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The Mutual Effect of Withholding Irrigation at Some Growth Stages and Potassium Fertilizer on Yield and Water Productivity of Wheat

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ABSTRACT

The limitation of water resources and remarkable increase in population should force research workers to find ways for saving water without significant reduction in yield. So, two field experiments were carried out at Water Management Research Station, El-Karda and Irrigation Development Area at El-Wazaria, Kafrelsheikh, Egypt, during the two growing seasons of 2013/14 and 2014/15 to study the mutual effect of withholding irrigation and potassium fertilizer on yield and water productivity of wheat. Split plot design with four replicates was used. The main plots were devoted to irrigation treatments while the subplots were assigned to potassium fertilizer. Irrigation treatments were full irrigation (W_1) including tillering (T), Jointing (J) , booting (B), heading (H) and milking (M) stage, and it has been added to a 60 cm of the root zone depth; full irrigation (W_2) including T,J,B, H and M stages, and it has been added to a 40 cm of the root zone depth; withholding irrigation (W_3) at M stage; withholding irrigation (W_4) at B stage; withholding (W_5) at J stage; withholding (W_6) at J and B stages and withholding (W_7) at J,B and M stages. All withholding irrigation treatments were irrigated to a 40 cm of the root zone depth. Potassium application treatments were 24 kg K_2O feddan as basil along with foliar spraying twice using 2 % of potassium sulphate at 35 and 55 days after sowing and control treatment without application. Results showed that insignificant increases between full irrigation treatments of W_1 and W_2 in spike No. m^{-2}, spike length, kernel No. spike^{-1}, 1000-kernel weight, grain weight spike^{-1} , straw and grain yields in both seasons .No significant differences in the most of these traits were noticed among withholding irrigation treatments of W_3, W_4 and W_5 that received four irrigation and W_1 especially in the first season that receive irrigation twice because of high rainfall. Seasonal water applied amounted 2517, 2025, 1815, 1722, 1758, 1456 and 1246 m^3/fed. and water consumptive use values were 1584, 1480, 1327, 1234,1270, 967 and 755 m^3/fed. over the two seasons for W_1, W_2,W_3,W_4,W_5, W_6 and W_7, respectively. Withholding irrigation treatments of W_7 resulted in the highest water productivity to be 2.5 kg grain m^{-3} over both season. Application K fertilizer (K1) significantly increased straw yield and grain yield and its components except spike length. The interaction between irrigation treatments and K fertilizer had significant effect on the most studied traits in both seasons. Application of K fertilizer diminished the negative effects of withholding irrigation on yield and its components. Application of K fertilizer did not effect on seasonal irrigation water and consumptive use, but it increased water productivity through increasing grain yield. At North Delta, Penman Monteith equation can be used in determining the actual consumptive use and the average of crop Coefficient (Kc) for the two seasons was found to be 0.87, 1.07, 1.11, 1.17, 1.23, 1.28 and 0.35 during emergence, tillering , jointing, heading, milking and ripening stages, respectively. Therefore, when water is becoming a limited factor for wheat production, it should applied withholding irrigation at J or M stages with potassium fertilizer to reduce the negative effect of withholding irrigation at some growth stages and to keep the productivity without significant reduction.

INTRODUCTION

Wheat (*Triticum aestivum* vulgare L.) is grown on roughly 1.4 million hectares of land with 9 million tons produced in Egypt during 2013/2014 winter season (FAO, 2014). Egypt remains the world's largest wheat importer. Wheat imports for the 2015/16 marketing year are estimated at 11 million tons, about the same as the previous year and the average for the last five years (FAO, 2015).

Possibilities to expand cultivated acreage in Egypt are limited by water scarcity. The challenge for the coming decades will be increasing wheat production with optimization of supplemental irrigation (Hafez and Gharib, 2016). The improve of water-use efficiency (WUE) is the most serious tool for increasing crop production with less water (Tari, 2016).

Several studies conducted to irrigation based on measuring soil moisture content in different soil layers and withholding water throughout different plant growth stages (Man *et al*., 2015; Maqbool *et al*., 2015 and Yi *et al*., 2013). The highest grain yield and water use efficiency were attained in testing the soil water content at soil layer 0-40 cm compare to 0-20 or 0-60 cm (Guo *et al*., 2014 and Man *et al*., 2016).

Mbave (2013) concluded that water-stress treatment by withholding water at the flowering stage reduced grain yield by range 33% to 35% in the two seasons while withholding water at stem elongation gave the highest WUE of 14.9 kg ha-^{1} mm^{-1} and reduced water use by 27%. Gupta *et al*. (2001) found that number of grains, test weight, grain yield, and biological yield and harvest index decreased largely when water stress was imposed at the anthesis stage, while imposition of water stress at the boot stage caused a greater reduction in plant height and number of tillers.

Potassium is an essential element in several physiological processes; enzyme activation, photosynthesis, stomatal regulation and osmotic regulation, osmotic potential, sugar translocation and water uptake (Damon *et al*., 2011; Pettigrew, 2008 and Wang *et al*., 2013). Imran *et al*. (2015) reported that potassium improve crop tolerance to water stress by well developed root system and accelerated the maximum water uptake and improved water use efficiency. Raza *et al*. (2014) concluded that application of potassium improve leaf water potential, osmotic potential, turgor potential , spike length, number of grain per spike and grain yields under water stress.

The objectives of this work were to study the application of potassium fertilizer to reduce the negative effect of withholding irrigation at some growth stages on yield and water relation of wheat

MATERIALS AND METHODS

Wheat cultivar Misr 1 (*Triticum aestivum* L.) was grown on a clay soil at Water Management Research

Station, El-Karda and Irrigation Development Area at El-Wazaria, Kafrelsheikh, Egypt, during the two growing seasons of 2013/14 and 2014/15, to study the application of potassium fertilizer to reduce the negative effect of withholding irrigation at some growth stages on yield and water relation of wheat. The preceding crop was the maize in the first season and cotton in the second season. The soils of the experimental field were clayey. Water table was ranged from 70-95 cm in both seasons. The soil physical properties were determined in the experimental sites (Table 1). Some chemical properties of the experimental soil in the two seasons according to Black *et al.* (1965) (Table 2).The experimental field was fertilized with 15.5 kg P_2O_5/feddan in the form of calcium superphosphate (15.5 % P_2O_5) during soil preparation.

Table 1. Soil physical properties for the experimental field in 2013/2014 and 2014/2015 seasons

Soil depth (cm)	Field capacity % 2013/14	Field capacity % 2014/15	Wilting point % 2013/14	Wilting point % 2014/15	Bulk density (g/cm^3) 2013/14	Bulk density (g/cm^3) 2014/15
0 - 20	44.46	42.82	24.19	23.16	1.10	1.16
20 - 40	39.03	38.92	21.22	21.21	1.16	1.25
40 - 60	36.72	35.65	19.79	19.73	1.24	1.32

Table 2. Chemical analysis of the experimental soil (0-30 cm depth) in 2013/14 and 2014/15 seasons.

Season	pH (1:2.5)	EC (ds/m)	Organic matter(%)	Available N (ppm)	Available P(ppm)	Available K (ppm)
2013/14	8.20	3.0	1.6	19.8	15.6	390
2014/15	8.06	2.8	1.5	18.7	17.3	378

Irrigation treatments were started after the first irrigation (sowing irrigation). Seven irrigation treatments were used as shown in Table 3. Irrigation treatments were full irrigation (W_1) including tillering (T), Jointing (J) , booting (B), heading (H) and milking (M) stage, and it has been added to a 60 cm of the root zone depth; full irrigation (W_2) including T,J,B, H and M stages, and it has been added to a 40 cm of the root zone depth; withholding irrigation (W_3) at M stage; withholding irrigation (W_4) at B stage; withholding (W_5) at J stage; withholding (W_6) at J and B stages and withholding (W_7) at J,B and M stages. All withholding irrigation treatments were irrigated to a 40 cm of the root zone depth as shown in Table 3. Soil samples were collected at each 20 cm soil depth to 60 cm to determine the percentage of moisture in each soil layer before irrigation. Amount of applied irrigation water were measured by a portable pump equipped with a water meter for each plot.

Table 3. Irrigation number, available soil moisture depth and stage withhold irrigation (stress stage).

Irrigation treatment					Growth stages				
Serial	I. No.	Depth (cm)	Stress stage	Symbol	Tillering (T)	Jointing (J)	Booting (B)	Heading (H)	Milking(M)
W_1	5	0-60	without	5I-D60	√	√	√	√	√
W_2	5	0-40	without	5I-D40	√	√	√	√	√
W_3	4	0-40	M	4I-D40-M	√	√	√	√	×
W_4	4	0-40	B	4I-D40-B	√	√	×	√	√
W_5	4	0-40	J	4I-D40-J	√	×	√	√	√
W_6	3	0-40	JB	3I-D40-JB	√	×	×	√	√
W_7	2	0-40	JBM	3I-D40-JBM	√	×	×	√	×

I = irrigation, D = depth of available soil moisture , √ = irrigation, × = withholding irrigation.
Potassium fertilizer was used as follows:
K_0: without K fertilizer (control)
K_1: application of 24 kg K_2O in the form of potassium sulphate (48 % K_2O) as top dressing in two equal doses (the first at sowing and the other at 21 days after sowing) along with two foliar sprays with solution of 2% potassium sulphate at 35 and 55 days after sowing.

The experimental design was split-plot with four replicates. Main plots were assigned to irrigation treatments and sub-plots to potassium application. The sub plot size was 20 m^2 (4 X 5 m). To avoid the effect of lateral movement of irrigation water, the main plots were isolated by levees 1.5 m wide. Wheat seed was drilled by hand in rows 20 cm a part at the rate of 50 kg seed feddan^{-1} on 20 and 21 November in first and second seasons, respectively. Each plot included 10 rows. Nitrogen fertilizer in the form of urea (46% N) was applied at the rate 75 kg N feddan^{-1} in two doses, 20% at sowing and 80% at the first irrigation (onset tillering stage). The normal of cultural practices for growing wheat were applied as recommended traits. Number of spikes m^{-2} (Spikes No. m^{-2}), spike length (cm), number of kernels per spike (Kernels No. spike^{-1}), grain weight per spike (g spike^{-1}) and 1000-grain weight (g) measured and taken at harvest. The harvest at maturity was 151 and 156 days from sowing in both seasons. The central area of 8 m^2 (2 X 4 m) were harvested and threshed to determine grain and straw yield (t feddan^{-1}). The weight of grain yield was adjusted to 14.5% moisture content.

Water Measurements

Amount of applied irrigation water were measured by a portable pump equipped with a water meter for each plot. Actual need for irrigation was determined by drying the soil samples for 24 hours to 110°C and the percentage of moisture was expressed on oven dry weight basis.

Soil moisture sampling at each 20 cm soil depth to 60 cm was taken before irrigation to calculate the needed amount of applied irrigation water to reach field capacity.Soil samples were obtained at each 20 cm soil depth to 60 cm before and after irrigation to calculate water consumptive use (WCU) of wheat plants according to Israelsen and Hansen (1962) equation as follows:

$$WCU = \frac{\theta_2 - \theta_1}{100} \times B.d \times D \times 4200$$

Where:

WCU = Amount of water consumptive use (m^3/feddan).
θ_2 = Soil moisture content % after irrigation.
θ_1 = Soil moisture content % before the next irrigation.
B.d = Bulk density (g/cm^3).
D = Depth of soil layer (m).

Water productivity for applied water ($WP_{water\ applied}$) and water consumptive use ($WP_{water\ consumptive\ use}$) were calculated according to El-Bably *et al.* (2015) as follows:

$$WP_{water\ applied} = \frac{Yield\ (kg/ha)}{Applied\ water\ (m^3/ha)}$$

$$WP_{\text{water consumptive use}} = \frac{\text{Yield (kg/ha)}}{\text{water consumpitive use } (m^3/ha)}$$

Crop coefficient (Kc) was calculated according to Penman Monteith method as the ratio between actual crop evapotranspiration (ET_a) and reference evapotranspiration (ET_o) as follows:

$$Kc = \frac{ETa}{ETo}$$

Reference evapotranspiration (ET_o) was calculated by FAO Penman Monteith (Allen *et al.*, 1998).

Analysis of variance (ANOVA) was assessed according to Gomez and Gomez (1984) and the means were compared by Duncan's Multiple Range Test (Duncan, 1955).The data was analyzed using CoStat software for windows (version 6.3).

RESULTS AND DISCUSSION

A. Weather condition:

The meteorological data for experimental sites during the two seasons are summarized in Figures 1, 2 and 3. Seasonal rainfall was 110.3 mm and 37.9 mm in 2013/2014 and 2014/2015 seasons, respectively (Fig. 1). Amount of rainfall was greater in the first season than the second season at any month during growing season. The maximum rainfall was recorded at March in the first season and at April in the second season. Fig. 2 illustrated that air temperature reduced by time progress from November to December then it slightly increased to February and sharply increased to April in the first season. In the second season, air temperature reduced by time progress from November to January then it slightly increased to February and sharply increased to April. Air temperature was lower at the period of November and December in the first season than in the second season and then it was higher at the remainder in the first season than in the second season. The lowest mean monthly of air temperature was obtained at December in the first season and at January in the second season, while the highest one was obtained at April in both seasons. Mean monthly of relative humidity gradually increased from November to January then it slightly decreased to February and severity decreased to April in both seasons (Fig. 3). Relative humidity was greater in the first season than in the second season at all growing months.

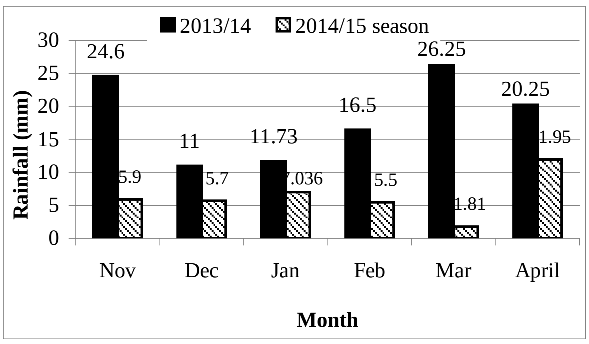

Fig. 1. Amount of monthly rainfall in 2013/2014 and 2014/2015 seasons.

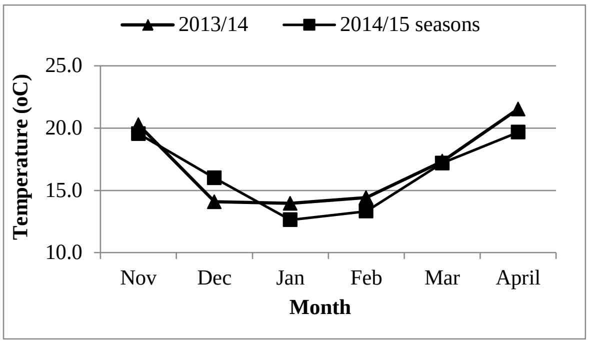

Fig. 2. Mean monthly of Temperature (°C) in 2013/2014 and 2014/2015 seasons.

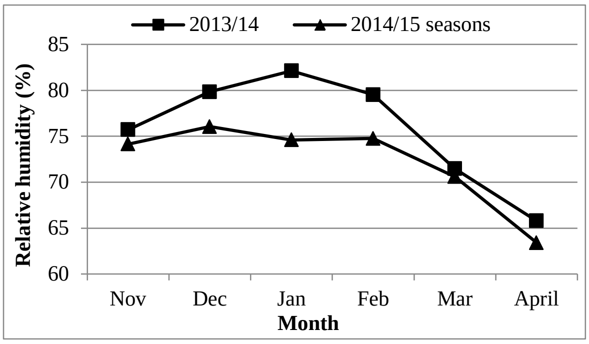

Fig. 3. Mean monthly of relative humidity percentage in 2013/2014 and 2014/2015 seasons.

B. Yield components:

1. Irrigation effect:

Irrigation treatments had significant effect on spikes number m^{-2}, spike length, kernels number $spike^{-1}$, 1000-kernel weight and grain weight $spike^{-1}$ in both seasons (Table 4 and 5).

Irrigation treatment of W_1 that received five irrigation resulted in significant increase in spikes number m^{-2} compared with four, three or two irrigations to the soil depth of 0-40 cm along with prevent irrigation at jointing growth stage (W_5, W_6 and W_7) in both seasons. There were no significant differences in this trait among five irrigation between W_1,W_2 and irrigation of W_3 at milking stage in the two seasons. Withholding one irrigation at booting stage (W_4) were statistically at par with the mentioned three treatments (W_1, W_2 and W_3) in spikes number m^{-2} in the first season, but it significantly reduced this trait than them in the second season. This may be due to increase rainfall amount in the first season than the second season at this stage.

Data in Table 4 show that withholding irrigation at jointing growth stage markedly reduced spikes number m^{-2} in both seasons. Water stress during jointing stage accelerates tiller death which causes reduction in number of survival active tillers (spikes number m^{-2}).Mehasen *et al.* (2014) reported that skipping irrigation at tillering, elongation and heading growth stages decreased number of spikes m^{-2} compared with skipping irrigation at filling stage. Also, Mekkei and El Haggan (2014) concluded that application of five irrigations at different wheat growth stages resulted in higher number of spikes m^{-2}, while skipping irrigation at stem elongation or booting or anthesis stage caused a reduction in number of spikes m^{-2}.These results are in agreement with those obtained by Attia and Barsoum (2013); Shirazi *et al*. (2014) and Tari (2016).

Table 4. Number of spike m^{-2}, spike length, number of kernels $spike^{-1}$ and 1000-kernel weight of wheat cv. Misr1 as affected by irrigation treatments and potassium application in 2013/14 and 2014/15 seasons.

Factor		Spikes (No m^{-2})		Spike Length (cm)		Kernels (No $spike^{-1}$)		1000-kernel weight (g)	
		2013/14	2014/15	2013/14	2014/15	2013/14	2014/15	2013/14	2014/15
Irrigation:									
W1	5I-D60	444 a	441 a	11.89 a	12.1 a	70.7 a	72.7 a	47.04 a	46.69 a
W2	5I-D40	442 a	436 a	11.72 ab	11.96 b	69.1 ab	72.1 ab	46.74 a	46.72 a
W3	4I-D40-M	439 ab	432 a	11.69 ab	11.94 b	68.1 ab	70.5 ab	46.19 ab	45.89 b
W4	4I-D40-B	423 ab	409 b	11.57 ab	11.94 b	67 bc	68.7 bc	46.48 a	46.26 ab
W5	4I-D40-J	420 b	410 b	11.49 ab	11.91 b	68.3 ab	69.4 abc	46.67 a	46.29 ab
W6	3I-D40-JB	399 c	406 bc	11.34 ab	11.79 c	64.6 c	66.2 cd	46.25 a	46.14 b
W7	2I-D40-JBM	394 c	394 c	11.1 b	11.51 d	61 d	63.2 d	45.47 b	45.35 c
	F test	*	**	*	*	**	*	**	**
Kg K_2O fed.$^{-1}$:									
K_0	0	421 b	414 b	11.45	11.85	66.1	67.7 b	46.18 b	46.04 b
K_1	24	425 a	422 a	11.64	11.91	67.8	70.3 a	46.64 a	46.34 a
	F test	*	*	NS	NS	NS	**	**	*
Interaction		**	*	NS	NS	*	*	*	*

*** and ** indicate P<0.05 and P<0.01. Means in each factor designated by the same latter are not significantly different at 5% level using Duncan's Multiple Range Test. I= irrigation, D= depth of soil layer, J,B and M= withholding irrigation at jointing, booting and milking stages, respectively.**

Table 5. Grain weight $spike^{-1}$, straw yield, grain yield and harvest index of wheat cv. Misr1 as affected by irrigation treatments and potassium application in 2013/14 and 2014/15 seasons.

Factor		Grain weight (g $spike^{-1}$)		Straw yield (t $feddan^{-1}$)		Grain yield (t $feddan^{-1}$)		Harvest index	
		2013/14	2014/15	2013/14	2014/15	2013/14	2014/15	2013/14	2014/15
Irrigation:									
W1	5I-D60	3.328a	3.396a	6.574a	6.655a	3.693a	3.5065a	0.36d	0.345c
W2	5I-D40	3.228a	3.369ab	6.233a	6.512ab	3.641a	3.4825a	0.366d	0.35bc
W3	4I-D40-M	3.146ab	3.235ab	6.038ab	6.287ab	3.503ab	3.387ab	0.366d	0.351bc
W4	4I-D40-B	3.115ab	3.179bc	6.002ab	6.145ab	3.489ab	3.33b	0.369cd	0.348bc
W5	4I-D40-J	3.188ab	3.215abc	5.746ab	6.072ab	3.472ab	3.385ab	0.379bc	0.358ab
W6	3I-D40-JB	2.988b	3.052cd	5.256bc	5.915bc	3.288bc	3.227c	0.385ab	0.353abc
W7	2I-D40-JBM	2.776c	2.868d	4.966c	5.351c	3.231c	3.048d	0.394a	0.363a
	F test	*	*	**	**	**	**	*	*
Kg K_2O fed.$^{-1}$:									
K_0	0	3.055b	3.116b	5.774	6.048b	3.410b	3.284b	0.372	0.352
K_1	24	3.165a	3.259a	5.887	6.219a	3.538a	3.392a	0.376	0.353
	F test	*	**	NS	*	*	**	NS	NS
Interaction		**	*	*	**	*	**	*	*

- **and ** indicate P<0.05 and P<0.01. Means in each factor designated by the same latter are not significantly different at 5% level using Duncan's Multiple Range Test.I= irrigation, D= depth of soil layer, J,B and M= withholding irrigation at jointing, booting and milking stages, respectively.**

Abundance of available soil moisture in irrigation treatment of W_1 resulted in a significant increase in spike length compared to withholding irrigation three times (W_7) at jointing, booting and milking stage in both seasons. These results agreed with those obtained by Attia and Barsoum (2013) and Shirazi *et al.* (2014).

Withholding irrigation at booting growth stage caused a significant decrease in number of kernels $spike^{-1}$ than W_1 treatment in the two seasons. W_1 irrigation treatment recorded the greatest number of kernels $spike^{-1}$ followed by W_2, W_3 and W_5 treatments in the two seasons. Kernel number is determined in the end of jointing and onset booting stages without significant differences in both seasons. Similar results were obtained by Guo *et al.* (2014); Sang *et al.* (2016) and Shirazi *et al.* (2014) .

Abundance available soil moisture at either W_1 or W_2 irrigation treatments resulted in substantial increase in 1000-kernal weight compared W_7 treatment in both seasons. Irrigation treatment of W_3 markedly decreased 1000-kernal weight in the second season compared with W_2 treatment, but they were statistically equal in this respect in the first season. This reduction in grain weight may be due to a shortage of carbohydrates supplied per grain, which is caused by raped maturation of grains. The fact that the water stress at milking stage shortened maturation period and the kernel ripened about one week earlier than those on control plants support this conclusion. On the other hand, the increase in rainfall in the first season compensated the shortage of irrigation water at this stage, which in turn increased 1000-kernal weight. In this connection, Guendouz *et al.* (2016) found that water deficit after anthesis stage decreased grain filling period and kernel weight. Mekkei and El Haggan (2014) found that skipping irrigation at various growth stages decreased 1000-kernel weight. These results are in agreement with those obtained by Shirazi *et al.* (2014) and Tari (2016).

Weight of grains $spike^{-1}$ was gradually increased by increasing irrigation number from 3 to 6 times in both seasons. There were no significant differences in weight of grains $spike^{-1}$ among irrigation treatments of W_1, W_3, W_4 and W_5, except W_4 in the second season. This is due to decrease number of kernel $spike^{-1}$ by shortage water irrigation at booting stage along with little irrigation in the second seasons, whereas, weight of spike grain is resulted from kernel number $spike^{-1}$ and kernel weight. These results are in agreement with those obtained by Hafez and Gharib (2016); Rizk and Sherif (2014) and Shirazi *et al.* (2014).

2. Potassium effect:

Data in tables 4 and 5 showed that application of potassium fertilizer had a significant effect on spikes number m^{-2}, 1000-kernel weight and grain weight $spike^{-1}$ in both seasons and kernels number $spike^{-1}$ in the second season. Application of 24 kg K_2O $feddan^{-1}$ significantly increased the mentioned treats compared the control treatment without potassium. However, spike length did not affect by potassium application in the two seasons. Potassium fertilizer increased grain weight $spike^{-1}$ through increasing weight kernel and number of kernel per spike.These results are agreement with those obtained by El-Abady *et al.* (2009) and El-Ashry and El-Kholy (2005).

3. Interaction effect:

The interaction between irrigation treatments and potassium application had significant effect on spikes number m^{-2}, kernels number $spike^{-1}$, 1000-kernel weight and grain weight $spike^{-1}$ in both seasons (Tables 6 and 7). However, spike length did not affect by the interaction of irrigation treatments and potassium in the two seasons.

Table 6. Number of spike m^{-2}, spike length, number of kernels $spike^{-1}$ and 1000-kernel weight of wheat cv. Misr1 as affected by the interaction between irrigation treatments and potassium application in 2013/14 and 2014/15 seasons.

Irrigation	K	Spikes (No M^{-2})		Kernels (No $spike^{-1}$)		1000-kernel weight (g)	
		2013/14	2014/15	2013/14	2014/15	2013/14	2014/15
W1(5I-D60)	K_0	442 ab	436 abc	70.2 ab	72.4 a	46.88 ab	46.47abc
	K_1	447 a	446 a	71.3 a	73.1 a	47.20 a	46.90 a
W2 (5I-D40)	K_0	438 ab	433 abc	68.0 ab	71.6 ab	46.57 a-d	46.53 ab
	K_1	446 a	439 ab	70.1 ab	72.6 a	46.92 ab	46.92 a
W3 (4I-D40-M)	K_0	437 ab	428 a-d	67.5 ab	68.8 abc	45.94 cde	45.8 cde
	K_1	442 ab	436 abc	68.7 ab	72.2 ab	46.45 a-d	45.97 bcd
W4 (4I-D40-B)	K_0	420 abc	405 cde	65.9 a-d	66.2 bcd	46.23 bcd	46.10 bcd
	K_1	425 abc	413 a-e	68.1 ab	71.2 ab	46.74 abc	46.43 abc
W5 (4I-D40-J)	K_0	418 bc	407 b-e	66.6 abc	67.8 a-d	46.41 a-d	46.20 bc
	K_1	421 abc	413 a-e	70.0 ab	71.1 ab	46.93 ab	46.38 abc
W6 (3I-D40-JB)	K_0	396 d	401 de	64.1 bcd	64.3 cd	46.02 b-e	45.97 bcd
	K_1	402 cd	410 bcde	65.1 a-d	68 a-d	46.48 a-d	46.30 abc
W7 (2I-D40-JBM)	K_0	394 d	389 e	60.6 d	62.5 d	45.19 e	45.22 e
	K_1	394 d	398 de	61.5 cd	64 cd	45.76 de	45.47 de

I= irrigation D= depth of soil layer J,B and M= withholding irrigation at jointing, booting and milking stages, respectively. * and ** indicate P<0.05 and P<0.01. Means in each column designated by the same latter are not significantly different at 5% level using Duncan's Multiple Range Test.

Data in Table 6 show that W_5 treatment adversely affected spikes number m^{-2} but potash application ameliorated the adverse effect of stress by increasing this trait, statistically similar to irrigation treatment of W_1 with K application in both seasons. W_1 treatment and 24 kg K_2O $feddan^{-1}$ produced the greatest spikes number m^{-2}, while irrigation treatment of W_7 without K fertilizer produced the lowest one in both seasons. W_2, W_3 and W_4 irrigation treatments with either K or no K were statistically at par with the irrigation treatment of W_1 with K application.

Data in Table 6 show that water deficit at booting stage (W_4) without K fertilizer significantly decreased number of kernel $spike^{-1}$ in the second seasons, while the increase in amount rainfall in the first season at this stage compensated the shortage of water and in turn increased this trait to equal that produced from W_1. Adding k fertilizer positively affected number of kernel $spike^{-1}$ at shortage water at booting stage in the second season. There were no significant differences in number of kernel $spike^{-1}$ among W_1, W_2, W_3 and W_6 treatments with or without k application in both seasons. Adding potassium improved kernel formation per spike when water deficit occurred at jointing and booting stages together in the two seasons. This indicates an integration of water deficit and potassium fertilization. Aown *et al.* (2012) reported that potash spray under drought at all growth stages of wheat ameliorated the adverse effects of stress by improving the number of grains per spike to a significant level.

The weight of 1000-kernel was significantly influenced by the interaction between irrigation treatment and k fertilizer in favour of irrigation treatments of W_1 and W_2 with or without potassium fertilizer compared to W_3, W_4 and W_5 in both seasons. Data showed that withholding irrigation significantly reduced the weight of 1000-kernrl when it was applied either at booting stage or at jointing stage alone or together and K ameliorated this negative effect to statistically equal to full irrigation in the two seasons. Water deficit at milking stage with or without k fertilizer severity decreased the weight of 1000-kernel in both seasons, but the increase in amount rainfall in the first season compensated the shortage of water at this stage with k fertilizer and increased this trait to pair with full irrigation with K fertilizer in both seasons.

Data in Table 7 show that W_1 and W_2 irrigation treatments with or without K fertilizer, being insignificant, increased grain weight $spike^{-1}$ than irrigation treatment of W_7 in both seasons. Adding potassium fertilizer decreased the negative effect of withholding irrigation at each of jointing, booting and milking stages alone or at jointing and booting stages together on grain weight $spike^{-1}$ in both seasons. Withholding irrigation at the mentioned stages with K fertilizer was statistically similar to full irrigation (control) in the grain weight $spike^{-1}$ in the two seasons. Amount of rainfall in the first season resulted in compensate water deficit at the mentioned stages and consequently it increased grain weight $spike^{-1}$ at no K fertilizer to equal that at full irrigation with or without K fertilizer. The trend of grain weight $spike^{-1}$ is similar to those of kernel number $spike^{-1}$ and similar discussion could be cited.

Table 7. Grain weight spike^{-1}, straw yield, grain yield and harvest index of wheat cv. Misr1 as affected by the interaction between irrigation treatments and potassium application in 2013/14 and 2014/15 seasons.

Irrigation	K	Grain weight (g spike^{-1})		Straw yield (t feddan^{-1})		Grain yield (t feddan^{-1})		Harvest index	
		2013/14	2014/15	2013/14	2014/15	2013/14	2014/15	2013/14	2014/15
W1(5I-D60)	K_0	3.291a	3.364ab	6.537a	6.538ab	3.653ab	3.485ab	0.358d	0.348cd
	K_1	3.365a	3.428a	6.61a	6.772a	3.733a	3.528a	0.361d	0.343d
W2 (5I-D40)	K_0	3.167ab	3.332ab	6.146abc	6.487ab	3.591abc	3.444ab	0.369bcd	0.347cd
	K_1	3.289a	3.406ab	6.319ab	6.536ab	3.69a	3.521a	0.369bcd	0.35bcd
W3 (4I-D40-M)	K_0	3.101abc	3.151a-d	6.022abc	6.235abc	3.433a-d	3.341bc	0.363cd	0.349bcd
	K_1	3.191ab	3.319abc	6.053abc	6.338ab	3.544abc	3.433ab	0.369bcd	0.351bcd
W4 (4I-D40-B)	K_0	3.047abcd	3.052cde	5.993abc	6.133abc	3.422a-d	3.298c	0.363cd	0.35bcd
	K_1	3.183ab	3.306abc	6.01abc	6.157abc	3.522abc	3.362abc	0.369bcd	0.353abc
W5 (4I-D40-J)	K_0	3.091abc	3.132bcd	5.617bcd	6.033bc	3.441a-d	3.348bc	0.38b	0.357abc
	K_1	3.285a	3.298abc	5.874abc	6.11abc	3.565abc	3.422ab	0.378bc	0.359ab
W6 (3I-D40-JB)	K_0	2.95bcd	2.956de	5.101d	5.815bc	3.197de	3.165d	0.385ab	0.352a-d
	K_1	3.026a-d	3.148a-d	5.41cd	6.014bc	3.379bcd	3.289c	0.384ab	0.354abc
W7 (2I-D40-JBM)	K_0	2.739d	2.826e	4.999d	5.093d	3.13e	2.905e	0.385ab	0.363a
	K_1	2.814cd	2.91de	4.932d	5.608cd	3.332cde	3.191d	0.403a	0.363a

I= irrigation D= depth of soil layer J,B and M= withholding irrigation at jointing, booting and milking stages, respectively.
*** and ** indicate P<0.05 and P<0.01. Means in each column designated by the same latter are not significantly different at 5% level using Duncan's Multiple Range Test**

C. Straw and grain yields:

Means of straw yield, grain yield and harvest index as affected by irrigation treatments and potassium application in 2013/14 and 2014/15 seasons are presented in Table 5.

1. Irrigation effect:

Irrigation treatments had significant effect on straw yield, grain yield and harvest index in the two seasons. Straw yield per feddan was significantly increased by increasing irrigation numbers to four or five times compared with two times. Full irrigation of W_1 produced the highest straw yield without any significant differences than W_2, W_3, W_4 and W_5 irrigation treatments in both seasons. The lowest straw yield was obtained from W_7 in both seasons. This may be due to decrease in survival number of tillers. Mekkei and El Haggan (2014) found that skipping irrigation at various growth stages decreased straw yield (ton ha^{-1}) compared with full irrigation in both seasons. These results are in agreement with those obtained by El-Abady *et al*. (2009); Rizk and Sherif (2014) and Shirazi *et al*. (2014) .

Grain yield per feddan was markedly affected by irrigation treatments in both seasons. Full irrigation treatments of W_1 and W_2 soil layers, being insignificant, resulted in a significant increase in grain yield compared to W_3, W_4, W_5 and W_6 irrigation treatments in both seasons. Irrigation treatments containing water deficit at booting stage severity reduced grain yield. In the first season, withholding irrigation treatment of W_4 had no significant effect on grain yield compared with full irrigation (W_1), because the amount of rainfall was increased and compensated the negative effect. These treatments decreased grain yield through decreasing number of spikes m^{-2} and kernels spike^{-1}. There were no significant differences in grain yield among full irrigation (W_1) and withholding irrigation treatments of W3 and W_5 in the two seasons. This may be due to the increase in yield components namely number of spikes m^{-2}, kernels spike^{-1}, 1000-kernel weight and grain weight spike^{-1}. In this connection, Adequate water at or after anthesis not only allowed the wheat plant to increase photosynthetic rate but also give extra time to translocate the carbohydrates in grains, which enhanced grain size and ultimately causes higher grain yield (Mirbahar *et al*., 2009). Seleiman *et al*. (2010) showed that increasing number of irrigations up to five increased grain yield. Abro (2012) reported that for obtaining maximum grain yield in wheat, the crop will need five irrigation because there was significant decrease in grain yield with decreasing the number of irrigation. Baloch *et al*. (2014) found that wheat crop irrigated five times produced maximum grain yield, while the minimum grain yield recorded in three irrigation. Mehasen *et al*. (2014) showed that skipping one irrigation at tillering, elongation and heading stages decreased grain yield compared with skipping irrigation at filling stage treatments. Zareian *et al*. (2014) found that water stress through withholding at the ear emergence and grain filling phases reduced grain yield and its components.

Harvest index was significantly increased by decreasing number of irrigation from 5 to 2 times in both seasons. Withholding irrigation treatments of W_3, W_4 and W_4 resulted in significant increase in harvest index compared with W_1 treatment in both seasons. The increase in harvest index is due to the decrease in biological yield at this treatment.

2. Potassium effect:

Application of potassium fertilizer had a significant effect on straw yield in the second season and grain yield in both seasons (Table 5). Application of 24 kg K2O feddan-1 significantly increased the mentioned treats compared the control treatment without potassium. Application of potassium fertilizer increased grain yield through increased spikes m-2, kernels spike-1, 1000-kernel weight and grain weight spike-1. Harvest index did not influenced by application of potassium fertilizer in both seasons.

3. Interaction effect:

The interaction between irrigation treatments and potassium application had significant effect on straw and grain yield as well as harvest index in both seasons (Table 7).

Data in Table 7 show that the highest straw yield was obtained from full irrigation treatment (W_1) without significant difference than W_2, W_3 and W_4 treatments with or without K fertilizer in both seasons. The lowest straw yield was obtained from W_7 irrigation treatment with or without K fertilizer in the two seasons. Withholding irrigation of W_5 without K fertilizer adversely affected straw yield, but application of K fertilizer ameliorated the adverse effect of stress by increasing this trait to statistically equal to the full irrigation to 0-60 cm soil layer (W_1) with K application in both seasons. The increase in straw yield was related by increasing number of tillers per unite area.

Data in Table 7 show that W_3 and W_4 irrigation treatments without potassium fertilizer significantly decreased grain yield in the second season, but the increase in amount rainfall in the first season at these stages compensated the shortage of water and in turn increased this trait to equal that produced from full irrigation. Adding potassium fertilizer positively affected grain yield at shortage water at booting or milking stages alone in the second season. There were no significant differences in grain yield among irrigation treatments of W_1,W_2 and W_5 with or without K fertilizer and W_4 or W_3 treatments with k application in both seasons. Abundance of available soil moisture with K fertilizer increased grain yield through increasing number of spikes m^{-2}, kernels $spike^{-1}$, 1000-kernel weight and grain weight $spike^{-1}$. Data indicate an integration of water deficit and potassium fertilization on grain yield. El-Ashry and El-Kholy (2005) reported that 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. Zareian *et al.* (2014) concluded that maximum values of grain yield could be achieved from wheat cultivar WS-82-9 giving normal irrigation and sprayed with 3.0% K_2O. These results are supported by the previous findings of Aown *et al.* (2012); El-Abady *et al.* (2009) and Niu *et al.* (2013).

Data in Table 7 show that withholding irrigation treatment of W_7 with or without K fertilizer significantly resulted in significant increase in harvest index compared with full irrigation to 0-60 cm soil layer (W_1) with or without K fertilizer in both seasons. W_6 and W_7 irrigation treatments did not significantly differ in harvest index at with or without K fertilizer in the two seasons.

D. Soil water relations:

1. Seasonal amount of applied water:

Seasonal water applied consists of the two main components; water applied delivered to the field plot and effective rainfall. The total amounts of the effective rainfall during the two growing seasons were 190.0 and 102.33 m^3 fed^{-1} in the first and second growing seasons, respectively. At the same irrigation treatment, plots of potassium fertilizer or without were received equal amount of irrigation water during growing season. The amounts of applied irrigation water from sowing to harvest as affected by irrigation treatment are presented in Table 8.

The amount of applied water was increased by increasing irrigation number and available soil water depth in both seasons. Treatments of W_1 that irrigated five times recorded the highest values of seasonal applied water to be 2583 and 2452 m^3 $feddan^{-1}$, while withholding irrigation at J, B and M stages recorded the lowest values 1325 and 1167 m^3/feddan in the two seasons. Withholding irrigation at any growth stage resulted in practically reduced in seasonal compared with full irrigation treatment of W_1 (control) in both seasons. Such increase in the amount of applied water by increasing irrigation number and available soil water depth may be attributed to considerable increase in leaf area, which resulted in a greater transpiration and in turn water requirement. The difference in seasonal water applied between the first and second seasons due to the variation in the amount of rain fall (Fig 1).

Table 8. Irrigation water, seasonal water applied (m^3 fed^{-1}) as affected by Irrigation and potassium treatments in 2013/2014 and 2014/2015 seasons.

Irrigation treatments		Water applied (m^3 fed^{-1}) 2013/14	Water applied (m^3 fed^{-1}) 2014/15	Seasonal water applied (m^3 fed^{-1}) 2013/14	Seasonal water applied (m^3 fed^{-1}) 2014/15	water saving (m^3 fed^{-1}) 2013/14	water saving (m^3 fed^{-1}) 2014/15
W1	5I-D60	2393	2350	2583	2452	-	-
W2	5I-D40	1923	1835	2113	1937	470	515
W3	4I-D40-M	1713	1625	1903	1727	680	725
W4	4I-D40-B	1624	1528	1814	1630	769	822
W5	4I-D40-J	1639	1585	1829	1687	754	765
W6	3I-D40-JB	1345	1275	1535	1377	1048	1075
W7	2I-D40-JBM	1135	1065	1325	1167	1258	1285

I= irrigation D= depth of soil layer J,B and M= withholding irrigation at jointing, booting and milking stages, respectively.

Full irrigation treatment of W_2 in the shallow soil layer 0-40 cm saved 470 and 515 m^3 of irrigation water than W_1 (control) treatment in both seasons. Withholding irrigation treatment of W_7 saved 1258 and 1285 m^3 of irrigation water per feddan than W_1 (control) treatment in both seasons. Withholding irrigation treatments of W_3 and W_5 saved 680 and 754 m^3 irrigation water in the first season and 725 to 765 m^3 in the second season than full irrigation treatment of W_1. Although, the irrigation treatments of W1 and W5 saved irrigation water than W1 (control treatment), they were statistically equal in grain yield in both seasons. Percentages of saving water obtained from withholding irrigation treatments or irrigation treatment of W_2 were ranged from 19.6 to 52.6% in the first season and from 21.9 to 54.7% in the second season compared with full irrigation treatment of W_1 in both seasons (Fig. 4). In this connection, Meleha (2016) reported that the seasonal values of water applied can be descended in order irrigation to reach the field capacity in soil depths 0-60 cm >0-40 cm > 0-20 cm. Jazy *et al.* (2012) reported that wheat may be irrigated after 90 mm cumulative pan evaporation not only may save about 22% in irrigation water with no significant loss in yield under condition similar to this experiment.

2. Seasonal actual water consumptive use:

Data in Table 9 show that the amount of water lost as evapotranspiration (seasonal water consumptive use) was increased by increasing irrigation number and soil water depth in the two seasons. Withholding irrigation at any growth stage and low available soil water depth substantially decreased seasonal water consumptive use (WCU) compared with full irrigation treatment of W_1 in the two seasons. Withholding irrigation treatments W_7 that irrigated twice recorded the lowest values of WCU 837 and 674 m^3 $feddan^{-1}$, while full irrigation treatment of W_1 during entire seasons recorded the highest values 1645 and 1524 m^3 $feddan^{-1}$ in the two seasons. Data indicated that seasonal water consumptive use was related positively with amount of applied water. Two irrigation in 0-40 cm soil depth with prevent three irrigation at J, B and M stages (W7) recorded the lowest values of WCU 837 and 674 m^3 $feddan^{-1}$, while five irrigation in 0-60 cm soil depth (W_1) during entire seasons recorded the highest values 1645 and 1524 m^3 $feddan^{-1}$ in the two seasons. The increase of actual water consumptive use at full irrigation treatment (W1) can be attributed to the increase in evaporation at high available moisture; more supplying plants with sufficient moisture led to an increase in green cover and hence increase transpiration. Rizk and Sherif (2014) reported that consumptive use was increased with increasing available soil moisture. Shirazi *et al*. (2014) found that water consumed by wheat genotypes throughout the growing season was about 293 mm / m^2 under control conditions. Tari (2016) reported that the seasonal water-consumptive use of experimental treatments varied between 206 and 571 mm. These results agree with those of Meleha (2016).

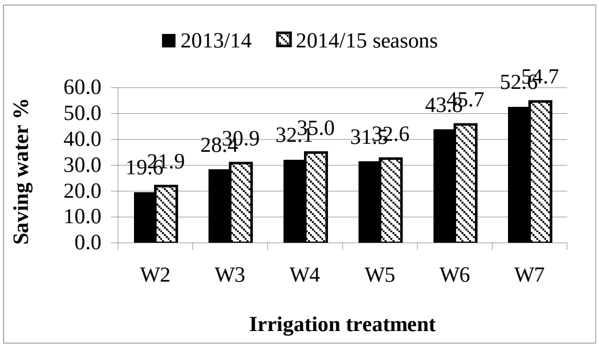

Fig. 4. Saving water percentage from W1 (control) as affected by irrigation treatment 2013/14 and 2014/15 seasons.

Application of K fertilizer slightly increased WCU compared with control (without k) in both seasons.

There were substantial differences in WCU among combination of irrigation treatments and K fertilizer in both seasons. At the same irrigation treatment, adding K fertilizer had a slight effect on WCU in the two seasons. However, WCU was markedly influenced by irrigation number, available soil water depth and withholding irrigation either with or without K fertilizer. Data show that irrigation treatments were more effective on WCU than K fertilizer. The highest values of WCU 1646 and 1524 $m^3 feddan^{-1}$ obtained from the interaction of full irrigation and K fertilizer (W1 x K1), while the lowest ones 835 and 673 $m^3 feddan^{-1}$ obtained from withholding three times without K fertilizer (W7 x K0) in both seasons. Although, potassium was ineffective on water consumption use, but it clearly affects translocate the carbohydrates in grains, which enhanced grain size and ultimately causes higher grain yield.

Table 9. Water consumptive use (WCU), water productivity (WP) and water productivity index (WPI) as affected by Irrigation treatments and potassium application in 2013/2014 and 2014/2015 seasons

Irrigation	K	WCU ($m^3 fed^{-1}$)		WP (kg m^3 AW)		WPI (kg m^3WCU)	
		2013/14	2014/15	2013/14	2014/15	2013/14	2014/15
W1(5I-D60)	-	1645	1524	1.43	1.43	2.25	2.30
W2 (5I-D40)	-	1525	1435	1.73	1.80	2.39	2.43
W3 (4I-D40-M)	-	1416	1238	1.83	1.96	2.47	2.74
W4 (4I-D40-B)	-	1327	1141	1.92	2.04	2.62	2.92
W5 (4I-D40-J)	-	1342	1198	1.92	2.01	2.61	2.83
W6 (3I-D40-JB)	-	1049	886	2.14	2.35	3.14	3.64
W7 (2I-D40-JBM)	-	837	674	2.44	2.61	3.87	4.53
	K0	1303	1155	1.88	1.99	2.71	3.00
	K1	1308	1158	1.95	2.07	2.81	3.11
W1(5I-D60)	K0	1643	1523	1.41	1.42	2.22	2.29
	K1	1646	1524	1.45	1.44	2.27	2.31
W2 (5I-D40)	K0	1523	1430	1.70	1.78	2.36	2.41
	K1	1527	1439	1.75	1.82	2.42	2.45
W3 (4I-D40-M)	K0	1413	1237	1.80	1.93	2.43	2.70
	K1	1418	1239	1.86	1.99	2.50	2.77
W4 (4I-D40-B)	K0	1324	1140	1.89	2.02	2.58	2.89
	K1	1330	1142	1.94	2.06	2.65	2.94
W5 (4I-D40-J)	K0	1339	1197	1.88	1.98	2.57	2.80
	K1	1344	1198	1.95	2.03	2.65	2.86
W6 (3I-D40-JB)	K0	1045	886	2.08	2.30	3.06	3.57
	K1	1052	886	2.20	2.39	3.21	3.71
W7 (2I-D40-JBM)	K0	835	673	2.36	2.49	3.75	4.32
	K1	838	675	2.51	2.73	3.98	4.73

I= irrigation, D= depth of soil layer, J,B and M= withholding irrigation at jointing, booting and milking stages, respectively.

3. Water productivity:

Grain yield per unit of applied water (AW) or water consumptive use (WCU) in kg grain m^{-3}water were used to determine water productivity. Data in Table 9 show that water productivity (kg grain m^{-3} water) for either AW or WCU was decreased by increasing irrigation number and irrigation depth in both seasons. Withholding irrigation at any growth stage resulted in substantially increase in water productivity for AW and WCU compared with full irrigation (control) in both seasons. Withholding three irrigations (W7) recorded the highest values of water productivity for AW to be 2.44 and 2.61 kg grain m^{-3} water and for WCU 3.87 and 4.53 kg grain m^{-3} water, while The control treatment full irrigation (W1) recorded the lowest values of this trait for AW to be 1.43 and 1.43 kg grain m^{-3} water and for WCU, it was (2.25 and 2.30 kg grain m^{-3} water) in both seasons. In this connection,Rizk and Sherif (2014) found that the highest value of water use efficiency when irrigation water was applied at 40 % available soil moisture for grain. Guendouz *et al.* (2016) found that water deficit increased water use efficiency. Tari (2016) reported that irrigation water-use efficiencies varied between 0.51 and 1.17 kg m^{-3}. These results agree with those of Man *et al*. (2016); Meleha (2016) and Tari (2016).

The water productivity for AW and WCU was slightly increased by application of K fertilizer in both seasons. The interaction between irrigation and K fertilizer distinctly influenced the water productivity for AW and WCU in both seasons. Application of K fertilizer slightly increased the water productivity for AW and WCU at the same irrigation treatment in the two seasons. Withholding irrigation with K fertilizer markedly increased the water productivity for AW and WCU compared with full irrigation without K fertilizer in both seasons. The highest value of water productivity for AW to be 2.51 and 2.73 kg grain m^{-3} water and for WCU, it was 3.98 and 4.73 kg grain m^{-3} water were produced from withholding three times without K fertilizer (W7 x K1), while the lowest values of this trait for AW (1.41and 1.42 kg grain m^{-3} water) and for WCU (2.22 and 2.29 kg grain m^{-3} water) were produced from the interaction of full irrigation and K fertilizer (W1 x K0) in both seasons.

4. Crop coefficient (Kc):

The crop coefficient (Kc) is the outcome of crop characteristics, climatic conditions and irrigation frequency on crop water requirements. It represents the relationship between reference evapotranspiration (ET_o) and actual crop evapotranspiration (ET_a). Results of calculated values of crop coefficient (Kc) from the best treatment (three irrigation in 0-40 cm soil depth and withholding one irrigation at J stage with K fertilizer, W5 x K1) are shown in Table 10. Kc value increased sharply from emergence to tillering stage and gradually from tillering until milking (grain filling) stage, then it severity decreased from end milking stage to ripening in both seasons. The maximum Kc value was at milking growth stage. This was expected because of the fast elongation occurred from jointing to heading stage and the peak of dry matter accumulation occurred during milking stage. The above mentioned stage is critical and has been shown to have the highest water requirement for wheat. The high soil moisture level was adapted in the present study during this stage in which wheat can be hurt the most when use exceeds supply.

The values of Kc for the best treatment (W5xK1) according the Penman Monteith equation were 0.90, 1.10, 1.11, 1.17, 1.22, 1.26 and 0.38 for the growth stages emergence, tillering , jointing, heading, milking and ripening stages, respectively in the first season, while these values were 0.84, 1.04, 1.11, 1.17, 1.24, 1.30 and 0.33 in the second season. The maximum value throughout the two seasons was during from heading to milking stages.

At North Delta, Penman Monteith equation can be used in determining the actual consumptive use and the average of crop Coefficient (Kc) for the two seasons was found to be 0.87, 1.07, 1.11, 1.17, 1.23, 1.28 and 0.35 during emergence, tillering , jointing, heading, milking and ripening stages, respectively.

Fig. 10. Computed empirical coefficient (Kc) of wheat cv. Misr 1 for the best combination between irrigation treatment and K fertilizer (W5 x K1) in 2012/13 and 2013/2014 season.

Growth stages	2012/13 season Actual WCU (mm/day)	Penman monteith (mm/day)	Kc	2013/14 season Actual WCU (mm/day)	Penman monteith (mm/day)	Kc
Emergence	1.40	1.56	0.90	1.39	1.65	0.84
Tillering	1.50	1.37	1.10	1.45	1.39	1.04
Jointing	1.52	1.37	1.11	1.61	1.45	1.11
Booting	2.21	1.89	1.17	2.18	1.87	1.17
Heading	3.01	2.46	1.22	2.44	1.97	1.24
Milking	3.83	3.05	1.26	2.63	2.03	1.30
Ripening	1.71	4.50	0.38	1.39	4.23	0.33

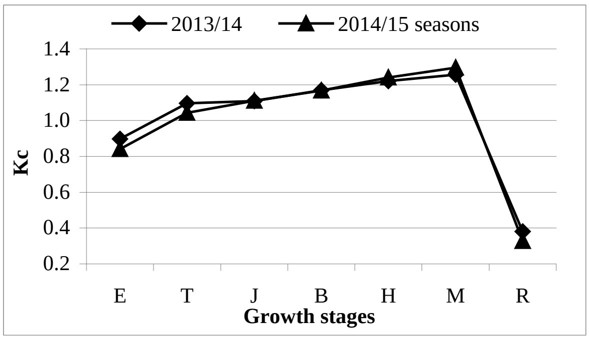

Fig 5. Crop coefficient for W_5 K_1 treatments in 2012/13 and 2013/14 seasons.

Abbreviations: Emergence (E), Tillering (T), Jointing (J), Booting (B), Heading (H), Milking (M) and Ripening (R)

REFERENCES

Abro, N. A. (2012). Effect of irrigation regimes on grain yield and harvest index of wheat varieties. M. Sc. Thesis, Sindh Agriculture University, Tandojam.

Allen, R. G.; L. S. Pereira; D. Raes and M. Smith (1998). Crop evapotranspiration-guidelines for computing crop water requirements-fao irrigation and drainage paper 56. FAO, Rome, (300): D05109.

Aown, M.; S. Raza; M. Saleem; S. Anjum; T. Khaliq and M. Wahid (2012). Foliar application of potassium under water deficit conditions improved the growth and yield of wheat (triticum aestivum l.). J. Animal Plant Sci., (22): 431-437.

Attia, M. and M. Barsoum (2013). Effect of supplementary irrigation and bio-fertilization on wheat yield productivity under rainfed conditions. J. Agric. Res., (58): 49-57.

Baloch, S. U.; L. Li-jun; M. N. Kandhroo; S. Fahad; S. A. Sabiel; S. K. Baloch and S. A. Badini (2014). Effect of different irrigation schedules on the growth and yield performance of wheat (*triticum aestivum* l.) varieties assessment in district awaran (balochistan). J. Biology Agric. Healthcare, (4): 5-17.

Black, C.; D. Evans; J. White; L. Ensminger and E. Clark (1965). Methods of soil analysis, part 2. Chemical and microbiological properties: Madison, Wis., American Society of Agronomy Monograph.

Damon, P.; Q. Ma and Z. Rengel (2011). Wheat genotypes differ in potassium accumulation and osmotic adjustment under drought stress. Crop Pasture Sci., (62): 550-555.

Duncan, D. B. (1955). Multiple range and multiple f tests. Biometrics, (11): 1-42.

El-Abady, M. I.; S. E. Seadh; A. El-Ward; A. Ibrahim and A. A. El-Emam (2009). Irrigation withholding and potassium foliar application effects on wheat yield and quality. Int. J. Sustain. Crop Prod, (4): 33-39.

El-Ashry, M. and M. El-Kholy (2005). Response of wheat cultivars to chemical desiccants under water stress conditions. J. of Appl. Sci. Res, (1): 253-262.

El-Bably, A. Z.; S. A. Abd El-Hafez; M. A. Mahmoud and S. A. H. Oud (2015). A new conceptual framework for water conservation based on addressing water balance, crop rotation and economics. Int. J. Water Res. Environ. Eng., (4): 120-127.

FAO (2014). Faostat. http://fenix.fao.org/ faostat/ beta/en/#data/QC.

FAO (2015). Fao. (2015) giews country brief on egypt., http://www.fao.org/giews/countrybrief/country.jsp?code=EGY.

Gomez, K. A. and A. A. Gomez (1984). "Statistical procedures for agricultural research," John Wiley & Sons.

Guendouz, A.; N. Semcheddine; L. Moumeni and M. Hafsi (2016). The effect of supplementary irrigation on leaf area, specific leaf weight, grain yield and water use efficiency in durum wheat (triticum durum desf.) cultivars. Ekin J, (2): 82-89.

Guo, Z.; Z. Yu; D. Wang; Y. Shi and Y. Zhang (2014). Photosynthesis and winter wheat yield responses to supplemental irrigation based on measurement of water content in various soil layers. Field Crops Res., (166): 102-111.

Gupta, N.; S. Gupta and A. Kumar (2001). Effect of water stress on physiological attributes and their relationship with growth and yield of wheat cultivars at different stages. Journal of Agronomy and Crop Science, (186): 55-62.

Hafez, E. and H. Gharib (2016). Effect of exogenous application of ascorbic acid on physiological and biochemical characteristics of wheat under water stress. Int. J. Plant Prod., (10): 4.

Imran, M.; M. Iqbal; E. Ullah and J. Šimunek (2015). Assessment of actual evapotranspiration and yield of wheat under different irrigation regimes with potassium application. Soil Environ., (34): 156-165.

Israelsen, B. O. and V. E. Hansen (1962). "Irrigation principles and practices," John Wiley and Sons, Inc, New York, USA.

Jazy, H. D.; K. N. Namini and M. Ameri (2012). Effect of deficit irrigation regimes on yield, yield components and some quality traits of three bread wheat cultivars (triticum aestivum l.). Int. J. Agri. Crop Sci., (4): 234-237.

Man, J.; Y. Shi; Z. Yu and Y. Zhang (2015). Dry matter production, photosynthesis of flag leaves and water use in winter wheat are affected by supplemental irrigation in the huang-huai-hai plain of china. PloS one, (10): e0137274.

Man, J.; Y. Shi; Z. Yu and Y. Zhang (2016). Root growth, soil water variation, and grain yield response of winter wheat to supplemental irrigation. Plant Prod. Sci., (19): 193-205.

Maqbool, M. M.; A. Ali; T. Haq; M. N. Majeed and D. J. Lee (2015). Response of spring wheat (triticum aestivum l.) to induced water stress at critical growth stages. Sarhad J. Agric., (31): 53-58.

Mbave, Z. A. (2013). Water stress effects on growth, yield and quality of wheat (*triticum aestivum* l.).Phd thesis, University of Pretoria.

Mehasen, S.; N. K. El-Gizawy; A. Sharoba; S. Soliman and T. Khalil (2014). Yield and chemical composition of bread wheat cultivars as affected by some skipping irrigation. Minufiya J. Agric. Res., (39): 1070-1086.

Mekkei, M. E. R. and E. A. M. A. El Haggan (2014). Effect of different irrigation regimes on grain yield and quality of some egyptian bread wheat cultivars. J. Agri-Food Appl. Sci., (2): 275-282.

Meleha, A. M. I. (2016). Effect of irrigation water management on wheat yield. Ph.D. Thesis, Fac., Agric., Kafrelsheikh Univ., Egypt.

Mirbahar, A. A.; G. Markhand; A. Mahar; S. A. Abro and N. A. Kanhar (2009). Effect of water stress on yield and yield components of wheat (triticum aestivum l.) varieties. Pak. J. Bot, (41): 1303-1310.

Niu, J.; W. Zhang; S. Ru; X. Chen; K. Xiao; X. Zhang; M. Assaraf; P. Imas; H. Magen and F. Zhang (2013). Effects of potassium fertilization on winter wheat under different production practices in the north china plain. Field Crops Res., (140): 69-76.

Pettigrew, W. T. (2008). Potassium influences on yield and quality production for maize, wheat, soybean and cotton. Physiol. Plant., (133): 670-681.

Raza, M.; M. Saleem; G. Shah; I. Khan and A. Raza (2014). Exogenous application of glycinebetaine and potassium for improving water relations and grain yield of wheat under drought. J. Soil Sci. Plant Nutr., (14): 348-364.

Rizk, A. H. and M. M. Sherif (2014). Effect of soil moisture depletion on the yield of wheat under sprinkler irrigation at toshka area, egypt. Middle East J. Agric. Res., (3): 981-987.

Sang, X.; D. Wang and X. Lin (2016). Effects of tillage practices on water consumption characteristics and grain yield of winter wheat under different soil moisture conditions. Soil Till. Res., (163): 185-194.

Seleiman, M.; S. Abdel-Aal; M. Ibrahim and G. Zahran (2010). Productivity, grain and dough quality of bread wheat grown with different water regimes. J. Agro Crop Sci., (2): 11-17.

Shirazi, M.; M. Khan; N. Bhatti; A. Unar; H. Bozdar; S. Mujtaba and M. Lashari (2014). Growth and water use efficiency in wheat genotypes grown under water stress condition. E3 J. Agric. Res. Develop, (4): 023-028.

Tari, A. F. (2016). The effects of different deficit irrigation strategies on yield, quality, and water-use efficiencies of wheat under semi-arid conditions. Agric. Water Manage., (167): 1-10.

Wang, M.; Q. Zheng; Q. Shen and S. Guo (2013). The critical role of potassium in plant stress response. Int. J. Mol. Sci., (14): 7370-7390.

Yi, L. P.; Z. W. Yu; Y. L. Zhang; D. Wang; Y. Shi and J. Y. Zhao (2013). Effects of supplemental irrigation based on the measurement of moisture content in different soil layers on the water consumption characteristics and grain yield of winter wheat. J. Applied Eco., (24): 1361-1366.

Zareian, A.; H. Abad and A. Hamidi (2014). Yield, yield components and some physiological traits of three wheat (triticum aestivuml.) cultivars under drought stress and potassium foliar application treatments. Int. J. Biosci., (4): 168-175.

التأثير المتكامل بين منع الرى فى بعض مراحل النمو و سماد البوتاسيوم على المحصول و إنتاجية المياه فى القمح

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أجريت تجربتين حقليتين على صنف القمح مصر ١ فى تربة طينية بمزرعة محطة بحوث المقننات المائية بالقرضا -كفر الشيخ – معهد بحوث إدارة المياه – المركز القومي لبحوث المياه فى السنة الأولى ٢٠١٤/٢٠١٣ والثانية بمنطقة الرى المطوربالوزارية-كفرالشيخ خلال السنة الثانية ٢٠١٥/٢٠١٤ لدراسة تأثير تكامل منع الرى عند بعض مراحل النمو مع السماد البوتاسى على محصول القمح والعلاقات المائية. إستخدم فى هذه الدراسة سبع معاملات ري ، تم تنفيذها بعد رية الزراعة. وقد تم الرى على أساس إضافة كمية المياة اللازمة لوصول رطوبة التربة للسعة الحقلية على عمق ٠-٦٠ سم فى معاملة المقارنة وعلى عمق ٠-٤٠سم فى باقى المعاملات. وشملت معاملات الرى: (W_1) معاملة المقارنة تم الرى ٥ مرات بعمق ٦٠ سم بواقع رية واحدة عند كل مرحلة من مراحل النمو: التفريع ، الإستطالة، الحبلان، طرد السنابل، الطور اللبنى، (W_2) الرى ٥ مرات بعمق ٤٠ سم ، (W_3، W_4، W_5) الرى ٤ مرات بعمق٤٠ سم ومنع الرى مرة واحدة عند مرحلة الإستطالة أو الحبلان أو الطور اللبنى، (W_6) الرى ٣ مرات بعمق٤٠ سم ومنع الرى مرتين عند مرحلتى الإستطالة و الحبلان، (W_7) الرى مرتين بعمق٤٠ سم ومنع الرى ثلاث مرات عند مراحل الإستطالة و الحبلان و الطور اللبنى. وتم أستخدام معاملتين من السماد البوتاسي: (K_0) بدون إضافة ، (K_1) إضافة ٢٤ كجم K_2O ارضى للفدان ثم الرش مرتين بمحلول ٢% من كبريتات البوتاسيوم. أثرت معاملات الري معنويا على جميع الصفات المدروسة في كلا الموسمين. سجلت المعاملة (W_1) أعلى القيم فى عدد السنابل بالمتر المربع و طول السنبلة و عدد الحبوب بالسنبلة و وزن ١٠٠٠-حبة ووزن حبوب السنبلة ومحصول القش ومحصول الحبوب بالفدان يليها معاملة الرى (W_2) بدون فروق معنوية فى الموسمين. أدى إستخدام معاملات الرى (W_7) أو (W_6) إلى إنخفاض معنوي فى معظم الصفات السابقة عن معاملة المقارنة فى كلا الموسمين. بينما لم تختلف معاملات منع الرى مرة واحدة (W_3، W_4، W_5) عن معاملة المقارنة فى معظم الصفات السابقة وخاصة فى الموسم الأول حيث كانت كمية الأمطار أعلى عن الموسم الثانى. فقد أدت زيادة كمية الأمطار في الموسم الأول الى تعويض العجز فى الماء الناتج من منع الرى مرة واحده في مراحل النمو المذكورة سابقا. قد أدى إستخدام معاملة الرى (W_5) الى نقص وزن ١٠٠٠ حبة المعاملة (W_4) الى نقص عدد الحبوب بالسنبلة. لم يوجد فرق معنوى في محصول الحبوب بين معاملة المقارنة ومعاملات الرى (W_3) أو (W_5) فى الموسمين. وقد أدى التسميد البوتاسى الى زيادة معنوية فى جميع الصفات السابقة فيما عدا طول السنبلة بالمقارنة بعدم إضافة البوتاسيوم. وقد أثر التفاعل بين معاملات الرى والسماد البوتاسى معنويا على محصول القش ومحصول الحبوب ومكوناتة فى الموسمين فيما عدا طول السنبلة. وقد أدى إستخدام السماد البوتاسى مع معاملات الرى الى تقليص الأثر السلبى لمعاملات حجب الرى عند بعض مراحل النمو على معظم الصفات السابق ذكرها. زادت كمية مياه الرى المستخدمة وكمية المياه المستهلكة طوال الموسم من الزراعة وحتى الحصاد بزيادة عدد مرات الرى وزيادة عمق التربة المستخدم فى كلا الموسمين. كانت كميات المياة المستخدمة ٢٥١٧، ٢٠٢٥ ، ١٨١٥، ١٧٢٢ ، ١٧٥٨، ١٤٥٦ و ١٢٤٦ م٣/فدان كمتوسط للموسمين و كان متوسط الإستهلاك المائى ١٤٨٠،١٥٨٤، ١٣٢٧،١٢٣٤ ، ١٢٧٠، ٩٦٧ و ٧٥٥ م٣/فدان فى معاملات الرى W_1، W_2، W_3، W_4، W_5، W_6، W_7 على الترتيب . وقد أدى حجب الرى عند أى مرحلة وتقليل عمق الرطوبة الى إنخفاض كبير فى كمية مياه الرى المستخدمة وكمية المياه المستهلكة والى زيادة إنتاجية المياة (كفاءة إستخدام المياة) للماء المستخدم أو للإستهلاك المائى (كجم حبوب/م٣ ماء) عن معاملة المقارنة فى كلا الموسمين. وكان تأثير السماد البوتاسى طفيف جدا لايذكر على الإستهلاك المائى ولكنة حسن الإنتاجية. في شمال الدلتا، يمكن استخدام معادلة بنمان مونتيث Penman Monteith فى تحديد الاستهلاك المائى الفعلي ووجد أن متوسط معامل المحصول (Kc) للموسمين ٠.٨٧، ١.٠٧، ١.١١، ١.١٧، ١.٢٣، ١.٢٨ و ٠.٣٥ فى مراحل التفريع ، الإستطالة، الحبلان، طرد السنابل، الطور اللبنى ، وطور النضج، على التوالي. يستنتج من النتائج أن أفضل المعاملات هى الرى ٤ مرات مع حجب الرى مرة واحدة عند مرحلة الإستطالة أو الطور اللبنى لتميزها بمحصول الحبوب العالى الذى لايختلف معنويا عن معاملة المقارنة (الموصى بها) مع إستخدام كمية أقل من مياة الرى والإستهلاك المائى في محافظة كفر الشيخ .