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Effect of Irrigation Scheduling at Different Management Allowable Deficit Using Pan Evaporation on Wheat Yield and Water efficiencies at North Delta

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Two field experiments were carried out at Sakha farm, Kafr El-Sheikh Governorate during 2016/2017 and 2017/2018 to investigate the effect of irrigation scheduling at different allowable soil moisture depletion (ASMD) levels by using Pan evaporation method (PEM) on wheat yield and water efficiencies at North Delta. Four irrigation treatments; 40, 50, 60, and 70% ASMD denoted as $I_{1,}$ I_2, I_3 and I_4, respectively. The design of the experiment was randomized complete block with three replicates. The obtained results showed that the highest amount of seasonal water applied was recorded under PEM at 60%ASMD. Meanwhile, the lowest value was recorded with I_4 treatment in both seasons.Both of actual water consumptive use and water stored have the same order; I_3> I_2> I_1> I_4. The highest water application efficiency values were achieved with I_4 treatment. Irrigation treatment (I_1) surpassed the other irrigation treatments in increasing the water productivity, productivity of irrigation water, wheat yields and its components as well as grain yield, total seasonal return, net seasonal revenue and benefitcost ratio.Irrigation treatment I_1 has superiority in increasing the grain yield by (4.36, 9.86 and 13.18 %) & (1.33, 7.17 and 10.55 %) for I_2, I_3 and I_4, in the 1st and 2nd seasons respectively.Under the conditions of the current study, irrigation treatment I_1(irrigation scheduling by PEM at 40% ASMD) is the proper treatment to obtain the higher production of wheat crop and higher profitability.

Keywords: Irrigation Scheduling, Pan evaporation, Economic return, Grain yield, Water efficiencies, Water consumptive use, Wheat plant.

Introduction

Under the water shortage facing Egypt due to the high annual rate of increasing national population along with the fixed allocation from Nile River. The situation results in decreasing the annual share per capita from water to less than the water poverty edge of 1000 m^3. Moreover, this share expected to be less thanthe level of 500 m^3 in the few coming decades.In Egypt agriculture relies greatly on irrigation water from Nile River, where the agriculture sector consumes more than 84% of the available water resources (EL-Beltagy and Abo Hadeed., 2008). However, water productivity is very low. Water users normally over irrigate their fields because the lack of proper knowledge about irrigation scheduling; and with the interesting that more water will produce more yield. However, more applications of water may result in low water productivity and low net income (Ashraf et al., 2001). Irrigation scheduling is very critical for obtaining optimal crop yields. For optimum irrigation scheduling, sound knowledge of the soil water status, crop water requirements, crop water stress status, and potential yield reduction under water stressed conditions is prerequisite to maximize profits and optimize the use of water and energy (Wen et al. 2017 and Wei et al. 2018). There are different methods of irrigation scheduling viz., critical crop growth stage approach, soil moisture depletion approach (whether in terms of soil water content or soil water potential), atmospheric evaporativity approach, irrigation water at different cumulative pan evaporation approach, etc. can be adopted for optimizing the timing of irrigation.Using pan

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evaporation for irrigation scheduling has been calculated by many workers in Egypt (Khalil, 1996; Ashraf et al.2002; Khalil et al, 2006) and it was proven to save up to 20% of the applied irrigation water.

Wheat (TriticumaestivumL.) is one of the important leading cereal crops regarding area and production in the world. Also wheat is important and most strategic crop in Egypt (Karrou et al, 2012). However, at the national level, there is a wide gap among wheat consumption and production varying from 40 to 50%.Due to the fast growth of population, maximizing wheat production should be achieved through cultivation of the high yielding wheat cultivars and appropriate agronomic practices such as irrigation, sowing pattern and its date, fertilizer and weed control. Sharshar (2010), AL Tahar et al. (2011), EL-Hag (2012), Zafarnaderi and Mohammadi (2013), Omar et al. (2014), Belal Hossain et al. (2015) and Zhang et al. (2017) showed that plants height, number ofspikes m^{-2}, grain and straw yields, harvest index, number of grains/spike and thousand grain weight were affected by different irrigation number.

Regarding to the effect of soil moisture depletion levels on wheat productivity, Beshara (2012) and EL- Agrodi et al. (2016) found that the highest mean value of wheat yields and biological yield were produced with 40% depletion of available water and application the first dose of nitrogen fertilizer at sowing and the remaining were applied before the successive irrigations in both seasons. Also, the growth indicators (plant height, spike length, average number of tillers per plant and weight of 1000 kernels) increased as the available soil moisture content and the number of N-dose increased. Data showed that the highest values of water application efficiency (Ea), field water use and crop water use efficiencies were obtained under 40% of available water in the two seasons.

Regarding to the shortage andlimited of water resources in Egypt, and using it in a lot of fields particularly in Agriculture, it demands to save much water by using different techniques in irrigation without decreasing the productivity of crops. So, the aim of this studyis to evaluate the effect of irrigation scheduling at different allowable soil moisture depletion levels by using pan evaporation method on wheat yield and some water relations at North Delta.

Materials and Methods

Experimental design

This study was conducted at Sakha experimental Farm, Kafr El-Sheikh Governorate. Site is located at 31^0 07^- N latitude and 30^0 57^- E longitude with an elevation of about 6 meters above sea level during winter seasons of 2016/2017 and 2017/2018. This location represented the conditions of the North Delta region.

The approach of pan evaporation method

To define the time of irrigation, measure water use for a short period of time, keeping track of the value or depth at the start of the season or when the pan is refilled following heavy rain or irrigation. A check book is used to schedule irrigations. The value for daily water use or for a few days is subtracted from the stored soil water is exhausted, it is time to irrigate. The design of the experiment was randomized complete block (RCB) with 3 blocks formed i.e. (A, B and C), Table (1) and 4 treatments:

I_1: irrigation depth applied 59.7 mm (40% × 149.2mm) according to allowable soil moisture depletion at 40% of available water had evaporated from pan evaporation.

I_2: irrigation depth applied 74.6 mm (50% × 149.2mm) according to allowable soil moisture depletion at 50% of available water had evaporated from pan evaporation.

I_3: irrigation depth applied 89.5 mm (60% × 149.2mm) according to allowable soil moisture depletion at 60% of available water had evaporated from pan evaporation.

I_4: irrigation depth applied 104.4 mm (70% × 149.2mm) according to allowable soil moisture depletion at 70% of available water had evaporated from pan evaporation.

Taking intoconsideration pan coefficient (0.8), crop coefficient of wheat for different growth stages was taken from FAO irrigation and drainage technical paper No.56.

The inflow rate was measured with a rectangular sharp crested weir. The flow rate was measured using the equation as described by (Masoud, 1969).

$$Q=C\ L\ H^{3/2}$$

where: Q= discharge (m^3/sec.), L = length of the crest in meters, H= head in meters, C= Empirical coefficient that must be determined from discharge measurement.

Experimentlayout:

Based on design, the total 12 plots with an average field size of 7.5m length × 7m width. An irrigation channel ditch of one-meter width was already existed on the sides of the field to ensure easy access of water to each plot. Wheat variety Sakha 93 planted on 18^{th} and 20^{th} November and harvesting operation was performed on 19^{th} and 23^{rd} April in the first and second seasons, respectively. All agricultural practices were implemented as recommended by Agriculture Research center (ARC) for the studied crop and area, except the studied treatments (irrigation treatments).

- Some soil characters:The textural class of soil was determined according to the pipette method as described by Dewis and Fartias (1970). Soil samples were collected from four depths (0-15, 15-30, 30-45 and 45-60cm). Field capacity (F.C) and permanent wilting point (PWP) were determined using pressure membrane at 0.33 and 15 atm(Klute, 1986). Soil bulk density was determined according to Klute (1986), as shown in Table 2.
- Some soil chemical properties(total soluble salts, soil reaction pH, soluble cations and anions were determined in the studied site according to methods described by Jackson (1973), as shown in Table 3.

TABLE 1. The experimental design

S.NO.	variable	level	Remarks
1	Irrigation depths treatment	4	Irrigation was applied according to different allowable soil moisture depletion of available water (40,50,60 and 70%)
2	Replications	3	Three blocks were formed i.e. A,B and c
3	Total number of experimental units		3×4 = 12 plots

TABLE 2. Mean values for some physical properties of the experimental site

Soil depth	Particle size distribution			Textural class	F.C. (%)	PWP (%)	AW (%)	Bulk density (Mg m^{-3})
	Sand (%)	Silt (%)	Clay (%)					
0-15	17.14	23.9	58.96	clayey	44.5	22.52	21.98	1.12
15-30	18.86	silt 24.4 clay 56.74		clayey	41.1	20.65	20.45	1.21
30-45	18.99	24.12	56.89	clayey	38.9	20.1	18.8	1.31
45-60	18.16	24.89	56.95	clayey	38.15	19.8	18.35	1.34
Mean	18.29	24.33	57.38	clayey	40.66	20.77	19.89	1.25

F.C. = Field capacity, PWP = permanent wilting point, AW = Available Water.

TABLE 3. Mean values for some chemical properties of the experimental site

Soil depth (cm)	EC (dS m^{-1})	pH (1:2.5) soil water suspension	Soluble cations (meq L^{-1})				Soluble anions (meq L^{-1})			
			Na^+	K^+	Ca^{++}	Mg^{++}	$CO_3^=$	HCO_3^-	CL^-	$SO_4^=$
0-15	2.22	8.77	17.6	0.3	5.0	1.5	-	3.0	7.1	14.3
15-30	2.63	8.69	16.0	0.6	7.6	5.3	-	5.0	8.2	16.3
30-45	2.96	8.64	24.4	0.2	8.4	4.3	-	3.0	13.3	21.0
45-60	3.7	8.26	33.8	0.2	3.0	2.1	-	4.0	11.2	23.9
Mean	2.88	-	22.95	0.33	6.0	3.3	-	3.8	9.95	18.9

TABLE 4. Meteorological data for Kafr El-Sheikh area during the two growing seasons

Month	T (c^o)			RH%			WS km/ day	Pan evapo. mm/month	Rain (mm /month)
	Max.	Min.	Mean	Max.	Min.	mean			
				1st season					
Nov.2016	24.9	17.9	21.4	77.9	56.8	67.35	56.0	198.1	-
Dec.2016	19.3	10.8	15.05	85.4	65.1	75.25	64.7	156.4	14.54
Jan.2017	18.2	5.7	11.95	87.3	62.9	75.10	51.9	136	9.6
Feb.2017	19.7	10.2	14.95	85.8	60.1	72.95	59.3	214.4	9.6
March2017	21.7	17.9	19.8	84.9	60.4	72.65	83.8	295.4	-
April2017	26.5	21.6	24.05	79.4	50.8	65.10	89.3	463.8	10.6
				2nd season					
Nov.2017	23.7	19.9	21.8	84.7	58.6	71.65	53.16	206.2	9.3
Dec.2017	21.5	18.4	19.95	88.2	64.8	76.5	42.9	147.8	5.9
Jan.2018	19.3	13.9	16.6	88.4	63.7	76.05	49.3	185.1	36.4
Feb.2018	21.6	14.9	18.1	87.6	63.4	75.5	34.7	277.5	16.6
March2018	25.4	16.6	21.0	82.3	48.3	65.3	46.4	421.9	-
April2018	27.8	20.0	23.9	80.9	43.9	62.4	74.0	531.6	-

WS km/day at 2 m height

Source: Meteorological station at Sakha Agriculture Research station.

Water measurements

Water consumptive use (Eta, m3fed-1)

Gravimetric method was used to determine thesoil moisture to compute the actual water consumptive use based upon soil moisture depletion (SMD). The actual water consumptive use (Eta) was calculated by Hansen et al. (1979).

$$Eta{=}S.M.D{=}\sum_{i=1}^{i=n} \theta 2 - \theta 1/100 \times Dbi \times Di \times A$$

where: Eta = water consumptive use (m^3), θ2= soil moisture % after irrigation in the i^{th} layer, θ1 = soil moisture % before the next irrigation in the i^{th} layer, Dbi = Bulk density(Mgm^{-3}) of the i^{th}layer, Di= depth of the i^{th}layer (m), A = irrigated area (m^2), I = number of soil layers and n = number of irrigations.

Water stored in the effective root zone (Ws)

Calculated using equation of:

$$Ws{=}\sum_{i=1}^{i=n} \theta 2 - \theta 1/100 \times Dbi \times Di \times A$$

where:θ2= soil moisture % after irrigation in the i^{th} layer, θ1 = soil moisture % before irrigation in the i^{th} layer, (i.e directly, before and after the same irrigation, Dbi= Bulk density in (Mgm^{-3}), Di= depth of the i^{th}layer, A = irrigated area (m^2).

Water application efficiency(Ea)

It is the ratio between the amount of stored water (m^3fed^{-1}.) and water applied (m^3fed^{-1}) as described by Downy (1970).

$$Ea= (ws/wa) \times 100$$

where:ws and wa are the volumetric water stored and the volumetric water applied respectively.

Water productivity: (WP,kg m-3)

It was calculated according to Ali et al. (2007) as follows:

$$Wp=Gy/ET$$

where:Wp= water productivity (kgm^{-3}), Gy= grain yield ($kgfed^{-1}$). ET= total water consumption.

Productivity of irrigation water (PIW, kgm-3)

It was calculated according to Ali et al. (2007)

$$PIW= Gy/wa$$

where: Wa = irrigation water applied. (m^3 fed^{-1}), Gy= grain yield ($kgfed^{-1}$)

Yield and some yield attributes

- Plant height (cm): was measured from the soil surface to the tip of the spikes excluding awns.
- Spike length (cm): Average spike length for ten randomly chosen spikes.
- 1000 grain weight (g): Random samples of 1000 grain were taken from each plot, hand counted and weighed (g).
- Biological yield(tonfed-1): it was recorded for the harvested area and then it was converted to tonfed-1.
- Grain yield (kgfed-1): was recorded for the harvested area after threshing at14.5 % moisture content.
- Straw yield (tonfed-1):was estimated in (kg m-2) by subtracting grain yield (kg m-2) from total yield (kg m-2), then it was converted to ton fed-1.
- Harvest index (HI):grain yield ratio with the total above ground dry matter of each plot.

All data were statistically analyzed according Gomez and Gomez (1984).

Economic evaluation

Cash inflows and outflows for various treatments (at prices of the Egyptian local market) were calculated, and some economic indicators were estimated such as:

- Net return: it can be calculated by deducting the total cost from the total return, (L.E fed^{-1}.)
- Benefit cost ratio (BCR): it can be determined by dividing the total seasonal return on total seasonal cost, (Atiea, 1986).
- Return per unit of water:This can be taken as index to the relationship between Net return (L.E fed^{-1}) and water applied(m^3 fed^{-1}).

Results And Discussion

Effect of treatments on

Irrigation interval and number of irrigation applied

During the growing season of wheat, four irrigations were applied for the I_1, I_2 and I_3 treatments, while I_4 received three irrigations because of frequent, amount of rainfall and variation in depth of water applied to different irrigation treatments. The irrigation interval between irrigation was also not uniform due to precipitation and different depth of water applied as shown in Table 5.

TABLE 5. Date of irrigation and irrigation interval for different treatments

Irrigation treatments	Planting irrigation	First irrigation	Irrigation intervals days	Second irrigation	Irrigation intervals days	Third irrigation	Irrigation intervals days
I_1	Nov.18	Dec.9	21	Jan.31	53	March,2	30
I_2	Nov.18	Dec.9	21	Feb.6	59	March,14	36
I_3	Nov.18	Dec.9	21	Feb.15	68	March,28	41
I_4	Nov.18	Dec.9	21	Feb.21	74	-	-

Irrigation water requirements (IWR, m3fed-1)

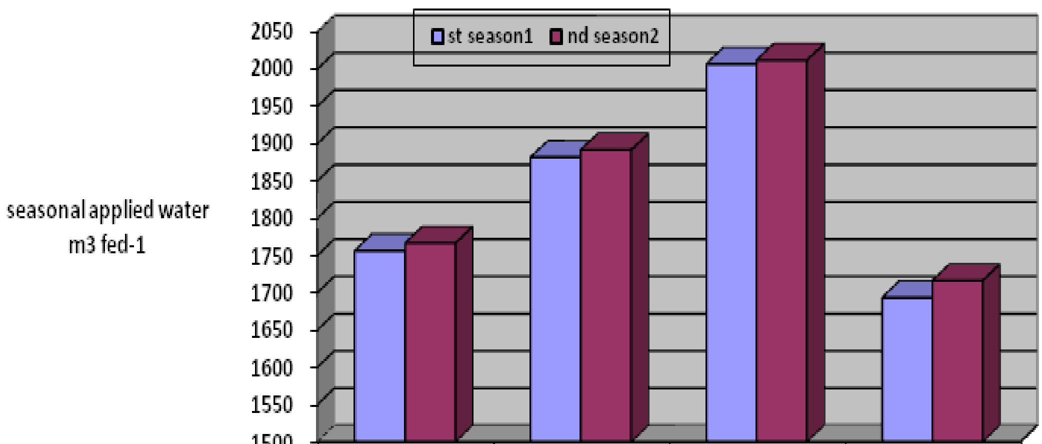
The amount of water requirements for wheat is summation of water applied and the effective rainfall which it equals the incident rainfall × 0.7 (Novica, 1979).

The values of seasonal applied water were affected by irrigation scheduling for different allowable soil moisture depletion by using pan evaporation method (I_1, I_2, I_3 and I_4) in the two growing seasons, (Figure 1).

The highest value of seasonal applied water was recorded with pan evaporation method at 60% allowable soil moisture depletion and the values are 2006.76 m^3fed^{-1}. and 2011.8 m^3fed^{-1}. in the first and second seasons, respectively. Meanwhile, the lowest values 1693.44 m^3fed^{-1}. and 1716.12 m^3fed^{-1}. were recorded with irrigation treatment I_4 in the first and second seasons, respectively. Generally, seasonal water applied values can be descended in the following order; $I_3 > I_2 > I_1 > I_4$ in the two seasons. Increasing values of seasonal applied water under irrigation treatment I_3 could be attributed to long period of irrigation interval and hence, increasing the amount of water applied. These results are in a great harmony with those obtained by Beshara (2012) and Omar et al. (2014).

Actual water consumptive use(Eta, m3fed-1)

Actual water consumptive use was clearly affected by irrigation scheduling by pan evaporation method for different allowable soil moisture depletion in the two seasons, Fig. (2). In the two growing seasons,the maximum water consumptive use values (1483.44 m^3fed^{-1}. and 1491 m^3fed^{-1}) were recorded under irrigation treatment 1_3 compared to the other irrigation treatments I_1, I_2 and I_4. On the other hand,the lowest values were obtained under irrigation treatment I_4 (1262.1 m^3fed^{-1} and 1285.2 m^3 fed^{-1}.), respectively. The values of water consumptive use can be arranged in the descending order as follows; $I_3 > I_2 > I_1 > I_4$. Increasing the values of water consumptive use under irrigation treatment I_3 could be attributed to increasing the amount of water applied and long period of irrigation interval. These results are in the same line with those obtained by Beshara (2012) and EL-Agrodi et al. (2016).



	I1	I2	I3	I4
1st season	1756.44	1881.6	2006.76	1693.44
2nd season	1766.54	1891.68	2011.8	1716.12

Fig. 1. irrigation water requirements for different treatments in the two growing seasons

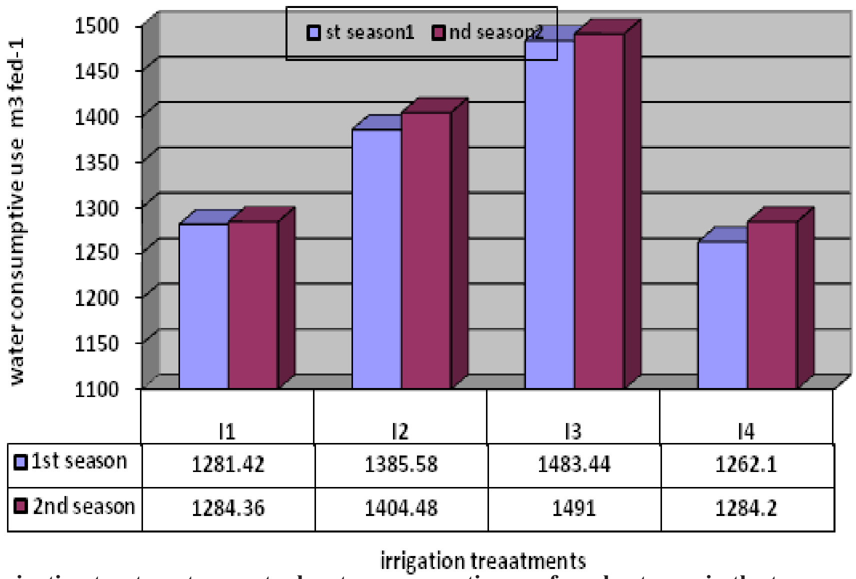


Fig. 2. Effect of irrigation treatments on actual water consumptive use for wheat crop in the two growing seasons

Water storedand water application efficiency

Data in Table 6 showed that, values of water stored (Ws) and water application efficiency (Ea) were clearly influenced by irrigation treatments. The highest mean values of water stored were observed in I_3 treatment, where the values are 1587.28 $m^3fed^{-1}$and 1595.37 m^3fed^{-1}. in the first and second seasons, respectively. The lowest values were obtained with I_4 treatment, where the values are 1350.45 $m^3fed^{-1}$and 1364.27 m^3fed^{-1}. in the first and second seasons respectively. Generally, values of water stored can be descended in order; $I_3> I_2> I_1>I_4$ in the first and second seasons, respectively. These results are in agreement with those obtained by Beshara (2012).

Regarding the effect of irrigation treatments on water application efficiency, the values were clearly affected by irrigation treatments where the maximum values (79.75 and 79.5%) were observed in I_4 treatment which exposed to strict water stress and received three irrigations during the growth stages in the first and second seasons, respectively. The minimum values (78.06 and 77.56%) were observed in I_1 treatment. Generally, the values of water application efficiency can be descended in order; $I_4> I_3>I_2> I_1$ in the first season, while in the second season the order was as follows; $I_4> I_2> I_3> I_1$. These results were confirmed by Awan and Ali (1988).

Water productivity and productivity of irrigation water

The values of WP and PIW were greatly affected by irrigation scheduling at different allowable soil moisture depletion in both seasons. The highest values were obtained with I_1 treatment where the WP values and PIW for wheat grain yield were found to be (2.26 and 1.65 kgm^{-3})in the first season, (2.28 and 1.66 kgm^{-3}) in the second season, respectively. The values of WP and PIW for wheat straw yield were found to be (2.77 and 2.02 kgm^{-3}) in the first season, while in the second season were (2.85 and 2.07 kgm^{-3}), respectively. Meanwhile, the lowest values of WP and PIW for wheat grain and straw yield were obtained with I_3 treatment in the first and second seasons, respectively,Table 7. The findings might be due to decreasing the amount of water consumptive use and water applied compared to other irrigation treatments. These results are in harmony with those obtained by EL-Agrodi et al. (2016) and EL-Mantawy and Khalifa (2018).

Yield and some yield attributes

Plant height (cm)

Data presented in Table 8 indicated that the plant height wasaffected significantlywith irrigation treatments in the first season, while in the second season there is no significant effect. It is clear that the tallest plants were produced under I_1 treatment where the values were (95 and 97 cm) in the first and second seasons, respectively. The shortest plants were recorded with I_4 treatment (89 and 91 cm) in the two growing seasons. The decreased in plant height may be due to the reduction of cell expansion under water stress. Also, the increase in number of irrigations lead to increased nutrition availability and thus increase plant growth especially plant height, increasing the size and number of cells between the internodes which resulting in increasing the plant height. These results are in harmony with those found by Sharshar (2010) , Omar et al., (2014) and Belal Hossain et al, (2015).

TABLE 6. Effect of irrigation treatments on water stored (m^3 fed^{-1}) and water application efficiency (%)

Irrigation treatments	1st season			2nd season		
	Water stored (m^3 fed^{-1})	Water applied (m^3 fed^{-1})	Water application efficiency (%)	Water stored (m^3 fed^{-1})	Water applied (m^3 fed^{-1})	Water application efficiency (%)
I_1	1371.12	1756.44	78.06	1370.16	1766.54	77.56
I_2	1482.57	1881.6	78.79	1502.79	1891.68	79.44
I_3	1587.28	2006.76	79.1	1595.37	2011.8	79.3
I_4	1350.45	1693.44	79.75	1364.27	1716.12	79.5

TABLE 7. Effect of irrigation treatments on water productivity (WP, kg m^{-3}) and productivity of irrigation water (PIW, kg m^{-3}) for grain and straw yield in the two growing seasons

Irrigation treatments	For Wheat grain yield				For Wheat straw yield			
	1st season		2nd season		1st season		2nd season	
	WP	PIW	WP	PIW	WP	PIW	WP	PIW
I_1	2.26	1.65	2.28	1.66	2.77	2.02	2.85	2.07
I_2	1.99	1.47	2.06	1.53	2.46	1.81	2.47	1.83
I_3	1.76	1.3	1.82	1.35	2.17	1.6	2.19	1.63
I_4	1.99	1.48	2.04	1.53	2.35	1.75	2.37	1.78

TABLE 8. Effect of irrigation treatments on plant height (cm), spike length (cm) and kernel weight (g) for wheat crop in the two growing seasons

Irrigation treatments	Plant height (cm)		Spike length (cm)		1000 grain weight (g)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season
I_1	95	97	10.1	10.2	49.9	50.1
I_2	93	95	9.8	9.9	47.8	48.2
I_3	91	92	9.4	9.6	46.1	46.9
I_4	89	91	9.1	9.3	45.2	45.7
F test	*	NS	**	**	**	**
L.S.D 0.05	3.996	-	0.3996	0.3996	0.4613	0.3996
L.S.D0.01	-	-	0.6054	0.6054	0.6988	0.6054

*, ** and NS indicate $p < 0.05$, < 0.01 and not significant, respectively.

Spike length (cm)

Spike length exhibited highly significant effect due to irrigation treatments. The maximum spike length was produced under I_1 treatment, while the minimum spike length was recorded under I_4 treatment in the two growing seasons, (Table 8).

1000 grain weight (g)

Irrigation treatments showed a highly significant effect on 1000 grain weight in the two growing seasons. It is clear from data that the highest value of 1000 grain weight was observed with I_1 treatment and the lowest value of grain weight was obtained with I_4 treatment, Table, 10. The increase of 1000 grain weight is due to increase the available water and nutrients from the soil to plant lead to increase vegetative growth and thereby increase the metabolic rate and thus storage in grain, hence resulted in increasing grain weight. It is agreement with those reported by Sharshar(2010), AL-Tahar et al., (2011) and Omar et al., (2014).

Biological yield

The different irrigation treatments had highly significant effect on biological yield in the two growing seasons. It is clear that the maximum biological yield values were produced under irrigation scheduling treatment at 40% allowable soil moisture depletion, while the minimum values were obtained under irrigation scheduling at 70% allowable soil moisture depletion, Table 9.

Grain yield

Data in Table 9 indicates that there is not significant effect on grain yield due to irrigation treatments in both seasons. The highest wheat grain yield values were achieved with I_1- treatment followed by I_2-treatment in the two growing season, respectively, while the minimal values of grain yield recorded with I_4 treatment. Several investigators reported that inadequate irrigation water or drought stress reduced photosynthesis and translocation rates and increased respiration which reduced available assimilation for grain and finally decreased grain yield. These results agreed with those obtained by Sharshar (2010); Omar et al., (2014); EL-Agrodi et al, (2016); EL-Mantawy and Khalifa (2018).

Straw yield

Irrigation treatments had nosignificant effect on straw yield in the two growing seasons. The topmost yield was obtained with I_1 treatment, while the lowest values of straw yield were recorded with I_4 treatment in both seasons, Table 9. The increase in straw yield could be due to augment the amounts of irrigation water and hence increases yield components such as number of productive tillers and growth attributes. These are in agreement with discussion obtained by EL-Hag (2011) and Farhat (2015).

Harvest index

Data in Table 9 revealed that the irrigation treatments had high significant effect on harvest index in the first season, while irrigation treatments had insignificant effect in the second season. The maximum harvest index value was obtained through I_1 treatment, while lowest value was obtained with I_4 treatment in both seasons.

Economic evaluation

Total seasonal returns

The mean total seasonal return values for different irrigation scheduling were 12353.4, 11832.6, 11159.4 and 10590.6LEfed^{-1} for I_1, I_2, I_3 and I_4 treatments respectively in the first season, while the corresponding values in the second season were 12594.6, 12257.4, 11538.6 and 10997.4 LEfed^{-1}for the stated treatments. The highest values in both seasonswere obtained with I_1 treatment and the lowly values was recorded with I_4 treatment, Table (10). It is worth to noting that the differences in the seasonal values of total return between and within treatments in the first season were less than those of the same treatments in the second season. These results may be due to variation in environmental or climatic factors during the two growing seasons.

Net seasonal return

Data in Table 10 revealed that the net seasonal revenue showed the same trend as in the abovementioned indicator (i. e. the seasonal total return). This trend may be due to that the production cost for each treatment separately seemed to be semifixed, or that the differences between them are relatively very small.The highest values of net return were achieved with I_1 treatment, while the lowest values were recorded with I_4 treatment in both seasons.

Benefitcost ratio (BCR)

From the presented data in Table 10, the same trend of the abovementioned economic indicators appears obviously, that it prevalent with this indicator in both growing seasons. The irrigation scheduling at 40% allowable soil moisture depletion by using pan evaporation increased the values of BCR compared to other irrigation treatments in both seasons. This finding may attributed to the relatively fixed cost between treatments on one hand, compared to considered differences in return between those treatments. The values of benefit cost ratio can be descended in the following order; $I_1 > I_2 > I_3 > I_4$ for both seasons.

TABLE 9. Effect of irrigation treatment on biological yield, grain yield, straw yield and harvest index in the two growing seasons

Irrigation treatments	Biological yield (ton fed^{-1})		Grain yield (ton fed^{-1})		Straw yield (ton fed^{-1})		Harvest index %	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
I_1	6.44	6.59	2.89	2.93	3.55	3.66	44.88	44.46
I_2	6.18	6.36	2.76	2.89	3.41	3.47	44.78	44.44
I_3	5.83	5.99	2.61	2.72	3.22	3.27	44.72	44.41
I_4	5.48	5.67	2.51	2.62	2.97	3.05	44.7	44.21
F test	**	**	Ns	Ns	Ns	Ns	**	Ns
L.S.D 0.05	0.057	0.045	-	-	-	-	0.098	-
L.S.D0.01	0.0856	0.068	-	-	-	-	0.148	-

*, ** and NS indicate $p < 0.05$, < 0.01 and not significant, respectively.

TABLE 10. Values of total return, cost, net return and some economic criteria for wheat production in the two growing season

Treatments	Productivity (kg fed^{-1})		Total seasonal return (LE Fed^{-1})	Total seasonal costs (LE Fed^{-1})	Net seasonal return (LE Fed^{-1})	IWR (m^3 Fed^{-1})	Water return (LE m^{-3})	BC R
	grain	straw						
				1st season				
I_1	2890.5	3550	12353.40	6224	6129.40	1756.44	3.49	1.98
I_2	2764.5	3410	11832.60	6224	5608.60	1881.6	2.98	1.90
I_3	2605.5	3220	11159.40	6244	4915.40	2006.76	2.45	1.79
I_4	2509.5	2970	10590.60	6154	4436.60	1693.44	2.62	1.72
				2nd season				
I_1	2929.5	3660	12594.60	6224	6370.6	1766.54	3.61	2.02
I_2	2890.5	3470	12257.40	6224	6033.4	1891.68	3.19	1.97
I_3	2719.5	3270	11538.60	6244	5294.6	2011.8	2.63	1.85
I_4	2620.5	3050	10997.40	6154	4843.4	1716.12	2.82	1.79

TABLE 11. Experimental return / costs by treatments during the two growing seasons

Item			Costs according to the Egyptian local market price (LE)
CHEMICAL FERTILIZER	N, as urea 46.5 % (90 unit per fed. was applied 193.5 kg fed$^{-1)}$		4000 LE ton^{-1}
	K, as potassium sulphate 48 % K_2o (50 kg per fed) as recommended rate in clay soil, 60 days after planting		6000 LE ton^{-1}
	P, as calcium superphosphate, 15.5 % P_2O_5 (150 kg per fed. as a recommended rate in clay soil during the last plowing before planting)		1200 LE ton^{-1}
Seeds (60 kg per fed)			7 LE/kg
Machinery costs	Tillage and planter		500 LE fed^{-1}
	Irrigation I1 (4 irrigations)		200 LE fed^{-1}
	Irrigation I2 (4 irrigations)		200 LE fed^{-1}
	Irrigation I3 (4 irrigations)		200 LE fed^{-1}
	Irrigation I4 (3 irrigations)		150 LE fed^{-1}
	Harvest		500 LE fed^{-1}
Labour wages	Fertilizer broad casting		200 LE fed^{-1}
	Irrigation + manual weed control	I1 (4 irrigations)	150 LE fed^{-1}
		I2 (4 irrigations)	150 LE fed^{-1}
		I3 (4 irrigations)	150 LE fed^{-1}
		I4 (3 irrigations)	130 LE fed^{-1}
Land rent for winter season			3000 LE fed^{-1}
Grain yield (ton)			2800 LE fed^{-1}
Straw yield (ton)			1200 LE fed^{-1}

Water returns

It is clear from the data exhibited in Table (10) that the water return for different treatments showed the same tendency to those of previous indicators, in which the water return increased with increasing allowable soil moisture depletion. The highest values were obtained with I_1 treatment, while the lowest values were recorded with I_3 treatment in both seasons, this may be due to increasing the amounts of water applied between the treatments.

Selecting the most profitable treatment for wheat crop production

Sixparameters were taken into account to select the profitable treatment for wheat crop production under Egyptian conditions. These parameters related to; grain yield, straw yield, weight of 1000 grain, water productivity, productivity of irrigation water and benefit cost ration as shown in Table (12).It is suggested to use a factor called overall relative factor of evaluation, Kt. This factor is expressed as follows:

$$K = R_1K_1 \times R_2K_2 \times R_3K_3 \times R_4K_4 \times R_5K_5 \times R_6K_6$$

(Beshara, 2012)

where

K_1= Grain yield for the tested treatment/the same criterion for I_1

K_2= Straw yield for the tested treatment/the same criterion forI_1

K_3 =Weight of 1000 grains for the tested treatment / the same criterion for I_1

K_4= Water productivity for the tested treatment/ the same criterion for I_1

K_5= Productivity of irrigation water for the tested treatment/ the same criterion for I_1

K_6= Benefit cost Ratio for the tested treatment / the same criterion for I_1

The combined of these parameters may help to set up an overall relative factor of evaluation for each treatment and selecting an optimum treatment that meet the best results of all or most evaluation features. The importance of each parameter differs according to marketing and environmental conditions. So, the values of Ri, I =1-6 were taken throughout this work to be equal the unity. This simplifies the abovementioned formula to be as follows:

$K_t = K_1 \times K_2 \times K_3 \times K_4 \times K_5 \times K_6$

It should be noted that I_1 treatment values were used in this research as a basis to calculate the values of the overall relative factor of evaluation (K_t) for all other treatments. So, the values of K_1 to K_6 for the treatment of I_1 should be equal unity, and consequently, the value of K_t for the base treatment (I_1) must also be equal to unity. Table (12) shows the values of K_1, K_2, K_3, K_4, K_5 and K_6 for the different investigated treatments and the corresponding values of overall factors of evaluation. From the data presented in Table (13), it is clear that the value of overall factor (K_t) of evaluation differs according to the investigated treatment. So, the different tested treatments of wheat production can be arranged in the following descending order:

$I_1 > I_2 > I_4 > I_3$ in the first and second seasons respectively.

TABLE 12. Values of some features used for selecting the profitable treatment for wheat in the two growing season

Treatments	Grain yield (kg fed^{-1})	Straw yield (kg fed^{-1})	Weight of 1000 grain (g)	WP (kg m^{-3})	PIW (kg m^{-3})	BC R
			1st season			
I_1	2890.5	3550	49.9	2.26	1.65	1.98
I_2	2764.5	3410	47.8	1.99	1.47	1.90
I_3	2605.5	3220	46.1	1.76	1.3	1.79
I_4	2509.5	2970	45.2	1.99	1.48	1.72
			2nd season			
I_1	2929.5	3660	50.1	2.28	1.66	2.02
I_2	2890.5	3470	48.2	2.06	1.53	1.97
I_3	2719.5	3270	46.9	1.82	1.35	1.85
I_4	2620.5	3050	45.7	2.04	1.53	1.79

TABLE 13. Relative coefficient and overall relative coefficient of different irrigation treatments in the two growing season.

Treatments	K1	K2	K3	K4	K5	K6	Kt	order
				1st season				
I_1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1
I_2	0.956	0.961	0.958	0.881	0.891	0.960	0.662	2
I_3	0.901	0.907	0.924	0.779	0.788	0.904	0.419	4
I_4	0.868	0.837	0.906	0.881	0.897	0.869	0.451	3
				2nd season				
I_1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1
I_2	0.987	0.948	0.962	0.904	0.922	0.975	0.731	2
I_3	0.928	0.893	0.936	0.798	0.813	0.916	0.462	4
I_4	0.895	0.833	0.912	0.895	0.922	0.886	0.497	3

Conclusion

Although I_1 irrigation treatment received fewer amounts of irrigation water among other treatments, it suppressed all values of studied parameters. Also, irrigation treatments have no significant differences in wheat yield and I_1 irrigation treatment also gave best values of yield and yield components. So, it can be concluded that the treatment I_1 is the best treatment (irrigation scheduling at allowable 40% depletion of available soil moisture) followed by I_2 treatment which meet the best desired results such as the highest grain and straw yields and the highest water functions.

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تأثير جدولة الري عند مستويات مختلفة من استنفاذ الرطوبة الأرضية الميسرة باستخدام وعاء البخر على محصول القمح وكفاءات الري في شمال الدلتا

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أجريت تجربة حقلية في محطة البحوث الزراعية بسخا – محافظة كفر الشيخ خلال موسمين زراعيين ٢٠١٧/٢٠١٦ &٢٠١٨/٢٠١٧ وذلك بهدف دراسة تأثير جدولة الري باستخدام وعاء البخر عند مستويات مختلفة من استنفاذ الرطوبة الأرضية الميسرة على محصول القمح وكفاءات الري في شمال الدلتا.

تم اختبار أربع معاملات للري: وهي جدولة الري باستخدام وعاء البخر عند استنفاذ نسب مختلفة من الرطوبة الأرضية الميسرة وهي ٤٠، ٥٠، ٦٠، ٧٠ ٪ والتي يشير الي I_1، I_2، I_3، I_4على الترتيب وكان تصميم التجربة قطاعات كاملة العشوائية.

ويمكن تلخيص النتائج المتحصل عليها: -

- سجلت أعلي القيم لكميات مياه الري المضافة بجدولة الري باستخدام وعاء البخر عند فقد ٦٠٪ من الرطوبة الأرضية الميسرة، بينما كانت أقل القيم سجلت مع معاملة الري ٧٠٪ فقد من الرطوبة الأرضية الميسرة في كلا موسمي الدراسة.
- يمكن ترتيب معاملات الري طبقا للاستهلاك المائي والماء المخزن في منطقة الجذور الفعالة في الترتيب التالي معاملة الري الثالثة <معاملة الري الثانية <معاملة الري الأولي < معاملة الري الرابعة
- اتضح من النتائج أن معاملة الري الأولي تفوقت على باقي المعاملات الأخرى في زيادة الإنتاجية المائية من الماء المستهلك (WP) والإنتاجية المائية من ماء الري المضاف (PIW)، إنتاجية القمح (حبوب وقشومكوناته) بالإضافة الي محصول الحبوب، العائد الموسمي الكلي، صافي العائد ونسبة العائد الي التكلفة.
- قيم كفاءة الري التطبيقية يمكن ترتيبها في الرتبة التالية: معاملة الري الرابعة <معاملة الري الثالثة<معاملة الري الثانية < معاملة الري الأولي في الموسم الاول بينما في الموسم الثاني كانت معاملة الري الرابعة <معاملة الري الثانية <معاملة الري الثالثة < معاملة الري الاولي
- ومن الجدير بالذكر أن معاملة الري الأولي كان لها الأفضلية في زيادة محصول القمح بنسبة ٤,٣٦، ٩,٨٦، ١٣,١٨٪ في الموسم الأول بينما القيم المناظرة في الموسم الثاني كانت ١,٣٣، ٧,١٧، ١٠,٥٥ ٪ لمعاملات الري I_2،I_3،I_4 على الترتيب.
- تحت ظروف الدراسة الحالية يمكن التوصية بالري بالمعاملة الأولي (وهي جدولة الري باستخدام وعاء البخر القياسي عند استنفاذ ٤٠٪ من الرطوبة الأرضية الميسرة) من الرطوبة الأرضية الميسرة للحصول علي أعلي إنتاجية من محصول القمح وأعلي عائد اقتصادي.