COMPARISON OF SHALLOW AND DEEP TILLAGE PRACTICES AT DIFFERENT SOIL MOISTURE CONTENT LEVELS UNDER CLIMATIC CONDITIONS OF SINDH

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ABSTRACT: *An experiment was conducted during 2015 at Latif Experimental Farm of Sindh Agriculture University Tandojam. Treatments included two tillage practices: mouldboard plow + cultivator and cultivator twice against three soil moisture content levels 11-13%, 14-16% and 17-19%. The highest operating speed (5.44km/hr), effective width (2.76m), effective field capacity (0.43ha/hr) and soil volume disturbed (502 m^3/hr) were recorded under cultivator twice at 11-13% soil moisture level, while lowest operating speed (4.85km/hr), effective width (1.97m), effective field capacity (0.28 ha/hr) and soil volume disturbed (456 m^3/hr) were recorded under mouldboard + cultivator at 17-19% soil moisture level. Similarly, lowest fuel consumption (20.53 lit/ha) was recorded under cultivator twice at 11-13% soil moisture level, while highest fuel consumption (32.43 lit/ha) was recorded under mouldboard + cultivator at 17-19% soil moisture level. However, the maximum effective depth (0.18 m) was recorded under mouldboard + cultivator at 17-19% soil moisture level, while minimum effective depth (0.11m) was recorded under cultivator twice at 11-13% soil moisture level. The higher infiltration rate (0.88cm/hr) and lower bulk density (1.31 g/cm^3) were achieved under mouldboard plow + cultivator at 11-13% soil moisture level, while lower infiltration rate (0.74 cm/hr) and higher bulk density (0.74 cm/hr) were obtained under cultivator twice at 17-19% soil moisture level. The maximum aggregate size distribution (20.53 mm) was recorded under mouldboard + cultivator at 11-13% soil moisture level, while minimum aggregate size distribution (13.43 mm) was recorded under cultivator twice at 17-19% soil moisture level. It is therefore suggested to perform deep tillage practices (mouldboard + cultivator) at 11-13% soil moisture level to obtain better tilth. However shallow tillage practices (cultivator twice) can also be adapted, when the available resources are limited.*

Keywords: Shallow and deep tillage, soil physical properties, moisture content levels

INTRODUCTION

Tillage implements are classified as primary and secondary. The primary tillage implements are used for breaking the soil to deeper depths, destroying weeds and reducing soil strength. They are mouldboard, disk plough, chisel plough. Secondary tillage implements are used for breaking the soil to shallow depths, to prepare a seedbed and to kill weeds. They include cultivator, harrows, rollers [1]. The selection of tillage implements depends on soil type and conditions [2]. However, farmers employ tillage practices in hard dry soil conditions, which not only create unfavorable seedbed conditions, also cause serious soil erosion. According to Dexter and Bird [3], if the soil is tilled in very dry conditions, it will require high amounts of energy and large clods will be produced. Keller [4] reported that there is optimum soil moisture content for tillage at which most favorable seedbed conditions could be achieved. In this context many studies have been conducted under different soil moisture conditions with different shallow and deep tillage implements in various parts of the world. Kailappan [5] tested the combination of primary and secondary tillage operations in black soil at 11.7% moisture content and red soil at 6.5% moisture content. They reported that combination of tillage tool after mouldboard or disc plow in black cotton or red soils promoted better moisture status in the sub-soil due to the formation of smaller size clods and their arrangements in the profile. Muhammad [6] studied the effect of tine cultivator twice (TC-2), chisel plow (CR), moldboard plow (MR), disk plow (DR) and tine cultivator once (TCR) followed by rotavator on soil physical properties of a silty clay loam soil at different soil moisture levels (5-10%, 10-15%, 15-20 and 20-25%). They found that deep tillage implements (chisel and moldboard plows) performed better than shallow tillage implements (tine cultivator) at 15-20% soil moisture content level. On the contrary, Alvarez and Steinbach [7] found higher aggregate stability and water infiltration rate in soils subjected to limited tillage systems than under plow tillage at moisture content of 10-15%.

However, no any particular study has provided the proper benchmark for the selection of tillage implements in specific soil conditions. Therefore, a study was carried out to compare the shallow and deep tillage practices at different soil moisture content levels under the climatic conditions of Sindh, Pakistan.

MATERIALS AND METHODS

The study was carried out at Latif Experimental Farm of Sindh Agriculture University Tandojam during 2015. The treatments included deep tillage (mouldboard + cultivator) at moisture level 11-13% (T_1), shallow tillage (cultivator twice) at moisture level 11-13% (T_2), deep tillage (mouldboard + cultivator) at moisture level 14-16% (T_3), shallow tillage (cultivator twice) at moisture level 14-16% (T_4), deep tillage (mouldboard + cultivator) at moisture level 17-19% (T_5) and shallow tillage (cultivator twice) at moisture level 17-19% (T_6). There were eighteen (18) plots arranged in Randomized Complete Block Design (RCBD). The water was added to the soil on the basis of initial moisture content to bring the soil at the desired moisture content levels (11-13%, 14-16% and 17-19%). Soil samples were collected at the depths of 15, 30 and 45 cm with help of soil auger to determine soil moisture content by gravimetric method. The textural class of each soil depth (i.e. 0-15, 15-30, 30-45 cm) was clay loam.

Performance parameters

Speed of operation: The operating speed was measured by following formula:

$$OS = \frac{D}{T}$$

Where;

OS = operational speed (km h^{-1})

D = distance (km)

T = time taken (h)

Effective field capacity: The effective field capacity of shallow and deep tillage implements was calculated using following formula:

$$C = \frac{A}{T_p + T_t}$$

Where;

C	=	Effective field capacity (ha/hr)
A	=	Area tilled (ha)
Tp	=	Productive time (hr)
Tt	=	Non-productive time (hr)

Soil volume disturbance: The total soil volume disturbance was calculated by multiplying the field capacity with the depth of cut and 10000.

$$V = 10000\ CD$$

Where,

V= Soil volume disturbed, m^3/hr

C = Field capacity, ha/hr.

D = Depth of cut, m

Effective Width: The effective width of the implement was measured from furrow wall to the tilled area using a steel tape at randomly selected sites of each plot.

Effective depth: The effective depth was measured from the bottom of the furrow to the surface level of the soil with help of scale at randomly selected sites of each plot.

Wheel slippage: The wheel slippage was determined by marking with a chalk on drive wheel of the tractor and measuring the distance covered by the tractor in 10 revolutions with no load (R) and with load (r). The following formula was used to determined wheel slippage:

$$T_r = \frac{R - r}{R}$$

Where;

Tr	=	Wheel slip, %
R	=	Distance traveled in ten revolutions with no load, m
r	=	Distance traveled in ten revolutions with load, m

Fuel consumption: The tank of M.F-375 diesel tractor was filled up to top level before testing mouldboard plow and cultivator in each plot. After ploughing, the fuel tank of the tractor was refilled up to the same level with 1000 milliliter graduate cylinder. The total quantity of fuel needed to refill the fuel tank up to the mark was recorded with the total time taken to plow the test plot. The fuel consumption per hour for hectare was calculated by following formula:

$$F.C = \frac{Fuel\ Consumption}{Area\ of\ Plot\ (m^2)} \times 10000$$

Soil physical properties

Soil texture: Soil samples were collected and air dried. A dispersion cup was filled with water and 10 ml of Sodium Hexametaphosphate. The material was dispersed for 5-10 minutes with the help of dispersion machine. Reading with hydrometer was taken after two hours and then the percentages of clay, silt and sand were calculated as follows:

$$Silt + Clay = \frac{1^{st}\ correct\ reading}{Wt.\ of\ soil\ sample} \times 100$$

$$Clay = \frac{2^{nd}\ correct\ reading}{Wt.\ of\ soil\ sample} \times 100$$

$$Silt = (Silt + Clay) - Clay$$

$$Sand = 100 - (Silt + Clay)$$

Soil bulk density: The soil samples were collected at the depths of 15, 30 and 45 cm; then the bulk density of the soil was determined by following formula:

$$bd = \frac{M}{V}$$

Where;

M = Mass of soil core of oven dry soil (g)

V = Volume of cylindrical core sample (cm^3)

Infiltration rate: Infiltration rate was measured at three selected placed in each treatment using a double ring infiltrometer.

Aggregate size distribution: The aggregate size distribution was evaluated using a set of six sieves with mesh of 75mm (3inches), 50mm (2mm), 25mm (1inch), 15.6mm (0.63inch), 12.5mm (0.48inch) and 8mm (0.32 inch). The mean weight diameter of soil clods was determined by following formula:

$$MWD = \frac{\sum WD}{\sum W}$$

Where

MWD = Mean weight diameter

W =Weight of soil clods or weight of soil held by a particular

D =Equivalent diameter of clod or size of sieve

Statistical analysis of the data: The data thus collected were subjected to statistical analysis using Statistix (version 8.1) statistical software package in General Linear Model (GLM). The LSD test was applied to compared the means among the treatments at probability level (p<0.05).

RESULTS AND DISCUSSION

Performance *of tillage implements*

Operating speed: The operating speed of tractor under (mouldboard plow + cultivator and cultivator twice) at 11-13%, 14-16% and 17-19% soil moisture levels is presented in Fig. 1. The highest operating speed (5.44 km/hr) was recorded under cultivator twice at soil moisture level 11-13%, while lowest operating speed (4.85 km/hr) was recorded under mouldboard + cultivator at 17-19% soil moisture level. It was observed that increasing soil moisture content caused significant decrease in operating speed.

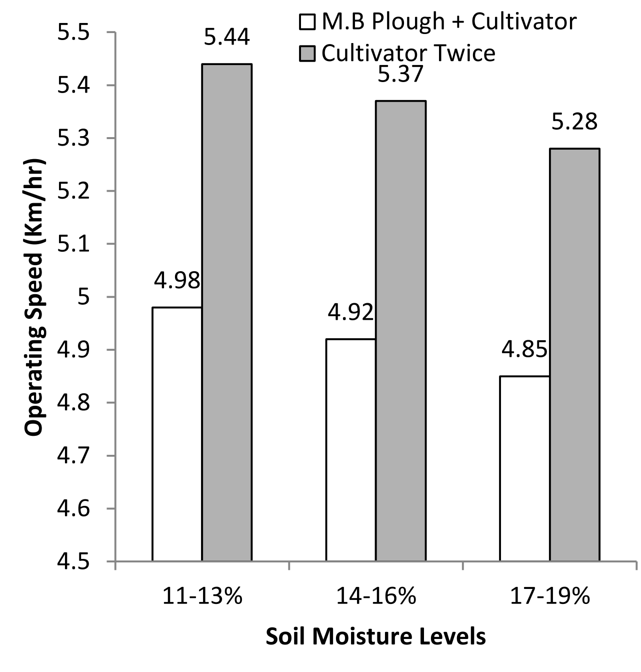

Figure 1. Operating Speed at various moisture levels

Wheel slippage: Wheel slippage of tractor under mouldboard plow + cultivator and cultivator twice at 11-13%, 14-16% and 17-19% soil moisture levels is presented in Fig. 2. The highest wheel slippage (18.37%) was recorded under mouldboard + cultivator at 17-19% soil moisture level, while lowest wheel slippage (11.49%) was recorded under cultivator twice at 11-13% soil moisture level. It was observed that increasing soil moisture level caused significant increase in the wheel slippage.

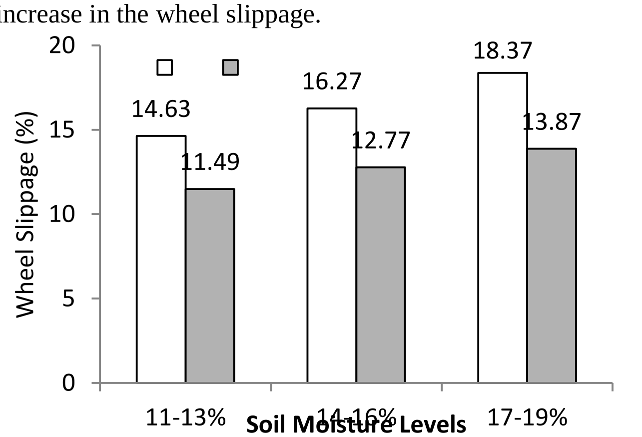

Figure 2. Wheel slippage at various moisture levels

Effective width: The effective width under (mouldboard plow + cultivator and cultivator twice) at 11-13%, 14-16% and 17-19% soil moisture levels is presented in Fig. 3. The maximum width (2.76m) was recorded under cultivator twice at 11-13% soil moisture level, while minimum width (1.97m) was recorded under mouldboard + cultivator at 17-19% soil moisture level. It was observed that increasing soil moisture content caused significant decrease in effective width.

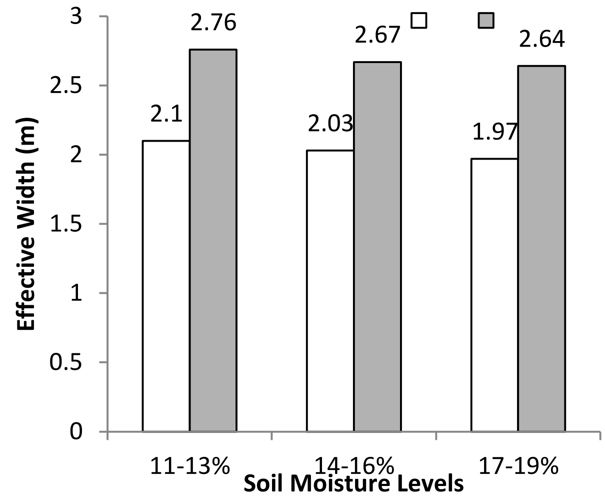

Figure 3. Effective plowing width at various moisture levels

Effective depth: The effective depth under (mouldboard plow + cultivator and cultivator twice) at 11-13%, 14-16% and 17-19% soil moisture levels is presented in Fig. 4 The maximum effective depth (0.18m) was recorded under mouldboard + cultivator at 17-19% soil moisture level, while minimum effective depth (0.11m) was recorded under cultivator twice at 11-13% soil moisture level.

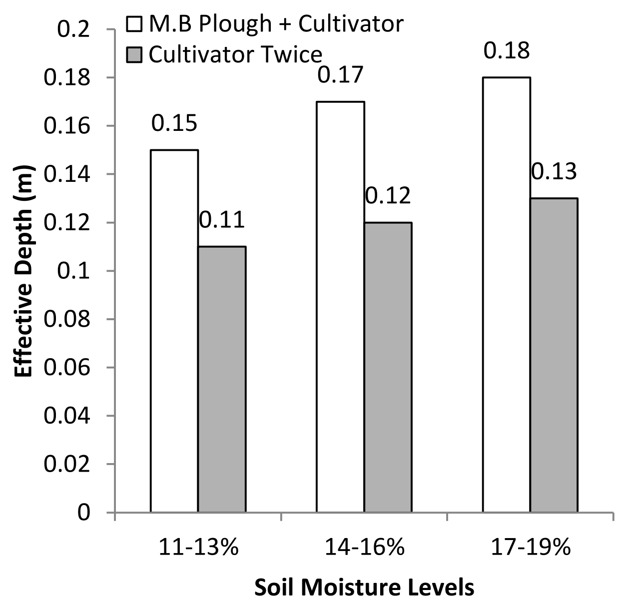

Figure 4. Effective Plowing depth at various moisture levels

Effective field capacity: The effective field capacity under (mouldboard plow + cultivator and cultivator twice) at 11-13%, 14-16% and 17-19% soil moisture levels is presented in Fig. 5. The highest effective field capacity (0.43 ha/hr) was recorded under cultivator twice under 11-13% soil moisture level, while lowest effective field capacity (0.28 ha/hr) was recorded under mouldboard plow + cultivator under 17-19% soil moisture levels.

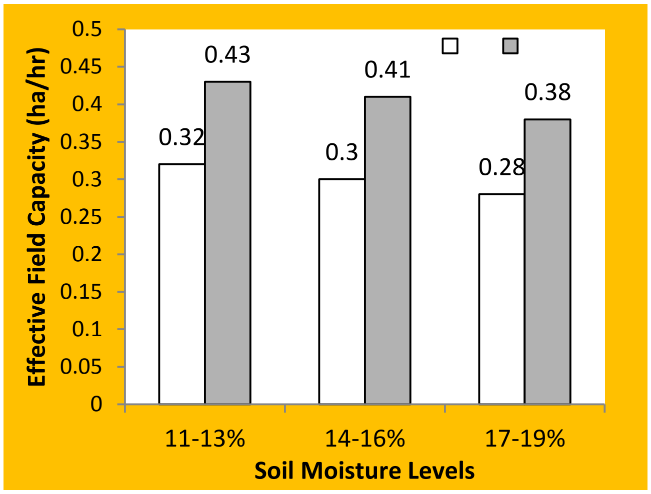

Figure 5. Effective field capacity at various moisture levels

Soil volume disturbed: The soil volume disturbed under mouldboard plow + cultivator and cultivator twice at 11-13%, 14-16% and 17-19% soil moisture levels is presented in Fig. 6. The highest soil volume disturbed (502 m^3/hr) was recorded under cultivator twice at 11-13% soil moisture level, while lowest soil volume disturbed (456 m^3/hr) was recorded under mouldboard plow+ cultivator at 17-19% soil moisture level.

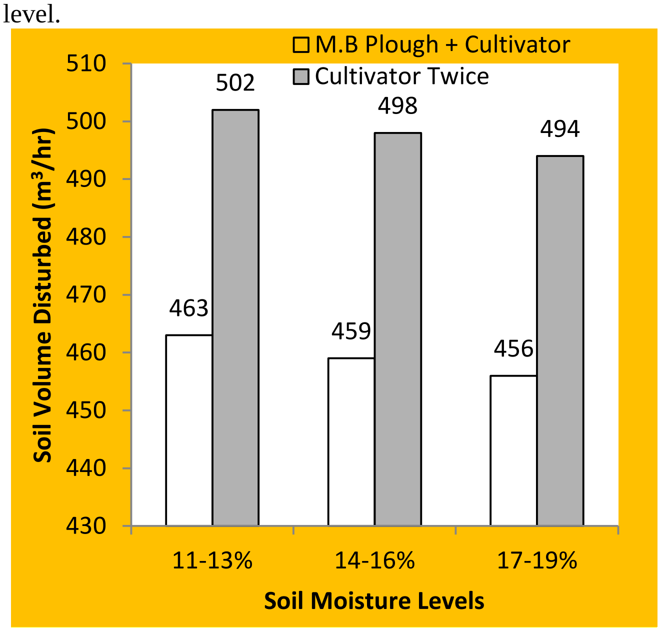

Figure 6. Soil volume disturbed at various moisture levels

Fuel consumption: The fuel consumption of tractor under mouldboard plow + cultivator and cultivator twice at 11-13 %, 14-16% and 17-19% soil moisture levels is presented in Fig. 7. The highest fuel consumption (32.43lit/ha) was recorded under mouldboard plow + cultivator at 17-19% soil moisture level, while lowest fuel consumption (20.53lit/ha) was recorded under cultivator twice under 11-13% soil moisture level.

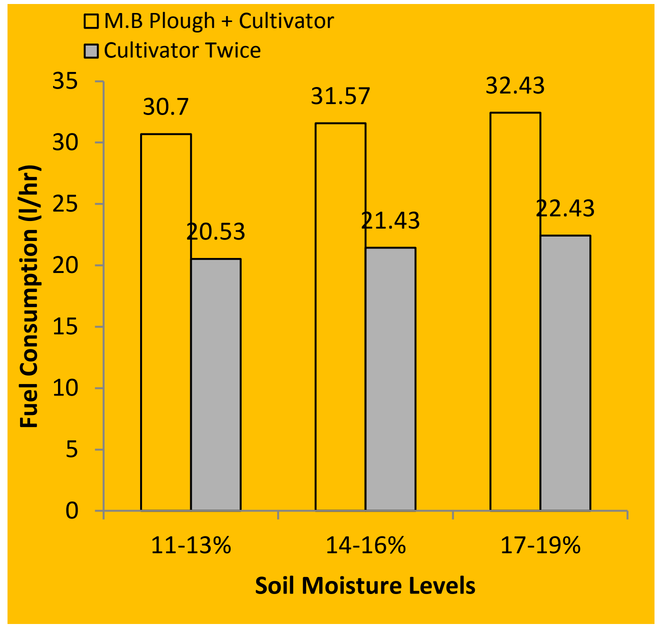

Figure 7. Fuel consumption at various moisture levels

Soil physical properties

Infiltration rate: The infiltration rate of experimental soil before and after tillage practices (mouldboard plow + cultivator and cultivator twice) at different soil moisture levels (11-13%, 14-16% and 17-19%) is presented in Fig. 8. The infiltration rate of soil before tillage was 0.77, 0.70 and 0.63 cm/hr at 11-13%, 14-16% and 17-19% respectively, which increased significantly to 0.88, 0.86 and 0.82 cm/hr under mouldboard plow + cultivator tillage, while it increased to 0.80, 0.77 and 0.74 cm/hr under cultivator twice at 11-13%, 14-16% and17-19% soil moisture levels respectively. However, highest infiltration rate (0.88cm/hr) was achieved under mouldboard plow + cultivator at 11-13% soil moisture level, while lowest infiltration rate (0.74cm/hr) was obtained under cultivator twice at 17-19% soil moisture level. It was observed that increasing soil moisture content caused significant decrease in infiltration rate.

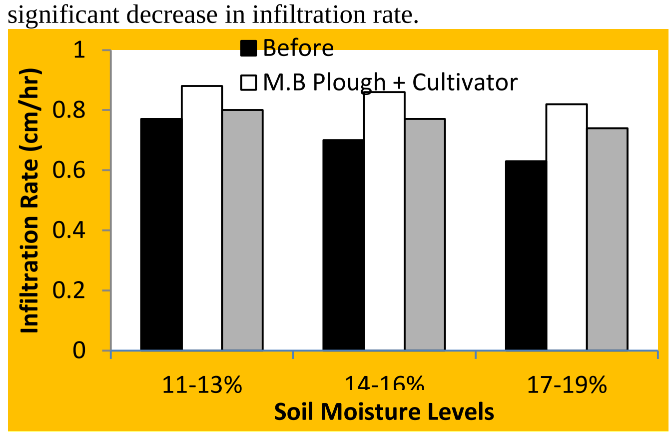

Figure 8. Infiltration rate at various moisture levels

Soil bulk density: The bulk density of experimental soil before and after tillage practices (mouldboard plow + cultivator and cultivator twice) at different soil moisture levels (11-13%, 14-16% and 17-19%) is presented in Fig. 9. The bulk density of the soil before tillage was 1.28, 1.29 and 1.33 g/cm^3 at 11-13%, 14-16% and 17-19% respectively, which decreased significantly to 1.14, 1.18, and 1.27 g/cm^3 under mouldboard plow + cultivator, while it decreased to 1.16, 1.21 and 1.30 g/cm^3 under cultivator twice at 11-13%, 14-16% and 17-19% soil moisture levels respectively. However, maximum bulk density (1.31 g/cm^3) was found under cultivator twice at 17-19% soil moisture level, while minimum bulk density (1.14 g/cm^3) was obtained under mouldboard + cultivator at 11-13% soil moisture level.

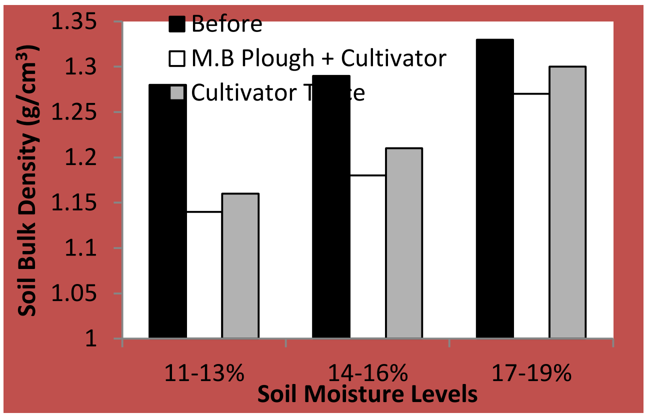

Figure 9. Bulk density at various moisture levels

Aggregate size distribution: The aggregate size distribution under mouldboard plow+ cultivator and cultivator twice at 11-13%, 14-16% and 17-19% soil moisture levels is presented in Fig. 10. The maximum aggregate size distribution (20.53 mm) was recorded under mouldboard+ cultivator at 11-13% soil moisture level, while minimum aggregate size distribution (13.43 mm) was recorded under cultivator twice at 17-19% soil moisture level. It was observed that increasing soil moisture level caused significant decrease in the aggregate size distribution.

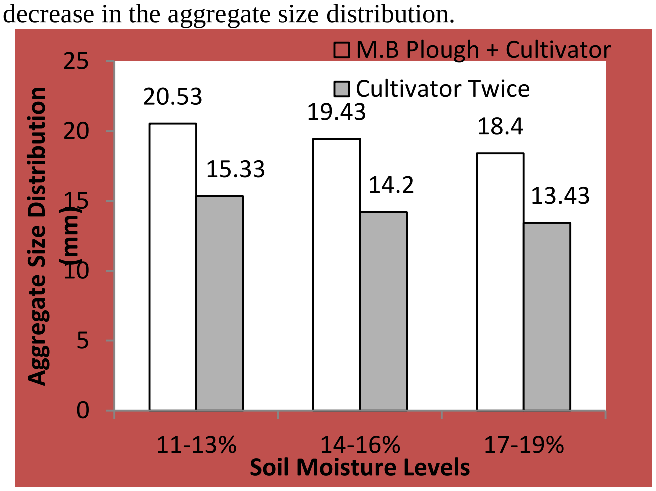

Figure 10. Aggregate size distribution at various moisture levels

The statistical analysis of the data (ANOVA) showed that tillage implements had significant ($p < 0.05$) effect on operating speed, wheel slippage, effective depth, soil volume disturbed, fuel consumption, infiltration rate, bulk density and aggregate size distribution soil moisture level; while non-significant ($p > 0.05$) effect was recorded on effective width and effective field capacity. This is attributable to Natsis and Papadakis [8], who showed that soil moisture content, was the major factor affecting the efficiency of tractor operation. The shallow tillage performed better than that of deep tillage at 11-13% soil moisture level compared to 14-16% and 17-19% soil moisture levels. The highest operating speed, effective width, effective field capacity and soil volume disturbed were recorded under cultivator twice at 11-13% soil moisture level, while lowest operating speed, effective width, effective field capacity and soil volume disturbed were recorded under mouldboard +cultivator at 17-19% soil moisture level. Similarly, lowest fuel consumption was recorded under cultivator twice at 11-13% soil moisture level, while highest fuel consumption was recorded under mouldboard + cultivator at 17-19% soil moisture level. However, the maximum effective depth was recorded under mouldboard + cultivator at 17-19% soil moisture level while minimum effective depth was recorded under cultivator twice at 11-13% soil moisture level. Gerhard [9] found high fuel consumption under mouldboard plow, while lowest under cultivator.

This study has obtained the better tilth under deep tillage at 11-13% soil moisture level. Similar results were also reported by Amin [10], who concluded that the deep tillage practices (moldboard plow, chisel plow) performed better than shallow tillage practices (tine cultivator), to reduce both soil bulk density and penetration resistance under semi-arid environment. The maximum infiltration rate was achieved under mouldboard plow + cultivator at 11-13% soil moisture level, while minimum infiltration rate was obtained under cultivator twice at 17-19% soil moisture level. Mohammed and Umogbai [11] reported highest infiltration rates after different tillage practices at 11-15% soil moisture level. Similarly, Alvarez and Steinbach [7] found highest infiltration rates at 10-15% soil moisture level. Likewise, the minimum bulk density was found under mouldboard plow + cultivator at 11-13% soil moisture level, while maximum bulk density was obtained under cultivator twice under 17-19% soil moisture level. However, Muhammad [6] recorded the lowest bulk density with moldboard plow at 15-20% soil moisture level. The maximum aggregate size distribution was recorded under mouldboard + cultivator at 11-13% soil moisture level, while minimum aggregate size distribution was recorded under cultivator twice at 17-19% soil moisture level. The similar findings are reported by Adam and Erbach [12], who concluded that aggregates formed by tillage at higher moisture content were larger and required greater force to crush than did aggregates formed at lower moisture contents. Yassen [13] reported that after tillage there were big clods in the field. With the higher soil moisture content, tillage equipment cannot be used in the field. Bauer and Kucera [14] in their research found that lower soil moisture content had optimal clod mean weight diameter. These results are further supported by any other research studies [8, 15, 16].

CONCLUSIONS

The study has showed that shallow tillage performed better than that of deep tillage at 11-13% soil moisture level compared to 14-16% and 17-19% soil moisture levels, while the better tilth was achieved under deep tillage at 11-13% soil moisture level. The highest operating speed, effective width, effective field capacity and soil volume disturbed were recorded under cultivator twice at11-13% soil moisture level, while lowest operating speed, effective width, effective field capacity and soil volume disturbed were recorded under mouldboard + cultivator at 17-19% soil moisture level. Similarly, lowest fuel consumption was recorded under cultivator twice at 11-13% soil moisture level, while highest fuel consumption was recorded under mouldboard + cultivator at 17-19% soil moisture level. However, the maximum effective depth was recorded under mouldboard + cultivator at 17-19% soil moisture level while minimum effective depth was recorded under cultivator twice at 11-13% soil moisture level.

The higher infiltration rate and lower bulk density were achieved under mouldboard plow + cultivator at 11-13% soil moisture level, while lower infiltration rate and higher bulk density were obtained under cultivator twice at 17-19% soil moisture level. The maximum aggregate size distribution was recorded under mouldboard + cultivator at 11-13% soil moisture level, while minimum aggregate size distribution was recorded under cultivator twice at 17-19% soil moisture level.

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