PERFORMANCE EVALUATION OF DIFFERENT TILLAGE SYSTEMS IN A CLAY LOAM SOIL*

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ABSTRACT:- Field experiments were conducted to assess the performance of different tillage systems in a clay loam soil. A completely randomized block design with four treatments i.e., conventional tillage (CT), minimum tillage (MT), zero tillage (ZT) and controlled traffic farming (CTF) was carried out to evaluate the performance of tillage systems. Results indicated that the soil pulverization was higher (P<0.05) under MT and lower under CT treatments while, it was non-significant between MT and CTF treatments. Similarly, soil volume disturbed and effective ploughing depth was maximum (P<0.05) under CT followed by MT, CTF and minimum under ZT. Similarly the operating speed was significantly higher (P<0.05) under CTF and lower under CT whereas, wheel slippage/travel reduction was significantly minimum (P<0.05) under CTF and maximum under CT. Significantly, higher field capacity was recorded under CTF and lower (P<0.05) under CT. The maximum fuel consumption (P<0.05) was recorded under CT while it was minimum under ZT. Almost similar trends were observed for all parameters in 2012 and 2013. The results suggested that the control traffic system was more efficient tillage system in terms of soil pulverization, operating speed, travel reduction and over all field capacity. While, zero tillage had minimum fuel consumption and conventional tillage had higher working depth hence, more soil volume was disturbed under this treatment.

Key Words: Tillage; Controlled Traffic; Soil Aggregation; Soil Volume Disturbed; Operating Speed; Travel Reduction; Fuel Consumption; Pakistan.

INTRODUCTION

Performance evaluation of tillage implements indicates efficiency of the tillage systems depends on working conditions. It is essential to evaluate the performance of tillage systems under varying soil conditions and implement types. Conventional tillage systems are considered more fuel demanding and labor-intensive systems (Zugec et al., 2000). The primary tillage alone requires 75% energy prior to seedling (Pelizzi et al., 1988). Likewise, energy consumption in heavy clay soil is 55- 65% (Pelizzi et al., 1988). However, the rate of energy consumption varies with tillage system applied for cultivation. Stajnko et al. (2009) observed that the conventional tillage system had the highest fuel consumption. There are tillage methods which consume less energy they are more efficient, cost effective and produce high yields hence can be adopted to increase the economy of the country (Bayhan et al., 2006). For example, conservative tillage systems enhance the efficiency of tillage systems by minimizing inputs for agriculture

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without affecting crop yields (Cociu, 2010). Huseyin et al. (2006) and Koga et al. (2003) found reduced fuel energy inputs with minimum tillage system the conventional tillage system.

Besides conservation tillage systems, the controlled traffic farming system prevents traffic of tillage machines and equipments over the growing zone of crops (Dumas et al., 1973). This system not only controls soil compaction, but also reduces tractor size and fuel requirement by 50% compared to wheeled plots (Tullberg, 2001). In England, Chamen et al. (1988, 1992) found that energy requirement for crop establishment could be 70% reduced by eliminating traffic from the cropped area and reported 19% increase in yield.

Many studies have been conducted to evaluate the performance of conventional and conservation tillage systems under various soil conditions and implement types. However, convincing information on the performance of conventional and conservation tillage systems and controlled traffic farming system in clay loam soils of Sindh, Pakistan, is not available therefore, present study was undertaken.

MATERIALS AND METHOD

The field experiments were conducted to evaluate the performance of different tillage systems in a clay loam soil during autumn 2012 and spring 2013. The experimental field is located near the Faculty of Agricultural Engineering, Sindh Agriculture University, Tandojam. It is located at 25° 25' 50" N and 68° 31' 44" E at a distance of 218 km from Karachi.

The experiments were arranged in a randomized complete block design (RCBD) with four treatments each replicated thrice. The experimental site was divided into 12 plots (60m × 20m). Three of the 12 plots were treated with conventional tillage (i.e., moldboard + cultivator (two passes)) designated as CT, three plots with minimum tillage (i.e., disk harrow (three passes)) designated as MT, three plots with zero tillage (i.e., direct drilling by seeder) designated as ZT and three plots were treated with controlled traffic farming (i.e., cultivator (two passes) designated as CTF. In controlled traffic farming the tractor wheel base was kept 1.94 m and the implement width was kept 2.88 m. The traffic lanes were designed with normal wheelbase of tractor without further modifications.

Soil Aggregation

This was evaluated using soil aggregation index mean weight diameter (MWD), which was determined by passing soil samples through a set of 10 sieves having mesh sizes of 75 mm, 63 mm, 50 mm, 37.5 mm, 31.5 mm, 25 mm, 15.60 mm, 12.50 mm, 8 mm and 2.36 mm, and weighing the aggregates retained on each sieve using electrical balance (0.0001g). The following formula was used to calculate mean weight diameter (RNAM, 1995; Van Bavel, 1949).

$$\text{Mean soil clod diameter} = \frac{\Sigma W_i D}{\Sigma W}$$

where,

W_i = Weight of soil retain in each sieve
W = Total weight of soil
D = Clods diameter or sieve size

Soil Volume Disturbed

It was product of field capacity, working depth and 10000 and measured in m^3h^{-1}. It was assumed that the soil was disturbed by implements up to working depth and covers entire area of undisturbed soil.

$$V = 1000 \times C \times D$$

where,

V = Disturbed volume of soil ($m^3 h^{-1}$)
C = Field capacity ($ha\ h^{-1}$)
D = Depth of cut (m)

Operating Speed

Along the boundaries of the experimental plots, two ranging poles designated as A and B were fixed at a distance of 25m apart in the center of experimental plot during trial. Parallel to A and B ranging poles, two ranging poles C and D placed on other side at 25m and frame a rectangle ABCD. The speed of tractor was measured by recording the duration of tractor to cover the distance of 25m between the supposed lines of two opposite ranging poles AC and BD (Figure 1). In this way five observations were recorded to obtain average speed of operation.

Effective Ploughing Depth

The working depths of moldboard plough, disk harrow, cultivator, and seed drill each was measured with the steel scale. The working depth was randomly measured from the soil surface up to the bottom of the furrow in each test plot.

Effective Ploughing Width

The working width of moldboard plough, disk harrow, cultivator and seed drill each was measured by using measuring tape. The width was measured from furrow wall to furrow wall of the total area tilled in each plot.

Travel Reduction

This was determined by making a mark with a chalk on the drive wheel

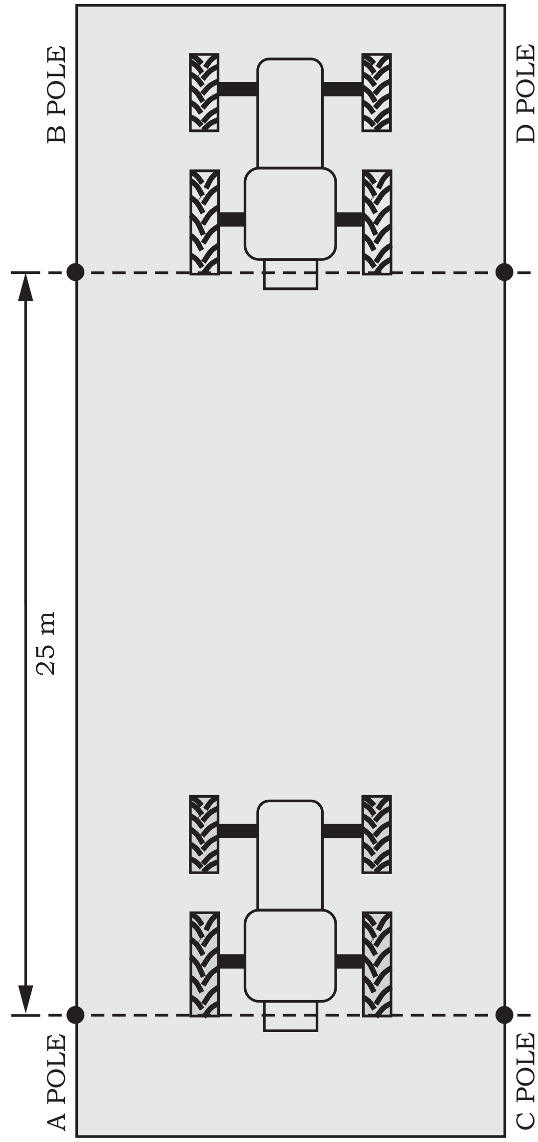

Figure 1. Measurement of operating speed

of the tractor and measuring the distance traveled by tractor in 10 revolutions with no load (R) and with load (r) (Figure 2). Five observations were taken at each test plot and the average travel reduction was calculated using following formula (RNAM, 1995).

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

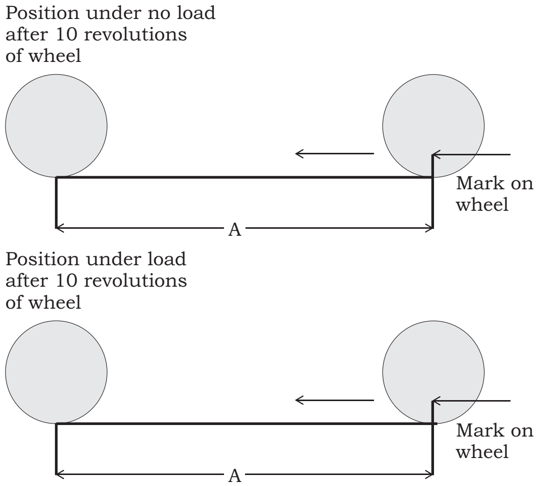

Figure 2. Measurement of travel reduction

where,

T_r = Wheel slip (%)
R = Distance traveled in ten revolution with no load (m)
r = Distance traveled in ten revolution with load (m)

Effective Field Capacity

It was measured as given by RNAM (1995).

$$C = \frac{A}{Tp + Tt}$$

where,

C = Effective field capacity(ha h^{-1})
A = Area tilled (ha)
Tp = Productive time (h)
Tt = Non-Productive time(h)

Fuel Consumption

Before testing moldboard, cultivator, disk harrow and seed drill the fuel tank of diesel tractor of 75 HP was fully filled. The fuel tank was refilled with 1000ml graduated cylinder after ploughing 60m x 20m plot. The total refilled quantity of diesel fuel was recorded in a particular time for calculation of fuel consumption per hour and per hectare.

RESULTS AND DISCUSSION

Soil Aggregation

The data on mean soil clod diameter by CT (mould board plough one pass + cultivator two passes), MT (disk harrow three passes) and CTF (cultivator two passes) showed that the disk harrow pulverized more soil; it was followed by cultivator, while the lowest pulverization was observed under mould board plough + cultivator (Table 1). Significant differences were found in soil pulverization between CT, MT and CTF treatments.

Soil Volume Disturbed Under Various Tillage Treatments

The results revealed that tillage treatments had significant effect on soil volume disturbed (Table 2). The soil volume disturbed under CT was 810 and 754 m^3 h^{-1}, under MT i.e., 624 and 552 m^3 h^{-1}, under ZT it was 234 and 234 m^3 h^{-1} and under CTF i.e. 612 and 636 m^3 h^{-1} during 2012 and 2013, respectively. The highest soil volume was disturbed under CT while the lowest soil volume was disturbed under ZT. The soil volume disturbed was higher in 2012 than in 2013 under all treatments except CTF.

Effective Ploughing Depth

The effective plowing depth of different implements used for three

Table 1. Soil aggregation produced by various tillage treatments

Tillage method	soil aggregation	
	2012	2013
CT	18.83^a	18.45^a
MT	12.08^b	12.26^b
CTF	13.51^c	13.08^c

Means followed by same letter do not differ significantly.

Table 2. Average operating speed measured under various tillage treatments during 2012 and 2013

Observations	Time taken (sec)	Speed (km h^{-1})	Time taken (sec)	Speed km h^{-1}
CT	20.0	4.49[d]	22.0	4.09[d]
MT	16.0	5.63[b]	18.0	5.00[b]
ZT	16.5	5.45[c]	17.5	5.27[c]
CTF	15.5	5.80[a]	15.0	6.00[a]

Means followed by same letter do not differ significantly.

tillage treatments varied significantly The average effective ploughing depth observed under MB plough, disk harrow, cultivator, and seed drill were 0.27, 0.13, 0.06 and 0.12 m, respectively during 2012. While during 2013, the effective ploughing depth observed were 0.26, 0.12, 0.6 and 0.12 m under CT, MT, ZT and CTF, respectively. It could be noted that the effective ploughing depths were almost similar for respective treatments. It should further be noted that CT had the highest ploughing depth while ZT had the lowest ploughing depth where usually seed drill is used.

Operating Speed

Data on average operating speed at a distance of 25m suggested that the speed was higher under CTF while it was lower under CT treatments (Table 2). These speeds under CT, MT, ZT and CTF treatments were 4.49, 5.63, 5.45 and 5.80 km h^{-1}, respectively during 2012. Almost similar trends were observed during 2013. The operation speeds during this year were 4.09, 5.00, 5.27 and 6.0 km h^{-1} under CT, MT, ZT and CTF treatments, respectively. It could be noted that CTF had the highest operation speed while CT had the lowest operational speed. Almost similar results were observed by Dickson et al. (1992), Lamers et al. (1986), Vermeulen and Klooster (1992) they reported that 13% increase in relative tractive efficiency under CTF as compared to conventional practices.

Travel Reduction (Wheel Slippage)

The data on travel reduction (wheel slippage) at 10 revolutions and 34.5 m travelled without load under different tillage implements i.e. MB plough, cultivator, seed drill and disk harrow showed the highest wheel slippage under MB plough where travel reduction was 29.42% as compared to 18.86% under disk harrow, 17.39% under seed drill and 15.21% under cultivator during 2012 (Table 3). Almost similar trends in travel reduction were observed, for respective treatments, during 2013. The reduc-

Table 3. Average travel reduction or wheel slippage in % measured with and without load for 2012 and 2013.

	2012		2013	
Operations	Distance traveled with load (m)	Wheel slippage (%)	Distance traveled with load (m)	Wheel slippage (%)
CT	24.35	29.42[a]	24.30	29.56[a]
MT	27.99	18.86[b]	28.00	18.84[b]
ZT	28.50	17.39[c]	28.50	17.39[c]
CTF	29.25	15.21[d]	29.40	14.78[d]

Table 4. Average effective field capacities under CT, MT, ZT and CTF treatments during 2012 and 2013

Treatments	Total time (min)	Effective field capacity (ha h^{-1})	Total time (min)	Effective field capacity (ha h^{-1})
CT	24	0.30^{c}	24.3	0.29^{d}
MT	15	0.48^{a}	15.5	0.46^{b}
ZT	18	0.39^{b}	18.5	0.39^{c}
CTF	14	0.51^{a}	13.5	0.53^{a}

tions recorded during this year were 29.56%, 18.84%, 17.39% and 14.78% under MB plough, disk harrow, seed drill and cultivator, respectively. Sommer et al. (1988) reported that increase in yield, reduction in erosion and improvement in trafficability under CTF.

Effective Field Capacity

The effective field capacity under various tillage treatments i.e. CT, MT, ZT and CTF was studied for two successive years (i.e. 2012 and 2013) suggested that CFT had the highest effective field capacity while CT had the lowest effective field capacity (Table 4). The lowest field capacity is attributed to mould board plough which requires additional force to operate which in turn affects the travel speed of the tractor hence less field is cultivated in same amount of time as compared to disk harrow and cultivator. Almost similar trends were observed during 2013. The effective field capacities during this year were: 0.29, 0.46, 0.39 and 0.53 ha h^{-1} under CT, MT, ZT and CTF. The differences between respective treatments were non-significant during both of the years, while the treatments significantly differed from each other. Osunbitana and Rahman (2004) and Sahu et al. (2006) indicated that tillage system affects working depth, soil volume disturbed, cumulative infiltration rate, soil aggregates, effective field efficiency, speed of operation, effective field capacity etc.

Fuel Consumption

The fuel consumption under different tillage treatments during two maize cropping seasons (autumn 2012 and spring 2013) were recorded under CT, MT, ZT and CTF treatments indicated significant effect (Table 5). It was observed that the maximum fuel was consumed under CT followed by MT and CTF. The minimum fuel consumption by 5.99 l ha^{-1} (3.15 l h^{-1}) under ZT during autumn 2012. Almost similar trends were observed during spring 2013. Results further revealed that as compared to conventional tillage, zero tillage consume minimum fuel. Results of fuel cons-

Table 5. Percent average travel reduction or wheel slippage measured with and without load for 2012 and 2013

Treatments	Time elapsed min	Fuel consumption (l)	l h^{-1}	l ha^{-1}
2012				
CT	24	2.75^{a}	6.87^{a}	22.90^{a}
MT	15	1.50^{b}	4.99^{b}	12.49^{b}
ZT	18	0.72^{d}	3.15^{d}	5.99^{d}
CT	14	1.12^{c}	4.39^{c}	9.32^{c}
2013				
CT	24.25	2.85^{a}	7.05^{a}	23.74^{a}
MT	15.30	1.75^{b}	5.68^{b}	14.57^{b}
ZT	18.48	0.75^{d}	3.21^{d}	6.22^{d}
CT	14.70	1.0^{c}	4.00^{c}	8.33^{c}

umption of implements showed significant differences. Fuel consumed on hourly basis increased with increase in the working depth during ploughing. Filipovic et al. (2004) and Moitzi (2005) also reported similar results.

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AUTHORSHIP AND CONTRIBUTION DECLARATION

S. No	Author Name	Contribution to the paper
1.	Mr. Ali Raza Shah	Conceived the idea, Wrote abstract, Methodology, Data collection, Introduction, Results and discussion
2.	Dr. Muhammad Saffar Mirjat	Statistical analysis, Technical input at every step, Overall management of the article
3.	Dr. Abdul Quadir Mughal	Methodology, Data collection, Technical input and overall management of the article
4.	Dr. Inayatullah Rajper	Statistical analysis, Checking the manuscript and Provide technical input at every step
5.	Mr. Asif Ali Mirani	Data analysis, References

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