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## Use of hydrogen peroxide in acclimatization of melon to salinity of irrigation water<sup>1</sup>

### Uso do peróxido de hidrogênio na aclimação do melão à salinidade da água de irrigação

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#### HIGHLIGHTS:

Hydrogen peroxide ( $15 \mu\text{mol L}^{-1}$ ) increases transpiration, stomatal conductance, and net  $\text{CO}_2$  assimilation in melon plants.

High concentrations ( $15 \mu\text{mol L}^{-1}$ ) of hydrogen peroxide in plants irrigated with  $5.0 \text{ dS m}^{-1}$  salinity reduce melon fruit production.

Hydrogen peroxide at  $6.35$  and  $10.23 \mu\text{mol L}^{-1}$  attenuates the deleterious effects of salt stress in melon plants.

**ABSTRACT:** In the semi-arid region of northeastern Brazil, soil and climate conditions can increase the risk of soil salinization, particularly when poor-quality water is used for irrigation. Therefore, techniques that improve the yields of melon culture under adverse conditions, such as salinity, are of great relevance to the production sector. The objective of this study was to evaluate the effectiveness of hydrogen peroxide ( $\text{H}_2\text{O}_2$ ) in acclimatizing melon trees subjected to irrigation water with different salinity levels. The treatments consisted of irrigation water with two electrical conductivities ( $0.3$  and  $5.0 \text{ dS m}^{-1}$ ) and four concentrations of  $\text{H}_2\text{O}_2$  ( $0$ ,  $5$ ,  $10$ , and  $15 \mu\text{mol L}^{-1}$ ). The experimental design used was randomized blocks, arranged in a  $2 \times 4$  factorial scheme, with four replicates and four plants per plot. Increase in salinity of irrigation water reduced the growth, gas exchange, and production of melon plants. However,  $\text{H}_2\text{O}_2$ , at a concentration of  $6.35 \mu\text{mol L}^{-1}$ , yielded improvements in physiology, growth, and production, in addition to reducing the deleterious effects of saline stress on melon production.

**Key words:** *Cucumis melo* L., physiology, saline water

**RESUMO:** No semiárido do Nordeste brasileiro as condições edafoclimáticas podem favorecer riscos de salinização do solo, principalmente quando se utiliza água de má qualidade para irrigação. Nesse contexto, técnicas que possibilitem melhorias nos rendimentos da cultura do melão em condições adversas, como a salinidade, são, portanto, de grande relevância para o setor produtivo. Logo, o objetivo deste estudo foi avaliar a eficácia do peróxido de hidrogênio ( $\text{H}_2\text{O}_2$ ) na aclimação do meloeiro submetido a diferentes níveis salinos na água de irrigação. Os tratamentos consistiram de duas condutividades elétricas da água de irrigação ( $0,3$  e  $5,0 \text{ dS m}^{-1}$ ) e quatro concentrações de  $\text{H}_2\text{O}_2$  ( $0$ ,  $5$ ,  $10$  e  $15 \mu\text{mol L}^{-1}$ ). O delineamento experimental utilizado foi o de blocos casualizados, em esquema fatorial  $2 \times 4$ , com quatro repetições e quatro plantas por parcela. O aumento da salinidade da água de irrigação reduz o crescimento, as trocas gasosas e a produção do meloeiro. No entanto, o  $\text{H}_2\text{O}_2$ , na concentração de  $6,35 \mu\text{mol L}^{-1}$  proporcionou melhorias na fisiologia, crescimento e produção, além de reduzir os efeitos deletérios do estresse salino na produção de melão.

**Palavras-chave:** *Cucumis melo* L., fisiologia, água salina



## INTRODUCTION

Melon (*Cucumis melo* L.) belongs to the Cucurbitaceae family and is an olericultural crop cultivated in several regions of the world, owing to its wide adaptability and high socioeconomic expression (Kesh & Kaushik, 2021). Brazil is prominent in the export of this species, with the northeast region responsible for more than half of the national production (Silva et al., 2024).

However, in semi-arid regions, such as Northeast Brazil, soil and climate conditions can increase the risk of soil salinization, particularly when poor quality water is used for irrigation. The amount of salt in irrigation water can impair the physicochemical properties of soils and reduce crop yields according to their degree of tolerance (Sousa et al., 2018).

The melon tree is considered moderately tolerant to salinity, presenting a threshold in terms of electrical conductivity of the saturation extract (EC<sub>e</sub>) of approximately 2.2 dS m<sup>-1</sup> (Terceiro Neto et al., 2014). Values above this threshold may result in significant production loss. Excess salts decrease the water potential, restrict the absorption of water, and cause the accumulation of toxic ions, mainly Na<sup>+</sup> and Cl<sup>-</sup>.

The use of hydrogen peroxide (H<sub>2</sub>O<sub>2</sub>) exogenously in small amounts in plants appears to be a potential alternative for acclimatization to saline stress. H<sub>2</sub>O<sub>2</sub> stimulates the activation of the antioxidative defense system, functioning as an important intracellular signal for the activation of stress responses and plant defense pathways that promote cross-tolerance (Silva et al., 2016).

Techniques that make it possible to improve the yield of melon trees under adverse conditions, such as salinity, are of great relevance to the production sector. Thus, the objective of this study was to evaluate the effectiveness of H<sub>2</sub>O<sub>2</sub> in acclimatizing melon trees to different salinity levels in irrigation water.

## MATERIAL AND METHODS

The experiment was conducted in a greenhouse located at the Federal University of Campina Grande, at the Center of Sciences and Agrifood Technology, in Pombal, PB, Brazil (coordinates: 06° 47' 03" S, 37° 48' 08" W, altitude of 194 m).

The climate conditions of the protected environment during the experiment were monitored using a digital thermohygrometer model HT-208 (ICEL-Manaus) to record air temperature with a maximum of 39.21 °C and minimum of 31.82 °C, as well as maximum relative air humidity of 80.30% and minimum of 60.15%. The mean photosynthetically active radiation, measured using a ceptometer, was 1317 μmol m<sup>-2</sup> s<sup>-1</sup>.

The treatments were composed of two levels of irrigation water (0.3 and 5.0 dS m<sup>-1</sup>) and four concentrations of H<sub>2</sub>O<sub>2</sub> (0, 5, 10, and 15 μmol L<sup>-1</sup>). The experimental design used was randomized blocks in a 2 × 4 factorial scheme, with four replicates and four plants per plot. The salinity levels were

obtained using supply water (0.3 dS m<sup>-1</sup>), and sodium chloride was added to obtain a level of 5.0 dS m<sup>-1</sup>. The salinity levels were based on the threshold water salinity of melon (2.2 dS m<sup>-1</sup>) (Ayers & Westcot, 1999), selecting a low salinity level and another level above the threshold. Due to the absence of research on H<sub>2</sub>O<sub>2</sub> in melon, the concentrations used in the present assay were based on studies carried out with zucchini (Dantas et al., 2022) with adaptations.

The H<sub>2</sub>O<sub>2</sub> used in this study was prepared from a pure peroxide (99%) dilution. Applications were performed 7 and 15 days after germination of the plants, at the end of the afternoon, with the aid of a manual sprayer. The solution was applied directly to the leaves until they were completely wet, as recommended by Santos et al. (2018).

The 'Gold Mine' yellow melon hybrid was used for the experiment. Pots with a capacity of 8 L were filled with sieved soil (mesh 2). The pots were distributed at 1.20 m × 0.5 m spacing. The soil used for the experiment was classified as Entisol clayey texture (coarse sand = 290; fine sand = 150; silt = 170; and clay = 390 g kg<sup>-1</sup>). The results of chemical analysis of the soil, before the experiment was begun were as follows: pH in H<sub>2</sub>O (1:2.5) = 5.8; P = 58.5 mg dm<sup>-3</sup> and K = 0.19 cmol<sub>c</sub> dm<sup>-3</sup>; Na = 0.12 cmol<sub>c</sub> dm<sup>-3</sup>; Ca = 4.0 cmol<sub>c</sub> dm<sup>-3</sup>; Mg = 0.8 cmol<sub>c</sub> dm<sup>-3</sup>; Al = 0.0 cmol<sub>c</sub> dm<sup>-3</sup>; H + Al = 6.63 cmol<sub>c</sub> dm<sup>-3</sup>; SB = 4.99; CTC effective = 4.99 cmol<sub>c</sub> dm<sup>-3</sup> and EC<sub>e</sub> 0.6 dS m<sup>-1</sup>.

Sowing was performed by placing three seeds per pot at a depth of 0.5 cm. When the plants reached the stage of two definitive leaves, thinning was performed, leaving one plant per pot.

Irrigation was carried out daily in the morning and afternoon according to the water requirements of the plants, and in the first 15 days after sowing (DAS), the plants were irrigated only with saline water of 0.3 dS m<sup>-1</sup>. The volume of water to be applied was determined by drainage lysimetry. After this period, in addition to the saline treatment, an adequate nutrient solution by Hoagland & Arnon (1950) was used at 75% of the total strength while maintaining a pH of approximately 5.6 (Table 1).

At 50 DAS, net CO<sub>2</sub> assimilation (A), stomatal conductance (g<sub>s</sub>), transpiration (E), intercellular CO<sub>2</sub> concentration (C<sub>i</sub>), instantaneous water use efficiency (WUE = A/E), and instantaneous carboxylation efficiency (iCE = A/C<sub>i</sub>) were evaluated on the fifth leaf counted from the apex of the branch to the base, using an infrared gas analyzer LCpro+ (Analytical Development, Kings Lynn, UK) with a constant light source of 1200 μmol m<sup>-2</sup> s<sup>-1</sup> photons. Growth characteristics were assessed at 62 DAS. The leaf area (LA) was obtained by relating the dry mass of eight leaf discs of known area (11.28 cm<sup>2</sup>) removed from intermediate leaves, with the dry mass of the leaves; dry mass of the aerial part (DMAP) comprising leaves and stems was obtained by drying the material in an oven with air circulation at 65 °C for 72 hours. For the fruit production (P), all the fruits of each treatment were analyzed to obtain their average mass.

**Table 1.** Concentrations of nutrients in the nutrient solution of Hoagland & Arnon (1950)

| Nutrients                             | N  | P | K | Ca | Mg | S | Fe   | Mn   | B    | Cu    | Zn     | Mo    |
|---------------------------------------|----|---|---|----|----|---|------|------|------|-------|--------|-------|
| Concentration (mmol L <sup>-1</sup> ) | 15 | 1 | 6 | 5  | 2  | 2 | 0.05 | 0.01 | 0.05 | 0.003 | 0.0008 | 0.001 |

The data of the evaluated variables were subjected to the F test at  $p \leq 0.05$ , using analysis of variance. For the salinity factor, the mean values were compared using Tukey's test, and the concentrations of  $H_2O_2$  were subjected to regression analysis. Statistical analyses were performed using SISVAR software (Ferreira, 2014).

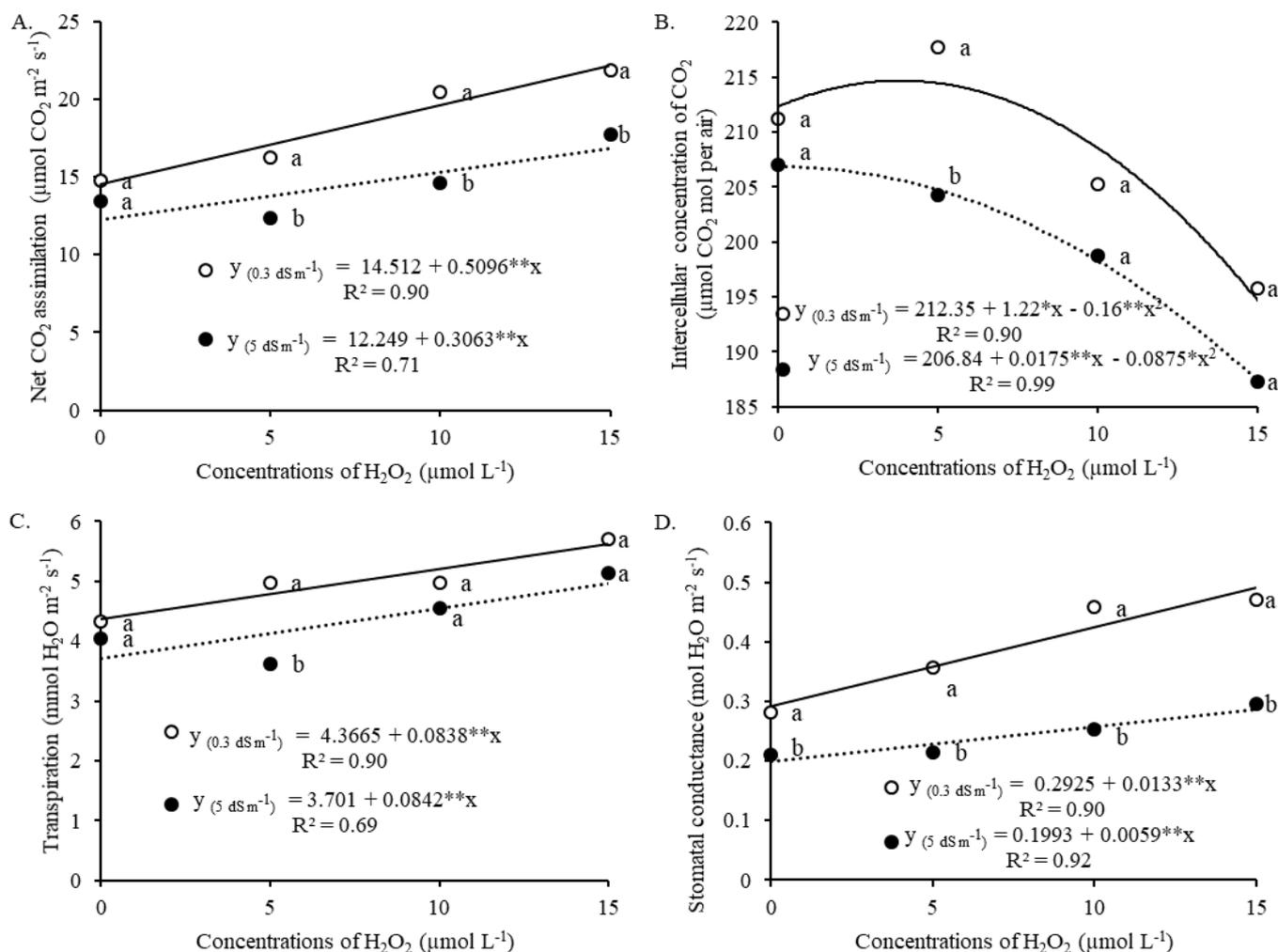
## RESULTS AND DISCUSSION

There was a significant interaction between salinity levels and  $H_2O_2$  concentrations for A,  $C_i$ , E, gs, LA, DMAP, and P per plant (Table 2).

**Table 2.** Summary of the F test for the net  $CO_2$  assimilation (A), intercellular  $CO_2$  concentration ( $C_i$ ), transpiration (E), stomatal conductance (gs), instantaneous carboxylation efficiency (iCE), water use efficiency (WUE), leaf area (LA), dry mass of the aerial part (DMAP), and fruit production (P) per plant in melon plants subjected to 0.3 and 5.0  $dS m^{-1}$  levels of salinity of irrigation water and various  $H_2O_2$  concentrations

| Source of variation                | F test |       |      |       |      |      |       |       |       |  |
|------------------------------------|--------|-------|------|-------|------|------|-------|-------|-------|--|
|                                    | A      | $C_i$ | E    | gs    | iCE  | WUE  | LA    | DMAP  | P     |  |
| Blocks                             | ns     | ns    | ns   | ns    | ns   | ns   | ns    | ns    | ns    |  |
| Salinity (S)                       | **     | **    | **   | **    | ns   | ns   | **    | **    | **    |  |
| Hydrogen peroxide ( $H_2O_2$ )     | **     | **    | **   | **    | ns   | ns   | *     | *     | *     |  |
| Interaction (S $\times$ $H_2O_2$ ) | **     | *     | *    | *     | ns   | ns   | *     | *     | *     |  |
| CV (%)                             | 6.26   | 3.54  | 8.79 | 13.26 | 7.49 | 6.54 | 23.10 | 15.57 | 16.06 |  |

ns, \*, and \*\* - Not significant, significant at  $p \leq 0.05$ , and at  $p \leq 0.01$ , respectively, by F test



\* and \*\*: significant at  $p \leq 0.05$  and at  $p \leq 0.01$  by F test, respectively

**Figure 1.** Net  $CO_2$  assimilation (A), intercellular concentration of  $CO_2$  (B), transpiration (C), and stomatal conductance (D) in melon plants in function of  $H_2O_2$  concentrations for 0.3 and 5.0  $dS m^{-1}$  levels of salinity of irrigation water

In contrast, iCE and WUE were not significantly influenced by either factor studied, possibly because they are mathematical relationships, such as the ratio between the carbon dioxide assimilation rate and intracellular  $CO_2$  concentration (iCE), as well as the ratio between the  $CO_2$  assimilation rate and conductance (WUE), as observed by Sousa et al. (2018).

For A, a linear behavior was observed with an increase of 52.61 and 37.5% between the lowest (0.0  $\mu mol L^{-1}$ ) and highest (15.0  $\mu mol L^{-1}$ ) concentrations of  $H_2O_2$  when irrigated with water at 0.3 and 5.0  $dS m^{-1}$ , respectively (Figure 1A). Increments in photosynthesis by  $H_2O_2$  priming can be related to carbon fixation enzyme activity, PSII efficiency, and protection

of cellular organelles, such as chloroplasts (Araújo et al., 2021). Analysis of the interaction for salinity levels at each concentration of  $H_2O_2$  showed that the net photosynthesis of melon plants irrigated with electrical conductivity of water (ECw) of  $0.3 \text{ dS m}^{-1}$  was significantly higher than that of melon plants subjected to water salinity of  $5 \text{ dS m}^{-1}$ .

Intercellular concentration of  $CO_2$ , which was adjusted to the quadratic polynomial model, exhibited decreases from the concentrations of  $3.81$  and  $0.1 \mu\text{mol L}^{-1}$  to the salinity levels of  $0.3$  and  $5.0 \text{ dS m}^{-1}$ , respectively (Figure 1B). The  $C_i$  was significantly higher in plants treated with  $0.3 \text{ dS m}^{-1}$ , only in those wherein  $5 \mu\text{mol L}^{-1}$  of  $H_2O_2$  was used; the other  $H_2O_2$  concentrations did not significantly influence this variable between salt levels.

The reduction in the  $CO_2$  influx may be associated with several factors. However, the accumulation of salts in the apoplast, the toxic effect of ions, or the reduction of the internal water potential has been proposed to initially promote a decrease in the process of  $CO_2$  fixation. This process may also have been accelerated by the accumulation of reactive oxygen species but not by interrupting photosynthetic activity (Ahanger et al., 2019). With an increase in photosynthetic activity, the plant consumes more  $CO_2$ , and when its influx decreases significantly, there can be a limitation in the substomatic cavity, and consequently, a decrease in the activity of the enzyme ribulose 1.5-bisphosphate carboxylase oxygenase (RuBisCO) (Souza et al., 2016). This limitation of  $CO_2$  fixation in the Calvin cycle by RuBisCO in plants under stress conditions reduces the oxidation of NADPH. When this occurs, the reduced ferredoxin electron that would be transferred to  $NADP^+$  goes to  $O_2$  and forms a superoxide radical ( $O_2^{\cdot-}$ ), which in excess can cause photooxidation (Barbosa et al., 2014).

For E, it was found that the concentration of  $15 \mu\text{mol L}^{-1}$   $H_2O_2$  resulted in an increase of 28.51 and 34.04% over the concentration of  $0.0 \mu\text{mol L}^{-1}$ , for the salinity levels of  $0.3$  and  $5.0 \text{ dS m}^{-1}$ , respectively (Figure 1C). At  $5 \mu\text{mol L}^{-1}$   $H_2O_2$ , E values were significantly higher in plants irrigated with water having  $0.3 \text{ dS m}^{-1}$  salinity level compared to those of plants irrigated with water having  $5 \text{ dS m}^{-1}$  salinity level.

The same was observed for gs, with higher increases (66.78 and 37.68%) for both salinity levels, in the same order as before, using the highest peroxide concentration (Figure 1D). Regarding the interaction of factors, it was observed that plants treated with  $0.3 \text{ dS m}^{-1}$  showed higher gs than plants treated with  $5 \text{ dS m}^{-1}$ , at all concentrations of  $H_2O_2$ . Lacerda et al. (2022) also observed a reduction in gs in corn plants subjected to  $2 \text{ dS m}^{-1}$ , at all concentrations of  $H_2O_2$ . As E decreases, gs follows the same behavior as that of the plant to avoid water loss in stress situations, as stated by Veloso et al. (2022). This stomatal behavior is responsible for determining the transpiration demand to which leaves are potentially subjected. Under optimal water availability conditions, plants generally have high transpiration rates; therefore, as water becomes scarce for indoor activities, there is usually a reduction in the transpiration rate. While culturing pistachio, Bagheri et al. (2019) found that pre-treatment with  $H_2O_2$  resulted in a better water status under osmotic stress, inducing tolerance and further increasing soluble sugar, proline, and polyamine

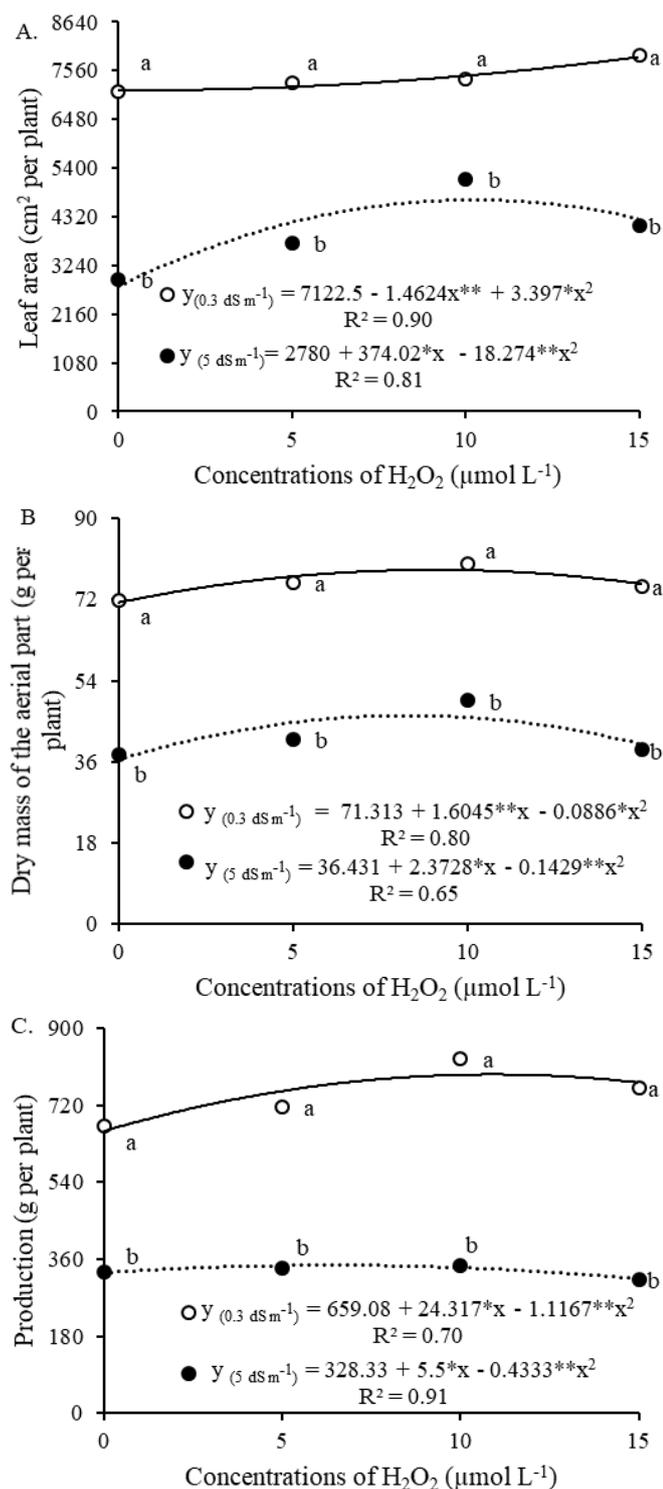
levels. Thus, it was noticeable in this study that the use of lower concentrations of  $H_2O_2$  in melon culture attenuated salinity, as it avoided the greater implication of the physiological parameters evaluated.

When analyzing the interaction between the electrical conductivity of irrigation water and  $H_2O_2$  concentrations, it was observed that the LA (Figure 2A), DMAP (Figure 2B), and P of melon plants (Figure 2C) subjected to ECw of  $0.3 \text{ dS m}^{-1}$  differed significantly from that of plants irrigated with water at  $5.0 \text{ dS m}^{-1}$ . This was due to high saline concentrations reducing melon growth and production (Sousa et al., 2018).

An increase in LA was noted, as a function of the increase in concentrations of  $H_2O_2$  to the salinity of  $0.3 \text{ dS m}^{-1}$  (Figure 2A). However, for the salinity level of  $5.0 \text{ dS m}^{-1}$ , a higher value ( $4694.01 \text{ cm}^2$ ) was obtained with a concentration of  $10.23 \mu\text{mol L}^{-1}$  of  $H_2O_2$ , from which the values started to decrease (Figure 2A). Probably with the highest salinity level, the plant increased the production of reactive oxygen species and began to suffer from oxidative stress; this process was further driven by the high concentration of  $H_2O_2$  applied, which may have overloaded the defense system of the plant, causing significant morphological changes in leaf expansion as a way of trying to survive such adverse conditions. According to Rutschow et al. (2011), low concentrations of  $H_2O_2$  activate signaling sites capable of relieving the most intense stress. However, the accumulation of higher amounts of these reactive oxygen species produces a strong stress signal, which can lead to cell death (Pan et al., 2021). Under normal conditions, plant cells activate molecules that function as antioxidants (e.g., ascorbic acid and glutathione), which promote the elimination of the  $H_2O_2$  molecule by reducing its concentration in water and free oxygen (Ahanger et al., 2019); this logic may explain the fact that plants irrigated with saline water at  $0.3 \text{ dS m}^{-1}$  respond better to peroxide accumulation.

DMAP was 78.62 and 46.34 g per plant under concentrations of  $9.11$  and  $8.35 \mu\text{mol L}^{-1}$  of  $H_2O_2$  and  $0.3$  and  $5.0 \text{ dS m}^{-1}$  salinity, respectively (Figure 2B). A similar behavior was observed by Oliveira et al. (2014) regarding salinity in the culture of gherkin (*Cucumis sativus* L.) plants, obtaining lower values for this variable in the treatment of  $5.0 \text{ dS m}^{-1}$ . Exposure to high  $H_2O_2$  concentrations also favored the decline of this variable, corroborating the results of Sathiyaraj et al. (2014), who reported that as concentrations and exposure of ginseng (*Panax ginseng* C.A. Mey.) seedlings to  $H_2O_2$  increased, there was a reduction in growth rates and acclimatization of this species to saline stress; in contrast, pre-treatment with  $H_2O_2$  at lower concentrations promoted greater growth and acclimatization of plants to saline stress by increasing the activity of antioxidative enzymes such as superoxide dismutase, peroxidase, ascorbate peroxidase, catalase, and glutathione reductase.

P per plant increased with the application of  $H_2O_2$ . For the water salinity of  $0.3$  and  $5.0 \text{ dS m}^{-1}$ , the increment was 791.39 and 345.76 g per plant for  $10.89$  and  $6.35 \mu\text{mol L}^{-1}$   $H_2O_2$ , respectively (Figure 2C), with successive reductions under higher concentrations of  $H_2O_2$ . Similar results regarding decreases caused by increased electrical conductivity of irrigation water were reported by Silva et al. (2014) in pumpkin (*Cucurbita pepo* L.) and by Pereira et al. (2018) in melon.



\* and \*\*: significant at  $p \leq 0.05$  and at  $p \leq 0.01$  by F test, respectively

**Figure 2.** Leaf area (A), dry mass of the aerial part (B), and production (C) in melon plants as a function of  $\text{H}_2\text{O}_2$  concentrations for 0.3 and 5  $\text{dS m}^{-1}$  levels of irrigation salinity

Terceiro Neto et al. (2013) stated that the losses that occurred in the production of melon under salinity reflect the negative effect of the osmotic potential of saline solution due to several factors, such as toxicity of salts, reduction in  $\text{CO}_2$  supply, and changes in enzyme activity and senescence. However, the use of  $\text{H}_2\text{O}_2$  has proven to be efficient to some extent, avoiding large production losses.

Bagheri et al. (2021) reported that acclimatization to the adverse effects of salt stress in plants treated with  $\text{H}_2\text{O}_2$  is

due to the fact that the same regular osmotic adjustment, by maintaining a low  $\text{Na}^+/\text{K}^+$  ratio, improves ionic balance, thereby increasing the absorption of  $\text{K}^+$  and increasing the levels of sugars and relative water content under saline conditions, consequently improving production.

## CONCLUSIONS

1. Irrigation with a water electrical conductivity of 5  $\text{dS m}^{-1}$  reduced growth and reduced melon production, compared to plants irrigated with 0.3  $\text{dS m}^{-1}$ .

2. The increase in  $\text{H}_2\text{O}_2$  concentration increased E, A, and gs in melon plants irrigated with water having 0.3 and 5  $\text{dS m}^{-1}$  of electrical conductivity.

3. The LA and DMAP increased with the application of  $\text{H}_2\text{O}_2$  up to concentrations of 10.23 and 8.35  $\mu\text{mol L}^{-1}$  of  $\text{H}_2\text{O}_2$ , respectively, in plants irrigated with 5  $\text{dS m}^{-1}$ .

4.  $\text{H}_2\text{O}_2$ , at a concentration of 6.35  $\mu\text{mol L}^{-1}$ , reduces the adverse effects of saline stress in the melon plant up to the production stage.

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## LITERATURE CITED

- Ahanger, M. A.; Qin, C.; Begum, N.; Maodong, Q.; Dong, X. X.; El-Esawi, M.; El-Sheikh, M. A.; Alatar, A. A.; Zhang, L. Nitrogen availability prevents oxidative effects of salinity on wheat growth and photosynthesis by up-regulating the antioxidants and osmolytes metabolism, and secondary metabolite accumulation. *BMC Plant Biology*, v.19, p.1-12, 2019. <https://doi.org/10.1186/s12870-019-2085-3>
- Araújo, G. dos S.; Paula-Marinho, S. de O.; Pinheiro, S. K. de P.; Miguel, E. de C.; Lopes, L. de S.; Marques, E. C.; Carvalho, H. H. de; Gomes-Filho, E.  $\text{H}_2\text{O}_2$  priming promotes salt tolerance in maize by protecting chloroplasts ultrastructure and primary metabolites modulation. *Plant Science*, v.303, p.1-11, 2021. <https://doi.org/10.1016/j.plantsci.2020.110774>
- Ayers, R.S.; Westcot, D.W.A. A qualidade da água na agricultura. 2.ed. Campina Grande: UFPB, 1999. 153p.
- Bagheri, M.; Gholami, M.; Baninasab, B. Hydrogen peroxide-induced salt tolerance in relation to antioxidant systems in pistachio seedlings. *Scientia Horticulturae*, v.243, p.207-213, 2019. <https://doi.org/10.1016/j.scienta.2018.08.026>
- Bagheri, M.; Gholami, M.; Baninasab, B. Role of hydrogen peroxide pre-treatment on the acclimation of pistachio seedlings to salt stress. *Acta Physiologiae Plantarum*, v.43, p.1-10, 2021. <https://doi.org/10.1007/s11738-021-03223-3>
- Barbosa, M. R.; Silva, M. M. de A.; Willadino, L.; Ulisses, C.; Camara, T. R. Geração e desintoxicação enzimática de espécies reativas de oxigênio em plantas. *Ciência Rural*, v.44, p.453-460, 2014. <https://doi.org/10.1590/S0103-84782014000300011>

- Dantas, M.V.; Lima, G.S.; Gheyi, H.R.; Pinheiro, F.W.A.; Silva, P.C.C.; Soares, L.A.A. gas exchange and hydroponic production of zucchini under salt stress and H<sub>2</sub>O<sub>2</sub> application. *Revista Caatinga*, v.35, p.436-449, 2022. <https://doi.org/10.1590/1983-21252022v35n219rc>
- Ferreira, D. F. Sisvar: A Guide for Its Bootstrap Procedures in Multiple Comparisons. *Ciência e Agrotecnologia*, v.38, p.109-112, 2014. <http://dx.doi.org/10.1590/S1413-70542014000200001>
- Hoagland, D. R.; Arnon, D. I. The water culture method for growing plants without soils. 2.ed. Berkeley: California Agricultural Experimental Station, 1950. 32p.
- Kesh, H.; Kaushik, P. Advances in melon (*Cucumis melo* L.) breeding: An update. *Scientia Horticulturae*, v.282, p.1-10, 2021. <https://doi.org/10.1016/j.scienta.2021.110045>
- Lacerda, F.H.D.; Pereira, F.H.F.; Silva, F.A.; Queiroga, F.M.; Brito, M.E.B.; Medeiros, J.E.; Dias, M.S. Physiology and growth of maize under salinity of water and application of hydrogen peroxide. *Revista Brasileira de Engenharia Agrícola e Ambiental*, v.26, p.771-779, 2022. <https://doi.org/10.1590/1807-1929/agriambi.v26n11p771-779>
- Oliveira, F. de A. de; Pinto, K. S. de O.; Bezerra, F. M. S.; Lima, L. A. de; Cavancante, A. L. G.; Oliveira, M. K. T. de; Medeiros, J. F. de. Tolerância do maxixeiro, cultivado em vasos, à salinidade da água de irrigação. *Revista Ceres*, v.61, p.147-154, 2014. <http://dx.doi.org/10.1590/S0034-737X2014000100020>
- Pan, T.; Liu, M.; Kreslavski, V. D.; Zharmukhamedov, S. K.; Nie, C.; Yu, M.; Kuznetsov, V. V.; Allakhverdiev, S. I.; Shabala, S. Non-stomatal limitation of photosynthesis by soil salinity. *Critical Reviews Environmental Science and Technology*, v.51, p.791-825, 2021. <https://doi.org/10.1080/10643389.2020.1735231>
- Pereira, E. D.; Queiroga, R. C. F. de; Silva, Z. L. da; Assis, L. E.; Sousa, F. F. de. Produção e qualidade do meloeiro sob osmocondicionamento da semente e níveis de salinidade da água. *Revista Verde de Agroecologia e Desenvolvimento Sustentável*, v.13, p.08-15, 2018. <http://dx.doi.org/10.18378/rvads.v13i1.5013>
- Rutschow, H. L.; Baskin, T. I.; Kramer, E. M. Regulation of solute flux through plasmodesmata in the root meristem. *Plant Physiology*, v.155, p.1817-1826, 2011. <https://doi.org/10.1104/pp.110.168187>
- Santos, A. da S.; Araújo, R. H. C. R.; Nobre, R. G.; Sousa, V. F. de O.; Rodrigues, M. H. B. S.; Formiga, J. A.; Gomes, F. A. L.; Santos, G. L. dos.; Onias, E. A. Effect of Hydrogen Peroxide in the Growth of Yellow Passion Fruit Seedlings Under Salinity Stress. *Journal of Agricultural Science*, v.10, p.151-162, 2018. <https://doi.org/10.5539/jas.v10n10p151>
- Sathiyaraj, G.; Srinivasan, S.; Kim, Y. J.; Yang, D. C. Acclimation of hydrogen peroxide enhances salt tolerance by activating defense-related proteins in *Panax ginseng* C.A. Meyer. *Molecular Biology Reports*, v.6, p.3761-71, 2014. <https://doi.org/10.1007/s11033-014-3241-3>
- Silva, E. M. da; Lacerda, F. H. D.; Medeiros, A. de S.; Souza, L. de P.; Pereira, F. H. F. Métodos de aplicação de diferentes concentrações de H<sub>2</sub>O<sub>2</sub> em milho sob estresse salino. *Revista Verde de Agroecologia e Desenvolvimento Sustentável*, v.11, p.1-7, 2016. <http://dx.doi.org/10.18378/rvads.v11i3.4343>
- Silva, J. E. S. B.; Torres, S. B.; Leal, C. C. P.; Leite, M. S.; Guirra, K. S.; Dantas, B. F.; Morais, M. B.; Guirra, B. S. Pre-germination treatments of melon seeds for the production of seedlings irrigated with biosaline water. *Brazilian Journal of Biology*, v.84, p.1-10, 2024. <https://doi.org/10.1590/1519-6984.257314>
- Silva, M. V. T. da; Lima, R. M. de S.; Oliveira, F. L. de; Silva, N. K. C.; Medeiros, J. F. de. Produção de abobora sob diferentes níveis de água salina e doses de nitrogênio. *Revista Verde de Agroecologia e Desenvolvimento Sustentável*, v.9, p.287-294, 2014.
- Sousa, V. F. de O.; Costa, C. C.; Diniz, G. L.; Santos, J. B. dos; Bomfim, M. P. Physiological behavior of melon cultivars submitted to soil salinity. *Pesquisa Agropecuária Tropical*, v.48, p.271-279, 2018. <https://doi.org/10.1590/1983-40632018v4852495>
- Souza, T. M. A. de; Souza, T. A.; Solto, L. S.; Sá, F. V. da S.; Paiva, E. P. de; Brito, M. E. B.; Mesquita, E. F. de. Crescimento e trocas gasosas do feijão caupi cv. BRS pujante sob níveis de água disponível no solo e cobertura morta. *Irriga*, v.21, p.796-805, 2016. <https://doi.org/10.15809/irriga.2016v21n4p796-805>
- Terceiro Neto, C. P. C.; Gheyi, H. R.; Medeiros, J. F. de; Dias, N. da S.; Campos, M. de S. Produtividade e qualidade de melão sob manejo com água de salinidade crescente. *Pesquisa Agropecuária Tropical*, v.43, p.354-362, 2013. <https://doi.org/10.1590/S1983-40632013000400007>
- Terceiro Neto, C. P. C.; Medeiros, J. F. de; Gheyi, H. R.; Dias, N. da S.; Oliveira, F. R. A. de. Crescimento e composição mineral do tecido vegetal do melão 'pele de sapo' sob manejos de água salina. *Irriga*, v.19, p.255-266, 2014. <https://doi.org/10.15809/irriga.2014v19n2p255>
- Veloso, L. L. de S. A.; Silva, A. A. R. da; Lima, G. S. de; Azevedo, C. A. V. de; Gheyi, H. R.; Moreira, R. C. L. Growth and gas exchange of soursop under salt stress and hydrogen peroxide application. *Revista Brasileira de Engenharia Agrícola Ambiental*, v.26, p.119-125, 2022. <https://doi.org/10.1590/1807-1929/agriambi.v26n2p119-125>