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WATER USE EFFICIENCY OF WHEAT UNDER DRIP IRRIGATION SYSTEMS AT AL – MAGHARA AREA, NORTH SINAI, EGYPT.

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ABSTRACT

A field experiment was conducted during 2004/2005 season in El – Maghara Research Station, about 90 Km South El-Arish city, North Sinai Governorate, Egypt to study water use efficiency of three wheat varieties (i.e. Sakha 8 , Giza 7 and Giza 69) as affected by four irrigation applied rates by means of adding 4 L/h – 8 L/h on one line and on two lines. Statistically Split – Split plot design was used.

The results revealed that grain and straw yields of wheat were increased by irrigating with drip irrigation on the two lines of laterals GR with 4 L/h application rate. Meanwhile, the variety Giza 7 was superior in grain and straw yields compared with the other two varieties. Seasonal amount of water applied for wheat crop was about 2087 m^3/fed, as calculated by Penman – Montieth meteorological equation. Moreover, the highest grain yields were 2145, 2120 and 2085 Kg/fed. for Giza 7, Sakha 8 and Giza 69, respectively with the two lines of 4 L/h application rate. Water use efficiency for the three varieties expressed as Kg/m^3 of water consumed was increased using (S_3 = 4 L/h on 2 lines) treatment and the highest WUE values were 1.20, 1.17 & 1.13 Kg/m^3 for Giza 7, Sakha 8 and Giza 69, respectively.

Keywords: Water use efficiency, water consumptive use, drip irrigation rate, Wheat cultivars (i.e. Giza 7, Giza 69 and Sakha 8)

INTRODUCTION

Wheat is conlinered the main cereal crop in Egypt. The percentage of production amounted to 53.2% of total consumption and so Egypt imports about 46.8% of its need from wheat yearly. Therefore, special emphasis should be directed towards the desert, which accounts for more than 95% of the total area. A proper irrigation system (sprinkler or drip irrigation) is recommended in such area. The main constrain to implement these study is the amount of water available. It is well known that the water resources in Egypt are limited to the share of Egypt in the flow of the river Nile by 55.5 BCM ($x10^9$ m^3), the deep groundwater in the deserts (mostly non-renewable), and a small amount of rainfall in the northern coastal area and Sinai. Meanwhile, water demand is continually increasing due to population growth, industrial development, and the increase of living standards. Because of population growth, the per capita share of water has dropped dramatically to less than1000 (≈ 700) m^3/capita, which, by international standards, is conlinered the "water poverty limit". The value may even decrease to 584 m^3/capita in the year 2025.

Dawood and Kheiralla (1994) stated that irrigation treatment had highly significant effect on plant height. It could be noted that average height of plants was described with imposing more water stress on plant. They added that the species Sakha 69 showed an increase of 13.5% spike/m^2 and

14.8% for the grain yield/fed. Ehdaie (1995) found that drought at boot stage and after anthesis reduced plant height by 16% and harvest index by 9%. Tomar et al. (1993) pointed out that wheat responded significantly to irrigation levels. Six irrigations increased grain and straw yields, followed by 4, 2 and 1 irrigations. They added that the variety HD 239 gave significantly the highest number of ears, and 1000 – grain weight followed by WH 147 and HD 1553. Doorenbos and Kassam (1986) reported that, in suitable climates, good wheat seed yields under irrigation ranged between 4 and 6 ton/ha. The water requirements of wheat ranged from 450 to 650 mm, depending on climate and length of total growing period (140 days). Evapotranspiration increases from establishment to flowering, and can be as high as 5 to 6 mm/day. They reported that the water utilization efficiency for harvested yield of seeds containing 12 to 15 percent moisture is about 0.8 to 1.0 Kg / m^3. The aim of this work is to study the possibility of enhancing water use efficiency of three wheat varieties (i.e., Sakha 8 , Giza 7 and Giza 69) under four irrigation application rates by means of 4 L/h and 8 L/h on one line and on two lines in sandy soils under desert conditions at El-Maghara, North Sinai, Egypt.

MATERIALS AND METHODS

The present study was carried out through 2004/2005 season at El-Maghara area, about 90 Km South El-Arish city, North Sinai Governorate, Egypt for studying water use efficiency of three wheat varieties (i.e., Sakha 8, Giza 7 and Giza 69) under four drip irrigation application rates (i.e., 4 L/h – 8 L/h) on one line and on two lines treatments:

S_1 = Irrigation with 4 L/h. drippers on one line.
S_2 = Irrigation with 8 L/h. drippers on one line.
S_3 = Irrigation with 4 L/h .drippers on two lines.
S_4 = Irrigation with 8 L/h. drippers on two lines.

Wheat grown on non-saline soils was planted at a seed rate of 50 kg/feddan on November, 15, 2004. Wheat plants received 60 kg N/fed (as ammonium nitrate 33.5 % N) in three equal portions during the growth period i.e., 20, 40 and 60 days from cultivation; 31 kg P/fed. (as calcium super phosphate 15.5% P_2O_5) before cultivation and 48 kg K/fed. (as potassium sulphate 48% K_2O) in two equal portions simultaneously with the second and third portions of nitrogen, respectively.

Statistically, this work was designed as factorial experiment in a split-split plot design with two variables. The first variable of irrigation practices are allocated in the main plots, while the second variable is the three wheat varieties as sub-plots with three replicates. So, the experiment includes 36 plots, each plot area was (4x15 m). The amount of water suffice the evapotranspiration needs in this location which calculated by using the meteorological approach (i.e. Penman – Montieth equation) Allen *et al*. (1998) without leaching fraction.

The amounts of irrigation water were calculated as follows:

$$D_{iw} = (ETo \times Kc \times D) / Ea$$

Where : (Dorrenbos and Pruitt, 1984)

D_{iw} = Applied irrigation water , (mm)

ETo = Potential evapotranspiration (mm / day)
Kc = Crop coefficient .
Ea = Irrigation system efficiency, (%) .
D = Depth, (mm).

Table (1) shows the irrigation water amounts.

Table (1) Computed daily irrigation water amounts in EL-Maghara area.

Months	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Average	m^3/fed/season
Irrigation water amounts (m^3/fed/day)	1.79	5.37	9.83	23.48	26.72	25.80	15.50	2087

The physical and chemical soil characteristics of the studied site are recorded in Tables (2 a, b) and were determined according to Richards (1954). The soil has loamy sand (LS) texture and non-saline and non-alkali class. The analysis of irrigation water given in Table (3) revealed that it belongs to high salinity, medium sodium, i.e., C_4S_2 water class.

Saline ground water (about 2600 ppm) was used for irrigation in drip system which the chemical analysis of irrigation water was carried out using the standard methods of Rainwater and Thatcher (1960), Table (3).

Table (2_a) Some Soil physical & chemical properties of El-Maghara location.

Depth (cm)	Particle size distribution %				Texture Class	$CaCo^3$ %	Bulk density (g/cm^3)	Moisture content %	
	Coarse Sand	Fine Sand	Silt	Clay				Field Capacity	Wilting Point
0-20	12.91	61.97	20.21	4.91	L.S.	17.25	1.66	10.96	4.56
20-40	15.22	63.58	18.21	4.99	L.S.	14.52	1.69	10.58	4.45
40-60	17.11	61.44	17.31	4.14	L.S.	15.58	1.68	10.02	4.70
60-80	14.19	66.04	15.22	4.55	L.S.	15.08	1.67	10.88	4.88
-100	20.15	61.55	14.11	4.19	L.S.	16.39	1.66	10.33	4.87
>100	23.22	56.34	16.61	3.83	L.S.	14.50	1.65	10.55	4.89

Table (2_b) Soil chemical properties of El-Maghara location.

Depth (cm)	E.C. (dSm^{-1})	pH	Cations me/l				Anions me/l			
			Na^+	K^+	Ca^{++}	Mg^{++}	Co^{3--}	HCo^{3-}	Cl^-	So^{4--}
0-20	0.76	7.9	0.72	0.31	2.81	3.76	0	0.30	3.22	4.08
20-40	0.67	7.9	0.73	0.30	2.82	2.85	0	0.32	3.09	3.29
40-60	0.49	7.8	0.65	0.29	1.89	2.06	0	0.28	2.81	1.81
60-80	0.50	7.8	0.61	0.32	2.71	1.36	0	0.28	2.85	1.87
-100	0.36	8.0	0.50	0.28	1.92	0.90	0	0.26	1.82	1.85
>100	0.43	8.0	0.42	0.28	1.89	1.71	0	0.28	1.89	2.13

Table (3) Chemical analysis for irrigation water

EC (dSm^{-1})	pH	Anions meq/l				Cations meq/l			
		SO^{4--}	Cl^-	HCO^{3-}	CO^{3--}	K^+	Na^+	Mg^{++}	Ca^{++}
4.06	8.36	3.57	32.2	4.4	-	0.69	24.6	3.48	11.4

To determine the actual water consumption the soil moisture content was determined gravimetrically and hence the crop water consumptive use was calculated by the following equation:

$ETa = (M._2 \% - M._1 \%) \times d_b \times D$

Where: Doorenbos and Pruitt (1984)

ETa = Actual evapotranspiration, mm.

$M._2$ = Moisture content after irrigation, % .

$M._1$ = Moisture content before irrigation, % .

d_b = Bulk density of soil, g / cm^3

D = Depth, mm.

Water use efficiency as kg/m^3 was calculated by dividing the grain yield on the amount of seasonal actual evapotranspiration (Giriappa, 1983). At harvest on April 4 $^{th.}$ in 2005, after 140 days from sowing of wheat plants, yield, yield components and plant characters were recorded and determined. Plant height (cm.), Leaf area (cm^2) (L x W x 0.75), number of spikes/m^2, spike length (cm.), number of grains/spike, weight of grains/spike (gm), weight of 1000-grain, grain yield in kg/fed. and straw yield (kg/fed.), were determined. Data were subjected to the analysis of variance of the split split plot design (ANOVA and L.S.D. at 0.05) according to the method described by Snedecor and Cochran (1989).

RESULTS AND DISCUSSION

The data obtained from this study will be presented and discussed as follows:

Growth Characteristics and Yield Components:

Table (4) presents the achieved plant height (cm), flag leaf area (cm^2) and number of spikes/m^2 for the whole treatments. From the table, it can be note:

1- Statistical analysis show highly significant differences for different responses for the studied species for the applied irrigation treatments.
2- The S_3 (4 L/h on 2 line) for plant height show 2 nd. grade among all irrigation treatments which could reflect beneficial use from the distribution of water from the two dripper lines.
3- The case with leaf area seams to be habhazardeous.
4- Difference among tested species for leaf area seems to be inheritance.

Table (4) Effect of the applied treatments on plant characteristics and components of the studied wheat varieties.

Treatments	Plant height (cm)			Flag leaf area (cm^2)			Number of (spikes/m^2)		
	Wheat varieties			Wheat varieties			Wheat varieties		
Irrigation rates	Sakha 8	Giza 7	Giza 69	Sakha 8	Giza 7	Giza 69	Sakha 8	Giza 7	Giza 69
S_1	114.7	101.3	104.7	77.6	63.4	38.5	346.7	383.3	322.7
S_2	108.7	110.3	101.7	64.3	58.0	35.4	464.0	417.3	401.3
S_3	112.7	106.7	108.3	62.1	58.2	33.9	473.3	449.3	434.7
S_4	108.2	105.7	111.0	55.7	54.2	30.7	510.7	538.7	473.3

According to statistical analysis the magnitude of mean values is in the order: Sakha 8 > Giza 69 ≥ Giza 7 and $S_3 > S_4 > S_1 \geq S_2$ for plant height; Sakha 8 ≥ Giza 7 > Giza 69 and $S_1 > S_2 \geq S_3 > S_4$ for flag leaf area and Sakha 8 ≥ Giza 7 > Giza 69 and $S_4 > S_3 > S_2 > S_1$ for number of spikes/m^2.

The same trend was proved by Kruse et al. (1990), Henggeler (1991). This is to be expected since variety and irrigation increased both plant height and flag leaf area which reflected on number of spike/m^2 as indicated in Table (4). Here it should be noted that flag leaf area plays an important role in synthesizing and sinking metabolites in the spike. This in turn may lead to present trend.

The present trend is in harmony with those stated by Dawood and Kheiralla (1994) who found that average height of plants was decreased with imposing more water stress on wheat plants. Plant height at harvest reacted significantly to the different varieties studied. Accordingly, the average flag leaf area of the long spike varieties (Table 5) surpassed those, which belong to sakha 8 i.e. Giza 7 and Giza 69. The average flag leaf area is ranged from 114.7 to 101.3 cm. for long spike varieties, which subjected to Sakha 8 and Giza 69, respectively.

Table (5) indicate the yield parameters as weight of grains/spike (gr.), number of kernels/spike and spike length (cm.). From the table it can be conclude the following:

1- Statistical analysis show highly significant differences for all yield parameters.
2- Superiority of two lines irrigation rate than one line for number of spikes/m^2. Also, high flow rate give higher values than lower one.
3- Other yield parameters; i.e. number of kernels/spike and spike length give contraverse data, by means of higher values with one line than two lines and low irrigation rate than higher one.
4- So, the net result of these two contraverse indications has been stocked in the following yield components.

Table (5) Effect of the applied treatments on plant characteristics and components of the studied wheat varieties.

Treatments	Weight of grains/spike (gr.)			Number of (kernels/spike)			Spike length (cm.)		
	Wheat varieties			Wheat varieties			Wheat varieties		
Irrigation rates	Sakha 8	Giza 7	Giza 69	Sakha 8	Giza 7	Giza 69	Sakha 8	Giza 7	Giza 69
S_1	2.66	3.15	3.27	71.3	72.0	61.7	14.0	16.2	15.6
S_2	2.57	2.87	2.51	60.7	56.7	55.3	15.2	15.5	14.5
S_3	2.29	2.33	2.32	53.3	53.7	49.0	12.7	14.4	13.8
S_4	2.17	1.71	2.18	43.3	44.3	46.3	12.3	12.7	13.0

From the statistical analysis the magnitude of mean values are in the order: Giza 69 > Giza 7 > Sakha 8 for weight of grains/spike; Sakha 8 ≥ Giza 7 > Giza 69 for number of kernels/spike and Giza 7 > Giza 69 > Sakha 8 for spike length under irrigated by $S_1 \geq S_2 > S_3 > S_4$ for all.

This means that the response of varieties varied from one rate to another even through the long spike varieties (i.e. Giza 7) 16.2 cm in Table (5), with irrigation rate S_1. While the short one variety (i.e. Sakha 8 with irrigation rate S_4). The present trend is expected since drip irrigation rate favoured weight of grains/spike in Table (5), and number of Kernel per spike in Table (5), of Giza 7 variety with irrigation rate S_1.

However, for all the three studied varieties either the long spike ones responded to drip irrigation rates in their productivity. This trend is in general accordance with these obtained by Dawood and Hamad (1985). Also, the data emphasized the success production of the *T. durum* varieties such as Sakha 8, Giza 7 and Giza 69 under the new modern systems of irrigation in newly reclaimed soils. In addition, the present results showed clearly that good management of irrigation water i.e. rationalization by using the irrigation rates particularly the drip system controlled the wheat infection by rusts especially the yellow or strip rust to the sensitive variety, (i.e. long spike). This is to be expected since drip irrigation may contribute largely in decreasing relative humidity around wheat plants. This, in turn, decreased the infection with rusts. Whereas the reverse was true with regard to average weight of grains / spike, number of kernel/spike and spike length in Table (5). This trend is in harmony with those obtained by Abd El- Gawad et al. (1986), Guizar et al. (1995), Govil and Pandey (1995) and El- Karamity (1998).

Yield and Yield Components:

Table (6) shows the yield components as grain, straw and total biological yield. From the data it is clear the following notices:

1- Statistical analysis show highly significant differences for all yield and yield components.
2- Superiority of S_3 (4 L/h on two line) in producing the highest yield in all components; grains, straw and total biological yield. This means that on a long-term scale the smaller dose of irrigation water could be distributed efficiently along the two lines of drippers. However, S_4 (8 L/h on two lines) took the 2 nd. grade behind S_3 which support the previous note.
3- For one line irrigation design the high irrigation rate (8 L/h) is more efficient than lower rate may be it compensates the weak distribution of moisture under these conditions.
4- From the statistical analysis the magnitude of mean values are in the order: Giza 7 > Sakha 8 > Giza 69 and $S_3 > S_4 \geq S_2 > S_1$ for grain, straw and total biological yields.
5- The highest wheat variety is Giza 7 (i.e. 2.145 ton / fed. as the highest grain yield) when S_3 is used as an irrigation rate. The increase in grain yield reached 20.17 % comparing with the lowest one (i.e. 1.785 ton/fed.) Giza 69 when S_1 is used.

Table (6) Effect of the applied treatments on yield and yield components of the studied wheat varieties.

Treatments	Grain yield (Kg/fed)			Straw yield (ton/fed)			Biological yield (ton/fed)		
	Wheat varieties			Wheat varieties			Wheat varieties		
Irrigation rates	Sakha 8	Giza 7	Giza 69	Sakha 8	Giza 7	Giza 69	Sakha 8	Giza 7	Giza 69
S_1	1840	2025	1785	2.29	2.48	2.24	4.13	4.50	4.02
S_2	2035	2065	2010	2.49	2.52	2.46	4.52	4.58	4.47
S_3	2120	2145	2085	2.57	2.60	2.54	4.69	4.74	4.62
S_4	2050	2080	2000	2.50	2.53	2.45	4.55	4.61	4.45

This trend is in general accordance with those stated by Kruse et al. (1990). This because two lines drippers increased water uptake efficiencies from the more concentrated root system close to emitters. Also, plant height at harvest responded significantly to the type of varieties studied. These results are in harmony with those obtained by Masoud (1986), Dawood and Kherialla (1994) and El- Karamity (1998). Finally, good management of irrigation water by using different rates of irrigation is promising for higher productivity.

Grain quality:

Table (7) reveals the protein % of the resulted grain yield for the studied wheat varieties under different irrigation rates. From the table, it can be concluding:

1- Statistical analysis show highly significant differences for protein %.
2- Generally, higher protein % values were contributed mainly with lower irrigation flow rate, except for Giza 7 in one line treatment.
3- From the statistical analysis the magnitude of mean values are in the order: Giza 69 ≥ Giza 7 ≥ Sakha 8 and $S_1 \geq S_3 > S_2 > S_4$ for protein %.

This trend could be ascribed to the dilution of protein by the increased grain yield which produced by drip irrigation rate. Data showed that the long spike variety (i.e. Giza 69) was characterized by higher protein percentage (Tomar et al., 1993).

Seasonal Water Consumptive Use (ETa):

Statistical analysis show highly significant differences for water consumptive use of wheat (Table, 7). Data in the table show that the seasonal water consumptive use decreased by decreasing irrigation water applied rate and Sakha 8 variety. The lowest seasonal values of ETa for all treatments were obtained from the amount added by S_1 = 4 L/h one line treatment for Sakha 8 < Giza 7 < Giza 69, while the highest values of seasonal ETa were obtained form the amount rate added by S_4 = 8 L/h two lines irrigation water treatment for Giza 69.

In brief the magnitude of mean values is in the order: Giza 69 > Giza 7 > Sakha 8 and $S_4 > S_2 > S_3 > S_1$ for water consumptive use of wheat.

This trend is due to the amount of water available to plants in addition to the higher evaporation from the wet rather than dry soil surface and to the higher transpiration from plants as well as the amount of water needed for plant growth development and building plant tissues. Similar results were obtained by Ehdaie (1995) and Allen et al. (1998).

Water Use Efficiency (WUE):

Table (7) includes the calculated water use efficiency data. From the table it can be tackled another fact about the good management of irrigation water which is the high irrigation water use efficiency (WUE) which could be achieved by saving irrigation rates under drip system. Statistical analysis show highly significant differences and significant increases for water use efficiency of wheat. The average values in this respect ranged from 0.99 to 1.20 kg / m^3 as indicated in Table (7). The highest values of WUE were obtained from the amount rate added by S_3 = 4 L/h two lines irrigation water treatment in the order of Giza 7 > Sakha 8 > Giza 69. Lonescu (1996) emphasized similar results in this respect. So, it is suggested that these practices activate both water and nutrient consumptions by roots of plants which, increased crop yield, thus increased W.U.E. values.

In brief the magnitude of mean values is in the order: Giza 7 > Sakha 8 > Giza 69 and $S_3 > S_2 > S_4 \geq S_1$ for water use efficiency of wheat. Similar results were obtained by Girriapa (1983); Ehdaie (1995) and Allen et al. (1998).

Table (7) Effect of the applied treatments on protein %, water consumptive use and grain water use efficiency of the studied wheat varieties.

Treatments	Protein (%)			Water consumptive use (m^3/fed)			Grain water use efficiency (kg/m^3)		
	Wheat varieties			Wheat varieties			Wheat varieties		
Irrigation rates	Sakha 8	Giza 7	Giza 69	Sakha 8	Giza 7	Giza 69	Sakha 8	Giza 7	Giza 69
S_1	15.6	15.1	15.7	1750	1770	1795	1.05	1.14	0.99
S_2	15.3	15.6	15.2	1850	1900	1874	1.10	1.09	1.07
S_3	15.4	15.5	15.4	1815	1790	1845	1.17	1.20	1.13
S_4	15.1	15.3	15.3	1900	1926	1940	1.08	1.08	1.03

Economic Evaluation:

The feasibility study reported in Table (8) proved that cultivating wheat variety Giza 7 and irrigated by drip irrigation system with two lines of laterals GR (4 L/h) is advisable economically. This is because it is characterized by the maximum values of total return with regard to grain, straw yield, return cost ratio and net profit – cost ratio.

Table (8) Investment ratio of the best treatments of the studied wheat varieties.

Item	Unit	L.E/fed.
Costs:		
Irrigation system costs	L.E /fed/season	400
Irrigation water		521.75
Fertilizers		250
Operations		200
Seeds		100
Rent/fed/season		400
Total inputs		**1871.75**
Productivity:		
Av. Grain/yield	Ardab / fed.	13.84
Av. Straw/yield	Heml / fed.	12.67
Prices:		
Grain	L.E/Ardab	110
Straw	L.E/Heml	50
Total Return:		
Grain	L.E/fed.	1522
Straw	L.E/fed.	634
Total Return		**2156**
Net Return		284
Net Profit cost ratio (LE/ILE)		**1.15**

CONCLUSION

From the aforementioned discussion, it is suggested to cultivate wheat variety Giza 7 and irrigated by drip irrigation system with two lines of laterals GR (4 L/h) to obtain the highest water use efficiency of wheat at the same conditions these should be carefully evaluated to the studied area.

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كفاءة استخدام المياه للقمح تحت نظم الري بالتنقيط فى منطقة المغارة – شمال سيناء – مصر

جمال عبد الرحمن
قسم كيمياء وطبيعة الأراضي - مركز بحوث الصحراء - المطرية – القاهرة - مصر

أقيمت تجربة حقلية خلال موسم ٢٠٠٥/٢٠٠٤ فى محطة بحوث المغارة لدراسة كفاءة استخدام المياه لثلاثة أصناف من القمح (سخا ٨ ، جيزة ٧ & جيزة ٦٩) تحت أربعة معدلات ري بالتنقيط (تصرف نقاط ٤ لتر / ساعة ، 8 لتر / ساعة على خَطٍّ واحد وعلى خطين لكل منهما) فى تصميم قطع منشقة مرتين.

أظهرت النتائج زيادة محصول الحبوب والقش بالرى بنظام ٤ لتر / ساعة على خطين ، بينما تفوق صنف جيزة ٧ على الأصناف الأخرى ، كانت كمية مياه الرى المضافة ٢٠٨٧ متر مكعب للفدان فى الموسم والتى حسبت بمعادلة بنمان-مونتيث. علاوة على ذلك، كَانَ محصول الحبوبَ ٢١٤٥ ، ٢١٢٠ & ٢٠٨٥ كيلوجرام / فدان لكل من جيزة ٧ ، سخا ٨ & جيزة ٦٩ على الترتيب. كفاءة استخدام القمح للمياه زادت باستخدام نقاط ٤ لتر / ساعة وعلى خطين وكانت أعلى القيم ١,٢٠ ، ١,١٧ & ١,١٣ كجم/م٣ لكل من جيزة ٧ ، سخا ٨ & جيزة ٦٩ على الترتيب.

لذلك ينصح بأستخدام نقاطات ذات تصرف ٤ لتر/ساعة على جانبي خط الزراعة تحت ظروف منطقة الدراسة المشابهة.