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Contribution of Groundwater to Wheat-Water Needs as Affected with Irrigation Scheduling in North Nile Delta

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ABSTRACT

Contribution of groundwater and the utilization of applied water are an effective ways in connection with water saving and increasing crop water productivity. A field experiment was conducted at Sakha Experimental Farm, Kafr ElSheikh Governorate, North Nile Delta area, Egypt during the two successive growing seasons of 2016/17 and 2017/18 to investigate the effect of irrigation scheduling i.e. irrigation amount and irrigation interval on wheat growth (cv. Sakha 93), yield, its components and crop – water relations. Split- plot design was used, the main plots were assigned to three levels of irrigation intervals; two, three and four weeks, while the sub-plots were three levels of irrigation; irrigation to field capacity + 10%, irrigation to field capacity and irrigation to field capacity - 10%. The obtained results revealed that the highest values of growth traits and the highest yield of wheat were obtained when plants were irrigated till field capacity - 10%. The highest values of both applied and consumed water were recorded under the same treatment, but it produced the lowest values of water efficiencies. It is recommended that irrigation every four weeks till field capacity - 10% resulted in an average contribution of groundwater of 30.52% in the North Middle Nile Delta, Egypt.

Keywords: Contribution of groundwater, wheat crop, water level and water efficiencies.

INTRODUCTION

In the recent decades, Egypt has been facing a serious crisis in the available water supplies due to the rapid growth of population alongside with the stability amount of fresh water resources. Due to the increasing of population worldwide, water demand for different purposes is increasing. Under the limitation of fresh water resources, it should be find other resources for irrigation such as groundwater with good quality. One of the practical procedures is the contribution of groundwater in crop water needs.

Both used groundwater by the growing crop and the applied irrigation water stored in the effective root zone, estimated rate at which stored water is depleted from soils reduced the amount of applied water and irrigation intervals could be increased. Thus, ultimately decreased both number of waterings and required amount of applied irrigation water. In case of the saline groundwater, the usefulness of groundwater for crop will be restricted by the plant- salt tolerance as well as the depth to groundwater. Shallow groundwater exists in many areas of the world. Thus, groundwater can be used by plants either as drainage water for irrigation or through in-situ use i.e. contribution to crop-water needs. In suite use of groundwater by crops is a complicated matter than irrigation with drainage groundwater. It depends on several factors such as depth to the water table, hydraulic properties of the soil, stage of the crop growth, groundwater quality ----- etc. Quantification of the water taken by the roots from the shallow water table is of great significance and has been a topic of extensive research in the last few decades.

Kahlown *et al. (2005)* investigated the effect of shallow water table on crop water requirements by using 18 large size drainage type concrete lysimerters. They found that when water table was kept at a depth of 0.5 m, wheat met its entire water requirement from the groundwater. *Udom et al. (2013)* found that greater amount of moisture was contributed from the 300-600mm soil depth which corresponded with the rooting depth of the crop, an area of greatest root proliferation of the crop. They also concluded that soil with shallow groundwater table may need no irrigation or the need for irrigation water may be reduced considerably.

Wajid *et al. (2002)* reported that wheat crop produced highest grain yield by applying irrigation at all definable growth stages. Because irrigation is an expensive input, farmer, agronomist, economist and engineer need to know the response of yield to irrigation. Aggarwal *et al. (1986)* reported that water use efficiency (WUE) i.e. crop-water productivity (WP) of wheat decreased with increasing ET. The use of frequent, but low water application volumes is superior to the more traditional scheduling of few applications of large irrigation volumes in terms of irrigation water utilization efficiency (IWUE) as stated by Dukes *et al. (2010)* and Zotarelli *et al. (2009)*.

The aim of this research is to investigate the effect of different irrigation scheduling in the presence of shallow water table on yield of wheat, some water relations and contribution of groundwater table in wheat water needs.

MATERIALS AND METHODS

Location of the studied area:

A field experiment was carried out during the two wheat seasons of 2016/17 and 2017/18 at Sakha

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Agricultural Research Station, Kafr El-Sheikh Governorate. The site is located at 31°-07' N latitude, 30°-57' E longitude. It has an elevation of about 6 meters above the mean sea level. It represents the conditions and circumstances of middle northern part of the Nile Delta region.

Climatic conditions:

Climatic elements were collected from the agro meteorological station and recorded during the two seasons of wheat and presented in Table (1).

Table 1. Climatological data of Sakha during the seasons (2016/17 and 2017/18).

Month	T (C^0)			RH (%)			W_s m sec^{-1}	Pan Evap. mm.	Rainfall (Rf) mm $month^{-1}$
	Max	Min	Mean	Max	Min	Mean			
2016/2017									
Nov.2016	24.9	17.9	21.4	77.9	57.0	67.4	0.88	2.02	0.00
Dec.	19.7	16.7	18.2	85.4	65.3	75.4	0.72	1.47	25.8
Jan.2017	18.2	5.7	11.9	87.8	62.4	75.1	0.60	1.36	9.6
Feb.	19.6	9.8	14.7	86.1	59.9	73.0	0.73	1.96	25.6
Mar.	22.5	18.0	20.2	84.9	60.3	72.6	0.97	2.97	0.00
April.	26.5	21.6	24.1	79.4	50.8	65.1	1.03	4.54	10.6
May	30.6	25.8	28.2	77.7	45.6	61.7	1.23	6.59	0.00
2017/2018									
Nov.2017	23.7	19.9	21.8	85.1	58.6	71.9	0.61	2.06	9.3
Dec.	21.5	18.4	20.0	88.2	64.8	76.5	0.50	1.47	5.6
Jan.2018	18.9	19.0	18.9	89.3	64.8	77.1	0.35	3.05	36.4
Feb.	21.5	14.5	18.0	87.8	63.5	75.6	0.37	2.74	16.6
Mar.	25.5	16.6	21.1	89.3	48.4	68.8	0.54	4.24	0.00
April.	27.2	19.9	23.6	80.9	43.9	62.4	0.85	5.78	0.00
May	31.2	23.9	27.6	75.6	43.3	59.4	1.10	6.34	0.00

Source: Sakha Meteorological Station. RH: Relative Humidity, Ws: Wind Speed

Soil characteristics:

Soil samples were taken before wheat cultivation from successive depths: 0-15, 15-30, 30-45 and 45-60 cm, air dried grounded, sieved for physical and chemical analysis as presented in Table (2). Particle size distribution for soil was carried out using the pipette method as described by *Gee and Bauder (1986)* and consequently to find out the soil texture. Bulk density: was determined as described by Black et al *(1965)*. Soil water constants: field capacity (F.C and permanent wilting point (PWP) were determined by using pressure membrane method at 0.33 and 15 atmosphere (*Klute 1986).*) and the chemical analysis of the experimental soil before sowing are tabulated in Table (2) as described by Jackson (1973).

Table 2. Some physical, chemical properties and soil moisture constants for studied area.

Soil depth, Cm	Particle Size Distribution %			Texture Class	Soil- water constants			Bulk density (Mg/m³)
	Clay	Silt	Sand		[1]F.C (%,wt/wt)	[2]P.W.P (%,wt/wt)	[3]A.W (%,wt/wt)	
0 – 15	54.36	33.00	12.64	Clayey	43.16	26.75	16.41	1.05
15 -30	45.50	36.01	18.49	Clayey	41.20	22.44	18.76	1.07
30 -45	39.08	41.30	19.62	Clay loam	39.07	21.26	17.81	1.13
45 – 60	37.50	40.09	22.41	Clay loam	35.40	20.83	14.57	1.18
Mean	44.11	37.60	18.29	Clay loam	39.71	22.82	16.89	1.11

Soil Chemical characteristics

	pH	Ec dSm^{-1}	Soluble cations, $meqL^{-1}$				Soluble anions, $meqL^{-1}$			
			Ca^{++}	Mg^{++}	Na^+	K^+	CO_3^{-}	HCO_3^{-}	Cl^-	SO_4^{-}
0 – 15	8.56	3.33	11.031	5.18	16.90	0.22	0.00	4.30	15.00	14.03
15 -30	8.41	3.64	11.54	8.60	16.10	0.19	0.00	3.90	14.90	17.63
30 -45	8.40	4.03	13.17	8.97	18.02	0.18	0.00	3.70	11.80	24.84
45 – 60	8.35	4.07	14.60	11.28	21.00	0.17	0.00	3.70	11.00	32.35
Mean		3.94	12.59	8.51	18.01	0.19	0.00	3.90	13.18	22.21

[1]FC = Field capacity, [2]PWP = Permanent wilting point and [3]AW = Available soil water.

Experimental layout:

The wheat crop (cv. Sakha 93) was grown during the two seasons of 2016/17 and 2017/18. Dates of sowing were 15th and 23th, November in the first and second seasons, respectively, while the dates of harvesting were 24th and 30th April, respectively. Agricultural practices were done as recommended by Agriculture Research center (ARC), Egypt, execpt irrigation scheduling i.e. irrigation intervals and applied irrigation water level. The plot area was 52.5 m^2 (1/80 fed., 1 fed=0.42ha). The design of the experiment was split plot with three replicates. The irrigation intervals treatments were assigned to the main plots irrigation every two weeks (A),irrigation every three weeks (B) and irrigation every four weeks (C),while the applied irrigation water levels were located in the sub-plots; irrigation with field capacity plus 10% (I_1),irrigation with field capacity (I_2)and irrigation with field capacity minus 10% (I_3).

Statistical analyses:

All statistical analyses were performed with Costat (version 6.3030 and Microsoft Office Excel 2010 programs.

Data collected:

Irrigation water (I.W):

Irrigation water was controlled and measured by rectangular weir according to *Michael, (1978*) as follows:

$$Q = 1.84\ LH^{1.5} \quad ----- (1)$$

Where:

Q = Water discharge, $m^3 sec^{-1}$,
L = width of weir, cm and
H = the head above weir crest, cm.

Soil moisture depletion:

Soil moisture depletion which considered as actual water consumed by the growing crop was calculated using the following equation according to *Hansen et al. (1979).*

$$ETa \cong Cu \cong SMD = \frac{\theta_2 - \theta_1}{100} * Db * d * A \quad ---- (2)$$

Where:

ETa = Actual evapotranspiration,
CU = Actual water consumptive use by the growing plants,
SMD = Soil moisture depletion,
Θ_2 = Mean soil moisture percentage, 48 hours following irrigation event,
Θ_1= Mean soil moisture percentage before the next irrigation,
Db = Mean soil bulk density (Mg m^{-3}) of 60 cm soil depth,
d = Soil wetting depth i.e. effective root depth of 60 cm and
A =Irrigated area, m^2.

Fluctuation of water table depth:

Fluctuation of water table depth was recorded by observation wells. Each observation well was a perforated plastic tube with two inch in diameter and two meters length. Daily reading of water table was recorded by the aid of a metallic sounder that was fixed with a sealed tape to measure the water table depth.

Contribution of groundwater table (C):

The contribution of groundwater table (c) to crop water needs was computed by the difference between crop evapotranspiration (ETc) computed according to *FAO Penman-Montieth* (1998) and actual consumptive use (ETa) during each irrigation period.

$$C = ETc - ETa \quad ------ (3)$$

$$C, \% = \frac{C}{ETc} * 100 \quad ------- (4)$$

C = Contribution of groundwater table, mm day^{-1},
ETc = Crop evapotranspiration according to FAO Penman- Montieth, mm day^{-1},
ETa =Actual consumptive use= soil moisture depletion, mm day^{-1} and
C %= Percentage of contribution of groundwater table, %.

It should be notified that ETc was calculated as follows:

$$ETc = ETo * Kc$$

Which:

ETo = Reference evapotranspiration based on Penman-Menthies, and
Kc = Crop coefficient as quoted from standard tables (FAO Irrigation & Drainage paper No. 56)

3. Yield and yield components:

Biological yield (Kg), Grain yield (kg), Straw yield (kg), Plant height (cm), 1000 grain weight (g) were determined and Harvest index was calculated as follows:

$$\text{Harvest index} = \frac{\text{Grain yield (kg)}}{\text{Biological yield (Kg)}} \quad ---- (5)$$

Crop-water relations:

Water productivity (WP):

Water productivity is generally defined as crop yield per each unit of water consumption. It was calculated according to *Ali et al. (2007).*

$$WP = \frac{Y}{ET} \ ..... (6)$$

Where:

WP = Water productivity (kg m^{-3} consumed),
Y = Yield (kg), and
ET = Seasonal water consumed by the growing crop (m^3).

Productivity of applied water (PWa):

Productivity of applied water (PWa) was calculated according to *Ali et al., (2007).*

$$PWa = \frac{Y}{Wa} \ .... (7)$$

Where:

PWa = productivity of applied water (kg m^{-3} applied),
Y = Yield (kg), and
Wa = Applied water (irrigation water + rainfall).

RESULTS AND DISCUSSION

1-Applied water and water Consumptive use:

The amount of applied water (Wa) which included the applied irrigation water plus rainfall and water Consumptive use (CU) are presented in Tables (3 and 4). The seasonal Wa in 2016/2017 growing period was higher than 2017/2018. This may be due to the differences in climatic conditions while mean temperature and pan evaporation values in 2017/18 growing period were higher than 2016/2017, rainfall, wind speed and relative humidity in 2016/17 growing period were higher than 2017/2018 (Table 1). As expected, in the irrigation to field capacity+10% treatment, I_1 the highest total applied irrigation water and seasonal consumptive use values were recorded 39.62, 40.23 cm in the first season and 37.29, 39.06 cm in the second season, respectively. On other hand, regarding treatments under water stress lower amount of Wa and seasonal CU which were 33.20, 36.95 cm for C treatment and 35.94, 38.36 cm for B treatment in the first season and were 31.87, 35.36 cm for C and 34.19, 36.46 cm for B in the second season. The increasing rate of CU by the decreasing water stress in the two seasons could be explained by higher applied water. The seasonal CU of the full-irrigated wheat plants in this study was similar to those obtained by *Abdelkhalek et al. (2015).*

Regarding the influence of water level data in Tables 3 and 4 also show that, both applied water and seasonal CU decreased by increasing water deficit (water level). The highest mean values of Wa and CU were produced from I_1 (irrigation with field capacity plus 10%) which were 42.69, 43.27 cm in the first season and 40.01, 41.96 cm in the second season under A treatment, respectively. On the other hand, the lowest mean values were obtained from I_3 (irrigation with field capacity – 10%) which were 31.00, 35.65 cm in the first season and 30.40, 34.78 cm in the second season under C treatment, respectively. The obtained results are in a good agreement with *Udom et al. (2013).*

Table 3. Seasonal wheat applied water (m^3 fed^{-1}, cm) as affected by different irrigation intervals and water levels in 2016/17 and 2017/18.

Irrigation intervals	Water level	1st season		2nd season		Mean	
		m^3fed^{-1}	Cm	m^3fed^{-1}	Cm	m^3fed^{-1}	Cm
A	I_1	1793.56	42.69	1680.48	40.01	1737.02	41.36
	I_2	1664.20	39.62	1562.43	37.20	1613.32	38.41
	I_3	1547.78	36.85	1456.19	34.67	1501.99	35.76
Mean		1668.51	39.72	1566.37	37.29	1617.44	38.51
	I_1	1617.37	38.51	1536.23	36.58	1576.80	37.54
B	I_2	1505.63	35.85	1432.61	34.11	1469.12	34.98
	I_3	1405.07	33.45	1339.35	31.89	1372.21	32.67
Mean		1509.36	35.94	1436.06	34.19	1472.71	35.06
	I_1	1490.14	35.48	1428.12	34.00	1459.13	34.74
C	I_2	1391.13	33.12	1335.31	31.79	1363.22	32.46
	I_3	1302.01	31.00	1251.78	29.80	1276.90	30.40
Mean		1394.43	33.20	1338.40	31.87	1366.42	32.53

A= Two weeks, B= Three weeks and C= Four weeks.

I_1= Irrigation to field capacity plus 10%, I_2= Irrigation to field capacity and I_3= Irrigation to field capacity - 10%.

Table 4. Seasonal wheat consumptive use (m^3 fed^{-1}, cm) as affected with different irrigation intervals and water levels in 2016/17 and 2017/18.

Irrigation intervals	Water level	1st season		2nd season		The average	
		m^3 fed^{-1}	Cm	m^3 fed^{-1}	cm	m^3 fed^{-1}	Cm
A	I_1	1817.18	43.27	1762.47	41.96	1789.83	42.62
	I_2	1685.46	40.13	1636.22	38.96	1660.84	39.54
	I_3	1566.92	37.31	1522.60	36.25	1544.76	36.78
Mean		1689.85	40.23	1640.43	39.06	1665.14	39.65
	I_1	1728.81	41.16	1641.57	39.09	1685.19	40.12
B	I_2	1607.93	38.28	1527.41	36.37	1567.67	37.33
	I_3	1497.14	35.65	1424.67	33.92	1460.91	34.78
Mean		1611.29	38.36	1531.22	36.46	1571.26	37.41
	I_1	1664.53	39.63	1590.70	38.87	1627.62	38.75
C	I_2	1548.08	36.86	1481.63	35.28	1514.86	36.07
	I_3	1443.27	34.36	1383.47	32.94	1413.37	33.65
Mean		1551.96	36.95	1485.27	35.36	1518.62	36.16

A= Two weeks, B= Three weeks and C= Four weeks.

I_1= Irrigation to field capacity plus 10%, I_2= Irrigation to field capacity and I_3= Irrigation to field capacity - 10%.

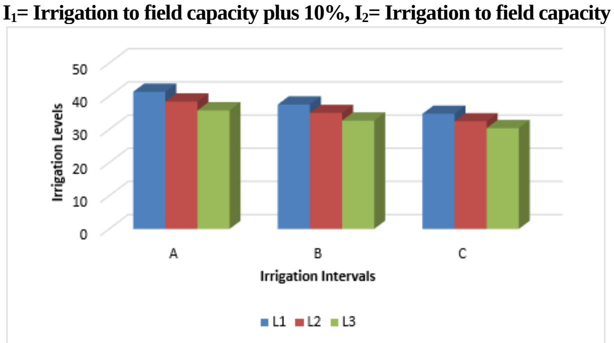

Fig. 1. Seasonal wheat applied water (cm) as affected with different irrigation intervals and water levels in 2016/17 and 2017/18.

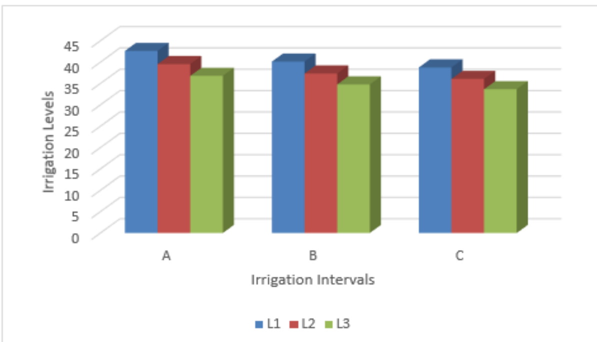

Fig. 2. Seasonal wheat consumptive use (cm) as affected with different irrigation intervals and water levels in 2016/17 and 2017/18.

Yield and yield components:

The difference in yield components, plant height (cm), 1000-grain weight (g), biological yield (kg fed^{-1}), straw yield (kg fed^{-1}), grain yield (kg fed^{-1}) and harvest index in 2016/17 and 2017/18 seasons under different treatments are presented in Table (5). Data show that, irrigation every two weeks led to significant increase and gave the highest values of all studied attributes compared to those irrigated every 3 and 4 weeks. The obtained results of harvest index showed no significant differences were obtained with irrigation treatments. This could be due to irrigation every 2 weeks supplied sufficient soil moisture in the root zone which increased the capacity of wheat plants in photosynthesis and consequently increased plant height, 1000-grain weight, grain yield and straw yield. As show in Table (5), grain yield data of irrigation intervals treatments followed the descending order A>B>C, however, it followed $I_1>I_2>I_3$ at irrigation water levels. These results are in full agreement with those reported by *Wajid et al. (2002).*

Regarding the irrigation water levels, data in Table (5) show that, biological yield, 1000-grain weight and plant height in both growing seasons were significantly differed. Therefore, the highest values were achieved by irrigation to field capacity plus 10%, while irrigation to field capacity minus 10% gave the lowest ones. Meanwhile, no significant differences were found between the irrigation level treatments in grain and straw yield in the first season while harvest index in both seasons were insignificant. The interaction effect between irrigation intervals and irrigation levels was insignificant.

Table 5. Wheat yield and yield components as affected by different irrigation intervals and water levels in 2016/17 and 2017/18.

Irrigation intervals	Water level	Grain yield, kg fed^{-1} 1st season	Grain yield, kg fed^{-1} 2nd season	Straw yield, kg fed^{-1} 1st season	Straw yield, kg fed^{-1} 2nd season	Biological yield, kg fed^{-1} 1st season	Biological yield, kg fed^{-1} 2nd season
A	I_1	2380.5	2349.6	3400.0	3425.0	5780.5	5774.6
	I_2	2310	2343.3	3350.7	3313.0	5660.7	5656.3
	I_3	2258	2274.5	3250.7	3263.0	5442.0	5541.8
Mean		2316.2	2322.5	2358.8	3333.7	5627.7	5657.6
B	I_1	2227.7	2271.0	3226.0	3194.5	5453.7	5465.5
	I_2	2205.0	2231.3	3100.0	3125.0	5305.0	5365.0
	I_3	2153.2	2139.9	2900.0	2950.0	5053.2	5089.9
Mean		2195.3	2214.1	3075.3	3089.8	5270.6	5306.8
C	I_1	2056.4	2099.7	2800.0	2775.0	4856.3	4874.7
	I_2	2048.3	2035.0	2736.0	2727.0	4784.3	4761.3
	I_3	2014.1	2005.6	2700.0	2675.0	4714.1	4680.6
Mean		2039.6	2046.8		2725.7	4784.9	4772.2
L.S.D 0.05(5%)							
Irrigation intervals		145.582	45.699	364.067	169.131	463.793	193.302
Water level		N.S	39.127	N.S	87.456	207.330	103.293
Interaction		N.S	N.S	N.S	N.S	N.S	N.S
L.S.D 0.01(1%)							
Irrigation intervals		----	75.782	-----	280.465	----	320.548
Water level		----	54.854	-----	122.607	----	144.809
Interaction		----	-----	-----	N.S	----	N.S

Cont.

Irrigation intervals	Water level	Plant height, cm (1)	Plant height, cm (2)	1000-grain weight, g (1)	1000-grain weight, g (2)	Harvest index, % (1)	Harvest index, % (2)
A	I_1	99.0	98.4	45.80	45.90	0.412	0.407
	I_2	98.5	98.2	45.43	45.40	0.408	0.414
	I_3	92.1	92.3	45.40	45.30	0.410	0.410
Mean		96.5	96.3	45.54	45.53	0.410	0410
B	I_1	92.0	91.5	44.90	44.80	0.410	0.416
	I_2	91.8	91.4	44.20	44.40	0.408	0.415
	I_3	91.0	90.3	43.20	43.00	0.416	0.420
Mean		91.6	91.1	44.10	44.07	0.427	0.417
C	I_1	90.2	90.2	41.58	41.32	0.417	0.421
	I_2	89.5	89.6	40.45	40.50	0.423	0.429
	I_3	84.3	83.5	40.10	40.30	0.432	0.428
Mean		88.0	87.8	40.71	40.71	0.427	0.429
L.S.D0 0.05(5%)							
Irrigation intervals		2.685	0.560	0.900	0.469	N.S	N.S
Water level		3.932	0.777	0.606	0.265	N.S	N.S
Interaction		N.S	***	N.S	**	N.S	N.S
L.S.D0 0.01(1%)							
Irrigation intervals		4.452	0.928	1.493	0.778	----	----
Water level		----	1.090	0.850	0.372	----	----
Interaction		----	***	N.S	**	----	----

(1) = The first growing season (2016/17) and (2) = the second growing season (2017/18).

Water efficiencies:

In this study, PWa values of B and C treatments nearly equaled compared with the A treatment in both seasons of study. Moreover, WP values of irrigation interval B was generally high compared to the other treatments of A and B as shown in Table (6). Values of PWa and WP were significantly affected by irrigation intervals and water levels in the two growing seasons. The two irrigation efficiencies of PIW and WP decreased with increasing irrigation level and decreasing irrigation intervals and reached the minimum values when wheat plants were irrigated at I_1 and B treatments. In both seasons, the average PWa of irrigation intervals treatments followed as C ≈ B > A in the average of the first season while WP were B > A > C resulted in contribution from groundwater the highest to I_3. But under irrigation levels, PWa and WP can be followed as $I_3 > I_2 > I_1$, respectively. The obtained findings in this study are in a good agreement with the observation of *Dukes et al. (2010) and Zotarelli et al. (2009).*

Table 6. Seasonal wheat water efficiencies (PWa and WP, kg/m^3) as affected with different irrigation intervals and water levels in 2016/17 and 2017/18.

Irrigation intervals	Water level	1st season		2nd season		The average	
		PWa, Kg m^{-3}	WP, Kg m^{-3}	PWa, Kg m^{-3}	WP, Kg m^{-3}	PWa, Kg m^{-3}	WP, Kg m^{-3}
A	I_1	1.33	1.31	1.40	1.33	1.37	1.32
	I_2	1.39	1.37	1.50	1.43	1.45	1.40
	I_3	1.46	1.44	1.56	1.49	1.51	1.43
Mean		1.39	1.37	1.49	1.42	1.44	1.38
B	I_1	1.38	1.29	1.48	1.38	1.43	1.34
	I_2	1.46	1.37	1.56	1.46	1.51	1.42
	I_3	1.53	1.44	1.60	1.50	1.57	1.47
Mean		1.46	1.37	1.55	1.45	1.50	1.41
C	I_1	1.38	1.24	1.47	1.32	1.43	1.28
	I_2	1.47	1.32	1.52	1.37	1.50	1.35
	I_3	1.55	1.40	1.60	1.45	1.58	1.43
Mean		1.47	1.32	1.53	1.38	1.50	1.35

A= Two weeks, B= Three weeks and C= Four weeks.

I_1= Irrigation to field capacity plus 10%, I_2= Irrigation to field capacity and I_3= Irrigation to field capacity - 10%.

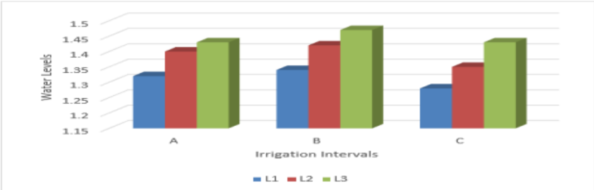

Fig. 3. Seasonal crop water productivity of wheat crop (WP, kg/m3) as affected with different irrigation intervals and water levels in 2016/17 and 2017/18.

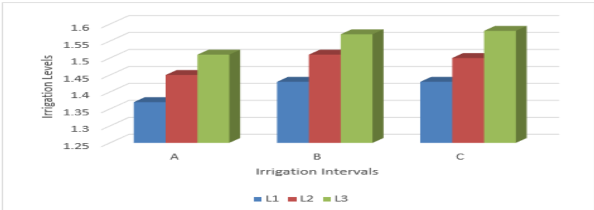

Fig .4. Seasonal Productivity of applied water for wheat crop (PWa ,kg/m3) as affected with different irrigation intervals and water levels in 2016/17 and 2017/18.

Contribution of groundwater (C %):

Fluctuation of water table depth was recorded by observation wells in Table (7). Data Presented in Table (8) shows that contribution of groundwater under different irrigation intervals and water levels were increased with increased irrigation interval and decreased water level in both the growing seasons. The highest average percentage for contribution of groundwater (C %) was 26.15 and 27.70%under C treatment in the two seasons. C% can be followed the descending order C > B >A and $I_3 > I_2 > I_1$ in the two seasons, respectively. The obtained results are in a good agreement with those reported by *Udom et al. (2013)* who recorded that crop water requirements determined for waterleaf varied from 1.32 to 4.76cm for the lysimeter that was solely supplied from groundwater source during the experimental period with no rainfall and no irrigation. Groundwater contribution in the different drums varied with the type of soil and depth from the water table. Greater amount of moisture was contributed from the 300-600mm soil depth which corresponded with the rooting depth of the crop, an area of greatest root proliferation of the crop. *Yonghua et al. (2018)* concluded that: (i) a piecewise root density distribution function was the most suitable for winter wheat; (ii) simulated seasonal the contribution groundwater to the root zone (CGWR) were 154, 128, and 136 mm in the dry, normal, and wet seasons, respectively; and (iii) the CGWR for winter wheat transpiration was about 58, 47, and 69% of the total in dry, normal, and wet seasons, respectively.

Table 7. Fluctuation of water table depth as affected with wheat irrigation scheduling in the two seasons of the study

1st season 2016/2017

Period	Treatment	Average water table, cm	Treatment	Average water table, cm	Treatment	Average water table, cm
5/2/2017-10/3/2017	AI_1	70.0	AI_2	70.5	AI_3	72.7
10/3/2017-25/3/2017		68.3		75.3		66.0
25/3/201-10/4/2017		86.0		92.0		62.5
10/4/2017-30/4/2017		71.8		80.5		73.8
Mean		74.0	Mean	79.6	Mean	68.8
5/2/2017-15/3/2017	BI_1	74.4	BI_2	69.5	BI_3	66.8
15/3/2017-6/4/2017		75.6		88.8		81.0
6/4/2017-30/4/2017		72.8		76.6		72.4
Mean		74.3		78.3		73.4
5/2/2017-25/3/2017	CI_1	81.0	CI_2	83.0	CI_3	71.0
25/3/2017-30/4/2017		84.6		82.3		78.6
Mean		82.8		82.7		74.8

2nd season 2017/2018

Period	Treatment	Average water table, cm	Treatment	Average water table, cm	Treatment	Average water table, cm
7/2/2018-5/3/2018	AI_1	84.0	AI_2	74.5	AI_3	79.8
5/3/2018-20/3/2018		81.0		71.0		76.2
20/3/2018-5/4/2018		90.0		82.5		83.8
5/4/2018-1/5/2018		84.0		79.2		81.0
Mean		84.8	Mean	76.8	Mean	80.2
7/2/2018-10/3/2018	BI_1	75.4	BI_2	68.5	BI_3	77.0
10/3/2018-1/4/2018		85.7		76.0		76.5
1/4/2018-1/5/2018		75.7		74.0		74.2
Mean		78.9	Mean	72.8	Mean	75.9
7/2/2018-20/3/2018	CI_1	79.2	CI_2	75.5	CI_3	74.2
20/3/2018-1/5/2018		85.3		86.0		82.3
Mean		82.3	Mean	80.8	Mean	78.3

Table 8. Computation of contribution of water table in percent to crop water needs as affected with wheat irrigation scheduling in the two seasons of the study

1st season 2016/2017

Period	Treatment	ET0	KC	ETC, mm day^{-1}	ETa, mm day^{-1}	C, mm day^{-1}	C, %	Treatment	ETa, mm day^{-1}	C, mm day^{-1}	C, %	Treatment	ETa, mm day^{-1}	C, mm day^{-1}	C, %	Average, C %
5/2/2017-10/3/2017	AI_1	2.6	1.15	2.99	2.63	0.36	12.04	AI_2	2.69	0.30	10.03	AI_3	2.51	0.48	16.05	12.71
10/3/2017-25/3/2017		3.3	1.15	3.80	3.36	0.44	11.58		3.12	0.68	17.89		3.22	0.58	15.26	14.91
25/3/201-10/4/2017		3.6	0.47	1.70	1.36	0.34	20.00		1.43	0.27	15.88		1.86	-.16	—	17.94
10/4/2017-30/4/2017		4.4	0.15	0.66	1.71	-1.05	—		1.41	0.75	—		3.07	-2.41	—	—
Mean							14.54	Mean			14.6	Mean			15.66	15.19
5/2/2017-15/3/2017	BI_1	2.7	1.10	2.97	2.37	0.60	20.20	BI_2	2.38	0.59	19.86	BI_3	2.30	0.67	22.56	20.81
15/3/2017-6/4/2017		3.6	0.83	2.99	2.44	0.55	18.43		2.39	0.60	20.06		2.40	0.59	19.73	19.41
6/4/2017-30/4/2017		4.4	0.15	0.66	2.56	-1.90	—		2.32	-1.66	—		3.86	-3.2	—	—
Mean							19.32				19.96				21.15	20.11
5/2/2017-25/3/2017	CI_1	2.8	1.10	3.08	2.07	1.01	32.79	CI_2	1.88	1.20	38.96	CI_3	2.10	0.98	31.82	34.52
25/3/2017-30/4/2017		4.3	0.53	2.28	1.90	0.38	16.67		1.85	0.43	18.86		3.00	-0.72	—	17.77
Mean							24.73				28.91				31.82	26.15

2nd season 2017/2018

Period	Treatment	ET0	KC	ETC, mm day^{-1}	ETa, mm day^{-1}	C, mm day^{-1}	C, %	Treatment	ETa, mm day^{-1}	C, mm day^{-1}	C, %	Treatment	ETa, mm day^{-1}	C, mm day^{-1}	C, %	Average, C%
7/2/2018-5/3/2018	AI_1	2.5	1.10	2.75	2.45	0.30	10.91	AI_2	2.28	0.47	17.09	AI_3	2.26	0.49	17.82	15.27
5/3/2018-20/3/2018		3.3	1.10	3.63	3.27	0.36	9.92		3.21	0.42	11.57		3.05	0.58	15.98	12.49
20/3/2018-5/4/2018		3.7	0.46	1.70	2.74	-1.04	---		3.11	-1.41	---		2.72	-1.02	---	---
5/4/2018-1/5/2018		4.4	0.15	0.66	2.26	-1.60	---		2.22	-1.56	---		2.23	-1.57	---	---
Mean							10.42	Mean			14.33	Mean			16.89	12.88
7/2/2018-10/3/2018	BI_1	2.6	1.10	2.86	2.37	0.49	17.13	BI_2	2.24	0.62	21.68	BI_3	2.20	0.66	23.08	20.63
10/3/2018-1/4/2018		3.4	1.10	3.74	2.87	0.87	23.26		3.00	0.70	18.72		2.95	0.79	21.12	21.03
1/4/2018-1/5/2018		4.4	0.18	0.79	2.56	-1.77	---		2.56	-1.77	---		2.42	-1.63	---	---
Mean							20.20	Mean			20.20	Mean			22.10	20.83
7/2/2018-20/3/2018	CI_1	2.8	1.10	3.08	2.28	0.80	25.97	CI_2	2.22	0.86	27.92	CI_3	2.18	0.90	29.22	27.70
20/3/2018-1/5/2018		4.3	0.40	1.72	2.49	-0.77	---		2.45	-0.73	---		2.30	-0.58	---	---
Mean							25.97	Mean			27.92	Mean			29.22	27.70

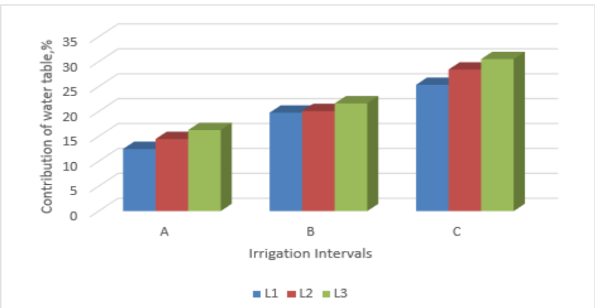

Fig. 5. Average of contribution of water table in percent to crop water needs as affected with wheat irrigation scheduling in the two seasons of the study

CONCLUSION

Under the conditions of North Nile Delta within clayey soils and shallow water table, it is recommended to irrigate wheat each four weeks as irrigation interval after sowing to field capacity – 10% as irrigation level. Several advantages could be obtained; 30.52% of wheat water needs as contribution from water table, less irrigation number and water saving.

More investigations should be carried out to find out the impact of contribution of water table to other crops-water needs in that area, particularly under the water shortage facing Egypt.

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تأثير مساهمة الماء الأرضى فى الاحتياجات المائية للقمح باستخدام جدولة الرى فى شمال دلتا النيل.

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أجريت تجربة حقلية بمحطة البحوث الزراعية بسخا خلال موسمي 2017/2016 و 2018/2017 لدراسة تأثيرجدولة الرى (معاملات مستويات الرى وفترات الري) على مساهمة الماء الأرضي وانتاجية محصول القمح وكان التصميم الإحصائي قطع منشقة مرة واحدة حيث كانت المعاملات الرئيسية (فترات الري) وتشمل ثلاث معاملات (أ = تروى كل أسبوعين، ب= تروى كل ثلاث أسابيع، ج = تروى كل اربعة أسابيع) وكانت القطع المنشقة (مستويات الري) وتشمل ثلاث معاملات (1) = تروى حتى السعة الحقلية + 10% و (2) = تروى حتى السعة الحقلية و (3) = تروى حتى السعة الحقلية – 10% وأقيمت التجربة في ثلاث مكررات. وكانت أهم النتائج كالآتي: *سجلت معاملة الري ($أ_1$) الري كل أسبوعين حتى السعة الحقلية + 10% أعلى القيم في صفات المحصول والإنتاجية لمحصول القمح خلال موسمي الزراعة. *سجلت أقل قيم لكفاءات المياه (كفاءة الإنتاجية من وحدة المياه المضافة وكفاءة إنتاجية المياه من وحدة المياه المستهلكة من الموسمين تحت المعاملة ($أ_1$). التوصية: توصى الدراسة بالري كل أربع أسابيع حتى السعة الحقلية – 10% حيث كان متوسط مساهمة الماء الرضى 30.52% من الاحتياجات المائية لمحصول القمح.