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Assessing the Effect of Water Discharge Rates and Cut-Off Irrigation on Wheat Production and Some Water Relations at North Nile Delta Region

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ABSTRACT

Two field experiments were conducted during the two consecutive growing seasons of 2013/2014 and 2014/2015 at Sakha Agriculture Research Station Farm, Kafr EL-sheikh governorate. The aim of study was to evaluate the effect of three irrigation discharge rates (2.5, 3.5 and 4 L.sec^{-1} m^{-1}) and three cut-off irrigations (100%, 90% and 85% from border length), which were randomly arranged under each irrigation discharge on wheat yield and its components, some water relations, irrigation efficiencies and the contribution of ground water table. The results revealed that the combination of irrigation discharge 4 L sec^{-1} m^{-1} and cut-off irrigation at 85% of border length achieved the lowest values of seasonal applied water and water consumptive use and the highest values of following parameters ; crop water use efficiency (CWUE), Irrigation water use efficiency (IWUE), water consumptive use efficiency (Ecu, %), water application efficiency (EI, %), Grain and straw yields, NP–uptake and crude protein and ground water contribution (Gwc, %). Moreover, it increased the amount and percentage of water saving 242.34 m3 fed-1 (about 9.60%), total income, net income, and net income per water unit for both wheat grain and biological yields. Also, the economic efficiency, during both seasons. On the other hand, the highest values of water distribution efficiency (Ewd, %) have resulted from the combination of irrigation discharge rates (4 or 3.5 L sec^{-1} m^{-1}) and cut-off irrigation at 100% of border length. It could be concluded that the combination of irrigation discharge 4 L sec^{-1} m^{-1} and cut-off irrigation at 85% of border length was the most profitable for irrigated wheat crop, as well as, the benefit of contributing ground water table in saving some of water requirements for the crop, ground water table contribution of great importance as an additional source of irrigation water, especially under the prevailing conditions of water shortage in Egypt.

Keywords *:(irrigation Discharge rates, cut-off irrigation, clay soil, water relations, irrigation efficiencies, wheat and ground water table contribution)*

INTRODUCTION

Irrigated agriculture is the dominant type of farming in Egypt. The per capita of water for different purposes is decreasing gradually to less than the water poverty edge (1000m^3 per annum). Water shortage that faces Egypt is continuously increasing, and it is prospected to reach the threshold level of less than 500 m^3 yr^{-1} capita^{-1}. (EL-Quosy, 1998). Under the existing limited water supply resources and the agriculture prevailing conditions in Egypt, a successful plan regarding water management is needed to reach the maximum water and land use efficiency, in the northern Nile delta region.

Improvements in irrigation practices such as precision leveling, proper border length as well as appropriate flow rates lead to more uniform water distribution, soil and water conservation and economic viability of irrigated agriculture (EL-Mowelhi et al, (1999b, 1995a&b and 1999a), El-Arqan et al (2008), Bochen et al, (2013) and Qingfeng Miao et al (2015).Also, the following cut-off irrigation event, the water front moves to irrigate more cultivated areas. This Technique considered as a direct simple effective way in water saving, Kassab and Ibrahim ;(2007) ;(Zeng Guang Wei et al, (2009); Amer (2011) and Kassab (2012).

Wheat (Tritcum aestivum L.) is one of the main winter cereal crops in Egypt, in terms of both area and production. There is a great gap between its consumption and production resulting from rapidly increasing the population. So increasing wheat production is becoming a must, which could be achieved by increasing cultivated area, planting of high yielding cultivars and using the most effective ways for irrigation.

The main objectives of the current study are to investigate the effects of three different irrigation discharges, cut-off irrigation from border length on wheat yield, yield parameters, some water relations and some irrigation efficiencies.

MATERIALS AND METHODS

Two field experiments were conducted at Sakha Agricultural Research Station, Kafr EL-Sheikh Governorate during the two consecutive winter seasons 2013/2014 and 2014/2015, to study and evaluate the effect of three irrigation discharge rates (2.5, 3.5 and 4.0 L sec^{-1} m^{-1}) and three cut-off irrigation (cut-off at 100%, 90% and 85% of border length) with land leveling 0.1% ground surface slope on some water relations, some irrigation efficiencies and yield of wheat crop. Strip block statistical design was employed. The main plots were randomly subjected to irrigation discharge rates, while subplots were devoted to cut-off irrigation. Table 1a&b shows some soil physical and chemical properties of the experimental area. The agrometeorological data at Sakha station, during the two seasons of study, are presented in Table 2.

Wheat (variety Gemmiza 9) was planted during the two growing seasons, field preparation (plowing and land leveling 0.1% ground surface slope) and agronomic practices were performed according to the usual agricultural practices, except the studied treatments (water discharges and cut-off irrigation) .Dates of planting and harvesting were Dec., 4 and May, 8 during the 1st season and Nov., 20 and May, 3 during the 2nd season, respectively. The previous crops were rice and maize during the1st and 2nd seasons, respectively.

All plots received an equal dose of phosphatic fertilization (15 kg P_2O_5 fed^{-1}) in the form of calcium superphosphate during preparing the soil for planting. While nitrogen was added in the form of ammonium nitrate (33.5%N), at the recommended dose of 75 kg N fed^{-1}., for the wheat crop. The application of the N fertilizer was divided into two equal doses, one added before post irrigation and the other before the 3rd irrigation.

The length and width of each border were 100m and 7m, respectively, therefore under each irrigation discharge rate water was stopped when the waterfront reached 100%, 90% and 85% of the border length. Each border was isolated by ditches of 1.5m width to avoid lateral movement of irrigation water to adjacent plots. Land leveling of 0.1% ground surface slope was conducted during preparing the soil for planting during both seasons. Along each cultivated border, different stations 10m apart were staked all the way till the end of the proposed irrigation run. The time consumed for reaching the water front during irrigation at each station as well at the end was recorded from the beginning of the watering event. Consequently, the corresponding time, to disappear water at each station was also recorded from the beginning irrigation. The difference between water advance time and recession time expressed as the opportunity time of irrigation water at each station. Observation wells were installed along different treatments and reading of water Table depth was recorded by using the ground water meter.

Table 1a: Mean physical properties of the studied soil, before carrying out the experiment, during the two growing seasons.

Soil depth, cm	Particle size distribution, %			Textural class	Basic IR., cm/hr	Bulk density, Mgm^{-3}	Total porosity, %	Soil moisture constant		
	Sand	Silt	Clay					Fc%	Pwp, %	Aw,%
					1st season					
0-15	17.7	27.10	55.10	Clay		1.272	52.0	45.66	24.27	21.39
15-30	18.4	28.30	53.30	Clay		1.354	48.91	44.17	22.92	21.25
30-45	18.5	29.40	52.10	Clay	0.86	1.369	48.34	39.42	21.42	18.00
45-60	20.2	30.30	49.50	Clay		1.385	47.74	37.17	21.26	15.91
Mean	18.17	28.80	52.50	Clay		1.345	49.25	41.61	22.47	19.14
					2nd season					
0-15	16.58	28.22	55.20	Clay		1.266	52.23	45.70	24.44	21.26
15-30	18.29	28.31	53.40	Clay		1.365	48.49	44.21	23.03	21.18
30-45	18.48	29.42	52.10	Clay	0.87	1.367	48.42	39.41	21.42	17.99
45-60	20.21	30.28	49.51	Clay		1.348	47.58	37.18	20.61	16.57
Mean	18.39	29.06	52.55			1.349	49.18	41.62	22.38	19.24

Table 1b: Mean chemical properties of the studied soil, before carrying out the experiment, during the two growing seasons.

Soil depth,cm	pH, (1:2.5) soil susp.	EC, dS m^{-1} Soil paste extract	SAR	Soluble cations, meq L^{-1}				Soluble anions, meq L^{-1}			
				Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{--}	HCO_3^{-}	CL^{-}	SO_4^{--}
0-15	8.76	3.66	6.37	6.96	9.86	19.51	0.27	—	5.00	15.54	16.06
15-30	8.80	3.68	6.78	6.69	10.15	19.73	0.23	—	5.50	15.75	15.55
30-45	8.94	4.30	8.36	7.65	10.15	24.90	0.30	—	5.00	19.51	18.49
45-60	8.84	4.58	8.68	6.65	10.16	25.18	0.31	—	5.10	20.62	16.58
0-15	8.74	3.53	6.29	7.10	9.76	18.23	0.22	—	4.86	16.32	14.12
15-30	8.81	3.57	6.53	6.71	10.10	18.46	0.20	—	5.22	16.15	14.33
30-45	8.92	4.13	7.78	7.68	10.10	23.19	0.29	—	4.88	19.66	16.76
45-60	8.82	4.51	8.76	6.68	10.13	25.40	0.31	—	4.89	21.15	19.10

Table 2: Monthly mean values of some Meteorological data at Kafr El-Sheikh Governorate during the two growing seasons of the wheat crop.

Months	Temperature, c^{o}			Relative humidity,%			Wind velocity, km/24h at 2m height	Pan evaporation cm day^{-1}	Rain, mm month^{-1}
	Max	Mini	Mean	Max	Mini	Mean			
					1st season				
Dec.2013	19.65	8.51	14.10	92.07	67.61	79.84	52.68	0.415	71.3
Jan.2014	20.34	7.55	13.95	93.69	70.55	82.12	46.67	0.776	17.4
Feb.2014	20.64	8.19	14.42	91.90	67.15	79.53	66.37	0.258	14.29
Mar.2014	22.94	11.71	17.33	86.10	56.80	71.45	82.80	0.346	24.11
Apr.2014	27.50	15.53	21.52	81.80	49.80	65.80	92.86	0.496	19.21
May.2014	30.47	19.57	25.02	77.20	48.6	62.90	68.27	0.587	—
					2nd season				
Nov.2014	21.46	11.46	16.46	91.6	64.9	78.25	60.4	0.227	10.40
Dec.2014	22.27	9.72	15.99	88.6	63.5	76.05	46.03	0.172	5.70
Jan.2015	18.79	6.46	12.63	88.1	61.1	74.60	70.8	0.271	54.37
Feb.2015	19.01	7.65	13.33	86.8	62.7	75.75	72.91	0.290	38.81
Mar.2015	22.69	11.69	17.19	82.36	58.82	70.59	87.64	0.323	6.25
Apr.2015	25.64	13.7	19.36	78.3	48.5	63.40	95.7	0.606	23.90
May.2015	30.19	18.79	24.49	77.3	46.1	61.70	114.6	0.715	---

***Effective rainfall= incident rainfall × 0.70 (Novica, 1979)** **Source: Meteorological Sakha station.**

Data collection:-

Irrigation water applied (IWA):-

For irrigation timing, soil samples were taken periodically until it reached the desired level of allowable moisture (50% of AW). The amount of applied water at each irrigation treatment was determined on the basis of raising the soil moisture content to its field capacity plus 10% as leaching requirements. Irrigation water applied at each water discharge rate was calculated by using the following: Q = 1.84 $LH^{1.5}$, where Q = Rate of discharge, m^3/min., L = length edge of weir, cm (50cm) and H = head of water above edge of weir, cm

Seasonal applied water :-

It was calculated as described by Giriappa (1983) as follows: AW=IW+ER+S, where IW= irrigation water applied (by multiplying discharge rates by required time for border irrigation), ER=effective rainfall and S= amount of soil moisture contribution to consumptive use from the shallow ground water Table

Water consumptive use (Cu):-

To compute the actual consumed water of the growing plants, soil moisture percentage was determined on weight basis before and 48 hr after each irrigation as well as at harvest time. The soil samples were taken from successive layers in the effective root zone (0-15, 15-30, 30-45 and 45-60 cm). This method of consumed water is depending upon soil moisture depletion (SMD) or so-called actual crop water consumed (ETc). The amount of Cu was calculated in the effective root zone of 60 cm as stated by Hansen et al, (1979).

$$Cu=SMD=\sum \frac{\theta_2 - \theta_1}{100} \times Dbi \times Di, \qquad \text{Where,}$$

Cu= water consumptive use (cm) in the effective root zone 60 cm depth.

θ_2 = Soil moisture percentage, 48 hours after irrigation

θ_1 = Soil moisture percentage before the next irrigation

Dbi = Bulk density of the specific soil layer (Mgm^{-3})

Di = soil layer depth (15 cm),

Water use efficiency (WUE):-

It was calculated according to Doorenbos and Pruitt (1975) as follows:-

$$WUE= Y/Cu$$

Were Y= the grain or straw yield of wheat (kg fed^{-1}), Cu= seasonal water consumptive use (m3/fed), and WUE= water use efficiency (kg m^{-3})

Irrigation water use efficiency (IWUE):-

It was calculated according to Doorenbos and Pruitt (1975) as follows:-

$$IWUE= Y/WA$$

where Y = the grain or straw yield of wheat (kg fed^{-1}), WA= seasonal water applied (m^3/fed), IWUE= water applied use efficiency (kg m^{-3})

Consumptive use efficiency (Ecu, %):-

It was calculated according to Doorenbos and Pruitt (1975) as follows:-

$$Ecu = ETc/ IWA \times 100$$

where Ecu= consumptive use efficiency (%), ETc = water consumptive use, and IWA= irrigation water applied to the field m^3Fed^{-1}.

Contribution of the ground water Table to crop water-need (GWC, %):-

It was calculated as follows:

$$GWC\% = (ETc-SMD)/ETc \times 100$$

where

ETc= crop evapotranspiration= ETo×Kc

SMD= soil moisture depletion

ETo was calculated using three methods: - Blaney & Criddle, Pan Evaporation (Doorenbos and Pruitt (1975) and penman montieth, average values was calculated and considered in calculations (Allen et al., 1998)

Irrigation application efficiency (EI, %):-

It was obtained by dividing the volume of water stored in the effective root zone to the applied irrigation water (Downy, 1970) as follows:

$$EI= (Da-(Dp+Ro)/Da \times 100$$

Where: Da= application water (cm), Dp= deep percolation (cm), Ro= Runoff (cm), EI= irrigation application efficiency

Water distribution efficiency (Ewd, %):-

It was calculated according to (James, 1988) as follows:

$$Ewd= (1- Y/d) \times 100$$

Where: Ewd= water distribution efficiency, d= average depth of soil water stored along the border length during the irrigation, and Y= average numerical deviation from-d.

Yield parameters:- the yield parameters expressed by:

1-Grain yield (kg fed^{-1})

2-Straw yield (kg fed^{-1})

3-Grain weight per panicle (g)

4-1000 grain weight (g)

Nutritional analysis:-

Plant samples (grains and straw) were collected from each plot at the end of the two growing seasons, each sample was washed with distilled water thoroughly and was dried in an oven at 70 c^o for 24 hours. Constant weight each sample was wet digested in H_2SO_4 - H_2O_2 mixture to determine the concentration of Nitrogen and Phosphorus in both grains and straw .N- content, % was determine using micro – kjeldahl method according to Jackson, 1967. P-content, % was determined by using hydroquinine method (Snell and Snell, 1967).

Crude protein content (%):-

It was calculated by multiplying the N, % by 5.7 (A.O.A.C., 1980)

The uptake of N and P by plant organs (grains and straw) of wheat:-

It was calculated by multiplying element concentration by yield of wheat (grain and straw yield, kg fed^{-1})

Statistical analysis:-

Some of the data collected (wheat yield and its components) were subjected to the statistical analysis according to Snedecor and Cochran (1967) and the mean values were compared by least significant differences according to Duncan (1955).

RESULTS AND DISCUSSION

Seasonal water applied

The amount of seasonal water applied for wheat crop consists of three components which are irrigation water (IW), Effective Rainfall (ER) and ground water contribution (Gwc). Presented data in Table 1 and Fig. 1 clearly showed that the highest values of seasonal water applied (2672.88 and 2662.80 m^3 fed^{-1}) were recorded under irrigation discharge of 2.5 L sec^{-1} m^{-1} and cut-off irrigation at 100% of border length during the 1st and 2nd seasons, respectively. On the other hand , the lowest values of seasonal water applied (2303.28 and 2282.7 m^3 fed^{-1}) were detected under irrigation discharge of 4.0 L sec^{-1} m^{-1} and cut-off irrigation at 85% of border length during both seasons ,respectively. It was noticed that seasonal water applied was decreased with increasing cut-off irrigation treatments under all irrigation discharge rates during both seasons of cultivation.

In comparison with cut-off irrigation at 100% of border length (no cut-off) under each irrigation discharge , the highest values of water saving 241.08 m3 fed-1 (9.48%) and 242.34 m^3 fed^{-1} (9.60%) were recorded with irrigation discharge of 4.0 L sec^{-1} m^{-1} and cut-off irrigation at 85% of border length , during the first and 2nd seasons , respectively, followed by irrigation discharge of 3.5 L sec^{-1} m^{-1} under the same cut-off irrigation .Based on the highest crop yield. Saved water could be used for irrigating more crops and for horizontal expansion in agriculture. These results are in a great harmony with those obtained by Kassab and Ibrahim (2007), Abd El-Fatah (2011), Beshara (2012), and Moursi et al, (2014).

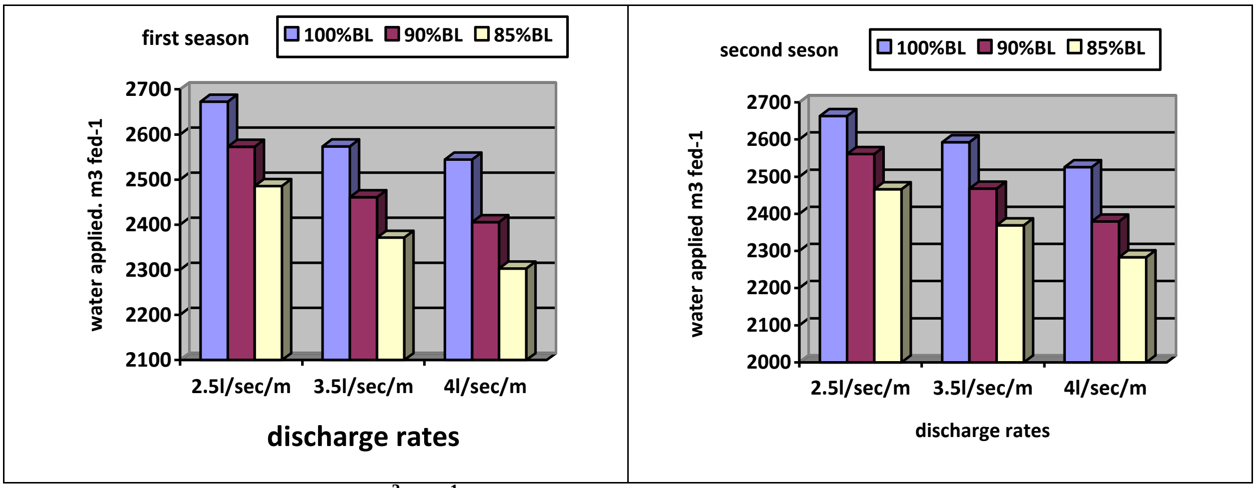

Fig. 1: Seasonal applied water (m^3 fed^{-1}) for wheat crop as affected by discharge rates and cut-off irrigation treatments during the two growing seasons

Water consumptive use (Cu):

The seasonal crop water consumptive had the same trend as that of seasonal water applied. The seasonal mean values of water consumptive use is a direct function of the soil water status which already are affected by the amount of irrigation water applied.

Data presented in Table 3 show that the highest seasonal mean values of water consumptive use {(1605.24 m^3 fed^{-1} (38.22cm) and 1634.64m^3 fed^{-1} (38.92 cm) } were recorded under irrigation discharge of 2.5 L sec^{-1} m^{-1} and cut-off irrigation at 100% of border length during the1st and 2nd seasons ,respectively, compared with other treatments. Meanwhile, the lowest consumptive use values 1498.56 m3 fed-1 (35.68cm) and 1499.82 m3 fed-1 (35.71 cm) were achieved with water discharge 4 L sec^{-1} m^{-1} and cut-off irrigation at 85% of border length during both seasons, respectively. It was observed that, values of seasonal water consumptive use were decreased with increasing cut-off irrigation under all irrigation discharge rates during both seasons. These results are in a harmony with those obtained by Kassab and Ibrahim (2007), Kassab (2012), El-Ramady et al, (2013) and Moursi et al (2014).

Irrigation water use efficiency (IWUE):

Presented data in Table 3 show that the highest values of IWUE for grain and straw yield of wheat were recorded under irrigation discharge of 4 L sec^{-1} m^{-1} and cut-off irrigation at 85% of border length , and found to be (1.29 and 1.37 kg/m^3) for grain yield and (2.01 and 2.09 kg/m^3) for straw yield during the1st and 2nd seasons , respectively, followed by 3.5 L sec^{-1} m^{-1} water discharge and the same above cut-off irrigation .On the other hand , the lowest values of IWUE were (0.89 and 0.96 kg/m^3) for grain yield and (1.41 and 1.50 kg/m^3) were detected under 2.5 L sec^{-1} m^{-1} water discharge and cut-off irrigation at 100% of border length during both seasons , respectively. These results are in agreement with those obtained by Abo-warda (2002), Kassab and Ibrahim (2007), Kassab (2012) and Moursi et al, (2014)

Water use efficiency (WUE)

Presented data in Table 3 showed that the highest values of WUE for grain yield (2.0 and 2.08 kg/m^3) and (3.10 and 3.14 kg/m^3) for straw yield were recorded for irrigation discharge of 4 L sec^{-1} m^{-1} under cut-off irrigation at 85% of border length during the first and the second seasons, respectively. While the lowest values of WUE (1.48 and 1.57 kg/m^3) for grain yield and (2.35 and 2.44 kg/m^3) for straw yield were detected under 2.5 L sec^{-1} m^{-1} water discharge and cut-off irrigation at 100% of border length during both seasons, respectively. It was noticed that, values of WUE increased with increasing cut-off irrigation under all irrigation discharge rates during both seasons. These findings are in a good accordance with those obtained by Shahin and Mosa (1994), Abo-warda (2002), Kassab and Ibrahim (2007) and Moursi et al (2014).

Table 3: Water relations of wheat as affected by water discharge rates and cut-off irrigation during the two growing seasons.

Treatments		1st season								2nd season									
Water discharge	Cut-off irrigation at	W.A. m^3/fed	Water saving		Cu $m^3\ fed^{-1}$	IWUE, kg m^{-3}		WUE, kg m^{-3}		W.A. m^3/fed	Water saving		Cu $m^3\ fed^{-1}$	IWUE, kg m^{-3}		WUE, kg m^{-3}			
			m^3/fed	%		Grain	Straw	Grain	Straw		m^3/fed	%		Grain	Straw	Grain	Straw		
2.5 L sec^{-1} m^{-1}	100%of BL	2672.88	-	-	1605.24	0.89	1.41	1.48	2.35	2662.80	-	-	1634.64	0.96	1.50	1.57	2.44		
	90%of BL	2572.92	99.96	3.74	1591.80	0.99	1.55	1.60	2.50	2560.74	102.06	3.83	1621.62	1.04	1.57	1.65	2.47		
	85%of BL	2485.56	187.32	7.01	1589.28	1.10	1.77	1.71	2.77	2466.44	196.56	7.38	1606.92	1.23	1.74	1.89	2.67		
3.5 L sec^{-1} m^{-1}	100%of BL	2573.76	-	-	1552.74	1.03	1.65	1.71	2.73	2592.24	-	-	1569.12	1.12	1.65	1.85	2.73		
	90%of BL	2460.78	112.98	4.39	1546.86	1.08	1.64	1.72	2.61	2467.92	124.32	4.80	1553.16	1.20	1.75	1.91	2.78		
	85%of BL	2371.32	202.44	7.87	1537.20	1.18	1.96	1.83	3.02	2369.22	223.02	8.60	1541.82	1.31	1.93	2.01	2.96		
4.0 L sec^{-1} m^{-1}	100%of BL	2544.36	-	-	1505.28	1.12	1.88	1.90	3.17	2525.04	-	-	1518.30	1.17	1.72	1.94	2.86		
	90%of BL	2405.76	138.60	5.45	1500.24	1.18	1.92	1.90	3.08	2379.30	145.74	5.77	1505.70	1.27	1.90	2.01	3.00		
	85%of BL	2303.28	241.08	9.48	1498.56	1.29	2.01	2.00	3.10	2282.70	242.34	9.60	1499.82	1.37	2.04	2.03	3.10		

BL= border length WA= water applied = irrigation water +effective rain + ground water contribution

Irrigation efficiencies

Water application efficiency (EI, %)

Data in Table 4 and Fig. 2 show that the highest values of water application efficiency (71.48 and 71.34%) were achieved from cut-off irrigation till 85% of border length under irrigation discharge of 4.0 L sec^{-1} m^{-1} during the1st and 2nd seasons, respectively, followed by cut-off irrigation at 90% of border length under the same irrigation discharge .While , the lowest values of water application efficiency (57.19 and 56.45%) were resulted from cut-off irrigation at 100% of border length under water discharge 2.5 L sec^{-1} m^{-1} during both seasons , respectively. Also, it was noticed that mean values of water application efficiency were increased with increasing both of irrigation discharge rates and cut-off irrigation during both seasons. These results are somewhat agreed with those obtained by El-Arqan et al, (2008), Mosalm (2009) and Amer (2011).

Table 4: Water application, water distribution and consumptive use efficiencies as influenced by water discharge rates and cut-off irrigation during the two growing seasons.

Treatments		1st season			2nd season		
Irrigation discharge rates	Cut-off irrigation	Water application efficiency (EI, %)	Water distribution efficiency (Ewd, %)	Consumptive use efficiency , (Ecu, %)	Water application efficiency (EI, %)	Water distribution efficiency (Ewd, %)	Consumptive use efficiency , (Ecu, %)
2.5 L sec-1 m-1	100% of BL	57.19	65.76	72.80	56.45	64.20	74.02
	90% of BL	61.27	62.86	75.65	61.39	62.14	76.69
	85% of BL	64.33	60.81	78.83	63.33	61.79	79.84
Mean		60.93	63.14	75.76	60.39	63.12	76.85
3.5 L sec-1 m-1	100% of BL	59.30	82.34	73.97	58.89	81.99	73.53
	90% of BL	63.38	80.79	77.95	62.87	79.67	77.42
	85% of BL	65.65	78.98	81.28	65.63	78.26	80.96
Mean		62.78	80.70	77.73	62.46	79.97	77.30
4 L sec-1 m-1	100% of BL	60.69	81.84	73.20	60.11	78.91	73.91
	90% of BL	68.44	80.26	78.33	67.63	78.26	79.11
	85% of BL	71.48	77.23	82.29	71.34	76.52	83.08
Mean		66.87	79.78	77.94	66.36	78.22	78.70
Seasonal mean of cut-off	100% of BL	59.06	75.65	73.32	58.45	75.03	73.82
	90% of BL	64.36	74.64	77.31	63.96	73.77	77.74
	85% of BL	67.15	72.34	80.80	66.77	72.18	81.29

Water distribution efficiency (Ewd, %)

Presented data in Table 4 and Fig. 3 show that the highest values of water distributed efficiency (82.34 and 81.99 %) were recorded with cut-off irrigation at 100% of border length under water discharge 3.5 L sec^{-1} m^{-1} during the1st and 2nd seasons, respectively, followed by irrigation discharge 4 L sec^{-1} m^{-1} and the same above cut-off during both seasons. While, the lowest values of water distribution efficiency (60.81 and 61.79 %) were resulted from cut-off irrigation at 85% of border length under irrigation discharge 2.5 L sec^{-1} m^{-1} during both seasons, respectively. It is obvious from the obtained data that the values of water distribution efficiency increased with increasing water discharge and decreased with increasing cut-off irrigation treatments during both seasons. These results are in the same agreement with those obtained by Mosalm (2009), Bochen et al (2013) and Amer (2011).

Consumptive use efficiency (Ecu, %)

Consumptive use efficiency is a parameter which indicates the capability of plants to utilize the soil water stored in the effective root zone. Data tabulated in Table 2 and Fig. 4 showed that the highest values of Ecu (82.29 and 83.08 %) were recorded during the1st and 2nd seasons, respectively, under cut-off irrigation at 85% of border length, with 4.0 L sec^{-1} m^{-1} water discharge .Therefore, by decreasing the applied water, the higher amount of irrigation water could be beneficially used by growing plants. On the other hand, the lowest values of Ecu (72.80 and 74.02%) were achieved from cut-off irrigation at 100% of border length under irrigation discharge of 2.5 L sec^{-1} m^{-1} during the1st and 2nd season, respectively. It is obvious that from the obtained data values of Ecu increased with increasing both of water discharge and cut-off irrigation treatments during both seasons .This finding is somewhat agreed with those obtained by Kassab and Ibrahim (2007) , Ibrahim and Emara (2009&2010) , Kassab (2012) .

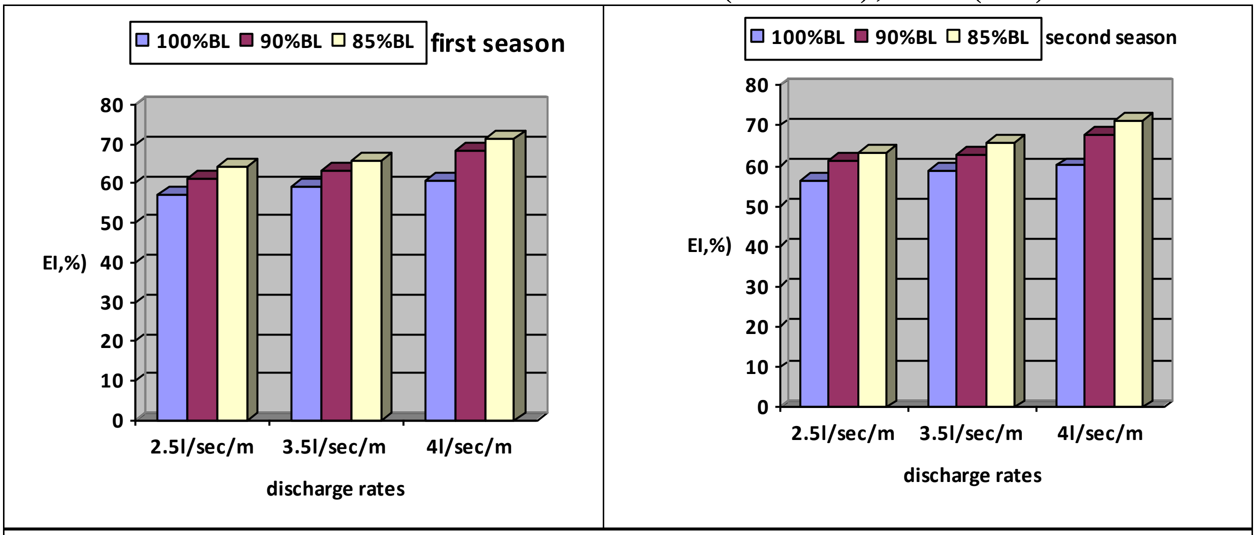

Fig.2 :Water irrigation application efficiency (EI, %) as affected by the combination of discharge rates and cut-off irrigation treatments during the two growing seasons

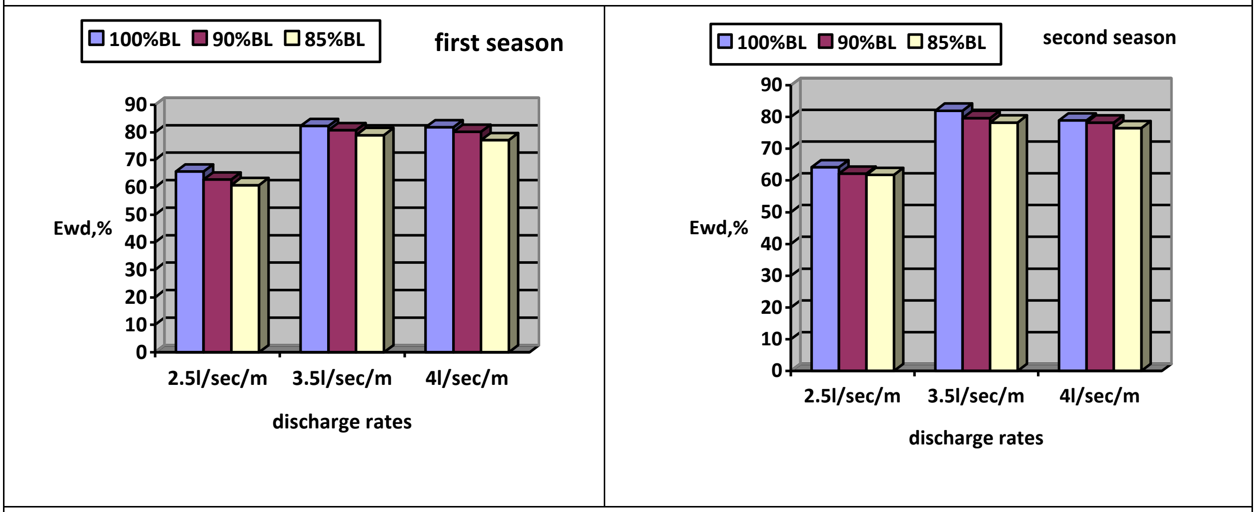

Fig.3 :Water distribution efficiency (Ewd, %) as affected by the combination of discharge rates and cut-off irrigation treatments during the two growing seasons

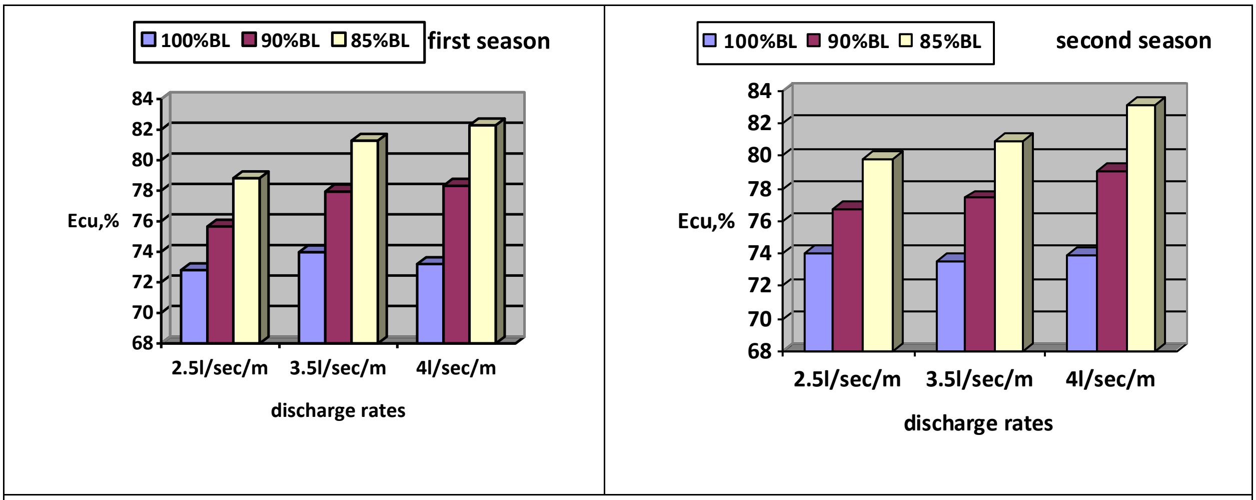

Fig.4 : Consumptive use efficiency (Ecu, %) as affected by the combination of discharge rates and cut-off irrigation treatments during the two growing seasons

Wheat yield and its components

Data in Table 5 show that irrigation discharge rates and cut-off irrigation treatments exerted a highly significant effect on grain weight /panicle (g) , 1000-grain weight (g) , grain yield (kg fed^{-1}) and straw yield (kg fed^{-1}) during both seasons .All the mentioned traits increased with increasing both of irrigation discharge and cut-off irrigation treatments during both seasons . The highest values of the abovementioned traits were recorded with 4.0 L sec^{-1} m^{-1} water discharge under cut-off irrigation at 85% of border length during both seasons. While the lowest ones were detected with 2.5 L sec^{-1} m^{-1} water discharge and cut-off irrigation at 100% of border length during both seasons .Also, data in Table 3 show that there were no significant effects on the most traits due to the interaction between water discharge and cut-off irrigation treatments, except grain yield which reached the level of significance during both seasons. These results are in accordance with those reported by Amer (2009), Kassab and Ibrahim (2007), Beshara (2012) and Moursi et al (2014)

Crude protein, % and NP-uptakes (kg fed^{-1})

Data in Table 5 show that irrigation discharge rates and cut-off irrigation treatments had a highly significant effect on crude protein and N,P-uptakes (kg fed^{-1}) by grain and straw of wheat during both seasons .All the mentioned traits increased with increasing both of water discharge rates and cut-off irrigation treatments during both seasons . The highest values of the aforementioned traits resulted from irrigation discharge of 4 L sec^{-1} m^{-1} and cut-off irrigation at 85% of border length treatments during both seasons .While the lowest values were recorded with 2.5 L sec^{-1} m^{-1} water discharge and cut-off irrigation at 100% of border length during both seasons .Also, data in Table (5) show that there was a significant effect on all traits due to the interaction between irrigation discharge rates and cut-off irrigation treatments during both seasons , except crude protein content and N-uptake during the2nd season which did not reach the level of significance . These results are in accordance with those reported by EL-Yamany (1994), EL-Sanat (2008), Mosalm (2009), EL-Zaher et al, (2001), Amer (2009) and Moursi et al, (2014)

Contribution of ground water to ETc-wheat crop (GWC):

Data presented in Table 6 and Figs. 5&6 shows that ground water Table contribution to wheat water needs was increased with increasing both irrigation discharge rates and cut-off irrigation during both seasons.

The seasonal mean values of GWC is affected by irrigation discharge since it increased from (0.91 and 0.86 cm) to (1.11 and 1.22 cm) and (1.49 and 1.44cm) for 2.5 ,3.5 and 4.0 L sec^{-1} m^{-1} discharge during the1st and 2nd seasons ,respectively. Meanwhile, the corresponding values are affected by cut-off irrigation and the mean values were (1.10 and 1.11cm), (1.14 and 1.18 cm) and (1.26 and 1.23 cm) for cut-off irrigation at 100%, 90% and 85% of border length during both seasons, respectively. It was noticed that the highest values of GWC resulted from 4.0 L sec^{-1} m^{-1} discharge rate under cut-off irrigation at 85% of border length during both seasons. The most probable explanation for these findings is due to the fact that as the amount of applied water increased , the contribution of water Table was decreased .So, irrigating wheat plant with 4.0 L sec^{-1} m^{-1} discharge under cut-off irrigation at 85% of border length received the lowest applied water as mentioned previously(see Table 3) and therefore achieved the highest values of ground water contribution percent, during both seasons .These results are in somewhat in agreement with that obtained by Kahlown et al ,(2005) , Khalifa (2013) and Akmal Kh.Karimove et al ,(2014).

Economic evaluation

Data in Table 7 show that cut-off irrigation at 85% of border length under 4.0 L sec^{-1} m^{-1} discharge gave the highest values of total income (9832.2 and 10219.6 L.E/fed) , net income (6012.2 and 6369.6 L.E/fed) , net income from water unit for grain yield (1.97 and 2.14 L.E/fed) and net income from water unit for biological yield (2.61 and 2.79 L.E/fed) during the1st and 2nd seasons ,respectively, followed by 3.5 L sec^{-1} m^{-1} discharge and the same cut-off irrigation treatments . While, the lowest values for the abovementioned parameters were achieved by cut-off at 100% of border length under 2.5 L sec^{-1} m^{-1} discharge during both seasons.

Also, the data obtained show that cut-off irrigation at 85% of border length under 4.0 L sec^{-1} m^{-1} discharge gave the highest values of economic efficiency (1.20 and 1.27) for grain yield and (1.57 and 1.65) for biological yield during the1st and 2nd seasons, respectively. Meanwhile, the lowest values of economic efficiency have resulted from the combination of 2.5 L sec^{-1} m^{-1} and cut-off irrigation at 100% of border length (no cut-off) during both seasons.

Table 5: Wheat grain and straw yield, crude protein and NP-uptakes as affected by water discharge and cut-off irrigation during the two growing seasons.

Treatments	Grain yield , kg fed^{-1}	Straw yield , kg fed^{-1}	Grain weight/ panicle, g	1000-grain weight, g	Crude protein,%		N-uptake, kg fed^{-1}		P-uptake ,kg fed^{-1}	
					Grains	Straw	Grains	Straw	Grains	Straw
Water discharge (D)					1st season					
D1=2.5 L sec^{-1} m^{-1}	2553.35^{c}	4056.5^{b}	2.30^{b}	39.67^{c}	10.80^{c}	2.47^{b}	44.12^{b}	16.01^{b}	9.19^{b}	3.04^{c}
D2=3.5 L sec^{-1} m^{-1}	2707.0^{b}	4305.0^{b}	2.60^{ab}	42.0^{b}	11.02^{b}	2.45^{b}	47.72^{b}	16.95^{b}	10.09^{b}	3.52^{b}
D3=4.0 L sec^{-1} m^{-1}	2896.88^{a}	4672.5^{a}	2.96^{a}	45.32^{a}	11.32^{a}	2.69^{a}	52.45^{a}	20.26^{a}	11.08^{a}	4.32^{a}
F-Test	*	**	*	**	**	**	**	**	**	**
Cut-off irrigation										
C1=100%BL	2632.98^{b}	4266.5^{b}	2.58	40.58^{b}	10.97^{c}	2.47^{c}	46.26^{b}	16.88^{b}	9.71^{b}	3.49^{b}
C2=90%BL	2685.76^{b}	4214.5^{b}	2.58	42.92^{a}	11.05^{b}	2.54^{b}	47.51^{b}	17.41^{b}	9.97^{b}	3.50^{b}
C3=85%BL	2838.49^{a}	4557.0^{a}	2.69	43.42	11.11^{a}	2.60^{a}	50.51^{a}	18.93^{a}	10.68^{a}	3.89^{a}
F -Test	*	**	Ns	*	**	**	**	**	**	**
Interaction D×C	*	Ns	Ns	Ns	**	**	*	*	*	**
Water discharge (D)					2nd season					
D1=2.5 L sec^{-1} m^{-1}	2760.3^{b}	4095.0^{b}	2.94^{b}	43.06^{b}	11.31^{b}	2.82	49.79^{b}	20.24^{b}	10.10^{c}	3.15^{c}
D2=3.5 L sec^{-1} m^{-1}	2989.0^{a}	4388.3^{a}	3.22^{ab}	47.13^{a}	11.95^{a}	2.85	57.87^{a}	21.93^{a}	11.36^{b}	3.69^{b}
D3=4.0 L sec^{-1} m^{-1}	3031.0^{a}	4503.9^{a}	3.39^{a}	48.41^{a}	11.96^{a}	2.86	57.89^{a}	22.54^{a}	11.69^{a}	4.28^{a}
F-Test	**	**	*	**	**	Ns	**	**	**	**
Cut-off irrigation										
C1=100%BL	2805.2^{c}	4204.9^{b}	2.99^{b}	44.84^{b}	11.49	2.75^{b}	51.76^{b}	20.22^{b}	10.43^{c}	3.47^{b}
C2=90%BL	2888.2^{b}	4281.92^{b}	3.23^{a}	46.51^{a}	11.76	2.92^{a}	54.34^{b}	21.94^{a}	10.97^{b}	3.65^{b}
C3=85%BL	3087.0^{a}	4500.32^{a}	3.33^{a}	47.25^{a}	11.97	2.86^{ab}	58.46^{a}	22.55^{a}	11.75^{a}	4.01^{a}
F -Test	**	**	**	**	Ns	**	**	**	**	**
Interaction D×C	*	Ns	Ns	Ns	Ns	Ns	Ns	Ns	**	**

Table 6: Ground water contribution to ETc of wheat as influenced by different treatments during the two growing seasons.

Irrigation discharge	Cut-off irrigation at 100%BL		Cut-off irrigation at 90%BL		Cut-off irrigation at 85%BL		Seasonal mean of irrigation discharge	
	GWC,cm	GWC,%	GWC,cm	GWC,%	GWC,cm	GWC,%	GWC,cm	GWC,%
			1st season					
2.5Lsec^{-1}m^{-1}	0.89	26.28	0.91	26.97	0.93	27.74	0.91	26.99
3.5 Lsec^{-1}m^{-1}	1.05	30.88	1.09	32.00	1.18	34.88	1.11	32.59
4.0 Lsec^{-1}m^{-1}	1.37	40.24	1.43	42.03	1.46	53.95	1.49	45.41
Seasonal mean of cut-off irrigation	1.10	32.47	1.14	33.67	1.26	38.86		
			2nd season					
2.5Lsec^{-1}m^{-1}	0.79	31.36	0.86	34.03	0.92	36.29	0.86	33.89
3.5 Lsec^{-1}m^{-1}	1.15	43.57	1.22	47.74	1.29	50.41	1.22	47.24
4.0 Lsec^{-1}m^{-1}	1.38	53.86	1.46	56.82	1.48	57.40	1.44	56.03
Seasonal mean of cut-off irrigation	1.11	42.92	1.18	46.20	1.23	48.03		

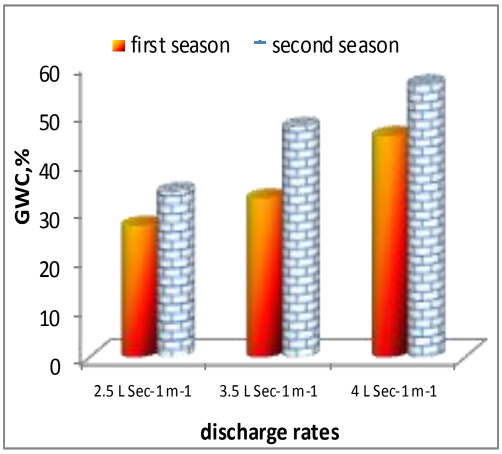

Fig.6: Seasonal mean of ground water Table contribution (%) to wheat crop as affected by discharge rates during the two growing seasons.

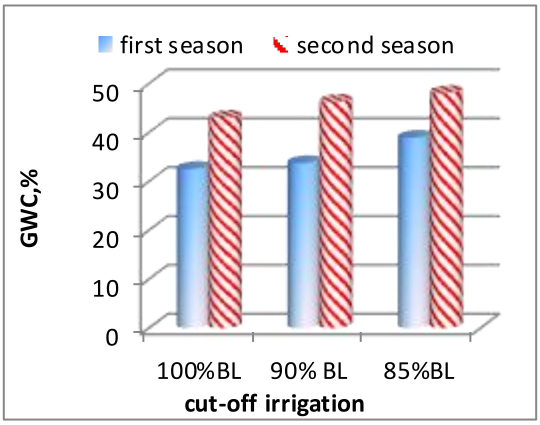

Fig.7: Seasonal mean of ground water Table contribution (%) to wheat crop as affected by cut-off irrigation during the two growing seasons.

Table 7: Total income, Net income, Net income from water unit and economic efficiency of wheat crop as affected by different treatments during the two growing seasons.

Treatments		Income ,L.E/ fed for		Total income L.E/fed	Total Coast L.E/ fed	Net Income L.E/ fed	Applied Water L.E/ fed	*Net income From water unit L.E/fed		** Economic Efficiency	
Irrigation discharge	Cut-off irrigation	Grain yield	Straw yield					Grain yield	Biological yield	Grain yield	Biological yield
					1st season						
2.5 L sec-1 m-1	100%BL	6673.8	1209.6	7883.4	3820	4063.4	2672.88	1.07	1.52	0.75	1.06
	90%BL	7147.3	1276.8	8424.1	3820	4604.1	2572.92	1.29	1.79	0.87	1.21
	85%BL	7627.2	1411.2	9038.4	3820	5218.4	2485.56	1.53	2.10	1.00	1.37
3.5 L sec-1 m-1	100%BL	7428.5	1357.44	8785.94	3820	4965.94	2573.76	1.40	1.93	0.94	1.30
	90%BL	7445.8	1290.24	8736.04	3820	4916.04	2460.78	1.47	2.00	0.95	1.29
	85%BL	7862.4	1485.12	9347.52	3820	5527.52	2371.32	1.70	2.33	0.95	1.45
4.0 L sec-1 m-1	100%BL	8012.76	1528.8	9541.56	3820	5721.56	2544.36	1.65	2.25	1.10	1.50
	90%BL	7967.4	1478.4	9445.8	3820	5625.8	2405.76	1.72	2.34	1.09	1.47
	85%BL	8353.8	1478.4	9832.2	3820	6012.2	2303.28	1.97	2.61	1.20	1.57
					2nd season						
2.5 L sec-1 m-1	100%BL	7186.2	1276.8	8463	3850	4613	2662.80	1.25	1.74	0.87	1.21
	90%BL	7471.8	1283.5	8755.3	3850	4905.3	2560.74	1.41	1.92	0.94	1.27
	85%BL	8526	1370.9	9896.9	3850	6046.9	2466.24	1.89	2.45	1.22	1.57
3.5 L sec-1 m-1	100%BL	8114.4	1368.9	9483.3	3850	5633.3	2592.24	1.65	2.17	1.11	1.46
	90%BL	8320.4	1382.3	9702.7	3850	5852.7	2467.92	1.81	2.37	1.16	1.52
	85%BL	8673.0	1461.6	10134.6	3850	6284.6	2369.22	2.04	2.65	1.25	1.63
4.0 L sec-1 m-1	100%BL	8261.4	1391.0	9652.4	3850	5802.4	2525.04	1.75	2.30	1.15	1.51
	90%BL	8467.2	1444.8	9912.0	3850	6062	2379.30	1.94	2.55	1.20	1.57
	85%BL	8731.8	1487.8	10219.6	3850	6369.6	2282.70	2.14	2.79	1.27	1.65

***Net income from water unit = Net income/ water applied (m^3 fed^{-1})**
**** Economic efficiency = Net income /total cost**

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تقييم تأثير كلا من معدلات التصرف وايقاف سريان مياه الري علي انتاجية محصول القمح وبعض العلاقات المائية في منطقة شمال الدلتا.

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أجريت تجربتان حقليتان بالمزرعة البحثية لمحطة البحوث الزراعية بسخا , محافظة كفر الشيخ خلال موسمين متتاليين 2014/2013 & 2014/ 2015. و الهدف من البحث هو دراسة وتقييم تأثير كل من 3 معدلات تصرف للري (2.5 ,3.5 ,4 لتر/ثانية/ م من عرض الشريحة) و 3 أطوال من شريحة الري الواجب ايقاف الري عندها (وقف الري عند 100% , 90% , 85% من طول الشريحة) تحت كل معاملة من معاملات الري – علي انتاجية نبات القمح ومكوناته وبعض العلاقات المائية (كمية الماء المضاف – الاستهلاك المائي – كفاءات استخدام المياه وكفاءة اضافة وتوزيع المياه وكذلك مساهمة الماء الأرضي في الأحتياجات المائية لمحصول القمح ثم التقييم الاقتصادي لنتائج هذه الدراسة. و أوضحت النتائج المتحصل عليها : أن أقل قيم للماء المضاف والاستهلاك المائي الموسمي و أعلي قيم لكلا من كفاءة استخدام الماء بواسطة المحصول وكفاءة اضافة الماء وكفاءة الأستهلاك المائي وانتاجية محصول الحبوب والقش. وكذلك نسبة البروتين ومعدل امتصاص النتروجين والفوسفور بواسطة الحبوب والقش , ومساهمة الماء الأرضي تم التحصل عليها عند معدل تصرف 4 لتر/ثانيه/م ووقف جبهة الري عند 85% من طول الشريحة ,علاوة علي زيادة النسبة المئوية لتوفير المياه لتصل لحوالي (9.6 %) . كما تحصل تحت هذه المعاملات علي اعلي قيم للناتج الكلي وصافي الناتج وصافي العائد من الوحدة المائية لكل من محصول الحبوب والمحصول البيولوجي لنبات القمح وأعلي كفاءة اقتصادية. لذلك يمكن أن نوصي بأن هذه الدراسة تلعب دورا مهما في تطوير نظام الري السطحي في الاراضي الطينية في منطقة شمال الدلتا.من خلال تقنيات ايقاف سريان مياه الري عند اطوال مختلفة من طول الشريحة (85%من طول الشريحة) ومعدلات التصرف (4لتر/ثانية/م) والتي أعطت أعلي عائد لمحصول القمح بالاضافة الي المساهمة الفعالة للماء الأرضي في الاحتياجات المائية لمحصول القمح , والتي لها اهمية عظمي كمصدر اضافي لمياه الري ,خاصة تحت ظروف نقص المياه في مصر