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Effect of different tillage systems on soil physical properties and yield of wheat (Case study: Agricultural lands of Hakim Abad village, Chenaran township, Khorasan Razavi province)

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Abstract

This research delves into investigating the effects of different soil management practices on soil physical properties, yield and yield's components of irrigated wheat. This experimental design was administered in the form of the nested testing with three treatments (no tillage, low tillage and conventional tillage) and three replicates in some of the farmlands of Chenran Township. The results obtained showed that different soil management practices could cause significant changes in the soil bulk density, porosity and weighted moisture content. With the change of management type from no tillage to conventional tillage, soil bulk density declined from 1.41 to 1.29 gr.cm-3 while soil porosity rose from 47.58 to 52.45 %. Weighted moisture content in the conventional management system produced the maximum quantity (that is 15.35%) while for the no tillage system this declined to as low as (6.75%). Different systems of soil management significantly affect yield and yield components of wheat. In this case, the conventional tillage produced the maximum level of grain yield (6825 kg.ha-1) as opposed to the no tillage system (5220.83 kg.ha-1). The conventional tillage system produced the highest level of thousand-grain weight (43.38g) as well as harvested crop (25.57%). Although the conventional tillage compared with no tillage reached higher levels of crop and crop yield but it seems that the results of long runs are quite different with those of short term application. On this ground, performing studies of longer time intervals for various climatic conditions is recommended.

Keywords: soil management, soil physical properties, wheat yield, irrigated agriculture, semi-arid regions

Introduction

Soil is an essential component of crop production, but soil management operations are capable of increasing crop yield economically. Different methods of tillage can affect the physical and chemical properties of soil and hence can make differences in plant establishment, root growth, aerial cover and eventually crop yield (Cassel et al, 1982). Sustainable agricultural systems, are those that rely on low energy inputs and small amounts of chemicals to reach long-term stability and environmental compatibility. In order to achieve sustainable agriculture, the use of soil management practices (reduced

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tillage or no tillage systems) are designed as practical means. Conservation tillage is not only a concept, but a collection of a series of field operations as well specifically aimed at protecting soil and water resources, securing agricultural income, reducing soil degradation and environmental degradation and conserving underlying resources (Kouchaki et al, 1997).

One feature that is almost always affected by soil tillage is the bulk density (Cassel, 1982). Conventional tillage using a moldboard plow turns a hunk of deep soil to the surface, which leads to the creation of large pores in the plow layer and hence reduction of bulk density and escalation of soil porosity (MousaviBougar et al., 2012 ; Gholami et al., 2013 ; Boloor et al., 2013 a).

For example, the implementation of conventional tillage and no tillage for winter wheat and grain sorghum bed preparation in the arid parts of Great Plains of America showed that in response to changing the system from no tillage to conventional tillage soil bulk density decreased from 1.64 to 1.60 $gr.cm^{-3}$ (Unger and Jones, 1998). Tillage systems impact on soil porosity and the amount of previous crop residue on the soil surface play an important role in maintaining soil moisture and securing agricultural production in arid and semi-arid areas (Hammel, 1995; De Vita et al, 2007). Infiltration and water movement in the soil can be affected by porosity and bulk density of the soil (Unger, 1978). For example, Rasnak and colleagues (1986) stated that moldboard plowing and other tillage systems, most of which relocating soil particles, will increase water infiltration into the soil in the short term, but after a few intervals infiltration rate decreases substantially as a result of soil surface crusting.

Lal (1989) associated soil water holding capacity of no tillage system to the amount of soil organic matter. Organic material can absorb up to 90 percent of their weight in water (Smith and Elliot, 1990) and can increase soil moisture storage. Bour and Khorgami (2008), investigated the effect of different tillage methods on yield and yield components of safflower in rain fed areas of Khorramabad, Iran. The results showed that no tillage system yields the lowest level of soil moisture content (16.2%) while moldboard plowing (18.2 %) and chisel plowing (19%) produced the highest amounts of moisture content.

Yield associated with various methods of tillage has been studied by many researchers. In this respect Karlen, and Gooden (1987) reported that, chisel plowing compared to the moldboard plowing leads to significantly higher yield quantities. They attributed the latter to the collapse of hard layer with the to-and-fro of the machineries, which makes better soil ventilation. Fenster and Domingo (1969) also reported that, disking compared with moldboard plow could produce the highest grain yields. They reported that the narrow leaf weeds in fallow season are well controlled by moldboard plow, but disk plowing is not the efficient in doing the task.

A study aimed at identifying key effects of soil management practices on the soil physical and chemical attributes along with yield components of wheat led by Mohammadi et al. (2009) showed that the tillage systems exercised and wheat variety determined grain production, yield components and root growth.

In the case of chisel plowing, because of preservation of soil moisture and improvement of soil physical properties compared to other tillage methods, highest levels of grain yield was reported (that is 1841.9 kg per hectare). Utilizing chisel led to the highest amount of Thousand Grain Weight (as 43.71 gr) and number of grains per spike (as 25:25). Soil management and wheat variety significantly affected plant height and biomass.

When evapotranspiration is high, reduction of the amount of soil moisture of the surface layer as a consequence of the conventional tillage is high, however soil water holding capacity in the lower layers in the conventional tillage exceeds that of the disk tillage (low tillage). Plant residues remaining atop soil

surface in cold areas may affect soil temperature regime and reduce performance. The poor performance of the no tillage method might be attributed to the residues maintained on the soil surface and lower soil temperature. However, absence of smooth germination under soil tillage could be due to poor contact of seed with soil. Adequate seed contact to soil is a prerequisite for rapid germination and good establishment of the plant. Tillage is done specifically to ensure acceptable creation of seed contact with the soil (Allen, 1988; Hadas, 1975). Reduced root growth and crop yield by increasing the bulk density of the soil in the no tillage systems in soybeans is reported by Lindemann and Randall (1982), in cotton by Tackett and Pearson (1964), in wheat by Wittsell and Hobbs (1965).

According Ossible et al (1992), compaction of the lower soil layer in no soil tillage systems leads to less production of wheat grain and straw. They believe that the yield reduction pertains directly to soil mechanical resistance or by the availability of oxygen or moisture and nutrients.

Fragile and sensitive ecosystems in arid and semi-arid countries and repeated droughts in recent years dictates the importance of seed bed preparation with the aim of increasing agricultural productivity, improving soil moisture conditions and reducing wind and water erosion in fertile soils. Therefore this study is an attempt to evaluate the effects of different tillage systems on some soil physical properties, crop yield and components in agricultural land area of Chenaran Township, which has a semi-arid climate.

Materials and Methods

Hakim Abad Village is located in northern Khorasan Razavi province. Latitude and longitude of the study area expands from 22˚47’ 36’’ to 14˚54’ 58’’. Average annual rainfall measures 212.6 in mm, maximum annual summer temperatures in July reach as high as 28.3 ℃, minimum annual winter temperatures in January reaches as low as 2.2 ℃ and annual mean temperature equals 15.2 ℃ respectively. The climate is semi-arid based on De Martonne climate classification method. Crops grown in the area with the aid of irrigation. Conventional tillage is commonly practiced for seedbed preparation, but in recent years (as a period of three years from 2009 crop year to date), modern methods of tillage (conservation tillage) in the region has been implemented.

In this study, three treatments and three replicates of each, were selected and examined in a nested experimental design. The treatments included conventional tillage (T1), reduced tillage (T2) and no tillage (T3). According to management systems implemented, three units of arable land were selected.

In order to investigate the physical and chemical properties of various parts of the lands, nine random samples from each replicate were taken by the Auger of 0-25 cm depth and then transported to the laboratory for further analysis. Cylinder method was exercised to determine soil porosity in the samples (Blake and Hartch, 1986). Soil porosity in each sample was calculated by the following equation (Daniel chipped and Sooterland, 1986).

Soil Porosity = [1-(bulk density/particle density)]*100 eq.1

To obtain soil weighted moisture content, the amount of 10 g of soil was poured into metal cans and was placed in the oven for 24 hours at a temperature of 110 ° C. Once cooled, the moisture content was calculated based on the oven-dried soil.

To determine yield components at the beginning of each iteration, wheat was harvested from four plots of 1 × 1 m and weighed. After weighing the sample, trial combine was used to separate the grains.

To determine stem height, number of 15 samples were randomly picked from each plot and measured and the obtained value was assigned as the average height of each plot. To determine spike length, number of 15 samples were randomly picked from each plot and measured and the obtained value was assigned as the average spike length of each plot. To determine number of grains in each spike, number of 15 samples were randomly picked from each plot and measured and the obtained value was assigned as the average number of grains in each spike of each plot. In the middle of each plot 3 samples of $1m^2$ were Selected and its plants were harvested in order to obtain the yield. Harvested Plants were weighed and expressed as the biological performance. Plants in the plots of 1 × 1 m were threshed by the trial combine, and the threshed grains were weighed and by identifying the difference between biological performance (Straw + grains) and grain yield, produced straw was calculated for each hectare of the field.

To determine the amount of the thousand grain weight, one thousand grains were separated by means of a counting machine and weighed. Having biological performance and grain yield by equation (2), harvest index was calculated for each plot.

(Biological yield / yield) = HI × 100 eq (2)

Once plants are matured, being concurrent with yellowing leaves, spikes and stems as well as grain hardening time, they were harvested by hand with a scythe. Traits measured in this experiment are some morphological characteristics (number of tillers, plant height) and some agronomic traits (thousand grain weight, seed yield, biological performance and harvest index) of wheat plants .

Results and Discussion

The results of variance analysis showed that tillage systems have a significant effect on the amount of soil bulk density at the level of 5% but no observed significant difference between different replications in each treatment was indicated (Table 1). The mean comparison of this variable based on the Duncan's test showed that the highest and lowest amount of bulk density exist in the no tillage and conventional tillage systems respectively (Table 2). Using moldboard plow lead to high soil porosity and low soil bulk density due to high production of soil aggregate and upturning topsoil. This result testifies to the findings of Safadoust et al (2004). They showed that under tillage treatment with moldboard plow, soil bulk density significantly decreased in 0-30cm depth in comparison with no tillage system. They also stated one of the reasons for increasing soil bulk density in no tillage system as disturbing of soil surface by seeder during planting. In lower depth high compression and soil bulk density are created due to the traffic of machines. Based on analysis of variance of data in table 1, different tillage methods have a significant effect on soil porosity. As in Table 2 can be seen, the highest amount of pore (soil porosity) is created by implementation of conventional tillage system. Lower manipulating of soil in reduced and no tillage system is the reason of high soil bulk density and low soil porosity. Similar results are reported by Gholami Hosseinpour et al (2011) and Mohammadi et al (2009). They stated that the amount of soil porosity in moldboard plow + rotavator is higher than no tillage system due to using rotavator blades that convert soil to lower aggregates and decrease soil compression subsequently. Different tillage methods had significant effects on soil moisture content such that highest soil moisture content was related to conventional tillage treatments. Reduction of soil compaction and increase of spaces among aggregates in conventional tillage system lead to increasing soil moisture content. Due to high level of organic matter under no tillage treatment and regarding the effects of organic matters on increasing water-holding capacity, it is expected to achieve high humidity in this treatment but results showed that the effects of decreasing soil compaction on soil moisture is very high in short time. This result is consistence with the findings of Rahimzade and Navid (2011). The result of this study is inconsistent with Ussiri and Lal

(2009). They stated that soil moisture content under no tillage system is higher than conventional tillage system because of maintaining crop residue on the soil surface. This condition makes reduction of evaporation, surface runoff, improving soil porosity and ultimately increasing soil moisture content.

Table 1. Analysis of Variance of soil physical properties changing under different tillage systems

Source of variation	Df	Mean of squares		
		Soil bulk density	Soil porosity	Soil moisture content
Treatment	2	0.114*	163.47*	531.49*
Experimental error	6	0.003	5.19	0.007
Sampling error	72	0.007	10.69	0.68

*significance at the 5% level ns non significant

Table 2. Mean comparison of soil physical properties under tillage systems using Duncan's test at 5% level

Treatment	Bulk density	Soil porosity (%)	Soil moisture content
No tillage	1.41[c]	47.58[a]	6.75[c]
Low tillage	1.36[b]	50.58[b]	9.75[b]
Conventional tillage	1.29[a]	52.45[c]	15.35[a]

Averages of each column having at least one alphabet in common, based on the Duncan's multiple range test at the 5% level, were not statistically different.

Based on data analysis, it was found that different methods of tillage have significant effect on yield. The results of Barzegar et al (1994), Dickey (1983), MousaviBougar et al (2012), Sadeghnejad and Eslami (2006), khosravani et al (2008), Azimzade and Koucheki (2002) are similar to the results of this study and confirmed our results in the field of product yield.

Table 3. Variance analysis of biological yield changes (Kg/ha) in different tillage systems

Source of variation	Df	Mean of squares								
		Grain yield	Thousand grain weight	Spike per square meters	Grains per spike	Spikelet per spike	Biological performance	Grass height	Spike length	HI
Treatment	2	8806858.3*	132.27*	1056.07ns	290.7*	378.77*	65449814.6*	3308.3*	23.33*	16.69*
Experimental error	6	8505.56	0.94	20.30	0.075	7.89	112513.9	0.05	0.006	0.01
Sampling error	27	248226.85	0.45	121.84	5.40	5.27	4150228	8.34	0.49	0.019

In this study, the highest grain yield was obtained in the conventional tillage (6825 kg ha) and the lowest grain yield per square meter in no-tillage system (5220.83 kg per ha).

Sadeghnejad and Islami (2006) in their studies found that reducing tillage operations, especially the use of no tillage and direct seeding method with continuous irrigation during the growth of wheat, in addition to the compaction of soil clods could make a reduction in the yield. The no tillage and reduced tillage treatments in the first year gain in appropriate level of production whilst this trend decreases in the second and third years.

Dickey (1983) in his study concluded that the continuing operations of soil tillage on fine textured soils result in compaction with poor aeration which *per se* reduces yield. Periodic use of the moldboard will enhance performance.

Schllinger findings (2005) indicate that the use of no tillage compared with conventional tillage systems leads to a significant reduction in wheat, oats and barley yield. Reduced seedling establishment and growth, exposure to heat at the end of season, weed density and changes in the physical properties of the soil are among reasons for the reduced grain yield reported by various researchers (Hemmatt, 1996; Farooq et al, 2007; Hammel, 1995).

Moldboard plow loosen 0-25 cm of top soil layer, put the plant residues in the lower depths of soil profile, causes root development and improves available water which once augmented with irrigation and suitable rainfall distribution, this could improve yield (Sadeghnejad and Islami, 2006).

From the differences between conventional and conservation tillage, low initial yield in the beginning and it's escalation in a long run in conservational tillage could be noted (Tabatabaeifar et al. 2007).

In the present study, the highest and lowest number of grains per spike, respectively, were obtained under the no tillage (36.33 grains per spike) and the conventional tillage (45.66 grains per spike). Also, highest and lowest levels of spikelet per spike were observed in the no tillage system (34.26) and the conventional tillage (44.54), respectively. The highest and lowest levels of spike length were observed in conventional tillage (10.47 cm) and no tillage systems (7.94 cm) respectively.

The results showed that the highest number of spikes per square meter has been obtained in the conventional tillage system (928) and the least number of heads per square meter has been obtained in the no tillage system respectively (910.58). In the no tillage system, seeds are lost because of poor soil coverage and staying at the soil surface and this will result in lower plant density compared with other treatments.

In this study, the lowest level of biological performance was those of no tillage (22195.8 $kg.ha^{-1}$) and reduced tillage systems (23367.9 $kg.ha^{-1}$) while the highest amount was observed in the conventional tillage system (26697.5 $kg.ha^{-1}$).

The least harvest index level was produced in the no tillage system (23.51%) and reduced tillage (23.54 %) and the highest amount was observed in the conventional tillage (89.20%)

and the no tillage systems (56.25%) respectively. The highest and lowest levels of plant height was observed in the conventional tillage (89.20 cm) and no tillage systems (56.25 cm). Providing proper bed for seeding facilitates growth of wheat roots and stems and its establishment (MohammadZamani et al., 2007).

Table 4 – mean comparison of wheat yield and yield components under different tillage systems using Duncan's test (at 5% level)

Treatment	Grain Yield	Thousand Grain Weight	Spikes per square meters	Grains per spike	Spikelet per spike	Biological Performance	Grass Height	Spike length	HI
No tillage	5220.83c	36.77c	910.58 c	36.33c	34.26 b	22195.8c	56.25c	7.94b	23.51 b
Reduced tillage	5501.67 b	40.52 b	925.33 a	38.32 b	43.33a	23367.9 b	69.14 b	10.21 a	23.54 b
Conventional tillage	6825a	43.38a	928a	45.66a	44.54a	26697.5a	89.20a	10.47 a	25.57a

The results of three years of work by Khosravani et al (1998) in different regions of Iran have shown that moldboard plowing is superior to superficial tillage in various ways including grain yield, number of panicles per unit area, number of grains per panicle, thousand grain weight, straw weight and harvest index while these advantages were significantly discernable in some areas.

No tillage system through soil compression and raising weed density is associated with severely less performances. Limited covering the seeds with soil along with plant debris accumulation atop soil surface, less seedling production due to low seed germination and more growth of weedy plants may have caused this greater yield loss (Unger, 1978).

The results are inconsistent with the results of Boloor and colleagues (2013 b). The results of their studies reflect lower product yield in conventional tillage systems compared with other tillage systems. They described he temperature and humidity stress in late stages of development and also reduction of plant residues in the conventional tillage as the main determinant factors. A number of researchers, including Azimzadeh et al (2002), Halvorson et al (2000) have stated that using a moldboard plow (the conventional tillage)

increases soil moisture loss. Also Asghari (2006), Mohammadi et al (2009) studies on the various systems of soil management practices under different arid climates show that the highest amount of soil moisture has been observed in conventional tillage systems. So any tillage system capable of preserving soil moisture during critical growth stages such as grain filling stage, will ultimately lead to increased performance, because it reduces grain hollowness, and increases thousand grain weight.

In general, according to the results of this study this could be concluded that the reduction in yield and yield components of wheat under no tillage systems are due to the following reasons:

Soil bulk density in no tillage system was greater than those of other treatments which gives indication of the existence of hard layers due to constant shallow plow or absence of moldboard plowing at this soil depth under this treatment. Effect of soil compaction on root growth may directly be affected by the mechanical strength of soil or indirectly by soil oxygen and nutrient availability and soil water status. Less developed root under this tillage system makes the plant unable to absorbs water needed (Azimzadeh and Kouchaki, 2002). Willhelm et al (1989) attributed the yield loss under the no tillage system to less growth and water uptake limitation. Ossible and colleagues (1992) reported roots in the compacted soil layer to be thicker and shorter such that it reduced the grain and straw performance. Weeds competence with the crop for environmental resources, especially the narrow leaf weeds, is also one of the causes of yield loss in the no tillage system.

Although conventional tillage compared with no tillage practice led to higher performance, but it seems in this treatment long-lasting product performance with short-term results may vary. Therefore, the authors propose such studies for longer timescales and for different environmental and climatic conditions.

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