J. of Plant Production, Mansoura Univ., Vol. 13 (1):17 - 24, 2022

Journal of Plant Production

Journal homepage & Available online at: www.jpp.journals.ekb.eg

Effect of Tillage Depths and Irrigation Regimes on Wheat Yield, Yield Components and Soil Physical Properties

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ABSTRACT

Two field trials were conducted in the Experimental Farm of Itai AL-Baroud Agricultural Research Station, Al-Behiara Governorate, Egypt, during 2018/2019 and 2019/2020 seasons. The purpose of these experiments was to investigate the effects of three irrigation regimes (excluding sowing irrigation) and three tillage depths (zero tillage (ZT), conventional tillage (CT), and deep tillage (DT)) on physical properties of soil, yield and its components, and water use efficiency (WUE) of wheat cultivar Misr-3. Results indicated that hydraulic conductivity was significantly affected by tillage depths and number of irrigations. Water holding capacity increases significantly under DT. There was a significant interaction effect of tillage and irrigation treatments on WHC. On the contrary, bulk density decreases significantly under DT and CT. The zero tillage gave lower values of total porosity in both soil layers. Soil penetration resistance was significantly lower under tillage (deep, conventional) and irrigation treatments. Plant height, number of spikes/m^2, number of grains/spikes, 1000- grain weight, flag leaf area, grain yield, and biological yield were all highest in wheat plants that were irrigated four times (IR3). Water usage efficiency declined as the number of irrigations increased, with wheat plants watered twice (IR1) having the best water use efficiency. Deep tillage had significantly positive effect on increasing the grain yield and its components compared to conventional tillage and zero tillage. Wheat plants under deep tillage showed the highest consumption of quantity of irrigation water, total used water. The highest consumption of irrigation water under deep tillage associated with the highest water use efficiency.

Keywords: Wheat, Tillage depths, irrigation regimes, Soil physical properties, Yield and its components.

INTRODUCTION

The staple food of the Egyptian people is wheat, it is one of the most important grain crops. Improving the productivity of this crop is a major task because of the lack of supply, which forces the import of about 50% of the required wheat (EL-Gizawy 2009).

The surface irrigation method is a traditional way used in wheat. This means excess water applied and low irrigation efficiency. There is a need to improve the input use efficiency in wheat production. Therefore, follow different conservation practices such as tillage, surface seeding and irrigation manipulation (Gaurav and Kushwaha 2016). Lack of water resources all over the world has become a limiting factor for the development of agriculture, which could lead to a serious threat to global food security (Guan *et al*. 2015)

Tillage improves soil bulk density, penetration resistance, hydraulic conductivity, water movement in the soil, soil compactness, water content and air-filled pore volume and porosity (Hamza and Anderson, 2005; Jabro *et al*., 2010). It also improves root penetration, infiltration of water, water holding capacity, weed control, and the provision of nutrients from the rapid decomposition of organic matter and crop production (Nweke, 2018). The physical properties of soil can be affected by soil tillage (Rashidi and Keshavarzpour.2008; Aikins *et al*., 2012). Various tillage methods showed a wide range of concerns regarding the results to hydraulic conductivity and bulk density of soils (Blanco-Canqui and Ruis,2018). Bulk density increased significantly in loamy soil in a semiarid region with a cool climate by tillage (Gozubuyuk *et al*., 2014; Alletto *et al*.,2015). Maintaining soil moisture requires proper tillage practices that not only improve water infiltration but also maintain sufficient soil moisture for plant growth. (Cornelis *et al*., 2013). Tillage depth affects the physical and chemical properties of soil that affect crop yields. Deep tillage plays a vital role in soil compaction, where breaks the hardpan. Which helps to better exploit the stored soil moisture and applied nutrients (Amanullah *et al*., 2010). Deep tillage increases yields on sites with root-restricting soil layers in areas with erratic rainfall and droughts. It is a tool to increase the availability of nutrients in farming systems with low-input surface soils lacking nutrients (Schneider *et al*., 2017). Deep tillage systems improve water leakage, internal drainage and soil ventilation, which increases the depth and density of the root and permits the deeper placement of fertilizers. Gaurav and Kushwaha (2016) pointed out that, zero tillage was increased bulk density, available water, mean weight diameter while deep tillage gave higher values of hydraulic conductivity. Wheat yield was not affected by tillage while affected by irrigation treatments. There was a significant increase in wheat yield with four irrigations. Water use efficiency values increase significantly with the number of irrigations.

The purpose of this study was to investigate the impacts of three irrigation regimes and three tillage depths on soil physical properties, wheat cultivar Misr-3 yield, yield characteristics and water use efficiency (WUE).

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DOI: 10.21608/jpp.2022.117980.1087

MATERIAL AND METHODS

A field experiment was conducted during the 2018/2019 and 2019/2020 wheat growing seasons in the experimental farm of Itai AL-Baroud Agricultural Research Station, Al-Behera Governorate, Egypt (latitude 30°.89´N and longitude 30º.64´E), Egypt. The preceding crop in both seasons was maize. Before sowing, soil samples were taken and mixed and analyzed (Table 1). The experiment was laid out in a strip-plot design in 3 replicates, three irrigation regimes, excluding sowing irrigation i.e., IR1 (2 irrigations), IR2 (3 irrigations) and IR3 (4 irrigations) were applied in the main plots, each irrigation regime (main-plot) was surrounded by a wide border (7meters) to minimize the underground water permeability. Meanwhile three tillage managements i.e., ZT (zero tillage), CT (conventional tillage with 20 cm depth using chisel plow) and DT (deep tillage with 40 cm depth using sub-soil plow) were placed in sub-plots and the sub-plot size was 42 m^2 (7m. Length x 6m. Width), Bread Wheat Cultivar Misr 3 was used in the study, it was sown on November 19th and November 20th in the first and second seasons respectively, the dry method for sowing was used. All the other recommended practices for wheat growing in the region were done as recommended.

Spile tubes used to measure irrigation water in each plot, The PVC tubes (7.5 cm inner diameter and 60 cm length) were used to allow water to enter into each plot. It calculated the amount of water delivered through the spile tube according to Majumdar, (2002) by the equation:

$$q=CA\sqrt{2gh}$$

Where:

q = Discharge of irrigation water (cm^3/S)
C = Coefficient of discharge = 0.62 (determined by experiment)
A = Inner cross section area of the irrigation spile (cm^2)
g = Gravity acceleration (cm/S^2)
h = Average effective head (cm)

The volume of water delivered for each plot was calculated by substituting Q in the following equation:

$$Q= q \times T \times n$$

Where:

Q = volume of water m^3/plot
q = discharge (m^3/ min)
T = total irrigation time (min)
n = number of spiles tube per each plot.

Table 1. Soil physical and chemical properties for the experimental site.

Properties	Soil
Particle size distribution (%)	
Clay	60.41
Silt	32.5
Sand	7.09
Textural class	Clay
O.M %	0.68
$CaCO_3$ %	3.15
pH (1:2.5)	7.80
EC (dS/m)	1.93
Soluble cations (meq/l)	
Ca^{++}	6.12
Mg^{++}	3.54
K^+	1.56
Na^+	8.17
Soluble anions (meq/l)	
Cl^-	10.11
HCO_3^-	0.85
SO_4^{-}	8.43

Data recorded:

1- Soil physical properties.

After wheat harvesting was taken soil sample from each plot and analyzed. Bulk density (Bd g/cm^3) according to (Blake and Hartge, 1986). Total porosity (TP %) was calculated according to (Klute, 1986). The water holding capacity (WHC %) according to (Inbar *et al*., 1993) hydraulic conductivity (Ks cm hr^{-1}) according to (Klute 1965). To measure penetration resistance (PR kg/cm^2) used a hand-held penetrometer (Eijkelkamp equipment type 1B). The water use efficiency (WUE) was computed as WE (kg ha^{-1} mm^{-1}) = grain yield (kg ha^{-1})/ total water use (mm).

2- Wheat studied traits:

Data for plant height (cm), and the number of spikes/m^2 were measured before wheat harvesting, meanwhile, data for No. of grains per spike (K/S), 1000- grain weight (g), Biological yield (ton/ha) and grain yield (ton/ha) were recorded at harvesting (All the plots area were harvested).

Statistical analysis:

Collected data were statistically analyzed, using the analysis of variance procedures and compared using the LSD test ($P< 0.05$), according to Gomez and Gomez (1984). Homogeneity of variance, of the two seasons, was tested following Bartlett's Test (Steel and Torrie 1980). Combined analyses of variance were performed among the two seasons with homogeneous variance, as outlined by Cochran and Cox (1957).

RESULTS AND DISCUSSION

Results

Effect tillage depths and irrigation regimes on soil physical properties

In all field measurements high homogenous between the two seasons mean square was showed so, data of all filed traits were described as combined data only.

Hydraulic conductivity (Ks) was significantly affected by the depth of tillage and the number of irrigations, which increased with the depth of tillage and water use (Table 2). Hydraulic conductivity increased under IR3 (0.93 and 0.34 cm h^{-1}) followed by IR2 (0.83 and 0.18 cm h^{-1}) and IR1 (0.71 and 0.09 cm h^{-1}), respectively in the 0-20 and 20-40 cm soil layer. Hydraulic conductivity (Ks) increased significantly under DT (0.94 and 0.29 cm h^{-1}) followed by CT (0.83 and 0.18 cm h^{-1}) and ZT (0.70 and 0.15 cm h^{-1}), respectively in the 0-20 and 20-40 cm soil layer. The values of Ks under DT with IR3 were higher than the other treatments. The effects of interaction tillage and irrigation treatments (DT with IR3 treatment) were significant in the 0-20 and 20-40 cm soil layers followed by CT with IR3 treatment.

As shown in Table (2) water holding capacity (WHC) increased significantly under DT (59.44 and 48.46 %) followed by CT (57.09 and 46.86%) and ZT (54.74 and 45.52 %), respectively in the 0-20 and 20-40 cm soil layer. While irrigation treatments did not affect WHC in both soil layers. It was observed that the water holding capacity decreased with depth. There was a significant interaction effect of tillage and irrigation treatments on Water holding capacity (WHC). The values of water holding capacity (WHC) under DT with IR3 were higher than the other treatments (59.80 %), in the 0-20 cm soil layer. As shown in Table 2, bulk density increased under ZT (1.16 and 1.17 g/cm3) followed by CT (1.10 and 1.14 g/cm3) and DT (1.09 and 1.11 g/cm3), respectively in the 0-20 and 20-40 cm soil layer. It was observed that the bulk density increased with depth. There was a significant interaction effect of tillage and irrigation treatments on bulk density (BD). The values of bulk density (BD) under DT with IR3 were less than the other treatments (1.08 g/cm^3), in the 0-20 cm soil layer.

Table 2. Effect of tillage depths and irrigation regimes on soil physical properties in surface 0-20 cm (A) and sub-surface 20-40 cm (B) layer.

Treatment		Hydraulic conductivity (Ks) cm hr^{-1}		WHC %		Bulk density BD g/cm^3	
		A	B	A	B	A	B
Irrigation regimes							
IR1		0.71	0.09	56.90	46.97	1.11	1.14
IR2		0.83	0.18	57.12	47.09	1.12	1.14
IR3		0.93	0.34	57.25	46.77	1.13	1.15
LSD 0.05		0.15	0.05	Ns	Ns	Ns	Ns
Tillage depths							
ZT		0.70	0.15	54.74	45.52	1.16	1.17
CT		0.83	0.18	57.09	46.86	1.10	1.14
DT		0.94	0.29	59.44	48.46	1.09	1.11
LSD 0.05		0.12	0.03	3.50	2.38	0.02	0.03
Interaction							
IR1	ZT	0.48	0.09	54.50	45.33	1.15	1.17
	CT	0.76	0.09	57.20	46.80	1.10	1.15
	DT	0.89	0.10	59.00	48.80	1.09	1.10
IR2	ZT	0.77	0.13	54.03	45.70	1.15	1.16
	CT	0.80	0.15	57.80	47.00	1.11	1.14
	DT	0.93	0.26	59.53	48.59	1.10	1.12
IR3	ZT	0.85	0.24	55.70	45.53	1.18	1.18
	CT	0.95	0.29	56.27	0 46.8	1.11	1.14
	DT	1.00	0.50	59.80	48.00	1.08	1.12
LSD 0.05		0.17	0.04	4.95	3.37	0.03	0.05

***Ns: Not significant**

The zero tillage gave the lower values of total porosity TP % Table (3). It was observed that total porosity TP % decreased with depth and increase with deep tillage. Where total porosity TP % increased under DT (58.87 and 57.99 %) followed by CT (58.24 and 56.86 %) followed by ZT (56.23 and 55.85 %), respectively in the 0-20 and 20-40 cm soil layer. Total porosity TP % was significantly at the deep tillage (0-20 and 20 to 40 cm). While irrigation treatments did not affect on total porosity in both soil layers. There was a significant interaction effect of tillage and irrigation treatments on total porosity. The values of total porosity under DT with IR3 were bigger than the other treatments (58.87 %), in the 0-20 cm soil layer

Table 3. Effect of tillage depths and irrigation regimes on soil physical properties in surface 0-20 cm (A) and sub-surface 20-40 cm (B) layer.

Treatments		Total porosity TP %		penetration resistance (PR) kg/cm^2	
		A	B	A	B
Irrigation regimes					
IR1		58.11	56.98	28.53	43.33
IR2		57.73	56.98	28.26	42.53
IR3		57.48	56.73	25.83	38.26
LSD 0.05		NS	NS	NS	3.43
Tillage depths					
ZT		56.23	55.85	32.20	45.60
CT		58.24	56.86	29.16	45.36
DT		58.87	57.99	21.26	33.16
LSD 0.05		0.88	1.21	3.50	2.94
Interaction					
IR1	ZT	56.60	55.85	33.30	50.00
	CT	58.49	56.60	30.00	45.00
	DT	59.25	58.49	22.30	35.00
IR2	ZT	56.60	56.23	33.30	47.50
	CT	58.11	56.98	30.00	46.60
	DT	58.49	57.74	21.50	33.50
IR3	ZT	55.47	55.47	30.00	39.30
	CT	58.11	56.98	27.50	44.50
	DT	58.87	57.74	20.00	31.00
LSD 0.05		1.24	1.71	4.95	4.16

***Ns: Not significant**

As shown in Table 3, penetration resistance (PR) gave the highest values in zero tillage. It was observed that penetration resistance (PR) increased with depth and decrease with deep tillage. The soil penetration resistance was found to be significantly lower under tillage (deep, conventional) and irrigation treatments. Where penetration resistance decreased under DT (21.26 and 33.16 kg/cm^2) followed by CT (29.16 and 45.36 kg/cm^2) followed by ZT (32.2 and 45.60 kg/cm^2), respectively in the 0-20 and 20-40 cm soil layer. The effects of interaction tillage and irrigation treatments to (DT with IR3 treatment) were significant in the 0-20 and 20-40 cm soil layers, compared with the other treatments. This may be due to the volume pore of soil as a result of compaction which affected the total porosity TP % and penetration resistance (PR). The values of penetration resistance (PR) under DT with IR3 were less than the other treatments (20 and 31 kg/cm^2), respectively in the 0-20 and 20-40 cm soil layer.

Effect of tillage depths and irrigation regimes on wheat yield and its components

In all field measurements high homogenous between the two seasons error mean square was showed so, data of all filed traits were described as combined data only.

The results presented in Table 4 confirmed the presence of the significant effect of irrigation treatments and tillage depths and their interaction on all characteristics of the grain yield and its components.

A- Effect of irrigation regimes.

It was clear from the data presented in Table 4 that the entire yield and its components traits gradually increased with the increase of number of irrigations. Wheat plants that irrigated 4 times during the growing season (IR3) gave the highest: plant height (108.11 cm), number of spikes/m^2 (398.89), number of grains/spike (52.96), 1000-grain weight (51.85 g), flag leaf area (43.31 cm²), grain yield per hectare (7.83 tons) and biological yield per hectare (21.94 tons). Except for plant height, number of spikes/m^2, and flag leaf area of wheat plants that irrigated three times (IR3) across the growing season. Meanwhile, wheat plants that irrigated four times (IR3) significantly outperformed wheat plants that irrigated twice (IR 1) or three times (IR2) during the growing season in all yield and yield component traits (IR2).

B- Effect of tillage depths.

The results presented in Table 4 showed that there was a significant difference in all yield and its components traits under different tillage depths, except for 1000-grain weight. Deep tillage (DT) had a considerable positive impact on increasing the grain yield and its components compared to conventional tillage (CT) and no tillage (ZT), as wheat plants under deep tillage gave the highest: plant height (110.07 cm), number of spikes/m^2 (396.33), number of grains per spike (52.31), flag leaf area (46.85 cm²), grain yield (7.33 tons/ha) and biological yield (20.61 tons/ha). Despite the superiority of deep tillage in the previous traits, this superiority was not significant compared to the overnight tillage for number of spikes/m^2 and grain yield per hectare. The results also confirmed that a gradual increase in all yield and its components with the increase of tillage depths.

C- Effect of the interaction.

Data in Table 4 confirmed that wheat plants differ their responses in all tested traits as a result of the difference tillage depths and irrigation regimes.

For plant height the results showed that wheat plants that irrigated four times (IR3) under conventional tillage (CT) were the tallest (111.56 cm) followed by wheat plants that irrigated three times (IR2) under deep tillage (DT) with an average of 110.22 cm. Under deep tillage (DT) wheat plant that irrigated three (IR2) and four times (IR3) showed the highest number of spike/m^2 (426.00 and 412.67 spike/m^2), respectively but these values did not differ significant with those obtained by wheat plants that irrigated three (IR2) and four times (IR3) under conventional tillage (CT) (401.33 and 396.33 spike/m^2). The highest grains number/spike was obtained by wheat plants that irrigated four times (IR3) under deep tillage (DT) with an average of 55.20. Respect to 1000-grain weight wheat that irrigated twice (IR1), three times (IR2) and four times (IR3) under deep tillage (DT) showed the highest 1000- grain weight (52.35, 51.53 and 51.66 g), respectively. wheat plants that irrigated four times (IR3) under conventional tillage (CT) had the highest flag leaf area (49.08 cm^2) followed by the same irrigation treatment under zero tillage (48.05 cm^2) then wheat plants that irrigated three times (IR2) under deep tillage with an average of 45.55 cm^2. The highest grain yield/ha was obtained under deep tillage from wheat plants that irrigated three times IR2 (8.58 tons/ha) flowed by IR3 (8.42 tons/ha). In the same line wheat plants that irrigated four times (IR3) under deep (DT) had the highest biological yield/ha (24.55 tons/ha).

Table 4. Effect of tillage depths, irrigation regimes and their interactions on wheat yield and yield components.

Treatments		Plant Height (cm)	No. of spikes/m^2	No. of grains /Spike	1000- grain Weight(g)	Flag leaf area(cm^2)	Grain yield (Ton/ha)	Biological yield(Ton/ha)
				Irrigation regimes				
IR1		107.15	361.56	48.62	48.43	41.17	6.217	16.55
IR2		106.97	377.50	50.24	49.68	44.02	6.701	18.33
IR3		108.11	398.89	52.96	51.85	43.31	7.834	21.94
LSD 0.05		0.67	25.81	0.44	1.32	1.48	0.34	0.56
				Tillage depths				
ZT		103.81	342.11	49.44	49.58	38.35	6.138	16.69
CT		108.82	404.89	50.07	50.52	43.54	7.333	19.60
DT		110.07	396.33	52.31	50.18	46.85	7.325	20.61
LSD 0.05		1.02	21.61	1.23	Ns	2.75	0.35	0.77
				Interaction				
	ZT	103.55	317.33	47.40	46.77	34.10	5.68	14.87
IR1	CT	103.22	351.00	50.00	49.63	39.99	6.23	17.22
	DT	104.67	358.00	50.93	52.35	40.97	6.50	17.97
	ZT	108.67	387.33	47.13	49.55	41.36	6.52	16.98
IR2	CT	107.56	401.33	50.33	50.47	43.70	6.90	18.52
	DT	110.22	426.00	52.73	51.53	45.55	8.58	23.28
	ZT	109.22	380.00	51.33	48.97	48.05	6.45	17.81
IR3	CT	111.56	396.33	50.40	49.90	49.08	7.10	19.48
	DT	109.44	412.67	55.20	51.66	43.42	8.42	24.55
LSD 0.05		1.45	30.61	1.75	2.05	3.9	0.49	1.10

***Ns: Not significant**

Effect of tillage depths, irrigation regimes on total used water and water use efficiency during 2018 and 2019 seasons:

Data in Table 5 revealed that quantity of irrigation water, total used water and water use efficiency were significantly affected by the number of irrigation and tillage depth and the interaction between them in both seasons.

Results in Table 5 showed that the quantity of irrigation water and total used water gradually increased while water use efficiency gradually decreased with the increase of the number of irrigations. Wheat plants that irrigated 2 times during the growing season (IR1) consumed the lowest quantity of irrigation water (413.31 and 373.54 mm) and total used water (470.72 and 493.09 mm) the lowest quantity of used water in this treatment associated with the highest water use efficiency (12.65 and 12.83). in contrast irrigated wheat plants 4 times (IR3) consumed the highest quantity of; irrigation water (669.63 and 623.84 mm), total used water (727.04 and 743.39 mm) and the same treatment showed the lowest water use efficiency (9.58 and 10.28) in both seasons, respectively.

Table 5. Effect of tillage depths, irrigation regimes and their interactions on water use efficiency.

Factors		2018/2019			2019/2020		
		Irrigation (mm)	TUW(mm)	WUE	Irrigation(mm)	TUW(mm)	WUE
			Irrigation regimes				
IR1		413.31	470.72	12.65	373.54	493.09	12.83
IR2		551.03	608.44	11.59	506.95	626.50	12.10
IR3		669.63	727.04	9.58	623.84	743.39	10.28
LSD 0.05		42.76	42.76	0.52	41.75	41.75	0.44
			Tillage depths				
ZT		492.49	549.90	11.23	453.84	573.39	11.42
CT		551.83	609.24	10.82	504.14	623.69	11.43
DT		589.66	647.07	11.76	546.35	665.90	12.36
LSD 0.05		29.98	29.98	0.37	29.16	29.16	0.33
			Interaction				
	ZT	373.17	430.58	12.66	329.43	448.98	13.16
IR1	CT	421.70	479.11	12.74	387.97	507.52	12.52
	DT	445.07	502.48	12.55	403.23	522.78	12.81
	ZT	486.30	543.71	11.87	452.65	572.20	11.51
IR2	CT	563.80	621.21	10.55	508.33	627.88	11.54
	DT	603.00	660.41	12.34	559.87	679.42	13.26
	ZT	618.00	675.41	9.17	579.45	699.00	9.60
IR3	CT	670.00	727.41	9.18	616.12	735.67	10.23
	DT	720.90	778.31	10.39	675.96	795.51	11.01
LSD 0.05		39.75	39.75	0.49	38.67	38.67	0.43

Note: the amount of rainfall was 57.41 mm in 2018/2019 and 119.55 mm in 2019/2020 season.

The results in Table 5 indicated that there was a significant difference in the quantity of irrigation water, total used water and water use efficiency under different tillage depths. Wheat plants under deep tillage (DT) showed the highest consumption of quantity of irrigation water (589.66 and 546.35 mm), total used water (647.07 and 665.90mm). the highest consumption of water under deep tillage is associated with the highest water use efficiency (11.76 and 12.36) in both seasons, respectively. On the other side, wheat plants under zero tillage (ZT) showed the lowest quantity of irrigation water, total used water, and the lowest water use efficiency in second seasons, respectively.

Wheat plants that were irrigated two times (IR1) under the three tillage depths consumed a low quantity of irrigation water, total used water and showed the highest water use efficiency in both seasons. Wheat plants that irrigated twice (IR1) under zero tillage (ZT) consumed the lowest quantity of irrigation water (373.17 and 329.43 mm) and total used water (430.58 and 448.98 mm) in both seasons, respectively. The highest water use efficiency was obtained when wheat plants were irrigated twice under conventional tillage in the first season (12.74) while the highest water use efficiency in the second season was obtained when wheat plants were irrigated three times under deep tillage (13.26).

Discussion

Hydraulic conductivity (Ks) was significantly affected by tillage and the number of irrigations. This is due to the depth of tillage, where leads to the reorganization of pores which increases the permeability of the soil. The results are in agreement with (Bhattacharyya *et al.,* 2008; Jabro *et al*., 2010; Gaurav and Kushwaha 2016). Soil hydraulic conductivity is affected by tillage, rainfall and wetting (Schwen *et al*.,2011). There was a significant interaction effect of tillage and irrigation treatments on Water holding capacity (WHC). This was mainly attributed due to the deep tillage and conventional tillage can help increase water holding pores and permeability of the soil to increase its water absorption capacity and helps in better uptake of water (Rodamin and Haydee 2009). Any tillage process changes the bulk density of the soil in turn modifies the pore size distribution, infiltration rate and water holding capacity (Kuzucua and Dökmen 2015). Deep tillage is more helpful to conserve moisture in the soil than shallow tillage practices (Amin *et al*., 2014). Kahlon and Khurana. (2017) reported that deep tillage (DT) enhances Ks and the rooting system by reducing the strength of soil which helps uptake better water and nutrients from the deeper layers. On the other side, conservation tillage enhances soil water transmission, moisture storage and crop yield. The soil penetration resistance was significantly lower under tillage (deep, conventional) and irrigation treatments (IR2, IR3). This may be due to the volume pore of soil as a result of compaction which affected the total porosity TP % and penetration resistance (PR) (Amin *et al*., 2014; Kahlon and Khurana 2017). Strudley *et al*., (2008) found that the bulk density, porosity, hydraulic conductivity, and infiltration rates were greatly affected by various tillage. Therefore, the choice of any tillage system is critical to maintaining the soil physical properties necessary for the growth of crops. No-till refers to the formation of a hard layer, which limits the downward movement of water and the penetration of roots. The depth of tillage improved soil physical quality (water content, bulk density, hydraulic conductivity) (Jabro *et al*., 2010; Gholami *et al* 2014; Karen *et al*., 2019; Xuezhang *et al*., 2020). It caused reduce in soil penetration resistance resulted in increased drainage (Agostini *et al*., 2012). The practice of tillage enhanced nutrient availability, retention of moisture in the soil, percent porosity, soil organic carbon, infiltration rate and efficient water uptake resulting in increased grain yield (Shahbaz *et al*., 2017). Tillage of soil is favorable for root proliferation. The practice of tillage improves soil structure and increases plants resistance to water stress (Shao *et al*., 2016).

It can be regarded as the tillage and irrigation of the most important management practices, both of which affect the productive capacity of crops and hydro-physical properties of soil **(**Blanco-Canqui and Lal 2007).

Our results confirmed that all the yield and its components traits gradually increased with the increase of the number of irrigations where wheat plants that irrigated 4 times during the growing season (IR3) gave the highest: plant height, number of grains/spikes, number of spikes/m^2, 1000-grain weight, flag leaf area, grain yield per hectare and biological yield per hectare.

In the previous studies, higher grain yield and straw yield of wheat were obtained when irrigations were applied five times. Whereas, water stress in the phases of tillering, flowering and grain filling stages led to a decrease in both the grain yield and plant biomass in wheat (Gaurav and Kushwaha 2016). applied 660 mm water to the wheat, which is 20% less than the average irrigation used by local farms, yet, increased growth and grain yield 4–18% greater than normal irrigation with a 38% increase of WUE than those obtained by local farms (Yang *et al*., 2011)**.** Water may activate many important morphological and physiological processes, such as stomatal conductance and leaf enlargement. Water stress for plants loses their turgor therefore cell expansion and growth are decreases (Siddique *et al*., 2000)**.**

Also, our findings revealed that water use efficiency gradually decreased with the increase of the number of irrigations where wheat plants that irrigated 2 times during the growing season (IR1) consumed the lowest quantity of irrigation water and total used water and the lowest quantity of used water in this treatment associated with the highest water use efficiency. Similar results were obtained before by, Bhattacharyya *et al*., (2006) who observed that WUE was higher on the most tilled plots compared to the no-till plots and reduce with an increasing number of irrigations**.** Deshmukh *et al*. (1997) also found that the highest level when one irrigation was applied is in the initiation stage of the crown roots. The WUE was decreased when the irrigation frequency was increased from one to five.

In this study, deep tillage (DT) had a significantly positive effect on increasing the grain yield and its components compared to conventional tillage (CT) and no-tillage (ZT)**.** In the previous study, conventional tillage for wheat results in more compact soil, and a hardpan is usually developed underneath the plow layer, hindering air and water movements, and consequently inhibiting root growth and reducing crop yield (Huang *et al*. 2012)**.** deep tillage can decrease the effect of soil compaction on crop growth (Jennings *et al*. 2012) as well as increase rooting depth and the amount of water available to the crop (Mohanty *et al*.2007). Deep tillage (DT) may be an effective measure to increase wheat yield (Guzha, 2004; Zheng *et al*., 2014). This may be due to deep tillage management practices help conserve soil moisture and improve grain yield. In this study wheat yield and growth were larger in conventional tillage than zero tillage. This find is in agreement with those of Gangwar *et al*., (2004) They observed that among the different tillering levels, conventional tillage registered the highest grain yield of wheat followed by ZT. Several workers also reported increased yields with conventional tillage over zero tillage in wheat (Singh *et al*. 2001).

In the present study, wheat plants under deep tillage (DT) showed the highest consumed quantity of irrigation water, total used water. the highest consumption of water under deep tillage associated with the highest water use efficiency**.** Agricultural conservation technologies maintain soil and water and increase soil moisture content (Balwinder-Singh *et al.*2011)**.** deep tillage improves soil water storage capacity (Fabrizzi *et al.*,2005)**.** Balwinder-Singh *et al.*(2011) and Ghuman and Sur (2001) found that conventional tillage improved the WUE and keep the best storage of soil water during the growth stages of wheat more than the minimum tillage and no-tillage and this may be due to deep tillage can effectively maintain soil moisture, efficiently reduce water and wind erosion, and significantly increase crop yield and WUE (Huang *et al*., 2008).

CONCLUSION

Based on the aforementioned discussion, it could be concluded that the hydraulic conductivity (Ks) was significantly affected by the depth of tillage and the number of irrigations. Water holding capacity (WHC) increases significantly under DT in both soil layers. On the contrary, bulk density decreases significantly under DT and CT. As well as irrigation treatments did not effect on WHC and bulk density in both soil layers. There was a significant interaction effect of tillage and irrigation treatments on water holding capacity (WHC). The zero tillage gave the lower values of total porosity TP % in both soil layers. The soil penetration resistance was significantly lower under tillage (deep, conventional) and irrigation treatments. While penetration resistance (PR) increases values with the deep layer. In order to get the highest yield of wheat crop in the clay soil and saving irrigation water, it can be recommended to use deep tillage practice (40 cm depth) and adding three irrigations (excluding sowing irrigation), since this treatment does not differ significantly from giving four irrigations with conventional tillage depth.

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تأثيرعمق الحرث ومعدلات الري على محصول القمح ومكوناته وعلى الخصائص الفيزيائية للتربة

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أجريت تجربتان حقليتان فى المزرعة البحثية لمحطة البحوث الزراعية بإيتاى البارود بمحافظة البحيرة – مصر خلال موسمي 2019/2018 و 2020/2019 بهدف دراسة تأثير كل من معدلات الري (ريتين و ثلاث ريات وأربعة ريات بخلاف رية الزراعة) وكذلك تأثير عمق الحرث (بدون خدمة و الحرث التقليدى والحرث العميق) على الخواص الفيزيائية للتربة وعلى المحصول ومكوناته وكفاءة استخدام مياه الري لصنف قمح الخبز مصر-3. اشارت النتائج الي التالي ان التوصيل الهيدروليكي تاثرا معنويا بعمق الحرث وعددالريات.كما ان سعة الاحتفاظ بالماء تزداد معنويا مع عمق الحرث.وكان لتداخل معاملات الحرث والري تأثير معنويا علي سعة الاحتفاظ بالماء. علي العكس من ذلك تقل الكثافة الظاهرية بشكل ملحوظ مع عمق الحرث.قلت المسامسة الكلية معنويا مع عدم الحرث في كلا طبقتين التربة.في حين ان مقاومة الاختراق قلت معنوياً مع الحرث العميق و الحرث التقليدي و معاملات الري. نباتات القمح التى أُعطيت أربعة ريات (معاملة الرى الثالثة) أظهرت أعلى القيم لكل من؛ ارتفاع النبات، عدد السنابل بالمتر المربع، عدد الحبوب بالسنبلة، وزن الألف حبة، مساحة ورقة العلم، المحصول البيولوجى ومحصول الحبوب. انخفضت كفاءة استخدام المياه تدريجياً مع زيادة عدد الريات حيث أظهرت نباتات القمح التي تم ريها مرتين خلال موسم النمو (معاملة الرى الأولى) أعلى كفاءة في استخدام المياه. كان للحرث العميق تأثير معنوي علي زيادة محصول الحبوب ومكونات المحصول مقارنة بالحرث التقليدي وعدم الحرث (الزراعة بدون خدمة) وأظهر محصول القمح تحت معاملة الحرث العميق أعلى كمية مستهلكة من مياه الرى.