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An Attempt to Alleviation of Irrigation Water Deficit Stress in Cabbage (*Brassica oleracea* Var. Capitata L.) by Exogenous Foliar Application with some Antioxidant

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ABSTRACT

Two field experiments were carried out during the two winter seasons of 2015 and 2016 under clay loamy soil conditions using surface improving irrigation system at the Experimental Station, Faculty of Agriculture, Mansoura University, Dakahlia governorate, Egypt. to study vegetative growth and yield of cabbage (cv. o.s. cross) influenced by irrigation water deficit treatments in three levels include without stress as control (full irrigation), moderate and severe stresses (75 % and 50 % from the control, respectively) and foliar application with some antioxidants consisted of (without exogenous antioxidant, 0.3 g /l ascorbic acid, 0.1 g/l chitosan and 4.0 g/l glycine betaine) and their interactions. The results showed that increasing of irrigation water deficit led to significant decreases of vegetative growth characters (i.e. Plant height, foliage weight, leaves fresh weight, number of leaves, leaves area), Chemical composition of outer leaves (chlorophyll a, chlorophyll b, carotenoids, N, P and K), Heads yield and its physical and chemical qualities (head weight, edible head weight, edible head diameter, edible head compactness rate, Vit. C, TSS and total heads yield /fed.) and leaf relative water content. On contrast, edible head dry matter, electrolyte Leakage and water use efficiency percentage were increased. As for the impact of foliar application of antioxidant, results exhibited that, the previous parameters were increased compared to the control (without antioxidant) except electrolyte leakage. Chitosan at 0.1 g/l followed by 0.3 g /l ascorbic acid were recorded the highest values of most effective mentioned parameters. The interaction between irrigation water deficit and foliar application with some antioxidants showed that the combination of full irrigation and 0.1 g/l chitosan gave the highest values of most effective previous parameters. Also, insignificant differences were noticed between full irrigation or moderate stress treatments with antioxidant for most effective mentioned parameters.

Keywords: cabbage, irrigation water deficit, antioxidants, water use efficiency and heads yield.

INTRODUCTION

Cabbage (*Brassica oleracea* var. capitata L.) is one of the Cruciferae family plants. It is the most important winter season vegetable crop of the genus Brassica grown in the world. Cabbage is rich in minerals and Vitamins (A, thiamine, riboflavin and C). Also, contains minerals like phosphorus, potassium, calcium and iron. Cabbage, beside tomato and onion is one of the most popular vegetable crop worldwide (Nyatuame *et al*., 2013).

The yield and quality of cabbage are affected with biotic and abiotic stress conditions such as flooding , environmental conditions, salinity, chemical toxicity, diseases, ultraviolet radiation, water deficit and foliar application such antioxidants (XU and Leskovar, 2014).

The water is very critical stress factors for the cabbage. It has effects on photosynthesis, plant growth, production and quality. Several studies have shown that water deficit reduced crop growth, canopy development, morphological characteristics (plant height, leaves fresh weight and head weight and dry matter accumulation) of cabbage plant (Ibrahim *et al*., 2011; Nyatuame *et al*., 2013 and XU and Leskovar, 2014). In addition, maximum leaf area, curd weight, curd dry matter % values of broccoli plants were found in subjected to full irrigation treatment (Erken *et al*., 2013 and Tangune *et al*., 2016). Also, several studies have shown that crop yields decreased with decreasing irrigation water for different crops such as cauliflour (Moniruzzaman *et al*., 2007). As well as, the highest marketable yields of cucumber were obtained with 100% of field capacity treatment and the yield reduction has been produced by reducing irrigation water (Hira *et al*., 2016). The same results were obtained by and (Farouk and Ramadan, 2012) on cowpea and (Ragab *et al*., 2015) on tomatoes.

Defenses of plants to water deficit is mostly connected with increasing of reactive oxygen species (ROS), such as hydrogen peroxide (H_2O_2), superoxide anion ($O_2^{\cdot}-$), singlet oxygen ($^1O_2$) avd hydroxyl radical (HO), which are very toxic for the cells (Chaves *et al*., 2003).

Water deficit stress leads to a defect in balance between antioxidant protection and the amount of (ROS) resulting in oxidative stress. ROS are vital for inter and intracellular signaling. On contrast, high concentration can led to damage at different levels of organization including chloroplasts. These ROS have the capacity to initiate lipid peroxidation and decay of lipids, proteins, DNA and RNA. Mechanism of retardation of lipid peroxidation consists of free radical scavenging enzymes such as superoxide dismutase, peroxidase and catalase. (Srivalli *et al*., 2003).

ROS are efficiently eliminated by enzymatic and non-enzymatic antioxidants under non-stressful conditions, whereas during water deficit stress the production of ROS increase more than exceeds the capacity of the systems of anti-oxidative to elimination them, resulting in oxidative stress. The non-enzymatic antioxidant system includes ascorbic acid, chitosan and glycine betaine (Farouk and Ramadan, 2012; Ragab *et al*., 2015; Hira *et al*., 2016).

Ascorbic acid (AsA) enables plants to defend against stresses by scavenging oxygen free radicals. It is generally distributed in the cytosol of cell. Moreover, low ascorbate synthesis plants are quite sensitive to various stresses which can adversely affect their growth and development. Exogenous application of AsA improving plant vegetative growth and development by altering phytohormone signaling, oxidative defense system, cell expansion or division, ion transports and other associated processes under non-stress or stress conditions (Karadeniz *et al*., 2005).

Hira *et al*. (2016) mentioned that AsA at 100 mg/ L was improved the shoot fresh and dry weights, chlorophyll a, relative water content, and proline contents on cucumber. Also, on faba bean, AsA acid mitigated all of the recorded harmful effects on shoot height, fresh and dry masses and water content of root and shoot, as well as leaf area under drought stress (Kasim *et al*., 2017).

Chitosan is a natural carbohydrate polymer, low toxic and inexpensive compound. It has_been used in agricultural applications for protect plants against oxidative stress and to improve plant growth (Farouk and Ramadan., 2011). Many investigators reported that using chitosan as foliar spray led to increasing on vegetative growth, yield and its component of vegetable crops including Cucumber (Shehata *et al*., 2012); strawberry (El-Miniawy *et al*.,2013); and tomato (Abd El-Gawad and Bondok, 2015).

Glycine betaine (GB) is an amino acid derivative that accumulates in a variety of plants in response to stresses. But, its production and accumulation is different from plant to other. Thus, as an alternative, exogenous application of GB may be a possible approach to tolerate stress (Ragab *et al*., 2015).

Several studies have shown that, application of foliar application of GB at 10 mM/l ameliorated the negative effects of water stress and produced the highest significant values of plant length, leaves number /plant, total leaves area/plant, fresh and dry weights of tomato leaves, leaf relative water content and photosynthetic pigments on tomatoes plants (Ragab *et al*., 2015). Abou El-Yazied (2011) reported that, application of GB at 2 mM/l under deficit of 30% available soil water increased number of leaf and plant dry weight, chlorophyll pigments, calcium percentage and decreased proline in leaves of common bean plants.. In addition, GB treatment at 20 mM significantly improved stem length, leaf petiole length, leaves number, fresh and dry weights of leaves and Fruit yield of Squash Plants compared the control. (Abdel-Mawgoud, 2017).

Therefore, the objective of this study was to evaluate the ability of ascorbic acid, chitosan and glycine betaine to overcome the deleterious effects of irrigation water deficit on growth and yield of cabbage.

MATERIALS AND METHODS

Two field experiments were carried out during the two winter seasons of 2015 and 2016 under clay loamy soil conditions using surface improving irrigation system at the Experimental Station, Faculty of Agriculture, Mansoura University, Mansoura governorate, Egypt. to study vegetative growth and yield of cabbage (cv. o.s. cross) influenced by irrigation water deficit treatments in three levels include without stress as control (full irrigation), moderate and severe stresses (75 % and 50 % from the control, respectively) and foliar application with some antioxidants include (without exogenous antioxidant, 0.3 g /l ascorbic acid, 0.1 g/l chitosan and 4.0 g/l glycine betaine) and their interactions. Physical and chemical analysis of soil were listed in (Table 1).

Table 1. Physical and chemical parameters from the top layer 0-30 cm depth during the two seasons of 2015 and 2016.

Seasons	Silt %	Clay %	Sand %	Texture soil	F.C %	W.P %	AW %	PH	E.C (dSm-1)	O.M %	$CaCO_3$ %	N ppm	P ppm	K ppm
2015	41.7	36.2	22.1	Clay loamy	35.5	18.8	16.7	8.17	1.54	1.87	3.38	52.9	5.9	298
2016	41.3	36.8	21.9	Clay loamy	35.1	18.3	16.8	8.19	1.68	2.01	3.43	53.5	6.3	292

F.C : Field Capacity - W.P.: Welting point - AW: Available water - OM: Organic matter

Cabbage transplants (cv. o.s. cross 45 days old) were transplanted on 20th and 24th of October during both seasons at distance of 0.5 m a part on one side of ridge. The plot area was 10. 5 m^2 which consist of five ridges of 0.7 m wide and 3.0 m long.

Irrigation water deficit treatments in three levels include without stress as control (full quantity water irrigation 100% based on quantity of each irrigation application), moderate stress and sever stress 75 % and 50 % of the water applied to the control of each one.

Equal amounts of irrigation water were added to all experimental units during germination at (260 and 257 m^3/ fed.) in the both seasons, respectively, as furrow irrigation through water counter. Irrigation water deficit treatments were started from the first irrigation which was 30 days after transplanting and repeated every 30 days for two times. Irrigation numbers were 3 for each treatment as improved furrow irrigation through pipe 63 mm in diameter, water irrigation amounts was determined through water counter (Table 2).

Table 2. Amounts of irrigation water applied (m^3 water/fed.) during the two seasons of 2015 and 2016.

Treatment	First season			Second seasons		
	100 %	75 %	50 %	100 %	75 %	50 %
Germination	260	260	260	257	257	257
First irrigation	158	118.5	79	160	120	80
Second irrigation	169	126.75	84.5	168	126	84
Third irrigation	182	136.5	91	180	135	90
Total	769	642.05	514.5	765	638	511

Foliar application with some antioxidants consisted of (without exogenous antioxidant (water alone), 0.3 g /l ascorbic acid, 0.1 g /l chitosan and 4.0 g/l glycine betaine) were add three times at 30, 60 and 90 day after transplanting. Volume of foliar solution was 200, 300 and 400 l/fed. at the 1st, 2nd and 3^{ed}, respectively. Ascorbic acid and glycine betaine from (Al-Gomhoreya Co. for Chemical Industries, Mansoura, Egypt), chitosan from the commercial chitosan extract (Chito-power) consist of (chitosan succinate 2.9 %).

Plants were fertilized with 80 units of N, 50 units of P_2O_5 and 50 units of K_2O kg/ fed. as ammonium nitrate (33.5 %), single calcium super phosphate (12.5 % P_2O_5) and potassium sulfate (50 % K_2O), respectively. Single calcium super phosphate was added during preparation of the soil. Ammonium nitrate and potassium sulphate and added as two equal dose before the first and the second irrigation time, Also, farmyard manure at 20 m^3/fed. was applied during soil preparation.

Experimental design:

The experiment was arranged in split plots in complete randomized blocks design with three replications. Irrigation water deficit treatments were arranged in the main plots, while foliar application with some antioxidants were assigned in the sub plots.

Measurements:

Four plants were randomly chosen from each plot after 115 days from planting date to determine the following parameters for the two seasons.

1-Vegetative growth characters:

Plant height (cm), Foliage weight (g) /plant (outer and inner stem plus outer and inner leaves), leaves fresh weight / plant, leaves number / plant and leaves area (m2) / plant.

2 – Chemical composition of outer leaves:

Chlorophyll a, chlorophyll b, carotenoids as mg/100 g fresh weight, N, P and K percentage were analyses according to AOAC (1990).

3- Heads yield and its physical and chemical qualities:

- Head weight (g)/plant (inner and outer stem plus inner leaves)
- Edible head weight (g)/plant (inner stem plus inner leaves)
- Edible head diameter (cm).
- Edible head compactness rate according to (Riad *et al.*, 2009). Where theoretically compactness rating of 1 means the edible head is very compact and it contains no air. The lower rate the more compactness and vice versa.

$$\text{Compactness rate} = \frac{\text{edible head volume } (0.75 \times 3.14 \times \text{radius}^3)}{\text{edible head weight}}$$

- **Edible head dry matter percentage.**
- **Vit. C, TSS according to AOAC (1990).**
- **Total heads yield (ton/ fed.)**

4- Plant water relations:

Leaf relative water content % and Electrolyte Leakage % were estimated according to (Xu and Leskovar, 2014), Water use efficiency was determined according to (Ragab *et al.*, 2015).

Statistical analysis:

All data were statistically analyzed using the analysis of variance according to Snedecor and Cochran (1980). Least significant difference (LSD) at the probability of 5 % was used due to the procedure reported by (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

1-Vegetative growth characters:

Irrigation water deficit caused an observed adverse action on vegetative growth characters. Plant height, foliage fresh weight g /plant, leaves number /plant, leaves area /plant and leaves fresh weight /plant were significantly reduced under irrigation water deficit (Table 3). The highest values of the previous parameters were recorded with full irrigation followed by moderate stress (75 % from full irrigation) treatment in both seasons. These increases parameter values in full irrigation can be due to that available more water are improve nutrient availability which led to improving of macro- and micro- elements absorption and uptake, on contrary, the decreasing in previous characters may be due to the reduction of cells growth, elongation and development in different plant organs especial in leaves and stem. So that, the influence of water deficit stress can be detected in smaller leaves or plant height, reduction in leaves area, light absorption and decreasing in total capacity of photosynthesis and which reflected negatively on plant growth. (Xu and Leskovar, 2014; Verma *et al.*, 2017) on cabbage.

Table 3. Impact of foliar application with some antioxidants after 115 days from planting on vegetative growth characters of cabbage under irrigation water deficit during the two seasons of 2015 and 2016.

Treatments		Plant height (cm).		Foliage FW g / plant		Leaves No / plant		Leaves area (m^2) / plant		Leaves FW g / plant	
		1st s	2ed s	1st s	2ed s	1st s	2ed s	1st s	2ed s	1st s	2ed s
irrigation water deficit											
Full irrigation		29.5	29.1	7054	6951	56.0	55.1	3.743	3.691	6767	6668
Moderate		27.7	27.3	6617	6520	52.5	51.7	3.511	3.459	6347	6254
Sever		24.2	23.8	5774	5689	45.8	45.0	3.063	3.019	5539	5457
LSD 5%		2.2	1.9	525	517	4.2	3.4	0.278	0.261	504	479
foliar application with some antioxidants											
Without		25.5	24.9	6080	5959	48.1	47.2	3.226	3.162	5833	5716
Ascorbic acid 0.3 g /l		27.6	27.2	6589	6495	52.4	51.6	3.496	3.450	6321	6231
Chitosan 0.1 g /l		28.3	27.9	6762	6674	53.7	52.8	3.588	3.541	6487	6403
Glycine betaine 4.0 g/l		27.2	26.8	6495	6418	51.4	50.8	3.446	3.405	6230	6157
LSD 5%		2.2	1.7	537	529	4.2	3.1	0.285	0.257	515	506
Interaction											
Full irrigation	Without	27.5	26.9	6564	6432	52.0	51.0	3.482	3.413	6296	6170
	AsA 0.3 g /l	29.8	29.4	7130	7016	56.6	56.0	3.783	3.732	6839	6730
	CH 0.1 g /l	31.2	30.8	7450	7353	59.3	58.3	3.953	3.901	7146	7053
	GB 4.0 g/l	29.6	29.3	7075	7004	56.0	55.3	3.754	3.716	6787	6719
Moderate	Without	26.3	25.7	6278	6152	49.6	48.6	3.331	3.264	6023	5902
	AsA 0.3 g /l	28.1	27.7	6696	6624	53.3	52.6	3.553	3.515	6424	6355
	CH 0.1 g /l	28.5	28.1	6801	6713	54.0	53.3	3.609	3.562	6525	6440
	GB 4.0 g/l	28.0	27.6	6691	6589	53.0	52.3	3.550	3.496	6419	6321
Sever	Without	22.6	22.1	5400	5292	42.6	42.0	2.865	2.808	5180	5076
	AsA 0.3 g /l	24.9	24.4	5941	5846	47.3	46.3	3.152	3.102	5699	5608
	CH 0.1 g /l	25.3	24.9	6036	5958	48.0	47.0	3.203	3.161	5791	5715
	GB 4.0 g/l	23.9	23.7	5718	5661	45.3	45.o	3.034	3.004	5485	5430
LSD 5%		3.8	2.9	931	916	7.3	5.4	0.494	0.446	893	876

AsA: ascorbic acid, CH: chitosan, GB: glycine betaine

Concerning the effect of spraying foliar application with some antioxidants, data in Table 3 revealed that the parameters mentioned previously were increased compared to untreated plants. The highest values of these parameters were produced by using chitosan 0.1 g /l followed by ascorbic acid 0.3 g /l in the two seasons. On the other hand, the lowest values were noticed with without antioxidants treatment. This improvement in vegetative growth criteria could be attributed to the water deficit stress long time, the plant will face the oxidative destruction inevitably, and can be resulted in producing (ROS) which are the result of incomplete reduction of oxygen (Cruz de Carvalho, 2008). Exogenously application of antioxidants enables plants to defend against stresses by reducing oxygen free radicals or prevent the high activity of ROS, Also, antioxidants such as chitosan or ascorbic acid has been very effective in improving cell division and expansion of root cells, enhancement the consumption of soluble carbohydrates to form young cell constituents, phytohormone signaling, regulates some physiological processes in plants such as related to growth and development, ion transports and membrane permeability under stress or non-stress conditions. Our results were in agreement with those obtained by Farouk and Ramadan, (2012) on cow pea and Hira *et al*., (2016) on cucumber.

Exogenous application of antioxidants increases polyamines content in the plant such as spermidine, putrescine and spermine which led to keeping of cell membrane and plant integrity through water deficit stress time, Also, results in increasing in gibberellins and cytokinins. On contrast, endogenous abscisic acid and auxins were decreased. Which lead to enhancing photosynthetic pigments and consequently increased vegetative and reproductive growth. These results are in agreement with those obtained by (Mady, 2009) on tomato.

As for the interaction between irrigation water deficit and spraying antioxidants showed that cabbage plants were irrigated full irrigation (control) treatment and foliar sprayed by 0.1 g/l chitosan gave the highest values of all mentioned characteristics. The lowest values were noticed with sever stress application (50 % from full irrigation) and without antioxidants in both seasons. Also, insignificant differences were noticed between full irrigation or moderate stress treatments with antioxidant. These results were in accordance with those reported by Nyatuame *et al.* (2013) and XU and Leskovar, 2014) on cabbage; Tangune *et al.* (2016) on broccoli and Shehata *et al*., (2012) on cucumber.

2- Chemical composition parameters of outer leaves:

Results in Table 4 demonstrate that increasing irrigation water deficit caused significant decreases in chlorophyll a, chlorophyll b, carotenoids content, N, P and K percentage in outer leaves tissue. The full irrigation recorded the highest values of the previous parameters followed by moderate treatment (75 % from full irrigation). Also, obtained data show that there were insignificant effect differences between the full irrigation and moderate treatment for previous characters. On contrast, the lowest values were recorded by sever treatment (50 % from full irrigation) in the both seasons. These results may be due to that irrigation water deficit was causes retarding of nutrients transports and uptake, the roots failed to absorb more valuable nutrient elements. Also, irrigation water deficit caused reducing in mineral content of leaf due to a reduction roots formation. These results indicate positive correlation between water deficit stress and the content of chlorophyll pigments and carotenoids. This improved in previous pigments may be attributed to increase macronutrients transport and uptake, especially N and Mg nutrient by decreasing water deficit, whereas N and Mg nutrient are essential for chlorophyll pigments synthesis. Similar results were obtained by Ashraf *et al.* (2013) on canola and Metwaly and El-Shatoury (2017) on potato

Table 4. Impact of foliar application with some antioxidants after 115 days from planting on pigments, N, P and K in outer leaves of cabbage under irrigation water deficit during the two seasons of 2015 and 2016.

Treatments		Chl. a mg/100 FW		Chl.b mg/100 FW		Carotenoids mg/100g FW		N %		P %		K %	
		1st s	2ed s	1st s	2ed s	1st s	2ed s	1st s	2ed s	1st s	2ed s	1st s	2ed s
irrigation water deficit													
Full irrigation		44.7	44.1	22.3	22.0	12.5	12.0	2.72	2.69	0.330	0.325	3.41	3.36
Moderate		41.9	41.3	20.9	20.6	11.7	11.3	2.55	2.52	0.310	0.305	3.20	3.15
Sever		36.6	36.1	18.3	18.0	10.2	10.0	2.23	2.20	0.270	0.266	2.79	2.75
LSD 5%		3.3	2.8	1.6	1.3	0.9	0.8	0.20	0.18	0.024	0.021	0.25	0.19
foliar application with some antioxidants													
Without		38.5	37.8	19.2	18.9	10.8	10.2	2.35	2.30	0.285	0.279	2.94	2.88
Ascorbic acid 0.3 g /l		41.8	41.2	20.9	20.6	11.7	11.4	2.54	2.51	0.309	0.304	3.19	3.14
Chitosan 0.1 g /l		42.9	42.3	21.4	21.1	12.0	11.7	2.61	2.58	0.317	0.313	3.27	3.23
Glycine betaine 4.0 g/l		41.2	40.7	20.6	20.3	11.5	11.2	2.51	2.48	0.304	0.301	3.14	3.10
LSD 5%		3.4	2.5	1.7	1.2	0.9	0.7	0.20	0.17	0.025	0.018	0.26	0.16
Interaction													
Full irrigation	Without	41.6	40.8	20.8	20.4	11.6	10.7	2.54	2.49	0.307	0.301	3.17	3.11
	AsA 0.3 g /l	45.2	44.5	22.6	22.2	12.7	12.3	2.75	2.71	0.334	0.329	3.45	3.39
	CH 0.1 g /l	47.2	46.6	23.6	23.3	13.2	12.9	2.88	2.84	0.349	0.344	3.60	3.56
	GB 4.0 g/l	44.8	44.4	22.4	22.2	12.6	12.3	2.73	2.71	0.331	0.328	3.42	3.39
Moderate	Without	39.8	39.0	19.9	19.5	11.1	10.4	2.43	2.38	0.294	0.288	3.04	2.98
	AsA 0.3 g /l	42.4	42.0	21.2	21.0	11.9	11.7	2.59	2.56	0.314	0.310	3.24	3.20
	CH 0.1 g /l	43.1	42.6	21.5	21.3	12.1	12.0	2.63	2.60	0.319	0.314	3.29	3.25
	GB 4.0 g/l	42.4	41.8	21.2	20.9	11.9	11.3	2.58	2.55	0.314	0.309	3.24	3.19
Sever	Without	34.2	33.5	17.1	16.8	9.6	9.5	2.09	2.04	0.253	0.248	2.61	2.56
	AsA 0.3 g /l	37.7	37.1	18.8	18.5	10.5	10.2	2.30	2.19	0.278	0.274	2.87	2.83
	CH 0.1 g /l	38.3	37.8	19.1	18.9	10.7	10.4	2.33	2.26	0.283	0.279	2.92	2.88
	GB 4.0 g/l	36.2	35.9	18.1	17.9	10.1	10.0	2.21	2.19	0.268	0.265	2.77	2.74
LSD 5%		5.9	4.3	2.9	4.2	1.6	1.2	0.36	0.30	0.043	0.031	0.45	0.28

AsA: ascorbic acid, CH: chitosan, GB: glycine betaine

Results in Table 4 revealed that mentioned characters were significantly increased in the both seasons with spraying antioxidants compared the control. Chitosan 0.1 g /l followed by ascorbic acid 0.3 g /l. gave the highest values of these parameters. On the other hand, the lowest amounts of previous values were found by application of without antioxidants treatment in first and second seasons.

This may be attributed to (ROS) has destructive impact for chlorophyll pigments under water deficit. Chitosan, ascorbic acid and glycine betaine decreases the worst influences of (ROS) on chlorophyll by enhancement antioxidant systems. Increasing of cell division and elongation, improving plant growth, ion transport and membrane permeability. Also, Chitosan, ascorbic acid and glycine betaine probably prevent chlorophyll oxidase enzymes therefore it will be inhibit breakdown of chlorophyll which led to increasing in photosynthesis. These finding are similar to those obtained by Farouk and Ramadan (2012) on cow pea and El-Miniawy *et al.* (2013) on strawberry

As for the interaction between irrigation water deficit and antioxidants, obtained data in Table 4 revealed that the interaction treatments significantly affected on the mentioned attributes, the highest values were obtained application of full irrigation and 0.1 g/l chitosan, On contrast, the lowest values were noticed with sever application (50 % from full irrigation) and without antioxidants in both seasons. Also, insignificant differences were noticed between full irrigation or moderate treatments with antioxidant. Tangune *et al.* (2016) on broccoli, Hira *et al.* (2016) on cucumber; Verma *et al.* (2017) on cabbage; Kasim *et al.* (2017) in faba bean were found the same trend.

3- Heads yield and its physical and chemical qualities:

Obtained data of Tables 5 and 6 indicate that head weight, edible head weight, edible head diameter, edible head compactness rate, total heads yield, Vit. C, TSS were affected significantly, by irrigation water deficit. The full irrigation gave the maximum values of the previous parameters followed by moderate stress treatment (75 % from full irrigation), Also, the obtained data revealed that there were insignificant effect differences between the full irrigation and moderate treatment for previous characters. On the other hand, the minimum values were noticed by application of sever stress treatment (50 % from full irrigation) in both seasons. On contrast, the maximum edible dry matter percentage was achieved by application of sever (50 % from full irrigation) followed by moderate stress (75 % from full irrigation) in the two seasons. But, the minimum values were recorded with full irrigation.

Table 5. Impact of foliar application with some antioxidants after 115 days from planting on heads yield and its physical quality of cabbage under irrigation water deficit during the two seasons of 2015 and 2016.

Treatments		Head FW g / plant		Edible head FW (g) / plant		Edible head diameter (cm).		Edible head compact-ness		Edible head DM%		Total heads yield (Ton/ fed.)	
		1st s	2ed s	1st s	2ed s	1st s	2ed s	1st s	2ed s	1st s	2ed s	1st s	2ed s
irrigation water deficit													
Full irrigation		6814	6714	5492	5412	37.2	36.6	2.80	2.69	7.50	7.38	81.7	80.5
Moderate		6383	6289	5152	5076	34.9	34.5	2.45	2.40	8.51	8.39	76.5	75.4
Sever		5552	5471	4495	4429	30.5	30.0	1.87	1.81	9.24	9.10	66.7	65.6
LSD 5%		517	510	409	403	2.7	2.8	0.40	0.40	1.01	0.73	6.2	6.0
foliar application with some antioxidants													
Without		5861	5744	4734	4639	32.1	31.6	2.09	2.03	8.00	7.84	70.3	68.9
Ascorbic acid 0.3 g /l		6357	6264	5130	5057	34.8	34.3	2.45	2.37	8.55	8.41	76.2	75.1
Chitosan 0.1 g /l		6525	6440	5265	5197	35.7	35.2	2.57	2.51	8.73	8.62	78.3	77.2
Glycine betaine 4.0 g/l		6255	6184	5057	4997	34.3	33.8	2.38	2.30	8.38	8.29	75.1	74.2
LSD 5%		529	521	418	412	2.8	2.2	0.40	0.29	0.62	0.49	6.3	6.2
Interaction													
Full irrigation	Without	6337	6210	5110	5008	34.7	33.9	2.42	2.31	7.01	6.87	76.0	74.5
	AsA 0.3 g /l	6890	6779	5551	5462	37.6	37.0	2.87	2.75	7.71	7.59	82.6	81.3
	CH 0.1 g /l	7202	7109	5800	5725	39.3	38.8	3.10	3.02	7.84	7.73	86.4	85.3
	GB 4.0 g/l	6827	6758	5508	5453	37.4	36.7	2.81	2.68	7.43	7.35	81.9	81.1
Moderate	Without	6056	5935	4888	4790	33.2	32.8	2.22	2.21	8.15	7.99	72.6	71.2
	AsA 0.3 g /l	6463	6385	5214	5157	35.4	35.0	2.51	2.45	8.69	8.55	77.5	76.6
	CH 0.1 g /l	6563	6478	5295	5226	35.9	35.5	2.59	2.53	8.69	8.58	78.7	77.7
	GB 4.0 g/l	6449	6360	5210	5130	35.3	34.8	2.50	2.43	8.52	8.44	77.3	76.3
Sever	Without	5191	5087	4204	4120	28.5	28.0	1.63	1.56	8.83	8.66	62.2	61.0
	AsA 0.3 g /l	5719	5628	4626	4552	31.4	30.9	1.98	1.91	9.26	9.11	68.6	67.5
	CH 0.1 g /l	5810	5734	4700	4639	31.9	31.5	2.03	1.98	9.67	9.54	69.7	68.8
	GB 4.0 g/l	5490	5436	4452	4407	30.2	29.9	1.83	1.79	9.19	9.10	66.2	65.2
LSD 5%		917	903	725	713	4.9	3.9	0.70	0.49	1.08	0.86	10.9	10.8

AsA: ascorbic acid, CH: chitosan, GB: glycine betaine

These results may be attributed to water deficit resulted in increasing ROS which cause death of cells due to interaction with vital membranes, DNA, RNA, and proteins. In addition, increasing production of ethylene and abscisic acid, on the other hand, decreasing approximately 10-30% of photosynthesis, nutritious elements uptake, gibberellins and cytokinins which will lead to reduction of chlorophyll pigments in plants which could be a great impact vegetative growth and yield. The same results obtained by (Nyatuame *et al.*, 2013 and XU and Leskovar, 2014) on cabbage.

Spraying of antioxidants on cabbage plants are shown in Tables 5 and 6. The results show that, the previous attributes were increased compared to untreated plants. The highest values of these parameters were recorded with chitosan 0.1 g /l followed by ascorbic acid 0.3 g/l, respectively, in the two seasons. On contrast, the lowest amounts of previous values were achieved by using without antioxidants treatment in both seasons.

This improvement in the yield and its component of cabbage may be antioxidants i.e. chitosan, ascorbic acid have a role as cofactors for some specific enzymes, such as dismutases, catalases, peroxidases, which led to breakdown of the toxic radicals (H2O2), (OH), (O-2). Also, antioxidants decreasing generation of ROS, inhibits of auxin oxidation, increasing ion uptake, cell expansion and membrane permeability and increase in protein amounts of leaves which lead to improvement of plant growth(Table 3) and reflected on the yield (Table 5). The synthase activity of 1-aminocyclopropane-1-carboxylic acid (ACC) which resulted in enhancement of ethylene production in the plant tissue may be decreases by using antioxidants. Ethylene will led to the reduction of chlorophyll pigments in plants (Li *et al*., 1992). Our results are in the same line with those recorded by Fariduddin *et al*. (2003) on mustrad and Hira *et al*. (2016) on cucumber.

Results in Tables 5 and 6 indicate that, the interaction was significant in the both seasons, the highest values of head weight, edible head weight, edible head diameter, edible head compactness rate, total heads yield, Vit. C and TSS were recorded with combination consist from full irrigation and 0.1 g/l chitosan. On contrary, the lowest values were recorded with sever treatment (50 % from full irrigation) and without antioxidants in both seasons. Also, insignificant differences were recorded between full irrigation or moderate treatments with antioxidant. On the other hand, the highest edible dry matter percentage was recorded by application of sever (50 % from full irrigation) application and chitosan 0.1 g /l in the two seasons. But, the minimum values were recorded with full irrigation and without antioxidants. Similar findings were recorded by Nyatuame *et al*. (2013) and XU and Leskovar (2014) on cabbage; Tangune *et al*. (2016) on broccoli; El-Miniawy *et al*. (2013) on strawberry.

4-Plant water relations

Tabulated data in Table 6 show that leaf relative water content % and electrolyte leakage % and water use efficiency were significantly affected by the irrigation water deficit. The obtained results revealed that increasing of irrigation water deficit led significantly to increases all mentioned parameters except leaf relative water content % during both seasons of study. Regarding leaf relative water content, the highest values were notice with full irrigation while the lowest values were recorded with sever treatment (50 % from full irrigation), Also, insignificant effect differences observed between the full irrigation and moderate treatments.

Table 6. Impact of foliar application with some antioxidants after 115 days from planting on Vit. C, TSS and some plant water relations parameters of cabbage under irrigation water deficit during the two seasons of 2015 and 2016.

Treatments		Vit. C mg/100g F.W		TSS %		Leaf relative water content %		Electrolyte leakage %		Water use efficiency (kg per m^3 water)	
		1^{st} s	2^{ed} s	1^{st} s	2^{ed} s	1^{st} s	2^{ed} s	1^{st} s	2^{ed} s	1^{st} s	2^{ed} s
irrigation water deficit											
Full irrigation		46.3	45.7	6.08	6.00	69.0	67.9	61.2	60.3	106.3	105.3
Moderate		43.4	42.8	5.70	5.62	64.7	63.7	70.1	69.1	119.3	118.3
Sever		37.9	37.3	4.98	4.89	56.4	55.6	74.7	73.6	129.6	128.4
LSD 5%		3.4	3.2	0.47	0.44	5.1	4.2	5.5	5.6	8.9	7.2
foliar application with some antioxidants											
Without		39.9	39.1	5.23	5.12	59.4	58.2	71.6	70.2	111.0	109.5
Ascorbic acid 0.3 g /l		43.2	42.7	5.67	5.61	64.4	63.5	68.8	67.7	120.5	119.5
Chitosan 0.1 g /l		44.4	43.8	5.84	5.75	66.1	65.2	64.4	63.6	123.5	122.6
Glycine betaine 4.0 g/l		42.6	42.1	5.61	5.53	63.5	62.7	69.8	69.1	118.5	117.7
LSD 5%		3.5	2.7	0.45	0.44	5.2	3.9	5.7	5.3	9.4	8.1
Interaction											
Full irrigation	Without	43.1	42.2	5.66	5.53	64.2	62.9	63.9	62.7	98.9	97.4
	AsA 0.3 g /l	46.8	46.4	6.13	6.10	69.7	68.6	60.6	59.6	107.5	106.3
	CH 0.1 g /l	48.9	48.3	6.43	6.33	72.8	71.9	57.2	56.5	112.3	111.5
	GB 4.0 g/l	46.4	46	6.10	6.03	69.2	68.5	62.9	62.3	106.5	106.0
Moderate	Without	41.2	40.4	5.40	5.30	61.4	60.1	72.1	70.6	113.2	111.6
	AsA 0.3 g /l	43.9	43.5	5.80	5.70	65.5	64.8	70.9	69.8	120.8	120.1
	CH 0.1 g /l	44.6	44.1	5.86	5.8	66.5	65.6	66.5	65.6	122.6	121.8
	GB 4.0 g/l	43.9	43.2	5.76	5.70	65.4	64.4	70.9	70.2	120.5	119.6
Sever	Without	35.4	34.7	4.63	4.53	52.8	51.7	78.9	77.4	121.0	119.5
	AsA 0.3 g /l	39.0	38.4	5.13	5.03	58.1	57.1	75.0	73.8	133.4	132.1
	CH 0.1 g /l	39.6	39.1	5.23	5.13	59.0	58.2	69.5	68.6	135.5	134.6
	GB 4.0 g/l	37.5	37.1	4.93	4.86	55.9	55.3	75.5	74.8	128.6	127.6
LSD 5%		6.1	4.8	0.78	0.77	9.1	6.6	9.8	9.2	16.3	14.0

AsA: ascorbic acid, CH: chitosan, GB: glycine betaine

These results may be attributed to irrigation water deficit resulted increasing ethylene, abscisic acid production and reduction of nutritious elements transport, gibberellins and cytokinins production which resulted in low roots formation, the stomata should be closed to avoid more water loss, the same results direction obtained by (Lahlou *et al*., 2003) on potato. On the other hand, full irrigation to plants led to keep higher water content in plant tissues. Irrigation water deficit results in the membrane damage and liberation of ions from the cell to extra cellular space and lipid peroxidation (Scandadalius, 1993).

Regarding the effect of spraying foliar application with some antioxidants the data in Table 6 show that leaf relative water content % and water use efficiency were increased compared to untreated plants. The highest values of the mentioned characters were achieved by using chitosan 0.1 g /l followed by ascorbic acid 0.3 g /l in both seasons. But, the lowest values of leaf relative water content % and water use efficiency (kg per m^3 water) were recorded with without antioxidants treatment. On contrast, electrolyte leakage % was decreased compared the control. The maximum values were obtained by application of without antioxidants. Chitosan 0.1 g /l gave the minimum values of electrolyte leakage % in the two seasons.

These results could be attributed to the role of antioxidants which decreasing generation of reactive oxygen species (ROS) and increasing dismutases, catalases, peroxidases, which led to damage of the toxic

(OH), (H2O2), (O-2) radicals, decreasing the production of ethylene (Li *et al*., 1992). Increasing soluble carbohydrates, protein and water content which enhancement plant growth and decreased electrolyte leakage. The increase in leaf relative water content may be connected to the role of chitosan, ascorbic acid and glycine betaine in accumulation of compatible osmolytes in plants tissues, which were depended on water stress. The same results direction obtained by Abd El-Gawad and Bondok, (2015) tomato and Hira *et al*. (2016) on faba bean

Regarding the interaction between irrigation water deficit and antioxidants, the obtained results in Table 6 demonstrated that the combination of full irrigation and 0.1 g/l chitosan was gave the highest values of leaf relative water content %, On contrast, the lowest values were recorded with sever treatment (50 % from full irrigation) and without antioxidants in the two seasons. Also, insignificant differences were observed between full irrigation or moderate treatments with antioxidant. On contrary, the maximum values of electrolyte leakage % were recorded with sever application (50 % from full irrigation) and without antioxidants, but the combination of full irrigation and 0.1 g/l chitosan gave the minimum values of electrolyte leakage %. The highest water use efficiency was achieved with treatment consist of serve application (50 % from full irrigation) and 0.1 g/l chitosan. On contrary, the lowest values were obtained with using combination of full irrigation and without antioxidants in two seasons.

These results are in agreement with those reported Nyatuame *et al*. (2013) and XU and Leskovar, 2014 on cabbage; Ayas *et al*. (2011) on broccoli; Shehata *et al*. (2012) on cucumber; El-Miniawy *et al*. (2013) on strawberry.

CONCLUSION

The negative impact of irrigation water deficit on the growth and productivity of cabbage can be mitigated by using of foliar antioxidant (chitosan, ascorbic acid and glycine betaine). The results presented in this study demonstrated that it is possible to ameliorate the influence of irrigation water deficit by using of foliar antioxidant. The interactions treatments between irrigation water deficit and spraying with antioxidant showed that the combination which consist of full irrigation and 0.1 g/l chitosan was the best combination. Also, insignificant differences were observed between full irrigation or moderate stress treatments with antioxidant. Therefore, it is recommended for cabbage grown under loamy soil conditions using surface irrigation system in order to get the maximum head yield and its physical and chemical quality using moderate treatments with 0.1 g/l chitosan.

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محاولة تخفيف اجهاد نقص مياه الرى فى الكرنب بتطبيق الرش الورقى ببعض مضادات الاكسدة.

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اجريت تجربتان حقليتان متتاليتان فى الموسم الشتوى لعامى 2015 و2016. فى ارض طميبية طينية تحت نظام الرى بالغمر المحسن بمحطة البحوث – كلية الزراعة جامعة المنصورة- محافظة الدقهلية- مصر. لدراسة النمو والمحصول فى الكرنب صنف او اس كروس المتأثر بنقص مياه الرى يشمل ثلاث مستويات بدون اجهاد (الرى الكامل ككنترول) والإجهاد المتوسط والحاد 75 و 50 % من الكنترول على التوالى) والرش بمضادات الاكسدة (بدون – 0.3 جم/ لتر اسكوربيك اسد – 0.1 جم/ لتر شيتوزان– 4.0 جم/لتر جليسن بيتن) .أوضحت النتائج ان زيادة نقص مياة الرى ادت الى نقص معنوي فى صفات النمو الخضرى (ارتفاع النبات –وزن النمو الخضرى - الوزن الطازج للاوراق - عدد الاوراق – المساحة الورقية للنبات) والتركيب الكيماوى للاوراق الخارجية (نسبة النتروجين والفسفور والبوتاسيوم – كلورفيل أ – كلورفيل ب – الكاروتينيدات) وكذلك محصول الرؤس وجودتها الفزيقية والكيمائية (وزن الرأس – وزن الجزء المأكول – قطر الجزء المأكول – معدل الإندماج للجزء المأكول – فيتامين س - المواد الصلبة الذائبة الكلية – المحصول الكلى للرؤس للفدان) وكذلك محتوى المياة النسبى للاوراق. وعلى العكس زادت كل من (النسبة المئوية للمادة الجافة للاوراق - التسرب الاكتروليتى – كفاءة استخدام المياة). بالنسبة لتأثير الرش بمضادات الاكسدة اوضحت النتائج زيادة جميع الصفات السابقة زادت باستخدام الرش الورقى بمضادات الاكسدة مقارنة بالكنترول (بدو بمضادات الاكسدة ن) عدا صفة التسرب الاكتروليتى . ولقد حقق 0.1 جم/ لتر شيتوزان متبوعا 0.3 جم/ لتر اسكوربيك اسد أعلى القيم لمعظم الصفات المذكورة. ولقد اوضح التفاعل بين نقص مياة الرى و استخدام الرش الورقى الرش بمضادات الاكسدة الى ان المعاملة المكونة من الرى الكامل +0.1 جم/ لتر شيتوزان حقق أعلى القيم لمعظم المؤثرة للصفات السابقة. ايضا لوحظ عدم وجود فرق معنوى بين الرى الكامل والاجهاد المتوسط مع مضادات الاكسدة.