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Effect of deep tillage on soil properties and crop (wheat) yield

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Abstract

A field experiment was conducted to evaluate the effects of various tillage depths on soil properties and wheat yield. Different implement used were: rotavator, modified rotavator, spade cultivator, chisel plow and combination of chisel and rotavator. The results showed significant effect of these tillage implements on soil properties and yield of crop. All the tillage implements showed nearly same bulk density on top layer but large variation was noted at greater depth. Penetration resistance (PR) at top layer (0-10 cm) was minimum 0.31 M Pa with chisel plow + rotavator and maximum 2.46 M Pa at depth of 20-30 cm with rotavator. The spade cultivator produces nearly the same bulk density for the whole depth of 0-30 cm varying from 1.16 to 1.23 M Pa. The minimum bulk density of 1.23g cm^{-3} at a depth of 20-30 cm was noted with spade cultivator and a maximum of 1.99 g cm^{-3} with rotavator. The highest wheat grain yield of 4070 kg ha^{-1} was achieved with spade cultivator and minimum of 2654 kg ha^{-1} with rotavator. The results generally showed that tillage depth effectively altered soil moisture content, soil PR, soil bulk density and crop yield.

Key Words: Soil physical properties, modified rotavator, spade cultivator, chisel plow, crop yield

Introduction

Soil physical properties are affected by various tillage practices and soil compaction increases the shear strength of soil. Compaction of soil increases dry bulk density, reduces pore space volume and requires higher tillage energy and impedes root growth. A reduction in pore space hinders water and air movement in the soil, reduces the water holding capacity and restricts root penetration in the soil (Sabir *et al*., 1990, Osunbitan *et al*., 2005). Soil physical conditions detrimental to root proliferation in subsoil are generally related to tillage pans that develop below tilled layer (Akhtar *et al*., 2005). Tillage operation with the same implement over several years may lead to compacted layer in field soil. Plowing at the same depth year after year reinforce the plow pan development, so use of different tillage implement may be the only solution to breakup this pan.

Tillage implements are used to weaken the soil strength, reduce compaction and allow the free movement of air and water in order to promote plant growth. Tillage operation is carried with the objective of changing the soil physical properties and to enable the plant to show their full potential. Soil physical properties are affected by various tillage practices (Singh and Panesar, 1991, Busscher and Bauer, 2004). Excessive soil manipulation by tillage implements is however detrimental to soil structure with serious consequences on the emergence and yield of crop (Sheikh, 1976).

Considering the importance of tillage operation, conventional tillage practices (use of rotavator and cultivator with planker) and associated low yield of wheat a study was conducted to assess the performance of different tillage implements. The specific objective of research work was to study the effect of different tillage implements (Rotavator, Modified Rotavator, Chisel Plow, Spade Cultivator) on soil physical properties, mechanical properties, emergence of seed and crop yield.

Material and Methods

The research work was accomplished in the research area of Agricultural Mechanization Research Institute, Multan in 2007-08. In accordance with the objectives, the experiment comprised five treatments, including conventional Rotavator (T_1), Modified Rotavator (T_2) Spade Cultivator (T_3), Chisel Plow + Rotavator (T_4) and Chisel plow with Modified Rotavator (T_5). Wheat variety Bhakhar 2002 was sown on November 24, 2007, with a seed rate of 120 kg ha^1 and harvested on April 25, 2008. There were three replication for each treatment and layout of experiment was in randomized complete block design. Recommended fertilizers were used for all treatments. Data for soil moisture content, soil penetration resistance, soil bulk density and soil shear strength was recorded for 0-10, 10-20 and 20-30 cm depths. The emergence rate m^{-2} and yield of crop was determined to see the effect of different tillage treatments. The data were collected and analyzed using RCBD with three replications. The analysis of

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variance was carried out using PROG GLM (General Linear Model) procedure of the SAS Institute (2009).

Results and Discussion

The results of the experiment relating to the soil physical properties, emergence and crop yield are discussed in the following sections.

Soil moisture content

The cultivation of soil is a drying process; therefore effects of tillage always need to be evaluated in terms of soil moisture availability in soil. Soil moisture data collected from different depths, before and after tillage treatments are presented in Table 1. The soil moisture changed with depth even before tillage treatments. The maximum moisture of 16.32% was found at depth of 20-30 cm and minimum of 13.7% at top 10 cm layer. After tillage treatments, analysis of variance showed significant difference in moisture content in top 10 cm layer. Maximum soil moisture was in T_3 (Spade cultivator) while all other treatments havd nearly same soil moisture. The higher moisture in T_3 might be due to the partial inversion of the soil, as spade cultivator tends to replace the top layer with lower layer of soil having more moisture. For soil depth from 10-20cm the moisture with T_3 was significantly lower (13.29%) than other treatments, while highest moisture was observed inT_1 followed by T_2, T_5 and T_4. In case of T_4 and T_5 though the lower layer are tilled but are not exposed to the top surface. Significantly higher moisture content in T_1 and T_2 was observed for depth of 20-30 cm due to greater depth, beyond the operational depth of rotavator. Though T_1, T_2, T_3 and T_4 are not statistically different but relative lower moisture in T_4 andT_5 was due to operation of chisel plow that disturb the lower soil profile (Huda and Arora, 2006; Jabro *et al*., 2008).

Penetration resistance (PR)

The analysis of variance for penetration resistance (Table 2) showed that PR is significantly affected by tillage depths. The variation in PR with depth by different tillage implement is also reported by Busscher and Bauer (2003) and Jabro *et al*. (2008). The PR was significantly greater in the T_3 (0.45 M Pa) than all other treatments at the top 10 cm layer. The lower value of PR was observed in T_4 which was not significantly different from T_1, T_2 and T_5, the reason being the use of rotavator, as sampling depth was within the operational depth of the implement. The spade cultivator produced lumps of soil having larger size as compared to pulverized soil by rotavator that is why the T_3 offered greater value of PR. Analysis of variance for 10-20 cm depth showed highly significant effect of treatment on penetration resistance. The minimum PR (1.02 M Pa) was with T_3 followed by T_5. The PR value for T_4 and T_5 were significantly lower than T_1 and T_2. The higher value of PR in T_1 and T_2 are due to the operational depth of these implements. Highly significant effect of treatment on PR of

Table 1 Moisture content (%) in the soil before and after tillage operation

	Parameter	Moisture content % (Dry basis)		
	Soil depth	0-10 c m	10-20 cm	20-30 cm
Before tillage	-	13.7	15.47	16.32
After tillage	T1	11.51b	14.25 a	16.31a
	T2	12.12b	14.23 a	16.45a
	T3	14.51a	13.29 b	13.44b
	T4	12.43b	13.75 ab	15.74a
	T5	12.17b	14.01 a	15.68a

Different letters within the columns indicate significant difference at 0.05 probability level

Table 2: Effect of tillage treatments on soil penetration resistance (PR)

	Parameter	Penetration resistance M Pa (Mega Pascal) (PR)		
	Soil depth cm	0-10 cm	10-20 cm	20-30 cm
Before tillage	-	0.64	1.35	2.47
After tillage	T1	0.34b	1.45a	2.46a
	T2	0.32b	1.46a	2.35a
	T3	0.45a	1.02 c	1.66c
	T4	0.31b	1.33b	1.9b
	T5	0.33b	1.29b	1.87 bc

Different letters within the columns indicate significant difference at 0.05 probability level

soil was observed for 20-30 cm depth. Minimum value was observed in plot treated with T_3 and that was due to its deeper depth and partial inversion of the soil. The value of PR for treatment T_1 and T_2 was same but higher than all treatments. The similar results were reported by Osunbitan *et al*. (2005) and Jabro *et al*. (2008).

Soil Bulk density (BD)

The bulk density increases with depth and significantly varies with tillage treatment (Table 3). The analysis of variance reveled that bulk density of soil for top layer (0-10 cm) was not different for all tillage treatment while for depth of 10-20 and 20-30 cm was highly significant. For the depth 10-20 cm the lowest BD was observed with T_3 treatment followed by T_4 and T_5, but not significantly different. Higher value of BD in T_1 and T_2 seems to be associated with shallow operational depth of rotavator. For the depth of 20-30 cm the value of BD for T_1 and T_2 are same and significantly higher than other treatments. Minimum value of bulk density of 1.23 g cm^{-3} was observed in T_3 (Spade cultivator) followed by T_5 and T_4. Similar result has been reported by Lampurlance and Canter-martines (2003), Oquist *et al*. (2006) and Jabro *et al*. (2008).

Excessive pulverization may affect the soil structure and zero tillage may hinder root growth. Statistically analyzed data for germination (Table 4) indicate significant effect of treatments on seed germination. The maximum seed germination 152 m^{-2} was found with spade cultivator and minimum 136 plant m^{-2} with rotavator. Only a small difference was observed within treatment T_4 and T_5 and within T_1 and T_2. The better germination with spade cultivator may be associated with higher moisture present in the top layer.

Table 4: Effect of tillage treatments on seed germination and crop yield

Parameters	Seed emergence m^{-2}	Yield (kg ha^{-1})
T1	136 c	2654 d
T2	142 bc	2743 d
T3	152 a	4070 a
T4	149 ab	3628 b
T5	144 bc	3126 c

Different letters within the columns indicate significant difference at 0.05 probability level.

Analysis of variance for wheat grain yield (Table 4) showed that different tillage treatments had highly significant effect on crop yield. All the deep tillage treatments (T_3, T_4 and T_5) showed higher yield as compared to shallow tillage implements (T_1, T_2). Highest grain yield of 4070 kg $ha^{-1}$was obtained with use of spade cultivator (T_3) followed by T_4 (3628 kg) and T_5 (3426 kg) for deep tillage but significantly different from each other. The lowest grain yield of 2654 kg ha^{-1} was obtained with T_1 which was slightly lower than T_2 (2743 kg ha^{-1}). From the results of crop yield it is clear that, though the rotavator leaves the soil surface very fine but up to only few centimeters and compact the soil below its operational depth having adverse effects on crop yield. On the other hand, spade cultivator and chisel because of their deeper penetration produce good soil condition for plant growth and ultimately result in higher yield. Similarly, Busscher *et al*. (2000), Akhtar *et al*. (2005) and Hada and Arora (2006) reported higher yield with deep tillage.

Table 3: Effect of tillage treatments on soil bulk density (BD)

	Parameter	Soil Bulk density (g cm^{-3})		
	Soil depth (cm)	0-10 cm	10-20 cm	20-30 cm
Before tillage		1.49	1.84	1.98
After tillage	T1	1.12 a	1.78a	1.99a
	T2	1.11a	1.81a	1.89a
	T3	1.16a	1.14b	1.23c
	T4	1.12a	1.22b	1.63b
	T5	1.11a	1.25b	1.59b

Different letters within the columns indicate significant difference at 0.05 probability level.

Sieve Analysis of Ploughed Soil

Soil granular size is affected by tillage implements and defines the air and light penetration into the soil. Figure 1 show that the maximum weight of smallest size particle was in T_4 followed by T_5, T_2 and T_1 and minimum in T_3, indicating that use of rotavator produces very fine particle as compared to spade cultivator. Similarly, Figure 1 also indicates that the maximum larger granules > 4 mm were present in case of T_3 (2.66 kg) and minimum in case of rotavator.

Seed germination and crop yield

Manipulation of soil ultimately affects the germination of seed and favorable environment within soil profile can only be achieved through proper and suitable implement.

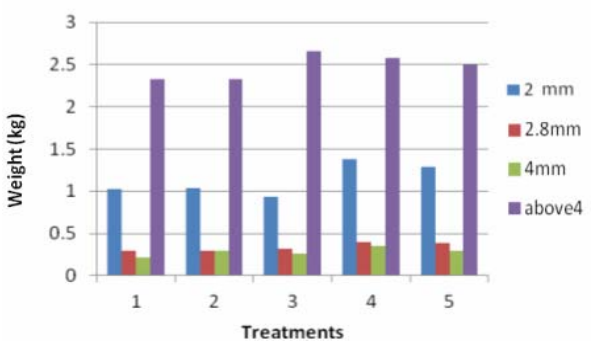

Figure 1: Soil particle size analysis for different treatment

Conclusions

The result of the experiment showed that tillage implement had significant effect on soil properties and ultimately on yield of crop. Rotavator though produced fine soil tilth at top layer but did not affect the soil at depth thus causing low yield. The high speed rotating action of blade may even compact the soil beneath its operational depth. Spade cultivator on the other hand produces good condition better for root growth and aeration of soil, thus increases yield. Chisel on the other hand may be good for breaking any hard layer developed by implement used for many years for the same depth.

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