EFEECT OF RATIONALIZATION IRRIGATION WATER USE AND RIDGE WIDTH ON WHEAT AND ITS SOME WATER RELATIONS

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ABSTRACT

Field experiment was carried out at Dar El-Ramad farm, Faculty of Agriculture, Fayoum University, Egypt during 2015/2016 and 2016/2017 seasons. The trials aiming at investigating the effects of ridge width as planting in wide ridges 120 cm (beds), 60 cm ridges and flat planting (basins) and irrigation scheduling regimes, based on 1.0, 0.8 and 0.6 coefficients of Cumulative Pan Evaporation (C.P.E.) records on yield, yield components and some crop - water relations of wheat variety, Giza 168. A split plot design with four replications was used in both seasons. The obtained results showed that planting in 120 cm ridges (beds) and irrigation at 1.0 C.P.E., gave the highest averages of spike number m^{-2}, grains $spike^{-1}$, 1000-grain weight, straw yield (7411 and 7289 kg ha^{-1}), and grain yield (6761 and 6581 kg ha^{-1}) in the two successive seasons, respectively. The lowest averages of yield and its components were obtained from flat planting (basins) and irrigation at 0.6 C.P.E., in both seasons. Seasonal consumptive use (ET_C) averages were 42.48 and 41.14 cm in 1^{st} and 2^{nd} seasons, respectively. The highest ET_C values were recorded with the interaction (R_3I_1), whereas, the lowest values resulted from the interaction (R_1I_3). Daily ET_C rates were low during November and December, then increased during January and February, to reach its maximum values during March and then declined again till harvesting at April. The crop coefficient (K_C) values (averages of the two seasons) were 0.47, 0.55, 0.65, 0.73, 0.93 and 0.51 for, Nov., Dec., Jan., Feb., Mar. and Apr., respectively. The highest water use efficiency, i.e., 1.61 and 1.62 kg grains m^{-3} water consumed were obtained from (R_1I_1) treatments in first and second seasons, respectively.

Key words: wheat yield, yield components, ridge width, rationalization, water consumption, water use efficiency.

INTRODUCTION

Wheat is one of the most important cereal crops in the world. In 2016, world production of wheat was 749 million tonnes making it the second most-produced cereal after maize with 1.03 billion tonnes **(FAO stat, 2016)**. Irrigation management plays an important role in the agriculture strategy, due to the limited water resources and the expansion of the water demand. Water use rationalization in irrigation can be achieved throughout many agricultural practices, i.e. tillage, ridging, drought tolerant varieties and fertilization, among others. In Egypt, wheat is considered one of the most important consumed cereal crops. It is cultivated area about 1.4 million hectares with a productivity of 9.2 million tons at an average production of 6.5 t ha^{-1} **(FAO stat, 2016)**. Though, Egypt is ranked among the first 12 countries for wheat productivity, just next to European countries, due to rapid increase in population, there is a huge gap between demand and domestic production. Different techniques have been developed for efficient utilization of irrigation water and for reducing water loss in the field. The bed and furrow irrigation systems are the most appropriate and efficient surface irrigation methods **(Kahlown *et al.*, 1998)**. Raised bed practices have been followed for a long time by farmers throughout the world to reduce the adverse impact of water stress on crop production in arid and semi-arid regions **(Sayre, 2004; Govaerts *et al.*, 2007)**. Wheat sown on beds saves 30% irrigation water and increases nutrient-use efficiency, consistently increasing yield by 10–18% over conventional tilled and flat sown wheat **(AsmhmTalukder *et al.*, 2002; Hossain *et al.*, 2004)**. Wheat grain yield significantly increased in ridge plantings with a ridge width of 40, 60 and 80 cm by 11.8%, 20.6% and by 4.5%, respectively compared with conventional flat method of planting **(Xiaolon Ren *et al.*, 2016)**. Water use efficiency in wheat planted on raised beds with furrow irrigation were 1.96- 1.99 kg m^{-3} water consumed as compared with 1.34- 1.41 kg m^{-3} water consumed on flat planting in the well irrigated area using underground water source; and 0.8- 1.0 kg m^{-3} water consumed of grown on flat planting in yellow river flood irrigation area **(Wang Fahong *et al.*, 2005)**. Water consumption, increasing water use efficiency, and higher yields were obtained in raised bed planted winter wheat than the flat planted one **(Zhang *et al.*, 2007)**.

Water is becoming one of the scarcest natural resources in the world especially in arid and semi-arid regions. Limited water availability and unfavorable moisture distribution during the main wheat growing period can lead to a high variability in yield and in protein content **(Bonfil *et al.*, 2004)**. Grain yield was reduced to 65% in the stressed plants compared to that of irrigated plants **(Karim et al., 2000)**. Applying water at 50% and 75% of crop water requirement led to significant decrease in yield by 12% and 20%, respectively, in the two successive seasons of experiment **(Mugabe and Nyakatawa, 2000)**. The highest yield, yield components and water use efficiency were recorded with two-week interval irrigation **(English and Nakamura 1989)**. Irrigation after 110 mm cumulative evaporation of class A evaporation pan significantly reduced grain yield and yield components as compared to that of irrigation after 70 mm **(Dehghanzadh *et al.*, 2009)**. The highest consumptive use of water (Cu) for wheat crop (47.78 – 56.48 cm) was recorded with 5 irrigation events, and the value tended to reduce to 41.91 –

48.72 cm and to 37.0 – 40.68 cm with 4 and 3 irrigation events, respectively. Water productivity exhibited an opposite trend, where it was the highest with 3 irrigation events and gradually decreased with 4 and 5 irrigation events **(Doorenbos *et al.*, 1979; El-Akram and Emam, 2014; Abdelkhalek *et al.*, 2015**; **Abdou and Emam, 2016)**.

MATERIALS AND METHODS

The current investigation was carried out at Dar El-Ramad farm, Faculty of Agriculture, Fayoum University, Egypt during 2015/2016 and 2016/2017 seasons with the aimed of studying the effect of ridge width and irrigation scheduling treatments and their interaction on yield, yield components and some crop water relations. To achieve this target, three ridge width treatments, i.e. R_1: ridges of 120 cm width (beds), R_2: ridges of 60 cm width and R_3: flat planting (basins), were integrated with three irrigation scheduling treatments, i.e. I_1: irrigation at 1.0 cumulative pan evaporation (C.P.E.), I_2: irrigation at 0.8 C.P.E., and I_3: irrigation at 0.6 C.P.E. The experimental arrangement was split-plot in randomized complete block design with three replicates. The main plot was irrigation scheduling treatments and the sub-plot was ridge width treatments. The plots were isolated from each other by allays 1.5 m between to avoid the lateral movement of water. The soil physical and chemical properties of the experimental plots were determined according to **(Klute, 1986)** and **(Page *et al.*, 1982)** and were illustrated in (Table, 1). The averages of Fayoum Governorate meteorological data during the two successive growing seasons were recorded in (Table, 2). Dates of irrigation and irrigation count for different treatments tested in both seasons are listed in (Table, 3). The sub -plot, area was 21.0 m^2 (3.5×6.0 m). During the field preparation, Calcium super phosphate (15.5% P_2O_5) was added at the rate of 360 kg ha^{-1}. Irrigation scheduling treatments started from the 2^{nd} irrigation. The soil moisture constants were gravimetrically determined on oven dry basis, as the technique of Water Requirements and Field Irrigation Dept., ARC, Egypt for soil layers, each of 15.0 cm from soil surface and down to 60.0 cm depth and recorded in (Table, 4). Wheat grains of Giza 168 cv., at the rate of 167 kg ha^{-1} were planted on November15th in both seasons. Whereas, harvesting was occurred on April 28th in the two successive seasons. Data of spike number m^{-2}, grains $spike^{-1}$, 1000-grain weight (g), grain yield ha^{-1} and straw yield ha^{-1} were recorded. Further, the biological yield ha^{-1} were estimated for the two successive seasons.

All the collected data were subjected to the statistical analysis according to **(Snedecor and Cochran, 1980)** and the means were compared by L.S.D. test at 5% level.

Crop - water relations

***Seasonal consumptive use (ET_C)*:** For determining the crop water consumptive use (ET_C), soil samples were taken from each sub-plot, just before and after 48 hours from each irrigation, as well as at harvesting time and the ET_C between each two successive irrigations was calculated according to the following equation **(Israelsen and Hansen, 1962)**.

$$Cu\ (ET_C) = \{(Q_2 - Q_1) / 100\} \times Bd \times D$$

Where: Cu = crop water consumptive use (cm).
Q_2= soil moisture percentage 48 hours after irrigation.
Q_1= soil moisture just before irrigation.
Bd = soil bulk density (g cm^{-3}).
D = soil layer depth (cm).

Table (1): Particle size distribution and some physical and chemical properties chemical of the experimental site in 2015/2016 and 2016/2017 seasons (two seasons average).

Particle size distribution							Organic Matter (%)				CaCO3 (%)			
Sand (%)	Silt (%)	Clay (%)	Textural class											
19.1	33.6	47.30	Clay				1.92				5.22			
P^H (soil paste)	EC (dSm^{-1})	Soluble cations ($meqL^{-1}$)					Soluble anions ($meqL^{-1}$)				CEC (meq/ 100 gm soil)	Exchangeable Cations (meq/100 gm soil)		
		Ca^{++}	Mg^{+}	Na^{+}	K^{+}		CO_3^{--}	HCO_3^{-}	Cl^{-}	SO_4^{--}		Ca^{++}	Mg^{++}	Na+	K^{+}
7.81	2.16	6.35	5.32	9.83	0.17		-	2.23	7.73	11.74	38.32	20.79	11.68	4.54	1.68

Table (2): The monthly averages of weather factors for Fayoum Governorate in 2015/2016 and 2016/2017 seasons.

Month	Year	Temperature C°			Relative Humidity %	Wind speed m sec^{-1}	Class A pan evaporation mm day^{-1}
		Max	Min	Mean			
Nov.	2015	27.7	15.7	21.7	41	1.49	2.2
	2016	28.1	15.6	21.4	42	1.48	2.1
Dec.	2015	21.6	9.9	15.7	43	1.04	1.5
	2016	21.1	9.5	15.3	42	1.05	1.5
Jan.	2016	20.2	8.4	14.3	43	1.18	1.5
	2017	20.4	8.5	14.5	42	1.21	2.3
Feb.	2016	24.6	9.5	17.0	41	1.65	2.7
	2017	22.0	8.3	15.1	42	1.64	2.3
Mar.	2016	28.0	13.4	20.7	36	2.11	4.0
	2017	26.7	12.7	19.7	37	2.10	3.5
Apr.	2016	36.1	17.0	26.5	35	2.43	6.1
	2017	31.2	15.6	23.4	34	2.41	5.2

***Daily ET_C rate (mm day^{-1})*:** Calculated from the ET_C between each two successive irrigations divided by the number of days.
***Reference evapotranspiration (ET_0)*:** Estimated as a monthly rate (mm day^{-1}), using the monthly averages of climatic factors of Fayoum Governorate and the procedures of the FAO-Penman Monteith equation **(Allen *et al.*, 1998)**.
***Crop Coefficient (K_C)*:** The crop coefficient was calculated as **Israelsen and**

Hansen (1962) equation:

$$K_C = ET_C / ET_0$$

Where: ET_C = Actual crop evapotranspiration (mm day^{-1})
ET_0 = Reference evapotranspiration (mm day^{-1}).

Water use efficiency (WUE): The water use efficiency as kg grains m^{-3} water consumed was calculated for different treatments **(Vites, 1965)**:

$$WUE = \text{Grain yield (kg ha}^{-1}\text{) / Seasonal } ET_C \text{ (m}^3\text{ ha}^{-1}\text{)}.$$

Table (3): Dates of irrigation, irrigation, irrigation intervals for different irrigation regime treatment in 2015/2016 and 2016/2017 seasons.

Seasons	**2015/2016**			**2016/2017**		
Number of irrigation	**Irrigation scheduling (C.P.E.)**			**Irrigation scheduling (C.P.E.)**		
	(I_1) 1.0	**(I_2) 0.8**	**(1_3) 0.6**	**(I_1) 1.0**	**(I_2) 0.8**	**(1_3) 0.6**
	Date	Date	Date	Date	Date	Date
Planting	15/11	15/11	15/11	15/11	15/11	15/11
1st irrigation.	6/12	6/12	6/12	6/12	6/12	6/12
2nd irrigation.	26/12	31/12	5/1	26/12	31/12	5/1
3rd irrigation.	15/1	26/1	5/2	16/1	27/1	6/2
4th irrigation.	5/2	20/2	8/3	7/2	22/2	10/3
5th irrigation.	27/2	17/3	8/4	28/2	18/3	10/4
6th irrigation.	18/3	10/4	-	20/3	12/4	-
7th irrigation.	7/4	-	-	9/4	-	-
Harvesting	28/4	28/4	28/4	28/4	28/4	28/4
Irrigation count	**7**	**6**	**5**	**7**	**6**	**5**

Table (4): Average values of some soil moisture constants and bulk density for the experimental field in 2015/2016 and 2016/2017 seasons (two seasons average).

Soil depth (cm)	**Field capacity (%, w/w)**	**Wilting point (%, w/w)**	**Available soil moisture (%, w/w)**	**Bulk density (gcm^{-3})**	**Available soil moisture (mm)**
0-15	45.81	24.36	21.45	1.28	41.18
15-30	43.62	23.75	19.87	1.31	39.04
30-45	41.01	23.42	17.59	1.37	36.15
45-60	40.31	23.37	16.94	1.43	36.34

RESULTS AND DISCUSSION

Yield and yield components

Effect of Ridge width (R)

The data revealed that planting in wide ridges 120 cm (beds) led to increase in of spike number m^{-2}, grains $spike^{-1}$, 1000-grain weight (g), grain yield, straw and biological yield (kg ha^{-1}) in both successive seasons, (Table, 5). Range of increment was 12.6, 13, 14.6, 7.9 and 5.3 % for spike number m-

^{2}, grains spike^{-1}, 1000 grain weight, grain yield and straw yield, in the first season, respectively, and in the 2nd season the increasing of the mentioned parameters was 13.5, 13, 14.7, 9.8 and 6.8 %, respectively, as compared wide ridges to those with flat planting (basins). These results may be related to the improving role of wide ridges in soil physical properties like bulk density and porosity, and increasing nitrogen use efficiency (NUE), thereby providing a suitable condition for wheat grains to emergence and growth accordingly yield formation **(Wang Fahong *et al.*, 2005 and Xiaolon Ren *et al.*, 2016).**

Effect of irrigation scheduling (I)

Concerning the effect of scheduling irrigation treatments, data recorded in (Table, 5) indicate that scheduling irrigation had significant effects on wheat grain yield and its components in both seasons. Irrigation at 1.0 C.P.E. gave the highest averages of grain and straw yields in 2015/2016 season, i.e. 6564 and 7236 kg ha^{-1} respectively, and in 2016/2017 season, i.e. 6373 and 7065 kg ha^{-1}, respectively. Grain and straw yields were reduced by 7.2 % and 4.05 % in 2015/2016, respectively, and by 6 % and 4.9 % in season 2016/2017, respectively, when irrigation intervals increased by irrigation at 0.8 C.P.E. Whereas, more decreases in grain and straw yields by 13.3 % and 9.3 % in 2015/2016 and by 12.2 % and 10.4 % in 2016/2017 season, respectively, when irrigation intervals increased by irrigation at 0.6 C.P.E. (dry level), compared with irrigation at 1.0 C.P.E. Such finding may be revered to the effect of water stress on reducing growth attributes, spike number/m^{2}, grains spike^{-1} and 1000-grain weight. These results are in agreement with those found by **El-Akram and Emam, 2014; Abdelkhalek *et al.*, 2015**; **Abdou and Emam, 2016.**

Regarding the interaction**,** results in Table (5) show that wheat grain yield significantly affect by the interaction between ridge width and scheduling irrigation treatments, The highest spike number m^{-2}, grains spike^{-1}, 1000-grain weight (g), grain yield ha^{-1} and Straw yield ha^{-1} and biological yield ha^{-1}, i.e., 411, 59.9, 44 (g), 6761 kg ha^{-1}, 7411 kg ha^{-1} and 14172 kg ha^{-1} in 2015/2016, respectively, and in 2016/2017, 405, 57.2, 42(g), 6581 kg ha^{-1}, 7289 kg ha^{-1} and 13870 kg ha^{-1} were detected from 120 cm ridge width and irrigation at 1.0 C.P.E. However, the lowest averages of yield and its components were resulted from flat planting (basins) and irrigation at 0.6 C.P.E. in both seasons.

Crop water relations

Seasonal evapotranspiration (ET_C)

As shown in Table (6), the mean values of seasonal water use by wheat under different ridges width and irrigation scheduling regimes were 42.48 and 41.14 cm in 2015/2016 and 2016/2017 seasons, respectively. Results indicated that flat planting (basins) gave the higher values of water consumptive use (45.04 and 43.55 cm) in the two successive seasons, respectively. Planting on ridges of 60 cm or 120 cm (beds) reduced seasonal water use to 42.40 and 40.00 cm, respectively, in 2015/2016 season and to 40.96 and 38.86 cm, respectively, in 2016/2017 season. The most probable explanation for these results is that: the bottoms numbers between even 60 cm ridges or wide ridges (beds) will be less than flat planting (basins) and this in turn reduced water runoff, evaporation and inadequate wetting area under beds, which may also reduced plant transpiration. These results are in the same trend with those reported by **Wang Fahong *et al.*, 2005** and **Zhang *et al.*, 2007.**

Regarding the effect of irrigation scheduling regimes, data in (Table, 6) show that irrigating wheat at 1.0 C.P.E. regime produced the highest values of ET_C reached 44.42 and 42.95 cm in 2015/2016 and 2016/2017 seasons, respectively. The lowest ET_C values e.g. 40.57 and 39.18 cm resulted from irrigation at 0.6 C.P.E. in two successive seasons. Moreover, irrigation at 0.8 C.P.E. decreased ET_C by 4.43 and 3.98 % in 2015/2016 and 2016/2017 seasons, respectively, comparable with that irrigated at 1.0 C.P.E. This could be attributed to increasing the available soil moisture in the root**.**

Table (5): Effect of ridge width and irrigation scheduling regime treatments on yield and yield components of wheat crop.

Treatments		Spike number m^{-2}		Grains $spike^{-1}$		1000 grain weight (g)		Grain yield kg ha^{-1}		Straw yield kg ha^{-1}		Biological yield kg ha^{-1}	
Ridge width	**Irrigation scheduling**	**2015/16**	**2016/17**	**2015/16**	**2016/17**	**2015/16**	**2016/17**	**2015/16**	**2016/17**	**2015/16**	**2016/17**	**2015/16**	**2016/17**
R_1 120 cm	I_1: 1.0 C.P.E.	411	405	59.9	57.2	44.0	42.0	6761	6581	7411	7289	14172	13870
	I_2: 0.8 C.P.E.	400	389	54.8	52.4	42.8	40.9	6316	6282	7105	6952	13421	13234
	I_3: 0.6 C.P.E.	396	388	51.7	49.4	40.4	38.6	5912	5943	6794	6528	12706	12471
Mean		**402**	**394**	**55.5**	**53.0**	**42.4**	**40.5**	**6330**	**6269**	**7103**	**6923**	**13433**	**13192**
R_2 60 cm	I_1: 1.0 C.P.E.	393	378	56.1	53.6	42.5	40.6	6579	6397	7225	7077	13804	13474
	I_2: 0.8 C.P.E.	372	360	52.2	49.9	40.2	38.4	6142	6031	6963	6708	13105	12739
	I_3: 0.6 C.P.E.	358	343	49.4	47.2	38.1	36.5	5715	5511	6506	6354	12221	11865
Mean		**374**	**360**	**52.6**	**50.2**	**40.3**	**38.5**	**6145**	**5980**	**6898**	**6713**	**13043**	**12693**
R_3 Basins	I_1: 1.0 C.P.E.	375	367	51.7	49.4	39.3	37.5	6352	6140	7073	6828	13425	12968
	I_2: 0.8 C.P.E.	357	349	49.4	47.2	37.5	35.8	5814	5654	6761	6504	12575	12158
	I_3: 0.6 C.P.E.	339	326	46.1	44.1	34.2	32.7	5440	5328	6396	6115	11836	11443
Mean		**357**	**347**	**49.1**	**46.9**	**37.0**	**35.3**	**5869**	**5707**	**6743**	**6482**	**12612**	**12190**
Mean of irrigation	I_1: 1.0 C.P.E.	393	383	55.9	53.4	41.9	40.0	6564	6373	7236	7065	13800	13437
	I_2: 0.8 C.P.E.	376	366	52.1	49.8	40.2	38.4	6091	5989	6943	6721	13034	12710
	I_3: 0.6 C.P.E.	364	352	49.1	46.9	37.6	35.9	5689	5594	6565	6332	12254	11926
Over all mean		**378**	**367**	**52.4**	**50.0**	**39.9**	**38.1**	**6115**	**5985**	**6915**	**6706**	**13029**	**12691**
L.S.D. at 5%													
R		8.3	7.6	2.5	2.2	1.7	1.8	146.4	150.0	141.2	142.5	158	162
I		9.6	8.4	2.7	2.5	1.5	1.7	164.1	170.3	160.6	164.3	159	164
R x I		4.5	6.1	1.9	1.6	1.2	1.4	128.3	131.5	125.6	132.7	170	172

zone of wheat plants, under irrigating at 1.0 C.P.E., resulted in higher ET_C values which are resulted from both higher transpiration rate from plants canopy and evaporative demands from soil surface. Under water stress i.e. irrigating at 0.8 or 0.6 C.P.E., the transpiration from plants may decreased as a result of poor vegetative growth and less evaporation from dry soil surface.

These results are in accordance with those reported by **El-Akram and Emam, 2014; Abdelkhalek *et al.*, 2015**; **Abdou and Emam, 2016.**

Data in (Table, 6) indicate that flat planting (basins), as interacted with irrigating at 1.0 C.P.E., gave the highest values of ET_C which comprised 47.31 and 45.45 cm in 2015/2016 and 2016/2017 seasons, respectively. Nevertheless, the lowest ET_C values (38.32 and 37.16 cm) in the two successive seasons were obtained from the interaction between planting on wide ridges (beds) and irrigating at 0.6 C.P.E.

Table (6): Effect of ridge width and irrigation scheduling regime on seasonal consumptive use of wheat crop (ET_C).

Ridge Width	2015/2016 C.P.E.			Mean	2016/2017 C.P.E.			Mean
	1.0	0.8	0.6		1.0	0.8	0.6	
R_1: 120 cm	41.85	39.84	38.32	**40.00**	40.65	38.91	37.16	**38.86**
R_2: 60 cm	44.11	42.42	40.66	**42.40**	42.76	41.20	38.92	**40.96**
R_3: Basins	47.31	45.09	42.72	**45.04**	45.45	43.61	41.60	**43.55**
Mean	**44.42**	**42.45**	**40.57**	**42.48**	**42.95**	**41.24**	**39.18**	**41.14**

Daily ET_C rate (mm day^{-1})

The results presented in (Table, 7) show that the daily ET_C rates as influenced by different treatments tested in both seasons were started with low values during Nov. and decreased more during Dec., then increased again during Jan. and Feb. to reach its maximum values on March. Thereafter, it redecreased again during April (plant maturity and harvesting). These results are referred to that at the initial growth stage, most of the water loss is due to evaporation from the bare soil (germination and seedling stages) and the reduction in ET_C rate during Dec. was due to the decrease in evaporative demands (temperature and solar radiation). Thereafter, as the plant cover and temperature increased, evaporation increased and transpiration took place beside it, then transpiration and evaporation reached maximum values during heading and grain filling stages (March), whereas at maturity stage the plants tended to be dry and the ET_C rate redecreased again during April (harvesting). The results of (Table, 7) indicate that the highest values of ET_C during all months of the two growing seasons duration (November – April) were resulted from flat planting (basins). However, planting on wide ridges (beds) gave the lowest values of daily ET_C rates in all growing season months for 2015/16 and 2016/17 seasons. It could be revealed that planting in wide ridges 120 cm resulted in decreasing the daily ET_C rate of wheat during all months of the growing season.

Data presented in (Table, 7) show that the daily ET_C rates of wheat during the growing season months (November – April) of both seasons, were increased by irrigation at 1.0 C.P.E., then the same values resulted from irrigation at 0.8, or 0.6 C.P.E. It is obvious that increasing the available moisture in wheat root zone (irrigation at short intervals) resulted in increasing the ET_C rate during the growing season duration months. These results are in the same line of those reported by **El-Akram and Emam, 2014; Abdelkhalek *et al*., 2015; Abdou and Emam, 2016.**

Reference evapotranspiration (ET_0)

Reference evapotranspiration rate (ET_0) in mm day^{-1} during the months of wheat growing seasons, i.e. 2015/2016 and 2016/2017, estimated using the FAO Penman- Monteith method and the meteorological data of Fayoum Governorate are recorded in (Table, 8). The obtained data indicated that the ET_0 rate values were somewhat high during Nov., and then decreased during Dec. and Jan. months. Thereafter, the daily rates of ET_0 increased from Feb. till April, in both seasons. These results may be attributed to the variation in climatic factors from one month to another. **Allen *et al.* (1998)** reported that the reference ET values depend mainly on the evaporative power of the air at each area, i.e. temperature, radiation, relative humidity and wind speed.

Crop coefficient (K_C)

The crop coefficient (K_C) reflects that the crop cover percentage on the reference ET values. Therefore, the K_C values were calculated from the daily consumptive use rates (Table, 7) and the daily ET_0 rates (Table, 8) for each month during the two growing seasons of wheat crop. The results presented in (Table, 8) show that the K_C values, as a function of ridge width and scheduling irrigation treatments (over all mean) were low during Nov. and Dec. months (initial growth period), then increased during Jan. (0.65 and 0.65) and Feb. (0.72 and 0.74), as the vegetative growth increased to booting stage in 2015/2016 and 2016/2017, respectively. The K_C values reached its maximum values, i.e. 0.91 and 0.95 during March (heading-grain filling stage). The K_C values redecreased again during Apr. (0.50 and 0.52), as plants started maturity and harvesting in 2015/2016 and 2016/2017, respectively.

These results may be attributed to the large diffusive resistance of bare soil during the initial growth stage (germination and seedling stages), which decreased gradually with increasing the crop cover until heading and grain filling stages. At maturity stage (Apr.) the transpiration decreased, as a result of leaves and stem drying causing the low values of K_C during Apr. month. The data recorded in (Table, 8) reveal that replacing flat planting (basins) by 60 cm ridges or wide ridges (beds) decreased the K_C values during the months of the two growing seasons, flat planting (basins) gave the highest K_C values during the growing season months in both seasons. On other hand, decreasing irrigation intervals from 0.6 to 0.8 or 1.0 C.P.E increased the K_C values in all months of the growing season duration in 2015/2016 and 2016/2017. The highest K_C values during the growth seasons months were resulted from irrigation at 1.0 C.P.E., whereas the lowest ones were detected from irrigation at 0.6 C.P.E. These results were true in both seasons. The K_C values of wheat, as a function of different treatments were 0.47, 0.55, 0.65, 0.73, 0.93 and 0.51 for Nov., Dec., Jan., Feb., March and Apr., respectively, (average of the two seasons). Such findings are in the same line of those reported by **Doorenbos *et al.*, 1979; El-Akram and Emam, 2014; Abdelkhalek *et al.*, 2015**; **Abdou and Emam, 2016.**

Table (7): Effect of ridge width and irrigation scheduling regime treatments and their interaction on daily water consumptive use (mm day^{-1}) in 2015/16 and 2016/17 seasons.

Treatments		2015/2016 season						2016/2017 season					
		Nov.	**Dec.**	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**Mar.**	**Apr.**
R_1 120 cm	I_1: 1.0 C.P.E.	1.53	1.11	1.43	2.42	4.69	3.65	1.45	1.13	1.45	2.30	4.70	3.32
	I_2: 0.8 C.P.E.	1.53	1.09	1.38	2.28	4.44	3.43	1.45	1.09	1.38	2.21	4.46	3.19
	I_3: 0.6 C.P.E.	1.53	1.05	1.33	2.28	4.23	3.21	1.45	1.05	1.33	2.05	4.36	2.93
Mean		**1.53**	**1.08**	**1.38**	**2.33**	**4.45**	**3.43**	**1.45**	**1.09**	**1.39**	**2.19**	**4.51**	**3.15**
R_2 60 cm	I_1: 1.0 C.P.E.	1.60	1.13	1.54	2.59	4.90	3.87	1.52	1.18	1.59	2.46	4.85	3.51
	I_2: 0.8 C.P.E.	1.60	1.13	1.47	2.45	4.74	3.65	1.52	1.13	1.45	2.40	4.70	3.38
	I_3: 0.6 C.P.E.	1.60	1.11	1.47	2.35	4.49	3.43	1.52	1.09	1.38	2.24	4.46	3.12
Mean		**1.6**	**1.12**	**1.49**	**2.46**	**4.71**	**3.65**	**1.52**	**1.13**	**1.47**	**2.37**	**4.67**	**3.34**
R_3 basins	I_1: 1.0 C.P.E.	1.67	1.26	1.68	2.94	5.05	4.16	1.58	1.30	1.70	2.69	4.95	3.84
	I_2: 0.8 C.P.E.	1.67	1.18	1.61	2.84	4.85	3.87	1.58	1.24	1.61	2.56	4.80	3.64
	I_3: 0.6 C.P.E.	1.67	1.13	1.56	2.66	4.59	3.58	1.58	1.16	1.54	2.43	4.66	3.38
Mean		**1.67**	**1.19**	**1.62**	**2.81**	**4.83**	**3.87**	**1.58**	**1.23**	**1.62**	**2.56**	**4.80**	**3.62**
Mean of irrigation	I_1: 1.0 C.P.E.	1.60	1.17	1.55	2.65	4.88	3.89	1.52	1.20	1.58	2.48	4.83	3.56
	I_2: 0.8 C.P.E.	1.60	1.13	1.49	2.52	4.68	3.65	1.52	1.15	1.48	2.39	4.65	3.40
	I_3: 0.6 C.P.E.	1.60	1.10	1.45	2.43	4.44	3.41	1.52	1.10	1.42	2.24	4.49	3.14
Over all mean		**1.60**	**1.13**	**1.50**	**2.53**	**4.66**	**3.65**	**1.52**	**1.15**	**1.49**	**2.37**	**4.66**	**3.37**

Table (8): Effect of ridge width and irrigation scheduling regime on crop coefficient (K_C) of wheat crop in 2015/2016 and 2016/2017 seasons.

treatments		**2015/16 season**						**2016/17 season**					
Ridge width	Irrigation scheduling	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
Reference ET_0 mm day^{-1}		3.4	2.1	2.3	3.5	5.1	7.3	3.3	2.1	2.3	3.2	4.9	6.5
R_1 120 cm	I_1: 1.0 C.P.E.	0.45	0.53	0.62	0.69	0.92	0.50	0.44	0.54	0.63	0.72	0.96	0.51
	I_2: 0.8 C.P.E.	0.45	0.52	0.60	0.65	0.87	0.47	0.44	0.52	0.60	0.69	0.91	0.49
	I_3: 0.6 C.P.E.	0.45	0.50	0.58	0.65	0.83	0.44	0.44	0.50	0.58	0.64	0.89	0.45
Mean		**0.45**	**0.52**	**0.60**	**0.66**	**0.87**	**0.47**	**0.44**	**0.52**	**0.60**	**0.68**	**0.92**	**0.48**
R_2 60 cm	I_1: 1.0 C.P.E.	0.47	0.54	0.67	0.74	0.96	0.53	0.46	0.56	0.69	0.77	0.99	0.54
	I_2: 0.8 C.P.E.	0.47	0.54	0.64	0.70	0.93	0.50	0.46	0.54	0.63	0.75	0.96	0.52
	I_3: 0.6 C.P.E.	0.47	0.53	0.64	0.67	0.88	0.47	0.46	0.52	0.60	0.70	0.91	0.48
Mean		**0.47**	**0.54**	**0.65**	**0.70**	**0.92**	**0.50**	**0.46**	**0.54**	**0.64**	**0.74**	**0.95**	**0.51**
R_3 basins	I_1: 1.0 C.P.E.	0.49	0.60	0.73	0.84	0.99	0.57	0.48	0.62	0.74	0.84	1.01	0.59
	I_2: 0.8 C.P.E.	0.49	0.56	0.70	0.81	0.95	0.53	0.48	0.59	0.70	0.80	0.98	0.56
	I_3: 0.6 C.P.E.	0.49	0.54	0.68	0.76	0.90	0.49	0.48	0.55	0.67	0.76	0.95	0.52
Mean		**0.49**	**0.57**	**0.70**	**0.80**	**0.95**	**0.53**	**0.48**	**0.59**	**0.70**	**0.80**	**0.98**	**0.56**
Mean of irrigation	I_1: 1.0 C.P.E.	0.47	0.56	0.67	0.76	0.96	0.53	0.46	0.57	0.69	0.78	0.99	0.55
	I_2: 0.8 C.P.E.	0.47	0.54	0.65	0.72	0.92	0.50	0.46	0.55	0.64	0.75	0.95	0.52
	I_3: 0.6 C.P.E.	0.47	0.52	0.63	0.69	0.87	0.47	0.46	0.52	0.62	0.70	0.92	0.48
Over all mean		**0.47**	**0.54**	**0.65**	**0.72**	**0.91**	**0.50**	**0.46**	**0.55**	**0.65**	**0.74**	**0.95**	**0.52**

Water use efficiency (WUE):

The results presented in (Table, 9) show that the WUE values, as affected by ridge width and scheduling irrigation treatments were: 1.44 and 1.45 kg grain m^{-3} water consumed in 2015/2016 and 2016/2017 seasons, respectively. The highest water use efficiency values were 1.58 and 1.59 kg grain m^{-3} water consumed, obtained from planting in wide ridges (beds) in both seasons, respectively. On the other hand, the lowest WUE values, i.e. 1.30 and 1.31 kg grain m^{-3} water consumed in 2015/2016 and 2016/2017 seasons, respectively, were obtained from flat planting (basins). These results may be referred to that in 2015/2016 season; the grain yield, obtained from flat planting decreased by 7.3%, while ET_C was decreased by 11.2 %., however, in 2016/2017 season grain yield was decreased by 9 %, while ET_C was decreased by 10.8 %, as compared to planting on wide ridges (beds). Data listed in (Table, 9) reveal that the highest WUE values, i.e., 1.48 and 1.49 kg grains m^{-3} water consumed in the 1st and the 2nd seasons, respectively, were detected from irrigating wheat plants at 1.0 C.P.E. However, irrigation at 0.6 C.P.E. gave the lowest WUE values, i.e., 1.40 and 1.41 kg grains m^{-3} water consumed in the two successive seasons, respectively. These results are in agreement with that reported by **El-Akram and Emam, 2014; Abdelkhalek *et al.*, 2015**; **Abdou and Emam, 2016.**

Table(9): Effect of ridge width and irrigation scheduling regime on water use efficiency, WUE (kg grain m^{-3} water consumed).

Ridge Width	2015/2016			Mean	2016/2017			Mean
	C.P.E.				C.P.E.			
	1.0	0.8	0.6		1.0	0.8	0.6	
R_1: 120 cm	1.61	1.59	1.54	**1.58**	1.62	1.61	1.53	**1.59**
R_2: 60 cm	1.49	1.45	1.41	**1.45**	1.50	1.46	1.42	**1.46**
R_3: Basins	1.34	1.29	1.27	**1.30**	1.35	1.30	1.28	**1.31**
Mean	**1.48**	**1.44**	**1.40**	**1.44**	**1.49**	**1.46**	**1.41**	**1.45**

CONCLUSION

Based on the study, it can be concluded that it is advisable to plant wheat on wide ridges (beds), irrigate at 0.8 in order to achieve rationalize of irrigation water under the limited irrigation water resources to maximize the benefit of water unit. As we can save about (700 m^3 ha^{-1}) were as the reduction in the yield was about (53 kg ha^{-1}) 0.48% (as an average of the two seasons) comparable to conventional flat planting and irrigating at 1.0 C.P.E. which it is considered an ordinary practice of farmers.

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تأثير ترشيد استخدام مياه الري وعرض الخط على محصول القمح وبعض العلاقات المائية له

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اقيمت تجربة حقلية بمزرعة دار الرماد - كلية الزراعة - جامعة الفيوم مصر خلال موسمي ٢٠١٥/ ٢٠١٦ ، ٢٠١٦ / ٢٠١٧ لدراسة تأثير معاملات عرض الخط وهي (الزراعه علي مصاطب بعرض ١٢٠ سم ، الزراعه علي خطوط بعرض ٦٠ سم ، الزراعه في احواض) ومعاملات الري عند (١,٠ ، ٠,٨ ، ٠,٦ من البخر التراكمي لوعاء البخر القياسي) وذلك علي المحصول ومكوناته وبعض العلاقات المائية لمحصول القمح (جيزه ١٦٨) في تصميم القطع المنشقة مرة واحدة في أربعة مكررات وفيما يلي أهم النتائج المتحصل عليها:-

* الزراعه علي خطوط بعرض ١٢٠ سم (مصاطب) والري عند ١,٠ من البخر التراكمي لوعاء البخر القياسي أعطي أعلي متوسطات من عدد السنابل /م٢، وزن حبوب السنبله (جم)، وزن ال١٠٠٠ حبة، محصول القش (٧٤١١، ٧٢٨٩ كجم/هكتار) في الموسمين المتعاقبين علي الترتيب ولمحصول الحبوب (٦٧٦١، ٦٥٨١كجم/هكتار) فى الموسمين على الترتيب. وكانت أقل المتوسطات المتحصل عليها هي عند الزراعه في احواض والري عند ٠,٦ من البخر التراكمي لوعاء البخر القياسي في الموسمين المتعاقبين في موقع الدراسة.

* كان متوسط الاستهلاك المائي الموسمي للمعاملات المختلفة (٤٢,٤٨، ٤١,١٤ سم) في الموسم الاول و الثاني علي الترتيب وكانت أعلي متوسطات الاستهلاك المائي تم التحصل عليها عند الزراعة فى احواض مع معاملة الرى ١.٠ بخر تراكمى من وعاء البخر القياسى (R_3I_1) بينما أقل المتوسطات للموسمين المتعاقبين قد نتجت من التفاعل عند الزراعة على مصاطب عرضها ١٢٠ سم ومعاملة الى ٠.٦ بخر تراكمى من وعاء البخر القياسى (R_1I_3).

* بدأ معدل الاستهلاك المائي اليومي بقيم منخفضة خلال شهرى نوفمبر وديسمبر ثم إزداد خلال شهرى يناير وفبراير ليصل الي اقصي قيمه له خلال شهر مارس ثم عاود الانخفاض مرة اخري خلال شهر ابريل وحتي الحصاد في الموسمين، وكانت قيم ثابت المحصول (Kc) ٠,٤٧ ، ٠,٥٥ ، ٠,٦٥، ٠,٧٣، ٠,٩٣و ٠,٥١ (متوسط الموسمين) للشهور نوفمبر، ديسمبر، يناير، فبراير، مارس ، ابريل علي الترتيب.

* كانت أعلي قيم لكفاءة الاستهلاك المائي (١,٦١ ، ١,٦٢ كجم حبوب/ م٣ ماء مستهلك) تم الحصول عليها عند الزراعة على مصاطب عرضها ١٢٠ سم مع معاملة الرى بمعدل ١.٠ بخر تراكمى من وعاء البخر القياسى (R_1I_1) خلال الموسمين المتعاقبين على الترتيب.

* تحت ظروف التجربه وفي حالة وجود نقص فى مياه يفضل الزراعة علي مصاطب عرضها ١٢٠ سم والري عند ٠,٨ من البخر التراكمي لوعاء البخر القياسي (الري كل ٢٥ يوم) وذلك لترشيد مياه الري حيث يوفر ما يقرب من ٧٠٠ متر مكعب مياه للهكتار مقارنة بمعاملة الزارعة العاديه فى احواض والتى يتم الرى فيها كل ٢١ يوم حيث كان النقص في المحصول ٠,٤٨ %.