52.19^c	51.95^c

Means within the columns for the treatments in the same soil types followed by the same letter are not significantly different at P≤0.05.

3.4. Effect of tillage implement on moisture content

The use of different tillage implements on clay soil was influence on the amount of moisture contained. Observations made on the level of soil moisture content from the date of planting up to harvesting indicated that there were no significant differences in moisture content at 30th and 75th days after planting in clay soil (Table 3). The higher moisture contents were observed at 60th days after planting under all treatments. This could be attributed to the high rainfall that occurred during the month of May (see Fig. 6). Hence the soil moisture content increase in all soils is due high rainfall rather than the effect and influence of soil types and types of tillage implements.

Table 3. Effect of tillage implement on soil moisture content days after planting

Mean moisture content (%)								
Treatments & soil types	**Days after planting**							
	15	**30**	**45**	**60**	**75**	**90**	**105**	**120**
Clay soil								
A	38.74^a	41.15^a	43.03^{ab}	44.69^a	42.14^a	37.35^a	36.09^a	34.53^{ab}
E	38.79^a	40.59^a	43.56^a	44.91^a	41.51^a	37.00^a	36.18^a	34.58^{ab}
R	39.72^a	41.13^a	43.11^{ab}	43.92^{ab}	41.27^a	37.53^a	36.04^a	34.89^a
L	39.60^a	40.69^a	43.00^{ab}	43.80^{ab}	41.11^a	36.67^{ab}	34.90^b	33.22^{bc}
C	35.85^b	38.51^a	40.16^b	41.53^b	41.26^a	35.60^b	35.00^b	33.07^c

Means within the columns for the treatments in the same soil types followed by the same letter are not significantly different at P≤0.05.

3.5. Effect of tillage implement on soil penetration resistance

In an effort to evaluate the persistence or durability of the induced changes due to the use different tillage implements, penetration resistances of the experimental soil were measured during the entire growth period. The effect of tillage implement on the soil penetration resistances in most cases is unpredictable. This could be due the inherent properties of the soil, and inefficiencies of the tillage implements to tear, break, and adequately crumble the soils (Table 4).

As can be seen from Table 4, the penetration resistances of clay soil, after 15 to 60 days, kept on increasing though it was not statistically significant under all treatments including no tillage. Similarly,[6] reported higher soil penetration resistance in the No Tillage treatment in comparison with the other treatment for Ferric Luvisol in the rain forest zone of Akure in Nigeria. After 60 days of treatments application the penetration resistance increased beyond the initial no tillage condition due to the natural settlement and high rainfall. Within a month time after tillage, regardless of tillage implements used the penetration resistance progressively increased indicated the poor durability of the induced physical properties of the soil using the implements which were under investigation.

Table 4. Effect of tillage implements on soil penetration resistance days after planting

Mean penetration resistance (KN/cm^2)								
Treatments & soil types	Days after planting of data collecting							
	15	30	45	60	75	90	105	120
Clay soil								
A	0.73^{b}	0.84^{a}	0.97^{a}	1.02^{a}	1.09^{b}	1.14^{c}	1.15^{d}	1.17^{c}
E	$0,74^{b}$	0.84^{a}	0.97^{a}	1.03^{a}	1.13^{ab}	1.15^{b}	1.17^{b}	1.18^{b}
R	0.74^{b}	0.84^{a}	0.97^{a}	1.04^{a}	1.12^{ab}	1.14^{c}	1.16^{cd}	1.18^{b}
L	0.75^{b}	0.86^{a}	0.98^{a}	1.04^{a}	1.13^{ab}	1.15^{b}	1.17^{bc}	1.18^{b}
C	1.07^{a}	1.08^{a}	1.10^{a}	1.14^{a}	1.15^{a}	1.17^{a}	1.18^{a}	1.20^{a}

Means within the columns for the treatments followed by the same letter are not significantly different at $P \leq 0.05$.

IV. CONCLUSION

A study was conducted to assess the effect of tillage implements on physical properties of soil and the durability of the induced changes. ARDU plough, AIRIC plough, Local maresha and Ripper maresha, were used to effect the tillage operation.

Measurements made on the level of soil moisture content from the date of planting up to harvesting indicated that there were no significant differences in moisture content at 30th and 75th days after planting in clay soil. The higher moisture contents were observed at 60th day after planting under all treatments. This could be attributed to the high rainfall that occurred during the month of May. Hence, the soil moisture content increases in all soils are due to the high rainfall rather than the effect and types of tillage implements.

The effect of tillage implement on the soil penetration resistances in most cases is unpredictable. This could be due the inherent properties of the soil, and inefficiencies of the tillage implements to tear, break, and adequately crumble the soil. The penetration resistances of clay soil, after 15 to 60 days, kept on increasing though it was not statistically significant under all treatments including no tillage. After 60 days of treatments application, the penetration resistance increased beyond the initial no tillage condition. Within a month time after tillage, regardless of tillage implements used, the penetration resistance progressively increased indicating the poor durability of this induced physical property.

All tillage implements used reduced soil bulk density. Hence, it can be concluded that the tillage implements had the same effect on bulk density and the tillage implements didn't affect bulk density of soil below depth of tillage.

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