Effect of conservative tillage on physical properties of soil in irrigated wheat production

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Abstract: In order to compare conservation tillage treatments on physical properties of soil, a randomized complete block design (RCBD) with three replications was conducted in the field of Agricultural Research, Education and Extension Center of Markazi Province of Iran, during the two cropping seasons (2012 and 2013). The treatments were: 1) Moldboard plow + disc (conventional method), 2) Chisel packer, 3) Combined Tillage Tools, and 4) Direct seeding. In both cropping seasons, the tillage operations were carried out based on the experimental treatments in a plot containing corn residues (var. SC-704). The physical properties of soil included soil bulk density, soil permeability (infiltration), mean weight diameter (MWD) of aggregates, and soil mechanical strength. Results showed that the tillage method had no significant effect (p>0.05) on wheat yield at the 5% level. The water infiltration rate for the conventional, chisel packer, combined plow, and direct seeding was 6.8, 8.9, 8.2, and 12.1 mm h^{-1} respectively. Tillage methods had no significant effects (p>0.05) on soil bulk density in depths from 0 to 10 cm. In depths from 10 to 20 cm, the lowest soil bulk density belonged to the conventional tillage.
Keywords: conservation tillage, wheat, physical properties of soil, infiltration, yields

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1 Introduction

Conventional tillage (CN) or Conventional tillage System (CS), No-Tillage (NT) and Minimum Tillage (MT) systems have effects on soil compaction (Troldborg et al., 2013; Kladivko, 2001; Hösl and Strauss, 2016). Soil tillage system and its intensity (CS and MT) are modified by direct and indirect action of soil temperature, moisture, bulk density, porosity, penetration resistance and soil structural condition (Moraru and Rusu, 2012). Measurements of resistance to penetration can provide a composite image of the effect of compaction and moisture status (Moraru and Rusu, 2010). Several authors have concluded that high penetration resistance in conservative systems reduces root growth (Ren et al., 2018; Moraru and Rusu, 2010). Low soil-surface temperatures due to accumulation of crop residues (Li et al., 2013; Alvarez and Steinbach, 2009) can adversely affect emergence and seedling growth under no-tillage in mid-latitudes (Munawar et al., 1990). Soil water content is also another factor that is affected by tillage because of changes produced in infiltration, surface runoff, and evaporation (Jemai et al., 2013; Aziz et al., 2013; Kahlon et al., 2013). The increase in soil water storage under conservation tillage can be attributed to reduced evaporation, greater infiltration, and soil protection from rain drop impact (Sarauskis et al., 2009). The soil conservation systems in different areas have to show specific features according to ecological properties and cultivated plant characteristics; thus, this system must be applied in different ways (Fabrizzi et al., 2005; Riley et al., 2005; Jitareanu et al., 2006). By increasing the plowing depth, the soil organic carbon and crop yields improve but there were no significant differences

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between the semi-deep and deep tillage systems (Alamouti and Navabzadeh, 2007). Tillage operations provide sufficient soil moisture and prepare appropriate environment for seed germination and longer root development by suppressing weeds and controlling soil erosion (Ehsanullah et al., 2013; Alamouti and Navabzadeh, 2007). Seedbed preparation is an important operation to achieve uniform crop emergence, plant growth and high yield under different soil and climatic conditions for any crop in drylands (Bayhan et al., 2005; Younesi and Navabzadeh, 2009). Conservation tillage (CT) has desirable effects on soil moisture content, field capacity, energy consumption, grain yield and production cost in rainfed wheat planting (Younesi and Mohammadi, 2015). Mixing plant residues with soil in wheat rotations after seven years can improve yield and also soil organic carbon stock (Moraru and Rusu, 2010; Alamouti and Navabzadeh, 2007). The results of a 10-year study by Chang and Lindwall (1990) revealed that, although saturated hydraulic conductivity and field capacity were higher at the depth range of 10 to 60 mm, no yield improvement was observed in any of the 10-year experiments. Soil penetration resistance as measured with a cone penetrometer is an important parameter in many soil management and geotechnical studies (Schneider et al., 2001; Whalley et al., 2008). One of the goals of tillage is to increasing soil porosity or reduces soil bulk density (BD). This effect of tillage on BD is temporary, and after tillage, the soil rapidly settles, recovering its former BD. In the first years of NT, BD of the soil may increase due to the repeated passes of the tractor and the lack of the loosening action of tillage. (Campbell and Henshall, 1991; Franzen et al., 1994; Franzluebbers et al., 1995). If the soil is plowed in very low soil moisture or high soil moisture content, it will produce large soil blocks in both cases (Shittu et al., 2017). Friable soil has higher pulverization than wet soil by percentage of 47.76% (Aday and Al-Edan, 2004). The moldboard plow had soil pulverization greater than chisel plow by 32.57% (Nassir, 2017). Low soil moisture content can make the cohesive force between soil particles to be very strong and a lot of energy is needed to overcome this during tillage (Kepner et al., 1982). In the silty clay loam and loam soil the best soil moisture content for tillage are 15%-18% and 13%-15%, respectively. However, with the higher soil moisture content, the effectiveness of tillage equipment in the field is reduced to prepare a good seedbed (Ahmadi and Mollazade, 2009). The aim of this study was to investigate different tillage systems on soil physical properties and wheat yield in order to achieve knowledge that reveals the importance of the conservation agriculture in some part of Iran.

2 Material and methods

A plot of land was selected in the Agricultural Research, Education and Extension Organization (AREEO) of Markazi Province (49°45'E, 33°51'N), in order to study the effects of the experimental treatments on the agronomic traits (crop characteristics), and some soil properties such as soil mechanical strength, mean weight diameter (MWD) of aggregates, soil permeability and soil bulk density, within two years of study. Fodder corn (var. Single Cross, SC-704) was planted in this field in early June. Following corn harvest (as fodder) at mid-September, the experimental treatments were carried out. In this study, 100% of plant residues were left on the ground (stalks were not collected after harvesting). The split-plot method in a randomized complete block design (RCBD) with three replications was used for comparison of the treatments. The study treatments were: 1) Moldboard plow + disc (conventional method), 2) Chisel packer, 3) Combined Tillage Tools, and 4) Direct seeding. The moldboard plow was used for primary tillage and 2 or 3 days after plowing, disk harrow was used as a secondary tillage operation before planting. The specifications of the tillage and seeding implements are given in Tables 1 and 2. Given the gravel, clay and silt percentages, the soil of the study field was classified as loamy-clay (FAO-UNESCO, 1989).

Table 1 Specifications of the study tillage implements

Implement type	Produced by	Working Width (cm)	Number of units
Chisel packer	Taka	200	5
Combined plow	Taka	200	5
Moldboard plow	Ahangari Khorasan	105	3

Table 2 Direct seed drill (Jiran Sanaat, Iran)

Implement width (cm)	Furrow opener type	Drill unit spacing (cm)	Number of drill units	Power source
250	Shovel	19	13	Using PTO

2.1 Soil mechanical strength

Using an Eijkelkamp penetrologger in AREEO, the mechanical resistance (MPa) of soil was measured at 10, 15, 20 and 25 cm depths at 30 points for each plot (ASAE, 2002).

2.2 Mean weight diameter (MWD) of aggregates

To determine the clod mean weight diameter, soil samples were randomly taken from the tilled plots, with three replications, using a special auger at the 0-30 cm depth soon after the tillage operation. The moist soil samples were allowed to air dry at room temperature for three months. The air dried soil sample was sieved using a set of sieves (mesh openings of 0.62, 1.2, 2.5, 3.7, 5, 6.2, 7.5, 88 and 10 cm) with a shaking time of 30 s (Eghball et al., 1993). The clod mean weight diameter was calculated by using the formula below (Smith et al., 1994):

$$MWD = \sum_{i=1}^{n} \frac{W_1}{W} \times D_i \quad (1)$$

where, W_i = Weight of soil crushed on sieve (kg); W = Total weight of crushed soil in each sample (kg); MWD = Mean Weight Diameter of aggregates (cm); D_i = Mean diameter of the sieve (cm).

2.3 Soil permeability

The double ring method was used to measure this parameter. The cumulative infiltration was determined using the following equation. Finally, the arithmetic means of water infiltration into soil was measured in cm h^{-1} (ASTM, 2009).

$$I = aT^n \quad (2)$$

where, I = Cumulative infiltration (cm); T = Time of cumulative infiltration (min); n = Infiltration slope.

2.4 Soil bulk density

To measure this parameter, samples were taken at multiple points in each plot (at least 3 samples) using a sampling cylinder (diameter = 76 mm, height = 42 mm). The samples were then dried in an oven to be prepared for bulk density measurement using Eq. (3) (Gardner, 1986).

$$B.D = \frac{M_2 - M_1}{V} \quad (3)$$

where, M_1 = Mass of empty cylinder (g); M_2 = Mass of full cylinder with dry soil (g); V = Volume of empty cylinder (cm^3).

In mid-July, by removing the edges or borders of from each experiment plot, a 6 m^2 frame was picked up by the worker and was threshed by a Wintersteiger combine. The weight of 1000 grains was then measured.

3 Results and discussion

3.1 Soil water infiltration

Table 3 shows the ANOVA results for the effect of tillage method on the infiltration rate. According to the table, the effect of tillage on infiltration rate was significant at the 5% level. Table 4 compares these parameters. According to the table, the water infiltration rate in soil was higher in the direct seeding treatment than other treatments. The infiltration rate in this treatment was in the same statistical level as direct seeding. The lowest infiltration rate belonged to the conventional tillage method. An important reason for the low infiltration rate in soils prepared by conventional tillage was the destruction of both capillary tubes and macroporosity of the soil as a result of using moldboard plows. A higher infiltration rate can lead to higher water holding capacity.

Table 3 ANOVA results for the effect of tillage method on soil water infiltration rates

Sources of variations	Degree of freedom	Mean squares of infiltration rate (cm h^{-1})
Replication	2	0.321
Tillage method	3	15.20*
Experimental error	6	3.3
Coefficient of variations (%)	22.5	

Note: *: Significant difference at the 5% level.

Table 4 Infiltration results of different tillage methods

Tillage method	Chisel plow	Combined moldboard plow	Direct seeding	Conventional method
Infiltration rate (mm h^{-1})	9.8 ab	8.2 b	12.1 a	6.8 b

3.2 Soil mechanical strength

Table 5 shows values for mechanical strength of soil at the 4 depths. According to the table, soil mechanical strength in the conventional method (moldboard plow) was lower than other treatments. Because moldboard plow loosens the soil profile up to a depth range of 25 to 30 cm (tillage depths for all treatments) while fully turning over the soil. The observed difference was negligible between chisel and combined plows. Regarding direct seeding, soil penetration resistance in the seed placement depth (about 5 to 8 cm below seedbed) was almost like other methods. Soil penetration resistance for depths larger than the seed placement depth (more than 10 cm), was equal to that of unplowed soil (untreated soil).Soil mechanical strength increased with increasing the soil depth so that the penetrologger didn't penetrate on the soil at depths greater than 20 cm. Large amounts of soil mechanical strength in the no-till method, may be due to the passing of the truck and the chopper for harvesting the previous product (wheat is planted in place of the forage maize). This result is similar with the other researchers that reported higher penetration resistance in no till systems (Ren et al., 2018, Moraru and Rusu, 2010).

Table 5 Soil penetration resistance (MPa)

Depth (cm)	Chisel packer	Combined moldboard plow	Moldboard tillage	No-till
10	0.69	0.86	0.15	4.16
15	0.98	1.27	0.19	3.9
20	1.8	5.4	1.8	24
25	1.6	3.5	1	-

3.3 Mean weight diameter

Table 6 shows WMDs of aggregates in detail. As shown, the WMD of aggregates was lower in the combined plow treatments than that in chisel plow and conventional methods. Combined plow has spring tooth cultivator (S shaped shank or stems) and discs. So the further crush and more pulverization of the soil aggregates (less than 7.5 cm) may be due to disks as well as the vibration of the plow stems.

In conventional method for preparing the fields, moldboard plow is used as a primary tillage and two or three days after plowing, three to four times, disk harrow is used as a secondary tillage operation for pulverizing the soil before planting. So the mean WMD of aggregates in conventional method is lower than the other methods (Table 6). Soil was cut better when using the combined moldboard plow, thus the aggregate diameter was lower. Another reason can be the higher weight of the combined moldboard plow. However, soil moisture content is an important parameter in soil preparation. If soil moisture is very low, soil blocks have a larger diameter. This is similar to the results of other researchers, who reported: when the soil is plowed in very low or high soil moisture content, it will produce large soil blocks in both cases (Shittu et al., 2017), Friable soil has higher pulverization than wet soil (Aday and Al-Edan, 2004), the moldboard plow had soil pulverization greater than chisel plow (Nassir, 2017) and Low soil moisture content can make the cohesive force between particles of soil to be very strong and a lot of energy is needed to overcome this during tillage. However, with the higher soil moisture content, the effectiveness of tillage equipment in the field is reduced (Ahmadi and Mollazade, 2009). This is an important issue that should be observed in tillage practices regardless of their type. The smaller the WMD of aggregates, lead to the easier germination of the grains and seeds (Guerif et al., 2001; Hakansson and Lipiec, 2002).

Table 6 MWD of aggregates (cm)

Sieve mesh size (cm)	Weight of aggregates (kg)		
	Chisel packer	Combined moldboard plow	Conventional
0.62	0.10	0.01	0.08
1.25	0.20	0.15	0.17
2.50	0.14	0.12	0.15
3.70	0.40	0.13	0.13
5.00	0.09	0.13	0.23
6.25	0.16	-	0.40
7.50	0.80	5.05	-
8.70	0.91	-	-
10.00	-	-	0.64
Mean weight diameter of aggregates (cm)	3.80	0.70	1.8

3.4 The effect of tillage treatments on soil bulk density

According to the ANOVA table (Table 7), the effect of tillage on soil bulk density was not significant (p>0.05) between the depths of 0 to 10 cm. However, the effect of tillage method on this parameter was significant (p<0.05) at the depth range of 10 to 20 cm.

Table 7 ANOVA results for the effect of tillage methods on soil bulk density

Source of variations	Degree of Freedom	Mean squares of soil bulk density (g cm^{-3})	
		Depths of 0 to 10 cm	Depths of 10 to 20 cm)
Replication	2	0.117^{ns}	0.002^{ns}
Tillage method	3	0.019^{ns}	0.041*
Experimental error	6	0.038	0.007

Note: Coefficient of variations (%).

3.5 Soil bulk density

Soil bulk density values were almost the same for all tillage methods for 0-10 cm of soil depth (Table 8). It may be due to the surface compaction of soil and disappearance and fade of the effects of tillage on the surface soil at the time of measurement (two weeks after the tillage operation). In a depth of 10 to 20 cm, the lowest specific weight belonged to the conventional tillage treatment. This is due to the high soil agitation caused by the moldboard plow and the disc, which in turn reduced the soil bulk density. Also in conventional method the soil plowing depth was more than the other methods. Effect of tillage on BD is temporary, and after tillage, the soil rapidly settles, recovering its former BD. (Campbell and Henshall, 1991; Franzen et al., 1994; Franzluebbers et al., 1995).

Table 8 Mean comparison results for the effect of tillage methods on soil bulk density

Soil depth (cm)	Tillage methods			
	Conventional method	Combined plow	Chisel packer plow	Direct seeding
0-10	1.18 [a]	1.11 [a]	1.09 [a]	1.11 [a]
10-20	1.08 [b]	1.24 [ab]	1.35 [a]	1.29 [a]

3.6 Yield and its components

Table 9 compares the mean values of the effects of tillage methods on the grain yield and the weight of 1000 grains at the 5% level. According to the table, there is no significant effect (p>0.05) between these two parameters.

Table 9 Mean comparison results for the effect seeding method on yield and 1000-grain weight

Seeding method	Conventional method	Combined plow	Chisel packer plow	Direct seeding
Grain yield (kg ha^{-1})	2860 [a]	3000 [a]	2951 a	3057 [a]
Weight of 1000 grains (g)	33.9 [a]	34.6 [a]	34.7 [a]	34.4 [a]

4 Conclusions

Results of this study showed that:

- The tillage method had no significant effect (p > 0.05) on wheat yield.
- Tillage methods had no significant effects (p > 0.05) on soil bulk density and depths from 0 to 10 cm.
- In depths from 10 to 20 cm, the lowest soil bulk density (specific weight) belonged to the conventional tillage.
- The soil water infiltration rates for the conventional, chisel packer, combined plow, and direct seeding was 6.8, 8.9, 8.2, and 12.1 mm h^{-1} respectively.

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