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Soil physical properties and wheat performance under various preparatory tillage practices in a subtropical dry land of Pakistan

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Abstract

Conventional methods of seed bed preparation involve intensive tillage which not only deteriorate the soil physical health but also increase input cost for resource poor farmers of developing countries. A field experiment was conducted to evaluate different less intensive tillage systems on soil physical properties and wheat yield. The tillage treatments applied at the time of wheat planting were minimum tillage (MT), rotavator (RT), disc plough (DP) and cultivator (CT) arranged in RCBD layout. Soil bulk density was lowest under DP at 0-15 cm and under MT at 15-30 cm soil depth. Consequently the highest total soil porosity was observed under DP at 0-15 cm depth and under MT and DP at 15-30 cm depth. Soil water content measured twelve times during crop period did not show significant difference among tillage treatments. Mean values of soil water content were 8.20% at 0-15 cm depth and 9.29 at 15-30 cm depth. Wheat biomass yield was higher under DP and MT than RT and CT. Grain yield was highest under DP followed by MT that was signifcnalty higher than CT. Regression analysis showed that variation in biomass and grain yield of wheat was mainly explained by the differences in bulk density with r^2 values of 0.566 and 0.623, respectively. The study indicates that minimum tillage and disc plough can be used as an alternative to conventional intensive tillage systems for better soil physical health and wheat crop in subtropical dry land conditions.

Keywords: *Tillage, aggregate stability, bulk density, wheat*

Introduction

The Potohar plateau is an important part of subtropical dryland zone and it covers an area of 1.8 million hectare in Pakistan. The Potohar plateau is comprised of districts Jhelum, Chakwal, Rawalpindi, Islamabad and Attock (Nizami *et al.,* 2004). The parent material of potohar plateau soils is diverse in nature and parent material is loess, alluvium, colluviums and mixed by nature (Khan *et al.,* 2001). The soils of the rainfed areas are classified as silt loam, silt clay loam, and clay loam (Kazmi and Rasool 2009).

Among the crop production factors, tillage contributes up to 20% (Khurshid *et al.,* 2006). Tillage affects plant emergence, supply of nutrients to plant and the availability of water to plants by improving soil physical properties (Barzegar *et al.,* 2003), influencing the soil water content and hydraulic conductivity of soils and the hydrological behaviour of agricultural watersheds (Xu and Mermud, 2001).

In conventional tillage, plowing and several discing are used to prepare soils, harrowing and dragging is sometimes performed during or after plowing (Oisat, 2005). It leaves less than 15% crop residue over the surface, the soil is left susceptible to water runoff, wind and water erosion, soil compaction is increased greatly, root growth is suppressed, aeration is reduced and causes water logging in wet conditions, produces a finer and loose soil structure as compared to conservation and no-tillage methods which leaves the soil intact (Rashidi and Keshavarzpour, 2007). Conservation tillage is defined as any tillage or planting system in which at least 30% of the soil surface is covered by plant residue reducing water and wind erosion (Evans *et al.,* 2000; Carthy, 2001; Veenstra *et al.,* 2006). It breaks the plough pans (Mati, 2005), results in conservation of natural or other resource (Fowler and Rocksterm, 2001), conserves water, protects the topsoil, reduces soil compaction, provides protection from the impact of rain drop, so that it can improve the soil condition (Steiner, 2002; Oisat, 2005). Reduced tillage minimizes soil disturbance and allows crop residues to remain on the ground instead of being thrown away or incorporated into the soil. At the same time it achieves a viable seedbed for crop growth, residues are usually burnt and/or incorporated into the soil (Steiner, 2002. Also this is more effective in erosion control than conventional tillage, but not as well as no-tillage practices (Simon *et al.* 2002). Minimum-tillage is a technique in which the soil is not disturbed between harvesting one crop and planting the next (Oisat, 2005).

The routine tillage practice in Pakistan is intense tillage followed by heavy planking which creates hardpan below

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the plough pan causing a blockage in the infiltration of salts and pesticides, water logging conditions, disturbance of upper soil structure and entry of plant roots. This study was designed to investigate the effects of different tillage techniques on temporal soil water changes, bulk density and soil porosity and to observe the effects of these changes on wheat growth and grain production.

Materials and Methods

Description of study area

The research study was carried out at the University Research Farm, Chakwal Road, Pir Mehr Ali Shah Arid Agriculture University; Rawalpindi. The research farm is located between 33° 1´ N to 33° 6´ N and longitude 73° 30´ to 73° 45° E, southeast of Rawalpindi. The texture of soil is sandy clay loam. The climate is semi-arid to sub-humid, sub- tropical continental and rainfall incidence pattern is bimodal, with two maxima in late summer and winter-spring periods. Rainfall is erratic, about 60-70 percent of the total is generally received during monsoon rainy season i.e. mid June to mid September. Concentrated rainfall and undulating topography are the main causes of erosion. However, winter rains come as gentle showers of longer duration, and, thus, are more useful for crops and other vegetation (Shafiq *et al*., 2005). Meteorological data including mean monthly rainfall, temperature and evaporation were also recorded.

Soil properties

Temporal soil water content was determined fortnightly by gravimetric method. Fresh soil samples were taken from each replication and the weight of soil samples was recorded. The soil samples were taken from two depths within each replication by King Tube Auger. The soil sampling depths were 0-15 and 15-30 cm. The samples were then dried in the oven at 105±5 °C for 24 hours. Then soil samples were removed from the oven and the weights were recorded and soil water contents were determined by thermo-gravimetric method (Gardner *et al*., 1991).

The bulk density of soil was determined by core method (Grossman and Reinsch, 1996). Soil samples were taken once during crop growing period from the two depths of soil from each replication using core sampler (Campbell and Henshall, 1991). Total porosity was calculated from the already measured bulk density values and assumed particle density, *i.e.* 2.65 Mg m^{-3}. Physico chemical characteristics of the experimental site are given in Table 1.

Crop growth parameters

The crop was harvested from each plot and crop growth parameters such as plant height, spike length, grain yield and biomass yield were recorded. The data collected for various characteristics from each replication were subjected to Analysis of Variance (Gomez and Gomez, 1984) using single factor of tillage and the means obtained were compared by using LSD at 5% level of significance (Steel *et al*., 1997). For this purpose MSTATC and MS Excel softwares were used.

Table 1: Physico-chemical analyses of the soil of experimental site

Characteristic	Unit	Value
Sand	%	56.0
Silt	%	22.8
Clay	%	21.2
Texture	-	Sandy clay loam
ECe (1:1)	dS m^{-1}	0.53
pH(1:1)	-	7.87
Available P	(μg g^{-1})	3.0
Extractable K	(μg g^{-1})	140
Total Nitrogen (μg g^{-1})	(μg g^{-1})	4.93
Total Organic Carbon	(g $100g^{-1}$)	6.06

Results and Discussion

Temporal soil water content

Results regarding soil water content (Table 2) revealed that there is a significant difference among different tillage treatments. The difference in temporal soil water contents (Figure 3) during crop growth period is related to the meteorology of the region. In 0-15 cm of soil depth, highest soil water content was recorded under minimum tillage (8.54%) followed by cultivator (8.19%). In 15-30 cm of soil depth, rotavator (RT) performed better than all other tillage treatments.

The temporal changes in soil water content (Figure 1) show that all the treatments followed similar trend during the crop growth period at different days after sowing. The meteorological data (Figure 2) of rainfall, temperature and evaporation show that in October total rainfall was 20.2 mm and mean temperature was 22.9 ^{0}C. This precipitation facilitated the sowing of wheat crop. During the month of November, no rainfall was received, and the mean temperature recorded was 16.2 ^{0}C, a lower temperature than the month of October. Water evaporation from soil surface was lower in November as compared to October. In December, although the minimum temperature fell to below 0 ^{0}C in most of the days the average temperature remained upto 8.5 ^{0}C. There was rainfall in the last days of month and the dry spell prolonged from October to the end of December. That was a critical stage for soil water retention to provide sufficient moisture for young seedlings of wheat. Water evaporation from the soil surface decreased from

Table 2: Soil physical properties as affected by differet tillage treatments

Treatment	Bulk Density (Mg m^{-3})		Soil Porosity (%)		Soil Water Content (%)	
	0 – 15 cm	15 -30 cm	0 – 15 cm	15 – 30 cm	0 – 15 cm	15 – 30 cm
Minimum Tillage	1.59 a	1.46 c	39.40 b	45.07 a	8.54 a	9.02 b
Rotavator	1.59 a	1.53 b	39.85 b	42.29 b	7.97 b	9.56 a
Disc plough	1.45 b	1.49 bc	44.21 a	45.82 a	8.12 b	9.20 ab
Cultivator	1.57 a	1.61 a	40.98 b	39.17 c	8.19 ab	9.38 ab

Table 3: Crop growth parameters as affected by different tillage treatments

Treatment	Spike Length (cm)	Plant Height (cm)	Total Biomass (Mg ha^{-1})	Grain yield (Mg ha^{-1})
Minimum tillage	10.72 b	51.51 c	3.41 a	1.23 ab
Rotavator	11.22 b	62.46 ab	2.09 b	1.00 bc
Disc plough	12.43 a	66.75 a	3.44 a	1.56 a
Cultivator	11.22 b	58.37 bc	1.86 b	0.88 c

October to December but humidity in the air increased (68%). In the first month of 2011, the rainfall was only 8 mm and mean temperature was 0.45 °C. Minimum temperature remained very low particularly in the first twenty days. The lower temperature resulted in lower evaporation of water from soil surface as compared to October, November and December. Humidity in the air was a bit high (70%) as compared to December. There was also low soil water content (118 DAS) but low evaporation also caused the retention of moisture in the soil. A heavy rainfall (87.7 mm) was received in the month of February with more intensity in the middle of month. Average temperature recorded was 11.3 ^{0}C and the minimum temperature did not fell below zero. In the month of February, rainfall, temperature and humidity (Figure 2) were high due to which evaporation from soil surface remained low. In the month of March, total rainfall measured was 25.5 mm that was less as compared to February; the mean temperature increased to 18.8 ^{0}C. Humidity in air decreased (62.5%) and evaporation from soil surface increased. In the month of April, there was a high rainfall of 44.2 mm that was more frequent in the first fortnight. The average temperature was 20 ^{0}C, a little higher than the previous month. Evaporation of water from soil surface was higher as compared to that in the previous month due to low humidity (53.8%) in the air and high temperature.

The period when soil water content under different tillage systems did not differ significantly came on the 5th of March-2011 (100 DAS) when the soil was recharged with rain water during the months of February and March. These conditions probably increased relative humidity in the air causing more soil water conservation due to lower water evaporation and thus minimizing the differences in different tillage treatments. The lowest soil water content was found on 119 days after wheat sowing. There was only 4 mm rainfall on 14th of January after a long spell of dryness from December-2010 and evaporation remained high although temperature fell below 0 °C.

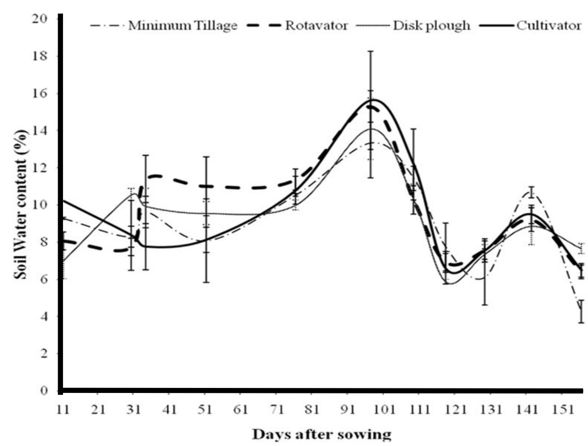

Figure 1: Temporal soil water contents under different preparatory tillage practices

The better performance of conventional tillage systems (MT and RT) over the other tillage systems in both the soil depths is in line with Khurshid *et al.* (2006) and Alam *et al.* (2002) who reported that the soils of the conventional tillage treatments had higher moisture content, lower bulk density and high porosity than the other treatments. These results are contradictory to Al-Iissa and Samarah (2007). In lower depth, the better results of soil water content under disc plough are mainly due to reduced compaction (Khurshid *et al.,* 2006).

Soil bulk density

The bulk density of soil was calculated in the month of March and significant difference was found in bulk density at 0-15cm and 15-30cm soil depth (Table 2). At 0-15 cm soil depth, soil bulk density was lowest under disc plough (DP) with the value of 1.45 Mg m^{-3}, but the bulk density values under RT (1.59 Mg m^{-3}), MT (1.59 Mg m^{-3}) and CT (1.57 Mg m^{-3}) did not vary significantly. At 15-30 cm of soil depth, the lowest bulk density was observed under MT (1.46 Mg m^{-3}) followed by DP (1.49 Mg m^{-3}), RT (1.53 Mg m^{-3}) and CT (1.61 Mg m^{-3}). Most of the researchers concluded that under limited tillage systems, the bulk density was high (Ozpinar and Anil*,* 2006; Rashidi and Keshavarzpour, 2007; Alvarez and Steinbach, 2009). However, in our studies lower bulk density was observed under limited tillage which may be due to increase in organic carbon (OC) concentration (Li *et al.,* 2007)**.**

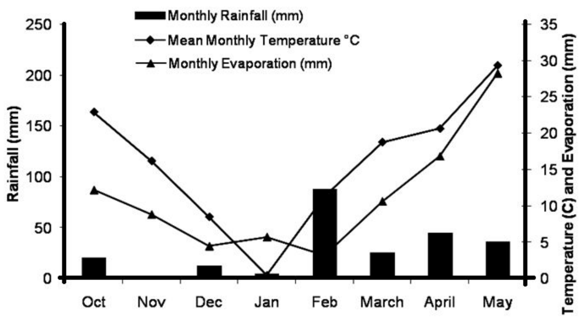

Figure 2: Meteorolgical data of the experimental site

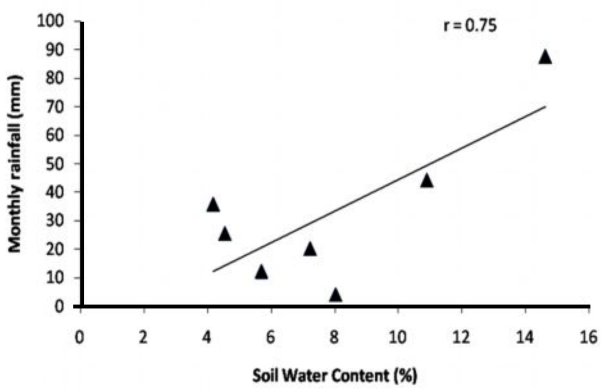

Figure 3: Correlation curve between monthly rainfall and mean soil water content

Soil porosity

Results regarding effect of different tillage systems on soil porosity (Table 2) showed that, at 0-15 cm soil depth, soil porosity was significantly lowest under MT (39.4%) and RT (39.85%). However the similarity in the results changed with an increase in the soil depth and soil prosity increased 4.98% with CT and 44.21% with DP. Similarly, Alam *et al.* (2002) reported that soil prosity increased with increasing tillage intensity. At 15-30 cm soil depth, the highest soil porosity was under DP (45.82%) and MT (45.07%). However, Lipiec *et al.* (2005) reported that different tillage systems decreased the soil prosity with increasing soil depth.

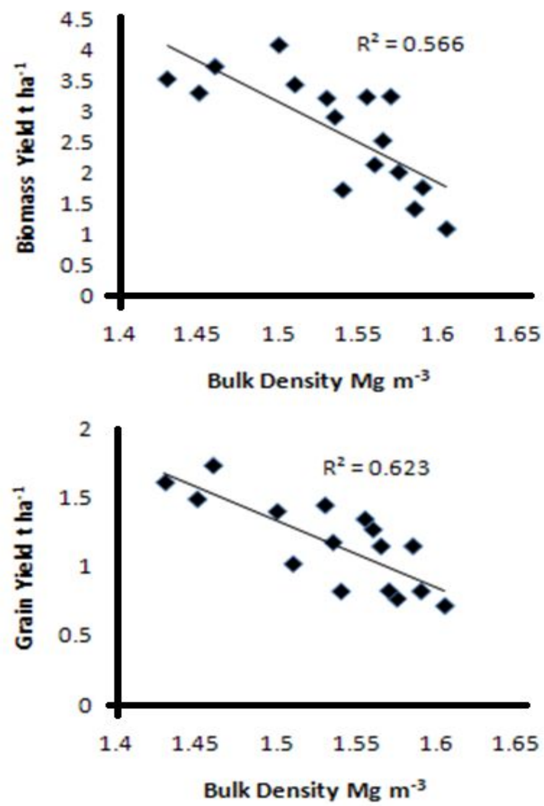

Figure 4: Correlation of bulk density with biomass yield and grain yield

Crop growth parameter

Plant height and spike length

Results regarding effect of tillage treatments on plant length and spike length (Table 3) revealed that highest plant length was observed under DP (66.75 cm), and lowest plant length was observed under MT (51.51cm). RT and CT gave intermediate plant length with the numeric values of 62.46 and 58.37 cm, respectively. Spike length (Table 3) was highest under DP (12.43 cm) as compared to RT (11.22 cm), CT (11.22 cm) and MT (10.72 cm).

Total biomass and grain yield

Data pertaining to wheat biomass grain yield (Table 3) indicated that DP (3.44 t ha^{-1}) and MT (3.41 t ha^{-1}) gave highest biomass as compared to RT (2.09 t ha^{-1}) and CT (1.86 t ha^{-1}). Wheat grain yield results showed that highest grain yield was observed under DP (1.56 t ha^{-1}) while the lowest grain yield was observed under CT (0.876 t ha^{-1}). MT and RT gave intermediate results with numeric values of 1.23 and 1.00 t ha^{-1}, respectively. Regression coefficient values obtained between yield parameters and bulk density (Figure 4) showed that both grain yield and biomass yield have significant negative correlations, 0.623 and 0.566, respectively with soil bulk density. Grain yield and biomass yield increased with decreasing bulk density, our results are inline with Atkinson *et al.* (2007) where they reported poor crop establishment with increased bulk density or vice versa.

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