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Effects of Deficit Irrigation Regimes and Potassium Fertilization Levels on the Drought Tolerance and Water Productivity of Three Wheat Cultivars

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ABSTRAT

A field experiment was conducted during winter season of 2011/2012 and 2012/2013 under sprinkler irrigation at Abdel Monem Riad Village (31 02 N latitude and 30 28 E longitude and altitude of 6.7 m above sea level), El-Bustan area, representing the newly reclaimed sandy soils of West Nile Delta, Egypt. The investigation aims to study the effect of deficit irrigation regimes and rates of potassium fertilizer on grain yield, № of spikesm^{-2}, 100–kernels weight, kernels№ spike^{-1}, days to heading (HD), days to maturity (MD), amounts of applied irrigation water, water productivity of three wheat cultivars *vs* Sakha 93 Giza168 and Gemmiza9. The drought tolerance indices e.g. Drought susceptibility index (DSI) and Drought Tolerance Efficiency (DTE%) were considered. The irrigation regimes were represented in main plots, and sub and sub-sub plots were assigned for K fertilization levels and wheat cultivars, and each treatment was replicated 3 times. The important findings could be as follows: -Wheat grain yield and the assessed yield components e.g. № of spikesm^{-2}, 100–kernels weight and kernels № spike^{-1} as well as HD and MD physiological traits were reduced due to the tested DI techniques, comparable with the control. Leaf water potential (-bar) was increased, whereas seasonal applied water was decreased under the assessed DI regimes, comparing with the control. The highest WP values were recorded with DI_{50} irrigation regime. -The assessed K levels exhibited inconsistent and undistinguished trends as affecting most of the tested parameters. Such findings may be attributed to the improper method of K application. -The drought tolerance indices DSI and DTE% referred that Gemmiza9 is the proper wheat variety to be cultivated under the present experiment circumstances and may be at similar locations as well. -The tertiary interaction of control$_{100\%\ ETc}$ irrigation regime, K_1 level and Gemmiza 9 wheat variety exhibited the highest grain yields i.e. 3.38 and 3.73 tonfed^{-1}in 1st and 2nd seasons, respectively.

Keywords: Wheat cultivars, Deficit irrigation regimes, K levels, Yield and its components, Water productivity, Drought tolerance.

INTRODUCTION

Wheat (*Triticum aestivum* L.), the key staple food crop in Egypt, and occupies about 33 percent of the total winter crop area, accounts for consuming 9 percent of water resources, and contributes 17 percent of the total value added in Egyptian agriculture. Because of its importance in the Egyptian diet, wheat is considered a strategic commodity in the country. Egyptian imports of wheat increased 21.8%, from 6.7 million metric tons to 8.1 million metric tons, between the 2000 and 2012. Because wheat is such an important component of the daily diet, and because Egypt is only 51 percent self-sufficient in wheat production, it follows that wheat policy and increasing its production using all available water resources efficiently is central to food security in Egypt.

Water scarcity has become an increasing constraint to the economic development of countries in arid and semi-arid region such as Egypt. With the increase of water stress and the limited potential for additional water supply in recent years, great emphasis has been given to improving water use efficiency. In the agricultural sector, this effort has been expressed as "more crop and higher value per drop" (FAO, 2000). At present time and as expected in the future, irrigated agriculture will be practiced under water scarcity conditions and irrigation management will shift from emphasizing production per unit area towards maximizing the production per unit of water consumed. This situation has stimulated the development and application of different water-saving technologies such as deficit irrigation (DI) and regulated deficit irrigation (RDI) in order to save water and increase water use efficiency in crops under semi-arid conditions. In addition, water supply is reduced below maximum levels and mild stress is allowed with minimal effects on the yield. Under conditions of scarce water supply and drought, deficit irrigation can lead to greater economic gains than maximizing yields per unit of water for a given crop, Kirda (2002). Panda *et al.* (2003) concluded that responses of wheat growth to water deficits varied depending on wheat species and growth stages. Bukhat (2005) stated that, exposing wheat crop to water stress depresses seasonal consumptive use and grain yield. Haikle and Melegy (2005) concluded that the maximum grain yield and lowest water use efficiency of wheat were recorded when irrigated with the recommended irrigation requirements under sandy soils and sprinkler irrigation system. Salemi *et al.* (2006) reported that about 19.3% decrease in grain yield was recorded due to 40% decrease in water use, and this water saving lead to 34.5% increase in water use efficiency, and the quality characteristics were increased. Quanqi *et al.* (2010) indicated that, irrigation at the jointing and heading stages resulted in high grain yield and water use efficiency, which would offer a sound measurement for developing deficit irrigation regimes. Akbari *et al.* (2011) found that the highest grain yield resulted from irrigation at all stages. Deficit irrigation was found to decrease grain yield by 5% at no irrigation before stem elongation, by 32% at no irrigation before flowering, and by 52% at no irrigation before grain filling. Abd El-Ghany *et al.* (2012) indicated that, withholding irrigation during tillering and/or flowering growth stages reduced significantly all vegetative growth, yield and yield components compared normal irrigation. Jazy *et al.* (2012) indicated that wheat irrigated after 90mm cumulative pan evaporation saved about 22% in irrigation water, and grain yield loss was insignificant, comparable with 110mm cumulative pan evaporation. Moghaddam *et al.* (2012) indicated that there were significant differences among the deficit irrigation treatments on grain yields, 1000 grain weight, spike length, plant height, no. of grains per spike, no. of spikes per m-2, and biomass and harvest index. Deficit irrigation significantly reduced grain yield and agronomic traits of all wheat cultivars. The highest reduction in all parameters was found in severe stress, and stress at vegetative and reproductive stages treatments. Jiang *et al.* (2012) found that, spring wheat was sensitive to water deficit, especially at the booting to grain-filling stages. Sallam (2014) found that leaf water potential decrease as plants become near maturity and/or as applying deficit irrigation treatments. The author added that no significant difference in grain yield under 75% ETc compared to full irrigation, and amounts of applied water (based on class A pan readings) were 6534 and 5151 m3ha-1 under full and 75% ETc regimes, respectively.

Potassium plays a vital role in: photosynthesis, protein synthesis, control of ionic balance, regulation of plant stomata and water use, activation of plant enzymes and, many other processes (Reddy *et al.* 2004). Wang *et al.* (2004) reported that accumulating K and free proline might play a role in drought adaptation in some plants. Cakmak (2005) reported that, despite acting as an essential macronutrient, K serves as a primary osmotic regulator to maintain turgor in plants, particularly under stressful environments. Therefore, abundant K+ accumulation in plant tissues under drought stress may play a vital role in water uptake from the soil. One of the mechanisms for improving plant tolerance to drought is to apply K which seems to have a beneficial effect in mitigating drought stress. Increased application of K has been shown to enhance photosynthetic rate, plant growth and yield in different crops under water stress conditions (Tiwari *et al.*1998). Spraying wheat plants with K before subjecting the plants to drought treatment diminished the negative effects of drought on growth and in turn increases yield per plant, since the plants are able to utilize foliar-applied K and translocate it to almost all plants parts, (El-Ashry *et al.* 2005). In addition, Raza *et al.* (2013) reported that the exogenous application of K to wheat cultivars under drought stress at critical growth stages enhanced tolerance of wheat by reducing toxic nutrient's uptake and improving the physiological efficiency. The tested wheat varieties showed uniform behavior and maximum improvement in all the recorded nutrients uptake and physiological parameters was achieved when K was applied at grain filling stage. Abd El-Hadi (2015) on sandy soil with sprinkler – irrigated wheat, found that yield was slightly affected by water regimes, K fertilizer levels, and their interaction.

This research aims to study the effect of deficit irrigation regimes and levels of potassium fertilizer on grain yield, yield components and the physiological traits e.g. days to heading (HD) and days to maturity (MD) of three wheat cultivars. Drought tolerance and water productivity for the assessed wheat varieties under sprinkler irrigation system on sandy soil were investigated.

MATERIALS AND METHODS

Site description:

A field experiment was conducted during 2011/2012 and 2012/2013 under sprinkler irrigation at Abdel Monem Riad Village (31 02 N latitude and 30 28 E longitude with an altitude of 6.7 m above sea level), El-Bustan area, representing the newly reclaimed sandy soils of west Nile Delta, Egypt. The investigation aims to study the effect of deficit irrigation treatments and rates of potassium fertilizer on grain yield, № of spikesm-2, 100–kernels weight, № of kernels/spike, days to heading (HD), days to maturity (MD), amounts of applied irrigation water, water productivity of three wheat cultivars namely Sakha 93 Giza168 and Gemmiza9. The drought tolerance indices e.g. Drought susceptibility index (DSI) and drought tolerance efficiency were considered. Particle size distribution and some soil – water constants and bulk density were determined according to FAO (1970) and Black and Hartge, 1986, respectively, and data are listed in Table 1. In addition, some chemical soil properties were determined as described by Page *et al.* (1982) is shown in Table 2.

Table 1. Bulk density, Particle size distribution and some soil moisture constants of soil at the experimental site.

Soil depth (cm)	Bulk density (Mg m^{-3})	Particle size analysis Sand (%)	Silt (%)	Clay (%)	Textural class	Moisture constants (%,w/w) Filed capacity	Wilting point	Available water
00-30	1.63	92.20	4.00	3.80	Sand	9.1	4.6	4.5
30-60	1.64	94.20	2.40	3.40	Sand	8.8	4.6	4.2
60-90	1.64	94.20	2.40	3.40	Sand	8.5	4.4	4.1
Average	1.64	93.53	2.93	3.53		8.8	4.5	4.3

Table 2. Main chemical properties of the soil at the experimental site.

Soil Depth (cm)	EC dS m^{-1}	pH 1:2.5	$CaCO_3$ (%)	Soluble cations (mmolc L^{-1}) Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Soluble anions (mmolc L^{-1}) CO_3^{--}	HCO_3^{-}	Cl^{-}	SO_4^{--}	OM (%)
00 30	0.68	8.89	1.84	1.50	1.00	4.19	0.18	1.50	1.50	3.50	0.37	0.64
30-60	0.72	8.91	1.49	2.00	1.50	3.66	0.22	2.00	1.50	3.00	0.88	0.40
60-90	0.54	8.78	1.43	1.50	1.00	2.66	0.11	1.50	1.50	2.00	0.27	0.24

Experimental design and tested variables:

A split-split plot experimental design with three replicates was adopted used. Five irrigation treatments were assigned to the main plots, four potassium fertilization rates were assigned to the sub-plots, and three wheat varieties were assigned to the sub sub-plots. Area of main plot was 120 m2, and the adopted treatments were arranged as follows:

The main plots, Regulated Deficit and Deficit irrigation regimes, where the applied irrigation water amounts were pre-calculated based on the readings of class A pan:

Applying 100% of actual crop evapotranspiration, at all growing stages, Control,100ETC

Applying 75% ETc at initial and late - season stages + 100% ETc during the other stages, RDI_{75}.

Applying 50% ETc at initial and late - season stages + 100% ETc during the other stages, RDI_{50}.
Applying 75% ETc at all growth stages, DI_{75}
Applying 50% ETc at all growth stages, DI_{50}

The sub-main plots: Potassium fertilization rates:

No K application, K0	12 $kgfed^{-1}$rate, K1
24 $kgfed^{-1}$rate, K2	48 $kgfed^{-1}$rate, K3

The sub sub-plots: Wheat varieties:

Sakha 93, V_1 Giza 168, V_2 Gemmiza 9, V_3

Cultural practices:

A solid set sprinkler irrigation system was used to irrigate the current experiment. The main and lateral lines consisted of PVC pipes with 110 and 75 mm diameters, respectively. The distance between sprinklers was 7m and between lateral was 6m. The actual precipitation rate was 9.06 $mmhr^{-1}$. The total area of each irrigation main plot was 120 m^2. Class A pan was used to determine the potential evapotranspiration (ETp) values, and crop evapotranspiration (ETc) values were calculated according to the following equations (Doorenbos and Pruitt, 1984):

$$ETp = Epan * Kpan$$

Where:

ETp = potential evapotranspiration ($mmday^{-1}$),
E_{pan} = measured pan evaporation daily values ($mmday^{-1}$),
K_{pan} = Pan coefficient which depend on the site's relative humidity, wind speed and its conditions (bare or cultivated). A k_{pan} value of 0.75 was used for the experimental site,
ETc = actual crop evapotranspiration values ($mmday^{-1}$), and
Kc = crop coefficient for wheat crop (FAO, 1984).

The wheat growth stages and crop coefficient (Kc) values (FAO, 1984) used in this experiment are presented in Table 3.

Table 3. Wheat growth stages and crop coefficient (Kc) values.

Wheat growth stage	Period (days)	Crop coefficients (Kc)
Initial	34	0.35
Crop development	48	0.75
Mid-season	30	1.13
Late-season	30	0.75

Wheat seeds (cv. Sakha 93, Giza 168, and Gemmiza 9) were sown on $26^{th}$and 30^{th} of November, and harvested on 1^{st} and 5^{th} of May 2011/2012 and 2012/2013, respectively. Fertilization was carried out as follows:

* During land preparations, P-fertilizer in the form of mono-calcium (MCP) phosphate (15.5% P_2O_5) at the rate 10.5 kg P_2O_5 fed^{-1} was incorporated into the soil surface. During the growing season, the tested rates of K-fertilizer as soluble K_2SO_4 (48% K_2O) were injected through the irrigation system (chemigation) in four equal doses as recommended.
* Phosphorus fertilizer as phosphoric acid H_3PO_4 (60% P_2O_5), at the rate of 19 kg P_2O_5 fed^{-1} and N fertilizer in the form of NH_4NO_3 (33.5% N) at the rate of 100 kg N fed^{-1} were injected through the irrigation system in 12 equal doses (two doses/week).
* A mixture of $FeSO_4$: $MnSO_4$: $ZnSO_4$: $CuSO_4$ micronutrients were added at two times e.g. 25-35 days and at 60 days after sowing as foliar spray at the ratio of 1:1:1: 0.2. In addition, Ca as Ca-EDTAT at the rate of 2 $kgfed^{-1}$ was executed four times, as foliar spray, during the growing season.

All other agronomic practices e. g. weeds and diseases control, etc. were done as recommended by the Ministry of Agriculture for wheat production in the area.

Crop and soil measurements:

Crop measurements:

The following parameters were measured after harvesting:

* Grain yield, $tonfed^{-1}$
* Spikes Nº m^{-2}
* Kernels Nº $spike^{-1}$
* 100–kernel weight, g

It is worthy to mention that the physiological traits e.g. days to heading (HD) and days to maturity (MD) were considered in the second season only, and recorded during the growing season.

Crop tolerance indices:

The drought susceptibility index and the drought tolerance efficiency parameters were used to evaluate the effect of water stress treatments on the tolerance of the tested wheat cultivars.

Drought susceptibility index (DSI) was calculated by the formula given by Fisher and Maurern (1978) as follows:

$$DSI=(1-Yd/Yp)/D$$

Where

Y_d: Grain yield of the genotype under moisture stress condition
Y_p: Grain yield of the genotype under non-stress condition
D: Mean yield of all genotypes under stress/Mean yield of all genotypes under non-stress

Drought tolerance efficiency (DTE) was estimated using formula given by Fisher and Wood (1981) as follows:

DTE(%) = Yield under stress/Yield under non-stress conditions X100

Leaf water potential and applied irrigation water measurements:

* **Leaf water potential (-bar):** It was measured with a portable pressure chamber apparatus (Soil Moisture Equipment Corp., Santa Barbara, CA, USA,). Measurements were carried out on one adult leaf from all treatments at mid - season growth stage.
* **Amounts of applied irrigation water:** The irrigation amounts were calculated according to the equation given by Vermeiren and Jopling (1984) as follows:

$$AIW= ETp*Kc*I/Ea(1-LR)$$

where:

AIW= depth of applied irrigation water (mm)
ETp= potential evapotranspiration (mmd^{-1}) values calculated using class A pan.
Kc= crop coefficient (FAO, 1984)
I= irrigation intervals
Ea= irrigation application efficiency of the sprinkler irrigation system (Ea = 75% for sprinkler system).
LR = leaching requirements, (LR was not considered to avoid the effect of excess water on the DI and RDI treatments).

***Water productivity (WP):** The WP values were calculated according to the following equation (Jensen, 1983):

$$WP = \frac{\text{Total grain yield (kg/fed)}}{\text{Applied irrigation water (m3/fed)}}$$

Statistical analysis:

The obtained data were statistically analyzed using the CoHort Software (1986) statistical package. Average values from the three replicates of each treatment were interpreted using the analysis of variance (ANOVA). The Duncan's Multiple Range Test was used for comparisons between different sources of variance according to Steel and Torrie (1984).

RESULTS AND DISCUSSION

Effect of the adopted treatments on grain yield and its components

1-Grain Yield (tonfed^{-1}):

Data in Table 4 show that the adopted irrigation treatments and K fertilization rates and wheat varieties as well significantly influenced wheat grain yield, and such trend was true in the two growing seasons. The highest grain yields i.e. 2.64 and 2.95 ton fed^{-1} were recorded with the control irrigation treatment. respectively, in 1st and 2nd seasons. The increases in grain yield under control irrigation treatment amounted 5.18, 50.00, 55.26 and 62.96% in 1st season and to 27.16, 63.89,71.51 and 59.46% in 2nd season higher than those under RD_{75}, RD_{50}, DI_{75} and DI_{50} irrigation treatments, respectively. Water stress during grain filling through withholding last or last two irrigations markedly reduced growth, straw and grain yields (El-Sabbagh *et al*, 2002). Moghaddam *et al.* (2012) indicated that there were significant differences among the deficit irrigation treatments on grain yields, and DI significantly reduced grain yield. Akbari *et al.* (2011) found that the highest grain yield resulted from irrigation at all stages. Deficit irrigation was found to decrease grain yield by 5, 32 and 52% with withholding irrigation before stem elongation, before flowering, and before grain filling stages, respectively. Zareian and Hamidi (2014) reported that water stress through irrigation withholding irrigation at the ear emergence and grain filling phases reduced grain yield and its components.

Table 4. Grain yield (tonfed^{-1}) as affected by the tested treatments in the two growing seasons.

Irrigation regime	K Level	2011/2012			Aver.	2012/2013			Aver.
		Sakha 93	Giza168	Gemmiza 9		Sakha 93	Giza 168	Gemmiza 9	
		Grain yield (ton fed^{-1})				Grain yield (ton fed^{-1})			
Control 100% ETc	K_0	1.86	2.83	3.04	2.58	2.99	3.04	2.99	3.01
	K_1	1.90	2.90	3.38	2.72	2.35	3.73	2.29	2.79
	K_2	2.58	2.54	3.02	2.72	3.20	2.77	3.04	3.00
	K_3	2.69	2.54	2.40	2.54	2.51	3.20	3.31	3.01
	Average	2.26	2.70	2.96	2.64	2.76	3.18	2.91	2.95
RDI_{75}	K_0	2.37	2.32	2.16	2.28	2.24	2.03	2.83	2.37
	K_1	1.95	2.94	2.98	2.62	2.24	2.19	2.77	2.40
	K_2	2.03	3.28	2.40	2.57	2.24	2.61	2.51	2.45
	K_3	2.03	2.67	2.98	2.56	1.92	1.76	2.51	2.06
	Average	2.10	2.80	2.63	2.51	2.16	2.15	2.66	2.32
RDI_{50}	K_0	1.33	1.84	2.06	1.74	1.60	1.76	2.56	1.97
	K_1	1.73	2.11	1.41	1.75	1.33	1.49	1.97	1.59
	K_2	1.28	2.24	2.32	1.95	1.92	1.60	1.49	1.67
	K_3	1.20	1.52	2.10	1.61	1.81	1.76	2.35	1.97
	Average	1.38	1.93	1.97	1.76	1.66	1.65	2.09	1.80
DI_{75}	K_0	1.44	1.39	1.87	1.57	2.03	1.71	2.26	2.00
	K_1	1.49	1.78	2.48	1.91	1.55	1.92	1.76	1.74
	K_2	1.84	1.26	2.13	1.74	1.28	1.49	1.60	1.46
	K_3	1.23	1.34	2.13	1.57	1.12	1.81	2.13	1.69
	Average	1.50	1.44	2.15	1.70	1.50	1.73	1.94	1.72
DI_{50}	K_0	1.36	1.65	1.87	1.63	1.49	1.44	1.36	1.43
	K_1	1.52	1.81	2.26	1.86	1.60	1.44	1.55	1.53
	K_2	1.33	1.14	1.66	1.38	1.28	1.17	1.55	1.33
	K_3	1.68	1.71	1.46	1.62	1.81	1.55	2.19	1.85
	Average	1.47	1.58	1.81	1.62	1.54	1.40	1.66	1.54
Average (Variety)		1.74	2.09	2.30		1.92	2.03	2.25	
LSD 0.05			0.256				0.208		
Irrigation regimes effect									
LSD 0.05			0.336				0.172		
K fertilization effect									
K_0			1.96				2.15		
K_1			2.17				2.01		
K_2			2.07				1.98		
K_3			1.98				2.12		
LSD 0.05			0.304				0.240		
Tertiary interaction (Irrigation regimes x K fertilization levels x Wheat varieties									
LSD 0.05			1.184				0.928		

Data concerning grain yield as affected by the assessed K rates indicated different trends in 1st and 2nd seasons were observed. In 1st season, K_1 level increased the grain yield by 10.71%, which declined to be 5.61 and 1.02% with K_2 and K_3 levels, comparable with K_0 level. In 2nd season, the highest grain yield was achieved with K_0 level (2.15 tonfed^{-1}), which tended to reduce by 6.51, 7.91, 1.40% with K_1, K_2 and K_3 levels, respectively, compared with K_0. Foliar application of potassium significantly increased grain yield of wheat (El-Sabbagh *et al*, 2002).

Data in Table 4 reveal that Gemmeiza 9 produced the highest grain yield reached to 2.30 and 2.25 tonfed^{-1}, respectively, in 1st and 2nd seasons. The increases in grain yield of Gemmeiza 9 were32.18 and 10.05% in 1st season, and 17.19 and 10.84% ln 2nd season, respectively, higher than those recorded for Sakha 93 and Giza 168. Esmail *et al.* (2016) evaluated 25 bread wheat genotypes under deficit water conditions and they found highly significant differences among the genotypes for all characters indicating the presence of considerable variability among them.

The tertiary interaction of control$_{100\%\ ETc}$ irrigation regime, K_1 level and Gemmiza 9 wheat variety exhibited the highest grain yields i.e. 3.38 and 3.73 tonfed^{-1}in 1st and 2nd seasons, respectively.

2-Grain yield components

Spikes № m^{-2}

Data in Table 5 indicate that the adopted irrigation treatments and K fertilization rates and wheat varieties as well significantly affected spikes №m^{-2}, and such trend was true in 1st and 2nd growing seasons. The highest spikes №m^{-2} i.e. 385.83 and 337.22 were recorded with control irrigation treatment. respectively, in 1st and 2nd seasons. The increases in spikes №m^{-2} under control irrigation treatment amounted 21.84, 23.24, 12.74 and 25.81% in 1st season and to 2.62, ,0.75,7.71 and 9.18% in 2nd season higher than those under RD_{75}, RD_{50}, DI_{75} and DI_{50} irrigation treatments, respectively.

Table 5. № Spike m^{-2} as affected by the tested treatments in the two growing seasons.

Irrigation regime	K Level	2011/2012			Ave.	2012/2013			Ave.
		Sakha93	Giza168	Gemmiza9		Sakha93	Giza168	Gemmiza9	
		no. Spike m^{-2}				no. Spike m^{-2}			
Control 100% ETc	K_0	253.33	380.00	376.67	336.67	343.33	360.00	316.67	340.00
	K_1	340.00	350.00	326.67	335.56	336.67	326.67	296.67	320.00
	K_2	423.33	366.67	420.00	403.33	293.33	340.00	430.00	354.44
	K_3	403.33	560.00	440.00	467.78	310.00	370.00	323.33	334.44
	Ave.	355.00	414.17	388.33	385.83	320.83	349.17	341.67	337.22
RDI_{75}	K_0	350.00	306.67	316.67	324.44	276.67	333.33	316.67	308.89
	K_1	326.67	370.00	303.33	333.33	280.00	336.67	363.33	326.67
	K_2	306.67	293.33	306.67	302.22	366.67	386.67	353.33	368.89
	K_3	400.00	256.67	263.33	306.67	356.67	293.33	280.00	310.00
	Ave.	345.83	306.67	297.50	316.67	320.00	337.50	328.38	328.61
RDI_{50}	K_0	303.33	316.67	256.67	292.22	131.33	293.33	346.67	317.78
	K_1	343.33	303.33	343.33	330.00	416.67	303.33	353.33	357.78
	K_2	266.67	353.33	293.33	304.44	356.67	280.00	313.33	316.67
	K_3	286.67	373.33	316.67	325.56	296.67	350.00	393.33	346.67
	Ave.	300.0	336.67	302.50	313.06	345.83	306.67	351.67	334.72
DI_{75}	K_0	273.33	320.00	286.67	293.33	316.67	363.36	336.67	338.89
	K_1	366.67	340.00	393.33	366.67	270.00	306.67	353.33	310.00
	K_2	326.67	373.33	326.67	342.22	346.67	283.33	286.67	305.56
	K_3	293.33	356.67	450.00	366.67	250.00	340.00	303.33	297.78
	Ave.	315.00	347.50	364.17	342.22	295.83	323.33	320.00	313.07
DI_{50}	K_0	256.67	320.00	266.67	293.33	296.67	336.67	353.33	328.89
	K_1	356.67	326.67	360.00	347.78	290.00	373.33	293.33	318.89
	K_2	323.33	340.00	320.00	305.56	303.33	256.67	286.67	382.22
	K_3	236.67	300.00	303.33	280.00	323.33	280.00	313.33	305.56
	Ave.	279.17	319.17	321.67	306.67	303.33	311.67	311.67	308.87
Average (Varieties)		319.00	344.83	334.83		317.17	325.67	330.67	
LSD0.05			22.75				NS		
Irrigation regimes effect									
LSD0.05			29.38				25.26		
K fertilization effect									
K_0			308.00				326.89		
K_1			342.67				326.67		
K_2			331.56				325.56		
K_3			349.33				318.89		
LSD0.05			26.30				NS		
Tertiary interaction (Irrigation regimes x K fertilization levels x Wheat varieties									
LSD0.05			101.76				78.49		

Data concerning grain yield as affected by the assessed K rates indicated greatly different trends in 1st and 2nd seasons were observed. In 1st season, K_3 level exhibited the highest spikes №m^{-2} e.g. 349.33, which increased by 13.42, 1.94 and 5.36% higher than those with K_0, K_1 and K_2 levels, respectively. In 2nd season, K_0

level resulted in the highest figure (326.89), which surpassed those with K_1 and K_2 and K_3 levels by 0.0006, 0.41 and 2.51%, respectively. Zareian and Tabatabaei (2014) stated that the Leaf stomatal conductance, transpiration rate, chlorophyll, biological yield and grain yield showed significant increase by increasing potassium foliar application.

Data in Table 5 reveal that Giza 168 produced the highest value of spikes №m^{-2} reached to 344.83 in 1^{st} season, which was higher by 8.10 and 2.99% than those recorded for Sakha 93 and Gemmiza 9 varieties, respectively. In 2^{nd} season, Gemmiza 9 exhibited the highest figure of spikes №m^{-2} amounted to 330.67, which is higher by 4.26 and 1.54% than those recorded for Sakha 93 and Giza 168 varieties, respectively.

The tertiary interaction of control 100% ETc, K_3 and Giza 168 resulted in the highest № Spikem^{-2} e.g. 560.00 in 1^{st} season and in 2^{nd} season interaction of control 100% ETc, K_2 and Gemmiza 9 exhibited the highest value reached to 430.00.

Kernels № spike^{-1}

Data in Table 6 indicated that the adopted irrigation treatments and wheat varieties significantly affected Kernels № spike^{-1}, and such trend was true in 1^{st} and 2^{nd} growing seasons. The highest Kernels № spike^{-1} i.e. 54.08 and 54.14 were recorded with the control irrigation treatment. respectively, in 1^{st} and 2^{nd} seasons. The increases in Kernels № spike^{-1}under control irrigation treatment amounted 14.92, 41.50, 65.28 and 124.58% in 1^{st} season and to 20.02, ,48.78 and 73.69% in 2^{nd} season higher than those under RD_{75}, RD_{50}, DI_{75} and DI_{50} irrigation treatments, respectively. Data concerning Kernels № spike^{-1} as influenced by the adopted K rates indicated that the highest figures were recorded with K_0 level, and such trend was true in 1^{st} and 2^{nd} seasons, Table 6. The reduction in Number of kernels spike^{-1} amounted to 3.46, 5.84 and 7.41% with K1, K_2 and K_3 levels, respectively, compared with K_0. The corresponding reduction values in 2^{nd} season were 2.10, 0.42, and 1.13%, respectively, in the same order of K levels. Data in Table 6 reveal that Gemmiza 9 produced the highest value of Kernels № spike^{-1}reached to 40.32 in 1^{st} season, which was higher by 4.51 and 3.92% than those recorded for Sakha 93 and Gemmiza 9 varieties, respectively. In 2^{nd} season, Sakha 93 exhibited the highest figure of Kernels № spike^{-1}amounted to 38.42, which is higher by 4.69 and 0.26% than those recorded for Giza 168 and Gemmiza 9 varieties, respectively.

Table 6. Kernels № spike^{-1} as affected by the tested treatments in the two growing seasons.

Irrigation regime	K Level	2011/2012			Aver.	2012/2013			Aver.
		Sakha93	Giza168	Gemmiza9		Sakha93	Giza168	Gemmiza9	
		No. of kernels spikes^{-1}				No. of kernels spikes^{-1}			
Control 100% ETc	K_0	51.00	51.33	57.33	53.22	54.67	49.67	52.67	52.33
	K_1	54.00	53.33	58.67	55.33	55.00	52.67	56.00	54.56
	K_2	53.33	54.33	52.33	53.33	59.33	52.33	56.33	56.00
	K_3	50.00	51.67	61.67	54.44	51.00	52.67	57.33	53.67
	Average	52.08	52.67	57.5	54.08	55.00	51.83	55.58	54.14
RDI_{75}	K_0	49.67	48.67	52.00	50.11	49.00	47.33	48.33	48.22
	K_1	42.00	46.67	47.33	45.33	43.67	43.33	44.00	43.67
	K_2	42.33	47.33	52.67	47.44	44.33	44.33	42.33	43.67
	K_3	43.33	49.33	43.33	45.33	43.00	46.33	45.33	44.89
	Average	44.33	48.00	48.83	47.06	45.00	45.33	45.00	45.11
RDI_{50}	K_0	39.00	39.67	40.67	39.78	38.33	36.67	36.00	37.00
	K_1	33.67	36.33	40.33	36.76	34.33	36.00	35.00	35.11
	K_2	39.00	40.67	35.67	38.44	32.67	40.00	38.00	36.89
	K_3	39.67	35.67	38.33	37.89	36.67	37.67	35.33	36.56
	Average	37.83	38.08	38.75	38.22	35.50	37.58	36.08	36.39
DI_{75}	K_0	39.33	36.00	35.67	37.00	22.33	20.67	23.33	22.11
	K_1	34.67	29.67	32.33	31.89	21.67	20.33	24.00	22.00
	K_2	35.33	29.33	32.67	32.44	22.33	20.33	23.67	22.11
	K_3	30.33	30.33	28.00	29.56	22.00	22.33	24.00	22.78
	Average	34.92	31.33	31.92	32.72	22.08	20.92	23.75	22.25
DI_{50}	K_0	21.00	21.67	25.00	22.56	33.00	28.67	31.67	31.11
	K_1	24.67	24.67	24.67	24.67	36.00	27.00	31.33	31.44
	K_2	21.67	26.33	25.00	24.33	35.00	27.67	31.33	31.33
	K_3	27.67	23.00	23.67	24.78	34.00	28.00	30.33	30.78
	Average	23.75	23.92	24.58	24.08	34.50	27.83	31.17	31.17
Varieties Average		38.58	38.80	40.32		38.42	36.70	38.32	
LSD0.05			1.08				0.98		
Irrigation regimes average									
LSD0.05			1.05				1.27		
K fertilization average									
K0			42.13				38.16		
K1			40.67				37.36		
K2			39.67				38.00		
K3			39.00				37.73		
LSD0.05			0.94				NS		
Tertiary interaction (Irrigation regimes x K fertilization levels x Wheat varieties									
LSD0.05			3.62				3.62		

In 1st season, the tertiary interaction of control $_{100\%\ ETc}$, K_3 and Gemmiza 9 exhibited the highest Kernels № spike^{-1} value (61.67), whereas interaction of control $_{100\%\ ETc}$, K_2 and Sakha 93 resulted in the highest value amounted to 59.33 in 2nd season.

100-kernel weight (g):

Data in Table 7 indicate that the adopted irrigation treatments and K fertilization rates and wheat varieties as well significantly affected 100-kernel weight, and such trend was true in 1st and 2nd growing seasons. The highest 100-kernel weight i.e. 4.27 and 4.23 g were recorded with the control irrigation treatment respectively, in 1st and 2nd seasons. The increases in 100-kernel weight under control irrigation treatment amounted 15.72, 57.56, 28.61 and 37.74% in 1st season and to 14.02, 53.82, 25.15 and 41.47% in 2nd season higher than those under RD_{75}, RD_{50}, DI_{75} and DI_{50} irrigation treatments, respectively.

Data concerning 100- Kernel weight as affected by the assessed K rates indicated different trends in 1st and 2nd seasons. In 1st season, 100- Kernel weight was slightly increased as K_1 level increased, where the increases reached to 1.18, 0.59 and 2.06%, respectively, higher than that with K_1, K_2 and K_3levels respectively, than with K_0 level. In the 2nd season a reverse trend was recorded, and 100- Kernel weight values slightly decreased with K level increased and comprised 1.16, 0.87 and 2.61%, respectively, K_1, K_2 and K_3 levels lower than that observed with K_0 level.

Table 7. 100- Kernel weight as affected by the tested treatments in the two growing seasons.

Irrigation regime	K Level	2011/2012 Sakha93	Giza168	Gemmiza9	Average	2012/2013 Sakha93	Giza168	Gemmiza9	Average
		100- Kernels weight				100- Kernels weight			
Control 100% ETc	K_0	4.01	4.11	4.22	4.11	4.18	4.27	4.57	4.34
	K_1	4.15	4.18	4.70	4.34	4.17	4.13	4.57	4.29
	K_2	4.27	3.83	4.30	4.13	4.27	4.13	4.00	4.13
	K_3	4.57	4.40	4.53	4.50	3.80	4.30	4.37	4.15
	Average	4.25	4.13	4.44	4.27	4.10	4.21	4.38	4.23
RDI_{75}	K_0	3.39	3.87	4.10	3.79	3.80	3.83	4.03	3.89
	K_1	3.86	3.52	3.94	3.78	3.57	3.47	3.93	3.66
	K_2	3.62	3.31	3.43	3.45	3.57	3.60	3.57	3.58
	K_3	3.40	3.73	4.10	3.74	3.23	3.90	4.00	3.71
	Average	3.57	3.61	3.89	3.69	3.54	3.70	3.88	3.71
RDI_{50}	K_0	2.80	2.70	2.90	2.80	2.67	2.53	2.87	2.69
	K_1	2.80	2.53	2.83	2.72	2.93	2.60	2.93	2.82
	K_2	2.77	2.53	2.57	2.62	2.90	2.77	2.70	2.79
	K_3	2.77	2.57	2.80	2.71	2.90	2.63	2.60	2.71
	Average	2.78	2.58	2.78	2.71	2.85	2.63	2.78	2.75
DI_{75}	K_0	3.63	2.83	3.27	3.24	3.53	2.97	3.47	3.32
	K_1	3.80	2.98	3.07	3.23	3.77	3.13	3.10	3.33
	K_2	3.83	2.83	3.77	3.53	4.10	3.17	3.67	3.64
	K_3	3.10	3.17	3.60	3.29	3.00	3.47	3.17	3.21
	Average	3.00	3.59	2.95	3.32	3.60	3.18	3.35	3.38
DI_{50}	K_0	3.16	2.57	3.43	3.05	3.10	2.93	2.97	3.00
	K_1	3.30	2.67	3.33	3.10	3.00	2.97	2.90	3.96
	K_2	3.20	2.83	3.43	3.16	3.00	2.97	2.97	2.98
	K_3	3.37	3.00	2.93	3.10	3.20	2.93	2.90	3.01
	Average	3.26	2.77	3.28	3.10	3.08	2.95	2.93	2.99
Varieties Average		3.49	3.21	3.56		3.43	3.34	3.46	
LSD0.05			0.07				0.06		
Irrigation regimes average									
LSD0.05				0.09				0.07	
K fertilization average									
K0				3.40				3.45	
K1				3.44				3.41	
K2				3.38				3.42	
K3				3.47				3.36	
LSD0.05				0.08				0.06	
Tertiary interaction (Irrigation regimes x K fertilization levels x Wheat varieties									
LSD0.05				0.30				0.25	

Data in Table 7 reveal that Gemmiza 9 produced the highest value of 100-kernel weight reached to 3.56 g in 1st season, which was higher by 2.01 and 10.90 % than those recorded for Sakha 93 and Giza 168 varieties, respectively. In 2nd season, Gemmiza 9 still exhibited the highest figure of 100-kernel weight amounted to 3.46 g, which is higher by 0.87 and 3.60% than those recorded for Sakha 93 and Giza 168 varieties, respectively.

The highest 100-kernel weight value (4.70 g) was attained due to the tertiary interaction of control 100% ETc, K_1 and Gemmiza 9 in 1st season, whereas in 2nd season interaction of control 100% ETc, K_3 and Gemmiza 9 resulted in the highest value comprised 4.37g.

As for the yield components as affected by the adopted treatments, Akbari *et al.* (2011) found that Deficit irrigation negatively affected the characteristics of number of spikes/m^2, and biomass and harvest index. In addition, Moghaddam *et al.* (2012) indicated that there were significant differences among the deficit irrigation treatments on grain yields, 1000 grain weight, spike length, plant height, no. of grains per spike and no. of spikes per m^{-2}. DI significantly reduced the agronomic traits of all wheat cultivars, and the highest reduction in all parameters was found in severe stress, and stress at vegetative and reproductive stages treatments. Abd El-Ghany *et al*. (2012) and Jazy *et al*. (2012) reported that deficit irrigation affected all vegetative growth, yield and yield components including number of spikes m^{-2}more than under normal irrigation. Zareian and Tabatabaei (2014) stated that water stress through withholding at the wheat ear emergence and grain filling phases reduced the Leaf stomatal conductance, transpiration rate, biological and grain yields. El-Sabbagh *et al*. (2002) stated that foliar application of potassium significantly increased number of spikesm^2, number and weight of grains spike^{-1}, 1000 – grain weight of wheat traits. Additionally, Mesbah (2009) found that the differences between foliar spraying of 1% K and the control (48 kg K_2Ofed^{-1} as soil application) were significant, while with 2 or 3% potassium spray the differences were insignificant of most studied attributes.

Days to heading (HD) and days to maturity (MD)

Data in Table 8 indicate that the adopted irrigation treatments and K fertilization rates and wheat varieties as well significantly affected the physiological traits vis. HD and MD, and such trend was true in 1st and 2nd growing seasons. It is obvious that the assessed deficit irrigation regimes resulted in reduction in both HD and values, and such findings were recorded in 2nd seasons. The reductions in HD were 1.35, 3.55, 2.68 and 2.59% under RDI_{75}, RDI $_{50}$, DI_{75} and DI_{50} irrigation regimes, respectively, comparing with the control one. Likely, the corresponding reduction values in MD comprised 0.74, 1.66, 0.97 and 2.69% in the same order of irrigation remiges. The obtained results coincided with that reported by Eman and Ismaiel (2013) who reported that wheat plants under any kind of stress is driven quickly to maturity to preserve the species. Data concerning HD and MD traits as affected by the assessed K levels, both traits values tended to increase with K level increase, where HD increased to be 0.8, 0.75,2.35% with K_1, K_2 and K_3levels, respectively, longer than K_0 level. Likely, MD value was increased by 1.56, 1.19 and 1.80%, respectively, in the same order of K levels. Data in Table 8 reveal that Gemmiza 9 reveal the highest HD and MD values reached to 97.78 and 148.07 days, which were longer by (7.03 and 8.50 days) and by (5.9 and 3.2 days) than those recorded for Sakha 93 and Giza 168 varieties, respectively.

Table 8. Days to heading (HD) and Days to maturity (MD) as affected by the tested treatments in second growing season

Irrigation regime	K Level	2012/2013 Sakha93	Giza168	Gemmiza9	Average	Sakha93	Giza168	Gemmiza9	Average
		Days to heading (HD)				Days to maturity (MD)			
Control 100% ETc	K_0	94.00	89.33	96.00	93.11	138.33	142.67	148.00	143.00
	K_1	94.00	93.33	98.67	95.33	145.33	148.67	150.00	148.00
	K_2	93.33	94.00	97.33	94.89	144.67	147.33	150.00	147.33
	K_3	93.33	94.00	97.00	94.78	148.67	148.00	150.00	148.89
	Average	93.67	92.67	97.25	94.53	144.25	146.67	149.50	146.81
RDI_{75}	K_0	90.33	88.00	97.33	91.89	142.00	149.33	138.00	143.11
	K_1	90.00	89.33	98.67	92.67	146.00	149.33	144.00	146.44
	K_2	90.00	89.33	98.00	92.44	145.33	148.67	151.33	148.44
	K_3	100.00	89.33	98.67	96.00	143.33	148.67	142.67	144.89
	Average	92.58	89.00	98.17	93.25	144.17	149.00	144.00	145.72
RDI_{50}	K_0	88.67	86.67	97.00	90.78	143.33	142.00	149.33	144.89
	K_1	88.67	86.67	97.00	90.78	138.00	142.67	150.67	143.78
	K_2	88.00	88.67	98.00	91.56	143.33	141.33	144.67	143.11
	K_3	88.67	89.00	97.00	91.56	143.33	143.33	150.67	145.78
	Average	88.50	87.75	97.25	91.17	142.00	142.33	148.33	144.37
DI_{75}	K_0	88.00	87.33	97.00	90.78	138.33	144.67	150.00	144.33
	K_1	88.67	88.67	96.33	91.22	144.67	144.00	150.00	146.22
	K_2	87.33	87.33	99.33	91.33	138.38	143.33	150.00	143.89
	K_3	95.33	89.33	99.33	94.67	144.00	148.00	149.33	147.11
	Average	89.83	88.17	98.00	92.00	141.33	145.00	149.83	145.39
DI_{50}	K_0	90.00	98.67	96.33	92.00	140.33	138.67	146.00	141.67
	K_1	98.33	88.67	98.67	92.22	139.33	143.33	148.67	143.78
	K_2	98.33	87.33	98.67	91.78	138.33	141.33	148.67	142.78
	K_3	88.00	98.67	99.33	92.33	138.33	142.00	149.33	143.22
	Average	89.17	88.83	98.25	92.08	139.08	141.33	148.17	142.86
Varieties average		90.75	89.28	97.78		142.17	144.87	148.07	
LSD0.05			0.86				0.55		
Irrigation regimes average									
LSD0.05			1.11				0.70		
K fertilization)									
K0			91.71				143.40		
K1			92.44				145.64		
K2			92.40				145.11		
K3			93.87				145.98		
LSD0.05:			0.99				0.63		
Tertiary interaction (Irrigation x K fertilization x Varieties)									
LSD0.05			3.84				2.44		

Drought tolerance indices

The Drought tolerance indices *vis.* Drought Susceptibility Index (DSI) and Drought Tolerance Efficiency (DTE) were considered in the present investigation in order to verify the performance of the assessed wheat varieties under the tested DI and RDI irrigation regimes. In the present investigation, DSI value for a wheat genotype is near the unity this means that such genotype is susceptible for drought stress condition, and vice versa. On such basis, and regardless DI treatments, data in Table 9 clear out that Gemmiza 9 is more drought- resistant than Giza 168 and Sakha 93 varieties in 1st season, whereas in 2nd season, the arrangement with respect to drought resistance changed to be Gemmiza 9 > Sakha 93> Giza 168. Furthermore, based on 2- season average the assessed varieties could be arranged as Gemmiza 9 > Sakha 93 > Giza 168 with respect to its drought resistance. In addition, according to Drought Tolerance Efficiency the tested wheat varieties could be arranged as Gemmiza 9 > Sakha 93 > Giza 168 with DTE values comprised 72, 66 and 62%, respectively. So, Gemmiza 9 could be recommended to be cultivated in areas with conditions similar to that where the present investigation was executed.

Table 9. Drought Susceptibility Index (DSI) and Drought Tolerance Efficiency (DTE%) values for the three wheat varieties as affected by the adopted irrigation regimes.

Irrigation treatments	2011/2012				2012/2013				2-year average			
	Sakha 93	Giza 168	Gemmiza 9	Aver.	Sakha 93	Giza 168	Gemmiza 9	Aver.	Sakha 93	Giza 168	Gemmiza 9	Aver.
	Drought Susceptibility Index (DSI)											
Control	-	-	-	-	-	-	-	-	-	-	-	-
RDI 75%	0.025	-0.013	0.039	0.017	0.087	0.130	0.034	0.08	0.056	0.059	0.037	0.051
RDI 50%	0.117	0.163	0.095	0.125	0.183	0.182	0.133	0.17	0.150	0.172	0.113	0.145
DI 75%	0.122	0.145	0.135	0.134	0.177	0.224	0.172	0.19	0.149	0.184	0.153	0.162
(DI 50%	0.136	0.099	0.117	0.117	0.159	0.192	0.113	0.15	0.147	0.146	0.115	0.136
Average stress treat.	0.100	0.098	0.097		0.151	0.182	0.113		0.126	0.140	0.104	
	Drought Tolerance Efficiency (DTE%)											
Control	100	100	100	100	100	100	100	100	100	100	100	100
RDI 75%	93	104	89	95	78	67	91	79	86	86	90	87
RDI 50%	62	71	66	66	60	52	72	61	61	62	69	64
DI 75%	67	54	73	64	54	54	66	58	61	54	70	61
(DI, 50%	65	58	62	62	56	44	57	52	61	51	60	57
Average stress treat.	71	72	72		62	54	72		66	62	72	

4. Plant - Water relationships

leaf water potential (Ψ_{leaf}, bar)

Data in Table 10 indicate that higher leaf water content were recorded under conrol$_{100\%ETc}$ regime, and amounted 9.6 and 11.4 -bar, respectively, in 1st and 2nd seasons. In the 1st season, leaf water potential values were higher with Control$_{100\%ETc}$ irrigation regime by 13.91, 26.67, 20.16% and 43.10%, respectively, than RDI $_{75\%}$, RDI $_{50\%}$, DI $_{75\%}$ and DI $_{50\%}$ irrigation regimes. The corresponding increase in leaf water potential values were 10.24, 27.85,20.28 and 40.00%, respectively, in the same order of irrigation regimes. The present findings are in parallel with Gupta *et al.* (1989) and Sallam (2014) who reported that leaf water potential increased as a result of applying deficit irrigation treatments.

Table 10. Effect of tested treatments on leaf water potential (-bar) at mid - season growth stage.

Irrigation regime	K level	2011/2012			Average	2012/2013			Average
		Sakha 93	Giza 168	Gemmiza 9		Sakha 93	Giza 168	Gemmiza 9	
Control 100% ETc	K_0	10.0	10.6	9.8	10.1	11.6	11.4	12.2	11.7
	K_1	10.6	8.4	9.0	9.3	15.6	12.6	10.4	12.9
	K_2	8.6	8.0	10.2	8.9	8.6	10.8	10.0	9.8
	K_3	10.2	9.8	9.8	9.9	12.0	11.4	10.4	11.3
	Average	9.9	9.2	9.7	9.6	12.0	11.6	10.8	11.4
RDI_{75}	K_0	11.6	11.4	10.4	11.1	12.6	11.6	11.4	11.9
	K_1	11.6	11.4	10.4	11.1	12.6	12.4	12.6	12.5
	K_2	11.6	11.6	10.6	11.3	12.8	13.6	12.6	13.0
	K_3	12.8	14.0	10.6	12.5	14.0	14.0	12.0	13.3
	Average	11.9	12.1	10.5	11.5	13.0	12.9	12.2	
RDI_{50}	K_0	15.0	15.2	14.2	14.8	15.8	16.0	15.2	15.7
	K_1	15.6	15.2	14.2	15.0	16.8	16.0	15.2	16.0
	K_2	15.6	15.6	14.6	15.3	15.8	16.0	15.2	15.7
	K_3	14.2	16.2	14.6	15.0	15.2	17.0	15.2	15.8
	Average	15.1	15.55	14.4	15.03	15.90	16.25	15.2	15.8
DI_{75}	K_0	14.2	14.8	12.2	13.7	14.6	15.4	13.4	14.5
	K_1	13.4	14.5	12.6	13.5	14.4	15.5	13.6	14.5
	K_2	13.0	12.6	12.0	12.5	14.0	13.2	14.0	13.7
	K_3	14.4	14.2	13.8	14.1	14.6	15.2	14.2	14.7
	Average	13.8	14.0	12.7	13.5	14.4	14.8	13.8	14.3
DI_{50}	K_0	18.0	16.2	16.0	16.7	20.0	18.2	17.2	18.5
	K_1	17.2	18.2	16.0	17.1	19.2	20.2	18.0	19.1
	K_2	18.6	18.8	17.0	18.1	18.0	20.2	19.0	19.1
	K_3	17.2	18.6	17.0	17.6	18.6	20.2	19.0	19.3
	Average	17.8	18.0	16.5	17.4	19.0	19.7	18.3	19.0
Average (varieties)		13.7	13.8	12.8	13.4	14.8	15.0	14.0	14.6

(average) K	K_0		K_1		K_2		K_3	
	2011/2012	2012/2013	2011/2012	2012/2013	2011/2012	2012/2013	2011/2012	2012/2013
	13.28	14.46	13.20	15.00	13.22	14.46	13.82	14.88

Concerning effects of K levels wheat leaf water potential, in 1st season, the assessed K level did not alter leaf water potential values, Table 10. In 2nd season, values of leaf water potential still inconsistent, and exhibited undistinguished trend. However, Egilla *et al.* (2005) indicated that adequate level of K supply improved leaf water content and leaf water relations.

Data reveal that leaf water potential for Gemmiza 9 were higher than by 6.57 and 7.25% in 1st season and by 5.41 and 6.67%, respectively, those reported for Sakha 93 and Giza 168 varieties.

Applied irrigation water

Data in Table 11 reveal that the highest figures of seasonal applied water were recorded for control irrigation regime, and reached to 548.6 and 536.0 mm in 1st and 2nd seasons, respectively. The seasonal water applied seemed to reduce under the adopted DI regimes, and the reduction amounted to 9.75, 19.10, 25.01 and 50.00% in 1st season, and to 9.42,18.83, 25.00 and 50.01% in 2nd season, respectively, with RDI_{75}, RDI_{50}, DI_{75} and DI_{50}, comparable with the control. Sallam (2014) studied the effect of DI and RDI techniques of the productivity of wheat crop in sandy soils, and stated that the amounts of applied water (based on class A pan records) were 6534 and 5151 m^3/ha with full and 75% ETc irrigation regimes, respectively.

Data also clear out that the highest values of seasonal water applied were observed at mid- season growth stage, under all the adopted irrigation regimes. Such growing stage is matching higher water requirement due to higher growth rate and higher evaporative demands as well. The maximum crop water need is reached at the end of the crop development stage which is the beginning of the mid-season stage, that extended to the beginning of late – season stage (FAO, Irrigation Water Management, Training manual no. 3, 1986).

Table 11 . Applied irrigation water at different growth stages and Seasonal (mm) as affected by the irrigation treatments.

Growth stage	Depth of irrigation water (mm) –2011/2012 Irrigation regimes				
	Control 100% ETc	**RDI_{75}**	**RDI_{50}**	**DI_{75}**	**DI_{50}**
Initial	36.2	27.1	18.1	27.1	18.1
Crop development	107.0	107.0	107.0	80.3	53.5
Mid- season	232.1	232.1	232.1	174.1	116.1
Late - season	173.3	129.9	86.6	129.9	86.6
Total	548.6	496.1	443.8	411.4	274.3
Depth of irrigation water (mm) –2012/2013					
Growth stage	**Irrigation regimes**				
	100%	**RDI_{75}**	**RDI_{50}**	**DI_{75}**	**DI_{50}**
Initial	37.96	28.5	19.0	28.5	19.0
Crop development	112.4	112.4	112.4	84.3	56.2
Mid- season	213.9	213.9	213.9	160.4	107.0
Late - season	159.2	119.4	79.6	119.4	79.6
Total	523.5	474.2	424.9	392.6	261.7

Water Productivity, WP

The term water productivity is used exclusively to denote the amount or value of product over volume or value of water depleted or diverted. The value of the product might be expressed in different terms e.g. biomass, grain, money (FAO, 2003). In the present investigation WP means gks of wheat grain yield that produced due to applying the unity of irrigation water. On such basis, with DI50 irrigation regime WP averaged 1.47 and 1.52 kgm-3 in 1st and 2nd seasons, whereas under control 100% ETc, RDI 75, RDI 50 and DI75 irrigation regimes, WP averaged (1.12 and 1.20 kgm-3), (1.01 and 1.02 kgm-3), (1.02 and 1.14 kgm-3) and (0.96 and1.00 kgm-3) in 1st and 2nd seasons, respectively. Zhang *et al*. (2005) reported that wheat grown under the RDI had 26% greater WUE compared with the control and grain yield and WUE of spring wheat can be greatly improved by regulated deficit irrigation with reduced amounts of water. In addition, Wang *et al*. (2012) found low irrigation treatment had a higher WUE than that with high irrigation over the 2 years.

Data of K fertilization affecting WP, K3 level exhibited higher values with increases reached 10.48, 10.48 and 4.50%, respectively, higher than those with K0, K1 and K2 levels in 1st season. The trend was slightly differed, where the highest WP e.g. 1.19 kgm-3 was recorded with K2 level, which is higher by 13.13,18.18 and 0.85% than K0, K1 and K3 levels. Mesbah (2009) found that water use efficiency were significantly increased with increasing potassium concentration from 1 to 2 or 3%. The bilateral interaction of DI50 irrigation regime and K2 level resulted in the highest WP figures comprised 1.69 and 1.79 kgm-3, respectively, in 1st and 2nd seasons.

Data reveal that Gemmeiza 9 variety exhibited higher WP e.g. 1.28 kgm-3, which were higher by 31.96 and 11.30%, than those observed with Sakha 93 and Giza 168 varieties in 1st season. In 2nd season, the corresponding increase in WP values were 16.07 and 13.04%, respectively, in the same order of wheat varieties. Furthermore, the bilateral interaction of DI50 irrigation regime and Gemmeiza 9 resulted in higher WP values amounted to 1.57 and 1.51 kgm-3, respectively, in 1st and 2nd seasons.

Table 12. Water productivity (WP, kg grainm^{-3}) as affected by the tested irrigation regimes, K fertilization levels and wheat varieties in 2011/2012 and 2012/2013 seasons.

Irrigation regimes	WP (kg m^{-3}), 2011/2012					WP (kg grain m^{-3}), 2012/2013				
	K_0	K_1	K_2	K_3	Ave.	K_0	K_1	K_2	K_3	Ave.
Control,$_{100ETc}$	0.99	1.11	1.12	1.14	1.09	1.11	1.09	1.08	0.94	1.06
RDI_{75}	0.75	0.75	0.83	0.92	0.82	0.73	0.87	1.00	0.85	0.87
RDI_{50}	1.05	1.06	1.11	1.16	1.10	1.11	1.13	1.21	1.19	1.16
DI_{75}	0.94	0.94	0.80	1.08	0.94	0.81	0.93	0.87	1.13	0.94
DI_{50}	1.51	1.39	1.69	1.51	1.53	1.51	1.46	1.79	1.79	1.64
Average	1.05	1.05	1.11	1.16		1.05	1.10	1.19	1.18	

Irrigation regimes	WP (kg grainm^{-3}), 2011/2012				WP (kg grain m^{-3}), 2012/2013			
	Sakha93	Giza168	Gemmiza9	Average	Sakha 93	Giza 168	Gemmiza 9	Average
Control,$_{100ETc}$	0.98	1.17	1.28	1.15	1.26	1.45	1.32	1.34
RDI_{75}	1.01	1.34	1.26	1.20	1.08	1.08	1.34	1.17
RDI_{50}	0.74	1.04	1.06	0.94	0.93	0.92	1.17	1.01
DI_{75}	0.87	0.83	1.24	0.98	0.91	1.05	1.18	1.05
DI_{50}	1.28	1.37	1.57	1.41	1.40	1.27	1.51	1.40
Average	0.97	1.15	1.28		1.12	1.15	1.30	

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تاثير معاملات نقص مياه الرى ومعدلات البوتاسيوم علي تحمل ثلاثة أصناف من القمح للإجهاد المائي و انتاجية مياه الري في الأراضي الرملية

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اجريت تجربة حقلية خلال الموسمين الشتويين في 2012/2011 و2013/2012 بقرية عبدالمنعم رياض منطقة البستان والتي تمثل مناطق استصلاح الاراضي بمنطقة غرب الدلتا (خط عرض 31,02 شمال وخط طول 30,28 شرق مع ارتفاع 6,7 م فوق سطح البحر). الهدف من التجربة دراسة تاثير نقص مياه الري ومعدلات البوتاسيوم علي محصول الحبوب ، وبعض مكونات المحصول مثل عدد السنابل في المتر المربع، عدد الحبوب في السنبلة، وزن ال 100 حبة، و كذا عدد الايام حتي طرد السنابل وعدد الايام حتي النضج، كمية مياه الرى المضافة، انتاجية وحدة المياه، وتحمل نقص المياه لثلاثة اصناف من القمح تحت ظروف الري بالرش في الاراضي الرملية. وكان تصميم التجربة هو القطع المنشقة مرتين مع ثلاث مكررات. وكانت معاملات الري عبارة عن 5 معاملات ري وهي 100 % من الاستهلاك المائي (مقارنة) ،نقص الري المنظم بنسبة 75% من الاستهلاك المائي في المرحلة الاولي والاخيرة من عمر النبات –الري بكمية 75% في كل المراحل من عمر النبات – المعاملة الري بكمية 50% في كل المراحل من عمر النبات والمعاملة نقص الري المنظم بنسبة 50% من الاستهلاك المائي في المرحلة الاولي والاخيرة من عمر النبات) وتمثل القطع الرئيسية و4 مستويات من البوتاسيوم (K0 = صفر - K1 = 12 كجم الفدان$^{-1}$- K2 = 24 كجم الفدان$^{-1}$–K3 = 48 كجم الفدان$^{-1}$) والتي تمثل القطع تحت رئيسية – وثلاث اصناف من القمح (V1 = سخا 93 –V2 = جيزة 168 –V3 = جميزة 9) والتي تمثل القطع تحت – تحت رئيسية. يمكن تلخيص أهم النتائج فيما يلي: - نقص محصول الحبوب ومكوناتة وكذا كلا من عدد الايام لطرد السنابل وعدد الايام لنضج المحصول مع استخدام اسلوبي الري الناقص، مقارنة بالري 100% من الاستهلاك المائي. زاد الجهد المائي بأوراق النيات تخت طروف نقص مياه الري، ولكن نقصت مياه الري المضافة خلال موسم النمو تحت ذات المعاملات. أعلي قيمة لانتاجية مياة الري سجلت مع الري 50% من الاستهلاك المائي طوال موسم النمو.- مستويات التسميد البوتاسي أظهرت اتجاهات مختلفة مع معظم الصفات تحت الدراسة في موسمي الدراسة وفي كثير من الحالات في الموسم الواحد. ريما تعزو هذه الاتجاهات الغير متوقعة نتيجة لاسلوب اضافة السماد البوتاسي من خلال مياة الري.- برهن مقياسيي تحمل الجفاف (DSI و DTE%) أن الصنف جميزة 9 هو المفضل زراعتة تحت ظروف التجربة الحالية.- تفاعل معاملات ري 100% من الاستهلاك المائي + المستوي K_1 من التسميد البوتاسي + الصنف جميزة 9 أعطيي أعلي محصول للحبوب في موسمي الدراسة