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Effects of tillage system and seed rate on dryland wheat production in the central region of Iran

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ABSTRACT

An experimental study was conducted under dryland conditions to determine the influence of conventional and conservation tillage systems as well as seed rate on grain yield and yield components of a wheat cultivar in the central region of Iran. The experimental design was a randomized complete block with three tillage and four seed rate treatments with three replications. Tillage treatments comprised of conventional tillage (CT: moldboard+disk), reduced tillage (RT: chisel plow+disk), and no-till (NT: direct drilling with plow no-till drill), while the seed rate treatments were 80, 100, 120, and 140 kgha^{-1}. Average grain yield was 1804, 1754 and 1789 kgha^{-1} for CT, RT and NT, respectively. The highest wheat yield was obtained from CT and NT treatments with seed rate of 100 kgha^{-1} and the lowest yield was obtained in RT treatment with seed rate of 80 kgha^{-1}. The trend of wheat yield with seed rate (number of plants per hectare) was approximately similar to the parabolic response curve of grain yield versus number of plants per unit area which increases quickly to a maximum and slowly decreases at higher plant densities. To achieve the maximum yield of dryland wheat in central region of Iran, applying no-till system with seed rate of 100 kgha^{-1} was recommended.

Introduction

Wheat (*Triticum aestivum L.*) is one of the most important cereal grains provides the bulk of energy consumed on earth. Wheat yield has increased through changing the traditional patterns of cultivation, and by increasing the use of machinery, high yielding grain varieties, and pumped groundwater (Stoskopf, 1985).

Wheat production was 651 million tons in 2010 where the first rank belonged to China and followed by India, USA and, Russian Federation with annual production of 116, 81, 60, and 42 million tons, respectively. Iran with production of 15 million tons is in rank of twelfth (Anonymous, 2012b). The area under dryland wheat in Isfahan, a central province in Iran, was 87,911 ha, about 79% of the total wheat cultivated area in this province in 2010 (Anonymous, 2012a).

The responses of cereal grains to different tillage systems are variable due to the complex interactions between tillage-induced soil edaphic, crop requirements, and weather conditions (Boone, 1988; Rao and Dao, 1996; Rasmussen et al., 1997). Lo´pez-Bellido et al. (1996) indicated that under rainfed Mediterranean conditions in which soil moisture limits the plant growth, the grain yield was equal or greater in conservation tillage system than that obtained under conventional tillage system with moldboard plowing, and positively correlated with earlier or greater seedling establishment and autumn growth. Hemmat and Eskandari (2006) indicated that the yield of dryland winter wheat was significantly affected by tillage system, and the average grain yields under reduced tillage, minimum till, no-till with standing stubble, and no-till with total residue were, respectively, 25, 6, 17, and 41% greater than that obtained under conventional tillage. Also the overall average grain yield for no-till system with total residue was significantly greater than grain yields using other tillage systems, similar to findings of other researchers (Ciha, 1982; Mrabet, 2000). The increased water storage is one of the most important advantages of no-till systems. The development of no-till fallow instead of conventional tillage fallow has improved the water storage (Smika, 1990). The high moisture in the soil associated with the no-till system is caused mainly by the presence of high amounts of wheat residue on the soil surface. The residue shades the soil surface; decreases soil evaporation (Latta and O'Leary, 2003; Griffith et al., 1986), reduces runoff, and increases infiltration (Johnson et al., 1984; Smika and Unger, 1986).

Unger (1994) found that the tillage systems have no effect on yield of dryland wheat and sorghum in long-term experiments. Lampurlane´s et al. (2002) have shown that no-till system is potentially the best system for executing fallow, but residues of the preceding crop must be left spread over the soil. Thomas et al. (2003) reported a general lack of winter wheat yield response to the improved water storage under no-till system in the early years of a long term fallow management, which was caused by the great level of yellow-spot disease (Pyrenophora tritici-repentis) and the large number of root-lesion nematode (Pratylenchus thornei) in wet seasons under no-till system than conventional tillage. Their results revealed that no-till system with standing stubble has the potential to improve winter wheat yield, provided the effect of diseases and nematodes are minimized in wheat and nitrogenous fertilizer is maintained at a sufficiently high level.

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Hammel (1995) obtained the lower wheat yield under no-till system than those obtained under conventional and minimum tillage systems in the clay soil. His research results showed that the continued use of no-till system on fine-textured soils can lead to adverse physical conditions in the top 30 cm layer of the soil.

In wheat, the seed rate for maximum grain yield can be derived from the parabolic response curve of grain yield versus number of plants per unit area or seed arte, which increases quickly to a maximum and slowly decreases at higher plant densities or seed rates (Kirby, 1967; Willey and Heath, 1969). The optimum seed rate is dependent on the different parameters such as seed quality, planting date, and seedbed condition (Smid and Jenkinson, 1979; Hemmat and Taki, 2001). New wheat cultivars, particularly if they differed from existing cultivars, should be tested at a wide range of seed rates to determine their optimum seed rate (Briggs and Aytenfisu, 1979; Faris and De Pauw, 1981). Delayed planting past the optimum time reduced grain yield and increasing the seed rate only partially compensated for the loss of grain yield (Briggs and Aytenfisu, 1979; Ciha, 1983). Mennan and Zandstra (2005) determined the effect of different seed rates of wheat cultivars on the competitive ability of *G. aparine* (kind of weed) and wheat yield.

There is limited information of the dryland wheat cropping systems such as reduced tillage and no-till systems. Thus the objective of the present study was to determine the effects of various tillage systems and seed rates on the yield and yield components of the dryland wheat grown in the central region of Iran.

Materials and methods

Study site

This experiment was conducted from 2005-2006 at the dryland farms of Fereydonshahr (30°43' and 34º27'N; 49º36' and 55º31'E), Isfahan province, Iran (Pishgar-Komleh et al., 2012). The average annual precipitation and temperature at the study region were 750 mm and 14.5 °C, respectively, with temperature variation from -20 °C to +30 °C. The majority of the precipitation is occurring in autumn, winter and the beginning of spring.

Properties of experimental design

The experimental design was a randomized complete block with three tillage and four seed rate treatments with three replications. Each plot consisted of 6 m long and 4 m width. The previous crop at the plots was wheat. The tillage system and the seed rate were taken as the major (main plots) and minor factors (sub-plots) on an unplanted soil (soil was fallowed prior the experiment), respectively. Three tillage treatments studied in this study were conventional tillage (CT), reduced tillage (RT), and no-till (NT) and the seed rate treatments were 80, 100, 120, and 140 kg ha^{-1}. A 3-bottom general purposed moldboard plow equipped with share points and operated at speed of 3 km h^{-1} was used in the CT system. The primary tillage implement used in the RT system was a chisel plow equipped with 6.2 cm points which is operating at 4 km h^{-1}. All plots under CT and RT were subsequently smoothed to a depth of 8-10 cm with a tandem disk harrow with seven disks in each gang and operated at 6 km h^{-1}. The diameter of each disk was 50 cm and the disk spacing was 21 cm. The only soil disturbance in NT occurred during the seeding operation.

Wheat (Sardari cultivar) was planted in subplots with specified seed rates at a depth of 6 cm, using a Hassia no-till drill having chisel-type openers with depth controlling press wheels and with a row spacing of 20 cm. The drill also banded N and P fertilizers 5 cm below the seeds at 50 kg ha^{-1} and 100 kg ha^{-1}, respectively, using ammonium nitrate and triple superphosphate. An additional 50 kg N ha^{-1} as urea was top dressed in the spring. For post-seeding broadleaf weed control, all the plots were sprayed with Granstar (methyl 2-[[[[N-(4-methoxy-6-methyl-1,3,5-triazin-2-yl) methylamino] carbonyl] amino] sulfonyl] benzoate) at a rate of 20 g ha^{-1}. In summary, all the treatments in this study were named as A_1: 80 kg seed ha^{-1}, A_2: 100 kg seed ha^{-1}, A_3: 120 kg seed ha^{-1}, A_4: 140 kg seed ha^{-1}, B_1: conventional tillage (CT), B_2: reduced tillage (RT), and B_3: no till (NT). Wheat was harvested on 15 July 2006.

Crop yield measurements

In this study, some of the plant growth parameters such as ears per square meter, 1000-kernel weight, kernels per ear, plant height, and grain yield were measured. Ears per square meter were determined from four 1 m^2 areas of each plot by clipping the plants at the soil surface. After oven drying and weighing, grain was threshed from the straw, cleaned, and weighed. Kernel weight was determined by counting and weighing five 300-kernel samples taken from the harvested grain of each plot. Kernels per harvested area were calculated by dividing the harvested grain weight by the weight per kernel. Kernels per ear were calculated by dividing the number of kernels per harvested area by the number of ears per harvested area. Plant height at maturity was determined by averaging the heights of 25 randomly selected plants per area from the soil surface to the highest point of the ear (Joseph et al., 1985; Hemmat and Eskandari, 2006).

Statistical analysis

All data were analyzed by analysis of variance (ANOVA) procedures using the SPSS15 statistical software package. Also, Duncan’s compare mean test was applied to compare the means. All significant differences are reported at the probability levels of 0.01 and 0.05.

Results and discussion

Significance of investigated factors on plant growth parameters

Tillage system, seed rate, and tillage × seed rate interaction effects on wheat grain yield, 1000-kernel weight, ears per square meter, kernels per ear, and plant height are presented in Table 1. The effects of tillage system and seed rate on all the above mentioned parameters are significant at P=0.01 probability level. Although the interactions between tillage system and seed rate are not observed for 1000-kernel weight, ears per square meter, kernels per ear, and plant height. There is a significant interaction between tillage system and seed rate for wheat grain yield ($P<0.01$).

Tillage effects on plant growth parameters

The results of wheat grain yield, 1000-kernel weight, ears per square meter, kernels per ear, and plant height for different tillage systems and seed rates are presented in Table 2. The effect of tillage system on wheat yield is significant. CT treatment has the highest yield (1,804 kg ha^{-1}), followed NT and RT treatments with average yields of 1,754 and 1,789 kg ha^{-1}, respectively. Average grain yield for the dryland wheat under CT treatment were, respectively, 2.8 and 0.8% greater than yields obtained under RT and NT treatments. The results were in opposition to the findings of others (Ciha, 1982; Patrick et al., 2003), where they found that as tillage operation decreases, wheat grain production increases, subsequently. The results of the present study are similar to the findings by Frederick et al., (2001), where it was reported that grain yield under deep tillage operation was about 27% greater than that in surface tillage operation (disked twice).

Two main reasons cited for lower yields under RT and NT treatments are increased weed infestation and soil physical properties. Applying RT or NT treatments needs the higher level of weed management and with lack of this kind of management; competition between wheat and weeds decreases the yield significantly (Camara et al., 2003). Unsuitable soil physical properties in RT and NT treatments limit crop growth and subsequently grain yield (Hajabbasi and Hemmat, 2000; Hammel, 1989, 1995).

Grain yield is the product of ears per square meter, kernels per ear, and kernel weight (Norwood, 2000). Examination of yield components showed that there was significant effect of tillage system on all the yield components. Hemmat and Eskandari (2006) and Kabakci et al. (1993) also found the significant effect of different tillage systems on ear density and kernels per ear.

The highest values of the yield components were obtained in CT treatment in comparison with RT and NT treatments (Table 2). The large ear density might be attributed to the better seedling establishment and better weed controlling in CT treatment. In this study, the conventional tillage with moldboard plow and disk harrow decreased the weeds growth in the wheat farms and increased the yield components. Another reason for high wheat yield component in CT treatment can be due to the better seed bed preparation with moldboard plow and disk harrow in comparison with other tillage systems.

Seed rate effects on plant growth parameters

As presented in Table (2), the effect of seed rate on wheat yield is significant. The highest wheat yield was obtained at seed rates of 100 and 120 kg ha^{-1}. On the other hand, the lowest quantity of wheat yield was obtained in seed rates of 80 and 140 kg ha^{-1} (Figure 1).

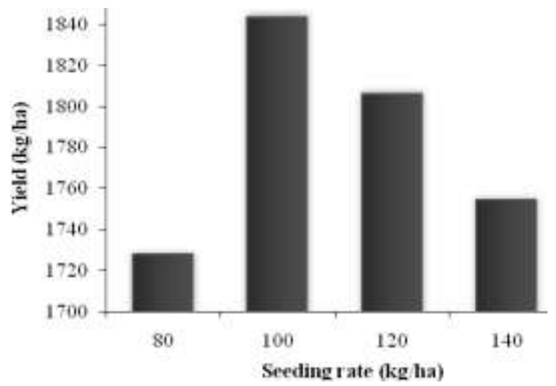

Figure 1. grain yield in different seeding rate values

An increase in seed rate from 80 to 100 kg ha^{-1}, led to an increase in wheat yield. Seed rate of 100 kg ha^{-1} had the highest grain yield and by increasing seed rate, the wheat yield decreased. The trend of wheat grain with seed rate or number of plants per unit area was approximately similar to the parabolic behavior of grain yield versus number of plants per unit area which increases quickly to a maximum and slowly decreases at higher plant densities as presented by Willey and Heath (1969). The most reasonable and probable explanation for this happen is that by increasing the plant densities or seed rates, the inter-plant competition for light, nutrients, and moisture in higher seed rates increases and the amount of yield will decreases significantly (Joseph et al., 1985).

The seed rate of 140 and 80 kg ha^{-1} had lowest and highest 1000-kernel weight, respectively. In other words, by increasing of seed rate, the weight of kernels reduced significantly. Moreover, by increasing of seed rate, the ear density increased significantly, however kernels per ear decreased. The highest wheat kernels per ear obtained from seed rate of 80 kg ha^{-1} while the lowest ones obtained from 140 kg ha^{-1}. By increasing of seed rate, wheat height decreased significantly (Table 2). Faris and De Pauw (1981) found the significant effect of seed rate on yield of three spring wheat cultivars.

Tillage system and seed rate interaction effects on wheat yield

Tillage and seed rate interaction effects on wheat yield was significant at P=0.05 probability level, while there was no significant interaction effects on other yield components (Table 3 and Figure 2).

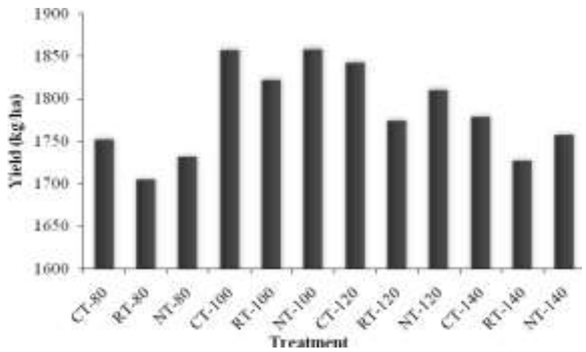

Figure 2. Interaction effect of tillage system and seed rate on wheat yield

The lowest amount of wheat yield of 1,701 kg ha^{-1} obtained from RT treatment with seed rate of 80 kg ha^{-1} and the highest yield of 1,854.33 kg ha^{-1} was obtained in CT and NT treatments with seed rate of 100 kg ha^{-1}. Therefore, because there was an equal yield value in two specified treatments of tillage systems (CT and NT) and because CT treatment needs more energy supply, NT treatment is recommended for wheat cultivation in the research area.

Conclusion

The influence of conventional and conservation tillage systems as well as seed rate on grain yield and yield components of a wheat cultivar under dryland conditions in the central region of Iran were experimentally investigated. Mean grain yield was 1,804 kg ha^{-1} for conventional tillage, 1,754 kg ha^{-1} for reduced tillage, and 1,789 kg ha^{-1} for no-till treatment. The highest wheat yield obtained from conventional tillage and no-till treatments with seed rate of 100 kg ha^{-1} and the lowest yield was obtained in reduced tillage treatment with seed rate of 80 kg ha^{-1}. The trend of wheat grain with seed rate or number of plants per unit area was approximately similar to the parabolic response curve of grain yield versus number of plants per unit area which increases quickly to a maximum and slowly decreases at higher plant densities. To achieve the maximum yield of dryland wheat in the central region of Iran, applying no-till system with seed rate of 100 kg ha^{-1} was recommended.

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Table 1. Tillage system, seed rate, and tillage × seed rate interaction effects on wheat growth parameters.

Source of variables	Yield (kg ha^{-1})		1000-kernel weight (g)		ears per square meter		kernels per ear		plant height (cm)	
	Mean squares	F	Mean squares	F	Mean squares	F	Mean squares	F	Mean squares	F
Tillage method	7733.4	1695.7**	7.87	36.5**	448.11	231.36**	30.58	42.05**	39.43	236.64**
Seed rate	24031.14	28.527**	12.43	57.63**	2045.96	1056.32**	94.4	129.8**	88.24	530.06**
Interaction	114.25	51.25**	1.18	5.46^{ns}	22.82	1.78^{ns}	4.62	3.35^{ns}	0.59	3.54^{ns}
Error	4.56	---	0.22	---	1.94	---	0.73	---	0.17	---

**: Corresponding to 1% probability.
*: Corresponding to 5% probability.
ns: Corresponding to No significant difference.

Table 2. Effect of tillage system and seed rate on yield and yield components of dryland wheat.

	Yield (kg ha^{-1})	1000-kernel weight (g)	ears per square meter	kernels per ear	plant height (cm)
Tillage system					
CT	1803.88^{c}	40.36^{b}	298.92^{a}	23.92^{b}	73.28^{b}
RT	1754.17^{a}	38.81^{a}	310.42^{b}	21.1^{a}	70.03^{a}
NT	1789.08^{b}	39.18^{ab}	308.25^{b}	21.33^{a}	70.04^{a}
Seed rate (kg ha^{-1})					
80	1727.61^{a}	40.99^{b}	289.22^{a}	24.78^{b}	74.41^{c}
100	1842.89^{b}	39.72^{ab}	298.67^{ab}	24.89^{b}	72.78^{bc}
120	1805.50^{b}	38.76^{a}	311.89^{bc}	20.12^{a}	70.34^{b}
140	1753.83^{a}	38.33^{a}	323.67^{c}	18.56^{a}	67.11^{a}

Note: Different letters (a, b, c, and d) show significant difference between mean values.
CT: Conventional Tillage; RT: Reduced Tillage; NT: no-till.

Table 3. Tillage and seed rate interaction effects on grain yield and yield components of wheat.

Treatment	Yield (kg ha^{-1})	1000-kernel weight (g)	ears per square meter	kernels per ear	plant height (cm)
CT-80	1749.67^{c}	41.83	283	26	76
RT-80	1701^{a}	40.67	292.67	24.33	73.27
NT-80	1732.17^{b}	40.67	292	24	73.97
CT-100	1854.33^{f}	40.23	289	38.67	75.47
RT-100	1820^{ef}	39.23	305.33	22.33	71.33
NT-100	1854.33^{f}	39.63	301.67	23.67	71.53
CT-120	1832.67^{f}	39.2	308.67	21	72.37
RT-120	1773.67^{cd}	38.5	313.33	20	69.17
NT-120	1810.17^{e}	38.6	313.67	19.33	69.5
CT-140	1778.83^{d}	40.17	315	20	69.27
RT-140	1723^{b}	36.83	330.33	17.373	66.33
NT-140	1759.67^{c}	38	325.67	18.373	66.03

CT: Conventional tillage; RT: Reduced tillage; NT: No-till

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