Effect of Conservation Tillage and Irrigation Regimes on Winter Wheat Yield and Water Productivity

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Abstract: Winter wheat yield and water productivity under conservation tillage methods and irrigation regimes were evaluated in this study. The research was conducted in the form of a split plot experimental design with nine treatments and three replications from 2012 to 2013. Main plots were irrigation regimes including irrigating every 7, 10, and 14 days, and subplots were conventional tillage (CT), reduced tillage (RT), and no-till (NT) methods. Soil moisture content, water consumption, wheat yield, and water productivity were measured in this experiment. Collected data were analyzed using SAS software. Results showed that irrigation every 7 days increased wheat yield by 3.5 and 31% compared to irrigating every 10 and 14 days, respectively. The maximum wheat yield (8070 kg/ha) was obtained from the reduced tillage treatment irrigated every 7 days, and the minimum wheat yield was related to the treatment involving reduced tillage and irrigating every 14 days. Water productivity increased by 90% when irrigating interval increased from 7 to 14 days. Water productivity was 1.9, 2.5, and 3 kg of wheat/m3 for irrigating every 7, 10, and 14 days, respectively. Water productivity for the conventional, reduced, and no-till methods were 2.6, 2.4, and 2.2 kg/m3, respectively.

Key words: Tillage methods, irrigation regimes, water productivity

INTRODUCTION

Water and soil resources are the most limiting factors for sustainable agriculture in the arid and semi-arid climate conditions. Applying conservation tillage and retaining crop residue on the soil surface can save water and soil, and lead to the sustainable agriculture. Conservation tillage improves soil and water resources, saves energy and time, and reduces the costs of agricultural products. This tillage method performance may be affected by the irrigation method used on the farm. Conservation tillage has the higher water use efficiency in wheat and corn production under tape irrigation method (Dehghanian and Afzalinia, 2012). Wheat productivity is higher under flat no-till method compared to the furrow irrigated raised bed and conventional till flat planting in maize-wheat cropping system (Jat et al., 2005). Conservation tillage reduces water consumption and increases wheat yield by 12% (Freebairn et al., 1986). Soil hydraulic conductivity, soil water absorption, and soil micro-organisms activity is higher in no-till system compared to the conventional tillage (McGarry et al., 2000). Sprinkle irrigation reduces water consumption compared to the surface irrigation by 30% (Haq, 1990). Tape irrigation increases cotton yield compared to the furrow and sprinkle irrigation by 21% and 30%, respectively and has the maximum water use efficiency compared to these irrigation methods (Cetin and Bilgel, 2002). Zero tillage method decreases evaporation from the top soil, soil temperature, and corn yield and increases water retention during the critical growth stage of corn, soil bulk density, and soil penetration resistance (Fabrizzi et al., 2005; De Vita et al., 2007). The lower cotton yield and water productivity is obtained from the minimum tillage method compared to the conventional tillage (Jalota et al., 2008). Conservation tillage methods (no-till and minimum tillage) provide the higher soil water content, cotton root growth, and cotton yield compared to the conventional tillage (Karamanos et al., 2004). Halvorson et al. (2006) showed that conservation tillage controlled soil erosion and increased soil moisture retention in the soil and water productivity in the semi-arid conditions of the Great Plains. Crop residues on the soil surface...
reduce soil moisture evaporation and increase microorganism's activity in the soil (Klocke 2003). Feng et al. (2009) and Barzegar et al. (2002) reported that conservation tillage increased wheat yield and rain fall productivity by reducing moisture evaporation and increasing moisture retention in the soil. Guzha et al. (2004) observed that wheat yield obtained from the no tillage and minimum tillage was lower than that of conventional tillage method. Reduction in crop yield obtained from the conservation tillage compared to the conventional method was also reported by Wang et al. (2007) and Gao et al. (2005). Objective of this study was to evaluate the effect of conservation tillage and irrigation regimes on the moisture retention in the soil, winter wheat water consumption, winter wheat yield, and water productivity.

MATERIALS and METHOD

This study was performed to evaluate the effect of conservation tillage methods and irrigation regimes on the winter wheat yield and water productivity in a silty-clay soil in Fars province, Iran. The research was conducted in the form of a split plot experimental design with nine treatments and three replications from 2012 to 2013. Main plots were irrigation regimes including irrigating every 7, 10, and 14 days, and subplots were conventional tillage (CT), reduced tillage (RT), and no-tillage (NT) methods. Soil moisture content, water consumption, wheat yield, and water productivity were measured in this experiment. Collected data were analyzed using SAS software and Duncan's multiple range tests was used to compare the treatments means. Irrigation regimes were applied using a sprinkle irrigation system with a Pirot zk30 sprinkler having 8 mm nozzles. The sprinkler operating pressure was 3 bars with coverage diameter of 38 m and height of 1.2 m from the ground level. Sprinkler discharge was 0.98 liter per second with the arrangement of 20×15 m. Water applied to the plots in each time irrigation was identical and calculated based on wheat water requirement for the irrigation with 7 days irrigating interval by considering 70% irrigation efficiency.

In the conventional tillage method, primary tillage was performed using a moldboard plow and secondary tillage operation was done using a disk harrow and land leveler. Seed bed was prepared in the reduced tillage method using a tine and disc cultivator which was able to complete the primary and secondary tillage operations simultaneously. Wheat seed was directly planted using a direct seeder without any seed bed preparation in the no tillage method. Plots had dimensions of 6×20 m and a local wheat variety (Chamran) was planted in the plots. Soil moisture content was measured using a time domain reflectometry (TDR) model TRIME-PICO IPH T3/44 from the soil depths of 0 to 20 cm. Wheat yield was measured by harvesting the crop planted in each plot during the harvesting process. Water productivity was computed using the following equation:

\[
WP = \frac{Y}{W}
\]

where:

\[ WP \] = water productivity (kg/m³),

\[ Y \] = crop yield (kg/ha), and

\[ W \] = water consumption (m³/ha).

RESULTS and DISCUSSION

Results of average moisture retention in the soil indicated that no-till method had the highest moisture retention in the soil and the conventional tillage had the lowest moisture retention in all the irrigation treatments (Figure. 1). The higher moisture content in the no-till method compared to the conventional tillage was because of crop residue retention on the soil surface and the minimum soil disturbance in the no-till treatment. Among the irrigation regimes, the maximum moisture content occurred in the treatment with 7 days irrigation interval (Figure 1) as it was expected. Considering the effect of interaction between tillage methods and irrigation regimes on the soil moisture content, no-till method irrigated every 7 days had the maximum soil moisture content.

![Figure 1. Soil moisture content in different tillage methods and irrigation regimes](image-url)
Average water consumption in different tillage methods and irrigation regimes are presented in Figure 2. Since identical amount of water was applied to the different tillage treatments in each irrigation regime, there was no difference between the tillage treatments from the water consumption point of view in each irrigation regime. According to Figure 2, experimental plots with 14 and 10 days irrigation interval consumed 57% and 24% less water compared to the 7 days irrigation regime. This proved that water saving can be achieved by increasing irrigation interval; however, increasing irrigation interval definitely reduces the crop yield.

![Figure 2. Water consumption in different tillage methods and irrigation regimes](image)

Average wheat yield comparison in different tillage methods and irrigation regimes showed that there was no significant difference between irrigation regimes of 7 and 10 days for wheat yield; while, wheat yield in 14 days irrigation regime considerably decreased compared to those of 7 and 10 days irrigation interval (Figure 3). This showed that the amount of water applied in 7 days irrigation interval was higher than the required amount of water for wheat. There was also no significant difference between the tillage methods for wheat yield in 7 and 10 days irrigation interval; whereas, the difference between wheat yield obtained from the tillage methods in 14 days irrigation interval was significant. Since the no-till method retained more water in the soil compared to the conventional tillage in 14 days irrigation interval (Figure 1), it was expected to have more wheat yield in the no-till rather than the conventional tillage. The lower wheat yield obtained from the no-till treatment compared to the conventional tillage in 14 days irrigation interval was probably because of the higher soil bulk density and soil compaction in the no-till. It should be noted that, the negative effects of soil compaction on the crop roots and growth can be intensified under low soil moisture content which occurred in 14 days irrigating interval.

![Figure 3. Wheat yield in different tillage methods and irrigation regimes](image)

Comparing water productivity in different treatments revealed that the highest amount of water productivity was obtained from the conventional tillage method irrigated with 14 days irrigation interval (Figure 4). Although the maximum wheat yield was obtained from 7 days irrigating interval treatment (Figure 3), the water productivity in this treatment was the lowest because of a large amount of water application in this treatment. Results of this study showed that water productivity can be increased for 90% by increasing the irrigating interval from 7 days to 14 days. In the arid and semi-arid climate conditions that water shortage is the most important limiting factor for agricultural products, increasing irrigation interval is a potential approach to increase water productivity.

![Figure 4. Water productivity in different tillage methods and irrigation regimes](image)
CONCLUSIONS
The followings were concluded from the study:

- No-till method irrigated with 7 days interval had the maximum moisture retention in the soil.
- Tillage treatments in the irrigation regimes with 14 and 10 days irrigation interval consumed 57% and 24% less water compared those with 7 days irrigation interval.
- The maximum wheat yield was obtained from the irrigation regime with 7 days irrigating interval; while, the minimum wheat yield was related to the irrigation regime with 14 days irrigating interval.
- Water productivity can be increased for 90% by increasing the irrigating interval from 7 days to 14 days.

ACKNOWLEDGEMENTS
The authors would like to acknowledge the financial support extended by the Agriculture Organization of Fars province. Technical supports from colleagues in the Department of Agricultural Engineering Research during the experimental work are also appreciated.

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