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Effects of different tillage systems, nitrogen and irrigation on growth indicators and water productivity of wheat (*Triticum aestivum*)

ABDOLHOSSEIN ZIAEYAN[1]*, SEYED MAJID MOUSAVI[2], ABOLFATH MORADI[3], ALIDAD KARAMI[4], GHOLAMREZA ZARAEIAN[5] and MOHAMMAD ZIAEIAN[6]

Fars Agricultural and Natural Resources Research and Education Center, AREEO, Shiraz, Iran

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ABSTRACT

During 2015-2017, by using the strip split-split plot design and three line-source sprinkler irrigation systems, effects of 0, 90, 135, and 180 kg N ha^{-1} as urea, 3395, 3850, 4240, and 4610 m^3 water ha^{-1} in conventional, minimum, and no-tillage systems were investigated to determine effects of tillage systems on the wheat (*Triticum aestivum* L) nitrogen and water requirements. Results indicated that the grain yield, component yield and water use efficiency were statistically significant across the tillage systems. Conventional tillage had the higher yield and water use efficiency followed by minimum tillage and then no-tillage. The highest grain yield in the conventional tillage system was achieved by combined application of 4610 m^3 water ha^{-1} and 180 kg N ha^{-1} and in minimum tillage and no-tillage systems were achieved by combined application of 4610 m^3 water ha^{-1} and 135 kg N ha^{-1}. In all tillage systems, combined application of 3850 m^3 water and 135 kg N per hectare is recommendable for the highest water use efficiency.

Key words: Line-source irrigation system, Tillage systems, WUE, Wheat

Wheat (*Triticum aestivum* L) is an important food source for human consumption. It contributes in approximately 29% of the global food grain production, and is vital to the nutritional security of 35% of the global population (Wakchaure *et al*. 2016). Fars province is one of the most important wheat production areas which located in the south of Iran and based on Koppen Climate classification system has mostly arid and semi-arid climate. In arid and semi-arid regions, nitrogen and water are the two major limiting factors controlling wheat production (Abbasi *et al*. 2016). Water stress effects on the photosynthesis and decreases water use efficiency and harvest index of plants (Earl and Davis 2003). Besides irrigation, another strategy to increase water efficiency is to adopt conservation tillage in dry regions (Seufert *et al.* 2012). Conservation tillage by increasing infiltration and soil water retention and reducing evaporation loss, as well as by improving nutrient balances and their availability can be improved water use efficiency (Dahiya *et al.* 2007). In addition, the conservation tillage system may improve nutrient uptake and increase water productivity due to the favorable soil water balance (Zhang *et al*. 2013). In contrast, Sepidedam and Ramroudi (2015) reported that unsuitable physical features influencing water and nutrient transport in soil, undesirable root aeration, and increased weed populations can be the reasons for the grain yield decreases in the conversation tillage. The low amounts of rainfall and low amounts of organic carbon in agronomic soils are main factors affecting crop production in south of Iran. The objective of this research was to study different tillage systems effects on the water use efficiency and yield of wheat and determine optimum amounts of irrigation water and nitrogen rates in theses tillage systems.

MATERIALS AND METHODS

This field study was conducted at the Zarghan Agricultural Research Station (29°77′N and 52°72′E), from October 2015 to July 2017. Each year, soil samples were collected from surface horizon (0 – 30 cm) of the soil. In soil samples, particle-size distribution determined by hydrometer method (Gee and Bauder 1986), TNV was determined by neutralization with HCl (Loeppert and Suarez 1996) and organic carbon were determined by Walkley Black method (Nelson and Sommers 1996). Available Zn, Fe, Mn, and Cu were determined by DTPA extraction (Lindsay and Norvell 1978), phosphorus were determined by sodium

[1]Corresponding author (Abdolhossein.ziaeian@mcgill.ca.), Soil and Water Research Department, Fars Agricultural and Natural Resources Research and Education Center, AREEO, Shiraz, Iran. [2]Soil and Water Research Institute, Agricultural Research Education and Extension Organization (AREEO), Karaj, Iran. majidmousavi@alumni.ut.ac.ir, [3]Soil and Water Research Department, Fars Agricultural and Natural Resources Research and Education Center, AREEO, Shiraz, Iran, moradi1373@gmail.com , Alidad_karami@yahoo.com, zareian48@yahoo.com, [4]M Sc Graduate in MBA, Shiraz University, Shiraz, Iran, Mahan, ziaeyan@gmail.com

Table 1 Some Soil physical and chemical characteristics at the experimental field

Ec	pH	T.N.V.	O.C.	P	K	Mn	Fe	Zn	Fc	PWP	BD	Texture
($dS.m^{-1}$)		($g.100g^{-1}$)				($mg.kg^{-1}$)				(%)	($g.cm^{-3}$)	
1.31	8.1	32.0	0.60	8.5	224	7.7	5.0	0.66	21	11	1.6	SiClL

Table 2 Results of chemical analysis of water used for field irrigation

pH	EC	HCO_3^-	Cl^-	SO_4^{--}	Total anion	Mg^{++}	Ca^{++}	Na^+	Total cation	SAR
	$dS.m^{-1}$					($meq.l^{-1}$)				
8.0	0.48	2.3	1.1	1.1	4.5	1.0	2.2	1.8	5.0	0.62

bicarbonate extraction (Olsen *et al*. 1954) and potassium were determined by NH_4OAc-K extraction.

The experiment design was as a strip split-split plot with 3 replicates. The main plots were no-tillage (NT), minimum tillage (MT) and conventional tillage (CT) systems, subplots were 0, 90, 180, and 270 kg N. ha^{-1} as urea and sub-subplots were 4610 (I1), 4240 (I2), 3850 (I3), and 3395 (I4) m^3. ha^{-1} of irrigation water.

In both years, tillage treatments were conducted after the harvest of previous corn crops according to the designed patterns. No-tillage operations were carried out in the no-tillage system, the land was prepared using a combined tillage machine for the minimum tillage and a moldboard plow, a disk harrow and a leveler were employed for the conventional tillage system. A seed drill was used for all three tillage systems to plant wheat (*Triticum aestivum* L. cv. Sirvan).

Irrigation was applied every 8 days by using the line-source sprinkler irrigation system (Hanks *et al*. 1976) and was calculated through measuring soil moisture amounts in treatment I_1 one day before irrigation using the following equation [1]:

$$I = [(\theta_F - \theta)\ \rho_b\ D]/100 \qquad [1]$$

where, I is the depth of irrigation water (cm), θ_F is the gravimetric soil moisture content at field capacity (%), θ is the available gravimetric soil moisture (cm), ρ_b the soil bulk density ($g.cm^{-3}$), and D is the effective root depth (30 cm). Water use efficiency (WUE) was determined using the following equation (Zhao *et al*. 2019):

$$\text{WUE} = \text{Yied } (kg.ha^{-1})/\text{water used } (m^3.ha^{-1}) \qquad [2]$$

The amount of nitrogen required for each treatment plot in both tillage systems was applied to the soil at planting time, tillering stage, and during the stem elongation periods. Based on the soil test results, triple superphosphate and zinc phosphate were uniformly applied to each plot at the rate of 200 and 40 $kg.ha^{-1}$, respectively. Prior to harvest, grain component and after harvesting water use efficiency and grain yield were measured and analyzed with SAS software, version 9.2. When main effects were significant, the means were compared by using Duncan's multiple range tests.

RESULTS AND DISCUSSION

Crop yield and yield components: The results showed that tillage systems had significant effects on the yield components and grain yield. There were not significant differences between CT and RT in the most of parameters but CT had significant differences with NT (Fig 1 and Table 3). In all tillage systems, by decreasing of the amounts of irrigation water the spike numbers, total yield and grain yield decreases (Fig 2). In a same nitrogen application rate, the amounts of the spike numbers, kernel numbers per spike and 1000-kernel weight were CT > MT > NT but the amounts of grain yield and water use efficiency were MT > CT >NT (Fig 3 and Table 4). As the yield components were significantly higher in CT, the grain yield was higher in CT than in MT and NT by 3.3% and 9.3%, respectively (Fig 1). Similar results have been reported by Ziaeian *et al.* (2018) and is in contrast with Zhang *et al.* (2018) and He *et al*. (2009). Some researcher reported that there were no differences between conservation and convention tillage (Alka Rani *et al*. 2019). The yield reduces of winter wheat in NT can be due to a significantly reduces in the tiller number, resulting in a significant reduction in the panicle number. In addition to, deep ploughing that used in conventional tillage can decrease subsoil density, thereby increase soil water storage and crop yield (Jin *et al*. 2007). Limited root growth due to soil compaction in the no-tillage system can leads to reduced contact between the crop roots and the soil in the root zone, and may decrease plant water and nutrients absorption (Afzalinia *et al*. 2016). Unsuitable physical features influencing water and nutrient transport in soil, undesirable root aeration, and increased weed populations can be the reasons for the decrease in grain yield in the no-tillage system (Sepidehdam and Ramroudi 2015). Reduced establishment of seedlings and their lower rate of early growth, delayed establishment of the seedlings, and high end-season temperatures have also been reported as the factors decreasing yields in no-tillage systems (Ziaeian *et al.* 2018).

In all figures and tables, CT, MT and NT are convention, minimum and no-tillage systems, respectively.

Similar letters in each column demonstrate insignificant differences between the two treatments related to the parameter.

Water use efficiency: Two years results showed that WUE varied with the years and were the higher during 2015–2016 than 2016-2017 by 13.6%, respectively (Fig 4). Irrigation water, nitrogen and tillage treatments had

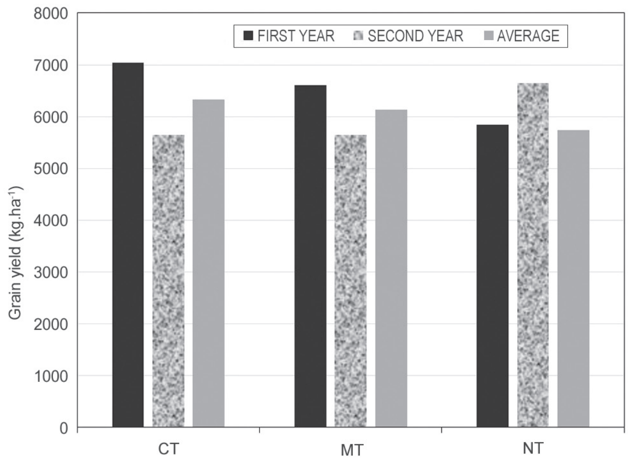

Fig 1 Effects of tillage on the grain yield.

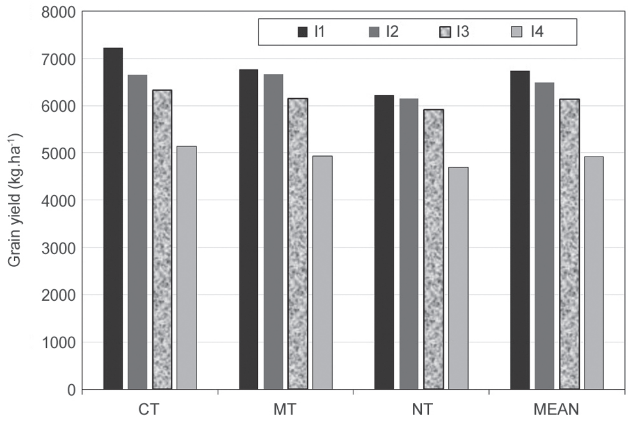

Fig 2 Combined effects of irrigation and tillage on the grain yield.

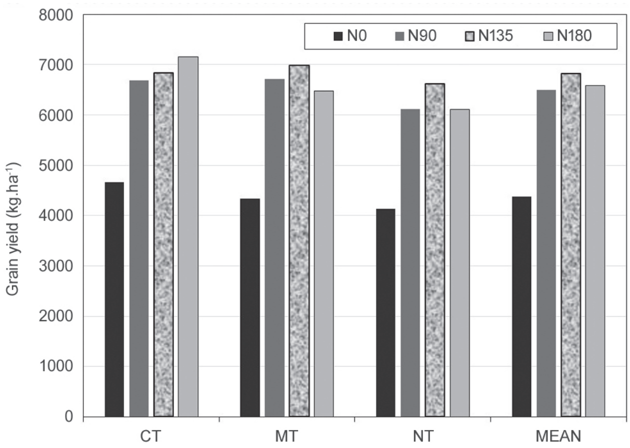

Fig 3 Combined effects of nitrogen and tillage on the grain yield.

significant effects on the water use efficiency. Maximum WUE of all three tillage systems were obtained from application of 3850 $m^3.ha^{-1}$ irrigation water. By decreasing of irrigation water amounts water use efficiency decreased (Table 5). In all three tillage systems maximum water use efficiency were observed from application of N135 treatment (Table 5). Mayres *et al*. (2015) also reported that tillage able to change soil water content by influencing on surface and subsurface soil conditions, continuity and conductivity

Table 3 Effects of tillage systems on the yield components, total yield and harvest index

Tillage treatment	Spike numbers	Kernel numbers per spike	1000-kernel weight (g)	Total yield ($kg.ha^{-1}$)	HI (%)
Conventional tillage (CT)	789 a	32.6 a	37.9 a	16587 a	40.7 a
Minimum tillage (MT)	688 b	31.1 ab	37.2 a	15659 a	39.1 ab
No tillage (NT)	669 c	30.7 b	34.9 b	15412 a	37.3 b

Table 4 Effects of irrigation and nitrogen treatments on the grain yield components in different tillage systems

	Spike numbers			Kernel numbers per spike			1000-kernel weight (g)		
	CT	MT	NT	CT	MT	NT	CT	MT	NT
I1	898 a	795 a	728 a	33.4 a	31.8 a	31.4a	38.6 a	37.3 a	35.2 a
I2	826 b	731 b	699 a	32.4 a	30.8 ab	32.2 a	38.6 a	37.7 a	35.5 a
I3	734 c	657 c	658 b	33.1 a	31.9 a	31.1 a	38.2 a	37.6 a	35.2 a
I4	701 d	570 d	590 c	31.4 a	30.0 b	30.0 a	36.1b	36.4 a	33.7b
N0	718 a	660 a	596 b	29.1 b	29.4 b	28.7 b	37.4 b	36.8 a	34.1 b
N90	747 a	719 a	698 a	33.0 a	31.8 a	30.9 ab	38.3 a	38.1 a	36.2 a
N135	810 a	694 a	707 a	33.1 a	32.1 a	31.1 ab	37.7 ab	37.5 a	35.0 ab
N180	782 a	679 a	674 a	35.1 a	31.3 a	32.1 a	38.1 a	36.6 a	34.4 ab

Similar letters in each column demonstrate insignificant differences between the two treatments related to the parameter

Table 5 Effects of different treatments on the grain yield and WUE

	Grain yield ($kg.ha^{-1}$)			WUE ($kg.m^{-3}.ha^{-1}$)		
	CT	MT	NT	CT	MT	NT
I1	7225 a	6771 a	6226 a	1.57 ab	1.47 b	1.35 c
I2	6652 b	6658 a	6146 a	1.57 ab	1.57 a	1.45 b
I3	6318 c	6154 b	5908 a	1.64 a	1.60 a	1.53 a
I4	5143 d	4927 c	4691 b	1.45 b	1.45 b	1.38 bc
N0	4668 c	4334 c	4136 c	1.16c	1.08 c	1.04 c
N90	6680 b	6711 ab	6111 b	1.66b	1.67 ab	1.52 b
N135	6831 b	6989 a	6623 a	1.70b	1.73 a	1.65 a
N180	7158 a	6475 b	6101 b	1.78a	1.60 b	1.51 b

Similar letters in each column demonstrate insignificant differences between the two treatments related to the parameter of soil pores, permeation rate of water in soil, evaporation rate from soil surface, and contact area between soil and the atmosphere. Adversely, Safari *et al.* (2013) reported that conservation tillage system can improved soil water-holding capacity and water use efficiency via decreasing soil bulk density, increasing soil porosity, and promoting the formation of soil water-stable aggregates, promoted crop yielding.

Irrigation water and nitrogen effects: Based on obtained data, amounts of yield and yield components in CT were higher than MT and MT were higher than NT (Table 6). Water use efficiency also were affected by studied variables and over different treatments ranged from 0·94 to 1·85 $kg.m^{-3}.ha^{-1}$ in conventional tillage, from 0.86 to 1.72 $kg.m^{-3}.ha^{-1}$ in minimum tillage and from 0.97 to 1.80 $kg.m^{-3}.ha^{-1}$

Table 6 Combined effects of various irrigation treatments and tillage systems on grain yield components

	Spike numbers			Kernel numbers per spike			1000-kernel weight (g)		
	CT	MT	NT	CT	MT	NT	CT	MT	NT
I1 N0	852be	779 ab	645ef	29.2 ef	28.9 de	29.5cde	38.5 ab	37.1 ab	33.8 b
I1 N90	899 ab	812 a	714bc	34.8ac	32.4abc	31.7abc	38.7 ab	39.0 a	37.5 a
I1 N135	896ac	813 a	784a	34.8ac	32.5abc	31.3abc	38.1ac	38.1 ab	33.4 ab
I1 N180	947a	776 ab	768a	34.8ac	33.5 ab	33.3 a	39.2 a	35.2 b	33.3 b
I2 N0	778 dg	705 bc	653df	27.6 f	28.3 e	27.7 e	38.4ac	37.3 ab	34.2 ab
I2 N90	852 be	745 ab	706bd	34.3 ad	32.7abc	31.6abc	38.6 ab	37.4 ab	36.3 ab
I2 N135	856 ad	736 bc	747ab	32.4 bf	30.8 ae	29.9 be	38.6 ab	38.4 ab	35.7 ab
I2N180	808 bf	737 bc	688ce	35.4 ab	31.5 ad	31.8abc	38.8 ab	37.7 ab	35.9 ab
I3 N0	642 ij	622 de	581g	29.5df	30.6 be	28.1 de	37.0 ad	37.4 ab	35.2 ab
I3 N90	836 be	710 bc	705bd	31.4 bf	31.9abc	31.0 ad	39.1a	38.3 ab	36.5 ab
I3 N135	759 fh	670 cd	695bd	33.2 be	33.8 a	32.7 ab	38.5ac	37.4 ab	34.6 ab
I3 N180	697ghi	625 de	651df	38.3 a	31.4 ad	32.8 ab	38.2ac	37.1 ab	34.7 ab
I4 N0	602 j	536 f	504h	30.1 cf	29.8cde	29.5cde	35.9 d	35.3 b	33.3 b
I4 N90	803 cf	609 de	667ce	31.6 bf	30.2cde	29.4cde	39.8bd	37.8 ab	34.3 ab
I4 N135	721fi	558 ef	602fg	32.2 bf	31.3 ad	30.6 ae	35.4 d	35.9 ab	33.4 b
I4N180	679 hij	580 ef	586 g	31.8 bf	28.7 de	30.4 ae	36.3 cd	36.5 ab	33.8 b

Similar letters in each column demonstrate insignificant differences between the two treatments related to the parameter

Table 7 Combined effects of different on the grain yield and water use efficiency

	Grain yield ($kg.ha^{-1}$)				WUE ($kg.m^{-3}.ha^{-1}$)			
	CT	MT	NT	Mean	CT	MT	NT	Mean
I1 N0	5179 fg	4324 fg	3963 gh	4488 f	1.12 e	0.94 g	0.86 e	0.97 h
I1 N90	7885 ab	7171 b	6154 cd	7070 b	1.71 ad	1.56cde	1..34 cd	1.53 e
I1 N135	7579 bc	8226 a	7729 a	7845 a	1.64bcd	1.78 ab	1.68 a	1.70 b
I1 N180	8255 a	7363 b	7057ab	7559 a	1.79 ab	1.60 be	1.53 ab	1.64bcd
I2 N0	4810 fg	4568 ef	4374 fg	4584 f	1.13 e	1.08 g	1.03 e	1.08 g
I2 N90	6976 cd	5256cde	7079 ab	7136 b	1.65 ad	1.73 ad	1.67 a	1.68 bc
I2 N135	7250 c	7288 b	6646 bc	7061 b	1.71 ad	1.72 ad	1.57 ab	1.67 bcd
I2N180	7572 bc	7424 b	6485 bc	7160 b	1.79 ab	1.75 ad	1.53 ab	1.69 bc
I3 N0	7604 gh	4703def	4764 f	4690 f	1.20 e	1.22 f	1.24 d	1.22 f
I3 N90	6571 d	6937 b	6285 c	6598cd	1.71 ad	1.80 a	1.63 ab	1.71 ab
I3 N135	7114 cd	7120 b	6601 bc	6945bc	1.85 a	1.85 a	1.72 a	1.80 a
I3 N180	6985 cd	5858 c	5982 cd	6275 d	1.81 a	1.52 e	1.55 ab	1.63 ce
I4 N0	4081 h	3743 g	3443 h	3756 g	1.20 e	1.10 fg	1.02 e	1.11 g
I4 N90	5288 ef	5384 cd	4925 ef	5199 f	1.56 d	1.59 cde	1.45 bc	1.53 e
I4 N135	5385 ef	5323 cd	5514 de	5407 e	1.59 cd	1.57 cde	1.62 ab	1.59 cde
I4N180	5821 e	5256 cd	4880 ef	5319 e	1.71 abc	1.55 de	1.44 bc	1.57 de

Similar letters in each column demonstrate insignificant differences between the two treatments related to the parameter

in no-tillage systems. Maximum WUE were obtained from N135I3 treatments in all three tillage systems (Table 7).

Wheat yield is a function of photosynthesis rate. Drought stress reduces net photosynthesis, accelerates leaf senescence and shortens plant growth, and eventually reduces yield components and grain yield (Kirigwi *et al.* 2004). The grain yield was increased under N fertilization due to the increase of yield components (Table 6), which is basically consistent with the previously reported results (Ziaeian *et al*. 2018). N fertilization significantly enhanced the grain yield due to the increase of productive panicle number, grain number per panicle, and grain filling percentage (Liu *et al.* 2018). Positive effects of nitrogen fertilization on the number of fertile spikelets in the main cluster may be due to increased duration of spikelet initiation caused by the prolonged tillering stage and improved floret fertility (Modhej *et al*. 2008). Based on Subedi *et al*. (2007) report application of sufficient nitrogen leads to increased root growth and improved capability to absorb water from the deeper soil layers under drought conditions while excessive N fertilizer may reduce grain yields and WUE (Bladenopoulos and Koutroubas 2003).

Conclusion

Tillage systems had effected on the irrigation and nitrogen rates, grain yield, yield components and WUE. In the terms of grain yield, maximum grain yield in conventional tillage were obtained from combined application of 4610 m^{-3}.ha^{-1} of irrigation water and 180 kg N.ha^{-1} and in minimum and in no-tillage systems were obtained from combined application of 4610 m^{-3}.ha^{-1} irrigation water and 135 kg N.ha^{-1} (I1N135). In the terms of WUE, I3N135 treatment are recommendable for all of CT, MT and NT systems.

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