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Sensitivity of tuberous roots crops to salinity in a protected environment

Sensibilidade de culturas de raízes tuberosas à salinidade em ambiente protegido

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ABSTRACT

Soil salinity has been a limiting barrier for the production of vegetables in protected environments. Thus, the understanding of the sensitivity of species to this stress factor must be explored, seeking better growing conditions. Under the hypothesis that beet and radish crops are sensitive to variations in soil salinity, even at low levels, the objective of this work was to evaluate the development and productivity of these two species in soils with different salinities in a protected environment. The experimental design was completely randomized and treatments were formed by the soil salinity levels, obtained with the application of saline solution (NaCl in water), considering the soil electrical conductivity of 0.36 dS m^{-1} as low salinity, of 1.05 dS m^{-1} as moderate salinity and 2.43 dS m^{-1} as elevated. For all variables analyzed, except for the relative chlorophyll index in beet plants, it was found that the increase in soil salinity resulted in significant development losses of beet and radish plants. Therefore, we concluded that beet and radish crops are sensitive to the variation in soil salinity, even in relatively low concentrations, making these species an unattractive choice for cultivation in systems that present this problem.

KEYWORDS: osmotic balance; photosynthesis; oxidation; nutrient uptake; soil solution; water potential.

RESUMO

A salinidade dos solos tem sido uma barreira limitadora para a produção de hortaliças em ambientes protegidos. Assim, o entendimento quanto a sensibilidade das espécies a esse fator de estresse deve ser explorado, buscando melhores condições de cultivo. Sob a hipótese de que as culturas de beterraba e rabanete são sensíveis às variações da salinidade do solo, mesmo em níveis baixos, o objetivo deste trabalho foi avaliar o desenvolvimento e a produtividade dessas duas espécies em solos com diferentes salinidades em ambiente protegido. O delineamento experimental foi inteiramente casualizado e os tratamentos foram formados pelos níveis de salinidade do solo, obtidos com a aplicação de solução salina (NaCl em água), considerando a condutividade elétrica do solo de 0,36 dS m^{-1} como baixa salinidade, de 1,05 dS m^{-1} como salinidade moderada e 2,43 dS m^{-1} como elevada. Para todas as variáveis analisadas, com exceção do índice relativo de clorofila em plantas de beterraba, verificou-se que o aumento da salinidade do solo resultou em perdas significativas de desenvolvimento de plantas de beterraba e rabanete. Assim, concluímos que as culturas de beterraba e rabanete são sensíveis à variação da salinidade do solo, mesmo em concentrações relativamente baixas, tornando essas espécies uma escolha pouco atrativa para cultivo em sistemas que apresentam este problema.

PALAVRAS-CHAVE: equilíbrio osmótico; fotossíntese; oxidação; absorção de nutrientes; solução do solo; potencial hídrico.

Salinity represents an important limiting factor for modern agriculture worldwide, affecting development capacity and productivity in crops of commercial interest (BALKAYA 2016). The increase in the area with the occurrence of problems with high soil salinity is accompanied by the expansion of the area with protected crops, where the leaching of salts by rainwater stops happening, resulting in an excess of accumulated salts and, consequently, becoming a problem to the intense cultivation in these environments (CHANG et al.

2013). In addition, in areas with water scarcity, there is an increase in the use of water with high levels of salts, affecting the morphophysiological characteristics of plants due to a series of deleterious effects (SILVA et al. 2013, SARABI et al. 2017, MORAIS et al. 2018, VENDRUSCOLO & SELEGUINI 2020).

The absorption of Ca^+ and K^+ elements considered essential for the plant are severely affected due to the salinity of water and soil when related to Na^+ and Cl^-, called deleterious effects, causing damage to the roots by decreasing their osmotic potential together with ionic variation (DADKHAH 2011, ARAUJO et al. 2016). In a low level of absorption of these essential nutrients, the loss of the physiological potential of plants occurs in a significant and harmful way to their vegetative development, reducing it, resulting in losses in productivity (ROUPHAEL et al. 2012, SILVA et al. 2013).

When there is an excess of Na^+ there is a decrease in the rate of K^+ and Ca^+, which can reach 50% in some cases, being approximately null for the K^+/Na^+ and Ca^+/Na^+ ratios (BALKAYA 2016). The accumulation of Na^+ is the biggest cause of leaf necrosis causing loss of photosynthetic capacity due to oxidation toxicity in its photosystem (RAHNESHAN et al. 2018, SAIDIMORADI et al. 2019). Low stomatal conductance decreased specific metabolic processes and atmospheric carbon sequestration are also consequences linked to this abiotic stress (ROUPHAEL et al. 2012).

These effects can be especially harmful to the development of species producing tuberous roots since the accumulation of salts directly affects the development of these organs. In addition, for beet and radish, two vegetable species of high commercial and nutritional importance, there are negative responses related to the physiological system of plants subjected to this abiotic stress (DADKHAH 2011, MUNIR et al. 2013, SILVA et al. 2013, CHAPARZADEH & HOSSEINZAD-BEHBOUD 2015, HOSSAIN et al. 2017). In this sense, adequate soil fertility management can be an important preventive technique for the accumulation of salts and consequent loss of production (NASCIMENTO et al. 2017).

Given the deleterious effects of elevated soil salinity, there is a need for studies that demonstrate the behavior of different species in this condition, assisting in decision-making regarding the implantation of a given crop. Thus, under the hypothesis that beet and radish crops are sensitive to variations in soil salinity, even at low levels, the objective of this work was to evaluate the development and productivity of these two species in soils with different salinities in a protected environment.

Two trials were conducted under protected cultivation conditions of the type of agricultural greenhouse, with dimensions of 18.0 x 8.0 x 4.0 m (144m²), covered with low-density polyethylene (LDPE) light diffuser film, with opening zenith sealed with 30% white screen, with black side and front screen of 30% shading closed at 90 ° and aluminized thermal reflective screen (LuxiNet®), under the LDPE film.

The soil used was classified as Neossolo Quartzarênico, composed by 12.5% of clay, 7.5% de silt and 80% of sand and containing the following chemical characteristics: pH ($CaCl_2$) = 5.6, organic matter = 33.5 g dm^{-3}, P (Mehlich^{-1}) = 636 mg dm^{-3}, K^+ = 1792 mg dm^{-3}, Ca^{2+} = 4.60 $cmol_c$ dm^{-3}, Mg^{2+} = 2.20 $cmol_c$ dm^{-3}, H+Al = 3.30 $cmol_c$ dm^{-3}, Al^{3+} = 0.01 $cmol_c$ dm^{-3}, CTC = 14.70 $cmol_c$ dm^{-3}, SB= 11.38 $cmol_c$ dm^{-3} , Zn = 43.7 mg dm^{-3}, Cu = 8.1 mg dm^{-3}, Fe = 40.0 mg dm^{-3}, Mn = 54.0 mg dm^{-3}, B = 2.02 mg dm^{-3}, S = 241.0 mg dm^{-3} and base saturation = 77.5%.

Sowing was performed directly in double fiber cement channels measuring 0.4 m x 0.6 m x 8.0 m with 1.9 m³ of soil. Planting with a spacing of 0.10 m between plants and 0.20 m between rows for beet (cv. Early Wonder) and 0.05 m between plants and 0.20 m between rows for radish (cv. Crimson Gigante). Cultural management such as weeding and thinning was carried out manually, with no need for pesticides to be applied during the crops cycle.

Irrigation was carried out using a semi-automated drip micro-irrigation system. Due to the characteristic of the irrigation system, the application intensity was 17 mm h^{-1}, equivalent to 0.30 mm min^{-1}, therefore dividing the ETc (obtained through the weather station installed inside the protected environment) by the application intensity, the necessary daily irrigation times for each crop were established.

The experimental design was completely randomized with 30 repetitions for beet and 15 for radish, considering each plant as an repetition. The treatments were formed by the soil salinity levels, obtained with the application of saline solution (NaCl in water), considering the soil electrical conductivity of 0.36 dS m^{-1} as low salinity, of 1.05 dS m^{-1} as moderate salinity and 2.43 dS m^{-1} as elevated.

The evaluations were carried out at 60 and 30 days after planting for beet and radish, respectively. At that moment, the height measurements of the plant were obtained, using a ruler graduated in centimeters, measuring the distance from the soil surface to the highest point of the plant; the relative chlorophyll content was measured with a digital chlorophyll meter (CCM-200, Opti-Sciences, Hudson, USA); the number of leaves was counted; the fresh mass of leaves (only for beet) and roots, were obtained by weighing after harvest; longitudinal and transverse diameter of the roots were measured with a digital caliper (DC1, Park

Tool, St. Paul, USA), with an accuracy level of ±0.01 mm; root productivity was estimated for one square meter (kg m^{-2}).

The data were submitted to preliminary tests of normality and homoscedasticity. As the data for all variables showed normal distribution and homogeneous variances, they were subjected to analysis of variance and the significance of the mean squares obtained in the analysis of variance was tested by the t-test (LSD) at the level of 5% probability, using the statistical software SISVAR (FERREIRA et al. 2014).

For bet, we found that, except for the relative chlorophyll content, all other variables were affected by different levels of salinity (Figure 1). For the height characteristic of the plants (Figure 1A), we observed that the levels of low and moderate salinity did not differ significantly from each other, however, differing from the higher level of salinity, while plants grown in the lowest level of salinity developed a smaller number of leaves (Figure 1C). In addition, the fresh weight of leaves in plants grown at a moderate level of salinity was significantly higher than those obtained in treatment with a high level of salinity, but not differing from those obtained at a low level of salinity (Figure 1D).

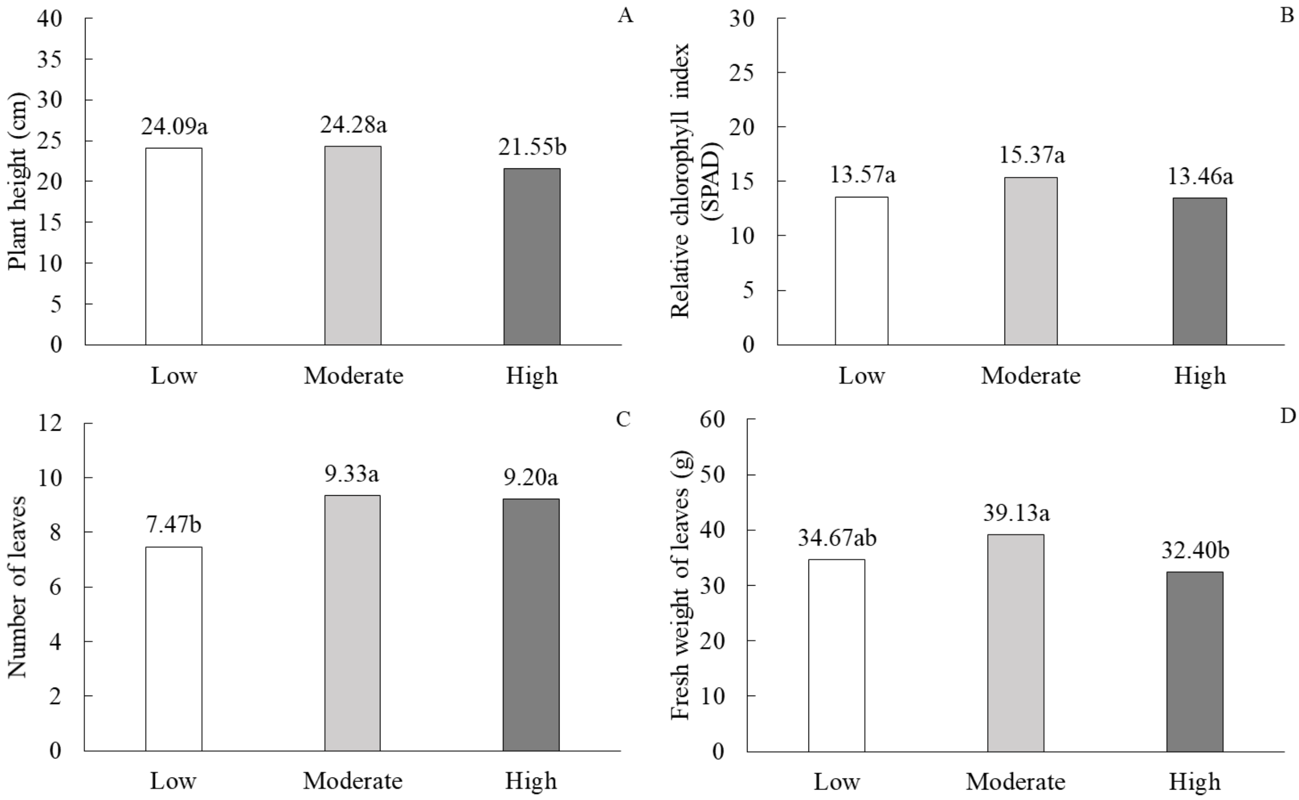

Figure 1. Plant height (A), relative chlorophyll index (B), number of leaves (C) and fresh weight of leaves (D) of beet plants submitted to different levels of salinity.

Considering the variables related to the roots, we verified that the lowest salinities provided better development conditions (Figure 2). In highlight, the treatment with low salinity was significantly superior to the others concerning fresh mass and root productivity (Figure 2C, 2D). The increase in salinity resulted in a decrease of 18.42%, when the level of salinity was moderate, and of 28.95%, when this salinity was present at a high level, in both variables.

For the radish, all the variables related to the aerial part were affected by the alteration of the soil salinity (Figure 3). In this sense, we observed that the levels of low and moderate salinity did not differ significantly for the variables of plant height and relative chlorophyll content, however, differing from the higher level of salinity (Figure 3A, 3B). In addition, the higher level of salinity resulted in a lower number of leaves, followed by a moderate level and a low level, which allowed for greater leaf production (Figure 1C).

We found that variables related to the roots at the lower level of salinity allowed the formation of larger roots (Figure 4A, 4B). For fresh mass and root productivity (Figure 2C, 2D), the increase in salinity resulted in a decrease of 22.87%, when the level of salinity was moderate, and 51.14%, when this salinity was present in high level, in both variables.

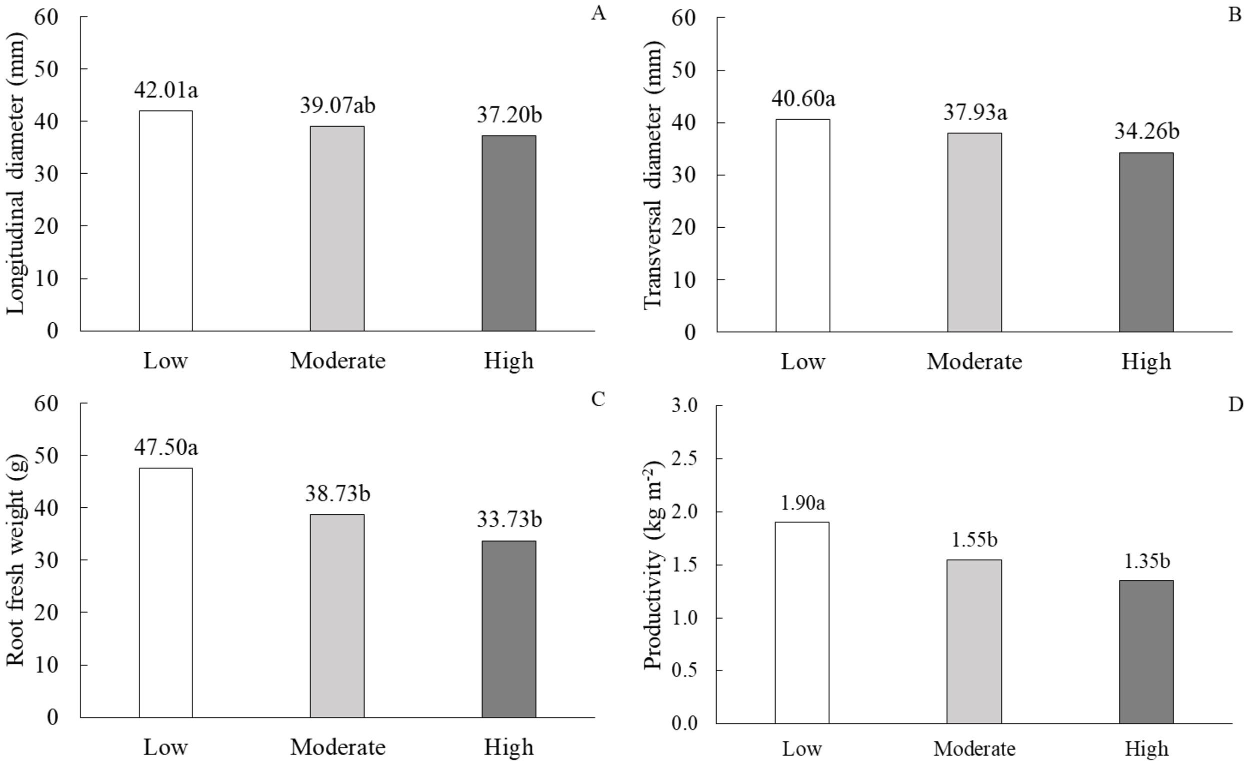

Figure 2. Longitudinal diameter (A), transversal diameter (B), fresh root weight (C) and productivity (D) of beet submitted to different levels of salinity.

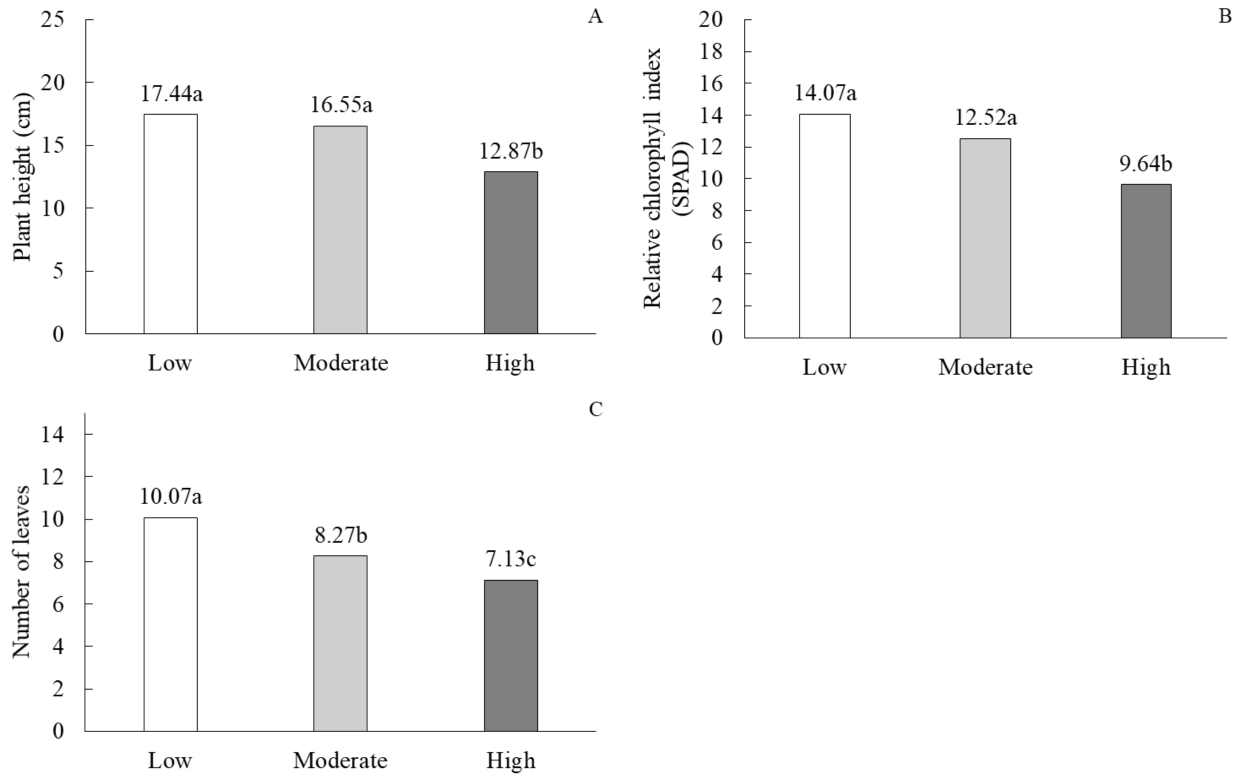

Figure 3. Plant height (A), relative chlorophyll index (B) and number of leaves (C) of radish plants submitted to different levels of salinity.

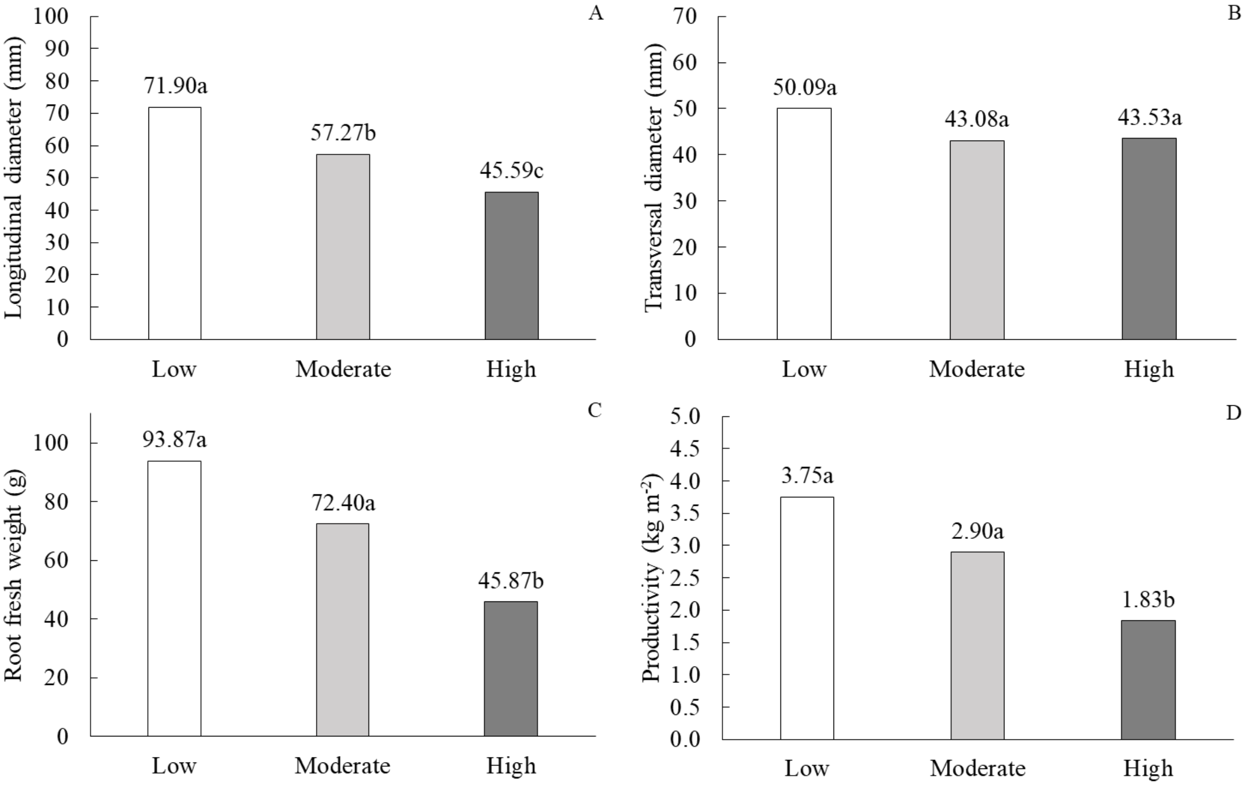

Figure 4. Longitudinal diameter (A), transversal diameter (B), fresh root weight (C) and productivity (D) of radish submitted to different levels of salinity.

When there is an excess of soluble salts in the planting area, it is called high salinity, this also refers to the exchangeable sodium in the horizons and in the topsoil of the soil, resulting in great difficulties for the correct development of the plant. Regarding the chemical and physical properties of the soil, their degradation occurs, the loss of their fertility is generated, causing the breakdown and increasing the density of the soil, resulting in this uncertain water infiltration due to a large number of sodium ions present there (CAVALCANTE et al. 2010, XIE et al. 2019), potentially caused by osmotic imbalance, making it difficult to establish plant species.

In germination, the seed loses the potential for water intake, decreasing the germination rates, that is, the main effect related to salinization is in the mineral nutrition of the plants, causing the delay in the nutrition of the plant due to the osmotic effect, nutritional imbalance according to high ionic concentration having no absorption of other cations by sodium and also through the toxic effect of sodium and chloride ions. The vastness of the damage caused by the excess of salts is only observed over time, aiming at the concentration, tolerance of the culture and the volume of water that is transpired by the plant (SCHOSSLER et al. 2012, MAIA JÚNIOR et al. 2021).

Tuberous roots such as beet and radish are widely used in crop rotations in protected environments, due to their developmental characteristics, commercial value and organoleptic composition. However, it appears that under salinity conditions the development of these cultures can be reduced, as observed by SILVA et al. (2013) for the condition of excessive salinity in the cultivation of beet, which directly affects the development and productivity of the plants of two cultivars (Early Wonder and Itapuã). In this study, the authors found that for both varieties, water consumption was lower than normal when there was an excess of salts. Bearing in mind that beets respond significantly to aspects of salinity, with changes in the physiological mechanism.

Among the main effects of salinity on beet and radish plants subjected to increasing levels of salinity, it can be seen that the damage caused to the physiological system is directly related to the loss of carbon fixation capacity (HOSSAIN et al. 2017), the drop in leaf K contents and consequent development of aerial organs (DADKHAH 2011). These results in the loss of photosynthetically active area, a drop in the production of photoassimilates, reflecting in the development of the roots, the main product for commercialization (DADKHAH 2011).

The responses to the excess of salts in the soil are diverse between species, as is the case when comparing beet to radish, and, despite being relatively more tolerant, the radish has similarities with the beet because there are difficulties during germination (ALMEIDA et al. 2018). Exposure to increasing levels of salinity also affects the development of the organs of the radish plant, similarly to beet, due to loss of photosynthetic capacity, gas exchange and water use efficiency (MUNIR et al. 2013), as well as the amount of photosynthetic pigments, which undergo the oxidation degradation process, due to the presence of reactive oxygen species (CHAPARZADEH & HOSSEINZAD-BEHBOUD 2015).

From this perspective, we were able to conclude that beet and radish crops are sensitive to the variation in soil salinity, even in relatively low concentrations, making these crop species an unattractive choice for cultivation in systems that present this problem. We also emphasize the importance of conducting frequent analyzes of the chemical quality of soils in protected environments, avoiding economic loss due to the occurrence of salt accumulation and the use of resistant species, which assist in the removal of salts present in the soil.

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