Relative Efficiency of Different Tillage Practices and Their Effect on Soil Physical Properties under Semi-Arid Climate of Tandojam, Pakistan

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ABSTRACT

Tillage practices affect physical properties of soil that are crucial for better crop production. The study was carried out to compare the efficiency of two different tillage implements and their effect on some soil physical properties. The tillage implements included cultivator and disc plow. The soil properties viz. soil moisture, bulk density and infiltration rate were determined before and after the tillage practices. However, the efficiency of tillage operation including operating speed, travel reduction and fuel consumption were taken during the tillage operation. The comparative analysis showed that the cultivator was better in reducing soil bulk density (12-18%) along with increasing the infiltration rate up to 61.5% and conserving soil moisture up to 95%. The disc plow, on the other hand, reduced the bulk density of soil more effectively with up to 21% efficiency and enhancing soil porosity (23%). However, disc plow was less efficient in increasing infiltration rate (38%) and conserving soil moisture (87-90%). Comparatively higher fuel consumption (23.3 L hr^{-1}) was observed in operating disc plow with less operating speed (4.1 km hr^{-1}) and higher travel reduction (27.5%). On the other hand, higher cultivator operating speed (4.76km hr^{-1}) was observed with less travel reduction (21.8%) and fuel consumption (14.9 Lhr^{-1}). The cultivator, being more economical and having good effects on soil properties, was the best option for tillage operations in the clay soils of cotton-wheat rotation system under semi-arid climate of Tandojam, Pakistan.

Key Words: Tillage, Efficiency, Soil Bulk Density, Soil Porosity, Fuel Consumption, Tandojam.

1. INTRODUCTION

Soil health is determined by its physical, chemical and biological properties. Tillage practices modify the soil physical properties including soil bulk density, porosity, infiltration, penetration resistance, aggregation [1]. Tillage contributes about 20% in the crop production [2] by increasing soil porosity & infiltration rate and by decreasing bulk density that ultimately helps in improved root growth [3-4]. However, the depth of tillage implement may change the intensity of effect on physical properties of soil. The disc harrow has been more effective in altering the upper soil conditions with increasing soil porosity and reducing bulk density of as compared to Chisel that resulted in higher bulk density and less porosity [5]. On the other hand, long term no

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tillage negatively affect the soil physical properties including compaction of upper soil layer, hampering root growth and water infiltration [6].

The controversy of using different tillage systems had diverted the research focus from determining the economic efficiency of tillage implements that may reduce the cost of crop production. Tillage is one of the highest energy consumers in crop production factors [7]. Economic efficiency of different tillage practices including chiseling and disc plowing recorded the most time consumption along with higher consumption of fuel [8]. An increase of 1 cm in ploughing depth of tillage implement may result in enhanced fuel consumption from 0.5-1.5 L ha^{-1} depending on the soil constituents as reported by Moitzi [7]. However, in Ethiopia, deep tillage implements of subsoiler, tie-ridger, and sweep have been developed that are economical, energy-efficient, break the soil hardpan along with increasing the root growth of plants [9]. On the other hand, the tillage implements with shallow depth, also called as non-inversion tillage has the potential in reducing cost of production through minimizing fuel costs and timeliness of field operations in addition to minimizing soil erosion, improving soil structure, porosity, infiltration and water holding capacity [10].

Pakistan economy is mostly based on agriculture. About 62% population of Pakistan is directly or indirectly involved to agriculture. Hence, promoting agriculture with reduced farmer financial inputs may contribute to cut off the cost of crop production leading to the prosperity of the farming community and nation. As the fuel prices in Pakistan are rising day by day, hence exploring the fuel efficient tillage methods has become indispensable. Therefore, the present study was conducted to evaluate the efficiency of two most widely used tillage implements for reducing cost of crop production along with positive effects on soil physical properties in agro-climatic conditions of Tandojam, Pakistan.

2. MATERIALS AND METHOD

The current study was carried out to evaluate the efficiency of cultivator and disc plow and their effect on physical properties of soil in year 2014. The study was conducted at Latif experimental farm Sindh Agriculture University, Tandojam. The plot size used was 20x30m ($600m^2$) replicated thrice. Two treatments viz. T1 = cultivator and T2 = disc plow, were used in RCBD (Randomized Complete Block Design). The physical properties of soil such as moisture, bulk density and infiltration rate were determined before and after the tillage practices. However, the economic efficiency of tillage operation including operating speed, travel reduction and fuel consumption were taken during the tillage operation. The data of operating speed, travel reduction and fuel consumption were recorded according to the recommendation of RNAM (Regional Network for Agricultural Machinery, USA) test codes and procedures for farm machinery [11].

2.1 Soil Analysis

Soil samples were collected at different depths (0-15, 15-30 and 30-45cm) from each plot. Composite of three samples per plot were mixed, air-dried and sieved through a 2mm sieve. Soil texture was determined using Bouyoucus hydrometer method [12] by calculating the proportion of sand, silt and clay and comparing in USDA textural class triangle. Soil moisture contents were calculated by loss in weight after drying soil in oven for 24 hours at 105^0C. Bulk density of soil was measured by core method [13] by calculating the soil mass collected in a defined volume of core. Soil infiltration rate was determined using infiltrometer rings as described by Murtaza, et. al. [14]. Two infiltrometer rings were inserted into soil; the small one was flooded with water with plastic sheet beneath. The same water level was maintained in

the large ring to prevent the lateral flow of water. Then the plastic sheet beneath small ring was removed gently and infiltration rate was recorded after the steady state reached.

2.2 Operating Speed

Outside the long boundaries of the test plots, two poles were placed at a distance of 25m in the middle of the test run. Similarly, two other poles were placed at a distance of 25m on the opposite side so that all four poles formed a rectangle. The operating speed was determined through the time required by the tractor plus tillage implement to cover the distance of 25m between the two poles. The time of travel by tractor equipped with implement was recorded using stop watch.

2.3 Effective Plowing Depth and Width

The plowing depths of cultivator and disc plow were measured with the steel scale. The depth was measured randomly from the bottom of the furrow to the surface level of the soil from test plots. While effective plowing width of cultivator and disc plow was measured by using the same scale. The width was measured from wall to wall of furrow for the total area tilled in each plot.

2.4 Travel Reduction

A simple method of determining travel reduction was used by making a mark with a chalk on the drive wheel of the tractor and the distance covered by tractor in 10 revolutions with no load (R) and with load (r). Five observations from each test plot were taken for measurement of travel reduction. The travel reduction was calculated by using the formula given by RNAM, [11].

$$T_r = \frac{R - r}{R} \times 100$$

Where T_r is Travel reduction (%), R is Distance traveled in ten revolution with no load (m), r is Distance traveled in ten revolution with load (m).

2.5 Fuel Consumption

The tractor (FIAT) tank was filled up to full level before operating tillage implements (cultivator and disc plow) in the test plot. After plowing of 600m^2 plot area, the fuel tank was refilled up to the full level using graduated cylinder of 1000 mL. The quantity of fuel required to refill the fuel tank up to the full level was recorded along with the total time taken to plow the test plot. The fuel consumption was calculated using the following formula

$$\text{Fuel Consumption Per Hectare (Liters)} = \frac{\text{Fuel Used Per Plot (Lit)}}{\text{Area of Plot}\left(m^2\right)} \text{ x } 10000$$

2.6 Effective Field Capacity

Effective field capacity (S) was calculated by the ratio of area covered by tractor to the productive and non-productive time as in the formula given below

$$S = \frac{A}{T_p + T_n}$$

Where S is Effective field capacity (ha/hr) A is Area covered (ha) T_p is Productive time (hr) T_n is Non-productive time (hr) (time lost for turning, loading and adjustment excluding refueling and machine trouble).

3. RESULTS AND DISCUSSION

The study was conducted in clay soil of Tandojam area having semi-arid climate as is evident from the Table 1. The soil had a mean bulk density of 1.41 g cm^{-3} and infiltration rate of 0.65 cm hr^{-1}. The soil history recorded as cotton-wheat rotation in the previous years. The two tillage implements tested had significant effect on soil

physical properties including bulk density, soil porosity, and infiltration rate and soil moisture content. Bulk density of soil tended to decrease with tillage. Disc plow having more effective plow depth (20.8cm), reduced soil bulk density (up to 21%) and increased soil porosity (23%) more efficiently when compared to cultivator with less plow depth (14.6cm) and before tillage as is evident from Figs. 1-2. Bulk density is generally used as a soil quality parameter in crop management and tillage studies. The same trend has also been reported early [15] where the bulk density reduced more profoundly by conventional tillage as compared to reduced tillage. Similarly the chisel plough with more plowing depth resulted in reduced bulk density along with enhanced moisture conservation [16] under wheat cultivation. Tillage on appropriate soil moisture level loosens the soil with consequent increase in soil porosity and aeration resulting in reduction of bulk density [17]. A negative correlation was recorded between bulk density and soil porosity in both cultivator and disc plow operated fields. Generally, the soil water content increases with reducing soil bulk density. In the current study, the reverse case may be due to presence of more macro pores resulting in water loss.

TABLE 1. SOIL ANALYSIS OF EXPERIMENTAL SITE

Soil Property	Unit		Value (%)	
Sand	(%)		43	
Clay	(%)		47	
Silt	(%)		9	
Textural class	-		Clay	
Infiltration rate	cm hr-1		0.65	
Other Soil Physical Properties				
	0-15 cm	15-30 cm	30-45 cm	Mean
Moisture content (%)	13.98	15.5	20.77	16.75
Bulk density (g cm-3)	1.37	1.41	1.46	1.41

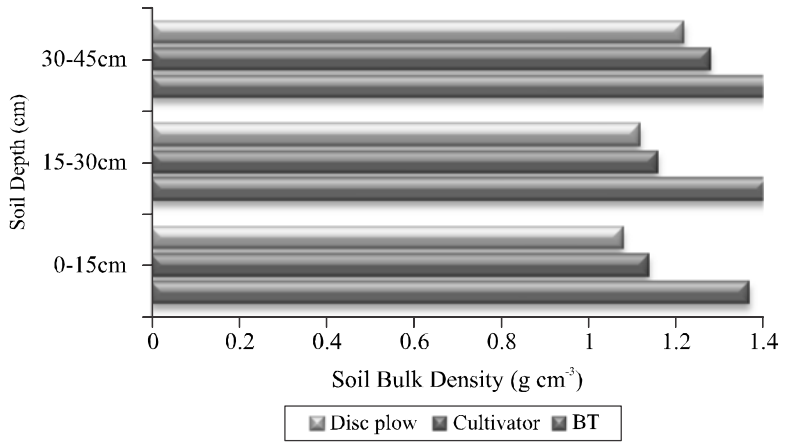

FIG. 1(a), SOIL POROSITY

The economic efficiency of tillage contributes much in cost of production. The current study divulges that using cultivator for tillage purpose can save 36% of fuel consumption as compared to disc plow. This may be attributed to high effective plough width (2.31m) in contrast to that of disc plow (1.69m). The same results have been reported by Filipovic, et. al. [18] in which conservation tillage methods (I and II) saved energy (36-59%) as compared to conventional tillage system. More variation in such data is expected depending on the type

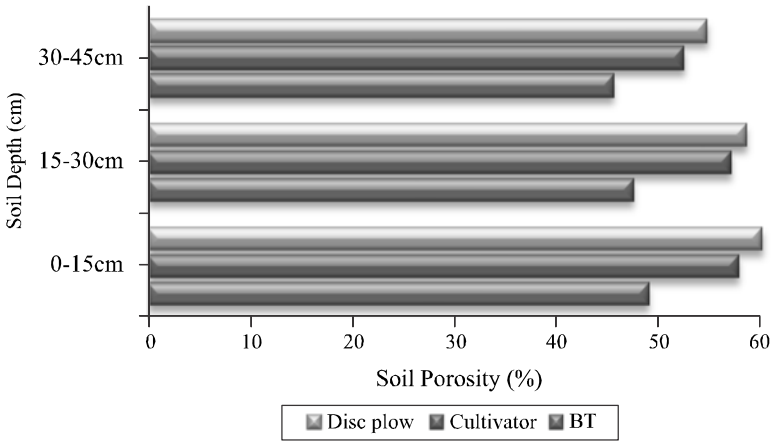

FIG. 1(b), MOISTURE CONTENT

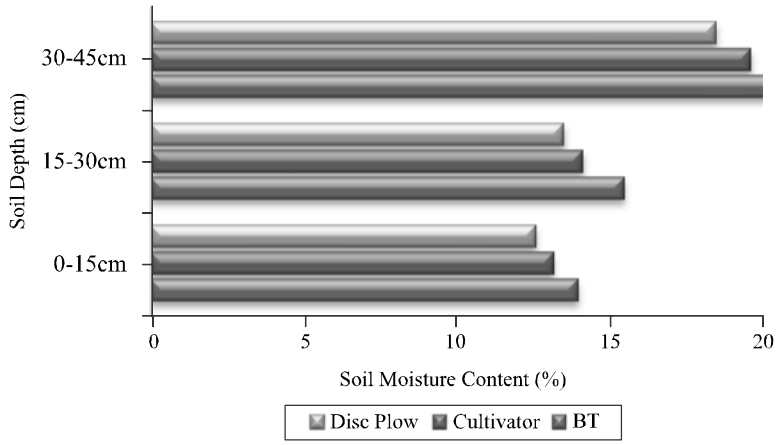

FIG. 1(c) AND INFILTRATION RATE

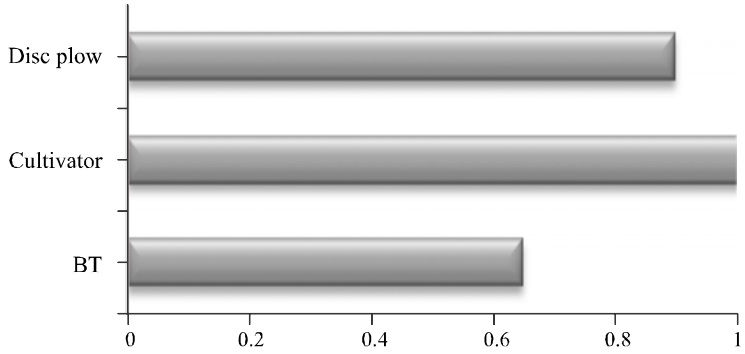

FIG. 1(d) AS AFFECTED BY OPERATING CULTIVATOR AND DISC PLOW BT=BEFORE TILLAGE

FIG. 1(a-d) SOIL BULK DENSITY

of soil, field conditions, plowing depth etc. For instance, fuel consumption values of 49.40L $ha^{-1}$for moldboard plough and 31.30 L ha^{-1} for chisel plough have been documented by Koller [19]. While Bashir, et. al. [20] reported fuel consumption of 15, 11.9 and 12.7 L ha^{-1} for disc plow, chisel plow and disc harrow, respectively. A positive correlation of fuel consumption was recorded with travel reduction and effective plough depth. However, effective plough width, operating speed and effective field capacity were found to be negatively correlated with fuel consumption. The same trend of significant increase in fuel consumption with increasing plough depth has been reported by Adewoyin and Ajav [21]. However, positive correlation of operating speed with fuel consumption was reported possibly due to different soil moisture content and tractor engine power. The effective plowing uching depth found negatively correlated with soil moisture content and bulk density (Table. 2). The results are in similarity with that of Parvin [22] who reported that the bulk density of soil tended to reduce with increased plough depth of moldboard plough in 0-15 and 15-30cm soil depth. However, the reduced moisture content with higher plough depth may be due to exposure of more soil volume to sunlight and low organic matter content that is reported to decrease with increasing depth of soil [23]. As shallow tillage has been recommended by some researchers [24-25], therefore, keeping in view the economic condition of Pakistani farmers, the study provides a clue to use cultivator for tillage operations in order to have positive effects on soil physical properties and farmer economy.

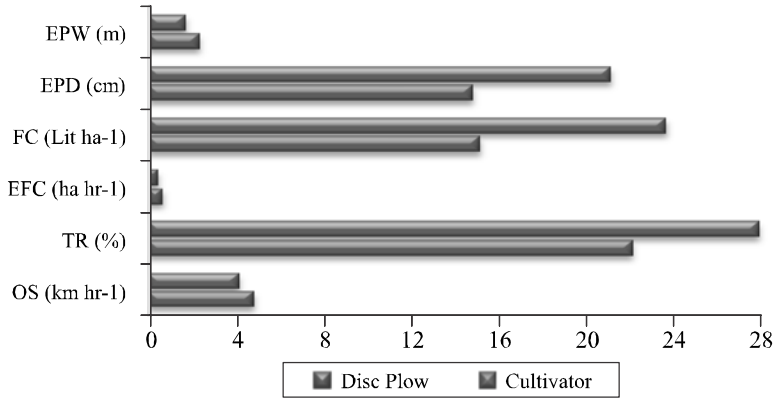

FIG. 2. RELATIVE EFFICIENCY OF DISC PLOW AND CULTIVATOR EPW/EPD=EFFECTIVE PLOW WIDTH (M)/PLOW DEPTH (CM), FC=FUEL CONSUMPTION (L HR^{-1}), EFC=EFFECTIVE FIELD CAPACITY (HA HR^{-1}), TR=TRAVEL REDUCTION (%), OS=OPERATING SPEED (KM HR^{-1})

TABLE 2. CORRELATION OF EFFECTIVE PLOWING WIDTH AND DEPTH OF TILLAGE IMPLEMENT WITH SOIL PROPERTIES

		EPD (cm)	EPW (m)	MC (%)	BD (g cm-3)
EPD (cm)	Pearson Correlation	1	-1.000**	-1.000**	-1.000**
	N	2	2	2	2
EPW (m)	Pearson Correlation	-1.000**	1	1.000**	1.000**
	N	2	2	2	2
MC (%)	Pearson Correlation	-1.000**	1.000**	1	1.000**
	N	2	2	2	2
BD (g cm-3)	Pearson Correlation	-1.000**	1.000**	1.000**	1
	N	2	2	2	2
** Correlation is significant at the 0.01 level (2-tailed).					

4. CONCLUSION

The efficiency of most widely used tillage implements was carried out under the agro-climatic conditions of Tandojam. The study revealed that efficiency of tillage implements may vary with type of soil, soil moisture content and prevailing climatic conditions. In the current study, between the two cultivation implements, the cultivator being economically more efficient and having positive effect on soil properties, has been found the best option for tillage operations in the clay soils of Tandojam in cotton-wheat rotation system under semi-arid climatic conditions.

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