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Short-term effect of different tillage systems on soil salinity, density and nutrients in irrigated wheat

Case study: Agricultural land, city of Chenaran– Khorasan Razavi

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Abstract

This study was designed to investigate the effects of different tillage systems on some parameters such as soil salinity (pH, EC, SAR), soil density and nutrients in a nested experimental design with three treatments (no tillage, reduced tillage and conventional tillage) and three replications. Chenaran city fields were selected as the case study areas. Result of the statistical analysis indicates that no tillage system with 0.12, 12.04 and 360.29 $mg.kg^{-1}$ of nitrogen, phosphorus and potassium respectively, produced the highest levels. As in the case of the conventional tillage, the lowest amounts of soil nitrogen, phosphorus and potassium was reached as respectively 0.07, 8.55 and 261.48 $mg.kg^{-1}$. By changing tillage system from conventional tillage to no tillage, soil bulk density and porosity changed to a range of 1.41 to 1.29 $gr.cm^{-3}$and 47.58 to 52.45%. Likewise, the no tillage had the highest electrical conductivity (1.78 decisiemens) and sodium adsorption ratio (9.22) and the lowest amount of acidity (7.65). In the case of the conventional tillage system, the lowest electrical conductivity (1.19 decisiemens) and sodium adsorption ratio (7.52) and the highest acidity (7.77) was observed. Although soil salinity and density under the conventional tillage treatment compared to the no tillage method show lower values, but it seems that improvement of the physiochemical properties of soil in the long-term approach is different from the short-term. So these studies on longer timescales and for different climatic conditions are recommended

Keywords: Tillage, salinity, density, soil nutrients, wheat

Introduction

Increasing population and the development of agricultural land needs maximize land utilization and sustainable agricultural operations (Javanshir et al, 2003). Soil could be regarded as the most important factor in crop production and soil tillage operations play an effective role in increasing crop yield economically. Soil's capacity to perform a particular function, depends on the inherent characteristics which themselves depend on soil genesis and management-induced changes in dynamic properties.

Sustainable agricultural systems, are those trying to reach long-term stability and environmental compatibility by relying on small amounts of chemicals and low energy inputs. In order to achieve sustainable agriculture, soil management techniques like differenttillage systems (reduced tillage or no tillage) are designed as practical means (Koochaki et al, 1997).

The problem of soil salinity is problematic for agricultural activities which is sensed by mankind throughout history. Agricultural operations can directly cause soil salinity. In another view, soil degradation is in operation all the while and poorly managed agricultural activities could intensify it and

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cause soil degradation (Jafari, 2000). Increasing use of low quality waters and traditional farming methods lead to more acute problem like soil salinity and increased sodium level (Lakhdar et al, 2008).

Agricultural mechanization and intensive and continuous tillage operations over the decades lead to soil degradation, declining fertility and increasing soil salinity (Niu & Wang, 2002).

High concentrations of salts in the soil hamper agricultural crop production through impeding plant nutrient uptake, increased physiological stress and predisposing plants against diseases and pests (Li et al., 2006). Conservation tillageis an effective method to improve soil fertility and structure and leads to a reduction of sol evaporation and salinity (Li et al, 2010).Ma et al, (2010) argued in their study that preserving plant residues atop soil surface can limit soil evaporation and salinity at that layer. The conservational tillage results in increased organic matter and soil permeability, salt leaching from the surface to deeper layers and ultimately amendment of salty and sodic soils (Qingjie et al, 2014)

In terms of quantitative definition, soil Compaction is the way soil behaves under stress and pressures manifesting itself through the bulk density, total porosity, aerial porosity, permeability as well as mechanical resistance (Barzegar, 2001). Soil compaction reduces the size of pores and their interconnection and thus reduces the permeability and air and moisture diffusivity in the soil (Ball, 1981).

One feature that is almost always changes by soil tillage is the bulk density (Cassel, 1982). Most changes in the physical environment are adjusted by soil bulk density. Magnitude and direction of changes in bulk density depends on previous soil properties, type and intensity of tillage and time passed from the tillage operation. Conventional tillage using a moldboard plow, turn a hunk of deep soil to the surface and leads to the creation of large pores in the plow layer which can lead to loss of soil bulk density (Mousavibougar et a1, 2012).Tillage systems by impacting soil porosity and the amount of previous crop residues left on the soil surface, play an important role in maintaining the soil moisture and crop 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 soil porosity and bulk density (Unger, 1978). For example , Rasnak and colleagues (1986) stated that moldboard plowing and other tillage systems, most of which relocating soil particles, increase water infiltration into the soil in the short term, but after a few turns of rainfall soil surface crusting interrupts water infiltration into the soil.

Tillage has impacts on soil phosphorus accumulation and distribution (Hedley et al, 1982). Accumulation of organic matter at the intact soil surface layer alters the distribution of phosphorous (Unger, 1991). Implementation of theno-tillage system for 5 years, increased total soil phosphorus atthe depth of 10 cm by 15% compared to conventional tillage (Selles, 1977).

Soil available potassium,in a silty loam texture in Kentucky and under the no-tillage systems at the depth of 0-5 cm, was 29% higher than that of the conventional tillage. But at a depth of 5 to 30 cm of soil and without applying nitrogen fertilizer, its value was13 to 16% less (Frye et al, 1985).

The accumulation rate of soil organic matter largely depends on the amount and quality of organic matter added to the soil. Under tropical conditions, producing agricultural crops with high decomposing rate and little carbon to nitrogen ratio (such as green manure and cover crops of leguminous family) facilitate the conditions for rapid decomposition process and short-term accumulation of nitrogen with high exchange rate during the growing season

The addition of plant residues with high carbon to nitrogen rates containing substantial amounts of lignin (such as cereal straw and grass) accelerate the conversion of minerals to organic material and production of humus, which in turn enhance soil structure (Asgari, 2012).

The results provided by Allen and colleagues (2005) in examining the effects of tillage on soil aggregate, soil carbon and nitrogen sequestration under wheat crop rotations in south Texas showed that the no tillage system due to maintaining crop residue on the soil surface increases the amount of nitrogen rates. The latter happened in the rotations of sorghum-wheat-soybean, wheat-soybean and in the monoculture scheme to ranges of 77, 57 and 76% respectively.

Sensitive and fragile ecosystems in arid and semi-arid parts of the country and repeated drought in recent years, show the necessity of exploring different methods of seed bed preparation. The purpose of this is to increase agricultural productivity, improve soil conditions, reduce salinity, reduce wind and water erosion.

In this study the effect of tillage systems on soil nutrients, salinity and density will be examined in the agricultural fields of Chenaran Township, which has a semi-arid climate.

Material and Methods

Hakim Abad village in the northern part of Khorasan Razavi province with geographic latitude and longitude of 36^o 47’ 22’’ and 58^o 54’ 14’’ recieves an average annual rainfall of 612 mm. Maximum summer temperatures in July reaches to an annual rate of 28.3°C while the annual winter temperature in January lowers to 2.2°C.Annual mean temperature measures 15.2°C. The climate is semi-arid based De Martonne climate classification. In this area cultivation is possible with some turns of irrigation. The conventional tillage, is the common measure in practice for seedbed preparation. But in recent four years, modern methods of tillage (conservation tillage) has been implemented. In this study, three tillage treatments and three replicates of each were selected and examined in a nested design. Research Treatments included conventional tillage (T1), reduced tillage (T2) and no tillage (T3).

In order to investigate the physical and chemical properties of soil, from different parts of the land nine randomly selected samples of each replicate under each treatment were taken from the depth of 0-25 cm via Auger. The samples then were transferred to laboratory for further analysis. Soil bulk density of the obtained samples was determined according to the cylinder method (Blake and Hartch, 1986). Soil porosity in each sample was calculated by the following equation (Danielson and Sutherland, 1986).

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

Soil pH was determined by the potentiometric method using an electronic pH meter and electrical conductivity (EC) was measured in the soil extract using an electronic EC meter (Bremner and Mulvaney, 1982). SAR was also calculated from the following equation:

$SAR = Na^{+} / \sqrt{} Ca^{2+} + Mg^{2+}$

Photometry was used to measure Na. Calcium and magnesium were measured in soil saturation extract via titration method.

Total nitrogen was measured by Kjeldahl method, phosphorus by Olsen (1982) and potassium Rowel 's method (1994).

Results and Discussion

The purpose of this study was to investigate the effects of different tillage systems on soil salinity and nutrients.

Analysis of variance of sodium adsorption ratio (SAR) affected by tillage systems shows a significant effect of tillage on soil SAR at the 0.05 level. However, no significant difference was observed between replications in each treatment (Table 1). Results indicate a significant difference between the mean of three tillage systems such that the highest rate of sodium absorption ratio was observed in the no tillage system whilest the lowest corresponds to the implementation of the conventional method (Table 2). The results of this study has been inconsistent with the results of (Hulugalle et al 1997) and (Qingjie et al, 2014). They believe that reduced salinity and sodium adsorption ratio in the case of no tillage systems is due to the increase of soil organic matter, porosity, reduced soil compaction and subsequent escalation of infiltration capacity and soil hydraulic conductivity and more soil leaching.

In this study, less soil manipulation in the no and reduced tillage systems and reduction of soil porosity in the short-term implementation of conservational tillage led to an increase in soil compaction thereby increased soil salinity and SAR ratio.

Table 1 - Analysis of variance of soil sodium adsorption ratio under different tillage systems

Source of variation	DF	SS	MS	significance
treatment	2	39/05	19.52	2029.69*
treatment error	6	0.00035	0.00005	0.01 ns
Sampling error	72	0.69	0.009	
total	80	39.75		

*significance at the 5% level ns non significant

Table 2 - Comparison of different tillage systems effect on soil sodium adsorption ratiounder different tillage systems using Duncan's test (at the 5% level)

Treatment	SAR
No tillage	9.22a
Reduced tillage	8.27b
Conventional tillage	7.52c

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.

According to the results, significant difference was observed in the electrical conductivity between three tillage systems, but between the replications of each treatment no significant differences was observed. In comparison of the conductivity data, the highest electrical conductivity goes to the no tillage system while the lowest level was observed in the conventional tillage (Table 3 and 4). The results of the study has been inconsistent with Chatterjee and Lal (2009). They stated that lower electrical conductivity of soil under the no tillage system compared with the conventional tillage pertains to the enhanced water movement in the soil and improved soil aggregate development.

Table 3 - Analysis of variance of soil electrical conductivity under different tillage systems

Source of variation	DF	SS	MS	significance
Treatment	2	5.026	2.513	982.55*
treatment error	6	0.003	0.005	0.22 ns
Sampling error	72	0.184	0.002	
Total	80	5.213		

*significance at the 5% level ns non significant

Table 4 - Comparison of changes in the electrical conductivity under different soil tillage systems using the Duncan's test (at the 5% level)

Treatment	EC (decisiemens)
No tillage	1.78a
Reduced tillage	1.61b
Conventional tillage	1.19c

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.

Analysis of variance of pH changes under different soil management practices showed that the latter has had a great influence on pH at the 5% percent. However, no significant difference was observed between replicates of each treatment (Table 5). Results indicate a significant difference between the mean of three tillage systems such that the lowest pH level corresponds to the no tillage system while the highest belongs to the conventional tillage (Table 6). Lime accumulation at the surface, due to slow mixing under the no tillage system leads to higher pH in this layer (Blevins and Fery, 1993). Chatterjee and Lal (2009) stated that the lower soil pH under the no tillage system compared with the conventional tillage is owing the formation of organic acids and nitrification of NH_4^+ in the application of fertilizer and mineralization of plant residues.

Table 5 – ANOVA of pH changes in different tillage systems

Source of variation	DF	SS	MS	significance
treatment	2	0.173	0.086	65.97*
treatment error	6	0.006	0.001	0.82 ns
Sampling error	72	0.094	0.001	
total	80	0.274		

*significance at the 5% level ns non significant

Table 6- Comparison of changes in soil acidity and tillage systems using Duncan's test (at the level of 5%)

Treatment	Acidity
No tillage	7.65a
Reduced tillage	7.69b
Conventional tillage	7.77c

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.

Analysis of variance of bulk density under the effects of tillage systems (Table 7) indicate that tillage has no significant effect on the amount of Soil bulk density at the 5% level, but the replication of each treatment had no significant difference.

Table 7 - ANOVA of soil bulk density under different tillage systems

Source of variation	DF	SS	MS	significance
treatment	2	0.229	0.114	15.29^{*}
treatment error	6	0.021	0.003	0.49^{ns}
Sampling error	72	0.540	0.007	
total	80	0.792		

*significance at the 5% level ^{ns} non significant

As has been observed, highest bulk density was observed in the no tillage system while the least amount corresponded to the conventional tillage (Table 8). One of the reasons why soil bulk density increases in no-tillage system is the superficial scrapes being made leaving under surface layers untouched and compacted by the come and go of the machineries whose end result would be a substantial increment in this soil property. This corroborates findings of Azimzadeh *et al.* (2002).

Table 8 - Comparison of soil bulk density measures under tillage systems using Duncan's test (at the 5% level).

Treatment	Soil bulk density ($gr.cm^{-3}$)
No tillage	1.41c
Reduced tillage	1.36b
Conventional tillage	1.29a

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.

The effects of different soil management practices on soil porosity were significant at the confidence level of 5%. However, the inter-treatment differences were not significant (Table

9). The lowest level of soil porosity was that of the no-tillage system (47.58%) and highest level corresponds to that of the traditional tillage (52.45%). The findings of Mohammadi*et al*. (2009) further support the results (Table 10).

Table 9- Results of the analysis of variance for soil porosity under different soil management practices

Source of variation	DF	SS	MS	Sig.
Treatment	2	326.95	163.47	15.29 *
Treatment Error	6	31.18	5.19	0.49 ns
Sampling Error	72	769.89	10.69	
Total	80	1128.03		

* Significant at the 5%, ns: non-significant

Table 10- Comparison of soil porosity alterations between different soil management practices applying the Duncan's test (at the level of 5%)

Treatment	Soil porosity (%)
No-tillage	47.58 a
Minimum-tillage	50.58 b
Conventional tillage	52.45 c

Columns of at least one similar alphabet doesn't show significant difference based on the Duncan's multiple range tests (at the 5% significance level)

As shown in Table (11), the effect of three tillage systems on soil nitrogen levels is significantly different at the 5% level. But the between the replication of each treatment, soil nitrogen levels were not significantly different.

Mean comparison results show that the highest rate of nitrogen deposition corresponds to the no tillage system while the lowest amount goes to the conventional system (Table 12).

The results is consistent with the results of Chen et al (2009), Lopez Fando and Pardo (2009). Their results indicate that the conservation compared with conventional tillage, result in increased soil nitrogen.

They argued that the reason of increased accumulation of nitrogen under the conservational tillage, is maintaining crop residue on the soil surface, reduced soil disturbance, increased soil aggregation and the formation of aggregates and increase in the amount of nitrogen and carbon storage in large soil lumps. Lower ratio of carbon to nitrogen (C / N) in the conventional tillage treatment suggests that organic matter is exposed to humification which is favorable for mineralization, resulting in the abrupt loss of nitrogen from the soil.

Table 11 - Analysis of variance of N in different tillage systems

Source of variation	DF	SS	MS	significance
Treatment	2	0.027	0.013	132.25*
treatment error	6	0.004	0.00007	0.73 ns
Sampling error	72	0.007	0.0001	
Total	80	0.034		

*significance at the 5% level ns non significant

Table 12 - Comparison of the average N content in different tillage systems using Duncan's test (at the 5% level)

Treatment	Nitrogen (mg/Kg)
No tillage	0.12 a
Reduced tillage	0.10 b
Conventional tillage	0.07c

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.

Analysis of variance of phosphorus influenced by tillage systems (Table 13) show a significant effect of tillage on soil phosphorus level at the 5% level. Within each treatment, a significant difference was observed between different iterations. The greatest amount of phosphorus corresponded to the no tillage system and the least to the conventional tillage systems (Table 14). Research results is in agreement with selles and colleagues (1997). Accumulation of organic matter in the surface layers of undisturbed soil is effective on phosphorus distribution.

Table 13 - ANOVA of phosphorus changes in different tillage systems

Source of variation	DF	SS	MS	Significance
treatment	2	166.07	83.03	568.41*
treatment error	6	0.009	0.0015	0.01 ns
Sampling error	72	10.51	0.14	
Total	80	176.59		

*significance at the 5% level ns non significant

Table 14 - Comparison of means of phosphorus in different tillage systems using Duncan's test (at the 5% level)

Treatment	Phosphorous (mg/Kg)
No tillage	12.04a
Reduced tillage	10.64 b
Conventional tillage	8.55c

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.

As shown in the table (15) the effect of tillage on soil potassium levels is significantly at the 5% level, while no significant difference was observed between replication within each treatment. The greatest amount of potassium corresponded with the no tillage system and the least with the conventional tillage (Table 16). The results provide testimony to the results of Rhoton and colleagues (1993). Potassium content in soil samples in the undisturbed soil, was because of the lack of tillage and the accumulation of crop residue in the no tillage system, more than other treatments.

Table 15 - ANOVA potassium changes in different tillage systems

Source of variation	DF	SS	MS	significance
treatment	2	139072.39	69536.19	1075.25*
treatment error	6	4.22	0.7	0.01 ns
Sampling error	72	4656.22	64.66	
Total	80	143732.83		

*significance at the 5% level ns non significant

Table 16 - Comparison of Average K tillage systems using Duncan's test (5%)

Treatment	potassium (mg/Kg)
No tillage	360.29a
Reduced tillage	290.81 b
Conventional tillage	261.48c

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.

Conclusions:

In addition to climatic factors and soil characteristics, selection and deployment of tillage operations in an area is influenced by socio-economic condition of farmers and beneficiary. As the results of this study show, those tillage systems that incorporate the least level of soil disturbance and relocation (no and reduced tillage) will bring about the highest quantities of soil nutrients (N, P, K) and soil stability.

The lowest salinity levels (electrical conductivity, sodium adsorption ratio and pH) were also observed in soils that have been cultivated by the Conservation tillage systems. These positive benefits are of importance, particularly in agricultural crop production in arid and semi-arid areas. There fore it seems that making change in the current system of planting to new ones will improve biophysical conditions and crop production. Although soil salinity and soil density under the conventional tillage treatment compared to the no tillage method show lower values, but it seems that improvement of the physiochemical properties of soil in the long-term approach is different from the short-term. So these studies on longer timescales and for different climatic conditions are recommended.

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