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Effect of drought stress and ascorbic acid foliar application on productivity and irrigation water use efficiency of wheat under newly reclaimed sandy soil

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ABSTRACT

A field experiment was carried out at the experimental Station of National Research Centre – El-Nubarya district, El-Behera Governorate, Egypt during two seasons of 2010/2011 and 2011/2012 to study the effect of drought stress (2504, 2003 and 1502 m^3/fed/Season) (100 % IR, 80 % IR and 60 % IR) and four foliar application levels of ascorbic acid (AA) (0.0, 100, 200 and 300 mg/L) and their interaction on yield, irrigations water use efficiency of wheat, protein content and protein yield under newly reclaimed sandy soil conditions Results indicated that water irrigation requirement varied significantly in all studied characters. The water irrigation requirement of (80 % IR) produced high grain yield per faddan and insignificantly outyielded the water irrigation requirements of (100 % IR). Increasing foliar application levels of ascorbic acid significantly increased grain and straw yields per plant and per faddan as well as protein content, protein yield, plant height, spike length, seed index, number of spikelet's per spike and water use efficiency. Results indicated that the interaction between water irrigation requirements and foliar application levels of ascorbic acid had significant effect on all studied characters. The interaction between the water irrigation requirements of (80% IR) and (300 mg/L) foliar application level of ascorbic acid gave the highest values of grain, straw and protein yields per faddan, water use efficiency and significantly outyielded the other all interactions. This means that we can save 20 % of irrigation water by using 80 % IR to irrigate the new lands under the conditions of this trail.

Introduction

Increasing cultivated of wheat production of unit area are the most important national objectives in Egypt for decreasing the gap between the production and population consumption. That could be achieved by improving agricultural practices especially in desert area such as irrigation and fertilizers. Wheat (*Triticum aestivium* L.) is considered the main cereal crop in the world as well as in Egypt. Therefore, increasing grain yield production is considered one of the most important national aims to face the great demand of the highly increasing human population. Wheat is considered the first strategic food crop in Egypt. It has maintained its position during that time as the basic staple food in urban areas and mixed with maize in rural areas for bread making. In addition, wheat straw is an important fodder (Gomma, 1999). In Egypt wheat plants are sometimes exposed to drought stress at different periods of growth. A possible approach to minimize drought stress that induces crop losses is the foliar application with chemical desiccant on wheat plants (Nicolas & Turner, 1993 and Gaballah & Mandour, 2000). Irrigation is used to maintain the soil moisture profile in the root zone to field capacity and satisfied evapotranspiration requirement of each crop on any area. Hussein (2004), Mousa and Abdel-Maksoud (2004), El-Afandy (2006) and Fang *et al*., (2006) found that subjecting wheat plants to drought –stress resulted in a significant reduction in grain yield and its components of wheat. Spray of vitamin C increased grain yield of wheat by influencing many physiological processes such as stimulates respiration activates, cell division and many enzymes activities as reported by Oertil (1987), Abd El-Hamed *et al*., (2004), Irfan *et al*., (2006) and Zewail (2007). Ascorbic acid (AA) is an organic compound required in trace amount to maintain normal growth in higher plants (Podh, 1990). AA influences mitosis and cell growth in plants (Noctor and Foyer, 1998; Smirnoff and Wheeler, 2000), affects phytohormone-mediated signaling processes during the transition from the vegetative to the reproductive phase as well as the final stage of development and senescence (Barth *et al*., 2006). Furthermore, AA affects nutritional cycle's activity in higher plants and plays an important role in the electron transport system (Liu *et al*., 1997). It is also important as a cofactor for a large number of key enzymes in plants (Belanger *et al*., 1995; Arrigoni and de Tullio, 2000). The potent impact of ascorbic acid on various areas of plant structure and function prompt many investigators to apply them to several crop plants aiming to control pattern of growth and development coupled with enhancement of systemic resistance against various hurtful agents which may appear in the surrounding environments. the beneficial effects of ascorbic acid upon growth and productivity have been reported on lemongrass (Tarraf *et al*., 1999); sugar beet (Salem *et al*., 2000); cucumber (El-Greadly, 2002), sweet pepper (Shawky, 2003) wheat (Abdel-Hameed *et al*., 2004).and on sunflower plants (El-Gabas (2006). Thus ascorbic acid could be expected to influence the growth and yield of wheat plants. Therefore, the present investigation was undertaken to study the impact of

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drought stress and spraying ascorbic acid, individually or in combination on some morphological criteria, yield as well as some biochemical constituents of wheat plants to improve growth, seed yield, grain quality and irrigation water use efficiency of wheat under newly reclaimed sandy soil conditions in Egypt.

Materials And Methods

A field experiment was carried out at the experimental Station of National Research Center – El-Noubarya Governorate during the two successive seasons of 2010/2011 – 2011/2012 to study the effect of drought stress and foliar application of ascorbic acid (AA) and their interaction on yield and its component of wheat under newly reclaimed sandy soil conditions. Soil sample was taken at depth of 60 cm for mechanical and chemical analyses as described by Chapaman and Pratt (1978) (Table 1, 2). Analysis of irrigation water is presented in Table (3).

The experimental design was split plot with three replicates. Water irrigation requirements (100% IR, 80% IR, and 60% IR) occupy the main plots and ascorbic acid treatments of (0.0, 100, 200 and 300 mg L) were allocated at random in sub-plots. Grains of wheat plants (*Triticum aestivum* L.) cv. Seds 12 were sown on the 15 November and the harvest date was 22 April in both seasons 2010/2011 – 2011/2012 and all details about the experiment design under solid set sprinkler system as shown as in fig. (1). the sprinkler is a metal impact sprinkler 3/4" diameter with a discharge of 1.17 m^3h^{-1}, wetted radius of 12 m, and working pressure of 250 KPa

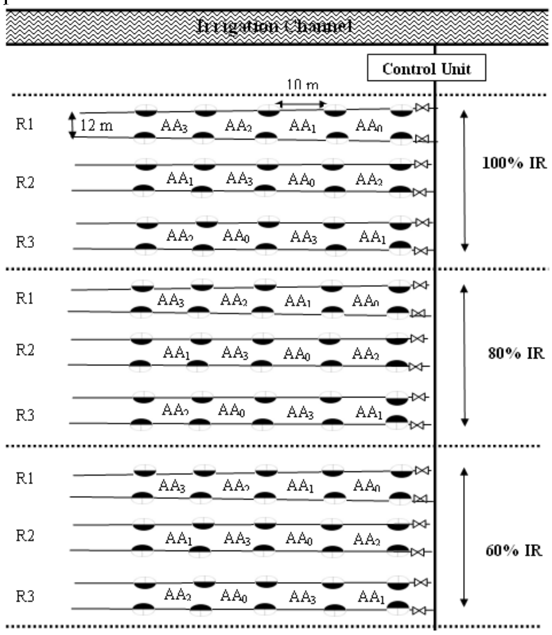

Fig. (1) Layout of Experiment Design under Solid Set Sprinkler System

Data Recording:

Total water irrigation (m^3 /fad./season) was estimated according to the meteorological data of the Central Laboratory for Agricultural Climate (CLAC) depending on Penman-Monteith equation. The seasonal water irrigation applied was found 2504 m^3 $fad.^{-1}$/season, 2003 m^3 $fad.^{-1}$/season and 1502 m^3 $fad.^{-1}$/season for 100% Irrigation Requirements, 80%IR, and 60%IR respectively.

The recommended agricultural practices of growing wheat were applied and the grain rate was 70 kg/fed. Pre-sowing, 100 (kg/fed.) of calcium super-phosphate (15.5 % P_2 O_5) was applied to the soil. Nitrogen fertilizer, 100 kg (N/fed.) of ammonium nitrate (33.5 % N) was applied at five equal doses before the first, third, fourth, fifth and sixth irrigations. Potassium sulfate (48.52 % K_2O) was added at two equal doses of 50 (kg/fed.) before the first and third irrigations.

Wheat plants were foliar sprayed with ascorbic acid at the concentration of 0.0, 100, 200 and 300 mg L. Combinations of the two factors were also applied. In both seasons, foliar application of ascorbic acid was carried out twice; the plants were sprayed with ascorbic acid after 30 and 60 days from sowing.

At harvest stage, the mean values of yield and yield characters, i.e., plant height, number of tillers/ plant, spikelet's/spike, spike length (cm), grain yield/ spike (g), grain index (100-grain weight (g)), grain, straw and biological yield per tiller (g) and per fed.

Irrigation water use efficiency ($IWUE_{Wheat}$) was calculated by using the following formula according to (James, 1988) as follows: $IWUE_{Wheat}$ (kg_{seed} /m^3_{water}) = Total yield, (kg_{seed} $fad.^{-1}$) / Total applied irrigation water, (m^3 $_{water}$ $fad.^{-1}$/season).

Total nitrogen was determined using the modified Micro-Kjeldahl method (A.O.A.C, 1988) and protein content (%) was calculated by multiplying N-content by 5.75 according to Chapman and Pratt (1978). Protein yield (Kg/fed) was calculated by protein content (%) X grain yield (kg/fed).

Combined analysis of data for two growing seasons was carried out according to Snedecor and Cochran (1990) and the values of least significant differences (L.S.D. at 5 % level) were calculated to compare the means of different treatments.

Results And Discussion

Effect of Drought Stress:

Results in table (4) reveal that there were significantly affected by drought stress in all studied characters under this trail. The results show that the grain yield of wheat (kg/fed.) was significantly affected by drought stress. It was observed that irrigation at 80 % IR significantly surpassed the irrigation at 60 % IR and 100 % IR respectively. This may be due to two factors, this factors happened in the same time. The first factor is volume of applied water and the second factor is concentration of nutrients in the root zone. In the case of increasing volume of applied water means, decreasing in the concentration of nutrients in the root zone hence, at 80% IR is the best case or suitable conditions. These conditions decreased from water stress or drought stress and also achieved excellent distribution for nutrients inside root zone. But at 100% IR we can get lowest water stress but we can not achieve excellent distribution for nutrients inside root zone because of increasing of leaching rate with increasing volume of applied water. At 60%IR is medium case between 80%IR and 100%IR. So, we found the highest values of plant height (cm), grain yield/ spike and 100 – grain weight (g) at 80 % IR, 60%IR and 100% IR respectively. Although the highest values of $IWUE_{wheat}$ were occurred at 60%IR (1502 m^3_{water}/season) but we can not apply with 60%IR because, there were significant difference in grain yield of wheat under 100%IR and 80%IR and 60%IR and this against with the definition of drought stress which say, (The manager needs to know the level of transpiration deficiency allowable without significant reduction in crop yields). The main objective of deficit irrigation is to increase the WUE of a crop by eliminating irrigations that have little impact on yield. The resulting yield reduction may be small compared with the benefits gained through diverting the saved water to irrigate other crops for which water would normally be insufficient under traditional

Table 1: Chemical and mechanical analyses of soil

Depth	Chemical analysis				Mechanical analysis			Texture
	OM (%)	pH (1:2.5)	EC (dSm^{-1})	$CaCO_3$ %	Course sand	Fine sand	clay + Silt	
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: Characteristics of soil

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^{+2}	Mg^{+2}	Na^{+}	K^{+}	CO^{-}_{3}	HCO^{-}_{3}	Cl^{-}	$SO^{=}_{2}$	
7.35	0.41	1	0.5	2.4	0.2	--	0.1	2.7	1.3	2.8

Table (4). Effect of drought stress on yield components, grain yield, irrigation water use efficiency of wheat, protein content and protein yield (combined data).

Drought Stress (m^3/fed. / season)	Plant height (cm)	No. of tellers /plant	Spike length (cm)	No. of spikelet's /spike	Biological yield /teller (g)	Grain yield /spike (g)	Straw yield /teller (g)	Grain index (g)	Straw yield (tons/fed)	Grain yield (kg/fed)	$IWUE_{wheat}$ (kg_{grain}/m^3_{water})	Protein content, %	Protein yield, kg/fed.
2504 (100% IR)	76.08	1.83	9.67	14.67	4.57	1.98	2.59	3.98	1.850	1157.63	0.46	8.87	102.70
2003 (80% IR)	80.33	1.00	9.92	16.33	5.30	2.58	2.72	4.85	2.550	1853.93	0.93	10.44	193.60
1502 (60% IR)	78.96	1.54	10.36	16.08	5.03	2.35	2.68	4.45	2.288	1521.28	1.01	8.62	131.12
LSD 0.05	1.78	0.16	0.50	0.86	0.10	0.16	0.10	0.02	0.032	63.06	0.21	0.23	5.33

Table (5). Effect of ascorbic acid treatments on yield components, grain yield, irrigation water use efficiency of wheat, protein content and protein yield (combined data).

Ascorbic acid (mg L)	Plant height (cm)	No. of tellers /plant	Spike length (cm)	No. of spikelet's /spike	Biological yield /teller (g)	Grain yield /spike (g	Straw yield /teller (g)	Grain index (g)	Straw yield (tons/fed)	Grain yield (kg/fed)	$IWUE_{wheat}$ (kg_{grain}/m^3_{water})	Protein content, %	Protein yield, kg/fed.
control	73.94	1.00	8.31	13.67	3.59	1.49	2.10	3.86	1.213	1216.94	0.65	8.71	105.95
100	77.83	1.39	9.67	15.44	4.39	2.21	2.19	4.47	2.067	1418.77	0.75	9.00	127.67
200	79.61	1.56	10.44	16.11	5.10	2.59	2.51	4.61	2.714	1551.44	0.82	9.55	148.09
300	82.44	1.89	11.50	17.56	6.77	2.92	3.85	4.76	2.922	1856.61	0.98	9.99	185.54
LSD 0.05	0.66	0.27	0.52	0.97	0.10	0.07	0.13	0.02	0.029	50.05	0.05	0.22	11.23

Table (6). Effect of interaction between drought stress and ascorbic acid levels on yield components, grain yield, irrigation water use efficiency of wheat, protein content and protein yield (combined data).

Drought Stress (m^3/fed/ season)	Ascorbic acid (mg L)	Plant height (cm)	No. of tellers /plant	Spike length (cm)	No. of spikelet's /spike	Biological yield /teller (g)	Grain yield /spike (g	Straw yield /teller (g)	Grain index (g)	Straw yield (tons/ fed)	Grain yield (kg/fed)	IWUE $_{wheat}$ (kg $_{grain}$ /m^3 $_{water}$)	Protein content (%)	Protein yield, (kg/fed.)
2504 (100% IR)	0	71.67	1.00	7.67	12.67	3.20	1.40	1.80	3.30	0.800	888.00	0.35	8.34	74.09
	100	76.00	1.67	9.33	14.67	3.93	1.77	2.17	4.10	1.600	1071.00	0.43	8.75	93.71
	200	77.67	2.00	10.33	15.67	4.63	2.13	2.50	4.20	2.400	1140.00	0.46	9.18	104.65
	300	79.00	2.67	11.33	15.67	6.50	2.60	3.90	4.30	2.600	1531.50	0.61	9.21	141.10
2003 (80% IR)	0	74.67	1.00	8.67	14.00	3.93	1.53	2.40	4.40	1.600	1535.00	0.77	9.54	146.44
	100	80.33	1.00	9.67	16.00	4.77	2.60	2.17	4.80	2.400	1753.20	0.88	9.91	173.74
	200	81.00	1.00	10.33	16.33	5.50	3.00	2.50	5.00	3.000	1954.00	0.98	10.73	209.73
	300	85.33	1.00	11.00	19.00	7.00	3.20	3.80	5.20	3.200	2173.50	1.09	11.59	251.84
1502 (60% IR)	0	75.50	1.00	8.60	14.33	3.63	1.53	2.10	3.87	1.240	1227.83	0.82	8.24	101.13
	100	77.17	1.50	10.00	15.67	4.48	2.25	2.23	4.52	2.200	1432.10	0.95	8.34	119.39
	200	80.17	1.67	10.67	16.33	5.17	2.65	2.52	4.62	2.743	1560.33	1.04	8.72	136.11
	300	83.00	2.00	12.17	18.00	6.82	2.96	3.85	4.78	2.967	1864.83	1.24	9.18	171.19
LSD 0.05		1.34	0.54	1.05	1.96	0.20	0.14	0.25	0.04	0.059	70.11	0.03	0.10	4.33

irrigation practices. Before implementing a deficit irrigation program, it is necessary to know crop yield responses to water stress, either during defined growth stages or throughout the whole season. Such results are agreement with this obtained by Vites, (1965), Shaddad *et al*., (1990), Sadek and Mikees (1997) and Salem (2005). So, our recommend was" cultivation wheat by applying 80%IR".

Effect of Ascorbic Acid:

Results presented in Table (5) indicated that the ascorbic acid treatments were significantly affected in all plant studied characteristics. Spraying ascorbic acid on wheat plants at the rate of (300 mg/L) surpassed the other treatment in grain yield (1856.61 kg/fed.). The application of ascorbic acid at 300- mg/L increased grain yield by 16.43, 23.58 and 34.45 % when compared to 200, 100 and unsprayed of ascorbic acid respectively,. These results may be due to the increase in plant height (cm), number of tillers /plant, spike length (cm), spikelet's number/ spike, grain yield/ spike and 100 – grain weight (g). Also, spray vitamin C influencing many physiological processes such as stimulates respiration activities cell division and many enzymes activities as reported by Oertil (1987), Hanna *et al*., (2001), Abd-El-Hamed *et al*., (2004), Irfan *et al*., (2006) and Zewail (2007). Or, the positive response of wheat plants may be due to that ascorbic acid activity of some enzymes which are important in regulation of photosynthetic carbon reduction (Helsper *et al*., 1982). In table (5) also, IWUE $_{wheat}$ increased by increasing concentration of ascorbic acid. The height value of IWUE $_{wheat}$ was 0.98 (kg $_{grain}$ /m^3 $_{water}$) at 300(mg L) and there are significant deference between this value and the others. This may be due to increasing yield of wheat which comes from the positive effect of ascorbic acid concentration.

Effect of Interaction between Drought Stress and Ascorbic Acid:

The data in Table (6) indicated that the interaction between drought stress and ascorbic acid were significantly affected in all plant studied characteristics. The results showed that ascorbic acid when sprayed on wheat plants with 300 (mg/L) at 80 % IR gave the highest value of grain yield (2173.50 kg/fed.). This increased in the grain yield due to the greatest values of plant height (cm), spikelet's number/spike, biological yield/teller (g), grain yield/spike and 100–grain weight (g). This may be due to three factors, the first factor is volume of applied water and the second factor is concentration of nutrients in the root zone and the third factor is spraying ascorbic acid on wheat plants. In the case of increasing volume of applied water means, decreasing in the concentration of nutrients in the root zone hence, at 80% IR is the best case or suitable conditions. These conditions decreased from water stress and also achieved excellent distribution for nutrients inside root zone and also the role of spraying ascorbic acid on plants. So, we found the highest values of plant height (cm), grain yield/ spike and 100 – grain weight (g) at 80 % IR, 60%IR and 100% IR respectively. Although the highest values of IWUE $_{wheat}$ 1.24 (kg $_{grain}$ /m^3 $_{water}$) were occurred at 60%IR (1502 m^3 $_{water}$/season) with 300 (mg L) of ascorbic acid but we can not apply with 60%IR because, there were significant difference in grain yield of wheat under 100%IR and 80%IR and 60%IR and this against with the definition of drought stress so, our recommend was" cultivation wheat by applying80%IR and 300 (mg/L) for spraying ascorbic acid on wheat plants.

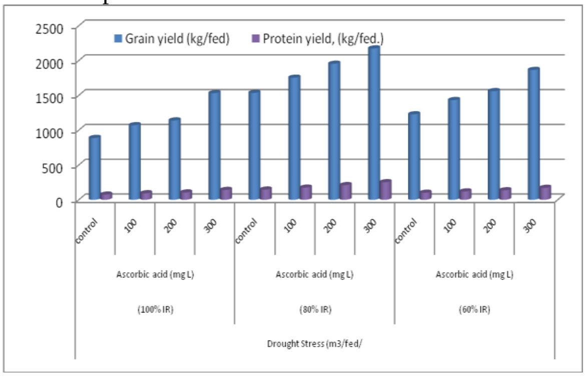

Fig (1): Effect of interaction between drought stress and ascorbic acid levels on grain yield and protein yield (combined data).

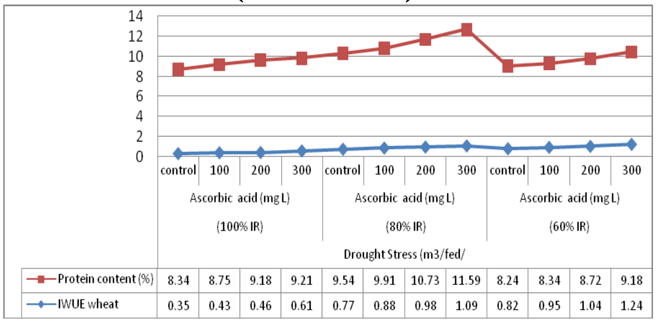

Fig (2): Effect of interaction between drought stress and ascorbic acid levels on protein content and water use efficiency of wheat (combined data)

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