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Interaction Effect of Tillage and Irrigation Methods on Phenology, Yield and Water Productivity of Three Wheat Cultivars

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ABSTARCT: Two-year field experiments were conducted at Shiraz University to evaluate the effects of tillage systems and irrigation methods on water productivity (WP) and yield of three wheat cultivars. Treatments included tillage systems in two levels as conventional tillage and reduced tillage, three irrigation methods as furrow irrigation, solid set sprinkler and wheel move sprinkler and three wheat cultivars. Results showed that interaction of cultivar × tillage system × irrigation methods was significant for plant height, 1000-seeds weight, and number of grains per spike, grain yield, biological yield and WP. Pishtaz cultivar produced more grain yield in conventional tillage system and furrow irrigation. However, this cultivar produced a good amount of yield in reduced tillage and solid set sprinkler irrigation method. Pishtaz cultivar had also the greatest WP in reduced tillage and solid set sprinkler. Reduced tillage also caused an increase in soil organic nitrogen and soil organic carbon.

Keywords: Water managements, water productivity, reduced tillage

INTRODUCTION

In recent years, water is increasingly becoming scarce worldwide. It has been reported that approximately one-third of the people in the world would surly faced with the water shortage by the year of 2025 (Seckler *et al.*, 1999 and Rosegrant *et al.*, 2002). Drought is known as one of the most important limiting factors which can affect field crop yield, especially in arid and semi-arid regions. In southern areas of Iran with an arid climate, the portion of available water for irrigating cropland is decreasing (Abbasi and Sepaskhah 2011).

Since most agricultural soil of Iran possesses poor physical conditions as a result of its low SOM, increasing SOM of Iranian fields' soil is of prime concern (Maftoun *et al*., 2004). Tillage greatly affects soil organic matter (SOM) storage (Allmaras *et al*. 2004). Beneficial effects of reduced tillage systems on soil properties and crops yields have been reported (Hao *et al*. 2001; Da-Silva *et al*. 2004; Kaschuk *et al*., 2006).

Wheat is one of the most important food crops in Southern Iran, Fars province. This province is also the largest wheat producer in Iran (Bijanzadeh *et al*,. 2015). Since the availability of water for irrigation is reducing and its price is increasing the search for alternative methods for irrigating crops such as wheat is of prime concern. Recently, both researchers and farmers are becoming aware of the water shortage problem in the province. Our farmers mostly use furrow irrigation method toirrigate their fields. They usually use ground water using deep tube wells. There have been attempts to adopt pressurized irrigation methods to irrigate wheat in several countries (Spanu *et al*., 1996). Use of sprinkler method has improved on-farm irrigation efficiencies up to 80% in the Indian Subcontinent (Sharma, 1984).

Farmers in many regions which apply furrow irrigation have not adopted to conservation tillage. However, conservation tillage technologies developed for rain fed or sprinkler irrigated conditions. Karim *et al*., (2014) reported that sprinkler irrigation and reduced tillage system night be an option to reduce rice production cost. Water productivity and benefit cost ratio also higher in sprinkler irrigation and reduced tillage system.

There is limited information about the performance of common cultivated cultivars of wheat as affected by tillage systems and irrigation methods in Fars province. Therefore, the present study conducted to evaluate the effects of conventional and reduced tillage and irrigation methods on yield and water productivity of three wheat cultivars in Southern Iran.

MATERIALS AND METHODS

Two-year field experiments were conducted in 2014 and 2015 at the Research Field of Agricultural College of Shiraz University, Iran (35°52'E, 40°29'N, altitude 1810 m above sea level), to evaluate the effects of two tillage systems and three irrigation methods on growth and yield of three wheat cultivars. Plots were located on a silty loam soil with 0.71% organic C content, 0.05% total N, 21.8 mg kg^{-1} phosphorus, 600 mg kg^{-1} potassium, pH of 7.64 and electrical conductivity (EC) of 0.62 dS m^{-1} in the surface horizon (0-20 cm).

The experimental design was randomized complete block with three replicates. Treatments included tillage systems in two levels as conventional tillage (moldboard plowing + two harrow disking + leveler) and reduced tillage (combined cultivator + leveler), three irrigation methods as furrow irrigation, solid set sprinkler and wheel move sprinkler and three wheat cultivars including Shiraz, Ronesans and Pishtaz.

Commercial wheat seeds were sown on November 5th 2014 and November 1st2015 in 3Ï5 m plots. In conventional tillage treated plots seeds were sown using neumatic planter and in reduced tillage treated plots seeds were sown using combined cultivator at a depth of 2 cm.

In moldboard plow treatment, moldboard plowing disturbed soil to a 30 cm depth followed by two harrow disking. For chisel treatment, soil was disturbed to a depth of 15-20 cm by using a chisel plow followed by a single harrow disking. Nitrogen fertilizer at the rate of 200 kg N ha-1 as urea was topdressed. Half of N fertilizer was hand-broadcasted at planting and half top-dressed at stem elongation. The water productivity (WP) was calculated from dry yield divided by the applied water.

Soil samples of each plot were collected at a soil depth of 0 to 30 cm to determine total N (Bremmer and Mulvaney, 1982), organic C (Nelson and Sommers, 1982) at the end of each growing season. Each soil sample was placed in a plastic bag and transformed to the laboratory. The samples were air-dried at room temperature after removing visible roots and crop residues, and ground to pass through a 2 mm sieve.

At crop maturity, July 1st, the two middle rows from each plot were sampled for determination of yield and yield components, oven-dried at 75ºC for 72 h, and weighed. Analysis of variance over years indicated that there is no significant (P> 0.05) year by tillage system by cultivar by irrigation methods interaction for all data. Thus, data of two years were combined. Data were subjected to analysis of variance (ANOVA) and the means were compared (Duncan's multiple range test, p<0.05) using SAS (Version 9.1 2002).

RESULTS AND DISCUSSION

A. Effects of the treatments on wheat growth and yield

Interaction of cultivar × tillage system × irrigation methods was significant for plant height, 1000-seeds weight, number of grains per spike, grain yield, spike length and biological yield (Table 1) (p<0.05). Shiraz cultivar plants had the greatest height in furrow irrigation and conventional tillage treated plots (Table 1).The lowest height was gain in Ronesans cultivar plants in reduced tillage and wheel move sprinkler treated plots (Table 1). 1000-seeds weight of Shiraz cultivar in furrow irrigation and conventional tillage was the greatest which was not significantly different from Ronesans cultivar in furrow irrigation and conventional tillage (Table 1). However, Pishtaz cultivar in conventional tillage and furrow irrigation produced the higher number of grains per spike followed by Pishtaz in reduced tillage and solid sprinkler and reduced tillage and furrow irrigation (Table 1). Pishtaz cultivar had the highest spike length in reduced tillage and solid set irrigation system which it was not significantly different from furrow irrigation. In general Pishtaz cultivar had greater spike length than the other cultivars (Table1).Our results showed that although Shiraz cultivar had a greater 1000-seeds weight than Pishtaz cultivar, Pishtaz cultivar had a greater number of grains per spike and spike length which this cultivar produced more grain yield than Shiraz cultivar. It shows that number of grains per spike and spike length are more important components than 1000-seeds weight related to wheat yield.

Conventional tillage and furrow irrigation in Pishtaz cultivar caused the greatest grain yield among all the treatments (Table 1). In general simple effect of the treatment showed that pishtaz (834.0 g m^{-2}) performed better than Shiraz (701.0 g m^{-2}) and Ronasans (440.4 g m^{-2}).

Pishtaz cultivar in reduced tillage and solid set sprinkler had the second place regarding the highest grain yield after conventional tillage and furrow irrigation treatment with approximately 10 % lower grain yield (Table 1). This yield is still acceptable by the farmers and it is common in Fras province.

Table 1: Interaction effects of the treatments on wheat traits.

Irrigation System	Cultivar	Tillage	H (cm)	MKW (g)	NGS	SL (cm)	SN	GY (g m^{-2})	BY (g m^{-2})
Furrow Irrigation	Shiraz	CT	98.7a	46.7a	24.3h	8.4 ef	800.0bcd	743.7f	1679.5e
		RT	95.2b	45cb	26.7fg	8.7 c-e	803.0bc	814.7de	1864.6b
	Ronesans	CT	83.5hj	45.4ab	21.4i	5.8 j	593.0j	497.8jk	962.4h
		RT	78.6j	43.8cd	20.2j	5.8 j	620.7ih	504.3j	968.6h
	Pishtaz	CT	93.2bcd	35.5i	39.8c	8.8 c	751.0e	1043.7a	1929.1a
		RT	89.3gf	36.4hi	37.2b	8.8 c	802.7bc	905.5c	1824.9bc
Solid set sprinkler	Shiraz	CT	95.2b	44.5bc	26.1g	8.3 f	775.7ed	789.1e	1765.9d
		RT	91.5ced	43.7cd	25.7g	8.5 e-d	831.7a	836.7d	1761.3d
	Ronesans	CT	79.1j	40.1e	22.1i	5.2 k	657.3gf	510.9j	939.7h
		RT	73.8k	42.5d	21.3i	5.2 k	636.7gh	518.2j	948.0h
	Pishtaz	CT	90.2def	37.4gh	32.8d	9.2 b	777.7cd	901.2c	1803.9dc
		RT	88.1gf	38.2gf	35.2a	9.5 a	821.0ab	944.2b	1820.4bc
Wheel move sprinkler	Shiraz	CT	86.4hg	39.8e	21.4i	6.9 hi	641.3gh	474.1k	1255.0f
		RT	83.1i	39.1ef	23.2h	6.7 i	670.7f	547.9i	1297.3f
	Ronesans	CT	71.1kl	35.6i	16.5k	4.7 l	507.3k	293.9l	653.6i
		RT	697l	37.3gh	17.4k	4.8 l	516.0k	317.1l	669.4i
	Pishtaz	CT	79.0j	33.9j	27.6f	7.1 h	600.7ij	576.8h	1195.0g
		RT	77.6j	31.5k	30.8e	7.6 g	606.7ij	632.6g	1261.1f

CT: conventional tillage, RT: reduced tillage
H: plant height (cm), MKW: 1000-seeds weight (g), NGS: number of grains in spike, SL: spike length (cm), SN: spike number/m^2, GY: grain yield (g m^{-2}), BY: biological yield (g m^{-2})

B. Effect of treatments on water productivity of wheat cultivars

Interestingly, the highest water productivity (WP) gained in Pishtaz cultivar which was treated with solid set sprinkler and reduced tillage (Fig.1). This treatment seems to be more beneficial due to its positive impact on WP and organic matter storage in our region with water scarcity problem and poor soil conditions as a result of low organic matter content. Al-Jamal *et al*. (2001) have also found that sprinkler irrigation has a higher WP than that of furrow irrigation. Jahadi *et al*. (2012) reported that WP and yield of sugar beet (*Beta vulgaris* L.) was higher in sprinkler irrigation compared to furrow irrigation. Iqbal *et al* (2014) found that drip irrigation had a greater WP compared to furrow irrigation in vegetables, however the yield of the vegetables were higher in furrow irrigation compared to drip irrigation. Hakim *et al*. (2014) found that sprinkler and reduced tillage was superior to furrow irrigation regarding WP, energy and production cost.

The highest used water amount was achieved from Shiraz cultivar and the lowest one was from Pishtaz cultivar. However, the highest value of water productivity was obtained from Pishtaz and the lowest one was obtained from Ronesans (Fig. 2). Between tillage systems, the highest water productivity and the lowest used water amount were obtained from reduced tillage (Figure 3) and among three irrigation systems, the lowest used water amount and the highest value for water productivity were measured from solid set sprinkler system. Wheel move sprinkler system had the lowest water productivity due to low grain yield (Fig. 4).

The greatest biological yield was gained in Pishtaz cultivar which treated with conventional tillage and furrow irrigation (Table 1). The lowest biological yield was obtained in Ronesans cultivar treated with conventional tillage and wheel move sprinkler which was not significantly different from Ronesans which treated with reduced tillage and wheel move sprinkler (Table 1).

C. Correlation and path analysis

Correlation analysis also showed a positive significant relationships between grain yield, number of grains per spike (r=0.84**), spike length (r=0.93**) and number of spike m-2(r=0.89**) compared to a weak correlation with 1000-seeds weight (r=0.13ns).

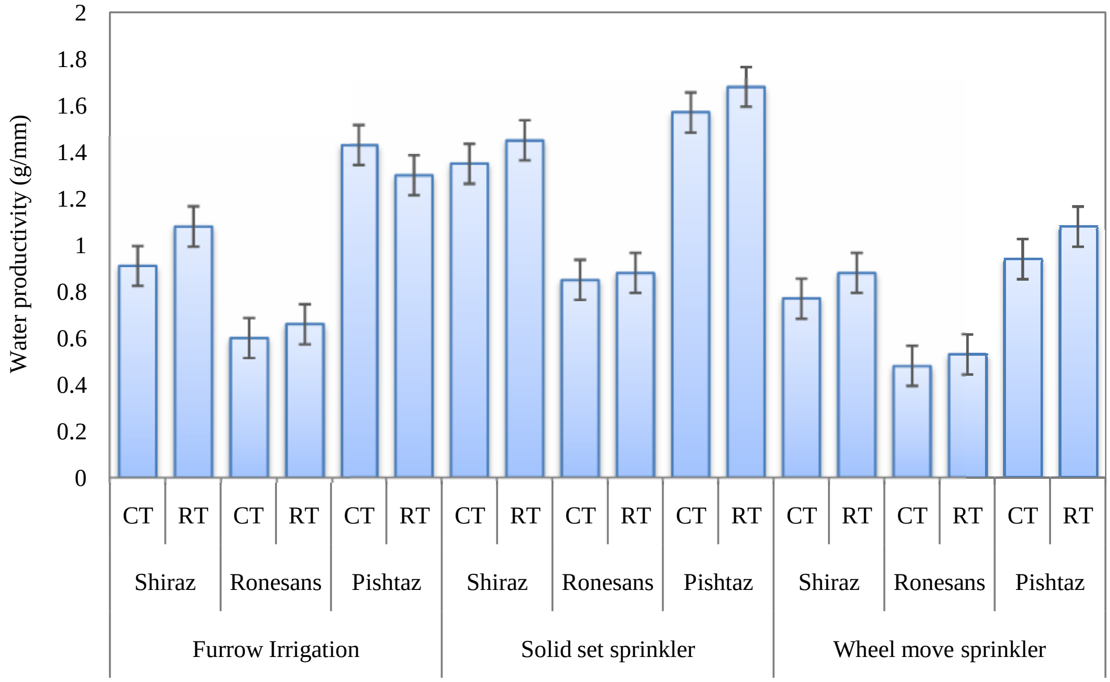

Fig. 1. Interaction effect of tillage systems and irrigation systems on water productivity of wheat cultivars.

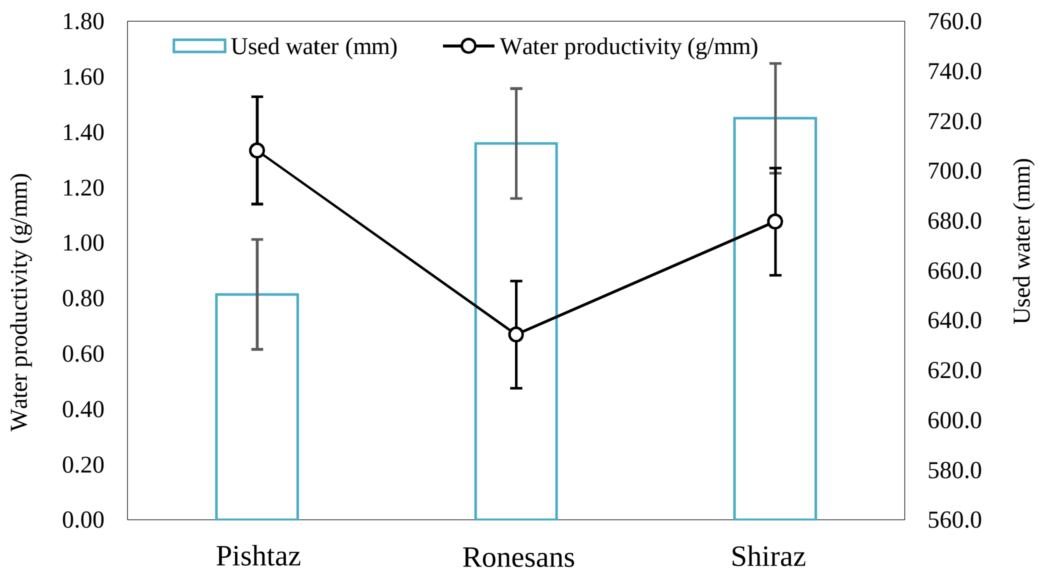

Fig. 2. Used water and water productivity of wheat cultivars.

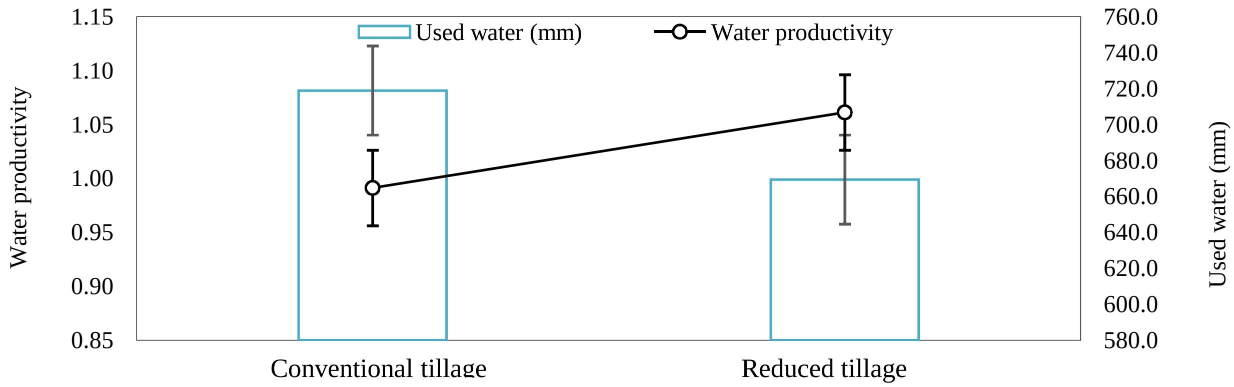

Fig. 3. Used water and water productivity of wheat under two tillage systems.

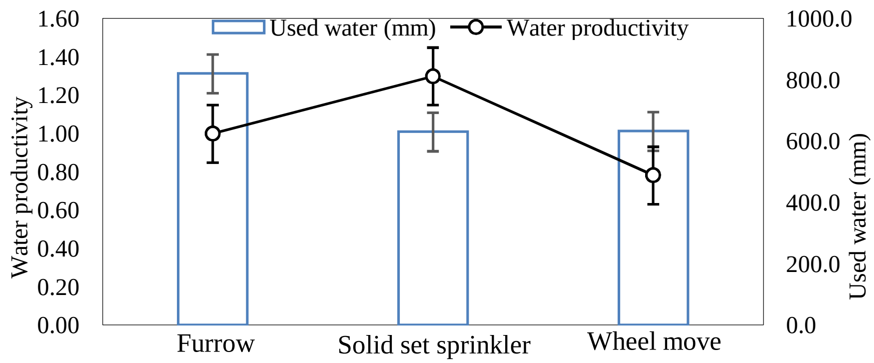

Fig. 4. Used water and water productivity of different irrigation systems.

Water productivity had a very strong correlation with grain yield (r=0.91**), grain weight per spike (r=0.88**), and spike length (r=0.89**) (Table 2). Dagustu (2008) also found significant and positive correlations between grain yield and spike length. Khan *et al.* (2013) also reported a positive correlation between wheat grain yield and number of spikes m^{-2}.

Table 2: Summary of correlation matrix of measured traits.

	UW	WP	SN	GWS	BY	MKW	GY	GNS	SL	HI
UW	1.00									
WP	-0.25	1.00								
SN	0.22	0.82*	1.00							
GWS	0.02	0.88**	0.82*	1.00						
BY	0.13	0.87**	0.94**	0.93**	1.00					
MKW	0.61*	-0.08	0.35	-0.05	0.14	1.00				
GY	0.15	0.91**	0.89**	0.90**	0.96**	0.13	1.00			
GNS	-0.10	0.87**	0.65*	0.85*	0.79*	-0.32	0.84**	1.00		
SL	0.07	0.89**	0.88**	0.96**	0.97**	0.01	0.93**	0.85*	1.00	
HI	0.17	0.27	0.19	0.05	0.05	0.19	0.31	0.32	0.03	1.00

UW: used water, WP: water productivity, SN: spike no/m^2, GWS: grain weight/spike, BY: biological yield, MKW: 1000-seeds weight, GY: grain yield, GNS: grain no/spike, SL: spike length, HI: harvest index

**and * is sign of significance at 0.01 and 0.05 level and no symbol is sign of non-significance.

Path analysis also showed that spike length had the greatest direct effect on grain yield (p=0.88**), followed by number of spike m-2 (p=0.49*). However, number of grains per spike and 1000 seeds weight showed a non-significant path coefficient (p=0.26ns and p=0.15ns, respectively) (Table 3). Our results are in agreement with those of Ahmadizadeh *et al*. (2011) who have shown that spike length had more direct positive effects on grain yield. Okuyama *et al* (2004) found that there was a positive path coefficient between grain yield and number of spikes per m^{-2}. However, Shamsi *et al*. (2011) reported that the most important yield component on grain yield was 1000 grain weight.

Table 3: Summary of path analysis parameters.

Variable	Parameter Estimate	Standard Error	t value	Pr > |t|
Spike number/m^2	0.620	4.24	0.15	0.8844
Grain number/spike	1028.34	357.39	2.88	0.0059
Spike length	118.42	22.73	5.21	<0.0001
1000 seeds weight	1.64	6.41	0.26	0.7992

D. Soil organic C and N

Soil tillage systems affected both soil organic C (SOC) and N (SON) significantly (p<0.05).Soil organic C was higher in reduced tillage (0.69%) compared to conventional tillage (0.65%). Also, soil organic nitrogen was higher in reduced tillage (0.05%) compared to conventional tillage (0.03 %). Neither cultivars nor irrigation methods had a significant effect on these traits (p>0.05). There was no significant interaction effect of any of the treatments (p>0.05) (Fig. 5).

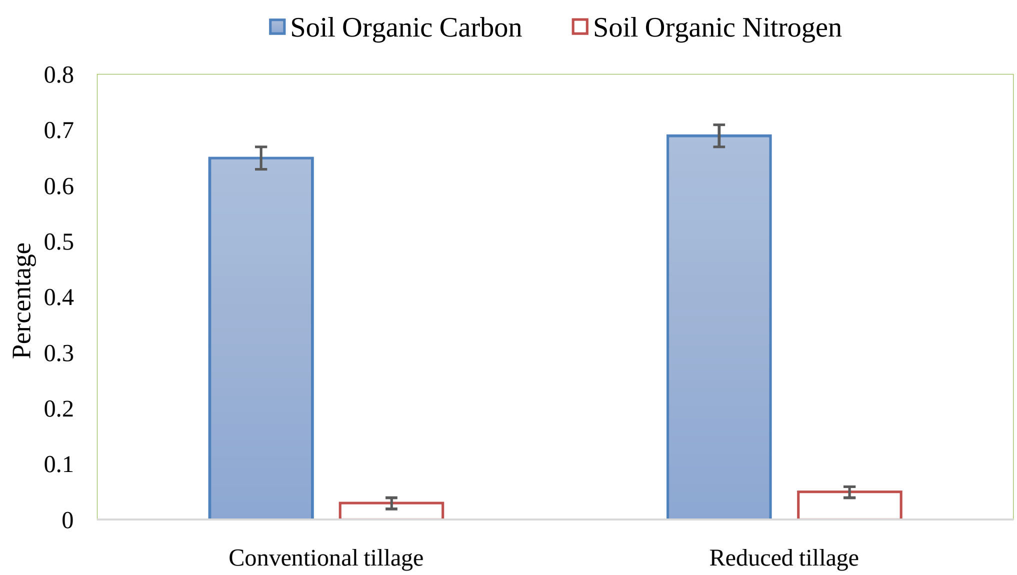

Fig. 5. Effect of tillage method on soil organic carbon and nitrogen percentage.

These results are in accordance with those of Alijani *et al*. (2012) and Naderi *et al*. (2016) who have reported that reduced tillage caused an increase in SOC and SON. Maltas *et al* (2013) also declared that reduced tillage had an increasing effect on soil organic matter in Switzerland's fields. Increasing SOC as a result of reduced tillage might be due to a lower loss by run-off and mineralization (Six *et al*. 2002; West and Post, 2002).

E. Wheat phenology

Fig. 6, 7 and 8 show the effect of tillage method and irrigation systems on wheat cultivars phenology and development rate. The selected phenology stages included sowing to emergence, emergence to stem elongation and stem elongation to physiological maturity.

Data of Fig. 6 shows that cultivar Pishtaz under conventional tillage and solid set sprinkler had the highest number of days (14.3 days) and the lowest development rate (0.07 day^{-1}) from sowing to emergence and cultivar Ronesans under reduced tillage and furrow irrigation had the lowest number days (8.1 days) and the highest development rate (0.123 day^{-1}) from sowing to emergence. On the other hand, under reduced tillage system the days required for emergence were lowered than conventional method. It shows that under reduced tillage system that we have some plant residue on the soil, tap water drops impact on the seeds were less effective and seeds were emerged earlier than conventional tillage system. Basir *et al* (2016) found that early emergence (10 days) was observed in minimum tillage rather than conventional and deep tillage system. The fast emergence in reduced tillage might be because of the minimum soil manipulation, that economize the soil water loss via less evaporation (Licht and Al-Kaisi, 2005) and the soften seedbed helped in fast emergence by early softening of the seed coat (Basir *et al*. 2016). The better emergence in minimum tillage could be due to adequate moisture availability being conserved in reduced tillage (Chiroma *et al*., 2006; Thomas *et al*., 2007; Slawinski *et al*., 2012).

The highest number of days (94.8 days) and the lowest development rate (0.0105 day^{-1}) from emergence to stem elongation was obtained from Ronesans cultivar under reduced tillage and furrow irrigation system and also, the lowest number of days (75.3 days) and the highest development rate (0.0133 day^{-1}) from emergence to stem elongation was obtained from Ronesans cultivar under conventional tillage and wheel move irrigation system (Fig. 7). These data revealed that under reduced tillage, soil temperature was lowered than conventional method and this difference in winter and cold season could affect the rate of development. Cultivar Shiraz under reduced tillage and furrow irrigation system had the highest number of days from stem elongation to physiological maturity (78.2 days) and the lowest development rate (0.0128 day^{-1}), cultivar Pishtaz under reduced tillage and wheel move irrigation system had the lowest number of days from stem elongation to physiological maturity (60.0 days) and the highest development rate (0.0167 day^{-1}) (Fig. 8). However, Basire *et al* (2016) showed that wheat phenology except days to emergence was not affected by different tillage system. Onyari *et al* (2010) reported that tillage system had no effect on crop phenology. It has also been reported that irrigation water applied was linearly related to the duration of the reproductive phase and grain yield (Singh Brar *et al*. 2016).

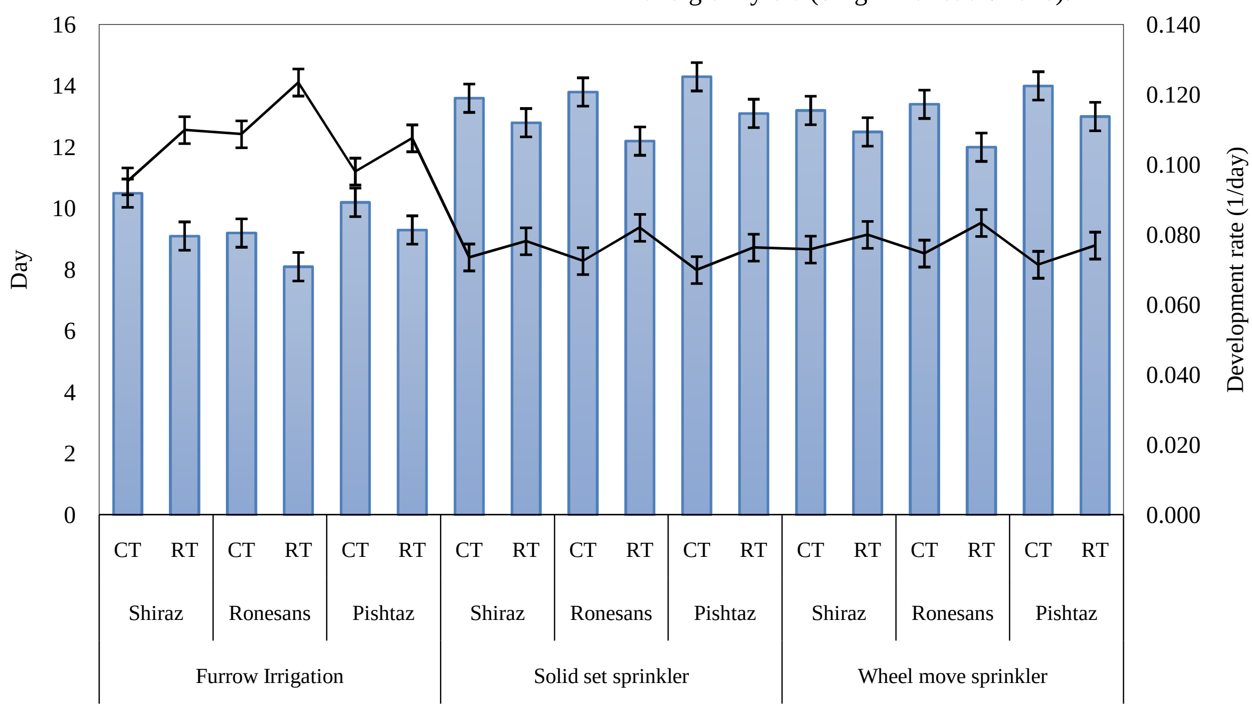

Fig. 6. Days from sowing to emergence for wheat cultivars under different irrigation and tillage systems.

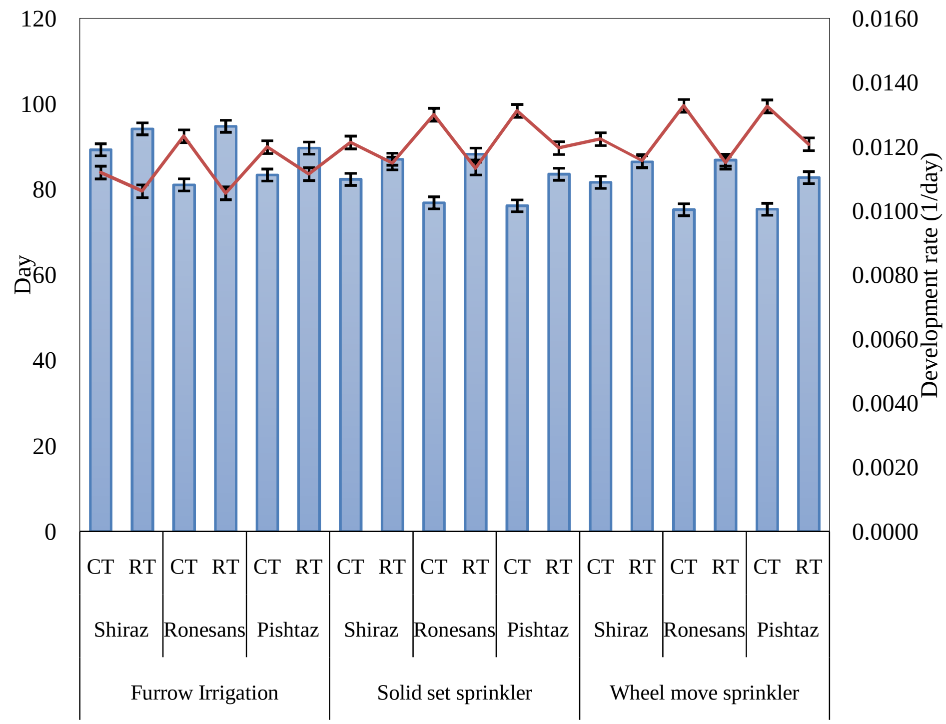

Fig. 7. Days from emergence to stem elongation for wheat cultivars under different irrigation and tillage systems.

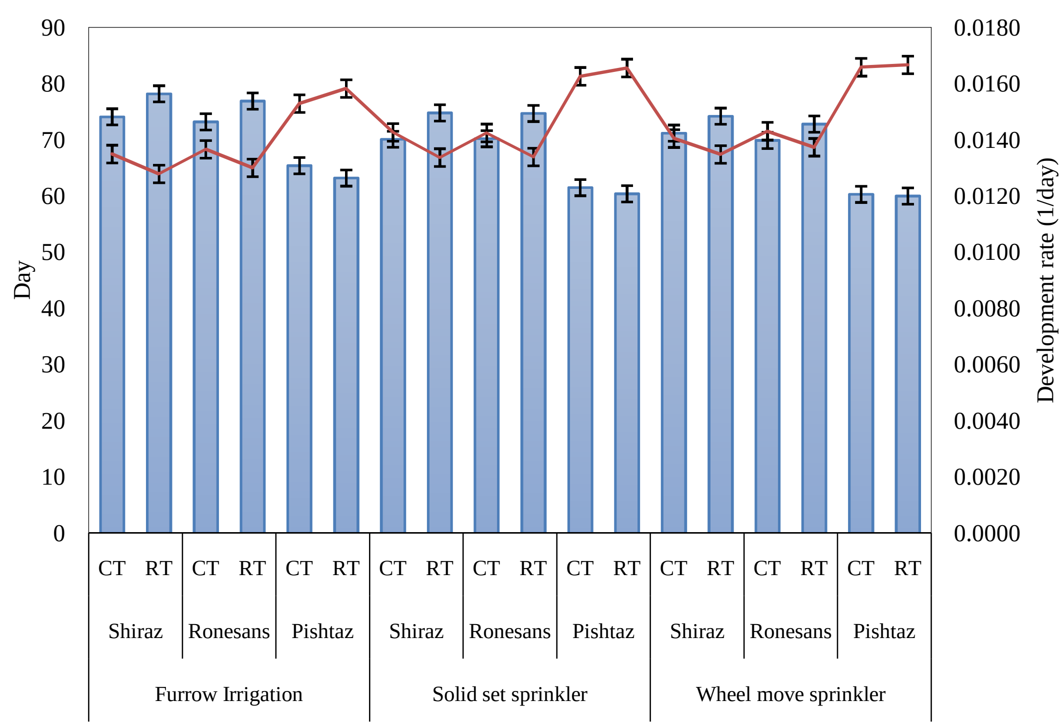

Fig.8. Days from stem elongation to physiological maturity for wheat cultivars under different irrigation and tillage systems.

CONCLUSION

Our results show that Pishtaz cultivar produced more grain yield in conventional tillage system and furrow irrigation. However, this cultivar produced an acceptable amount of yield in reduced tillage and solid set sprinkler irrigation method. Pishtaz cultivar had also the greatest WP in reduced tillage and solid set sprinkler. Therefore, Pishtaz cultivar is good to be recommended to the farmers of the region where water saving is vital over recent water scarcity. Reduced tillage also caused an increase in SON and SOC. Further work should be conducted regarding evaluation of management options to maximize yield and water productivity along with economic evaluation of the different systems.

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