Effect of conservative tillage on physical properties of soil and yield of rainfed wheat

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Abstract: In order to study the effect of conservative tillage on a number of physical properties of soil and the yield of rainfed wheat, an experiment in form of a randomized complete block design (RCBD) with three replications was conducted in a field in Aliabad County, Iran. The study treatments included: T_1) Conventional method, T_2) Combined moldboard plow method, T_3) Chisel-packer method, and T_4) Direct planting method. During early October, the study soil was prepared based on these treatments in a field which was used for rainfed wheat farming in the the previous year. The apparent specific gravity of soil, weighted mean diameter (WMD) of soil aggregates, soil mechanical resistance, and soil permeability were measured. Data were analyzed in statistical software MSTAT-C. Results showed that the tillage practice had no significant effect on grain yield ($p < 0.05$). Soil permeability was 10.9, 16.3, 15.7 and 17.9 mm h^{-1} for T_1, T_2, T_3 and T_4, respectively. Effect of tillage on bulk density was significant at 1% level. The highest and lowest soil bulk density values belonged to the conventional and direct seeding. The highest and lowest infiltration rates were for the direct seeding and conventional treatments, respectively. In rainfed farming, the tillage method and direct seeding had no significant effect on the grain yield. The water infiltration in soil for direct seeding and conservative tillage was 1.8 and 1.5 times higher than that in the conventional method. In rainfed farming, the direct seeding is recommended due to the lower weed population.

Keywords: rainfed agriculture, conservative tillage, energy consumption, wheat

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1 Introduction

The reasons to use low-till practices in rainfed agriculture include minimized tillage costs considering the lower yield than irrigated agriculture, increased water pemeability in soil, reduced evaporation from soil surface, and increased soil organic materials (Stockfisch et al., 1999; Gajri et al., 2002). Several authors have concluded that high penetration resistance in conservative systems reduced root growth (Ren et al., 2018, Moraru and Rusu, 2010). Soil water content is also another factor which 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 rainfall impact (Šarauskis et al., 2009). Soil

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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). 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 47.76% (Aday and Al Edan, 2004). The moldboard plow has soil pulverization greater than chisel plow by 32.57% (Nassir, 2017). Low soil moisture content can make the cohesive force between particles of soil to be very strong and a lot of energy is 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). 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; Alamouti and Navabzadeh, 2007). In conventional tillage practices, plant residues are buried in soil, which contributes to faster decomposition of carbon compounds and organic nitrogen. Intensive farming can degrade soil aggregates, which in turn extensively decreases soil organics due to erosion. The tillage practice can affect soil aggregate stability (Lampurlanés et al., 2001). 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). Conservation tillage can increase the weed density (Alamouti et al., 2015). In general, the weight diameter of aggregates prepared using the conservative tillage system is larger than that of aggregates from the traditional system (Martínez et al., 2008; Fuentes et al., 2009). At a depth of 0 to 15 cm from soil surface, soil structure, soil water holding capacity, and root development are improved under no-till conditions (Acharya and Sharma, 1994; Acar et al., 2017). However, the compaction challenge in relatively heavy soils cannot be overlooked in the conservative tillage system (Alvarez and Steinbach, 2009). In these soils, tractor passes at high soil moisture contents can compress the upper soil layer. The Bulk density of soil is higher due to less soil displacement. Abu-Hamdeh (2004) studied the effects of three field preparation methods (i.e. moldboard plow, chisel plow, and disc plow) on soil permeability and bulk density in irrigated farming. Results showed that the tillage method had a significant effect on these two characteristics. According to the findings, permeability was highest in field preparation by the chisel plow. Soil bulk density in the chisel plow treatment was lower than that in the other two treatments. De Vita et al. (2007) examined the effects of the no-till and conventional methods on the wheat yield in Vasto, Italy (rainfed conditions in Europe is largely different from Iranian conditions in terms of rainfall). Results showed that their dry grain yields were nearly the same. The objective of this study was to evaluate the effects of conventional and conservation treatments on yield and some soil physical properties in rainfed wheat production.

2 Materials and methods

A land plot located in Jalalabad Village, Farahan Region (79.27° 33′ 34″ longitude and 68.08° 39′ 49″ latitude with an altitude of 1817 MAMSL) was selected. The last year's rotation was wheat. Land preparation based on the study treatments was conducted in early fall. The study treatments were: T_1) Conventional method, T_2) Combined moldboard plow method, T_3) Chisel-packer method, and T_4) Direct planting method. The specifications of the implements are given in Tables 1 and 2. The soil type was clay loamy.

Table 1 Specifications of the study tillage implements

Implement type	Produced by	Working width (cm)	Number of units
Chisel packer	Taka	2	5
Combined plow	Taka	2	5
Moldboard plow	Ahangari Khorasan	105	3

Table 2 Direct seed drill (Jiran Sanaat, Iran)

Working Width	Furrow opener type	Unit spacing (cm)	Number of drill units	Meter rotation method
2.5	Shovel	18	13	Using PTO

Soil mechanical strength: Using an Eijkelkamp penetrologger, the mechanical resistance of soil was measured at 5, 10, 15 and 20 cm depths (Anonymous, 1983).

Mean weight diameter (MWD) of aggregates: Special grading sieves were used for measuring this parameter. MWD was measured using Equation 1 (Anonymous, 1983; 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)

Soil permeability measurement: The double ring method was used to measure this parameter. Kostiakov's equation was employed to determine cumulative infiltration and thus mean permeability (Singh and Yu, 1990).

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

Where I = Cumulative infiltration (cm)

a = Infiltration in the first minute

T = Time of cumulative infiltration (min)

n = Infiltration slope

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 Equation 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)

Yield and its components: In mid-July, a 6 m^2 frame was taken by a worker from each plot (excluding the borders) and was fed to a stationary thresher to remove stalks from seeds. The weight of 1000 wheat grains was measured after separation.

3 Results and discussion

Table 3 shows the analysis of variance (ANOVA) results for the effect of study treatments on the measured parameters. Table 4 also lists the results of mean comparison. According to Table 3, the effect of conservative tillage on grain yield and 1000-grain weight was not significant (De Vita et al., 2007).

Table 3 ANOVA results for the effects of different treatments on agronomic traits during the two-year experiment

Source of variations	Degree of Freedom	Mean squares				
		Grain yield ($kg.ha^{-1}$)	Bush length (cm)	Harvest index	Weight of 1000 grains (g)	Panicle length (cm)
Year	1	1438494*	12.6ns	15.1*	3.6ns	23.9*
Experimental error	4	33471	33.9	159	8.5	0.3
Tillage method	3	13112 ns	9.4ns	32.4ns	5.40	0.3ns
Year×Tillage method	3	37488ns	9.1ns	14.2ns	2.2ns	0.05ns
Experimental error	12	19756	2/6	41.2ns	4	0.4
Coefficient of variations (%)		13.5	5.8	17	11	12.5

Note: *: Significant at the 5% level. ns: Non-significant at the 5 % level.

Table 4 Mean trait values during the two-year study

Tillage method	Yield ($kg\ ha^{-1}$)	Stem length (cm)	Panicle length (cm)	Harvest index	Weight of 1000 grains (g)
Conventional method	a1053	a50.3	a3.8	a40.1	a38.8
Combined moldboard plow	a1054	a49.7	a4.2	a42.5	a37.2
Chisel plow	a1011	a48.5	a4.5	a36.9	a37.7
Direct seeding	987a	a51.3	a4.4	a39.1	a36.8

Note: Similar letters indicate significant difference at the 5% level.

Soil bulk density: Table 5 shows the ANOVA results for the effect of conservative tillage on the bulk density of soil and other measured parameters. Since variations in soil physical properties like grain yield are independent from the cropping year, the related measurements were also performed in one year. It should be added that the depth range for bulk density measurement was between 0 to 15 cm. According to the table, the effect of tillage on this parameter was significant at 1% level. Moreover, considering the mean comparisons (Table 6), the highest and lowest bulk density values belonged to the conventional and direct seeding practices (Abu-Hamdeh, 2004).

Table 5 ANOVA results for the effect of tillage method on soil bulk density

Source of variations	Degree of Freedom	Mean squares of bulk density (g cm^{-3})
Replication	2	0.007*
Tillage method	3	0.078*
Experimental error	6	0.00
Coefficient of variations (%)		16

Table 6 Mean comparison for bulk density (g cm^{-3})

Tillage method	Moldboard	Combined	Chisel packer	Direct planting
Bulk density (g cm^{-3})	1.08 ^{d}	1.29 ^{c}	1.40 ^{b}	1.44 ^{a}

Note: Similar letters indicate significant difference at the 5% level.

Mean weight diameter: Table 7 shows MWD of aggregates. The MWD of aggregates in the chisel-packer plow was higher than that of other two treatments (Funtes et al., 2009). The amount of this parameter was almost equal in the conventional and combined moldboard plow methods. This can be due to their disc plows. In fact, soil was cut better when using the combined moldboard plow, thus the aggregate diameter was lower than that in the chisel-packer method. Another reason can be the higher weight of the combined moldboard plow. The difference of this parameter is equal for both conservative treatments.

Table 7 Mean weight diameter of aggregates in the first year

	Tillage method	10	8.7	7.5	6.2	5	3.7	2.5	1.25	0.62	MWD (cm)
Aggregate weight (kg)	Conventional	-	-	-	0.4	0.18	0.34	0.71	1.15	1.37	2.09
	Chisel packer	0.77	-	0.89	-	0.47	0.61	0.52	1.25	1.39	3.9
	Combined	-	-	0.32	0.20	0.84	0.60	0.63	1.04	0.34	3.2

Water infiltration in soil: Table 8 shows ANOVA results for the effect of experimental treatments on the infiltration rate of water in soil. According to the table, the effect of tillage on infiltration rate was significant at 5% level. Table 9 shows infiltration results (mm h^{-1}) for different treatments. According to the table, the highest and lowest infiltration rates were for the direct seeding and conventional treatments, respectively (Abu-Hamdeh, 2004). Higher infiltration can bring about less erosion in rainfed regions. Additionally, less water will remain on the surface that would lead to less soil crusting. Finally, it can improve soil water holding capacity.

Table 8 ANOVA results for the effect of experimental treatments on the infiltration rate of water in soil

Sources of variations	Degree of Freedom	Mean squares for water infiltration in soil (mm h^{-1})
Year	1	9.7*
Experimental error	4	35.8
Tillage	3	53.25*
Year×Tillage	3	0.73^{ns}
Experimental error	12	5.09
Coefficient of variations (%)	15	

Note: *: Significant at the 5% level. ns: Non-significant at the 5 % level.

Table 9 Mean comparison results of infiltration in different treatments

Treatment	Conventional method	Combined moldboard plow	Chisel plow	Direct seeding
Infiltration rate (mm h^{-1})	10.9b	16.3a	15.7a	17.9a

Note: Similar letters indicate significant difference at the 5% level.

Soil mechanical strength: Table 10 shows the values for mechanical strength of soil at 4 depths. According to the table, soil mechanical strength in the conventional method (moldboard plow) was lower than that in other treatments. The combined moldboard plow and chisel packer had almost equal results in this parameter.

Table 10 Mean comparison of soil mechanical strength at different depths (MPa)

Tillage treatment	Soil mechanical strength at different depths			
	Depth 10 cm	Depth 15 cm	Depth 20 cm	Depth 25 cm

Chisel packer	0.42	0.72	1.3	1.6
Combined moldboard plow	0.72	1.09	3.6	2.9
Moldboard	0.12	0.13	1.6	1
Control	3.14	2.9	16	32

4 Conclusion

Results showed that:

1. Effect of tillage on bulk density was significant at 1% level. The highest and lowest soil bulk density values belonged to the conventional and direct seeding.

2. The effect of tillage on infiltration rate was significant at 5% level. The highest and lowest infiltration rates were for the direct seeding and conventional treatments, respectively.

3. Aggregates size after plowing in the chisel-packer plow was higher than the conventional tillage and combined moldboard plow.

4. In rainfed farming, the tillage method and direct seeding had no significant effect on the grain yield.

5. The water infiltration in soil for direct seeding and conservative tillage was 1.8 and 1.5 times higher than that in the conventional method.

6. In rainfed farming, the direct seeding is recommended due to the lower weed population.

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