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Pesponse of Some Wheat Varieties to Drought Stress Under Sandy Soil Conditions

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ABSTRACT

Two field experiments were conducted during 2010-2011 and 2011-2012 seasons in the Research and Production Station of the National Research Centre in El-Nubaria El-Behera Governorate, Egypt. The investigation aimed to study the response of some wheat varieties i.e. Sakha 93, Sakha 94, Giza 168 and Misr 1 to drought stress (irrigation with different levels of water supply <100% Irrigation Requirements, IR). The adopted water treatments were 100, 75 and 50% IR, which was corresponded to 2304, 1728 and 1152 m3 water/feddan/season, respectively. The results showed that yield characters were significantly reduced when the plants were subjected to drought in both seasons. The same trend could be observed concerning WUE. On the other hand, crude protein content in grains was increased by decreasing the amount of irrigation water. Moreover, significant differences were observed among the tested wheat varieties. The data clearly showed that Giza 168 variety was superior in grain yield compared to the other varieties. Therefore, it could be concluded that Giza 168 variety seemed to be more suitable under drought conditions and might be cultivated under the experiment conditions to achieve better results.

Key words: Drought Stress, Wheat Varieties, WUE, Biological Yield.

Introduction

Water is the most important component of life. It is rapidly becoming a critically scarce commodity for humans and their crops. Drought is one of the environmental stresses seriously limiting crop production in the majority of agricultural fields of the world and recent global climate change has made this situation more adverse (Al-Ghamdi, 2009). Drought affects morphological, physiological, biochemical and molecular processes in plants resulting in growth inhibition. The extent of these changes is dependent on the time, stage and severity of environmental stress (Cao *et al*., 2011). Plant responses to drought is a complex physical – chemical process, in which many biological macromolecules and micromolecules are involved, such as nucleic acids (DNA, RNA, micro RNA), proteins, carbohydrates, lipids, hormones, ions, free radicals and mineral elements (Ingram and Bartles, 1996).

Water stress at anthesis reduces pollination and thus less number of grains is formed per spike which results in the reduction of grain yield (Ashraf, 1998). Adequate water at or after anthesis period not only allows the plant to increase photosynthesis rate but also gives extra time to translocate the carbohydrates to grains (Zhang and Oweis, 1998) which improves grain size and thereby lead to increase grain yield. Decrease in growth rate is caused by reduction in radiation use efficiency when drought was imposed at various growth stages, such as tillering, booting, earing, anthesis, and grain development stages (Ashraf, 1998b). Better performance of crop depends upon availability of water during these stages (Ashraf *et al*., 1994; Sarwar, 1994 and Jamal *et al*., l996).

The effect of irrigation regimes on wheat productivity and water use efficiency (WUE) was investigated under subtropical arid conditions. Results showed that irrigation regimes significantly affected grain, straw and biological yields which were significantly increased as the volume of irrigation water increased. Irrigation regime of 9750 m3/ha recorded the highest WUE for grain, straw and biological yields. (Al-Barrak, 2006).

Turgor maintenance plays an important role in drought tolerance of plants which may be due to its involvement in stomatal regulation and hence photosynthesis. Plants generally accumulate some kinds of compatible solutes such as proline, betaine and polyols in the cytosol to raise osmotic pressure and thereby to maintain both turgor and driving gradient for water uptake. Errabll, *et al*. (2006) reported that proline plays an important role in the stabilization of cellular proteins and membranes in the presence of a high osmotic concentration. Forooq, *et al*. (2010) indicated that the accumulation of malondialdehyde (MDA), a product of fatty acid peroxidation, in plants due to cellular membrane lipid peroxidation is a measure of oxidative stress induced membrane damage during water stress. Development of stress tolerant varieties is always a main objective of many breeding programs, but success has been limited by adequate screening techniques, and the lock of genotypes that show clear differences in response to various environmental stresses. Therefore, wheat breeders are always looking for means and sources of genetic improvement for grain yield and other agronomic traits.

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Plant breeders are also adopting new technologies such as molecular markers to increase wheat grain yield under drought stress conditions.

The objectives of this study, therefore, were to screen wheat varieties with high yield potential, stability, yield components and quality traits under water stress conditions and to determine suitable selection criteria for selecting genotypes tolerant to drought stress conditions.

Materials and Methods

Two field experiments were carried out at the Agricultural Research and Production Station of the National Research Centre (NRC), El Nubaria Governorate, Egypt, during the two successive winter seasons 2010/2011 and 2011/2012, to study selecting tolerant genotypes of wheat to drought stress conditions in the newly reclaimed sandy soil. Soil sample was taken at depth 0 - 60 cm for physical and chemical analyses as described by Chapaman and Pratt (1978) (Table 1 and 2). Analysis of irrigation water is presented in Table (3).

Table 1: Physical and Chemical analyses of soil in the experimental site.

Depth	Chemical analysis				Physical analysis			Texture
	OM (%)	pH (1:2.5)	EC (dSm^{-1})	$CaCO_3$ %	Course sand	Fine sand	Silt+ clay	
0-20	0.65	8.7	0.35	7.02	47.76	49.75	2.49	Sandy
20-40	0.40	8.8	0.32	2.34	56.72	39.56	3.72	
40-60	0.25	9.3	0.44	4.68	36.76	59.40	3.84	

Table 2: Soil water characteristics.

Depth	SP (%)	F.C (%)	W.P (%)	A.W (%)	Hydraulic conductivity(cm/hr)
0-20	21.0	10.1	4.7	5.4	22.5
20-40	19.0	13.5	5.6	7.9	19.0
40-60	22.0	12.5	4.6	7.9	21.0

Table 3: Chemical characteristics of irrigation water.

pH	EC (dSm^{-1})	Cations and anions (meq/L)								SAR %
		Cations				Anions				
		Ca^{++}	Mg^{++}	Na^{+}	K^{+}	$CO3_{--}$	HCO3-	Cl^{-}	SO4--	
7.35	0.41	1	0.5	2.4	0.2	--	0.1	2.7	1.3	2.8

The split plot design with three replicates was used where the irrigation requirements (100%, 75%, and 50% IR) were distributed in the main plots while the wheat varieties were assigned in the subplots. Layout of experiment design: Sprinkler is a metal impact sprinkler 3/4" diameter with a discharge of 300 L^3h^{-1}, wetted radius of 12 m, and working pressure of 250 KPa and all details about the experiment design under solid set sprinkler system are shown as in fig. (1).

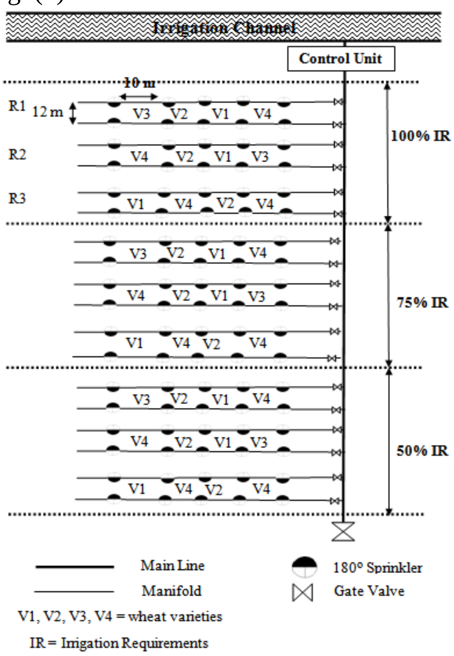

Fig. 1: Layout of Experiment Design under Solid Set Sprinkler System.

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The recommended doses of chemical fertilizers were added. Nnitrogen fertilizer was added at a rate of 80 kg /faddan as ammonium sulfate (20.6 % N) in three equal doses at 15, 30 and 45 days after sowing, while phosphorus and potassium were added during seed bed preparation at a rate of 100 kg/faddan for both calcium superphosphate (15.5 % P_2O_5) and potassium sulfate (48 % K_2O), respectively.

Total irrigation water (m^3/fed./season) was calculated from the meteorological data of the Central Laboratory for Agricultural Climate (CLAC) depending on Penman-Monteith equation , the seasonal irrigation water applied was found to be 2304 m^3/fed. (100 % IR), 1728 m^3/fed (75 % IR), and 1152 (50 % IR).as shown in Fig. (2).

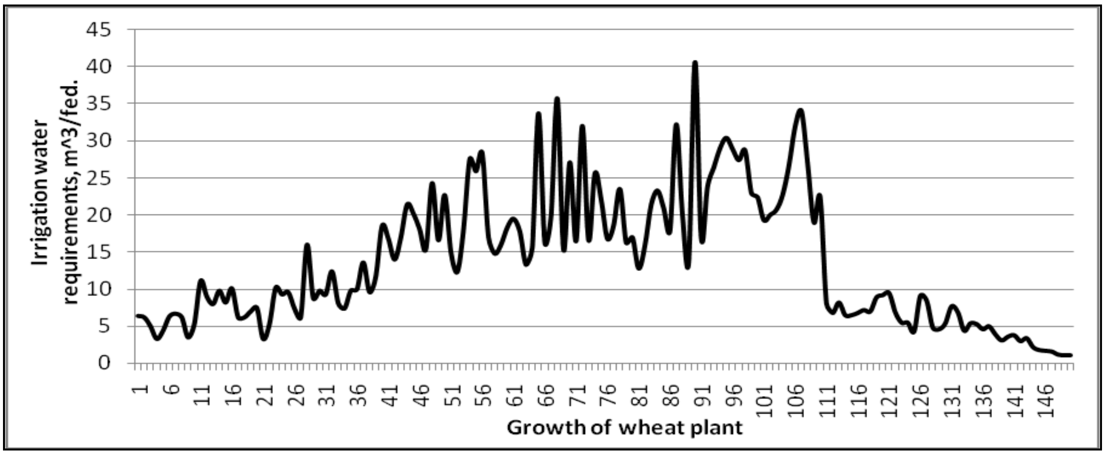

Fig. 2: The relation between growth of wheat plant and irrigation water requirements.

All other agricultural practices of growing wheat were conducted as usually done by the farmers in the district.

Data recorded:

Yield and yield attributes:

At harvest, a random sample of 25 X 25 cm was taken from each subplot to determine, grain, straw and biological yields in the mentioned area and then converted to yield (ton/fed).

Water use efficiency (WUE):

Was calculated according to (Stanhill, 1987) as follows: WUE $_{\text{wheat crop}}$ (kg $_{\text{grain}}$ /m^3_{water}) =Total yield, (kg/fed./season) / Total applied irrigation water, (m^3_{water}/fed./season).

Protein yield/ fed.:

Total N- content in seeds was determined and then protein% was calculated by multiplying N-content by 6.25 according to Chapman and Pratt (1978).

Statistical analysis:

Data were subjected to statistical analysis of variance as described by Snedecor and Cochran (1990) and the combined analysis of the two seasons results were conducted according to the method adopted by Steel and Torrie (1980). Mean values of the recorded data were compared by using the least significant differences (L.S.D 0.05).

Results and Discussion

1- Effect of Drought Stress on Grain Yield, Protein Content and Water Use Efficiency of Wheat:

Date shown in Table (4) reveal that decreasing the amount of irrigation water from 2302, to 1152 m^3/fed./season caused a significant reduction in the yields of grain, straw and biological per feddan in both seasons. it could be suggested that increasing water quantity applied to wheat plants led to keep higher moisture content in the soil, and this in turn might favored the plant metabolism that leads to the production of higher dry matter.

According to Hayat (2007) addition of adequate water decreased absisic acid and increased cytokinins, giberelline and indole acetic acid hormones, which reflecting good plant growth, good carbohydrate anabolism and finally attaining higher yield. In addition, Reddy *et al* (2004) pointed out that the photosynthetic rate in higher plants decreases more rapidly than respiration rate with increased water stress, since an early effect of water reduction in leaves is usually a partial or complete stomatal closure which markedly decreasing the movement of carbon dioxide into the assimilating leaves and reducing the photosynthetic rate up to ten times, according to the amount of water removal and the sensitivity of the plant. Similar results were obtained by Kandil *et al* (2001) and Raza *et al*. (2012).

The present data clearly show that protein content in wheat grains was significantly affected by different water treatments. Protein content was increased with increasing water stress (irrigation with 50% IR). This means that high water stress increased remarkably protein content. Similar results were also reported by Kandil *et al* (2001).

The obtained results reveal further that WUE expressed as a kg grains / m^3 of water consumed was significantly affected by the different water treatments.

It is obvious that irrigation with the highest amount of water (2304 m^3/fed.) resulted in higher WUE value as compared with the two other treatments in both seasons. Our results are in accordance with those of (Al-Barrak, 2006; Ashraf *et al*., 1994; Sarwar, 1994 and Jamal *et al*., l996).

Table 4: Effect of irrigation on grain yield, protein content and water use efficiency of wheat during grown the two seasons of 2010/2011 and 2011/2012.

Irrigation treatments (m^3/fed./season)	Biological yield (ton/fed.)	Straw yield (ton/fed.)	Grain yield (ton/fed.)	Protein content, (%)	WUE (Kg /m^3)
	First Season 2010-2011				
100% IR (2304)	4.301 a	2.788 a	1.513 a	8.65 c	0.657 a
75% IR (1728)	3.713 b	2.428 b	1.285 b	8.94 b	0.558 b
50% IR (1152)	3.225 c	2.167 b	1.050 c	9.51 a	0.456 c
	Second Season 2011-2012				
100% IR (2304)	4.728 a	2.911 a	1.667 a	8.56 c	0.724 a
75% IR (1728)	3.832 b	2.491 ab	1.344 b	8.92 b	0.584 b
50% IR (1152)	3.364 c	2.208 b	1.161 c	9.35 a	0.504 c

IR: Irrigation Requirements, WUE: Water Use Efficiency

2- Effect of Varieties on grain yield, protein content and water use efficiency of wheat:

The results given in Table (5) show that grain, straw and biological yields/fed and protein content in grains as well as WUE were significantly different among the four tested varieties. In this respect, Giza 168 was superior compared to the other ones, as it recorded the highest grain yield reaching 1.517 and 1.670 ton/fed. in the first and second seasons, respectively. The other characters followed the same trend as that of grain yield/fed. Such results might be due to the differences among the tested varieties in genetical makeup and response of each variety to the environmental conditions. Similar varietal differences were also reported by Kandil, *et al*. (2001) and Abedl-Hady and El-Naggar (2010).

Table 5: Effect of Varieties on grain yield, protein content and water use efficiency of wheat during the two grown seasons of 2010/2011 and 2011/2012.

Varieties	Biological yield (ton/fed.)	Straw yield (ton/fed.)	Grain yield (ton/fed.)	Protein content, (%)	WUE (Kg /m^3)
First Season 2010-2011					
Sakha 93	3.549 c	2.301 bc	1.248 c	9.02 b	0.542 c
Sakha 94	3.887 b	2.534 b	1.353 b	9.05 ab	0.587 b
Giza 168	4.47 a	2.944 a	1.517 a	9.22 a	0.658 a
Misr 1	3.079 d	2.065 c	1.013 d	8.83 c	0.440 d
Second Season 2011-2012					
Sakha 93	3.676 c	2.326 c	1.316 c	8.96 ab	0.571 c
Sakha 94	4.152 b	2.598 b	1.447 b	9.07 ab	0.628 b
Giza168	4.718 a	3.020 a	1.670 a	9.130 a	0.725 a
Misr1	3.352 d	2.203 c	1.129 d	8.84 b	0.490 d

WUE: Water Use Efficiency

3- Effect of Interaction between irrigation treatments and Varieties on Grain Yield, Protein Content and Water Use Efficiency of Wheat:

Concerning the interaction effects between the two investigated factors (irrigation treatments and wheat varieties), it could be noticed from Table (6) that in both seasons the interaction significantly affected all studied parameters except protein content. The most pronounced effect in grain yield was detected with Giza 168 plants irrigated with 100% IR. Moreover, greater performances were observed for such variety, than the other ones. On the other hand, the lowest grain yield was realized from Misr 1 plants when they were normally irrigated. or subjected to drought stress. The combined effect of irrigation and varieties on WUE was significant (Table 6).

Table 6: Effect of interaction between irrigation and varieties on grain yield, protein content and water use efficiency of wheat during the two growing seasons of 2010/2011 and 2011/2012.

Irrigation treatments (m^3/fed./season))	Varieties	Biological yield (ton/fed.)		Straw yield (ton/fed.)		Grain yield (ton/fed.)		Protein content, (%)	WUE (Kg /m^3)	
		First Season 2010-2011								
100% IR (2304)	Sakha 93	3.951	c	2.510	c	1.441	bc	8.587 N.S.	0.625	cd
	Sakha 94	4.470	b	2.907	b	1.563	b	8.747 N.S.	0.679	b
	Giza 168	5.329	a	3.498	a	1.831	a	8.907 N.S.	0.795	a
	Misr 1	3.454	ef	2.237	cde	1.215	e	8.343 N.S.	0.527	f
75% IR (1728)	Sakha 93	3.507	def	2.272	de	1.236	de	8.947 N.S.	0.536	ef
	Sakha 94	3.818	cd	2.463	c	1.355	cd	8.963 N.S.	0.588	de
	Giza 168	4.428	b	2.897	b	1.531	b	9.090 N.S.	0.665	bc
	Misr 1	3.098	g	2.079	ef	1.019	g	8.747 N.S.	0.442	h
50% IR (1152)	Sakha 93	3.187	fg	2.12	def	1.067	fg	9.537 N.S.	0.463	gh
	Sakha 94	3.373	efg	2.23	cde	1.14	efg	9.430 N.S.	0.495	fgh
	Giza 168	3.654	cde	2.436	cd	1.188	ef	9.670 N.S.	0.516	fg
	Misr 1	2.685	h	1.879	f	0.805	h	9.407 N.S.	0.350	i
		Second Season 2011-2012								
100% IR (2304)	Sakha 93	4.348	d	2.636	c	1.558	c	8.470 N.S.	0.676	c
	Sakha 94	5.102	b	3.008	b	1.817	b	8.700 N.S.	0.789	b
	Giza 168	5.662	a	3.557	a	1.965	a	8.823 N.S.	0.853	a
	Misr 1	3.798	e	2.442	cde	1.328	de	8.243 N.S.	0.576	de
75% IR (1728)	Sakha 93	3.442	f	2.252	def	1.251	ef	8.647 N.S.	0.573	ef
	Sakha 94	3.951	e	2.549	cd	1.348	de	8.930 N.S.	0.585	de
	Giza 168	4.639	c	2.945	b	1.640	c	8.970 N.S.	0.712	c
	Misr 1	3.298	f	2.22	efg	1.138	f	8.813 N.S.	0.494	f
50% IR (1152)	Sakha 93	3.239	f	2.090	fg	1.140	f	9.470 N.S.	0.495	f
	Sakha 94	3.403	f	2.237	efg	1.175	f	9.577 N.S.	0.510	f
	Giza 168	3.852	e	2.557	c	1.406	d	9.603 N.S.	0.610	d
	Misr 1	2.961	g	1.947	g	0.922	g	9.453 N.S.	0.400	g

IR: Irrigation Requirements, WUE: Water Use Efficiency

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