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Effect of different tillage practices on soil physical properties under wheat in semi-arid environment

Muhammad Amin[1*], Muhammad Jamal Khan[2], Muhammad Tariq Jan[3], Masood ur Rehman[1], Javaid Akhtar Tariq[2], Muhammad Hanif[1] and Zahir Shah[4]
[1]Deparment of Agricultural Mechanization, The Univeristy of Agricutlure, Peshawar, Pakistan
[2]Department of Water Management, The Univeristy of Agricutlure, Peshawar, Pakistan
[3]Department of Agronomy, The Univeristy of Agricutlure, Peshawar, Pakistan
[4]Department of Soil and Environmental Sciences, The Univeristy of Agricutlure, Peshawar, Pakistan

Abstract

To study the effect of different tillage practices on physical properties of a silty clay loam soil under irrigated wheat in a semi-arid environment, a field experiment was conducted at the research farm of the University of Agriculture Peshawar, Pakistan during 2009-10 and 2010-2011, The tillage practices consisted of five treatments i.e. tine cultivator twice (TC-2), chisels plow (CR), moldboard plow (MR), disk plow (DR) and tine cultivator once (TCR), each followed by a rotavator except the first treatment. Soil moisture content, bulk density and soil penetration resistances were recorded. The results showed that tillage practices had significant ($p < 0.05$) effect on soil moisture content, soil penetration resistance and bulk density at both soil depths (0-20 cm, 20-40 cm). The highest soil moisture content and lowest bulk density or soil penetration resistance were recorded for soil tilled with chisel plow or moldboard plow at both soil depths. Soil physical conditions were generally improved with time as moisture conservation in soil increased while soil bulk density and soil penetration resistance decreased at both soil depths in second year as compared to first year of study. These results suggested that deep tillage practices (chisel plow, moldboard plow) performed better than shallow tillage practices (tine cultivator), and hence is recommended to improve soil moisture conservation and reduce both soil bulk density and penetration resistance under semi-arid environment.

***Keywords**: Tillage practices, soil moisture, bulk density, penetration resistance, wheat*

Introduction

Tillage operations are generally performed to break up and pulverize the soil and to facilitate the movement of air and water to promote plant growth. The success or failure of crop production systems amongst other factors largely depends on seedbed environment. A hard seedbed may result in the failure of seedling growth and severely affect crop productivity. Generally tillage improves the soil bulk density, water storage capacity and soil penetration resistance. A thorough understanding of tillage effect on soil physical properties is essential for successful crop production (Erbach, 1987). The soil physical properties are vital to plant growth. The influence of tillage implements on moisture content, penetration resistances and bulk density are important soil physical properties. Tillage techniques that conserve moisture are important for increasing crop yields. Soil penetration resistance is a measure of the soil strength and an indicator of how easily roots can penetrate into the soil and thus a measure of plant growth and crop yield. Soil strength is affected by soil type, clay content, water content, bulk density, soil depth and soil tillage system. Implement types had a consistent significant effect on the moisture content and inconsistent effect on the bulk density and porosity (Carman, 1997). Chisel plow resulted the highest soil moisture content as compared to ridger and disk plow (Makki and Mohamed, 2008). Field prepared by chisel plow once plus tine cultivator twice and moldboard once plus tine cultivator twice resulted in higher soil moisture content, lower bulk density and soil strength as compared to no tillage or shallow tillage treatment on sandy loam soil under wheat in rain-fed condition (Khan *et al.*, 2006).

The soil moisture content in case of chisel plow plus disk plow plus cultivator shows considerable improvement in soil moisture storage than a single use of cultivator in clayey soil. One of the other implements is the rotary tillers, which are increasingly used in various operations in agriculture; give high quality of soil cultivation, uniform mixing of soil with plant residues, organic and mineral fertilizers, (Manian *et al.*, 1999). The rotary tiller in combination with chisel plow and mouldboard plow reduced penetration resistance. The minimum decrease in

*Email: dr.amin_mechanization@yahoo.com

soil moisture was observed in chisel plow plus disk harrow. The least bulk density value was determined at mouldboard plow plus rotary cultivator and chisel plow plus rotary cultivator (Karayel and Ozmerzi, 2003). Keeping in view the importance of tillage practices, the present study was conducted to find the effect of different tillage practices on soil properties under wheat crop in semi-arid environment, in KPK Pakistan.

Materials and Methods

A field experiment was conducted at the Research Farm, University of Agriculture Peshawar, Khyber Pakhtunkhwa, Pakistan during 2009-10 and 2010-2011 to study the effect of different tillage practices on physical properties of silty clay loam soil under irrigated wheat crop. The tillage implements combination used in the experiment were, tine cultivator twice (TC-2), chisels plow (CR), moldboard plow (MR), disk plow (DR) and tine cultivator (TCR) each followed by a rotavator. Before the tillage operation each implement was checked, adjusted and then used in the same plot in each season. The experimental site is located at latitude of 34^{o} 01N', longitude of 71^{o}.3E with elevation of 350 meters above sea level. Before sowing, the crop composite soil samples at 0-20 and 20-40 cm were collected for site characterization (Table 1). The experimental site was hard warm to hot, semi-arid and subtropical climate with the total rainfall of 284 mm during the study period. Most of the rainfall at the site occurred during the months of January, February and April.The crop water requirement was fulfilled by irrigation when needed.

$$\text{Moisture content (\%)} = \frac{\text{(Wet soil weight)- (Oven dried soil weight)}}{\text{(Oven dried soil weight)}} \times 100$$

Soil bulk density

For the determination of soil bulk density, soil samples were collected in soil cores of known dimension and fresh weight of soil plus core was recorded immediately after sampling. The cores along with soil sample were dried in an oven at 105^{o}C for 24 hours. The bulk density was determined by the following formula (Tan, 1995).

$$\text{Bult density} = \frac{\text{Mass of oven dried soil (g)}}{\text{Total volume of soil (cm}^3\text{)}}$$

Soil penetration resistance

Soil penetration resistance is a measure of the soil strength and an indicator of how easily roots can penetrate into the soil. Soil strength (N cm^{-2}) was determined by using hand Penetrometer Eijkelkamp in each treatment before and after tillage during the growing season at 0-20 cm and 20-40 cm depth. Cone base area of 1 cm^2 was used for taking a penetrometer reading in each plot.

Statistical analysis

The data were statistically analyzed by using analysis of variance technique appropriate for randomized complete block design and means were compared using LSD test at 0.05 level of probability as described by Steel and Torrie (1980).

Table 1: Soil properties of the experimental site at 0-20 and 20-40 cm depth before the experiment

Soil property	Unit	Soil depth (cm)	
		0-20	20-40
Sand	%	18.7	21.8
Clay	%	30.7	32
Silt	%	50.6	46.2
Soil Texture		**Silt clay loam**	**Silt clay loam**
Soil moisture	%	13.08	13.85
Bulk density	g cm^{-3}	1.63	1.68
Penetration resistance	N cm^{-2}	435	480
pH (1:5)		7.96	8.03

Soil moisture content

The moisture content in soil was determined gravimetrically. For this, known amount of soil samples were taken in a beaker and dried in an oven at 105 ^{0}C for 24 hours. Any loss in sample weight after drying was considered as moisture content expressed as percent of dry soil weight. The soil moisture content was determined by the following formula (Ryan *et al.*,2001).

Results and Discussion

Soil moisture

Data pertaining to soil moisture content at 0-20 and 20-40 cm depth after the tillage operation and during the growing period of wheat are presented in the Table 2. The analysis of variance revealed that soil moisture contents

were significantly different among tillage practices at varying soil depths in both years. Maximum soil moisture contents were observed in soil tilled with chisel plow at each soil depths followed by that in soil tilled with moldboard plow during both years and it was at par with the chisel plow and disk plow treatments.

conservation in soil tilled with chisel plow and mouldboard plow whereas the rotary harrow further increased the soil moisture contents with all tillage implements. Similarly, Makki and Mohamed (2008) also observed the highest moisture conservation in soil tilled with chisel plow compared to other tillage implements, while Laddha *et al.*

Table 2: Percent soil moisture content at 0-20 and 20-40 cm depth during the study period in wheat plots as affected by tillage practices

Year	Tine cultivator twice	Chisel plow	Moldboard plow	Disk plow	Tine cultivator	Mean
			0-20 cm			
2009-10	12.7	14.7	14.5	14.0	12.8	13.7b
2010-11	13.4	15.1	14.7	14.5	13.7	14.3a
Mean	13.1c	14.9a	14.6ab	14.2b	13.2c	LSD 0.58
			20-40 cm			
2009-10	12.9	15.8	15.4	14.5	13.9	15.2b
2010-11	14.2	16.7	15.8	15.7	13.7	14.7a
Mean	13.6d	16.3a	15.6ab	15.1bc	13.8d	LSD 1.16

Means sharing similar letters do not differ significantly at $p = 0.05$

Table 3: Soil bulk density (g cm^{-3}) at 0-20 and 20-40 cm depth during the study period in wheat plots as affected by tillage practices

Year	Tine cultivator twice	Chisel plow	Moldboard plow	Disk plow	Tine cultivator	Mean
			0-20 cm depth			
2009-10	1.55	1.53	1.52	1.52	1.51	1.53
2010-11	1.49	1.48	1.46	1.48	1.48	1.48
Mean	1.52a	1.50ab	1.49b	1.50ab	1.50ab	LSD=0.02
			20-40 cm depth			
2009-10	1.58	1.56	1.54	1.57	1.55	1.56
2010-11	1.53	1.51	1.53	1.55	1.50	1.52
Mean	1.56a	1.54ab	1.54ab	1.56a	1.52b	LSD=0.03

Means sharing similar letters do not differ significantly at $p = 0.05$

However, differences in soil moisture contents between the chisel plow and disk plow were significant. The significantly lowest moisture contents were observed in plots tilled once or twice with tine cultivator at both depths during both years. Averaging across tillage treatments, the soil moisture contents were significantly higher during second year than first year. Similarly, the soil moisture contents were greater at (20-40 cm) than at surface soil (0-20 cm) during both years. The greater moister contents in the soil tilled with chisel plow or moldboard plow could be due to deep cutting of soil which allowed moisture to retain in soil for longer period and hence helped in water conservation in the soil. These results are in agreement with those reported by Shafiq *et al.* (1987), Boydas and Turgut (2007), Rashidi and Keshavarzpour (2008) and Jawadi *et al.* (2009). They stated that tillage implements had significant effect on soil moisture content with maximum moisture

(1997) reported that deep tillage operation (25-40 cm deep) were superior to shallow tillage as disk and chisel plowing significantly improved soil moisture content. Mari *et al.* (2011) reported that soil tilled with shallow tillage implement (such as cultivator) retained lowest moisture content in soil compared to deep tillage implements (such as chisel plow, moldboard plow).These results thus suggested that deep tillage implements (chisel plow amd mouldboard plow) are more helpful to conserve moisture in soil than shallow tillage (cultivator) practices particularly in a silty clay loam soil in the semi-arid environment.

Soil bulk density

The soil bulk density before tillage operation in the experimental plot at 0-20 and 20-40 cm depth were 1.63 g cm^{-3} and 1.68 g cm^{-3}, respectively (Table 1). Data relating to soil bulk density (g cm^{-3}) at 0-20 and 20-40 cm depth

after the tillage operation and during the growing period of wheat are presented in Table 3. The perusal of the table showed that soil bulk density was also influenced significantly with the tillage practices at both soil depths during both years. The lowest soil bulk density (1.49 g cm^3) was recorded in soil tilled with moldboard plow but it was at par with bulk density values for soils tilled with disk plow (1.50 g cm^3), chisel plow (1.50 g cm^3) or tine cultivator once (1.50 g cm^3). However, the significantly highest bulk density (1.52 g cm^3) was noted for soil tilled with tine cultivator twice. The same trend was observed at both soil depths with respect to the influence of tillage operations on soil bulk density. Averaging across tillage treatments, the soil bulk density at both soil depths were generally lower in year 2 than in year 1 but difference was non-significant. These results are in agreement with, Rashidi and Keshavarzpour (2008), Karayel and Ozmerzi (2003), who recorded the lowest bulk density values for soil tilled with moldboard plow + rotary tiller. Similarly, Alvarez and Steinbach (2009) stated that soil bulk density were higher under limited tillage systems than under moldboard plow tillage. Barezgar *et al.* (2003) also observed significant differences in soil bulk density among tillage practices. Laddha *et al.* (1997) reported that deep tillage operation (25-40 cm) were superior to shallow tillage as chisel plowing reduced the bulk density significantly.

These results suggested that deep tillage practices reduced the soil bulk density by making the soil more porous for better plant growth. Chisel plow or moldboard plow is therefore important for silty clay loam soil to maintain proper soil porosity in the field especially in the semi-arid environments.

of experimental plot at 0-20 and 20-40 cm depth were 435 N cm^2 and 480 N cm^2, respectively. Data pertaining to soil penetration resistance at 0-20 and 20-40 cm depth after tillage and during the growing period of wheat are presented in Table 4. The effect of tillage practices on soil penetration resistance was significantly different. The highest mean soil penetration resistance of 301 N cm^{-2} at 0-20 cm depth was observed for soil tilled with tine cultivator twice followed by 276 N cm^{-2} at 0-20 cm depth that was recorded for soil tilled with tine cultivator once at same depth. Soil penetration resistance of 239 N cm^{-2} at 0-20 cm depth was recorded for soil tilled with chisel plow. However, differences in soil penetration resistance at 0-20 cm between moldboard plow and disk plow tillage practices were non-significant, but were significantly higher than chisel plow. The average soil penetration resistance at 0-20 cm depth decreased significantly from 300 N cm^{-2} in first year to 231 N cm^{-2} in second year. The same pattern of effect of tillage practices and years on soil penetration resistance was at 20-40 cm depth. The highest soil penetration resistance of 323 N cm^{-2} was recorded at 20-40 cm depth for soil tilled with tine cultivator twice while the lowest soil penetration resistance of 255 N cm^{-2} was noted for soil tilled with chisel plow. Similarly, the average soil penetration resistance reduced significantly from 316 N cm^2 in first year to 252 N cm^2 in second year of study. These results are in agreement with those reported by Alvarez and Steinbach (2009), Rashidi and Keshavarzpour (2008) who stated that soil penetration resistance was higher under shallow tillage systems than under plow tillage. Boydas and Turgut (2007) reported that soil penetration resistance increased with tillage depth

Table 4: Soil penetration resistance (N cm^2) at 0-20 cm and 20-40 cm depth during the study period in wheat plots as affected by tillage practices

Year	Tine cultivator twice	Chisel plow	Moldboard plow	Disk plow	Tine cultivator	Mean
			0-20 cm depth			
2009-10	361	260	278	284	318	300 a
2010-11	242	218	230	230	234	231 b
Mean	301a	239d	254c	257c	276b	LSD=13.62
			20-40 cm depth			
2009-10	381	272	294	301	331	316 a
2010-11	264	238	252	248	256	252 b
Mean	323a	255d	273c	275c	293b	LSD=15.59

Soil penetration resistance

Soil penetration resistance is a measure of the soil strength and an indicator of how easily roots can penetrate into the soil and thus a measure of plant growth and crop yield. Soil penetration resistance before tillage operation under all tillage implements.

These results suggested that deep tillage practices were significantly superior with respect to reducing the soil penetration resistance compared to shallow tillage practices in silty clay loam soil.

Conclusion

This experiment has shown that deep tillage practices like plowing with chisel plow or moldboard plow performed better than shallow tillage practices with tine cultivator, as deep tillage improved soil moisture content, bulk density and penetration resistance in silty clay loam soil under irrigated wheat crop, and hence such deep tillage practices are recommended for silty clay loam soil in semi-arid environment for better crop production.

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