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EFFECT OF SOME ANTITRANSPIRANT SUBSTANCES ON GROWTH, YIELD AND FLAG LEAF STRUCTURE OF WHEAT PLANT (*Triticum aestivum* L.) GROWN UNDER WATER STRESS CONDITIONS

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ABSTRACT

Two pot experiments were conducted during 2010/ 2011 and 2011/2012 successive growing winter seasons under greenhouse conditions at the Experimental Station, Faculty of Agriculture, Zagazig University, Sharkia Governorate, Egypt to evaluate the response of wheat plants (*Triticum aestivum* L.) cv. Sakha 93 to different levels of foliar application of some antitranspirant tested substances as Kaolin (Ka) at 4 and 6% , Magnesium carbonate ($MgCO_3$) at 6 and 10% and Fulvic acid (FA) at 160 and 320 ppm, with respect vegetative criteria, some physiological properties *i.e.* photosynthetic pigments, photochemical activity, yield components as well as anatomical structure of flag leaf blade grown under water stress conditions, 45% and 25% of water holding capacity (WHC). Data indicated that, all studied vegetative criteria of wheat plants, expressed as plant height (cm), leaf area (cm^2) and dry weight (g) of different plant organs were significantly decreased under water stress condition compared to 65% WHC (adequate water). Spraying antitranspirant substances seemed to partially overcome the harmful effects of water stress on the above mentioned characters of wheat plants compared with unsprayed plants. Significant decrements in the concentrations of photosynthetic pigments (chl.a+b and caroteniods) and photochemical activities were observed in fresh wheat leaves in response to water stress treatments. Also, application of tested antitranspirants significantly increased photosynthetic pigment concentrations and photochemical activities in leaves under water stress condition. Antitranspirants can overcome the deleterious effects of water stress compared with the untreated plants. Yield components *i.e.,* number of spikes/plant, number of grains/ spike, number of grains/plant, dry weight of grains/plant (g) and 1000-grain weight (g) were significantly decreased under water stress. Highest values were obtained under 65% WHC while low values were obtained under 25% WHC. Spraying water stressed plants with antitranspirant substances increased significantly vegetative criteria, photosynthetic pigments, photochemical activities and yield components compared with unsprayed ones. Fulvic acid (FA) at 320 ppm was the helpful one in improving these parameters but was still lower than those under 65% WHC. The data also indicated that, anatomical features of leaf blade decreased with increasing water stress level meanwhile, thickness of scalaranchyma tissue was increased. Foliar spray with antitranspirants under water stress condition improved all the histological features, except thickness of scalaranchyma tissue was decreased. FA specially at 320 ppm gave the best results compared to the untreated plants under the two levels of water stress. It could be recommended that, spraying FA at 320 ppm on wheat plant partially overcame the negative effects of water stress on vegetativ criteria, physiological propareties, yield components as well as anatomical structure of leaves.

Key words: Wheat plants, antitranspirant substances, anatomical structure, physiological analyses, growth criteria, water stress.

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INTRODUCTION

Wheat is the most important cereal crop. Its stable diet for the world population and contributes more calories and protein to the world diet more than only other cereal crop. It is grown on roughly 200 million hectares with an average production of 600 million tons (Rajarm and Braun, 2006).The cultivated area of wheat in Egypt is about 1.3 million hectares with an average production of 8 million tons (Anonymous, 2012).

Water deficit is a polygenic stress, considered as one of the main abiotic stress, limiting the productivity of wheat and causes significant alternations in plant physiology and biochemistry (Al-Meselamani *et al.,* 2012). It changes patterns of wheat plant growth and development, depressed water potential, cell division, organ growth, net photosynthesis, protein synthesis and alter hormonal balance of major plant tissue as mentioned by Guttieri *et al.* (2001) and leads to a loss in yield by reducing total biomass, membrane stability index, relative water content, chlorophyll content which directly or indirectly transfer their effects to number of spikes/plant, number of grains/spike and 100-grain weight (Al-Meselamani *et al.* 2011).

It's well known that only 5% of plant water uptake is used for its growth and development, while the remaining 95% is lost for transpiration. Actively growing plants would transpire a weight of water equal to their leaf fresh weight each hour under condition of arid and semi-arid regions if water is supplied adequately (Moftah, 1997). This figure makes it necessary to find way, by which available water could be economically utilized. One way achieve this goal is to reduce the transpiration rate in order to minimize the amount of irrigation water.

Antitranspirants are chemical substances with some biological activities could be applied on the transpiration surface of plant to reduce the transpiration rate and mitigate plant water stress by increasing the leaf resistance and diffusion water vapor.

Therefore, the present study was undertaken to investigate the effect of foliar application of three antitranspirants, i.e. Kaolin (Ka) at 4% and 6%, Magnesium carbonate ($MgCO_3$) at 6% and 10% and Fulvic acid (FA) at 160 and 320 ppm on vegetative criteria, some physiological and biochemical properties, anatomical structure of leaf blade as well as yield components of wheat plants grown under different levels of water stress.

MATERIALS AND METHODS

Pot experiments were carried out during the two successive growing winter seasons of 2010/ 2011 and 2011/2012, under greenhouse conditions at the Experimental Station, Fac. Agric., Zagazig Univ., Sharkia Governorate, Egypt, to study the effect of foliar application of antitranspirants as Kaolin (Ka), Magnesium carbonate ($MgCO_3$) and Fulvic acid (FA) on plant vegetative criteria, some physiological and biochemical properties, anatomical structure of wheat plants leaf blade as well as yield component of wheat plants(*Triticum aestivum* L.) cv. Sakha 93 grown under water stress conditions.

Wheat grains were obtained from Wheat Research Section, Crops Research Institute, Agriculture Research Centre, Giza. Grains were sown on the 29th November in both seasons in plastic pots 33 cm inner diameter and 25 cm in depth. Each pot contained 10 kg of air dried clay soil (Table 1).

Table 1. Mechanical and chemical analyses, of the used soil

Mechanical analyses			Chemical analyses										
			Cations mg/100g soil				Anion mg/100g soil						
Coarse Sand %	Silt %	Clay %	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	$CO3^{-}$	$HCO3^{-}$	Cl^{-}	$SO4^{-}$	$E.C^{a+}_{25c}$ ds/m (mmhos/cm)	PH Soil Reaction	W. H. C.
52.95	27.95	19.3	3.0	1.8	2.5	0.1	0.00	0.5	1.18	5.72	2.96	7.71	34.64

The treatments were 65% of water holding capacity (WHC) as plants received adequate water ; two levels of water stress as W1 (45%), and W2 (25%) WHC, and different levels of antitranspirants as Kaolin at 4 and 6%, Magnesium carbonate at 6 and 10% and Fulvic acid at 160 and 320 ppm as a foliar spray treatments. Fifteen grains/pot were sown at equal distances and depth. After two weeks from sowing, seedlings were thinned to eight seedlings /pot.

The recommended agricultural practices of growing wheat plants were applied and phosphorus fertilizer in the form of calcium super phosphate (15.5% P_2O_5) was mixed with the soil before planting at the rate of 1.8 g/pot. While, potassium and nitrogen fertilizers in the form of potassium sulphate (48% K_2O) and urea (46% N) were added individually with water irrigation after thinning at the rate of 1.3 g/ pot and 1.3 g/ pot , respectively.

After germination, pots were weighted daily and the needed amount of irrigation water was added.

Foliar applications of Kaolin , Magnesium carbonate as well as Fulvic acid were carried out three times using hand atomizer and wetting agent after 25, 45 and 65 days from sowing under W1 and W2 water stress conditions. Control plants were sprayed with distilled water and the volume of the spraying solution of the tested antitranspirant was maintained just to cover completely the plant foliage till drip.

The experiment included 15 treatments (5 pots for each) in 3 replicates, so the experiment contained 225 pots.

A random sample of three plants were taken from each treatment at 75 days old (booting stage) during each growing season to record plant vegetative characters and physiological properties.

Plant Vegetative Characters

Plant height (cm), blade leaf area (cm^2) of flag leaf on main stem), and dry weight/plant (g) of shoot, and root systems. Plant samples were dried using an electric oven with drift fan at 70°C for 48 h. till a constant weight was reached.

Physiological Properties

Photosynthetic pigments

The photosynthetic pigments (chlorophyll a, b and carotenoids) were extracted from fresh flag leaf on main stem samples (three samples, 0.1g for each) by pure acetone according to Fadeel's method (Fadeels, 1962). The pigments were filtered, the optical density of the filtrate was determined spectro-photo-chemically using the wave length 662, 644, 440.5 nm for Chl. a, Chl. b and carotenoids, respectively. The pigments contents (mg/g fresh weight) were calculated using the formula adapted by Wettestein (1957) as follows:-

Chl. a=(9.784xE 662) – (0.99 x E 644): in mg / liter.

Chl. b=(21.426 x E644)–(4.65xE 662): in mg / liter.

Carot. = (4.695 x E 440.5) – (0.268 x chl.a + chl.b): in mg/ liter.

Where: E is the reading of the optical density at given wave length. The concentrations of pigments were then expressed in mg/g fresh weight of leaves.

Photochemical activity

Photochemical activity in fresh flag leaf on main stem samples (three samples, 0.5g for each) were determined according to Jagendorf (1956) and modified by Avron (1960) using Ferricyanide 0.2g of fresh leaf tissues was ground with 1.5ml. phosphate buffer (pH 7.5) and then transferred to conical flasks.

Two ml of leaf tissue homogenate was transferred to a small beaker and 0.5ml of Ferricyanide was added and exposed to light for 10 minutes, then centrifuged at 3000; 4000 xg for 10 minutes. The optical density of supernatant was determined spectrophotometrically at 420 nm.

At the same time, the optical density of supernatant resulted from exposure the suspention to dark for 10 minutes was also spectrophotometrically determined. Chlorophyll concentration was also determined spectrophotometrically at 652nm. The photochemical activity was estimated as mM/g chl (micro mole /mg chl. Per 10 min.).

Yield and its Components

At harvesting stage, three random plants/ treatment were taken to record the values of yield components, *i.e.,* number of spikes/plant, number of grains/spike, number of grains/plant, dry weight of grains/plant (g) and1000-grain weight (g).

Anatomical Responses

At booting stage, through the second growing season, two plants/ treatment were subjected to anatomical studies. Specimens from the blades of flag leaves on the main stems were obtained from various treatments.

The specimens were kept for killing and fixation in FAA (10 ml. formalin, 5 ml glacial acetic acid, 85 ml ethyl alcohol 70%). The fixed materials were then washed in 50% ethyl alcohol, dehydrated in ascending concentrations of normal butyle alcohol series, then cleared in transferring concentrations of xylene and absolute alcohol. Finally specimens were embedded in pure paraffin wax of 56-60°C mp.

Sections at thickness of 14 micron (μ) were cut using a rotary microtome. Paraffin ribbons were mounted on slides. Sections stained with safranin and light green, then cleared in xylol before mounting in Canada balsam (Nassar and El-Sahhar, 1998). The prepared slides were examined with a light microscope equipped with a digital camera (canon power shot S80) connected to computer; the photographs were taken by zoom browsers ex. program.. Sections were examined to detected histological manifestations of the chosen treatments and photomicrographed. The following data were recorded in micron: thickness of blade, thickness of mesophyll tissue, thickness of midrib, width of midrib, thickness of midrib vascular bundle, Width of midrib vascular bundles, thickness of schalaranchyma tissue and width of schalaranchyma tissue.

Statistical Analysis

Data were subjected to statistical analysis according to Snedecor and Cochran (1990). Mean values were compared at $P< 0.05$ using the least significant different test (LSD).

RESULTS AND DISCUSSION

Plant Vegetative Parameters

Data presented in Table 2 showed that plant vegetative parameters in wheat plant were generally decreased by increasing water stress levels *i.e.,* the highest values were recorded with 65% of WHC (adequate water) and the lowest ones were obtained with 25% of WHC. These results are in accordance with those obtained by Khan *et al.* (2001) on maize, where they concluded that plant height, stem diameter, leaf area decreased noticeably with increasing water stress. On wheat plants, Golam and Goswami (2004), showed that plant height was significantly reduced under water deficit at crown root initiation (CRI) and tillering stages.

Water stress inhibits cell enlargement more than cell division. It reduces plant growth by affecting various physiological and biochemical processes, such as, translocation and growth promoters (Jaleel, *et al.,* 2008). It has been established that drought stress is a very important limiting factor at the initial phase of plant growth and establishment. It affects both elongation and expansion growth (Shao, *et al.*, 2008).

The reduction in plant height could be attributed to decline in the cell enlargement and more leaf senescence in the plant under water stress (Manivannan *et al.*, 2007).

It is interest to mention that drought stress caused in general a significant reduction in roots and shoots dry weight of wheat plants. In this respect, Ashraf *et al.* (1998) stated that water stress decreased plant dry weight in all affected wheat cultivars. Also, water deficit resulted in a decline in metabolic activity of plant cells, which could be inevitably reflected in inhibition of their growth. Gao ZhiHong *et al.* (2007) on winter wheat found that shoot dry weight reduced by soil water stress.

Results obtained by El-Tayeb and Ahmed (2010) on wheat plants showed that water stress reduced the dry weight of shoots and roots.

It is interest to mention that foliar application of Kaolin, Magnesium carbonate and Fulvic acid at tested concentrations promoted plant height, leaf area as well as dry weight of roots and shoots / plant of wheat compared to corresponding untreated plants under water stress conditions. In most cases, the increments in growth parameters were often significant in comparison with untreated ones.

In this respect, Fulvic acid at 160 ppm or 320 ppm was in general more effective than Kaolin and Magnesium carbonate treatments in increasing plant vegetative characters of wheat

Table 2. Effects of the interactions between foliar application with three tested antitranspirants and two levels of water stress on some plant vegetative parameters of wheat plant during 2010/2011 and 2011/2012 growing seasons

WHC	Treatments	Plant height (cm)		leaf area (cm^2)		Dry weight of roots /plant (g)		Dry weight of shoots /plant (g)	
		2010 /2011	2011/ 2012	2010 /2011	2011/ 2012	2010 /2011	2011/ 2012	2010 /2011	2011/ 2012
65 %	0.00	46.33	46.88	13.85	14.94	0.1059	0.1112	0.387	0.420
W1 (45%)	0.00	41.94	41.78	10.54	9.14	0.1118	0.1064	0.298	0.347
	Ka 4%	43.50	45.70	13.16	11.91	0.1134	0.1135	0.366	0.393
	Ka 6%	44.16	46.20	13.22	13.22	0.1139	0.1107	0.376	0.404
	$MgCO_3$ 6%	42.05	44.74	11.20	11.07	0.1091	0.1090	0.334	0.370
	$MgCO_3$ 10 %	42.33	45.44	11.46	11.53	0.1124	0.1119	0.361	0.386
	FA 160 ppm	45.28	47.66	13.27	13.53	0.1187	0.1159	0.379	0.410
	FA 320 ppm	45.94	49.52	15.65	13.90	0.1264	0.1188	0.383	0.412
W2 (25%)	0.00	26.11	26.24	4.32	4.80	0.0349	0.0618	0.133	0.110
	Ka 4%	30.22	30.54	6.61	6.71	0.0617	0.0584	0.233	0.254
	Ka 6%	30.88	31.33	7.96	6.77	0.0586	0.0549	0.185	0.269
	$MgCO_3$ 6%	28.78	29.40	5.31	6.21	0.0614	0.0595	0.236	0.233
	$MgCO_3$ 10 %	30.27	29.18	5.69	6.46	0.0604	0.0684	0.235	0.254
	FA 160 ppm	31.00	31.98	8.56	7.15	0.0593	0.0703	0.217	0.287
	FA 320 ppm	31.88	33.36	9.18	7.27	0.0723	0.0735	0.270	0.311
L.S.D	0.05	5.56	3.47	3.19	1.66	0.010	0.021	0.066	0.048

Abbr.: W (Water Stress), WHC (water holding capacity), 65% of WHC (plants received adequate water) control, W1 (45% of WHC), W2 (25% of WHC), 0.00. (plants were sprayed with distilled water), Ka (Kaolin), FA (Fulvic acid), $MgCO_3$ (Magnesium carbonate)

plants grown under water stress condition (45% and 25% WHC). The increment in plant height, leaf area, dry weight of roots and shoots/plant reached maximum values at 320 ppm of FA as compared to untreated plants. Kaolin at 6% occupied in general the second rank in increasing vegetative parameters. In this concern, many investigators found that low concentrations of Kaolin enhanced growth of wheat plants (Gaballah and Moursy, 2004 and Kachhadiya *et al.*, 2010). Magnesium carbonate at 6 and 10% recorded the lowest values of wheat plant vegetative parameters compared with other treatments of antitranspirants (Kaolin and Fulvic acid). However, these results indicated that antitranspirants have the potential effect help plant to a well- develope root system for vegetative and reproductive growth, similar findings were reported by Liang *et al.* (2002).

Also, Bafeel and Moftah (2008) showed that shoot and root dry weights of egg plant were significantly increased by foliar application of antitranspirants as compared with the control.

It is likely to mention that the antitranspirants overcame the adverse effect of water stress and generally gained positive effect on plant height, leaf area, dry weight of roots and shoots /plant comparing with corresponding untreated plants.

In conclusion, the adverse effects of water stress on the growth of wheat plants cv. Sakha 93 can be partially overcame by foliar spray of Kaolin at 6% and Fulvic acid (FA) at 160ppm and 320ppm.

Gaballah and Moursy (2004) carried out a pot trial on plants of two wheat cultivars grown under saline condition and treated with two types of reflecting ($MgCO_3$ and Kaolin). Data indicated that shoot length decreased by salinity levels while spraying with Kaolin or $MgCO_3$ increased shoot length compared with untreated plant.

Chitodkar *et al.* (2005) studied the effect of irrigation regimes and antitranspirant on summer groundnut. They indicated that antitranspirant treatments, including plastic film + Kaolin spray treatment recorded the highest 100 pod weight.

Leaf Pigments and Photochemical

Activity

The obtained results in Table 3 illustrated significant variations among water stress levels for the concentration of chlorophyll A+B, carotenoids and photochemical activity of flag leaves of wheat plant . The results showed that the highest values of chlorophyll A+B, carotenoids and photochemical activity were recorded with the treatment of 65% WHC, while, the lowest values of chlorophyll A+B, carotenoids and photochemical activity were recorded with the treatment W2 (25% WHC).

The above mentioned effect of drought stress on the concentrations of different photosynthetic pigments in plant leaves may be substantiated by the findings published by Farooq *et al.* (2009). They noticed that, drought stress produced changes in the ratio of chlorophyll a, b and carotenoids.

The limitation of photosynthesis under drought metabolic impairment is more complex phenomenon than stomatal limitation and mainly through reducing photosynthetic pigments contents (Reddy *et al.,* 2004). Drought stress decreases progressively CO_2 assimilation rates due to the reduction of stomatal conductance. Also drought stress induces reduction in the contents and activities of photosynthetic carbon reduction cycle enzymes, including the key enzyme, ribulose- 1, 5-bisphosphate carboxylase/ oxygenase. Drought stress caused a large decline in chlorophyll a, chlorophyll b, and total chlorophyll contents in different sunflower varieties (Kiani *et al.,* 2008 and Manivannan *et al.,* 2007).

Abdul Jaleel *et al.* (2009) recorded that, water deficit is one of the major abiotic stresses, which adversely affects crop growth and yield. These changes are mainly related to altered metabolic functions, one of those is either loss or reduced synthesis of photosynthetic pigments. These changes in the amounts of photosynthetic pigments are closely associated to plant biomass yield. The drought induced changes in morphological, physiological and pigments composition in higher plants.

The reduction of photosynthetic activity under drought stress may be due to stomatal or non-stomatal mechanisms (Del Blanco *et al.,* 2000 and Samarah *et al.,* 2009).

The obtained results concerning the effect of drought stress on photochemical activity of wheat leaves homogenate are in agreement with those obtained by Reddy *et al.* (2004).

Low water availability can also cause physical limitations in plants. Stomata are plant cells that control movement of water, carbon dioxide, and oxygen into and out of the plant. During moisture stress, stomata close to conserve water. This also cause closes the pathway for the exchange of water, carbon dioxide, and oxygen resulting in decreases in photosynthesis. Leaf growth will be affected by moisture stress more than root growth because roots are more able to compensate moisture stress (Jim, 2003).

Anjum *et al.* (2011) indicated that drought stress in maize led to considerable decline in net photosynthesis by (33.22%), as compared to well watered plants (control).

Spraying plants with Kaolin, $MgCO_3$ and Fulvic acid under water stress condition (45% and 25% WHC) showed significant differences in chlorophyll A+B, carotenoids and photochemical activity.

Generally, Kaolin and Fulvic acid were more effective than Magnesium carbonate in increasing the different photosynthetic pigments; as there was a gradual increase in chl. A+ b, carotenoids and photochemical activity with increasing applied concentration of Kaolin up to 6% and Fulvic acid up to 320ppm over their corresponding control (0.00 treatment). Similarly, Fu *et al.* (1994) indicated that application of FA to rape plant increased chlorophyll content and intensity of photosynthesis, this indicating that Fulvic acid may improve the drought-resistance capacity of the plant. Also, Tworkoski *et al.* (2002), revealed that the particle-film-type antitranspirant enhanced chl biosynthesis and increased the chl. content of bean leaves. The explanation suggested by Jifon and Syvertsen (2003), when demonstrated that Kaolin particle film increased leaf reflectance and reduced midday leaf temperature and increase photochemical activity and CO_2 assimilation.

Table 3. Effects of the interactions between foliar application with three tested antitranspirants and two levels of water stress on photosynthetic pigments Chl. (A+ B) and caroteniods as well as photochemical activity of wheat plant during 2010/2011 and 2011/2012 growing seasons

WHC	Treatments	Photosynthetic pigments Chl. A+ B		Caroteniods mg/g fresh leaves		Photochemical activity (Micromole/mg chl. per10min.)	
		2010 /2011	2011/ 2012	2010 /2011	2011/ 2012	2010 /2011	2011/ 2012
65 %	0.00	2.232	2.047	1.240	1.085	239.22	234.31
W1 (45%)	0.00	2.050	1.856	0.947	0.978	166.66	186.91
	Ka 4%	2.114	1.937	0.980	1.104	215.20	224.07
	Ka 6%	2.098	1.958	1.031	1.000	226.03	227.58
	$MgCO_3$ 6%	2.153	1.899	0.966	1.125	209.31	214.48
	$MgCO_3$ 10 %	2.075	1.904	0.939	1.113	222.85	223.09
	FA 160 ppm	2.174	1.980	1.222	1.223	224.23	228.54
	FA 320 ppm	2.191	2.003	1.189	1.086	229.49	232.39
W2 (25%)	0.00	1.836	1.345	0.938	0.727	116.78	111.90
	Ka 4%	1.951	1.604	1.039	0.952	131.81	131.81
	Ka 6%	1.972	1.607	0.884	1.031	141.12	141.77
	$MgCO_3$ 6%	1.928	1.500	0.951	0.911	129.12	131.54
	$MgCO_3$ 10 %	1.934	1.527	1.162	0.919	124.01	126.12
	FA 160 ppm	1.992	1.624	1.006	0.900	148.75	150.28
	FA 320 ppm	2.029	1.665	0.951	1.032	149.85	157.13
LSD	0.05	N.S.	0.181	0.217	0.110	24.45	19.51

Abbr.: W (Water Stress), WHC (water holding capacity), 65% of WHC (plants received adequate water) control, W1 (45% of WHC), W2 (25% of WHC), 0.00.(plants were sprayed with distilled water), Ka (Kaolin), FA (Fulvic acid), $MgCO_3$ (Magnesium carbonate)

Moftah and Al-Humaid (2004) reported that the application of both antitranspirants (Kaolin and Vapo Gard VG) was found to improve photochemical activity. However Kaolin particle film was found to have greater effect than VG.

Mao-Song *et al.* (2005) observed that spraying winter wheat plant with Fulvic acid antitranspirant increased chlorophyll content.

The interaction effects between foliar application with antitranspirants Kaolin, $MgCO_3$ and Fulvic acid as well as two levels of water stress (45% and 25%) on chlorophyll A+B, carotenoids and photochemical activity in fresh leaves, were studied. It was likely to mention that the three antitranspirants in most cases improved the bad effect of water stress and gained significantly the most chlorophyll content and photochemical activity compared with water stressed plants.

Furthermore, kaolin at 6% and Fulvic acid at 160 ppm and 320 ppm were more effective treatments in increasing chlorophyll A+B, carotenoids and photochemical activity under the two levels of water stress.

El-Kheir (2000) observed the effect of antitranspirant on wheat plants grown under two levels of water supply. He found that decreasing water supply caused significant reduction in photosynthetic pigments content (chlorophyll a, chlorophyll b, total chlorophyll a+b and carotenoids) in wheat leaves.

Yield Components

From the data in Table 4, it could be clearly noticed that increased water stress from W1 to W_2 resulted in a significant reduction in number of spikes/plant, number of grains/spike, number of grains/plant, dry weight of grains/plant and weight of 1000 grains.

Table 4. Effects of the interactions between foliar application with three tested antitranspirants and two levels of water stress on yield components of wheat plant during 2010/2011 and 2011/2012 growing seasons

WHC	Treatments	Number of spikes/plant		Number of grains/ spike		Number of grains/plant		Dry weight of grains /plant (g)		1000-grain weight (g)	
		2010/ 2011	2011/ 2012	2010/ 2011	2011/ 2012	2010/ 2011	2011/ 2012	2010/ 2011	2011/ 2012	2010/ 2011	2011/ 2012
65 %	0.00	2.80	2.81	36.66	41.27	102.64	115.96	3.91	4.41	38.10	38.02
W1 (45%)	0.00	1.65	1.89	33.00	33.92	54.45	64.11	1.96	2.28	35.94	35.59
	Ka 4%	2.00	2.33	33.66	36.55	67.32	85.16	2.46	3.12	36.49	36.64
	Ka 6%	2.56	2.79	34.44	36.19	88.17	100.97	3.25	3.74	36.81	37.06
	$MgCO_3$ 6%	1.78	1.56	32.88	34.79	58.53	54.27	2.13	1.98	36.35	36.50
	$MgCO_3$ 10 %	1.66	2.00	32.55	35.40	54.03	70.80	1.97	2.58	36.47	36.49
	FA 160 ppm	2.66	2.64	35.33	37.23	93.98	98.29	3.47	3.65	36.96	37.14
	FA 320 ppm	2.78	2.78	36.11	37.02	100.39	102.92	3.77	3.86	37.54	37.53
W2 (25%)	0.00	1.10	1.10	13.33	14.79	14.66	16.27	0.38	0.47	26.25	29.14
	Ka 4%	1.44	1.33	15.11	17.10	21.76	22.74	0.67	0.73	30.80	31.97
	Ka 6%	1.22	1.44	15.11	17.23	18.43	24.81	0.57	0.81	30.83	32.83
	$MgCO_3$ 6%	1.55	1.00	13.66	15.62	21.17	15.62	0.65	0.48	30.73	30.94
	$MgCO_3$ 10 %	1.00	1.22	14.66	16.27	14.66	19.85	0.45	0.62	30.50	31.16
	FA 160 ppm	1.66	1.67	16.44	17.83	27.29	29.78	0.85	0.98	31.06	32.89
	FA 320 ppm	1.76	1.78	17.88	18.14	31.47	32.29	0.98	1.07	31.10	33.03
LSD	0.05	0.372	0.252	1.48	5.42	10.43	13.66	0.782	0.932	2.54	3.33

Abbr.: W (Water Stress), WHC (water holding capacity), 65% of WHC (plants received adequate water) control, W1 (45% of WHC), W2 (25% of WHC), 0.00. (plants were sprayed with distilled water), Ka (Kaolin), FA (Fulvic acid), $MgCO_3$ (Magnesium carbonate)

Regardless significancy, the moderate water stress treatment W1 (45% WHC) reduced number of spikes/plant, number of grains/plant, 1000 grain weight comparable to 65% WHC as adequate water treatment in the first and second seasons.

The severe water stress treatment W2 (25% WHC) increased the reduction in yield components when compared to the control plants in the 1st and 2nd seasons. These decrements in yield components due to increasing water stress was accompanied by decreasing number of spikes/plant, number of grains/spike, number of grains/plant, dry weight of grains/plant and weight of 1000 grains.

According to the present study, water stress (45% and 25% of WHC) resulted in a significant decrease in wheat yield components as compared to the plants received adequate water (65% WHC). These observations are in full agreement with findings of Nakamura *et al.* (2003) and Golam and Goswami (2004) on wheat plants and Monneveux *et al.* (2006) on maize plants.

It was reported that water stress affected many physiological process that reduced growth and yield of wheat plant. Also, it decreased 1000 grain weight and grain yield (El-Banna *et al.*, 2002). Exposure maize plants to drought stress at teaseling stage, led to substantial reduction in yield and yield components (Anjum *et al.*, 2011). The deficiency of water leads to severe decline in yield traits of crop plants. This effect might be due to disrupting leaf gas exchange properties which not only limited the size of the source and sink tissues but the phloem loading, assimilate translocation and dry matter partioning are also impaired (Farooq *et al.*, 2009).

Regarding the effect of Kaolin at 4 and 6%, Magnesium carbonate at 6 and 10% and Fulvic acid at 160 and 320 ppm on wheat plants, grown under water stress conditions, it was noticed that Fulvic acid at both concentrations was more effective than other treatments in increasing yield and its component of wheat plants in both seasons. The increments in number of spikes/ plant, number of grains/ spike, number of grains/ plant, dry weight of grains/ plant and weight of 1000 grains reached maximum values at 320 ppm of FA compared to untreated plants under both W1 and W2 water stress.

Similar results were obtained by Mao-Song *et al.* (2005), they reported that the new antitranspirant FA increased wheat grain yield by 7.2% under the optimum concentration of 1.5 ml/litre compared with the water-treated control.

Concerning the interaction effect of antitranspirants treatments and water stress, spraying wheat plants with FA at the rate of 320 ppm overcame the adverse effect of water stress and significantly gained the yield components compared with the control (unsprayed plants).

In conclusion, the results showed that wheat yield components were markedly reduced under water stress conditions. Although, spraying plants with antitranspirants especially FA at 320 ppm was helpful in improving plant yield components under moderate water stress (W1 and W2) as compared to unsprayed control plants.

Anatomical Responses

Data presented in Table 5 and Fig. 1 showed that 65% of WHC as adequate water, increased thickness of leaf blade comparing with 45% and 25% WHC treatments due to a corresponding increase in thickness of mesophell tissue. In addition, thickness and width of midrib were increased due to increasing thickness and width of midrib vascular bundle, while thickness and width of scalaranchyma tissue were decreased. Data showed that water stress 25% & 45% of WHC decreased thickness and width of midrib due to decrease in the thickness and width of midrib vascular bundle. In addition, high water stress level (W2) markedly decreased leaf blade thickness, this reduction was due to decrease in thickness of mesophell tissue. Moreover, thickness and width of scalaranchyma tissue were increased. These results are in harmony with the findings of Khodos *et al.* (1976), El-Sharkawi *et al.* (1999) on wheat plant and El-Hadidi *et al.* (2007) on canola plant.

In this connection, Khafagy *et al.* (2009) on sweet papper plant stated that drought stress may have an inhibition effect on the activity of the various initial cells forming the leaf blade with regard to cell division and enlargement. Generally, the high level of drought stress caused a reduction in the conductive tissues of wheat plant. The decrease in mesophyll tissue, xylem and phloem leads to slow rate in the translocation of photoassimlates towards the developing grains. Furthermore, the decrease in size of vascular bundle in leaf blade result in lowering the accumulation of necessary water required for photosynthesis.

Application of the three tested antitranspirants at lower and higher concentrations under water stress conditions increased thickness of wheat leaf blade due to the increase in the thickness of mesophyll tissue compared with unsprayed plants.

In addition, the thickness of leaf blade through midrib region was also increased, due to increasing the size of vascular bundle. On the other hand, antitranspirants treatments decreased width and thickness of schalaranchyma tissue copared to the control. Fulvic acid was the more effective one in increasing the thickness of leaf blade, thickness of mesophyll tissue and dimensions vascular bundle.

These results are in accordance to those obtained by Abou-Bakr *et al.* (1998), they studied the effect of antitranspirants abscisic acid (ABA) or phenyl-mercuric acetate (PMA) on anatomical feature of wheat plant. These compounds increased the midrib diameter and the mean distance between vascular bundles in proportion to the flag leaf area.

Concerning the interaction between both water levels and antitranspirants treatments, the interactions increased all histological characters of wheat leaf blade grown under low water levels while width and thickness of scalaranchyma tissue were decreased compared to the corresponding unsprayed plants.

Table 5. Mean values in micron of certain histological features of flag leaf blade on wheat main stem as affected with the interactions treatments between foliar application with three tested antitranspirants and tow levels of water stress during the second growing season (2011/2012)

WHC	Treatments	T. of blade	Activity	T. of mes. tissue	Activity	T of midrib	Activity	Width of midrib	Activity	T. of Sch. tissue	Activity	Width of Sch. tissue	Activity	T. of midrib V. B.	Activity	width of midrib V. B.	Activity
65 %	0.00	202.16	100.00	159.60	100.00	476.88	100.00	695.84	100.00	110.90	100.00	176.1	100.00	120.96	100.00	150.90	100.00
W1 (45%)	0.00	162.59	80.43	127.18	79.69	397.92	83.44	419.20	60.24	136.16	122.78	191.72	108.87	98.54	81.46	114.24	75.71
	Ka 4%	170.24	84.21	127.68	80.00	414.96	87.02	489.44	70.34	120.44	108.60	179.94	102.18	104.72	86.57	128.52	85.17
	Ka 6%	180.88	89.47	148.96	93.33	453.28	98.17	559.68	80.43	122.34	110.32	171.36	97.31	106.62	88.14	137.56	91.16
	$MgCO_3$ 6%	163.15	80.70	127.68	80.00	400.48	83.98	451.12	64.83	125.2	112.89	182.8	103.80	99.96	82.64	130.94	86.77
	$MgCO_3$ 10 %	166.69	82.45	138.32	86.67	404.32	84.78	478.80	68.81	123.58	111.43	179.94	102.18	99.58	82.32	131.38	87.06
	FA 160 ppm	184.43	91.23	138.32	86.67	436.24	91.48	563.92	81.04	121.58	109.63	181.38	103.00	109.48	90.51	139.28	92.30
	FA 320 ppm	198.61	98.24	148.96	93.33	468.16	95.05	512.88	73.71	120.09	108.29	180.4	102.44	109.48	90.51	142.32	94.31
W2 (25%)	0.00	134.32	66.44	95.76	60.00	234.08	49.09	234.08	33.64	146.16	131.79	209.46	118.94	66.64	55.09	92.82	61.51
	Ka 4%	143.96	71.21	106.40	66.67	256.64	53.82	276.64	39.76	137.1	123.62	200.38	113.79	76.16	62.96	102.34	67.82
	Ka 6%	156.15	77.24	112.04	70.20	257.40	53.98	385.60	55.42	135.2	121.91	199.8	113.46	87.58	72.40	110.62	73.31
	$MgCO_3$ 6%	153.69	76.02	108.04	67.69	256.64	53.82	319.20	45.87	139.16	125.48	201.86	114.63	71.40	59.03	109.48	72.55
	$MgCO_3$ 10 %	141.87	70.18	106.40	66.67	257.28	53.95	308.56	44.34	139.4	125.70	201.52	114.43	85.68	70.83	97.58	64.67
	FA 160 ppm	155.15	76.75	113.04	70.83	260.56	54.64	389.84	56.02	136.06	122.69	197.1	111.93	89.02	73.59	111.86	74.13
	FA 320 ppm	158.43	78.37	114.32	71.63	266.60	55.91	399.20	57.37	134.72	121.48	190.46	108.15	89.48	73.97	112.90	74.82

Abbr.: W (Water Stress), WHC (water holding capacity), 65% of WHC(plants received adequate water)control , W1 (45% of WHC), W2 (25% of WHC), 0.00 (plants were sprayed with distilled water), Ka (Kaolin) , FA (Fulvic acid), $MgCO_3$ (Magnesium carbonate) , T. (thickness), ,mes. (mesophyll, Sch. (schalaranchyma) and V. B. (Vascular bundles)

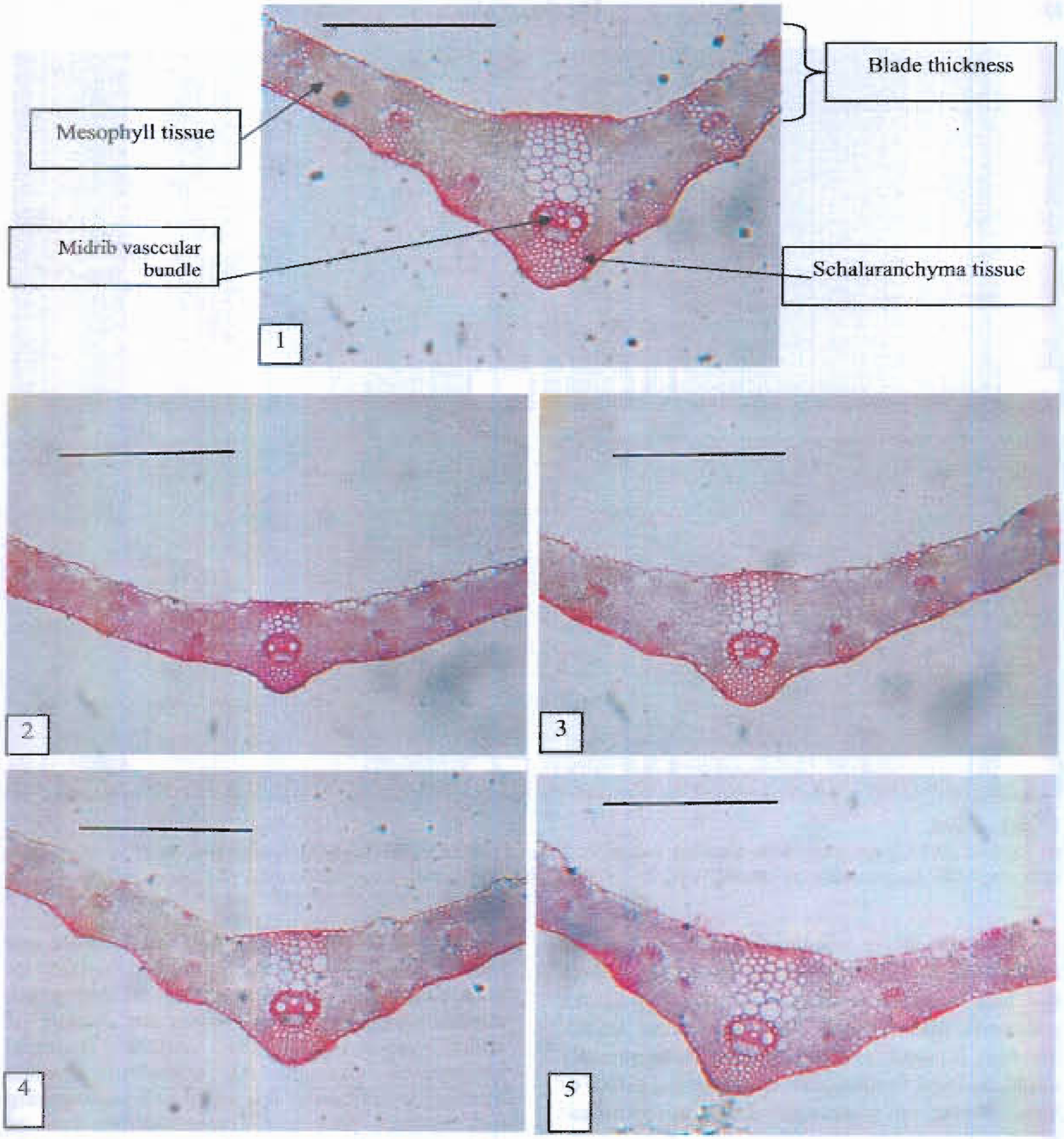

Fig. 1. Transverse sections in the flag leaf blade on wheat main stem as affected with the interaction treatments between foliar application with three tested antitranspirants and two levels of water stress during the second growing season (2011/2012). Scale bars 0.5 mm

1: 65% of water holding capacity (WHC) spraying with distilled water, **2:** 45% of (WHC) spraying with distilled water, **3:** 45% of (WHC) spraying with kaolin 6%, **4:** 45% of (WHC) spraying with magnesium carbonate 10%, **5:** 45% of (WHC) spraying with Fulvic acid 320 ppm.

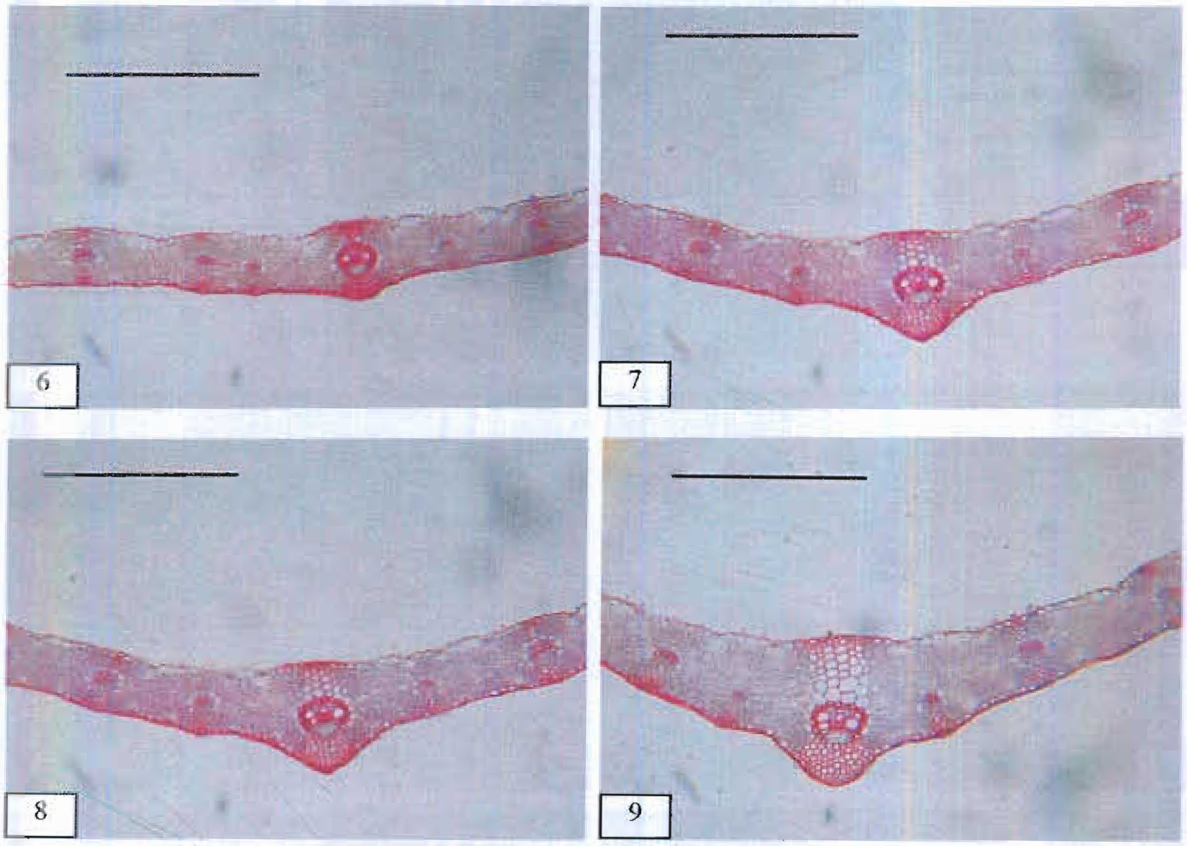

Fig. 1. Cont.
6: 25% of (WHC) spraying with distilled water, **7:** 25% of (WHC) spraying with kaolin 6%, **8:** 25% of (WHC) spraying with magnesium carbonate 10%, **9:** 25% of (WHC) spraying with Fulvic acid 320 ppm.

From the above results obtained, it could be mentioned that FA especially at 320ppm gave the best anatomical features compared to the untreated plants under all water stress levels. Though, it could be concluded that FA generally could be used to minimize that harmful effect of water stress on anatomical structure of wheat plant.

In this respect, Jifon and Syvertsen (2003) found that the increase in xylem tissue due to antitranspirants may help plants in obtaining its requirement from water, so increased plant growth and yield of wheat plant.

Results of present study indicated that application of antitranspirant has a meliorative effect against water deficit stress by reduce transpiration in three ways: (1) reflecting materials reduce the absorption of radiant energy and thereby reduce leaf temperature and transpiration rates (2) emulsion waxes, latex or plastic materials dry on the foliage to form a thin transparent film which hinders the escape of water vapor, and (3) certain chemical compounds can prevent complete stomata opening by affecting the guard cell surrounding the stomatal pore,thus decreasing the loss of water vapor from the leaf (Davenport *et al.*, 1969).

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تأثير بعض مواد مضادات النتح علي النمو والمحصول وتركيب ورقة العلم لنبات القمح النامي تحت ظروف الإجهاد المائي

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أجريت هذه الدراسة خلال شتاء موسمين متعاقبين هما ٢٠١١/٢٠١٠م، ٢٠١١/ ٢٠١٢م بصوبة التجارب بكلية الزراعة، جامعة الزقازيق، مصر، لدراسة استجابة نباتات القمح (صنف سخا ٩٣) للرش الورقي بمضادات النتح مثل الكاؤلين (٤ و ٦%) وكربونات الماغنسيوم (٦ و ١٠%) وحمض الفولفيك (١٦٠ و ٣٢٠ جزء في المليون) وتأثيرها على الصفات الخضرية وبعض الصفات الفسيولوجية كصبغات البناء الضوئي والنشاط الكيموضوئي ومكونات المحصول والصفات التشريحية لورقة العلم تحت ظروف الإجهاد المائي (٤٥ و ٢٥% من السعة التشبعية العظمي). أظهرت الصفات الخضرية الممثلة في ارتفاع النبات(سم) ومساحة نصل الورقة (سم٢) والوزن الجاف (جم) لمختلف أعضاء النبات- نقص معنوي تحت ظروف الإجهاد المائي مقارنة بمستوى ٦٥% من السعة التشبعية العظمى. أوضحت النتائج أن استخدام الرش الورقي ببعض مواد مضادات النتح أدي جزئياً إلى تقليل التأثير الضار للإجهاد المائي علي الصفات التى درست مقارنة بالنباتات التى لم ترش. حدث نقص معنوي في تركيزات كل من كلوروفيل (أ + ب) والكاروتينويدات والنشاط الكيموضوئي في أوراق القمح وذلك نتيجة لتعرض النباتات لمعاملات الاجهاد المائي كما لوحظ أن استخدام مضادات النتح أدي إلي زيادة معنوية في تركيز صبغات البناء الضوئى والنشاط الكيموضوئي فى الاوراق تحت ظروف الاجهاد المائى مما أدى إلى تقليل الآثار الضارة الناتجة عن معاملات الإجهاد المائي بالمقارنة بالنباتات الغير معاملة. انخفضت مكونات المحصول معنويا وذلك نتيجة لتعرض النباتات لمعاملات الاجهاد المائي وكانت أعلى القيم في كل من عدد السنابل للنبات وعدد الحبوب للسنبلة وعدد الحبوب للنبات والوزن الجاف للحبوب ووزن الألف حبة تحت مستوي ٦٥% من السعة التشبعية العظمي وكانت اقل النتائج المتحصل عليها تحت مستوي إجهاد مائي ٢٥% من السعة التشبعية العظمي. أدى رش النباتات بمضادات النتح إلى زيادة الصفات الخضرية وصبغات البناء الضوئى والنشاط الكيمو ضوئي ومكونات المحصول. أوضحت النتائج أن رش النباتات بمضاد النتح حمض الفولفيك بتركيز ٣٢٠جزء في المليون كان مفيداً في تحسين تلك الصفات مقارنة بالنباتات التى لم ترش ولكن ما زالت أقل من تلك تحت ظروف ٦٥% من السعة التشبعية العظمى. انخفضت قياسات الصفات التشريحية لنصل الورقة مع زيادة الاجهاد المائى على العكس من ذلك زاد سمك النسيج الاسكلرانشيمي. أدى الرش بمضادات النتح تحت ظروف الاجهاد المائي إلى زيادة قياسات الصفات التشريحية بينما قل سمك النسيج الاسكلرانشيمي. لوحظ أن حمض الفولفيك بتركيز ٣٢٠جزء في المليون أعطى أفضل النتائج بالنسبة لقياسات الصفات التشريحية مقارنة بالنباتات الغير معاملة. من نتائج الدراسة يمكن التوصية برش مضاد النتح حمض الفولفيك بتركيز ٣٢٠ جزء في المليون على نباتات القمح كمحاولة لتقليل الآثار السلبية للإجهاد المائي علي الصفات الخضرية والخصائص الفسيولوجية ومكونات المحصول والتركيب التشريحي للأوراق.

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