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 cauliflower (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 (H2O2), superoxide anion (O2−), singlet oxygen (O2) and 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.

<table>
<thead>
<tr>
<th>Seasons</th>
<th>Shift</th>
<th>Clay (%)</th>
<th>Sand (%)</th>
<th>Texture</th>
<th>F.C (%)</th>
<th>W.P (%)</th>
<th>AW (%)</th>
<th>PH</th>
<th>E.C (dSm-1)</th>
<th>O.M (%)</th>
<th>CaCO₃ ppm</th>
<th>N ppm</th>
<th>P ppm</th>
<th>K ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>41.7</td>
<td>36.2</td>
<td>22.1</td>
<td>Clay loamy</td>
<td>35.5</td>
<td>18.8</td>
<td>16.7</td>
<td>8.17</td>
<td>1.54</td>
<td>1.87</td>
<td>3.39</td>
<td>52.9</td>
<td>5.9</td>
<td>298</td>
</tr>
<tr>
<td>2016</td>
<td>41.3</td>
<td>36.8</td>
<td>21.9</td>
<td>Clay loamy</td>
<td>35.1</td>
<td>18.3</td>
<td>16.8</td>
<td>8.19</td>
<td>1.68</td>
<td>2.01</td>
<td>3.43</td>
<td>53.5</td>
<td>6.3</td>
<td>292</td>
</tr>
</tbody>
</table>


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 m² which consist of five ridgets 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 m³/ 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 (m³ water/fed.) during the two seasons of 2015 and 2016.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>First season</th>
<th>Second seasons</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100 %</td>
<td>75 %</td>
</tr>
<tr>
<td>Germination</td>
<td>260</td>
<td>260</td>
</tr>
<tr>
<td>First irrigation</td>
<td>158</td>
<td>118.5</td>
</tr>
<tr>
<td>Second irrigation</td>
<td>169</td>
<td>126.75</td>
</tr>
<tr>
<td>Third irrigation</td>
<td>182</td>
<td>136.7</td>
</tr>
<tr>
<td>Total</td>
<td>769</td>
<td>642.05</td>
</tr>
</tbody>
</table>
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.

   edible head volume (0.75 X 3.14 X radius³)

Compactness rate = ————————————————————
                            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 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.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Plant height (cm)</th>
<th>Foliage FW g / plant</th>
<th>Leaves No / plant</th>
<th>Leaves area (m²) / plant</th>
<th>Leaves FW g / plant</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1st s</td>
<td>2nd s</td>
<td>1st s</td>
<td>2nd s</td>
<td>1st s</td>
</tr>
<tr>
<td>Full irrigation</td>
<td>29.5</td>
<td>29.1</td>
<td>7054</td>
<td>6951</td>
<td>56.0</td>
</tr>
<tr>
<td>Moderate</td>
<td>27.7</td>
<td>27.3</td>
<td>6617</td>
<td>6520</td>
<td>52.5</td>
</tr>
<tr>
<td>Sever</td>
<td>24.2</td>
<td>23.8</td>
<td>5774</td>
<td>5689</td>
<td>45.8</td>
</tr>
<tr>
<td>LSD 5%</td>
<td>2.2</td>
<td>1.9</td>
<td>525</td>
<td>517</td>
<td>4.2</td>
</tr>
</tbody>
</table>

- 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.

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 oxidative stress duration 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). Exogenous 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 giberellins and cytokinins. On contrast, endogenous absicic 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 pigments and carotenoids. This improved in previous values were found by application of without stress application (50 % from full irrigation) and without antioxidants treatment in first and second seasons.

Table 4 demonstrated 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 under water deficit. These results are in accordance with those reported by Nyatuame 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.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Chl. a mg/100 FW s</th>
<th>Chl.b mg/100 FW s</th>
<th>Carotenoids mg/100g FW s</th>
<th>N %</th>
<th>P %</th>
<th>K %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full irrigation</td>
<td>44.7 44.1 22.3 22.0 12.5 12.0 2.72 2.69 0.33 0.325 3.41 3.36</td>
<td>Moderate</td>
<td>41.9 41.3 20.9 20.6 11.7 11.3 2.55 2.52 0.31 0.305 3.20 3.15</td>
<td>Sever</td>
<td>36.6 36.1 18.3 18.0 10.2 10.0 2.23 2.20 0.270 0.266 2.79 2.75</td>
<td>LSD 5%</td>
</tr>
<tr>
<td>Without</td>
<td>38.5 37.8 19.2 18.9 10.8 10.2 2.35 2.30 0.285 0.279 2.94 2.88</td>
<td>Ascorbic acid 0.3 g/l</td>
<td>41.8 41.2 20.9 20.6 11.7 11.4 2.54 2.51 0.309 0.304 3.19 3.14</td>
<td>Chitosan 0.1 g/l</td>
<td>42.9 42.3 21.4 21.1 12.0 11.7 2.61 2.58 0.317 0.313 3.27 3.23</td>
<td>Glycine betaine 4.0 g/l</td>
</tr>
</tbody>
</table>

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. Tangue 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.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Head FW g/plant</th>
<th>Edible head FW (g)/plant</th>
<th>Edible head diameter (cm)</th>
<th>Edible head compact-ness</th>
<th>Edible head DM%</th>
<th>Total heads yield (Ton/fed.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1st s 2nd s</td>
<td>1st s 2nd s</td>
<td>1st s 2nd s</td>
<td>1st s 2nd s</td>
<td>1st s 2nd s</td>
<td>1st s 2nd s</td>
</tr>
<tr>
<td>Full irrigation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full</td>
<td>6814</td>
<td>6714</td>
<td>5492</td>
<td>5412</td>
<td>37.2</td>
<td>36.6</td>
</tr>
<tr>
<td>Moderate</td>
<td>6383</td>
<td>6289</td>
<td>5152</td>
<td>5076</td>
<td>34.9</td>
<td>34.5</td>
</tr>
<tr>
<td>Sever</td>
<td>5552</td>
<td>5471</td>
<td>4495</td>
<td>4429</td>
<td>30.5</td>
<td>30.0</td>
</tr>
<tr>
<td>LSD 5%</td>
<td>517</td>
<td>510</td>
<td>409</td>
<td>403</td>
<td>2.7</td>
<td>2.8</td>
</tr>
<tr>
<td>foliar application</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Without</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ascorbic acid 0.3 g/l</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chitosan 0.1 g/l</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glycine betaine 4.0 g/l</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LSD 5%</td>
<td>529</td>
<td>521</td>
<td>418</td>
<td>412</td>
<td>2.8</td>
<td>2.2</td>
</tr>
</tbody>
</table>

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 Leskovic, 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-aminocyclop propane-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 mustard 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 diameter, edible head compactness rate, total heads yield, interaction was significant in the both seasons, the highest and Hira with those recorded by Fariduddin in plants (Li et al., 2016) on cucumber.

Ascorbic acid 0.3 g /l 43.9 43.2 5.76 5.70 65.4 64.4 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 5.22 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

These results may be attributed to irrigation water deficit resulted increasing ethylene, ascorbic acid production and reduction of nutritious elements transport, gibberellins and cytokinins production which resulted in low roots formation, the stomata should be avoided to allow 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 m² 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.
by using foliar antioxidant (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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