Journal of Soil Sciences and Agricultural Engineering

Journal homepage: www.jssae.mans.edu.eg
Available online at: www.jssae.journals.ekb.eg

Using Raised Bed and Irrigation cut-off for Saving Irrigation Water and Increasing Wheat Productivity in North Nile Delta

Cross Mark

Mona S. M. Eid* and H. M. Abo Elsoud

Soils, Water & Environment Res. Institute (SWERI), Agric. Res. Centre (ARC), Giza, Egypt

ABSTRACT

In Egypt, surface irrigation and irrigation till the tail end of the furrows or borders are commonly used with wheat (Triticum aestivum L.) and other crops, but they lead to poor aeration and ineffective use of water and fertilizers. Therefore, raised beds planting method and cut-off irrigation improve wheat productivity and raise water and fertilizer use efficiencies. A field experiment was carried out in two winter growing seasons (2017/18 and 2018/19) at Sakha Agricultural Research Station Farm, Kafr EL-sheikh Governorate. The objective was to evaluate the impact of raised bed and irrigation cut-off on growth and yield of wheat (Misr^{-1} variety), some water relations and the contribution of ground water table on water consumption. A split plot design was used with three replicates. The main plots were occupied by raised bed treatments: farmer's conventional flat planting method (F_1), furrow 60 cm width (F_2) and furrow 120 cm width (F_3). The sub plots were devoted to irrigation cut-off treatments: cut-off at 100% of strip length, $C_{100\%}$ (control), cut-off at 90% of strip length ($C_{90\%}$) and cut-off at 80% of strip length ($C_{80\%}$). The results revealed that C90% combined with F_3 achieved the lowest values of seasonal applied water and water consumptive use and the highest values of water productivity (9.69 L.E m^{-3}), water application efficiency (Ea) and grain and straw yields. On the other hand, C80% recorded the highest contribution value of ground water table (CGWT) of water consumption (21.4%), leading to increase of water saving. (with 34.05% increase)

Keywords: Surface irrigation, irrigation cut-off, raised beds, water relations, water productivity, grain yield, wheat and ground water table contribution.

INTRODUCTION

Limitation of water resources and the obvious increase in population forced the researcher to find how to save water without significant reduction in crop yield. The conventional irrigation method is a highly consumed of water, thus saving the water is becoming decisive factor for agricultural expansion. Agricultural policies in Egypt assisted agricultural reforms to increase the farm incomes and food crop production. This study will significantly improve the lives of many Egyptians who depend on agriculture.

Hobbs and Morris (1996) compared between sowing of wheat in flat strip and raised bed technology and they stated that using of flat strip under flood irrigation reduces the binding of soil to support the plant due to wet condition around its roots. However, use of raised bed technology not only saves irrigation water, but also prevents the wet soil surface around the roots to avoid lodging especially under windy conditions. Ahmad and Mahmood (2014) concluded that bed planting was found to be useful to control lodging of wheat in comparison with the conventional flat sowing. They added that, raised bed method ensures easy drainage of excessive water from the field after irrigation which gives the plants chances to restore their stand because plants on adjacent beds are not intermingled. Also, they found that this technology is a substantial saving in irrigation water (40–50%) with increase in yield (10-25%) which improves water productivity (2.35 kg/m^3). Ortega *et al* (2000) stated that wheat cultivation on raised bed was better than the conventional cultivation in terms of crop production and nitrogen use efficiency (NUE), which can be increased from about 30% with the traditional planting method to higher levels with best management practices.

The relationship between grain yield and irrigation water applied is economically important more than its relationship with the evapotranspiration (Farré and Faci, 2006). The higher water productivity produces either from the same yield and less water applied, or from a higher yield with the same water applied (Kijne *et al*., 2003). The water productivity, WP_{ET} (kg m^{-3}), which is originally referred to 'water use efficiency', is defined as the marketable yield from actual evapotranspiration.

Cut-off irrigation is considered as the recent developed technique in surface irrigation which is the most wide spread irrigation method in Egypt as well as worldwide. This technique is preferable in clay soils with low infiltration rate due to high horizontal lateral water movement comparing with the vertical downward movement. Such procedure could be achieved by find out the suitable irrigation run length at which irrigation should be stopped instead of watering till the tail end of cultivated field.

Mostafazadeh and Farzamnia (2000) pointed out that deep percolation and run off ratios were less in the cut-back irrigation method compared to the conventional method. Therefore, the cut-back methods have higher application efficiency in heavy textured soils as compared to light textured soils. Kassab *et al* (2012) reported that using irrigation cut-off at 90 % of strip length in North Nile Delta gave the same yield of berseem as obtained from irrigation cut-off at 95% of strip length, but it saved 7.9% of irrigation water and gave the highest water use efficiency (24.80 kg m^3) and water productivity (16.58

*** Corresponding author.**
E-mail address: drsobhyeid92@gmail.com
DOI: 10.21608/jssae.2020.108905

kg m^3). Darwesh and Farrag (2014) advised to irrigate cantaloupe crop using 90% irrigation cut-off under North Nile Delta conditions. Kassab and Ibrahim (2007) stated that irrigation cut-off with wheat was effective technique for water saving; and the irrigation cut-off at 90% of strip length gave the highest values of water use efficiency (1.73kg.m^{-3}) and water productivity (1.61kg.m^{-3}). Therefore, the objectives of this study are to: (1) improve on-farm irrigation management to achieve higher water productivity from unit of water and land; (2) optimize irrigation management by stopping the inflow of irrigation water before the water has reached the end of the irrigated field to reduce the amount of surface runoff entering the surface drainage system and (3) maximize application efficiency of surface irrigation.

MATERIALS AND METHODS

Description of the study area:

The experiment was carried out at Sakha Agric. Res. Station Experimental Farm, Agric. Res. Center (ARC), which located at 31° 07' N Latitude, 30°05' E Longitude with about 6 meters elevation above sea level. The site represents the North Nile Delta conditions. Water table level in such area ranged from 70-110 cm using observation wells. The climate of the region is typically Mediterranean Semi-arid, with less than 100 mm of annual rainfall, concentrated mainly from autumn to spring, and an average annual reference evapotranspiration (ET_o) of about 426 mm. Soil texture of the experimental site was clayey with 48.3% clay, 25.9% silt and 25.8% sand. The soil bulk density at the experimental site is 1.3 Mg m^{-1}. The electrical conductivity of the irrigation water was 0.48 dSm^{-1}.

Treatments and the experimental design:

Split-plot design with two factors and three replicates was used. Planting methods occupied the main plots: farmer's conventional flat planting method (F_1), furrow with 60 cm width (F_2) and furrow with 120 cm width (F_3). The sub plots devoted to cut-off irrigation treatments: at 100% of strip length ($C_{100\%}$) as a control, at 90% of strip length ($C_{90\%}$) and at 80% of strip length ($C_{80\%}$). The plots (4×100 m for each) were isolated by ditches of 1.5 m width to avoid the lateral movement of water. The experimental field was leveled at 0.1% ground surface slop using LASER leveler and wooden stakes were installed along each strip at 10 m interval to record the advance time.

Agronomic practices:

Wheat cultivar (*Triticum aestivum*L.), Misr-1 variety was sown on November, 5th and 10th and harvested on May, 1st and 5th in the 1st and 2nd seasons, respectively. All agricultural practices except the two studied factors were performed as recommended by the Egyptian Ministry of Agricultural and Land Reclamation for the crop and the area.

Some water relationships:

Applied irrigation water: Irrigation water was conveyed to each plot through the spile tubes and calculated according to Majumdar (2002);

$$q = CA\sqrt{2gh} \qquad (1)$$

Where; **q: Discharge of irrigation water (cm^3/s), C: Coefficient of discharge (0.62), determined by experiment, A: Inner cross section area of the irrigation spiel (cm^2), g: gravity acceleration (cm/s^2 and h: average effective head (cm).**

Irrigation was stopped when the water front reached 100%, 90% and 80% of the strip length. Along each experimental plot, some stations 10 m apart were staked all the way till the end of the proposed irrigation run to record the time consumed for reaching the water front to each station from the beginning of the watering event. Also, the corresponding time to disappear of water at each station was recorded from the beginning of irrigation. The difference between water advance time and recession time (opportunity time) at each station was recorded. Observation wells were installed along each strip for daily recording of water table depth.

Seasonal water applied (Wa):

Seasonal water applied (mm) was calculated according to Giriappa (1983):

$$Wa = IW + ER + CWT \qquad (2)$$

Where; **IW: irrigation water applied (mm), ER: the effective rainfall, mm (effective rainfall=incident rainfall × 0.7, Chavan *et al*, 2010) and CWT: the contribution of the ground water table to crop water use.**

Crop evapotranspiration (ETc):

Crop evapotranspiration (ETc) or crop consumptive use (Cu) was calculated directly from the soil moisture depletion in the effective root zone.

ETc was computed by the indirect method according to Doorenbos and Pruitt (1983):

$$ETc = ET_0 * Kc \qquad (3)$$

Where; **ET_c: Crop evapotranspiration (mm), ET_0: reference crop evapotranspiration (mm), and K_c: crop coefficient.**

Contribution of the ground water table to crop water use (s):

Water movement by capillary rise from water table into the active plant root zone is recognized as an important supplementary water resource for irrigation. The contribution of ground water (%) of the consumptive use was calculated according to Ibrahim *et al.* (1995) and Liu and Luo (2011):

$$CWT\% = (ETc - SMD)/ETc * 100 \qquad (4)$$

Where; **ETc: crop evapotranspiration (ET_0×Kc) and SMD: soil moisture depletion.**

The reference evapotranspiration (ET_0):

ETo was calculated by CROPWAT model v.8.0 based on the agro-metrological data collected for the studied area (Smith, 1992).

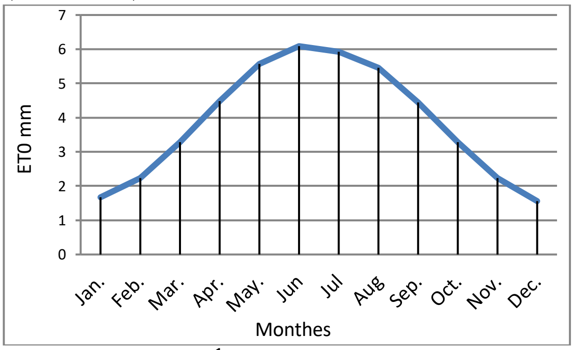

Fig. 1. ET_0 mm day^{-1} for the region of study located at 31° 07' N Latitude, 30°75' E Longitude and elevation 6 meters (mean of two years)

Crop coefficient (Kc):

Values of the Kc were quoted from FAO (Allen *et al.*, 1998). The four distinct growing stages of wheat and their corresponding Kc values were 0.4, 0.8, 1.2, 0.7 for the initial growth stage (20 days), development (50 days), mid-season (45 days) and late season (30 days).

Crop evapotranspiration:

The crop evapotranspiration ETc was estimated as described by Allen *et al.* (1998):

$$ETc = ET_0 \times Kc$$

Where; **Kc: crop coefficient; ET_0: reference evapotranspiration (mm).**

Consumptive use (CU):

Water consumptive use was calculated according to Hansen *et al.* (1979) as follow:

$$Cu = SMD = \sum_{i=1}^{i=N} \frac{\theta_2 - \theta_1}{100} * Dbi * Di \qquad (5)$$

Where; CU: water consumptive use (cm) in the effective root zone (60 cm), Θ_2: soil moisture % 48 hours after irrigation, Θ_1: soil moisture % before the next irrigation, Dbi: soil bulk density (Mg m^{-3}) for the given depth, D_i: soil layer depth (15 cm),i: number of soil layers.

Soil moisture (%) measurements were carried out before and after irrigation using Time Domain Reflectometer (TDR).

Water application efficiency (Ea):

Application efficiency is the ratio of the average depth of irrigation water infiltrated and stored in the root zone to that applied. It was calculated for the 60 cm soil depth according to Michael (1978) and James (1988) as follow:

$$\mathbf{Ea} = \frac{Ws}{Wf} \times \mathbf{100} \qquad (6)$$

Where; Ea: water application efficiency (%), W_s: amount of water stored in the root zone (m^3) and W_f: amount of water added to each plot (m^3).

Yield:, One square meter was randomly selected in each sub-plot at maturity stage to estimate the grain and straw yields.

Water productivity:

Agricultural water productivity is the physical mass of production (e.g., biomass, grain yield) or economic value of production to quantum of water used or delivered for the production (Molden, 1997) according to the following equation:

$$\mathbf{WP\ (kg/m3)\ or\ (\$/m3)} = \frac{Output\ derived\ from\ water\ use\ (kg/m2\ or\ \$\ /m2)}{Water\ input\ (m3\ /m2\ )} \qquad (7)$$

Statistical analysis:

All data were statistically explored according to the technique of analysis of variance (ANOVA) according to Gomez and Gomez (1984). All parameters were analyzed as a split-plot design, where, furrow wide (F) as main plot, and irrigation cut-off (C) as sub plot. Means were separated using the LSD at 0.05 and 0.01%.

RESULTS AND DISCUSSION

Seasonal water applied (Wa):

The seasonal water applied for wheat crop consists of irrigation water (IW) + effective rainfall (ER) + contribution of ground water table (CWT) as shown in Table (1) and Figure (2). Seasonal effective rainfall was 199.6 and 214.9 m^3/fed during the 1st and 2nd growing seasons (2017/18 and 2018/19), respectively. The obtained results reveal that the total amount of water applied under wide furrow treatments were in the following order: traditional treatment (F_1) > furrow 60 cm width (F_2) > furrow 120 cm width (F_3). So, F_1 planting method recorded the highest value of irrigation water during the 1st season (2149.7 m^3 fed^{-1}) and the 2nd season (2275.7 m^3 fed^{-1}), while the lowest values in both growing seasons (1729.7 and 1747.0 m^3 fed^{-1}, respectively) were achieved with F_3 practice. On the other hand, irrigation water was increased with decreasing irrigation cut-off rate during both seasons of cultivation. It could be noticed that the amount of irrigation water under cut-off irrigation treatments take the following order $C_{100\%}$ > $C_{90\%}$ > $C_{80\%}$. Therefore, $C_{100\%}$ technique recorded the highest values of irrigation water in both seasons (2091.7 and 2145.0 m^3 fed^{-1}, respectively), while $C_{80\%}$ technique achieved the lowest values in both growing seasons (1757.0 and 1810.7 m^3 fed^{-1}, respectively).

Table 1. Irrigation water (IW), effective rain fall (ER), contribution of ground water table (CGT) and seasonal water applied (Wa)

Raised bed	cut-off	1st Season				2nd Season				Mean of two seasons (m^3 Fe^{-1})			
		IW	RE	CGW	Wa	IW	RE	CGW	Wa	IW	RE	CGW	Wa
	$C_{100\%}$	2394.0	200.0	0.0	2594.0	2459.0	215.0	0.0	2674.0	2426.5	207.5	0.0	2634.0
F_1	$C_{90\%}$	2177.0	200.0	27.0	2404.0	2265.0	215.0	0.0	2480.0	2221.0	207.5	13.5	2442.0
	$C_{80\%}$	1878.0	200.0	120.0	2197.0	2103.0	215.0	32.0	2350.0	1990.5	207.5	76.0	2274.0
Mean F_1		2149.7	200.0	49.0	2398.3	2275.7	215.0	10.7	2501.3	2212.7	207.5	29.8	2450.0
	$C_{100\%}$	1966.0	200.0	142.0	2307.0	2120.0	215.0	78.0	2413.0	2043.0	207.5	110	2360.5
F_2	$C_{90\%}$	1862.0	200.0	157.0	2219.0	1879.0	215.0	148.0	2243.0	1870.5	207.5	152.5	2230.5
	$C_{80\%}$	1833.0	200.0	169.0	2202.0	1688.0	215.0	229.0	2133.0	1760.5	207.5	199.0	2167
Mean F_2		1887.0	200.0	156.0	2242.7	1895.7	215.0	151.7	2263.0	1891.3	207.5	153.8	2252.7
	$C_{100\%}$	1915.0	200.0	173.0	2288.0	1856.0	215.0	202.0	2273	1885.5	207.5	187.5	2280.5
F_3	$C_{90\%}$	1714.0	200.0	279.0	2193.0	1744.0	215.0	253.0	2212	1729.0	207.5	266.0	2202.5
	$C_{80\%}$	1560.0	200.0	369.0	2129.0	1641.0	215.0	324.0	2180	1600.5	207.5	346.5	2154.5
Mean F_3		1729.7	200.0	273.7	2203.3	1747.0	215.0	259.7	2221.7	1738.3	207.5	266.7	2212.5
Mean $C_{100\%}$		2091.7	200.0	105.0	2396.3	2145.0	215.0	93.3	2453.3	2118.3	207.5	99.2	2425.0
Mean $C_{90\%}$		1917.7	200.0	154.3	2272.0	1962.7	215.0	133.7	2311.7	1940.2	207.5	144.0	2291.7
Mean $C_{80\%}$		1757.0	200.0	219.3	2176.0	1810.7	215.0	195.0	2221.0	1783.8	207.5	207.2	2198.5

Meanwhile, the data showed that the IW values were clearly affected by the interaction between planting methods and irrigation cut-off techniques in both growing seasons. The highest values of irrigation water applied (2394 and 2459 m^3 fed^{-1}) during the 1st and 2nd seasons, respectively were recorded under $C_{100\%}$ x F_1 treatment. On the other hand, the lowest values of irrigation water (1560.1 and 1640.95 m^3 fed^{-1}) were detected under $C_{80\%}$ x F_3 treatment during both seasons, respectively. So, the same interaction recorded the highest values of water saving during the 1st season (834 m^3 fed^{-1} with 34.8% increase) and the 2nd season (819 m^3 fed^{-1} with 33.3% increase). These results are in harmony with those obtained by EL-Hadidi *et al* (2016), Kassab and Ibrahim (2007), Abd El-Fatah (2011), Beshara (2012) and Moursi *et al* (2014).

Contribution of ground water to wheat evapotranspiration (CGW %):

The data indicated that the seasonal contribution of groundwater to wheat crop (CGW) was affected by irrigation cut-off techniques and furrow width. The CGW value was increased by increasing the irrigation cut-off rate. So, the CGW values were increased from 105.0 and 93.3 m^3fed^{-1} with $C_{100\%}$ to 154.3 and 133.7 m^3fed^{-1} with $C_{90\%}$ or 219.3 and 195.0 m^3fed^{-1} with $C_{80\%}$ in the 1st and 2nd seasons, respectively. Also, CGW values were increased from 49.0 and 10.7 m^3fed^{-1} with F_1 to 156.0 and 151.7 m^3fed^{-1} with F_2 or 273.7 and 259.7 m^3fed^{-1} with F_3 in the 1st and 2nd seasons, respectively. This indicated that no or less contribution under F_1 technique but it may feed the groundwater due to increasing of the applied water.

Meanwhile, the seasonal mean values of CGW were affected by the interaction between irrigation cut-off technique and furrow width. Therefore, CGW value was increased with increasing of irrigation cut-off and furrow width ($C_{80\%}$ x F_3) due to decreasing of water applied, while less or no contribution was recorded due to increase of water applied with $C_{100\%}$ x F_1 during the two growing seasons. The mean values of CGW in the two seasons were 0, 13.5, and 76.0

m^3/fed (0, 5.65, and 13%) with $C_{100\%}$, increased to 110.0, 152.5 and 199.0 m^3/fed (6.88, 17.27 and 26.15%) with $C_{90\%}$ or 187.5, 266.0 and 346.5 m^3/fed (15, 28.27 and 37.85%) with $C_{80\%}$ under F_1, F_2 and F_3 techniques, respectively. These results are in somewhat in agreement with that obtained by Kahlown *et al* (2005) and Khalifa (2013). The non-contribution from groundwater during both early and ripening stage periods may be attributed to the less water consumed by plants (Eid, 1994).

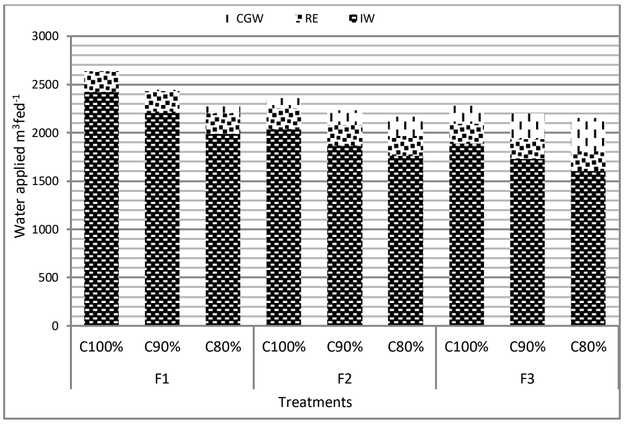

Fig. 2. Irrigation water (IW), rain fall (ER) and contribution of ground water table (CWT) as a mean of the two seasons

Water consumptive use (Cu):

The seasonal water consumptive use (Cu) or a "crop evapotranspiration ETc" is computed on the basis of moisture depletion from the effective root zone (60 cm depth). The obtained data showed that the change the irrigation cut-off from 100 to 90 or 80% was associated with decrease of Cu values in both growing seasons as shown in Table (1). Mean values of Cu for the three irrigation cut-off techniques were 36.61, 34.69 and 32.78 cm with F_1, F_2 and F_3, respectively. The Cu and water applied values were affected by the irrigation treatments and had the same trend in both seasons. The highest Cu values (41.75 and 42.60 cm) were recorded for with $C_{100\%}$ x F_1 followed by $C_{90\%}$ F_2 (39.40 and 40.50 cm) while the lowest values (27.70 and 29.75 cm) were obtained under $C_{80\%}$ x F_3 in the 1st and 2nd seasons, respectively. These results indicate that $C_{80\%}$ x F_3 and $C_{90\%}$ x F_2 decreased Cu as a mean of the two seasons by approximately 27.1 and 28.8%, respectively, as compared with the conventional treatment ($C_{100\%}$ x F_1). The Cu value with $C_{80\%}$ x F_3 was lower than that with $C_{100\%}$ x F_1, may be due to the fact that wheat plants grown under $C_{80\%}$ x F_3 treatment conditions were subjected to water stress resulting from lower amount of water applied. Also, this treatment resorted to contribution of ground water to compensate due to shortage of water applied and soil water content remained near the wilting point, while $C_{100\%}$ x F_1 treatment never had water stress since the soil water content remained above or near field capacity during the whole season. These results are in a harmony with those obtained by Kassab and Ibrahim (2007), Kassab *et al* (2012), and Moursi *et al* (2014).

Grain yield (GY) and straw yield (SY) as affected by irrigation cut-off and raised beds:

The Gy and SY values were significantly affected by irrigation cut-off techniques and they had the same trend in both growing seasons as shown Table (2).

Grain yield (GY):

The Gy values were significantly affected by cut-off irrigation techniques and the mean values of Gy for the two seasons were 3022.31, 3582.38 and 2759.17 kg fed^{-1} with $C_{100\%}$, $C_{90\%}$ and $C_{80\%}$, respectively. The increases of GY due to $C_{90\%}$ in relation to $C_{100\%}$ and $C_{80\%}$ were 15.6% and 22.9%, respectively. Concerning the effect of raised bed, the values of GY was highly significantly affected by this planting method. The GY means of the two seasons under F_1, F_2 and F_3 were 3001.52 3137.26, and 3214.94 $kgfed^{-1}$ respectively. Thus, F_3 treatment gave the highest GY and was superior to F_1 and F_2 by 8.9% and 4.3%, respectively.

Table 2. Grain and straw yields ($kgfed^{-1}$) as affected by raised bed and irrigation cut off technique

Raised bed	Cut-off	1st Season		2nd Season		Mean of two seasons	
		Grain	Straw	Grain	Straw	Grain	Straw
F_1	$C_{100\%}$	2864.23 b	4085.90 b	2950.16 b	4251.37 b	2907.2	4168.64
	$C_{90\%}$	3419.30 a	4773.23 a	3521.88 a	4956.20 a	3470.59	4864.72
	$C_{80\%}$	2617.53 c	3777.60 c	2696.06 c	4040.77 c	2656.8	3909.19
Mean F_1		2967.0 c	4212.24 c	3036.03 c	4416.29 c	3001.52	4314.27
F_2	$C_{100\%}$	2991.93 b	4235.70 b	3081.69 b	4434.93 b	3036.81	4335.32
	$C_{90\%}$	3556.63 a	4919.80 a	3663.33 a	5047.00 a	3609.98	4983.4
	$C_{80\%}$	2724.10 c	3938.97 c	2805.83 c	4153.67 c	2764.97	4046.32
Mean F_2		3090.9 b	4364.82 b	3183.61 b	4545.20 b	3137.26	4455.01
F_3	$C_{100\%}$	3076.90 b	4353.33 b	3169.21 b	4543.37 b	3123.06	4448.35
	$C_{90\%}$	3612.47 a	4932.00 a	3720.84 a	5142.73 a	3666.66	5037.37
	$C_{80\%}$	2812.97 c	4024.33 c	2897.35 c	4256.43 c	2855.16	4140.38
Mean F_3		3167.4 a	4436.56 a	3262.47 a	4647.51 a	3214.94	4542.04
$C_{100\%}$		2977.6 b	4224.97 b	3067.01 b	4409.85 b	3022.31	4317.41
$C_{90\%}$		3529.4 a	4875.01 c	3635.35 a	5048.64 a	3582.38	4961.83
$C_{80\%}$		2718.6c	3913.63	2799.74c	4150.29c	2759.17	4031.96
F		**	**	**	**		
C		**	**	**	**		
F×C		**	ns	**	ns		

In addition, the grain yield (GY) was significantly affected by the interaction between irrigation techniques and planting methods in both seasons. The mean values of GY with F_1 under $C_{100\%}$, $C_{90\%}$ and $C_{80\%}$ techniques were 2907.20, 3470.59 and 2656.80 $kgfed^{-1}$, respectively with increases due to $C_{90\%}$ by 16.2 and 23.4% compared to $C_{100\%}$ and $C_{80\%}$, respectively. The GY values with F_2 under $C_{100\%}$, $C_{90\%}$ and $C_{80\%}$ techniques were 3036.81, 3609.98 and 2764.97 kg fed^{-1}, respectively. So, the increases due to C90% in relation to $C_{100\%}$ and C80% were 15.8% and 23.4% respectively. With F_3, the Gy values were 3123.06, 3666.66 and 2855.16 kg fed^{-1} for $C_{100\%}$, $C_{90\%}$ and $C_{80\%}$, respectively; while the increases due to $C_{90\%}$ in relation to $C_{100\%}$ and $C_{80\%}$ were 14.8 % and 22.1% respectively. Therefore, the highest values of GY in the 1st and 2nd seasons (3612.47 and 3720.84 $kgfed^{-1}$, respectively) were achieved with F_3 under $C_{90\%}$. On the other hand, the lowest values of Gy in both growing seasons (2617.53 and 2696.06 kg fed^{-1}, respectively) were detected under F_1 combined with $C_{80\%}$. These finding are similar to that reported by Ahmad and Mahmood (2014).

Straw yield (SY):

The straw yield (SY) was significantly affected by the irrigation cut-off techniques in both growing seasons and the mean SY values of both seasons were 4317.41, 4961.83 and 4031.96 $kgfed^{-1}$ under $C_{100\%}$, $C_{90\%}$ and $C_{80\%}$ techniques, respectively. The increases in SY due to $C_{90\%}$ in relation to $C_{100\%}$ and $C_{80\%}$ were 12.9 and 18.7%, respectively.

Concerning the effect of planting on raised beds, the mean SY values of both two seasons were 4314.27, 4455.01 and 4542.04 $kgfed^{-1}$ under F_1, F_2 and F_3, respectively. Thus, the increase of SY by F_3 was 7.0 and 3.2% over than that with F_1 and F_2, respectively.

Meanwhile, the SY value was significantly affected by the interaction between irrigation cut-off techniques and planting methods in both growing seasons. The Sy values with F_1 were 4168.64, 4864.72 and 3909.19 kg fed^{-1} under $C_{100\%}$, $C_{90\%}$ and $C_{80\%}$, respectively; with increases of 14.3 and 19.6% due to $C_{90\%}$ in relation to $C_{100\%}$ and $C_{80\%}$, respectively. Also, with F_2, the Sy values were 4335.32, 4983.40 and 4046.32 kg fed^{-1} under $C_{100\%}$, $C_{90\%}$ and $C_{80\%}$ techniques, respectively with the increases of 13.0 and 18.8% due to $C_{90\%}$ in relation to $C_{100\%}$ and $C_{80\%}$, respectively. Finally, the Sy values with F_3 were were 4448.35, 5037.37 and 4140.38kg fed^{-1} under $C_{100\%}$, $C_{90\%}$ and $C_{80\%}$, respectively; with the increases of11.7 and 17.7% with $C_{90\%}$ over that with $C_{100\%}$ and $C_{80\%}$, respectively.

Therefore, the highest values of SY (4932.00 and 5142.73 $kgfed^{-1}$) were recorded under $C_{90\%}$ technique combined with F_3 method during the 1st and 2nd seasons, respectively, while the lowest values (3777.60 and 4040.77 kg fed^{-1} were detected under $C_{80\%}$ technique with F_1 treatment during both seasons, respectively. These finding are similar to that given by Ahmad and Mahmood (2014).

Water productivity (WP):

The mean of WP values of the two growing seasons are illustrated in Table (3). The mean of WP were clearly affected by irrigation cut-off and the mean values of WP with $C_{100\%}$, $C_{90\%}$ and $C_{80\%}$ were 6.67, 8.56 and 7.26 $L.E.m^{-3}$, respectively. Concerning the effect of raised beds, the data showed that the greatest WP value was achieved with F_3 followed by F_2 then F_1. The mean values for WP of the two growing seasons due to F_1, F_2 and F_3 were 7.7, 9.5 and 10.8 L.E m^{-3}, respectively. So, the increases in WP given by F_3 over that obtain by F_1 and F_2 were 27.7 and 12.0%, respectively.

Regarding the effect of the interaction of furrow width with irrigation cut off during the two growing seasons. The values of WP with F_1 under $C_{100\%}$, $C_{90\%}$ and $C_{80\%}$ were 5.53, 7.16 and 6.20 L.E m^{-3}, respectively and the increases due to $C_{90\%}$ in relation to $C_{100\%}$ and $C_{80\%}$ were 22.7 and 13.4%, respectively. The WP values with F_2 were 6.85, 8.83 and 7.31 L.E m^{-3} for $C_{100\%}$, $C_{90\%}$ and $C_{80\%}$, respectively with the increases of 22.4 and 17.2% due to $C_{90\%}$ in relation to $C_{100\%}$ and $C_{80\%}$, respectively. With F_3, the values of WP were 7.63, 9.69 and 8.26 L.E m^{-3} for $C_{100\%}$, $C_{90\%}$ and $C_{80\%}$ respectively with increases of 21.2 and 14.7% due to $C_{90\%}$ in combined to $C_{100\%}$ and $C_{80\%}$, respectively. So, the highest WP value (9.69 L.E) was achieved by F_3 combined with $C_{90\%}$, while and the lowest value (5.53 L.E m^{-3}) was occurred with F_1 in combined with $C_{100\%}$ technique. These results are agreed with Kassab *et al* (2012) and Kassab and Ibrahim (2007).

Table 3. Water productivity and application efficiency as influenced by irrigation cut-off and raised bed techniques.

Raised bed	Cut-off	Application efficiency, Ea (%)			Water productivity, WP (Kg m^{-3})						WP ($L.E.m^{-3}$)
		1st season	2nd season	Mean	1st season		2nd season		Mean		
					WP_g	WP_s	WP_g	WP_s	WP_g	WP_s	
F_1	$C_{100\%}$	44.34	45.65	45.00	1.20	1.71	1.20	1.73	1.20	1.72	5.53
	$C_{90\%}$	62.54	63.65	63.10	1.57	2.19	1.55	2.19	1.56	2.19	7.16
	$C_{80\%}$	69.36	70.78	70.07	1.39	2.01	1.28	1.92	1.34	1.97	6.20
Mean-F_1		58.75	60.03	59.39	1.39	1.97	1.34	1.95	1.37	1.96	6.30
F_2	$C_{100\%}$	60.43	61.98	61.21	1.52	2.15	1.45	2.09	1.49	2.12	6.85
	$C_{90\%}$	65.54	66.55	66.05	1.91	2.64	1.95	2.69	1.93	2.67	8.83
	$C_{80\%}$	71.79	72.25	72.02	1.49	2.15	1.66	2.46	1.58	2.31	7.31
Mean-F_2		65.92	66.93	66.43	1.64	2.31	1.69	2.41	1.67	2.37	7.66
F_3	$C_{100\%}$	62.00	63.44	62.72	1.61	2.27	1.71	2.45	1.66	2.36	7.63
	$C_{90\%}$	72.71	73.76	73.24	2.11	2.88	2.13	2.95	2.12	2.92	9.69
	$C_{80\%}$	77.06	78.01	77.54	1.80	2.58	1.77	2.59	1.79	2.59	8.26
Mean-F_3		70.59	71.74	71.17	1.84	2.58	1.87	2.66	1.86	2.62	8.53
Mean-$C_{100\%}$		55.59	57.02	56.31	1.44	2.04	1.45	2.09	1.45	2.07	6.67
Mean-$C_{90\%}$		66.93	67.99	67.46	1.86	2.57	1.88	2.61	1.87	2.59	8.56
Mean-$C_{80\%}$		72.74	73.68	73.21	1.56	2.25	1.57	2.32	1.57	2.29	7.26

Water application efficiency (Ea):

The values of Ea were obviously affected by irrigation cut-off and raised bed techniques as shown in Table (3). The mean values of Ea in the two growing seasons were increased from 56.31% with $C_{100\%}$ to 67.46 and 73.68 with $C_{90\%}$ and $C_{80\%}$ techniques, respectively. Regarding the effect of raised beds, the mean values of Ea of both seasons were increased from 59.39% with F_1 to 66.43 and 71.17% with F_2 and F_3 techniques, respectively.

Meanwhile, the interaction between the irrigation cut-off and raised bed techniques. The highest values of Ea (77.06 and 78.01%) were achieved from $C_{80\%}$, combined with F3 ($C_{80\%}$*F_3) during the 1st and 2nd, respectively, while the lowest values in both seasons were 44.34 and 45.65%, respectively. These results are in harmony with those obtained by Kassab *et al* (2012) and Kassab and Ibrahim (2007).

CONCLUSION

I could be concluded that:

a- Irrigating till 90% strip length with raised bed with 120 cm width ($C_{90\%}$*F_3) gave the highest yields of wheat grain (3.72 $tonfed^{-1}$) and straw (4.05 $tonfed^{-1}$).

b- Irrigating till 80% strip length with raised bed with 120 cm width ($C_{80\%}$*F_3) gave the highest level of water saving during the 1st and 2nd seasons (834 and 819 m^3 fed^{-1}, respectively) which represent 34.8 and 33.3%, respectively.

REFERENCES

Abd EL-Fatah, I.M., (2011). Climate change impacts on maize under surface irrigation with gated pipes in North Nile Delta. M.Sc. Thesis, Fac. Of Agric., Mansoura Univ.

Ahmad R. N. and N. Mahmood (2014). Impact of raised bed technology on water productivity and lodging of wheat. See discussions, stats, and author profiles for this publication at: https://www.researchgate.net/ publication/256542962.

Allen R.G., L.S. Pereira, D. Raes and M. Smith (1998). Crop evapotranspiration. Guidelines for computing crop water requirements. FAO Irrigation and Drainage Paper No.56.FAO, Rome.

Beshara, A.T. (2012). Effect of soil moisture depletion and nitrogen fertilizer application date on wheat yields, water and fertilizer use efficiencies in North Africa .Ph.D. Thesis .Fac.of Agric .Cairo Univ., Egypt.

Chavan M.L., U.M. Khodke and N.M. Changade (2010). Estimation of crop water requirement for irrigation planning in a semi arid region. Int. J. of Agril Engg. 2010;2(2):236-242.

Darwesh, R.Kh. and D. Kh. Farrag (2014). Irrigation Cut-off as Efficient Scheme For Maximizing Cantaloupe Productivity And Quality Under Different Iron Application Techniques

Doorenbos, J. and W.O. Pruitt (1983). Crop Water Requirements. FAO Irrigation and Drainage Paper Rome. Italy. Principles and Practices. John Wiley & Sons, Inc. New York.

Eid, S.M. (1994). Some water applications and yield of sugar beet and sunflower crops as influenced by frequency and amounts of irrigation water in Northern Delta . M.Sc. esis, Fac. Agric Tanta Univ.

EL-Hadidi, E. M. , M.M. Saied; Fatma M. Ghaly and R. M. Khalifa (2016). Assessing the Effect of Water Discharge Rates and Cut-Off Irrigation on Wheat Production and Some Water Relations at North Nile Delta Region.*J. Soil Sci. and Agric. Eng., Mansoura* Univ., Vol. 7 (6): 397 – 407,2016

Farré. I. and J.M. Faci (2006). Comparative response of maize (*Zea mays* L.) and sorghum (*Sorghum bicolor* L. Moench) to deficit irrigation in a Mediterranean environment. Agric. Water Manage., 83: 135-143.

Giriapa, S. (1983). Water use efficiency in agriculture. Oxford-IBH Publishing Co., New Delhi, 6-9.

Gomez, K. A. and A. Gomez (1984). Statistical procedures for agricultural research . 1st ed. John Wiley Sons, New Yourk

Hansen, V.W.; D.W. Israelsen and D.E. Stringharm (1979). Irrigation Principle and Practices, 4th ed. Johns Wiley & Sons., New York.

Hobbs, P.R. and M.L. Morris. (1996). Meeting South Asia's Future Food Requirements from Rice-Wheat Cropping Systems: Priority Issues Facing Researchers in the Post Green Revolution Era. NRG Paper 96-01. Mexico, DF.:CIMMYT.

Ibrahim M.A.; M.M. Ibrahim; S.A. Gaheen and S.M. Ismail (1995). Role of irrigation Management on water parameters and yield of Sugar Beet in Shallow water table soils of Nlie delta. Water Resources Management in Arid counturies, Muscat Sultanate of Oman, March 1995., 98-106.

James, L.G., (1988). Principles of farm irrigation System Design. John Willey and Sons.Inc. New York.543.

Kahlown, M.A.; M. Ashraf and Zia-UL-Haq (2005). Effect of shallow ground water table on crop water requirements and crop yields. Agri. Water management 76: 24-35.

Kassab, M.M and M.A.M. Ibrahim (2007). Cut-off Wheat (triticum Sp.) Irrigation as an Effective Technique for Improving Water Management. Alexandria science exchange journal, vol. 28, no. 160 4 October- December 2007.

Kassab, M.M.; R. Kh. Darwesh and M.A.M. Ibrahim (2012). Response of Egyptian Clover to cut-off irrigation technique on clay soils at North Nile Delta. Alexandria Science Exchange Journal, 33(3) July- Sept. 2012.

Khalifa, R.M. (2013).Water requirements of maize and sugar beet crops as affected by soil moisture depletion and water table level .M.Sc. Thesis, Fac.of Agric .Kafr el-sheikh Univ., Egypt.

Kijne, J.W., R. Barker, D. Molden (2003). Water Productivity in Agriculture: Limits and Opportunities for Improvement. CAB International, Wallingford UK.

Liu, T. and Y. Luo (2011). Effects of shallow water tables on the water use and yield of winter wheat ('Triticum aestivum'l.) Under rain-fed condition. Australian Journal of Crop Science, 5(13), 1692-1697.

Majumdar, D.K. (2002). Irrigation Water Management: Principles and Practice. 2nd ed. Prentice Hall of India, New Delhi 110001, 487p.

Michael, A.M. (1978). Irrigation theory and particle. Vikas Publishing House PVTLTD New Delhi Bombay.

Molden, D. (1997)."Accounting for water use and productivity," *SWIM Paper* 1, International Water Management Institute, Colombo, Sri Lanka (1997)

Mostafazadeh; B. and M. Farzamnia (2000). The study of hydraulic performance of furrow irrigation under different methods of discharge management. J. of Sci. and Technology of Agric. and Natural Resources. 4 (3): 1-11.

Moursi, E. A.; Manal, A. Aziz and Mona, A. M. EL- Mansoury (2014). Effect of length of irrigation run and nitrogen rates on productivity of some wheat cultivars, some water relations and nitrogen content in heavy clay soils. J. Agric. Kafr. EL-Sheikh Univ., 40 (3): 630-658.

Ortega L., A. Sayre and C.A. Francis (2000). Wheat nitrogen use efficiency in a bed planting system in northwest Mexico, Agron. J. 92 (2000) 303–308.

Smith, M. (1992). CROPWAT-a computer program for irrigation planning and management. FAO Irrigation and Drainage Paper 46, p. 126, ISBN 92-5-103106-1.

الزراعة على مصاطب وتقنية الـ cut-off لزيادة انتاجية القمح وتوفير مياة الرى فى شمال دلتا النيل

منى صبحى محمد عيد* وهشام محمود ابوالسعود

معهد بحوث الأراضى والمياة والبيئة- مركزالبحوث الزراعية - الجيزة- مصر

الرى السطحى شائع في مصر مع القمح. ويتم ري المحصول بواسطة الري بالغمر حتى نهاية الشريحة، وهذه الطريقة من الرى تؤدى الى تقليل كفاءة الاسمده بسبب سوء التهوية وفقدها بواسطة الرشح وتطايرها. ومن ناحية اخرى فان تقنية ال cut-off وزراعة القمح على مصاطب توفر ماء الرى وتؤدى لتحسين كفاءة استخدام الاسمدة وزيادة الانتاج. أجريت تجربة حقلية خلال موسمي الزراعة المتتاليين 18/2017 و19/2018 بمزرعة محطة البحوث الزراعية بسخا -محافظة كفر الشيخ. واستخدم تصميم القطع المنشقة حيث كانت معاملات طريقة الزراعة بالقطع الرئيسية وتقنية ال cut-off بالقطع المنشقة في ثلاث مكررات. وكانت المعاملات تحت الدراسة:كالأتي: أولاً: طرق الزراعة: زراعة الفلاح العادية (F_1) والزراعة على خطوط عرض الخط 60 سم (F_2) والزراعة على خطوط عرض الخط 120 سم (F_3). ثانياً: معاملات ال cut-off : الرى كامل الشريحة (C100%) و C90% و C80%الرى حتى 90% و 80% من طول الشريحة او الخط. والهدف من هذا البحث هو دراسة ثلاث طرق من طرق الزراعة وثلاث اطوال من طول الشريحة او الخط الواجب ايقاف الرى عندها للقمح (Triticum aestivum L) صنف مصر-1، من حيث تأثيرها على النمو، والانتاج، وبعض العلاقات المائية، ومساهمة منسوب المياه الارضى فى الاحتياجات المائية للقمح. أوضحت النتائج أن معاملة F3* $C_{90\%}$ حققت أدنى قيم للاستخدام الموسمي للمياه واستهلاك المياه وأعلى قيم لإنتاجية المياه WP، كفاءة استخدام المياه (Ea،٪) ، محصول الحبوب والقش على التوالي. واعطت المعاملة F_3 *$C_{80\%}$ أعلى قيمة لمساهمة المياه الارضى (21.4٪) وبلغت أعلى قيم لتوفيرالمياه (34.04٪) خلال موسمي النمو على التوالي