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EFFECT OF DEFICIT IRRIGATION AND RAISED BED ON WHEAT YIELD , WATER PRODUCTIVITY AND WATER SAVING IN NORTH NILE DELTA, EGYPT

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ABSTRACT

The limitation of water resources and the remarkable increase in population should be forced research workers to find ways for saving water without significant reduction in yield. The objective of this paper is to study the interaction effect of deficit irrigation and raised bed on wheat yield, water productivity and water saving in north Nile delta, Egypt. Two field experiments were conducted at Sakha Agricultural Research Station, Kafr El-Sheikh governorate during the two successive seasons of 2012/2013 and 2013/2014. A split plot design with four replications was used. Irrigation treatments occupied the main plots, while planting methods arranged in sub-plots. Three planting methods were flat (traditional method, F_1), bed 70cm wide (F_2) and raised bed 140cm wide (F_3). Four deficit irrigation treatments were irrigated every 21 days (farmer treatment, I_1); the second one after 60% (I_2) , the third one after 70% (I_3) and the fourth one after 80% (I_4) depletion of available soil moisture (ASMD).

Results showed that mean of amount of irrigation water applied for DI_1, DI_2, DI_3 and DI_4 were 4759.2, 4497.6, 3808.8, and 3360.0 m^3/ha., respectively, and means of water table contribution to ET_c were 559.2 and 765.6 m^3/ha. for I_3 and I_4 , respectively. Means of irrigation water applied were 4524, 4034.4 and 3763.2 m^3/ha. for F_1, F_2 and F_3, respectively. F_3 and F_2 saved 17% and 11% of irrigation water compared with F_1, respectively. F_3 significantly increased grain and straw yields by 16 and 18% compared to F_1. The interaction between DI_2 and F_3 and between DI_1 and F_1 resulted in higher grain and straw yields. Means values of water productivity were 5.7, 6.1 and 6.1 L.E /m^3 correspond to 1.2 , 1.18 and 1.5 kg grain/m^3 water applied for F1, F2 and F3 respectively .

INTRODUCTION

In Egypt, water is a scarce natural resource, of which the agricultural sector uses about 85%.The country's main source of water is the Nile. Its share of the Nile water is 55.5 billion m^3 $year^{-1}$. Egypt receives low rainfall that averages about 1.0 milliard m^3 $year^{-1}$ (about 100–200 mm $year^{-1}$ in the northern coastal area in which few winter crops can be grown). El-Sabbagh *et al,*. (2002) showed that seasonal water consumptive use rates were 39.70, 35.72 and 29.79 cm for the treatments irrigated at 45, 65 and 85% SMD, respectively. They showed that seasonal water consumptive use increased with the decrease of irrigation intervals. Wheat plants extracted about 80.06 and 19.94% of its water requirements from the first upper 30 cm soil surface layer and the second 30 cm soil layer, respectively, when plants irrigated at 45% SMD. El-Bably, (1998) found that values of water consumptive use were 38.50, 31.56 and 24.16 cm for the 50, 70 and 90% soil moisture depletion, respectively. Abul-Naas *et al.* (2000) indicated that wheat plants received four irrigations significantly out yielded those received three, two or one irrigation.

Plant production per given amount of water should be basis for organizing possibilities and invests to increase water profitability (Fereres and Soriano, 2007; Blum, 2009). The necessity of planning to increase the water use efficiency is inevitable from world population growth and water amount.

Deficit irrigation is a water management method in which water will be saved with accepting little yield reduction without any severe damage to the plant (English 1990). Medium stress may be a delay in irrigation for a few days or reduced water consumption in each irrigation, but plant shouldn't encounter severe drought stress at any mentioned situation. El-Sabbagh *et al.* (2002) showed that maximum water use efficiency was recorded from infrequent irrigation every 35 days. Depths of water table modify greatly the irrigation requirement. When water table is very shallow, soil waterlogging limited the root growth of winter wheat due to the reduced oxygen concentration of the soil (Brisson *et al.,* 2002). In general, water table contribution decreases with the increase of water table depth or irrigation quantity, or the reduction of irrigation spacing (Ayars et al.,2006). When water table is very shallow, irrigation may be eliminated to maximize water table contribution and avoid waterlogging problem.

Bed planting systems have been used in cultivation for centuries. The origin of raised bed cultivation has traditionally been associated with water management issues either by providing opportunities to reduce the impact of excess water in rainfed conditions or to more efficiently deliver irrigation water in high production irrigated systems (Sayre, 2003).

Hobbs et al. (2000) reported that raised-bed planting contributes significantly to the improvement of water distribution and efficiency, and increases fertilizer-use efficiency and reduces weed infestation, lodging and seed rate without sacrificing yield.

The objective of this study is to investigate the mutual effect of deficit irrigation and raised bed technique on wheat and water productivity growing in north delta, Egypt.

MATERIALS AND METHODS

A field experiment was carried out during the two successive wheat growing seasons of 2012/2013 and 2013/2014 at Crops Water Requirement Research Field, Sakha Agricultural Research Station, Kafr El-Sheikh Governorate. The site is located at 31^{0}-57′ N latitude and 30^{0}-57′ longitude with an elevation of about 6 meter above mean sea level. The site represents the conditions and circumstances of North Nile Delta region.

Field capacity, wilting point and bulk density values in the soil profile (0 to 60 cm) were, in average, 40.6, 22.4 and 1.2 gcm^{-3}, respectively. The effective of rainfall received were 82 and 105.4 mm during the 2012/2013 and 2013/2014 growing seasons, respectively.

Weather data for the experimental site were obtained from Sakha agro-meteorological station are presented in Table 1.

A split plot design with four replications was used. planting methods occupied the main plots, while Irrigation treatments arranged in sub-plots. The planting methods were flat (traditional method, F1), raised bed 70cm wide (F2) and 140cm wide (F3). Sub plots were devoted to deficit irrigation treatments, the first one was every 21 days (farmer treatment, DI_1) ;the second one after 60% (DI_2) , the third one after 70% (DI_3) and the fourth one after 80% (DI_4) depletion of available soil moisture (ASMD) irrigation. Each individual plot was 7m × 7.5 m= 52.5 m^2 No. of plots = 4×3×3=36 plots.

Irrigation scheduling

Irrigation scheduling was based on the percentage depletion of available soil water in the root zone. The available soil water was taken as the difference between root zone water storage at field capacity and permanent wilting point. The maximum allowable depletion (MAD) values of the available soil water were fixed at 60, 70 and 80%. Using the data of soil moisture measured by gravimetric measurement, the percentage depletion of available soil water in the effective root zone was estimated by the equation (Martin *et al.*, 1990),

$$\text{Depletion \%} = 100 \cdot \frac{1}{n}\sum_{1}^{n}\frac{F.c - \emptyset}{F.c - Pw}.$$

Where

n is the number of sub-divisions of the effective rooting depth used in the soil moisture sampling,

F.c is the soil moisture at field capacity for layer,

Ø is the soil moisture in layer and

Pw is the soil moisture at permanent wilting point.

Control and seasonal water applied (Wa):

The amount of water applied after the attainment of predefined , maximum allowable depletion (MAD) was calculated as:

$$V_d = \frac{MAD\ (\%) * (FC - WP) * R * A}{100} \quad \text{...... (Martin et al., 1990)}$$

Where:

V_d is the volume of irrigation water,

R is the effective rooting depth and

A is the surface area of the plot.

The surface area of each plot was 52.5 m^2. Each 7.5m x 7.0m plot was made to small basins, which was furrowed and each furrow was fed individually. Measured amounts of water were applied to the furrows using a constructed rectangular weir with a discharge of 0.01654 $m^3 sec^{-1}$ at effective head of 10 cm.

Soil moisture monitoring

Soil samples were taken at sowing, before each irrigation, 2 days after Irrigation or rainfall, 25 days intervals between irrigation and at the time of harvesting, from four layers (15 cm each) for each treatment. At each sampling date, duplicate soil samples were taken and were immediately packed in tightly loosed cans and transported to the laboratory, then weighed, dried in electrical oven at 105 C° for 24 hours, then weighed again and their moisture content were calculated on dry weight basis. Wheat (*Triticum aestivum L.*) Masr 2 variety was planted in 15 November 2012 and repeated in 2013. All cultural practices in the experimental field were the same as implemented in the area except planting methods and deficit irrigation . The soil samples were collected in 15cm increments to 60cm depth for analysis (Table, (2) according to Kim (1996). To monitor water table fluctuation, nine observation wells were installed However, amounts and timing were recorded. Irrigation scheduling for other treatments was based on crop evapotranspiration (ET_c).was calculated from the reference evapotranspiration ET_o and the FAO crop coefficients (Kc) for wheat (Allen *et al.*, 1998). ET_0 was calculated using the Penman-Monteith equation.(cropwat program) ET_c was computed weekly and irrigation water was added accordingly to maintain the full water requirement for the F_0 treatment. On average, the number of irrigations was five

Table (1): Sakha agro-meteorological data during 2012/2013and 2013/2014 seasons.

Seasons	Months	Air temperature (°C)			Relative humidity (%)			Wind speed km d^{-1}	Pan evaporation mm d^{-1}	Rain, mm/mon.	Effective rain, mm/mon.
		Max.	Min.	Mean	Max.	Min.	Mean				
2012/2013	Nov	25.3	15.4	20.35	89.2	61.8	75.2	56.9	1.87	29.0	18.0
	Dec.	21.3	10.5	15.9	84.7	60.7	72.7	62.9	2.2	13.2	6.2
	Jan.	19.2	7.6	13.4	90.9	65.4	78.15	46.3	1.9	78.74	55.3
	Feb.	20.8	8.9	14.85	90.2	63.8	77	61.1	2.9	-	
	Mar.	24.4	12.4	18.4	79.5	50.9	65.2	89.2	4.4	-	
	Apr .	26.0	15.8	20.9	74.2	43.9	59.05	96.3	5.0	8.4	2.6
	May	31.4	21.8	26.6	75.0	45.7	60.35	102.6	6.1	-	
Total											82.0
2013/2014	Nov	25.3	15.1	20.2	87.0	64.4	75.7	68.7	2.2	----	
	Dec.	19.6	8.5	14.05	92.0	67.6	79.8	52.6	4.4	81.9	57.7
	Jan.	20.3	7.5	13.9	93.6	70.5	82.05	46.6	1.6	20.7	11.8
	Feb.	20.6	8.1	14.35	91.9	67.1	79.5	66.3	2.5	16.5	8.6
	Mar.	22.9	11.7	17.3	86.1	56.8	71.45	82.8	3.1	26.2	15.9
	Apr .	27.5	15.5	21.5	81.8	49.8	65.8	92.8	4.9	20.2	11.4
	May	30.4	19.5	24.95	77.2	48.6	62.9	98.8	5.8	-	
Total											105.4

Effective Precipitation (mm) = (Rain - 5) x 0.75

Crop water use:

Crop water use is directly related to ET. The crop's water use can be determined by multiplying the reference ETo by a crop coefficient (Kc). The crop coefficient adjusts the calculated reference ETo to obtain the crop evapotranspiration ETc. Different crops will have a different crop coefficient and resulting water use.

ETc = ETo x Kc

Where ETo = calculated reference ET for grass (mm)
available from *www.farmwest*.com
Kc = crop coefficient
ETc = crop evapotranspiration or crop water use (mm)

Crop coefficient Kc

Values of the Kc were quoted from FAO (Allen *et.al.*, 1998). The four distinct growing stages of growing period are initial (35 days), crop establishment (60 days), mid-season (70 days) and late season (40 days). The corresponding values are 0.4, 0.75, 1.05, and 0.6 respectively. The length of growing stages of wheat identified with respect to (Allen, *et al.*, 1998)

Table (2): The mean values of some soil physical properties and some water constants of the experimental site before cultivation in the two growing seasons

Soil depth (cm)	Bulk density Mg/m^3	F.C		P.W.P		A.W		60% depletion		70% depletion		80% depletion	
		%	mm	%	mm	%	mm	%	mm	%	mm	%	mm
0-15	1.22	47.0	86.0	25.3	46.2	21.7	38.8	13.02	23.28	15.19	27.16	17.36	31.04
15-30	1.24	39.0	72.5	21.8	40.5	17.2	32.0	10.32	19.2	12.04	22.4	13.76	25.6
30-45	1.30	38.0	74.1	21.9	42.7	16.1	31.4	9.66	18.84	11.27	21.98	12.88	25.12
45-60	1.20	38.5	69.1	20.8	37.4	17.7	31.7	10.62	19.02	12.39	22.19	14.16	25.36

Water consumptive use (CU):

Water consumptive use (CU) or crop evapotranspiration (ETc) of wheat was determined directly as soil moisture depletion(SMD) using the following equation (Hansen *et al.*, 1980).

$$\text{Cu} = \text{SMD} = \sum_{i=1}^{I=4} D_I \times D_{b1} \times \frac{PW_2 - PW_1}{100}$$

Where:

Cu = Water consumptive use (cm) in the effective root zone (60 cm).
D_1 = Soil layer depth (15 cm each).
D_{b1} = Soil bulk density, (Mg/m^3) for this depth.
PW_1 = Soil moisture percentage before irrigation (on mass basis, %).
PW_2 = Soil moisture percentage, 48 hours after irrigation (on mass basis, %)..
I = Number of soil layers each (15 cm) depth.

The summation of Cu between each two irrigation from planting up the harvest give the seasonal crop water consumptive use .The consumptive use values was corrected for the time days from irrigation event to the time of sampling after irrigation using the daily average of the considered period.

Contribution of the ground water table (S):

Water movement by capillary rise from water table into active plant root zone is recognized as an important supplementary water resource for irrigation. The contribution of groundwater as percentage of the consumptive use was calculated as follow:

$S = [(ET_c - SMD)$

Where :

ET_c = Crop evapotranspiration = $ET_0 \times K_c$

SMD = Soil moisture depletion.

Reference evapotranspiration (ET_o):

CROPWAT for windows is a program that uses the FAO (1992) Penman-Monteith methods for calculating reference crop evapotranspiration. These estimates are used in crop water requirements and irrigation scheduling calculations. The methods supersede the older FAO 24 procedures published in 1977 which are no longer recommended as they overestimate evapotranspiration.

Fluctuation of ground water table:

In order to establish the diagram of ground water table fluctuation during the growing seasons under wheat crop, a nine observation wells were installed along different treatment. Perforated plastic tube with each observation well was two inches in diameter and two meter long. Daily reading of ground water table was recorded by the aid of a metallic sounder that fixed in a sealed tape to measure the water table depth.

Yield and yield components:

straw yield, biomass yield and wheat grain yield kg $ha.^{-1}$ at maturity were determined from central area of each subplot to avoid any effect and recorded in the two growing seasons. The grains were separated from the straw, and the grains were weighed. Grain yield was calculated based on the adjustment to grain moisture content of 140 g kg^{-1}. Biomass yield express grain plus straw yields.

Water measurements.

Water productivity (WP) was calculated according to Molden, (1997)

$$WP\ (kg\ m^{-3}\ or\ \$\ m^{-3} = \frac{\text{Output derived from water use } (kg/m^3 \text{ or } \$ /m^3}{\text{Water input } (m^3)}$$

Application efficiency (Ea):

This parameter is so-called consumptive use efficiency (Ecu) and computed according to Doorenbos and Pruitt (1975) as:

$$Ea = (CU/Wa)*100$$

where:

Wa = Water applied, and

CU = Crop evapotranspiration or crop consumptive use.

Measurements of Yield and Water productivity:

The reductions in yield and water saving were calculated from the following equations:

$$\textbf{reduction in yield} = 100 - \left(\frac{yield\ of\ I2\ or\ I3}{yield\ of\ I1}\right) \times 100$$

$$\textbf{Water saving} = 100 - \left(\frac{\textbf{water consumption of } I2\ or\ I3}{water\ consumption\ of\ I1}\right) \times 100$$

RESULTS AND DISCUSSION

Fluctuation of water table depth during the growing seasons:

Seasonal average of maximum and minimum values of water table depth, for each observation well, under each treatment. during the two growing seasons were given in table (3). The obtained data showed that the depth of water table reached the lowest value immediately before irrigation. While the maximum water depth reached at 2 days after irrigation. Following irrigation, the water table decreased gradually in between irrigation. Maximum values of water table depth varied between 67 and 80 cm in the first and second seasons respectively. The corresponding values of the minimum water table depth were 95 and 123.5 cm. the fluctuation of the water table depends of the deficit irrigation and the distance from both the irrigation canal and in the north and main surface drain in the south of the experiment area. The absolute values of both minimum and maximum depth of water table increased directly with increasing deficit irrigation and as much as close to the main open drain in the site. So , by increase the deficit irrigation, more water being allowed to be depleted by growing plants and consequently further through fall could be obtained. This technique of elongate deficit irrigation in Nile Delta have the advantage of proper aeration in the effective root zone, minimizing the water logging hazard in the area and save a reasonable amount of irrigation water.

Seasonal water applied (Wa)

Under the conditions of the present study, the seasonal water applied (Wa) consists of the three components; irrigation water (IW), rainfall (R) and contribution of water table (S). Wheat as a winter crop rainfall were 344 and 442 mm in the first and second season respectively. Water applied decreased by increasing maximum allowable depletion.

Water consumptive use (CU).

The obtained results in Table (4) show that seasonal CU values were greatly affected by deficit irrigation, where CU values decreased with increasing the irrigation intervals. Seasonal average values of CU during the two seasons. These results indicate that consumptive use decreased as the available soil moisture decreased in the root zone. These results are in agreement with those obtained by El-Tantawy *et al.,* (2007)

Irrigation water (IW):

As shown in table(5) the total number of irrigation events were 5 ,5,4 and 3 for DI_1 , DI_2 , DI_3 and DI_4 respectively, including sowing irrigation. Amounts of irrigation water (IW) throughout the two seasons for different treatments, are tabulated in Table (3). Mean values of irrigation water were 4831.2, 4663.2, 3856.8 and 3328.8 m^3/ha. for DI_1 , DI_2 , DI_3 and DI_4 respectively as the deficit irrigation treatments in the first season while it was , 4687.2, 4332.0 , 3758.4 and 3228.0 m^3/ha. In the second season respectively. Irrigation water for I_4 treatment was the lowest, and the amount for DI_1 treatment was the highest. These data indicate that using irrigation at depletion 80% from available water (DI_4 irrigation treatment) saved water by about 31.1% (617m^3) compared with irrigation treatment I_1(the conventional irrigation), while wide furrow treatments Mean values of irrigation water were 4676.2 , 4063.2 and 3775.2 m^3ha^{-1}. for F_1 , F_{72} and F_3 in the first season while it was 4250.4 , 4003.2 and 3748.8 m^3ha^{-1}. In the second season respectively. Also data show that using raised bed (F_3) saved water by about 19% (900 m^3/ha..) in the first season while the second season was 14% (621.6 m^3/ha) Compared with (F_1).

Table (3): Maximum, Minimum and mean values of water table depth cm. during the two growing seasons 2012/2013 and 2013/2014.

Observation well	Treat.		Season 2012/2013			Season 2013/2014		
			Maxi	. Mini.	Mean	Maxi	. Mini.	Mean
1	Flat (F_1)	DI_1	67	87	96.8	80.4	113.1	96.75
2		DI_2	75	88	102.2	90.0	114.4	102.20
3		DI_3	78	82	100.1	93.6	106.6	100.10
4		DI_4	83	81	102.5	99.6	105.3	102.45
5	Furrow.(F_2	DI_1	70	80	94.0	84.0	104	94.00
6		DI_2	75	84	99.6	90.0	109.2	99.60
6		DI_3	80	84	102.6	96.0	109.2	102.60
7		DI_4	83	89	107.7	99.6	115.7	107.65
8	Bed (F_3)	DI_1	72	85	98.5	86.4	110.5	98.45
9		DI_2	75	89	102.9	90.0	115.7	102.85
10		DI_3	80	92	107.8	96.0	119.6	107.80
11		DI_4	85	95	112.8	102.0	123.5	112.75

Contribution of water table (%):

Values of contribution of water table to crop evapotranspiration during the two seasons are given in Table (6).

Data revealed that by increasing irrigation water, less value was obtained. For the maximum irrigation water (treatment DI_1 and DI_2) there was no contribution from water table. For the other treatments (I_3 and I_4) average values of contribution are 211and 325 m^3 for first season while it was 255 and 313 m^3 for second season respectively. This slight contribution of water table was occurred during about the middle of the season. This finding indicated that by increasing the applied water in the short irrigation interval of (treatment DI_1 and DI_2) almost no contribution but the feeding to groundwater table took the same direction with that applied depth. Also, this feeding may be from the neighboring fields. The reason for the non contribution from water table during other periods may be attributed to the less water consumed by plants at both early and ripening stage (Eid, 1994).

Table (4): Seasonal irrigation (IW), rainfall (R) , contribution from water table (S) , seasonal water applied (Wa)and contribution of ground water as percentage (%) for wheat in the two seasons

Treat.		Season 2012/2013						Season 2013/2014					
		IW		R	S	Wa	%	IW		R	S	Wa	%
		No.	M^3					No.	M^3				
Fla F_1)	DI_1	5	5400.0	825.6	0	6226	0.00	5	5400.0	1060	0	6461	0.00
	DI_2	5	5136.0	825.6	0	5962	0.00	5	4411.2	1060	0	5472	0.00
	DI_3	4	4392.0	825.6	367.2	5585	8.36	4	3907.2	1060	439.2	5407	11.24
	DI_4	3	3768.0	825.6	662.4	5256	17.58	3	3763.2	1060	604.8	4949	16.07
Furrow.(F_2	DI_1	5	4608.0	825.6	0	5434	0.00	5	4368.0	1060	0	5429	0.00
	DI_2	5	4488.0	825.6	0	5314	0.00	5	4312.8	1060	0	5374	0.00
	DI_3	4	3696.0	825.6	472.8	4994	12.79	4	3816.0	1060	472.8	5350	12.39
	DI_4	3	3456.0	825.6	655.2	4937	18.96	3	3520.8	1060	655.2	5237	18.61
Bed (F_3)	DI_1	5	4488.0	825.6	0	5314	0.00	5	4296.0	1060	0	5357	0.00
	DI_2	5	4368.0	825.6	0	5194	0.00	5	4272.0	1060	0	5333	0.00
	DI_3	4	3480.0	825.6	681.6	4987	19.59	4	3552.0	1060	921.6	5534	25.95
	DI_4	3	2760.0	825.6	1020.0	4606	36.96	3	2880.0	1060	996.0	4937	34.58

Table (5) amount of irrigation water in m^3 ha^{-1}. For wheat crop during the two growing seasons 2012/2013 and 2013/2014

Treatments	season 2012/2013				season 2013/2014			
	Flat (F1)	furro (F2)	Bed (F3)	I - Mean	Flat (F1)	furrow (F2)	Bed (F3)	I - Mean
DI1	5400.0	4608.0	4488	4831.2	5400.0	4368.0	4296.0	4687.2
DI2	5136.0	4488.0	4368	4663.2	4411.2	4312.8	4272.0	4332.0
DI3	4392.0	3696.0	3480	3856.8	3907.2	3816.0	3552.0	3758.4
DI4	3768.0	3456.0	2760	3328.8	3763.2	3520.8	2880.0	3228.0
F(Mean)	4675.2	4063.2	3775.2		4370.4	4003.2	3748.8	

Table (6) Contribution of water table (m^3 ha^{-1}.) for wheat crop during the two growing seasons 2012/2013 and 2013/2014.

Treatments	season 2012/2013				season 2013/2014			
	F1	F2	F3	I - Mean	F1	F2	F3	I - Mean
DI1	0	0	0	0	0	0	0	0
DI2	0	0	0	0	0	0	0	0
DI3	367.2	472.8	681.6	506.4	439.2	472.8	921.6	612.0
DI4	662.4	655.2	1020.0	780.0	604.8	655.2	996.0	751.2
F - Mean	256.8	283.2	424.8		261.6	283.2	480.0	

Grain yield (kgha^{-1})

Means of grain yield in kg./ha. of wheat as affected by deficit irrigation and wide furrow regime in both seasons of study are shown in Table (7 ,8) .deficit irrigation regime significantly influenced grain yield per ha. In both seasons, generally, grain yield was highest under I2 water regime as compared with the other three regimes. This occurred in both seasons. The mean grain yields for the two seasons obtained by I1, I2,I3 and I4 water regimes are 6741.336, 7231.992, 6381.336 and 5882.664 kg ha-1 in the first season while it was 7399.99 , 7954.66 , 7020.00 and 6469.34 kg ha-1. in the second season .respectively .(Table 6 ,7).

Effect of raised bed:

Regarding the effect of raised bed treatments, grain yield was greater with F_3 treatment than the other two raised bed treatments. This occurred under each of the deficit irrigation regimes since the interaction between the raised bed treatment and deficit irrigation was significant (Table 7,8). Mean yields for the two seasons due to raised bed treatments of F_1, F_2 and F_3 are 6304.8, 6306and 7237.9.14 kg/ha. in the first season while it was, 6735.00 , 6936.00 and 7962.00 kg/ha. .in the second season .respectively. Thus the F_3 treatment gave the highest yield. F_3 significantly increased grain and straw yields by 16 and 18% compared to F_1..

The highest grain yield was obtained by I_2F_3 treatment which gave 8119.2 and 8935.99 kg/ha. The lowest yield was obtained by the I_4F_1 treatment which gave 5508.0 and 6055.99 kg/ha in the first and second season respectively .

Deficit irrigation (DI) and water productivity (WP)

When water supplies are limiting, the farmer's goal should be to maximize net income per unit water used rather than per land unit. Recently, emphasis has been placed on the concept of water productivity, defined here either as the yield or net income per unit of water used in ET.table 9-10 show that WP increases under DI, relative to its value under full irrigation, as shown experimentally for many crops. There are several reasons for the increase in WP under DI. Small irrigation amounts increase crop ET, more or less linearly up to a point where the relationship becomes curvilinear because part of the water applied is not used in ET and is lost. At one point, yield reaches its maximum value and additional amounts of irrigation do not increase it any further. The location of that point is not easily defined and thus, when water is not limited or is cheap, irrigation is applied in excess to avoid the risk of a yield penalty. The amount of water needed to ensure maximum yields depends on the uniformity of irrigation. Under low uniformity, irrigation efficiency decreases and water losses are high. Because water cannot be applied with perfect uniformity, variations in applied water over the field are ranked and plotted against the fraction of the area. The depth of water is normalized against the required depth. Generalized relationships between applied irrigation water, ET, and crop grain yield. In addition to the factors associated with the disposition of irrigation water, WP is also affected by the yield response to irrigation.

Table (7) Effect of deficit irrigation and wide furrow on grain and straw yield of wheat (kg ha^{-1}.) during 2012/2013 growing season

Treat.	Grain yield 2012/2013				straw yield 2012/2013			
	Flat (F_1)	Furrow (F_2)	Bed (F_3)	I-Mean	Flat (F_1)	Furrow (F_2)	Bed (F_3)	I-Mean
DI_1	6480.0 a	6655.9a	7087.9 b	6741.336	7864.0 a	8143.2 a	8664.0 b	8223.7
DI_2	6691.9 a	6907.9 a	8119.2 a	7231.992	8136.0 a	8444.0 a	9944.0 a	8841.3
DI_3	5880.0 b	6103.9 b	7159.9 b	6381.336	7206.0 b	7456.0 b	8752.0 b	7804.5
DI_4	5508.0 c	5556.0 c	6583.9 c	5882.664	6741.0 c	6784.0 c	8048.0 c	7190.9
F- Mean	6304.8	6306	7237.9	6561.504	7487	7706.8	8852.0	8014.1

In a column, means followed by a common letter are not significantly

Comparison	S.E.D	LSD (5)	LSD (1)	S.E.D	LSD (5)	LSD (1)
2- I means at each F	154.3	324.36	444.4	442.99	387.82	531.33

Table (8) Effect of deficit irrigation and wide furrow on grain and straw yield of wheat (kg ha^{-1}.) during 2013/2014 growing season

Treatments	Grain yield 2013/2014				straw yield 2013/2014			
	Flat (F_1)	Furrow (F_2)	Bed (F_3)	I-Mean	Flat (F_1)	Furrow (F_2)	Bed (F_3)	I-Mean
DI_1	7080.00 a	7320.00 a	7800.00 b	7399.99	8850.24 a	9151.99 a	8850.24 a	9252.26
DI_2	7327.99 a	7600.01 a	8935.99 a	7954.66	9157.44 a	9500.81 a	9157.44 a	9943.99
DI_3	6475.92 b	6712.01 b	7872.00 b	7020.00	8099.04 b	8386.39 b	8099.04 b	8770.66
DI_4	6055.99 c	6112.01 c	7240.01 c	6469.34	7579.20 c	7638.41 c	7579.20 c	8089.34
F- Mean	6735.00	6936.00	7962.00	7210.99	8421.60	8669.40	9951.19	9014.06

In a column, means followed by a common letter are not significantly

Comparison	S.E.D	LSD (5)	LSD (1)	S.E.D	LSD (5)	LSD (1)
2- I means at each F	164.59	347.5	473.7	206.33	433.51	592.8

Yield responses to irrigation and to ET deficits have been studied empirically for decades. It turned out that it is not only biomass production that is linearly related to transpiration, but the yield of many crops is also linearly related to ET.

The design of a DI program may must be based on knowledge of this response but the exact characteristics of the response function are not known in advance. Also, the response varies with location, stress patterns, cultivar, planting dates, and other factors. In particular, many crops have different sensitivities to water stress at various stages of development, and the DI program me must be designed to manage the stress so that yield decline is minimized. However, when the yield decline, in relative terms, is less than the ET decrease, WP under DI increases relative to that under full irrigation. Nevertheless, from the standpoint of the farmer, the objective is not WP, but net income, low risk, and other issues related to the sustainability of irrigation are more important. Knowledge of the crop response to DI is essential to achieve such objectives when water is limited.

Consumptive use efficiency (Ecu):

Consumptive use efficiency reflects the capacity of roots to utilize the moisture stored in the soil between irrigation intervals. Data in Table (8) show that the highest value of Ecu is 74 and 72.3% (DI_4) in the first and second season respectively . So, the decreasing the dominator of water applied the increasing in Ecu. Such results are agreed with those reported by Doorenbos et al.(1979) who stated that the consumptive use efficiency increased with the increase of consumptive use and with the decrease in water applied.

The use of the RB technique increased water productivity from around 1.06 kg/m^3 for the farmers' usual water management practice to 1.67 kg m^{-3}. In general, the relationship between water productivity and yield was significant with a coefficient of determination (R^2).

Our data showed that, for similar amounts of applied water, raised bed (RB) gave in most cases higher WP than DI. Hobbs et al. (2000) demonstrated that RB planting contributed significantly to improved water distribution and efficiency, increased fertilizer use efficiency and reduced weed infestation, lodging and seed rate without sacrificing yield. These values varied from about 2.0 Egyptian Pounds/m^3 under high water application (FT and FWR treatments) to 2.8 Egyptian Pounds/m^3 for the water saving methods (DI and RB treatments) in wheat

Table.(9a) Amounts of applied irrigation water, grain yield and water productivity (WPg) of wheat under different irrigation techniques in Egypt in 2012/2013 and 2013/2014.

Treatments		Season 2012/2013									
		Wa, m^3/ha	SMD=CU, m^3/ha	Ea= cu/wa*100	Grain yield Kg/ha	Straw yield Kg/ha.	L.E grain /ha	WP Grain kg/m^3	IWP Grain kg/m^3	WP (L.E /m3)	IWP (L.E /m3)
Flat (F_0)	DI_1	6226	3696	59.37	7081.2	7800	20252.23	1.10	1.14	5.45	3.24
	DI_2	5962	3600	60.39	7326.0	8400	20952.36	1.34	1.23	5.76	3.48
	DI_3	5585	3552	63.60	6476.4	7200	18522.50	1.20	1.16	5.15	3.28
	DI_4	5256	3408	64.84	6055.2	6600	17317.87	1.22	1.15	5.03	3.26
Furrow(F_{70})	DI_1	5434	3336	61.40	7318.8	8400	20931.77	1.35	1.35	6.21	3.81
	DI_2	5314	3312	62.33	7599.6	8400	21734.86	1.41	1.43	6.49	4.04
	DI_3	4994	3276	65.59	6710.4	7200	19191.74	1.25	1.34	5.80	3.80
	DI_4	4937	3264	66.12	6109.2	6600	17472.31	1.17	1.24	5.30	3.50
Bed (F_{140})	DI_1	5314	3600	67.75	7801.2	8400	22311.43	1.46	1.47	6.12	4.15
	DI_2	5194	3576	68.85	8935.2	9900	25554.67	1.68	1.72	5.14	3.54
	DI_3	4987	3504	70.26	7873.2	9000	22517.35	1.42	1.58	6.36	4.47
	DI_4	4606	3408	74.00	7239.6	7800	20705.26	1.47	1.57	6.01	4.45

Table (9b)

Treatments		Wa, m^3/ha	SMD=CU, m^3/ha	Ea= cu/wa*100	Grain yield Kg/ha	Straw yield Kg/ha.	L.E grain /ha	L.E straw	WP Grain/m^3	IWP Grain/m^3	WP (L.E /m3))	IWP (L.E /m3)
			Season 2013/2014									
Flat (F_1)	DI_1	6461	3840	59.44	7081.2	9000	20299.2	1800	1.84	1.10	5.75	3.42
	DI_2	5472	3576	60.96	7326.0	9000	21002.4	1800	2.05	1.34	6.84	4.17
	DI_3	5407	3432	63.47	6476.4	7800	18566.4	1560	1.89	1.20	5.88	3.73
	DI_4	4949	3216	64.99	6055.2	7800	17359.2	1560	1.88	1.22	5.87	3.81
Furrow(F_2)	DI_1	5429	3336	61.45	7318.8	9000	20980.8	1800	2.19	1.35	6.82	4.19
	DI_2	5374	3360	62.53	7599.6	9000	21784.8	1800	2.26	1.41	7.03	4.39
	DI_3	5350	3504	65.50	6710.4	7800	19236.0	1560	1.92	1.25	5.95	3.90
	DI_4	5237	3456	65.99	6109.2	7800	17512.8	1560	1.77	1.17	5.51	3.63
Bed (F_3)	DI_1	5357	4056	67.20	7801.2	9000	22363.2	1800	1.92	1.46	5.95	4.51
	DI_2	5333	3840	70.21	8935.2	9000	25615.2	1800	2.33	1.68	6.89	5.15
	DI_3	5534	3720	71.55	7873.2	7800	22569.6	1560	2.12	1.42	6.11	4.37
	DI_4	4937	3600	72.3	7239.6	7800	20752.8	1560	2.01	1.47	5.80	4.51

Table (10): Water productivity L.E/m^3 affected by deficit irrigation and wide furrow during the two growing seasons

Treatments	WP 2012/2013				WP 2013/2014			
	Flat (F1)	Furrow (F2)	Bed (F3)	I-Mean	Flat (F1)	Furrow (F2)	Bed (F3)	I-Mean
DI_1	5.45	6.21	6.12	6.11	5.75	6.82	5.95	6.17
DI_2	5.76	6.49	5.14	5.80	6.84	7.03	6.89	6.92
DI_3	5.15	5.80	6.36	5.77	5.88	5.95	6.11	5.98
DI_4	5.03	5.30	6.01	5.45	5.87	5.51	5.80	5.73
F-Mean	5.35	5.95	6.04		6.09	6.33	6.19	

CONCLUSION

From this study, we can conclude that DI and the use of the RB technique reduce irrigation water application and improve water productivity, if water saving is a major issue, then, some yield reduction must be accepted as shown by the trade-off in this study between water saving and yield loss. An alternative would be to introduce the wide-furrow (RB) technology because, according to our study and others, it did not involve any yield reduction

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تأثير نقص الرى والزراعة على مصاطب على كل من محصول القمح وانتاجية وتوفير مياة الرى فى شمال دلتا النيل بمصر

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بسبب الزيادة الهائلة فى عدد السكان ومحدودية المياة كان من الضرورة اجراء ابحاث تعمل على توفير مياة الرى دون المساس بانتاجية المحصول ويهدف هذا البحث الى دراسة التاثير المتبادل بين كل من نقص الرى وطريقة زراعة القمح على انتاجية المحصول والمياة وتوفير مياة الرى فى شمال دلتا النيل ولهذا اقيمت تجربتان حقليتان فى محطة البحوث الزراعية بسخا خلال موسمى ٢٠١٢/ ٢٠١٣ و ٢٠١٣/٢٠١٤ وقد كان التصميم الاحصائى المتبع هو القطع المنشقة مرة واحدة حيث كانت المعاملات الرئيسية طريقة الزراعة F1 الطريقة العادية و (F2) الزراعة على مصاطب عرضها ٧٠ سم و (F3). الزراعة على مصاطب عرذذنضها ١٤٠سم وكانت معاملات نقص الرى المعاملات تحت رنيسية حيث كانت I1 هى معاملة الفلاح العادية حيث الرى كل ٢١ يوم و I2 الرى عند استنفاذ ٦٠ % من الرطوبة و I3 الرى عند استنفاذ ٧٠% من الرطوبة و I4 الرى عند استنفاذ ٨٠% من الرطوبة من مياة الرى المتاحة وقد اوضحت النتائج ان كمية مياة الرى كانت ٤٧٥٩ و ٤٤٩٧ و ٣٨٠٨ و ٣٣٦٠ م٣/للهكتار للمعاملات الاربعة على التوالي - مساهمة الماء الارضى فى الرى ٥٥٩ م٣ و٧٦٥ م٣ لمعاملات الرى DI_3 و DI_4 بينما كانت كمية مياة الرى ٤٥٢٤ و ٤٠٣٤ و ٣٧٦٣ م٣ / للهكتار للمعاملات F_1 و F_2 وF_3 على الترتيب معاملة F_3 و F_2 وفرت ١٧% و١١% على الترتيب بالمقارنة بمعاملة الفلاح العادية التفاعل بين كل من نقص الرى DI_2 و F_3 اعطت اعلى محصول حبوب وتبن – متوسط كفاءة الرى WP كانت ٥.٧ و ٦.١ و ٦.١ جنية مصرى/ م٣ توصى الدراسة بتطبيق معاملة F_3 و DI_2.