HYDROGEN PEROXIDE AS A PRIMING AGENT FOR ALLEVIATING SOIL SALINITY STRESS ON WHEAT (Triticum aestivum) SEEDLINGS.

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ABSTRACT

This work investigated the potential of two concentrations of H$_2$O$_2$ (0.10 and 0.20 mM) applied through irrigation water, as a priming factor, in reducing the detrimental effects of soil salinity stress on wheat (Triticum aestivum L.). Two wheat genotypes, Gemaiza 9 (G9) as a moderately salt sensitive and Sakha 93 (S93) as a salt tolerant, were grown in pots containing a saline clay soil (EC$_e$ of 7.35 dS/m) under greenhouse conditions for 45 days. The obtained results showed that H$_2$O$_2$ application at 0.10 and 0.20 mM stimulated the germination of G9 genotype by 10 and 20%, respectively. Both fresh and dry shoot weights of G9 had increased by 9.92 and 7.70 and 8.52 and 8.2% for 0.1 and 0.2 mM H$_2$O$_2$ treated plants, respectively, as compared to control treatment. In contrast, In S93 genotype, negative effects on germination and fresh and dry weight were recorded. The irrigation with 0.1mM H$_2$O$_2$-treated water markedly increased the tillers to about 100% and 22.2% in G9 and S93, respectively, while 0.2mM H$_2$O$_2$ treatment increased the tillers number to 28.6% more in G9 and decreased it 16.7% in S93. Addition of 0.2 mM H$_2$O$_2$ had a negative effect on chlorophyll A content in both cultivars. In G9, chlorophyll B and carotene content were promoted particularly by 0.2mM H$_2$O$_2$. Significant decreases in Na$^+$ content in both cultivars were observed with H$_2$O$_2$ application while potassium was not markedly affected. The K$^+$/Na$^+$ ratio of G9 was lower than that in S93 in all treatments and tended to increase in both genotypes with H$_2$O$_2$ applications. It can be conducted that application of H$_2$O$_2$ as a physiological priming factor may play a significant role in growth improvement of moderately salt sensitive wheat genotypes such as G9 through promotion of Chlorophyll B synthesis and reduction of Na$^+$ content.

INTRODUCTION

Soil salinity, one of the most severe abiotic stresses, limits the production of nearly over 6% of the world’s land and 20% of irrigated land which represent about 15% of total cultivated areas and negatively affects crop production worldwide (Hasanuzzaman et al., 2012). Plants are frequently exposed to adverse environmental conditions, termed abiotic stresses such as salinity, drought, heat, cold, flooding, heavy metals, ozone, UV radiation, etc. therefore, they pose serious threats to the sustainability of crop yield (Bhatnagar-Mathur et al. 2008) . Abiotic stresses remain the greatest constraint to crop production worldwide. It leads to a series of morphological, physiological, biochemical and molecular changes that adversely affect plant growth and productivity (Wang et al. 2001). It has been estimated that more than 50% of yield reduction is the direct result of abiotic stresses (Acquaah 2007). However, the rapidity and efficiency of these responses may be decisive for the viability of the given species. Poor
germination and poor seedling establishment are the results of soil salinity, which adversely affects growth and development of crop plants and results in low agricultural production (Garg and Gupta 1997). The adverse effects of salinity have been attributed to an increase in sodium (Na\(^+\)) and chloride (Cl\(^-\)) ions and hence these ions produce the critical conditions for plant survival by intercepting different plant mechanisms. Both Na\(^+\) and Cl\(^-\) produce many physiological disorders in plants (Mahajan and Tuteja, 2005). A plant's response to salt stress depends on the genotype, developmental stage, as well as the intensity and duration of the stress. The outcome of these effects may cause the disorganization of cellular membranes, inhibit photosynthesis, generate toxic metabolites and decline nutrient absorption, ultimately leading to plant death (Mahajan and Tuteja 2005). In general, the response of a crop plant to salinity is reduced growth (Tavakkoli et al. 2011). Osmotic stress due to salinity leads to a slow growth rate and developmental characteristics such as vegetative development, net assimilation capacity, leaf expansion rate and leaf area index (Zheng et al. 2008 ; Hasanuzzaman et al. 2009 ). A reduction in photosynthesis is also one of the most conspicuous effects of salinity stress (Leisner et al. 2010 ; Raziuddin et al. 2011 ).

Wheat is grown in all types of soils and is classified as a moderate to salt tolerant crop (Mass and Hoffman, 1977). The effects of salinity at seedling stage of wheat range from reduction in germination percentage, fresh and dry weight of shoots and roots to the uptake of various nutrient ions. It is thought that the depressive effect of salinity on germination could be related to a decline in endogenous levels of hormones (Afzal et al., 2006).

Hydrogen peroxide (H\(_2\)O\(_2\)), is one of the reactive oxygen species, plays two divergent roles in plants: at low concentrations, it acts as signaling molecule for the activation of defense responses under stresses, whereas at high concentrations, it causes exacerbating damage to cellular components (Hasanuzzaman et al., 2012).

Several reports confirmed that enhanced antioxidant defense combats oxidative stress induced by abiotic stressors like salinity (Hasanuzzaman et al., 2011a,b; Hossain et al., 2011) and drought (Selote and Khanna-Chopra, 2010; Hasanuzzaman and Fujita, 2011). Addition of H\(_2\)O\(_2\) to the nutrient solution induces salt tolerance by enhanced activities of antioxidants and reduced peroxidation of membrane lipids in leaves and roots of maize as an acclimation response (Azevedo Neto et al., 2005). Several research works had been done on the use of H\(_2\)O\(_2\) in seed pretreatments to alleviate the abiotic salt stress (Çavusoglu and Kabar, 2010; He et al., 2009; Abdul Wahida et al., 2007; Hameed et al., 2004). To date, there is limited information on the use of H\(_2\)O\(_2\), a stress signaling molecule for crop growth treatments. Here we investigate the effects of H\(_2\)O\(_2\) application, as priming factor, with irrigation water on salt tolerance of winter wheat seedlings of salt-sensitive and salt-tolerant genotypes through studying of several growth and physiological parameters.

**Amal H. Mahmoud.**

- Garg and Gupta, 1997
- Mahajan and Tuteja, 2005
- Tavakkoli et al., 2011
- Zheng et al., 2008
- Hasanuzzaman et al., 2009
- Leisner et al., 2010
- Raziuddin et al., 2011
- Mass and Hoffman, 1977
- Afzal et al., 2006
- Hasanuzzaman et al., 2011a,b
- Hossain et al., 2011
- Selote and Khanna-Chopra, 2010
- Hasanuzzaman and Fujita, 2011
- Azevedo Neto et al., 2005
- Çavusoglu and Kabar, 2010
- He et al., 2009
- Abdul Wahida et al., 2007
- Hameed et al., 2004

**456**
MATERIALS AND METHODS

Greenhouse growth experiment Two wheat (Tritium aestivum L.) cultivars; Gemaiza 9 (G9) and Sakha 93 (S93) were obtained from Crop Research Institute, Agricultural Research Center, MALR, Giza, Egypt. The selection of these two cultivars is based on the classification of wheat with respect to salt tolerance, where G9 and S93 are classified as salt sensitive and salt tolerant, respectively (El-Hendawy et al., 2005). The seeds were surface sterilized with 0.1 % (m/v) HgCl₂ for 10 min. then washed several times by distilled water (Abdul Galeel et al., 2008). Under greenhouse conditions, ten dried seeds were sown in plastic pots containing one kg of an air-dried saline alluvial soil. The main physico-chemical properties of the used experimental soil are presented in Table 1. Before seeds sowing, one-third of recommended doses of phosphorus (45 kg P₂O₅/Fed.) and potassium (50 kg K₂O/Fed.) in the forms of single-super phosphate (15.5% P₂O₅) and potassium sulfate (50% K₂O) were added and mixed with soil. The pots were irrigated with tap water containing 0.0, 0.1 and 0.2 mM H₂O₂ for the first 30 days of sowing for both cultivars using three replicates to minimize the experimental error. Seeds in pots were watered by the mentioned solution to field capacity and the frequent irrigations were conducted by the compensation of weight loss.

At harvest, number of tillers was recorded for all treatments, and then the fresh weight of plant shoots for each treatment was measured and calculated for each plant. The harvested plants were washed several times

<table>
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<th>Property</th>
<th>Value</th>
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<tbody>
<tr>
<td>Particle size distribution:</td>
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<tr>
<td>Sand (%)</td>
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</tr>
<tr>
<td>Silt (%)</td>
<td>17.20</td>
</tr>
<tr>
<td>Clay (%)</td>
<td>76.59</td>
</tr>
<tr>
<td>Soil texture:</td>
<td>Clay</td>
</tr>
<tr>
<td>Total carbonate (%)</td>
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</tr>
<tr>
<td>Cation exchange capacity (CEC, cmol/kg)</td>
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</tr>
<tr>
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</tr>
<tr>
<td>pH</td>
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<tr>
<td>Water soluble cations (meq/L)</td>
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<tr>
<td>Mg²⁺</td>
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<td>K⁺</td>
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<tr>
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<tr>
<td>SO₄²⁻</td>
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</tbody>
</table>
Amal H. Mahmoud.

with distilled water, and divided into two parts. One part was oven dried for 24 hours at 70 °C (Jonse and Case, 1990). The dry weight was recorded and calculated for each plant. From the other part, 0.500 gram of fresh shoot was separated to chlorophyll (a and b) and carotene determinations.

Chlorophyll and carotene content
Extraction and determination of chlorophyll A (ChlA) and B (ChlB) and carotene (CAR) was performed according to the method of Arnon (1949) where 0.500 g of fresh shoot material was ground with 10 ml of 80% acetone and centrifuged at 2500 rpm for 10 minutes at 4°C. This procedure was repeated until the residue became colorless. The extract was transferred to a graduated tube and made up to 10 ml with 80% acetone and assayed immediately. Three milliliters aliquots of the extract were transferred to a cuvette and the absorbance was read at 645, 663 and 480 nm with a spectrophotometer (UV/VIS double beam JENWAY model 6850) against 80% acetone as a blank. Chlorophyll content was calculated using the formula of Arnon and expressed in mg g⁻¹ fresh weight (FW) as follow:

\[
\text{Total chlorophyll (mg/ml)} = (0.0202) \times (A.645) + (0.00802) \times (A.663)
\]

\[
\text{ChlA (mg/ml)} = (0.0127) \times (A.663) – (0.00269) \times (A.645)
\]

\[
\text{ChlB (mg/ml)} = (0.0229) \times (A.645) – (0.00468) \times (A.663)
\]

CAR content was estimated using the formula of Kirk and Allen (1965) and expressed in mg g⁻¹ FW.

\[
\text{Carotene} = A.480 + (0.114 \times A.663 – 0.638 \times A.645).
\]

Sodium and potassium content
For the determination of sodium (Na⁺) and potassium (K⁺), the oven-dried plant material of 0.500 g of ground and sieved (0.5 mm) shoots were transferred into porcelain crucibles and subjected to dry ashing at 550 °C for 5 hours in muffle furnace (Chapman and Pratt, 1961). The cold plant ash was dissolved in 5.0 mL 2.0N HCl and complete with distilled water to 50 mL then filtered using Whatmann No. 42 filter paper. The concentrations of Na⁺ and K⁺ were measured using flame photometer (JENWAY model PFP7/C) and their contents in plant shoots were calculated.

The obtained results were statistically analyzed and analysis of variance was conducted using Costat under windows software (CoHort Software, http://www.cohort.com/index.html)

RESULTS AND DISCUSSION

Effect of H₂O₂ treatment on germination
Figure (1) represents the early growth or seed germination of Gemaiza 9 (G9) and Sakha 93 (S93) under salinity conditions in the absence and presence of H₂O₂. It is important to mention that the salinity of the saturated extract of soil was 7.35 dSm⁻¹ (Table 1) and that the level of soil salinity (control) had reduced seed germination percentage to 80% of G9 while did not affect S93 (100% germination). Treatment with both concentrations of H₂O₂ (0.1 and 0.2 mM) improved the growth of G9 by the same percentage but those treatments decreased the germination of S93 by 10 and 20% respectively (Fig. 1). The negative response of S93 to H₂O₂
stimulation may be attributed to that S93 has a defense strategy against the mentioned level of salinity rather than G9 and, therefore, is classified as salinity tolerant cultivar. Recent studies showed that S93 is more salt tolerant than G9 (e.g., Mahmoud, 2009 and El-Hendawy et al., 2005) therefore the germination improvement action of H$_2$O$_2$ was effective with the latter cultivar. In the same time, other studies pointed to the role of H$_2$O$_2$ in alleviating the hazardous effect of salinity stress on wheat seed germination where H$_2$O$_2$ was able to promote germination (Christophe et al. 2008) or formation and development of adventitious roots (Li et al. 2009). Similar concentrations of H$_2$O$_2$ (50 – 200 uM H$_2$O$_2$ led to significant increase in the germination rate of the seeds of drought sensitive wheat cultivars whereas and vice versa with drought tolerant ones (Lu et al., 2013).

![Figure (1). Seed germination percentage of G9 and S93 wheat cultivars as a result of H$_2$O$_2$ treatment.](image)

**Fresh and dry weight of seedlings**

Figure (2) represents the priming effect of H$_2$O$_2$ on the fresh weight (FW) and dry weight (DW) of 45-days old shoot of G9 and S93 wheat cultivars. Water treatments with H$_2$O$_2$ increased both FW and DW of the shoot of G9 by 9.92 and 7.70 and 8.52 and 8.2 for 0.1 and 0.2 mM H$_2$O$_2$ treated plants, respectively, comparing to control treatment. While H$_2$O$_2$ application had a negative effect on the FW and DW of S93 shoot except that 0.1 mM H$_2$O$_2$ treatment increased the FW by 11.6% (Fig. 2).

**Effect of H$_2$O$_2$ treatment on tillers formation**

Tillering stage in wheat growth cycle starts after 20 days of planting date and continued to the end of experiment. As shown before, the saturation extract of the used soil used for wheat growth had electrical conductivity (EC$_e$) of 7.37 dSm$^{-1}$ which consequently had an influence on the growth and tillering development. According to Fig. (3), number of tillers, at forty five days
of growth, reached to 7 and 18 per pot for G9 and S93, respectively, for control treatment. The irrigation with 0.1mM H$_2$O$_2$-treated water markedly increased the tillers to about 14 (100%) and 22 (22.2%) per pot in G9 and S93, respectively. While the 0.2mM H$_2$O$_2$ treatment increased the tillers number to 9 (28.6% more) in G9 and decreased it to 15 (16.7% less) per pot in S93 (Figure 3). The adverse effect of high concentration of H$_2$O$_2$ (0.2 mM) on S93 wheat cultivar as compared to the control (irrigation water without H$_2$O$_2$) may be due to the effect of exogenous H$_2$O$_2$, as one of the reactive oxygen species (ROS), on salt-tolerant genotypes of wheat such as S93 which is considered as another stress (oxidative stress). The enhanced ROS concentration under salt stress induces phytotoxic reactions such as lipid peroxidation, protein degradation, and DNA mutations (Tanou et al. 2009). Furthermore, these physiological disorders may be reflected on the growth parameters such as tillering formation in salt tolerant genotypes (Hasanuzzaman et al., 2012).

**Chlorophyll and carotene contents**

The ChlA, ChlB and CAR contents in plant shoots were determined after 45 day of plantation. It was observed that, addition of H$_2$O$_2$ had a negative effect on ChlA content in both wheat cultivars particularly with 0.2 mM H$_2$O$_2$ treatment (Fig. 4). ChlB and CAR content increased in 0.2mM H$_2$O$_2$-treated G9 and decreased in S93 (Fig. 4). The data of total chlorophyll content showed that H$_2$O$_2$ stimulated the syntheses of chlorophyll in G9 wheat cultivar, while in S93 cultivar, it had not effect (0.1mM level) or negative (0.2mM level) as compared to the H$_2$O$_2$-non treated plants (Fig. 5). On the other hand, the calculated ratio of ChlA/ChlB indicated that there was a difference between the two tested wheat cultivars with respect to their response to hydrogen peroxide treatments (Fig. 6). In G9 cultivar, H$_2$O$_2$ application led to decrease the ChlA/ChlB ratio while seedlings of S93 showed reverse behavior Fig. (3). The tillers number of G9 and S93 wheat cultivars as a result of H$_2$O$_2$ application with irrigation water, particularly in 0.2 mM H$_2$O$_2$-treated plants. It seems that, in salt sensitive plants, the pretreatment with H$_2$O$_2$ promotes the synthesis of ChlB under salt stress and therefore, the ratio of ChlA/ChlB had decreased (Yasmeen et al., 2013). As shown from the obtained results, increasing the concentration of ChlB, and subsequent increasing total chlorophyll and decreasing the ratio of ChlA/ChlB, in the shoot of the moderately-salt tolerant G9 cultivar is considered as an exogenous promoting adaptation mechanism against salt stress in saline soil by H$_2$O$_2$. 

460
Fig. (2). The fresh and dry weight of 45-days old two wheat cultivars as influenced by H$_2$O$_2$ treatments.
Fig. (3). The tillers number of G9 and S93 wheat cultivars as a result of H2O2 application with irrigation water.

**Sodium and potassium uptake**

Figure (7) demonstrates the shoot content of Na\(^+\) and K\(^+\) and the shoot K\(^+\)/Na\(^+\) ratio in G9 and S93 genotypes of wheat as a result of H\(_2\)O\(_2\) treatment. In general, Na\(^+\) content in S93 was less than in G9 in the control and H\(_2\)O\(_2\) treatments (Fig. 7 A). Irrigation with H\(_2\)O\(_2\)-containing water (0.1 and 0.2 mM H\(_2\)O\(_2\)) led to significant decreases in Na\(^+\) content in both cultivars. Potassium content, on the other hand, was not markedly affected but, in general, it tended to slight decrease with the treatments of H\(_2\)O\(_2\) (Fig. 6 B). The ratio of shoot K\(^+\)/Na\(^+\) in G9 was lower than in S93 in all treatments (Fig. 7 C) and tended to increased with H\(_2\)O\(_2\) applications. It is known that one of the key features of salt-tolerant plant was the ability for cells to maintain high K\(^+\)/Na\(^+\) ratio (Tester and Davenport, 2003) as shown with the seedlings of S93 cultivar comparing to G9 (less salt-tolerant genotype) in the control treatments. The H\(_2\)O\(_2\) treatments maintained a higher K\(^+\)/Na\(^+\) ratio in the salt tolerant genotype (S93) compared with the salt sensitivity seedlings (G9) with both concentrations of hydrogen peroxide. Cuin et al. (2003) concluded that high K\(^+\)/Na\(^+\) ratio is more important for many species than maintaining a low concentration of Na\(^+\). The current results of Na\(^+\) and K\(^+\) content showed that addition of H\(_2\)O\(_2\) with irrigation water, for the first 30 day after sowing, significantly decreased Na\(^+\) (chiefly in the moderately sensitive wheat G9) while approximately maintained the level of K\(^+\) in both genotypes (Fig. 7).

Data of analysis of variance (Table 2) demonstrate that the measured variables, which significantly related to H\(_2\)O\(_2\) application, were the tillering development, sodium content and the K\(^+\)/Na\(^+\) ratio whereas the fresh and dry weight of shoots, tillering development, Na\(^+\) and K\(^+\)/Na\(^+\) ratio were highly related to the type of wheat cultivar.
Fig. (4) Chlorophyll A and B and carotene content in the shoots of 45-day old wheat seedling cultivars; G9 and S93 as influenced by H₂O₂ application with irrigation water.
Fig. (5) Total Chlorophyll content in the shoot of 45-day old wheat seedling cultivars G9 and S93 as a function of H$_2$O$_2$ application with irrigation water.

Fig. (6) Chlorophyll A/B ratio in the shoot of 45-day old wheat seedling cultivars G9 and S93 as a function of H$_2$O$_2$ application with irrigation water.
Fig. (7) The concentrations of sodium and potassium and K:Na ratio in shoots of G9 and S93 wheat cultivars after 45 days of treatment with H₂O₂.
Table (2) ANOVA analysis of the effect of H$_2$O$_2$ application and wheat cultivars on the means of fresh and dry weight of shoot, tillering, pigments content and sodium and potassium ionic balances.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Treatment</th>
<th>FW (g/pot)</th>
<th>DW (g/pot)</th>
<th>Tellers (No/pot)</th>
<th>Chl.A (mg/g)</th>
<th>Chl.B (mg/g)</th>
<th>CAR (mg/g)</th>
<th>ChlA/B</th>
<th>Na (%)</th>
<th>K (%)</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>0</td>
<td>28.58 a</td>
<td>4.485 a</td>
<td>12.667 b</td>
<td>5.353 a</td>
<td>2.342 a</td>
<td>4.910 a</td>
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<tr>
<td></td>
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<td>0.1 mM</td>
<td>29.78 a</td>
<td>4.928 a</td>
<td>18.000 a</td>
<td>5.138 a</td>
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<td>.817 b</td>
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<td></td>
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<td>0.2 mM</td>
<td>27.28 a</td>
<td>4.565 a</td>
<td>12.333 b</td>
<td>4.922 a</td>
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<tr>
<td>LSD 0.05</td>
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<td>2.807</td>
<td>0.533</td>
<td>3.911</td>
<td>0.726</td>
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<td>1.45</td>
<td>0.88</td>
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<tr>
<td>Cultivar</td>
<td>G9</td>
<td>29.96 b</td>
<td>4.377 a</td>
<td>10.111 b</td>
<td>5.227 a</td>
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<td>S93</td>
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<td>18.556 a</td>
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<tr>
<td>LSD 0.05</td>
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</tr>
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</table>

Significance

- H$_2$O$_2$: ns ns * ns ns ns ns *** ns
- Cultivar: * * *** ns ns ns ns *** ns
- Interaction: ns ns ns ns ns ns ns ns ns

Conclusion

From the obtained results, it can be concluded that

1. Application of H$_2$O$_2$ at low concentrations with irrigation water during the germination and seedling development stages of wheat plants can improve the germination percentage and growth of moderately sensitive cultivars such as gemaiza 9.

2. The low concentration treatment of H$_2$O$_2$ (0.10 mM) applied with water of irrigation stimulate the tillers number in both moderately salt sensitive (G9) and salt tolerant (S93) wheat cultivars.

3. The higher concentration of applied H$_2$O$_2$ (0.20 mM) stimulated G9 genotypes to compensate the reduction in ChlA concentration by increasing the concentration of ChlB and subsequent increasing the total chlorophyll content in the shoot.

4. The irrigation with H$_2$O$_2$-containing water significantly decreased Na$^+$ content and increased K$^+$/Na$^+$ ratio in both tested wheat cultivars which reflected on the reduction of Na$^+$ phytotoxic effect on certain physiological processes, such as plant growth and total chlorophyll content.

5. The obtained results may be a basis for improving abiotic stress tolerance in salinity sensitive and moderately sensitive wheat cultivars.
REFERENCES


تبحث هذه الدراسة امكانية استخدام فوق أوكسيد الهيدروجين مع مياه الري كعامل تحفز فسيولوجي يعمل على تقليل الإثار الضارة لملوحة التربة على نمو صنفين من نباتات الفحم حما جمیزة 9 (متوسط الحساسية للأملاح) وسمآ 93 (تحمل للألام). في أصحاح تحوى على أرض طينية ملحة (التوسيط الكهربي لمستخلص خميرة الأرض 7.35 ديسيمترز / متر) في الصوية لمدة 45 يوم. بيت النتائج المتحصل عليها أن إضافة فوق أوكسيد الهيدروجين بتركيزات 0.1 و0.2 مللي جزيئي في ماء الري في اليوم الأول من الزراعة عملت على تحقيق الأتات لصف جمیزة 9 نسبة 10 و ۲۰% على التوالي. كما زاد كل من الوزن الرطب والوزن الجاف في صف جمیزة 9 بنسبة 9.2 و ۷.۷ و 8.2 و ۸.۸ و ۸.۲ و ۸٪ في النباتات المعملة بتركيز 0.1 و 0.2 ملي جزيئي على التوالي مقارنة بمعالجة الأنتروول. وعلى عكس ذلك، تأثر كل من النتائج والأوزن الرطب والجاف ملحة بنسبة صنف سخا 93 نتيجة تلك المعالجات. أدت إضافة 0.1 مللي جزيئي من فوق أوكسيد الهيدروجين إلى ماء الري إلى زيادة معمد إلى التفرعات ونجلة إلى 100٪ في صنف سخا 93 بينما أدى الري بماء جمیزة 9 بنسبة 9 و ۲۲٪ في سخا 93 بينما أدت الري بماء جمیزة 9 بنسبة 28.6٪ في جمیزة 9 وانخفاض قدره ۱۶.۷٪ في سخا 93 مقارنة بالأمات المعملة (الكلترو). انخفاض تركيز الكلوروفيل (أ) في كل الصنفين نتيجة اضافة التركيز المرتفع من فوق أوكسيد الهيدروجين بينما عمل هذا التركيز على تخفیف تقلیل تلف من من الكلروفل (ب) والكارتوتین في صنف جمیزة 9 وأوضحت النتائج أيضاً حدوث انخفاض معنوي في الصوديوم الممتلء وعدم تغير في البوتاسيوم وزيادة كبيرة في نسبة البوتاسيوم إلى الصوديوم في كلا الصنفين نتيجة المعالمة فوق أوكسيد الهيدروجين. خلصت الدراسة إلى أن إضافة فوق أوكسيد الهيدروجين مع ماء الري يمكن أن يكون له دور إيجابي في تخسيس ظروف ات لمصفرة الفحم متوسطة الحساسية لملوحة التربة مثل جمیزة 9 عن طريق تخفیف تخليق كلوروفيل (ب) وخفض امتصاص الصوديوم.

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470