Physiological responses of the beet crop under agricultural environment and saline stress

ARTICLES doi:10.4136/ambi-agua.2868

Received: 19 Jun. 2022; Accepted: 14 Sep. 2022

Francisco Rafael de Oliveira¹; Geocleber Gomes de Sousa¹; José Thomas Machado de Sousa²*; Kelly Nascimento Leite³; José Marcelo da Silva Guilherme²; Rafaella da Silva Nogueira¹

¹Instituto de Desenvolvimento Rural. Universidade da Integração Internacional da Lusofonia Afro-Brasileira (UNILAB), Avenida da Abolição, nº 3, CEP: 62790-000, Redenção, CE, Brazil. E-mail: rafaeloliveira@aluno.unilab.edu.br, sousagg@unilab.edu.br, rafaeannogueira@unilab.edu.br
²Departamento de Engenharia Agrícola. Universidade Federal do Ceará (UFC), Avenida Mister Hull, s/n, CEP: 60455-760, Fortaleza, CE, Brazil. E-mail: jose.marcelosilva98@gmail.com
³Centro Multidisciplinar. Universidade Federal do Acre (UFAC), Rua Estrada da Canela Fina, Km 12, CEP: 69895-000, Cruzeiro do Sul, AC, Brazil. E-mail: knleite.ufac@gmail.com
*Corresponding author. E-mail: thssousa2015@gmail.com

ABSTRACT
The deleterious effects of salts on plants exposed to high solar radiation tend to be more accelerated due to the increase of toxic ions in the aerial plant part. Consequently, the physiological and biochemical processes will be affected. These effects can be minimized, however, with the use of management strategies, such as the use of a shading screen and a protected environment. In this sense, the objective of this work was to evaluate the physiological responses of sugar beet cultivated in different environments and irrigated with saline water. The experiment was conducted in an experimental design entirely randomized, using the factorial scheme 3 × 2, equivalent to three environments (FS = full sun; SSOS = shading screen open on the sides and PE = protected environment) and two electrical conductivities of the irrigation water (0.5 and 6.2 dS m⁻¹), with four repetitions. At 45 days after sowing (DAS) the following variables were analyzed: stomatal conductance, liquid photosynthesis, transpiration, internal CO₂ concentration, leaf temperature, instantaneous water use efficiency, instantaneous carboxylation efficiency, intrinsic water use efficiency, and relative chlorophyll index. Irrigation with water of higher salinity negatively affected stomatal conductance, net photosynthesis, leaf temperature and instantaneous water use efficiency of sugar beet plants grown in a full sun environment. The protected environment and open shading on the sides partially mitigated the deleterious effects of salinity.

Keywords: Beta vulgaris L., gas exchange, salinity levels.

RESPONSA FISIOLOGICAS DA CULTURA DA BETERRABA SOB AMBIÊNCIA AGRÍCOLA E ESTRESSE SALINO

Os efeitos deletérios dos sais nas plantas expostas a altas radiações solares tendem a ser mais acelerados em razão do aumento de íons tóxicos na parte aérea vegetal, consequentemente,
os processos fisiológicos e bioquímicos serão afetados. No entanto, esses efeitos podem ser minimizados com a utilização de estratégias de manejo, como o uso de tela de sombreamento e ambiente protegido. Nesse sentido, objetivou-se avaliar as repostas fisiológicas da cultura da beterraba cultivada em diferentes ambientes e irrigada com águas salinas. O experimento foi conduzido em delineamento experimental inteiramente casualizado, fazendo uso do esquema fatorial $3 \times 2$, equivalente a três ambientes (PS = pleno sol; TS = telado de sombreamento aberto nas laterais e AP = ambiente protegido) e duas condutividades elétricas da água de irrigação (0,5 e 6,2 dS m$^{-1}$), com quatro repetições. Aos 45 dias após a semeadura (DAS) foram analisadas as seguintes variáveis: condutância estomática, fotossíntese líquida, transpiração, concentração interna de CO$_2$, temperatura foliar, eficiência instantânea no uso da água, eficiência da carboxilação instantânea, eficiência intrínseca do uso da água e índice relativo de clorofila. A irrigação com água de maior salinidade afetou negativamente a condutância estomática, a fotossíntese líquida, a temperatura foliar, eficiência instantânea no uso da água de plantas de beterrabas cultivadas em ambiente pleno sol. O ambiente protegido e o telado aberto nas laterais atenuou parcialmente os efeitos deletérios da salinidade.

Palavras-chave: Beta vulgaris L., níveis de salinidade, trocas gasosas.

1. INTRODUCTION

Beet (Beta vulgaris L.) is a biennial vegetable, component of the Chenopodiacea family, originated in southern European and northern African countries (Filgueira, 2008). The consumption of beet roots in recent years in the world has intensified, due to the chemical properties and bioactive compounds that offer beneficial physiological effects against cardiovascular diseases, diabetes, atherosclerosis and hypertension (Clifford et al., 2015).

The use of irrigated agriculture becomes fundamental for a safe production (Léllis et al., 2022; Lacerda et al., 2020). This practice becomes indispensable in regions that present a high climatic variability, as is the case of the semi-arid region of Brazil; however, the vast majority of water sources available for irrigation in this region present a high content of salts (Fernandes et al., 2016; Pereira et al., 2019; Dias et al., 2020).

The use of saline water in agriculture and agricultural crops in saline soils significantly modifies the physiological and biochemical processes of plants, resulting in a reduction in the growth, development and productivity of crops (Muhammad et al., 2021). The direct effects of salinity on photosynthesis start with a reduction in stomatal opening, consequently, there will be a reduction in the availability of CO$_2$ for RUBISCO, resulting in a low fixation of C (Batista-Santos et al., 2015). The combination of all salinity-induced imbalances in photosynthetic mechanisms causes alterations in the Calvin cycle and ATP synthesis (Shahid et al., 2020).

Cultivation in a protected environment mitigates seasonal variations in production, reduces the adverse effects of excess rainfall, high incidence of radiation, and extremes of air temperature (Reis et al., 2012). The shading, partial or total, emerges as an alternative to minimize the damaging effects caused by salts on plants, due to the maintenance of photosynthetic mechanisms, CO$_2$ assimilation and increased chlorophyll content (Aras et al., 2021; Gálvez et al. 2020). Similarly, Nojosa Lessa et al. (2022) on passion fruit and Pinho et al. (2022) in the culture of Anadenanthera colubrina (Vell.) verified positive effects of shading nets on seedling establishment and physiological responses of cultures, especially under salinity conditions.

Therefore, the aim of this study was to evaluate the physiological responses of sugar beet cultivated in different environments and irrigated with saline water.
2. MATERIAL AND METHODS

The experiment was conducted from October to December 2019 in the experimental area of the Auroras Seedling Production Unit (UPMA), belonging to the Universidade da Integração Internacional da Lusofonia Afro-Brasileira (UNILAB) in the municipality of Redenção, CE, Brazil, at the geographical coordinates 4º13'33" S, 38º43'39" W and altitude of 88 m. According to Köppen (1923), the climate of the region is of type Aw', described as a tropical dry winter, with an average temperature of the hottest month above 38°C and the coldest month below 20°C.

The experimental design was entirely randomized (DIC), using a 3 × 2 factorial scheme with four repetitions, equivalent to three growing environments (FS = full sun; SSOS = shading screen open on the sides and PE = protected environment) (Table 1) and two electrical conductivity of the irrigation water - ECw (water supply 0.5 dS m\(^{-1}\) and saline solution 6.2 dS m\(^{-1}\)). The experimental unit consisted of two pots (two plant per pot), totaling forty-eight experimental units.

Table 1. Mean values of temperature and relative humidity of the environments (full sun, open shading screen on the sides and protected environment) during the experiment.

| Environments             | Relative humidity (%) | Temperature |
|--------------------------|-----------------------|-------------|
|                          | Min       | Max       | Min       | Max       |
| Full sun                 | 45.9      | 58        | 32.6      | 33.7      |
| Open screen on the sides | 45.7      | 52        | 33.6      | 34.5      |
| Protected environment    | 50        | 57        | 30.5      | 39.2      |

Max - Maximum; Min – Minimum.

Beet seeds (cultivar Early Wonder Tall Top) were used and five seeds were sown 2 cm deep in 8 L pots. To fill the pots, a layer of gravel 2 to 3 mm thick was used to help drainage, then, to supplement the remaining volume, a substrate was used obtained from the mixture of arisco, sand and bovine manure in the proportion of 5:3:2, respectively. To determine the chemical attributes of the substrate, a soil sample was collected before the application of the treatments (Table 2).

At 20 DAS, thinning was performed, leaving only two plants per pot. The saline solution used for irrigation was formulated from the dilution of soluble salts (NaCl, CaCl\(_2\).2H\(_2\)O and MgCl\(_2\).6H\(_2\)O), in the equivalent proportion of 7: 2: 1 between Na, Ca and Mg, obeying the relationship between ECw and its concentration (mmolc L\(^{-1}\) = EC × 10), following the methodology contained in Medeiros (1992).

Irrigation with saline water, started at 10 days after sowing and was performed manually each day with leaching blade of 15% according to Ayers and Westcot (1999), calculated according to the drainage lysimeter principle (Bernardo et al., 2019), keeping the soil at field capacity. The volume of water to be applied to the plants was determined by Equation 1:

\[
VI = \frac{(Vp-Vd)}{(1-LF)}
\]  

(1)

Where:

- VI – Volume of water to be applied in the irrigation event (mL);
- Vp – volume of water applied in the previous irrigation event (mL);
- Vd – Volume of water drained (mL); and,
- LF – leaching fraction of 0.15.
Table 2. Chemical and physical characteristics of the substrate sample before applying treatments.

| OM     | N     | C     | P    | Ca  | Mg  | Na  | Al  | H + Al | K    | Ecse | ESP | C/N | V   | pH |
|--------|-------|-------|------|-----|-----|-----|-----|--------|------|------|-----|-----|-----|----|
|        | (g Kg⁻¹) | (mg Kg⁻¹) | (cmol.dm⁻³) | (dS m⁻¹) | (%) | (%) | H₂O |
| 14.59  | 0.93  | 8.46  | 27   | 4.5 | 0.7 | 0.67| 0.15| 1.49   | 0.78 | 0.08 | 8   | 9   | 82  | 6.4|
| SD (g cm⁻³) | CS | FS | Silt | Clay | Textural classification |
| 1.47   | 2.76  | 665  | 201  | 92  | 42  | Loamy Sand |

OM - Organic matter; ESP - Percentage of exchangeable sodium; ECse – Electrical conductivity of the soil saturation extract; V - Base saturation; SD - Soil density; CS Coarse sand; FS - Fine sand.

At 45 DAS, readings of gas exchange and relative chlorophyll index were taken. The measurements took place between 09h00 and 11h00 a.m., only on one plant and on the fully expanded leaves, and the following variables were determined: stomatal conductance (gs) net photosynthesis (A), transpiration (E), internal CO₂ concentration (Ci), leaf temperature (LT), using an infrared gas (IRGA, LI-6400XT, LI-COR, Inc., Lincoln, Nebraska, USA) equipped with a radiation source regulated at 2000 µmol m⁻² s⁻¹. Using the gas exchange data, instantaneous water use efficiency (A/E), instantaneous carboxylation efficiency (A/Ci) and intrinsic water-use efficiency (A/gs) were determined.

The relative chlorophyll content was measured by the non-destructive method in five readings per leaf, with the aid of a chlorophyll meter (SPAD 502, Minolta Co. Ltd, Osaka, Japan), occurring in the same leaves used to quantify leaf gas exchange. Results were expressed as a mean value referred to as the relative chlorophyll index (RCI).

The variables analyzed in the study were submitted to the Kolmogorov-Smirnov test (p ≤ 0.05) to assess normality. The data were submitted to analysis of variance (ANOVA). In the occurrence of significance for the interaction between environments versus salinity or single factors, Tukey’s test (p ≤ 0.05) was performed using the program ASSISTAT 7.7 BETA (Silva and Azevedo, 2016).
3. RESULTS AND DISCUSSION

According to the analysis of variance (Table 3), there were significant interactions between the different growing environments and salinity levels for all the variables analyzed, except for the transpiration and intrinsic water use efficiency variable.

Table 3. Summary of analysis of variance for stomatal conductance (gs), net photosynthesis (A), transpiration (E), internal CO$_2$ concentration (Ci), leaf temperature (LT), instantaneous water use efficiency (A/E), efficiency of instantaneous carboxylation (A/Ci), intrinsic water use efficiency (A/gs) and relative chlorophyll index (RCI) in sugar beet plants cultivated in different environments irrigated with saline waters.

| Sources of variation | Mean Square |   |   |   |   |   |   |   |   |
|----------------------|-------------|---|---|---|---|---|---|---|---|
|                      | DF | gs | A  | E  | Ci | LT | A/E | A/Ci | A/gs | RCI  |
| Treatments           | 5  | 0.032** | 67.30** | 0.117ns | 1268.85* | 3.756** | 2.672** | 0.001** | 90.87ns | 113.52** |
| Environments (E)     | 2  | 0.056** | 139.33** | 0.008ns | 1269.38** | 6.402** | 5.403** | 0.002** | 49.01ns | 154.96** |
| Salinity (S)         | 1  | 0.032** | 3.68ns  | 0.039*  | 2664.50** | 1.125*  | 0.014ns | 0.000ns | 270.75*  | 104.01*  |
| E x S                | 2  | 0.009*  | 27.09** | 0.089ns | 570.50*  | 2.426** | 1.271** | 0.000** | 42.79ns  | 4.05*    |
| Residue              | 18 | 0.002   | 2.23    | 0.06    | 131.44   | 0.16    | 0.07    | 0.00005 | 55.3     | 18.94    |
| Total                | 23 | -       | -       | -       | -        | -       | -       | -       | -        |
| CV (%)               | -  | 12.75   | 11.01   | 4.89    | 4.03     | 1.17    | 10.19   | 14.72   | 19.11    | 10.09    |

DF - Degrees of freedom; CV - Coefficient of variation; * - Significant by the F test at p ≤ 0.05; ** Significant by the F test at p ≤ 0.01; ns - Not significant.
According to Figure 1A, it is possible to observe that gs was statistically superior when irrigated with water of lower salinity (0.5 dS m\(^{-1}\)) in the PE environment followed by FS, but did not differ statistically in SSOS. Regarding plants irrigated with high salinity water (6.2 dS m\(^{-1}\)), it was found that plants grown in PE and SSOS were statistically different from plants in FS, demonstrating a reduction in stomatal opening.

![Figure 1](image-url)

**Figure 1.** Gs: Stomatal conductance (A) and A: Net photosynthesis (B) in sugar beet plants grown in different environments (FS - Full sun; SSOS - Shading screen open on the sides and PE - Protected environment) irrigated with saline water. Means followed by the same lowercase letters for salinity levels or uppercase letters in the same environment do not differ significantly by Tukey test (p ≤ 0.05). Vertical bars represent standard error (n = 4).

In an attempt to regulate or reduce the loss of water to the atmosphere due to saline and thermal stress, plants reduce the opening of the stomata, through hormones generated by branches and roots, limiting the net photosynthetic rate and the influx of CO\(_2\) necessary for the assimilation process (Taiz et al., 2017; Pereira et al., 2019; Muhammad et al., 2021). Thus, the decrease in stomatal conductance in the full sun environment in water of higher Ecw is possibly related to the sensitivity of the stomata of C3 plants, such as beetroot, to the increase in the vapor pressure deficit (VPD) (Pinho et al., 2022); and the high concentration of salts in the irrigation water, making it difficult to supply CO\(_2\) to rubisco, consequently, the photosynthetic machinery will increase energy dispersion (Chaves et al., 2009).

Nojosa Lessa et al. (2022), state that plants exposed to sunlight under salt stress show higher rates of uptake and translocation of potentially toxic ions when compared to shaded plants. In a study evaluating the responses of sweet cherry to salt stress under different shading, Aras et al. (2021), found that the stomatal conductance of the plants reduced when grown under salt stress in a non-shaded environment.

Net photosynthesis of sugar beet was statistically reduced by the higher salinity water in the FS, but there was an increase in the SSOS and PE (Figure 1B). In the full sun environment, the plants, when irrigated with high salinity water (6.2 dS m\(^{-1}\)), showed a reduction in the net photosynthetic rate of 48% when compared to plants cultivated in PE and 44% when compared to cultivated plants.

The increase in net photosynthesis with the increase in salinity in the protected environment and open shading on the sides demonstrates that it possibly promoted a physiological acclimation, partially alleviating thermal stress and excess light, (Mupambi et al., 2021).
2018) and salinity (decreasing the translocation of toxic ions to leaves and favoring CO₂ assimilation in the biochemical phase, even under stress) (Dias et al., 2018; Shahid et al., 2020).

Similar results were found by Gálvez et al. (2020), in peppers shaded with red screens and not shaded under salt stress, where they found an increase in net photosynthetic rate under salinity conditions in shaded pepper plants.

The transpiration of sugar beet plants (Figure 2) was negatively influenced by increasing the electrical conductivity of irrigation water (6.2 dS m⁻¹), causing a drop in transpiration equivalent to 5.62%, when compared to low salinity water (0.5 dS m⁻¹). The increase in the concentration of salts in the soil caused a decrease in osmotic potential, driving plants to use a strategy to decrease water loss to the environment, since the transpiration rate is higher than water uptake by plants (Silva et al., 2019). Linked to the strategy of reducing water loss to the environment, the reduction of transpiration in saline environments decreases the absorption of salts; consequently, the translocation to part of the area occurs (Pinho et al., 2022).

![Figure 2. Transpiration (E) in sugar beet plants irrigated with saline water. Lowercase letters compare the means by Tukey test (p ≤ 0.05). Vertical bars represent standard error (n = 4).](image)

In studies with sugar beet, Tahjib-UI-Arif et al. (2019) and Zou et al. (2019) found that under high salt stress conditions there was a decrease in plant transpiration. However, contrary results to the studies were observed by Melo Filho et al. (2020), who, working with table beet, observed that stomatal conductance had an average increase at 30 DAI, keeping transpiration unchanged, with a decrease occurring in both variables only at 60 DAI.

Regarding the internal concentration of CO₂ (Figure 3A), the lower salinity water was statistically superior in full sun and shade cloth open on the sides compared to the higher salinity water and was not statistically different from plants irrigated with high salinity water in PE. This increase in Ci, demonstrates that CO₂ accumulation supposedly occurred in the leaf mesophyll in these environments; however, it happened as a result of microclimate and biochemical effects, generating damage to the carbon metabolism (Neves et al., 2019; Dias et al., 2020).

Regni et al. (2019), describe that plants under stress present a decrease in stomatal conductance, due to an increase in internal CO₂ concentration and a decrease in transpiration. Results contrary to the present study were observed by Sales et al. (2021), who verified that the increase in irrigation water salinity reduced the internal CO₂ concentration in okra culture.
When analyzing the average comparison test (Figure 3B) for the interaction between factors in leaf temperature, it was verified that the beet plants irrigated with water with a lower saline level (0.5 dS m\(^{-1}\)) differed statistically between the environments, presenting lower leaf temperatures (34.83; 33.23 and 32.90°C, respectively). On the other hand, the increase in the electrical conductivity of the irrigation water increased the leaf temperature in the different types of environments, showing higher temperature values (36.00; 34.20 and 34.20°C, respectively) and not differing statistically between the environments.

The combined effect of the high concentration of salts and the direct radiation in the full sun environment caused an increase in stomatal resistance, hindering the main method responsible for adjusting leaf temperature, transpiration (Taiz et al., 2017). Excess latent heat in leaves of C3 plants, as is the case of sugar beet, causes deleterious effects on photosynthesis. Consequently, there is a lower activation in rubisco (Deva et al., 2020).

Costa Freire et al. (2021) studied the gas exchange of bean varieties under irrigation water salinity conditions in a protected environment and found that all bean varieties showed a linear increase in leaf temperature with an increase in irrigation water salinity.

For the lowest salinity level on instantaneous water use efficiency (A/E), significant differences were found between environments, where the highest instantaneous water use efficiency was observed in plants grown in protected environment (4.16 \((\mu\text{mol m}^{-2} \text{s}^{-1}) (\text{mol H}_2\text{O m}^{-2} \text{s}^{-1}))\). In contrast, the increase in irrigation water salinity in plants grown in the protected environment and open shading screen on the sides promoted an increase in A/E (3.19 and 3.10 \((\mu\text{mol m}^{-2} \text{s}^{-1}) (\text{mol H}_2\text{O m}^{-2} \text{s}^{-1})\), respectively) when compared to the full sun environment irrigated with low salinity water and not statistically different from the protected environment (Figure 4A).

The increase in A/E in water use in plants irrigated with low salinity water in the protected environment is possibly related to quantitative effects of water in the leaf and qualitative effects on osmotic potential, because the shaded plants are not directly exposed to the external environment (Gálvez et al., 2020). Furthermore, Fernandes et al. (2016) describe that in saline environments, the A/E increase is a strategy of moderately tolerant crops, which aims to decrease high salt concentrations in the plant area.
Physiological responses of the beet crop under …

Figure 4. A/E: Instantaneous water use efficiency (A) and A/Ci: Instantaneous carboxylation efficiency (B) in sugar beet plants grown in different environments (FS - Full sun; SSOS - Shading screen open on the sides and PE - Protected environment) irrigated with saline water. Means followed by the same lowercase letters for salinity levels or uppercase letters in the same environment do not differ significantly by Tukey test (p ≤ 0.05). Vertical bars represent standard error (n = 4).

Similar to the results obtained in the present study, Nojosa Lessa et al. (2022) analyzed the production of yellow passion fruit seedlings under saline stress and agricultural environment, and found that A/E was superior when irrigated with low salinity water in certain types of environments.

Figure 4B shows the values of instantaneous carboxylation efficiency (A/Ci) under the salinity levels and different environments. It was found that for lower salinity water the environments differed statistically from each other, with an increase in A/Ci in the protected environment of 160.00 and 110.81% compared to full sun and shade screen open on the sides, respectively. In water with a higher salinity, it was found that the environments differed statistically, where the plants grown in full sun showed a reduction of 50% when compared with the protected environment.

Under salinity conditions, the instantaneous carboxylation efficiency is influenced by the increase in internal CO₂ concentration, due to the decrease in photosynthetic rate (Dias et al., 2018). Opposite results to the present study were found by Lacerda et al. (2020) when analyzing the morphophysiological responses and salt tolerance mechanisms in four perennial ornamental species grown in a greenhouse, found a decrease in A/Ci with increasing electrical conductivity of irrigation water.

The intrinsic water-use efficiency (A/gs) (Figure 5) increased significantly by 22.15% when irrigated with high salinity water, differing statistically from plants irrigated with low salinity water. This result, corroborates with Oliveira et al. (2017), when they detected that high intrinsic water-use efficiency in plants under salt stress, is a mechanism arising from a greater reduction in stomatal conductance when compared to net photosynthesis.

Similarly, Moles et al. (2016) also found an increase in intrinsic water-use efficiency in tomato varieties subjected to salt stress. Boari et al. (2019) observed that saline stress increased osmotic effects and caused a reduction in xylem potential in the toment culture, consequently increasing the intrinsic efficiency of water use.

The chlorophyll index of beet culture was influenced by the interaction between the salinity levels of irrigation water and the different environments (Figure 6), with significant differences between the protected environment and shading screen open on the sides to the full sun environment in low salinity water. On the other hand, when the plants were irrigated with high salinity water, it was observed that there were no statistical differences between the
environments and an increase of 19.06, 6.47 and 27.68% was observed when compared to the plants grown in the three types of environments irrigated with 0.5 dS m⁻¹ water.

**Figure 5.** Intrinsic water use efficiency (A/gs) in sugar beet plants irrigated with saline water. Lowercase letters compare the means by Tukey test (p ≤ 0.05). Vertical bars represent standard error (n = 4).

**Figure 6.** Relative chlorophyll index (RCI) in sugar beet plants grown in different environments (FS - Full sun; SSOS - Shading screen open on the sides and PE - Protected environment) irrigated with saline water. Means followed by the same lowercase letters for salinity levels or uppercase letters in the same environment do not differ significantly by Tukey test (p ≤ 0.05). Vertical bars represent standard error (n = 4).
The increase in the relative chlorophyll index in beet plants irrigated with high salinity water is possibly related to a process of acclimation to salt stress and ambience by the crop, in order to ensure photosynthetic rates according to physiological needs and growth (Adhikari et al., 2019). Furthermore, Fan et al. (2019) described that shading plants contain more chlorophyll for efficient light capture. Similar results to the present study were observed by Aras et al. (2021) in the sweet cherry tomato crop grown in a protected environment and under salt stress.

4. CONCLUSIONS

Irrigation with water of higher salinity negatively affected stomatal conductance, net photosynthesis, leaf temperature and instantaneous water use efficiency of sugar beet plants grown in full sun.

The protected environment and open side-shade partially attenuated the deleterious effects of salinity on stomatal conductance, net photosynthesis and the relative chlorophyll index.

Salt stress negatively affects the transpiration of beet plants, but increases the intrinsic water use efficiency and the relative chlorophyll index in the growing environments.

5. REFERENCES

ADHIKARI, N. D.; SIMKO, I.; MOU, B. Phenomic and physiological analysis of salinity effects on lettuce. Sensors, v. 19, n. 21, p. 4814, 2019. https://doi.org/10.3390/s19214814

ARAS, S.; KELES, H.; BOZKURT, E. Shading Treatments Improved Plant Growth and Physiological Responses of Sweet Cherry Plants Subjected to Salt Stress. Alinteri Journal of Agricultural Science, v.36, n. 1, p. 66-70, 2021. https://dx.doi.org/10.47059/alinteri/V36I1/AJAS21011

AYERS, R. S.; WESTCOT, D. W. A qualidade de água na agricultura. 2.ed. Campina Grande: UFPB, 1999. 153p.

BATISTA-SANTOS, P.; DURO, N.; RODRIGUES, A. P.; SEMEDO, J. N.; ALVES, P.; COSTA, M.; RAMALHO, J. C. Is salt stress tolerance in Casuarina glauca Sieb. ex Spreng. associated with its nitrogen-fixing root-nodule symbiosis? An analysis at the photosynthetic level. Plant Physiology and Biochemistry, v. 96, p. 97-109, 2015. https://doi.org/10.1016/j.plaphy.2015.07.021

BERNARDO, S.; MANTOVANI, E. C.; SILVA, D. D. DA; SOARES, A. A. Manual de Irrigação. 9. ed. Viçosa: Editora UFV, 2019. 545p.

BOARI, F.; CANTORE, V.; VENERE, D.; SERGIO, L.; CANDIDO, V.; SCHIATTONE, M. I. Pyraclostrobin can mitigate salinity stress in tomato crops. Agricultural Water Management, v. 222, p.254-264. 2019. https://doi.org/10.1016/j.agwat.2019.06.003

CHAVES, M. M.; FLEXAS, J.; PINHEIRO, C. Photosynthesis under drought and salt stress: regulation mechanisms from whole plant to cell. Annals of botany, v. 103, n. 4, p. 551-560, 2009. https://doi.org/10.1093/aob/mcn125

CLIFFORD, T.; HOWATSON, G.; WEST, D. J.; STEVENSON, E. J. The potential benefits of red beetroot supplementation in health and disease. Nutrients, v. 7, n. 4, p. 2801-2822, 2015. https://doi.org/10.3390/nu7042801
COSTA FREIRE, M. H.; SOUSA, G. G.; CEITA, E. D. A. R.; BARBOSA, A. S.; GOES, G. F.; LACERDA, C. F. Trocas gasosas de variedades de fava sob condições de salinidade da água de irrigação. Agrarian, v. 14, n. 51, p. 61-70, 2021. https://doi.org/10.30612/agrarian.v14i51.11958

DEVA, C. R.; URBAN, M. O.; CHALLINOR, A. J.; FALLOON, P.; SVITÁKOVA, L. Enhanced leaf cooling is a pathway to heat tolerance in common bean. Frontiers in plant science, v. 11, p. 1-17, 2020. https://doi.org/10.3389/fpls.2020.00019

DIAS, A. S.; LIMA, G. S.; GHEYI, H. R.; NOBRE, R. G.; FERNANDES, P. D.; SILVA, F. A. Trocas gasosas e eficiência fotoquímica do gergelim sob estresse salino e adubação com nitrato-amônio. Irriga, v. 23, n. 2, p. 220-234, 2018. https://doi.org/10.15809/irriga.2018v23n2p220-234

DIAS, A. S.; LIMA, G. S.; GHEYI, H. R.; SOARES, L. A. DOS A.; FERNANDES, P. D. Growth and gas exchanges of cotton under water salinity and nitrogen-potassium combination. Revista Caatinga, v. 33, n. 2, p. 470-479, 2020. https://doi.org/10.1590/1983-21252020v33n219rc

FAN, Y.; CHEN, J.; WANG, Z.; TAN, T.; LI, S., LI, J.; YANG, F. Soybean (Glycine max L. Merr.) seedlings response to shading: leaf structure, photosynthesis and proteomic analysis. BMC plant biology, v. 19, n. 1, p. 1-12, 2019. https://doi.org/10.1186/s12870-019-1633-1

FERNANDES, P. D.; BRITO, M. E. B.; GHEYI, H. R.; ANDRADE, A. P.; MEDEIROS, S. S. Halofitismo e agricultura biosalina. In: GHEYI, H. R.; DIAS, N. S.; LACERDA, C. F.; GOMES FILHO, E. Manejo da salinidade na agricultura: Estudos básicos e aplicados. Fortaleza: Instituto Nacional de Ciência e Tecnologia em Salinidade, 2016. Cap.15, p.35-50.

FILGUEIRA, F. A. R. Novo manual de olericultura: Agrotecnologia moderna na produção e comercialização de hortaliças. 3. ed. Viçosa: UFV, 2008. 421p.

GÁLVEZ, A.; ALBACETE, A.; DEL AMOR, F. M.; LÓPEZ-MARÍN, J. The Use of Red Shade Nets Improves Growth in Salinized Pepper (Capsicum annuum L.) Plants by Regulating Their Ion Homeostasis and Hormone Balance. Agronomy, v. 10, n. 11, p. 1766, 2020. https://doi.org/10.3390/agronomy10111766

KÖPPEN, W. P. Die klimate der erde: Grundriss der klimakunde. Berlin: Walter de Gruyter & So., 1923. 369p. https://doi.org/10.1515/9783111491530

LACERDA, C. F.; OLIVEIRA, E. V.; NEVES, A. L. R.; GHEYI, H. R.; BEZERRA, M. A.; COSTA, C. A. G. Morphophysiological responses and mechanisms of salt tolerance in four ornamental perennial species under tropical climate. Revista Brasileira de Engenharia Agrícola e Ambiental, v. 24, n. 10, p. 656-663, 2020. https://doi.org/10.1590/1807-1929/agriambi.v24n10p656-663

LÉLLIS, B. C.; MARTÍNEZ-ROMERO, A.; SCHWARTZ, R. C.; PARDO, J. J.; TARJUELO, J. M.; DOMÍNGUEZ, A. Effect of the optimized regulated deficit irrigation methodology on water use in garlic. Agricultural Water Management, v. 260, p. 107280, 2022. https://doi.org/10.1016/j.agwat.2021.107280
Physiological responses of the beet crop under…

MEDEIROS, J. F. DE. Qualidade da água de irrigação utilizada nas propriedades assistidas pelo “GAT” nos Estados do RN, PB, CE e avaliação da salinidade dos solos. 1992. 173f. Dissertação (Mestrado em Engenharia Agrícola) - Universidade Federal de Campina Grande, Campina Grande, 1992.

MELO FILHO, J. S.; SILVA, T. I.; GONÇALVES, A. C. DE M.; SOUSA, L. V. DE; VÉRAS, M. L. M.; DIAS, T. J. Physiological responses of beet plants irrigated with saline water and silicon application. Comunicata Scientiae, v. 11, p. 1-8, 2020. https://doi.org/10.14295/cs.v11i0.3113

MOLES, T. M.; POMPEIANO, A.; REYES, T. H.; SCARTAZZA, A.; GUGLIELMINETTI, L. The efficient physiological strategy of a tomato landrace in response to short-term salinity stress. Plant Physiology and Biochemistry, v. 109, p. 262-272, 2016. https://doi.org/10.1016/j.plaphy.2016.10.008

MUHAMMAD, I.; SHALMANI, A.; ALI, M.; YANG, Q. H.; AHMAD, H.; LI, F. B. Mechanisms Regulating the Dynamics of Photosynthesis Under Abiotic Stresses. Frontiers in Plant Science, v. 11, p. 1-25, 2021. https://doi.org/10.3389/fpls.2020.615942

MUPAMBI, G.; MUSACCHI, S.; SERRA, S.; KALCSITS, L. A.; LAYNE, D. R.; SCHMIDT, T. Protective netting improves leaf-level photosynthetic light use efficiency in ‘Honeycrisp apple’ under heat stress. HortScience, v. 53, n. 10, p. 1416-1422, 2018. https://doi.org/10.21273/HORTSCI13096-18

NEVES, L. H.; SANTOS, R. I. N.; TEIXEIRA, G. I. DOS S.; ARAUJO, D. G. DE; SILVESTRE, W. V. D.; PINHEIRO, H. A. Leaf gas exchange, photochemical responses and oxidative damages in assai (Euterpe oleracea Mart.) seedlings subjected to high temperature stress. Scientia Horticulturae, v. 257, p. 108733, 2019. https://doi.org/10.1016/j.scienta.2019.108733

NOJOZA LESSA, C. I.; GOMES DE SOUSA, G.; CASTELO SOUSA, H.; BARBOSA SILVA, F. D.; PRIMOLA GOMES, S.; ARAÚJO VIANA, T.V. Agricultural ambience and salt stress in production of yellow passion fruit seedlings. Comunicata Scientiae, v. 13, p. 1-8, 2022.

OLIVEIRA, W. J.; SOUZA, E. R.; CUNHA, J. C.; SILVA, É. F. DE F.; VELOSO, V. DE L. Leaf gas exchange in cowpea and CO2 efflux in soil irrigated with saline water. Revista Brasileira de Engenharia Agrícola e Ambiental, v. 21, n. 1, p. 32-37, 2017. https://doi.org/10.1590/1807-1929/agriambi.v21n1p32-37

PEREIRA, J. V.; VIANA, T. V. D. A.; SOUSA, G. G. D.; CHAGAS, K. L.; AZEVEDO, B. M. D.; PEREIRA, C. Physiological responses of lima bean subjected to salt and water stresses. Revista Brasileira de Engenharia Agrícola e Ambiental, v. 23, n. 12, p. 959-965, 2019. https://doi.org/10.1590/1807-1929/agriambi.v23n12p959-965

PINHO, L. L.; LACERDA, C. F. D.; SOUSA, J. A. D.; SANTOS, A. M.; BEZERRA, A. M. E.; CAVALCANTE, E. S. et al. Effects of artificial shading and irrigation with brackish water on the initial development of Anadenanthera colubrina (vell.) brenan plants. Revista Árvore, v. 46, p. 1-12, 2022. https://doi.org/10.1590/1806-908820220000007

REGNI, L.; DEL PINO, A. M.; MOUSAVID, S.; PALMERINI, C. A.; BALDONI, L.; MARIOTTI, R. et al. Behavior of four olive cultivars during salt stress. Frontiers in plant science, v. 10, p. 1-9, 2019. https://doi.org/10.3389/fpls.2019.00867
REIS, L. S.; SOUZA, J. L.; AZEVEDO, C. A. V. DE; LYRA, G. B.; FERREIRA JUNIOR, R. A.; LIMA, V. L. A. DE. Componentes da radiação solar em cultivo de tomate sob condições de ambiente protegido. Revista Brasileira de Engenharia Agrícola e Ambiental, v. 16, p. 739–744, 2012. https://doi.org/10.1590/S1415-43662012000700006

SALES, J. R. DA S.; MAGALHÃES, C. L.; FREITAS, A. G.; GOES, G. F.; SOUSA, H. C. DE; SOUSA, G. G. de. Physiological indices of okra under organomineral fertilization and irrigated with salt water. Revista Brasileira de Engenharia Agrícola e Ambiental, v. 25, p. 466-471, 2021. https://doi.org/10.1590/1807-1929/agriambi.v25n7p466-471

SHAHID, M. A.; SARKHOSH, A.; KHAN, N.; BALAL, R. M.; ALI, S.; ROSSI, L.; GARCIA-SANCHEZ, F. Insights into the physiological and biochemical impacts of salt stress on plant growth and development. Agronomy, v. 10, n. 7, p. 938, 2020. https://doi.org/10.3390/agronomy10070938

SILVA, A. A. R.; LIMA, G. S.; AZEVEDO, C. A. V.; GHEYI, H. R.; SOUZA, L. DE P.; VELOSO, L. L. DE S. A. Gas exchanges and growth of passion fruit seedlings under salt stress and hydrogen peroxide. Pesquisa Agropecuária Tropical, v. 49, p. 1-10, 2019. https://doi.org/10.1590/1983-40632019v4955671

SILVA, F. DE A. S.; AZEVEDO, C. A. V. DE. The Assistat Software Version 7.7 and its use in the analysis of experimental data. African Journal of Agricultural Research, v. 11, n. 39, p. 3733-3740, 2016. https://doi.org/10.5897/AJAR2016.11522

TAHJIB-UI-ARIF, M.; SOHAG, A. A. M.; AFRIN, S.; BASHAR, K. K.; AFRIN, T.; MAHAMUD, A. G. M. et al. Differential response of sugar beet to long-term mild to severe salinity in a soil–pot culture. Agriculture, v. 9, n. 10, p.223, 2019. https://doi.org/10.3390/agriculture9100223

TAIZ, L.; ZEIGER, E.; MOLLER, I. M.; MURPHY, A. Fisiologia e Desenvolvimento Vegetal. 6.ed. Porto Alegre: Artmed, 2017. 888p.

ZOU, C. L.; WANG, Y. B.; LIU, L.; LIU, D.; WU, P. R.; YANG, F. F. et al. Photosynthetic capacity, osmotic adjustment and antioxidant system in sugar beet (Beta vulgaris L.) in response to alkaline stress. Photosynthetica, v. 57, n. 1, p. 350-360, 2019. https://doi.org/10.32615/ps.2019.010