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ORIGINAL ARTICLE

Production and quality of hydroponic kale under salt stress and KNO_3 concentrations[1]

Produção e qualidade da couve folha hidropônica sob estresse salino e concentrações de KNO_3

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HIGHLIGHTS:

The cv. Manteiga da Geórgia of kale is more tolerant to salinity than the cv. Manteiga.
Extra KNO_3 concentration of 25% in nutrient solution increases tolerance of kale to salinity.
Kale quality, in terms of soluble solids, is increased by salt stress and KNO_3 concentrations.

ABSTRACT: Potassium is a nutrient with the potential to increase plant tolerance to salt stress. The aim of this study was to evaluate the production and quality of kale subjected to salt stress and potassium concentrations in a protected environment. The experimental design was in split plots, with plots composed of five nutrient solutions (control treatment, S1 - standard nutrient solution prepared in low-salinity water, 0.5 dS m^{-1} (500 mg L^{-1} of KNO_3), and four nutrient solutions prepared in brackish waters (3.5 dS m^{-1}) containing four concentrations of KNO_3 (S2 - 500 mg L^{-1}, S3 - 625 mg L^{-1}, S4 - 750 mg L^{-1}, S5 - 1,000 mg L^{-1}), and subplots represented by two leaf kale cultivars (Manteiga and Manteiga da Geórgia). Leaf production variables and post-harvest physical and chemical qualities were evaluated. The saline nutrient solution with the addition of NaCl (S2) reduced production but did not reduce the post-harvest quality of kale. The extra addition of KNO_3 at 25% (S3) was efficient in reducing the deleterious effects of salt stress on the variables leaf length, leaf area, leaf production, and number of bunches. The cv. Manteiga da Geórgia was more tolerant to salt stress than the cv. Manteiga.

Key words: *Brassica oleracea* L., salinity, potassium fertilization, post-harvest quality

RESUMO: O potássio é um nutriente com potencial para aumentar a tolerância das plantas ao estresse salino. O objetivo deste estudo foi avaliar a produção e a qualidade da couve submetida ao estresse salino e às concentrações de potássio em ambiente protegido. O delineamento experimental adotado foi em parcela subdivididas, sendo as parcelas compostas por cinco soluções nutritivas (tratamento controle, S1 - solução nutritiva padrão usando água de baixa salinidade, 0,5 dS m^{-1} (500 mg L^{-1} de KNO_3), e quatro soluções nutritivas preparadas em águas salobras (3,5 dS m^{-1}) contendo quatro concentrações de KNO_3 (S2 - 500 mg L^{-1}, S3 - 625 mg L^{-1}, S4 - 750 mg L^{-1}, S5 - 1.000 mg L^{-1}). As subparcelas foram representadas por duas cultivares de couve folha (Manteiga e Manteiga da Geórgia). Foram avaliadas as variáveis de produção de folhas e qualidades físicas e químicas pós-colheita. A solução nutritiva salinizada com adição de NaCl (S2) reduziu a produção, mas não reduziu a qualidade pós-colheita da couve folha. A adição extra de KNO_3 em 25% (S3) foi eficiente para reduzir o efeito deletério do estresse salino sobre as variáveis comprimento de folha, área foliar, produção e número de maços. A cv. Manteiga da Geórgia se mostrou mais tolerante ao estresse salino que a cv. Manteiga.

Palavras-chave: *Brassica oleracea* L., salinidade, nutrição potássica, qualidade pós-colheita

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Introduction

Kale has gained great importance because it is presented as a functional food due to the presence of specialized metabolites or phytochemicals whose bioactivity is linked to beneficial effects on human health (Šamec et al., 2019).

Due to the scarcity of water resources, water with high concentrations of salts has been used in agricultural production. However, its use requires the adoption of management strategies, especially in the production of leafy vegetables, which are sensitive to salt stress (Soares et al., 2020; Silva et al., 2023a, b).

The kale crop is classified as moderately sensitive to salt stress, showing a threshold salinity of 1.8 dS m^{-1} for the electrical conductivity of the saturation extract (Ayers & Westcot, 1999). Under salt stress, kale can be affected in different ways, with emphasis on the reduction in leaf development and crop production (Silva et al., 2023a).

This reduction is a consequence, among other factors, of the ionic imbalance caused mainly under conditions with high concentrations of Na^+ (sodium) ions, which can reduce the absorption of other cations, such as K^+ (potassium), due to the antagonistic relationship between them, increasing Na^+/K^+ ratios (Šamec et al., 2021).

A key trait which has long been recognized to improve salinity tolerance in many plants is the maintenance of a low Na^+/K^+ ratio, while maintaining K^+ homeostasis (Wu et al., 2021). According to Šamec et al. (2021), kale has developed mechanisms to accumulate Na^+ in the root tissue and prevent the influx of Na^+ into the aerial part of the plants. Given the above, the aim of this study was to evaluate the production and quality of kale subjected to salt stress and potassium concentrations in a protected environment.

Material and Methods

The experiment was conducted from February 28, 2021 to June 25, 2021, in a greenhouse at the Department of Agricultural and Forestry Sciences of the Universidade Federal Rural do Semi-Árido, Mossoró, in the State of Rio Grande do Norte, Brazil (5º 12' 04" S; 37º 19' 38" W; mean altitude of 18 m).

The greenhouse has an area of 126 m^2 (length of 18 m and width of 7 m), an upper cover of transparent light diffuser low-density polyethylene film (LDPE with 150 μm thickness), treated against ultraviolet rays.

The adopted experimental design was randomized blocks, in a 5 × 2 scheme, with four replicates and four plants per plot. Kale was grown under two levels of electrical conductivity of water (ECw) used for the preparations of the nutrient solutions: 0.5 dS m^{-1} - control (low-salinity water obtained from the local supply system) and 3.5 dS m^{-1}, obtained by addition of NaCl.

This salinity level was adopted because, according to Amaral & Navoni (2023), water in the semi-arid region has an average electrical conductivity of 3.5 dS m^{-1}. In the other four treatments the cultivation was performed only with salinity (3.5 dS m^{-1}), but with different concentrations of potassium nitrate (S2 - 500, S3 - 625, S4 - 750, and S5 - 1,000 mg L^{-1}). The subplots represented two kale cultivars (Manteiga and Manteiga da Geórgia). Each experimental unit was composed of two 10 dm^3 capacity pots containing one plant.

The water used to prepare the standard nutrient solution came from the local supply system, whose chemical analysis showed the following characteristics: pH = 7.30, EC = 0.50 dS m^{-1}, Ca^{2+} = 3.10, Mg^{2+} = 1.10, K^+ = 0.30, Na^+ = 2.30, Cl^- = 1.80, HCO_3^- = 3.00, and CO_3^{2-} = 0.20 ($mmol_c$ L^{-1}).

The standard nutrient solution adopted was the one recommended by Furlani et al. (1999) for macronutrients, with the following fertilizer concentrations in mg L^{-1}: 750 for calcium nitrate, 500 for potassium nitrate, 150 for monoammonium phosphate, and 400 for magnesium sulfate.

Micronutrients were supplied using a commercial compound named Rexolin® (Yara Brasil S.A., Porto Alegre), containing the following composition: 2.1% boron (B), 2.66% iron (Fe), 0.36% copper (Cu), 2.48% manganese (Mn), 0.036% molybdenum (Mo), and 3.38% zinc (Zn); besides 11.6% potassium oxide (K_2O), 1.28% sulfur (S), and 0.86% magnesium (Mg). The dose applied was as indicated by the manufacturer (30 g of the compound for the preparation of 1,000 L of nutrient solution). In order to adjust the pH of the solution, between 6.0 and 6.5, solutions of 0.1 mol L^{-1} of KOH or HCl was used. After preparing the nutrient solutions, their electrical conductivity was measured, obtaining values of 2.29, 5.11, 5.92, 6,63, and 7.54 dS m^{-1}, for S1, S2, S3, S4, and S5, respectively.

Kale was sown in polystyrene trays with 128 cells, using coconut fiber substrate. After emergence, thinning was performed, leaving one seedling per cell. Transplanting into pots filled with substrate and washed sand (2:1, weight basis) was done when the seedlings reached four true leaves, at 35 days after sowing.

Cultivation was carried out in a semi-hydroponic system, using coconut fiber. The pots (10 dm^3) used had dimensions of 0.33 m in height, with 0.30 m upper diameter and 0.20 m lower diameter. At the bottom of the pot, a drainage system was installed, consisting of a layer of number 1.0 gravel and a geotextile blanket. The pots were filled with granular coconut fiber substrate (Golden Mix® 80) and washed sand (2:1, in volume) and were arranged at a spacing of 0.40 m between plants and 1.0 m between rows of plants.

For each nutrient solution, an independent irrigation system was used, composed of polyvinyl chloride (PVC) reservoir (210 L), lateral lines of flexible tubes (16 mm), and microtube emitters (spaghetti) with 10 cm length and mean flow rate of 3.5 L h^{-1}. During the experiment, neither the electrical conductivity nor the pH of the nutrient solutions was monitored or controlled. When the volume of nutrient solution reached the minimum level for suction by the motor pumps, the residual solution was discarded. Then the reservoir was washed and filled with a new nutrient solution.

To control irrigation, a digital timer was used, adjusting the duration of each irrigation throughout the crop cycle. Initially, the timer was programmed for six daily events (07:00, 09:00, 11:00, 13:00, 15:00, and 17:00 hours) lasting 1.0 minute each until 30 days after transplanting (DAT). After this period, it was programmed again with events lasting 2.0 minutes each until the end of the experiment (Silva et al., 2023a).

Six leaf harvests (57, 64, 71, 78, 87, and 95 DAT) were carried out, harvesting leaves with a main leaf blade length greater than 20 cm, leaving five leaves per plant (Trani et al., 2015). Leaf production was analyzed based on the accumulated production during the experiment. According to Azevedo et al. (2021), to obtain a coefficient of determination of 85%, six evaluations are required for production of leaves.

Production of leaves was evaluated based on the following variables: Number of leaves (NL), obtained directly by counting commercial standard leaves; leaf blade length (LBL) and width (LBW), determined using a ruler measured in cm; production of leaves (PL), determined by weighing commercial standard leaves using an analytical scale (0.01 g). Leaf area (LA) was determined by the product between the number of harvested leaves (NL) and the leaf blade area. Leaf blade area was obtained through linear measurements of the LBL and LBW (LA = (0.82012 + 0.71913 × (LBL × LBW), R^2 = 0.98), according to Marcolini et al. (2005) for kale. Leaf area values were obtained in cm^2 and multiplied by the factor 0.0001 to convert to m^2. Number of bunches was obtained by dividing the number of commercial leaves by five (number of leaves used to make up a bunch, according to the local market standard).

The samples were crushed in a domestic blender and then the quantities necessary for each analysis were collected. Post-harvest quality was analyzed based on the following variables: soluble solids (SS) determined using a digital refractometer, PR-100 Palette model (Atago Co., Ltd., Japan), with results expressed in °Brix; titratable acidity (TA) determined according to analytical standard of IAL (2008), by the titration method, using 10 g of juice; vitamin C (Vit C), determined according to Strohecker & Henning (1967), using a 10 g sample of the crushed material, diluted to 100 mL of oxalic acid, followed by the collection of a 5 mL aliquot and addition of 45 mL of water, With titration performed with 2,6-dichlorophenolindophenol (0.094 mg mL^{-1}) until reaching a pinkish color; and the SS/TA ratio, obtained by the division of the variables SS and TA.

The data obtained were subjected to the Shapiro-Wilk normality test and, if normal, to analysis of variance and F-test ($p \le 0.05$) were performed. The means were compared using the Tukey's test ($p \le 0.05$) The statistical analyses were performed using the SISVAR statistical software (Ferreira, 2019).

Results and Discussion

The interaction of NS x C factors affected the leaf blade length (LBL) ($p \le 0.05$), as well as the number of commercial leaves (NL), leaf area (LA), and number of bunches (NB) ($p \le 0.01$). Production of leaves (PL) was affected only by nutrient solutions ($p \le 0.01$). Leaf blade width (LBW) was not affected by the treatments applied (Table 1).

The number of commercial leaves (NL) was affected by the addition of NaCl only in cv. Manteiga, with a reduction of 17.56%, compared to the NL obtained in the standard solution (S1). For cv. Manteiga da Geórgia, there was no effect of salinity on NL, except that the extra addition of KNO_3 at 25% (S3) caused a reduction of 18.40%. For both cultivars, doses of extra KNO_3 above 50% (S4 and S5) did not affect the NL (Table 2).

This behavior is a morphological response to prevent or reduce water stress, characterizing itself as an adaptive strategy for plants to survive salt stress (Petretto et al., 2019).

Reduction in the number of commercial leaves of kale under salt stress has also been reported by other authors (Viana et al., 2021), as well as in a study with other Brassica species (Soares et al., 2020).

Leaf blade length (LBL) was affected by nutrient solutions only in cv. Manteiga da Geórgia, for which salt stress (S2) caused a 12.34% reduction in LBL, compared to the LBL obtained in the standard nutrient solution (S1). Furthermore, it appears that the extra addition of KNO_3 at 25% (S3) reduced the effect of salinity on LBL (Table 2).

The leaf blade width (LBW) was not affected by the nutrient solutions, regardless of the cultivars analyzed.

Although the size of the leaf blade is related to its linear dimensions (LBW and LBL), the results presented show that the effect of the applied treatments was greater on LBL. In a study carried out with cauliflower subjected to salt stress, Silva et al. (2023b) also observed that LBL was more affected compared to LBW.

For leaf area (LA), there was a significant effect between the nutrient solutions for the two kale cultivars. The nutrient solution salinized with NaCl (S2) caused a reduction in LA in both cultivars, resulting in losses of 36.46% for cv. Manteiga and 20.31% in cv. Manteiga da Geórgia, compared to the LA values obtained in S1.

The cultivars showed different responses to the extra addition of KNO_3. In cv. Manteiga, the S3 solution was efficient in reducing the effect of salt stress on LA, but increased the effect

Table 1. Summary of the analysis of variance for the number of commercial leaves (NL), leaf blade length (LBL) and width (LBW), leaf area (LA), production of leaves (PL), and number of bunches (NB) in kale cultivars grown in a semi-hydroponic system subjected to different salinized nutrient solutions and potassium concentrations

Source of variation	Mean squares					
	NL	LBL	LBW	LA	PL	NB
Nutrient solutions (NS)	34.57 *	15.92 *	3.925 ns	21,554.21 **	300,134.06 **	1.383 *
Block	13.49 ns	4.34 ns	2.662 ns	304.85 ns	40,242.70 ns	0.539 ns
Error 1	9.12	4.89	4.868	1,007.13	44,846.72	0.365
Cultivars (C)	55.69 ns	0.95 ns	11.618 ns	447,12 ns	6,733.50 ns	2.23 ns
NS × C	70.00**	8.18 *	3.544 ns	6,763.31 **	58,478.84 ns	2.80 **
Error 2	12.69	2.71	1.703	777.97	35,556.29	0.51
CV 1 (%)	6.71	6.46	8.41	13,43	16.16	6.71
CV 2 (%)	7.91	4.81	4.97	15,41	14.39	7.91

ns; *; ** - Not significant, significant at $p \le 0.05$ and $p \le 0.01$, respectively by F test; CV 1 - Coefficient of variation of the nutrient solutions factor; CV 2 - Coefficient of variation of the cultivar factor; DF - Degrees of freedom

Table 2. Mean values for the number of commercial leaves, leaf blade length, leaf blade width, leaf area, production of leaves, and number of bunches in two kale cultivars grown in a semi-hydroponic system subjected salinized nutrient solutions and potassium concentrations

Nutrient solutions	Cultivars		
	Manteiga	Manteiga da Geórgia	Mean
Number of commercial leaves			
S1	46.25 a A	49.63 a A	47.94
S2	38.13 b B	46.43 ab A	42.28
S3	48.00 a A	40.50 b B	44.25
S4	43.38 ab A	48.25 a A	45.82
S5	43.50 ab A	46.25 ab A	44.88
Mean	43.85	46.21	
Leaf blade length (cm)			
S1	35.19 a A	37.60 a A	36.40
S2	32.29 a A	32.96 b A	32.63
S3	34.06 a A	34.02 ab A	34.04
S4	35.86 a A	33.62 b A	34.74
S5	34.76 a A	32.41 b A	33.59
Mean	34.43	34.12	
Leaf blade width (cm)			
S1	28.07	26.68	27.37 a
S2	25.89	27.05	26.47 a
S3	26.52	24.60	25.56 a
S4	26.61	25.55	26.08 a
S5	26.95	24.76	25.86 a
Mean	26.81 A	25.73 A	
Leaf area (m^2 per plant)			
S1	4.56 a A	4.75 a A	4.65
S2	2.89 c B	3.78 bc A	3.34
S3	3.77 b A	3.20 c B	3.48
S4	3.64 b A	3.88 b A	3.76
S5	3.79 b A	3.37 bc A	3.58
Mean	3.73	3.79	
Production of leaves (g per plant)			
S1	1,580.11	1,489.71	1.534,91 a
S2	977.38	1,130.31	1,053.85 b
S3	1,384.99	1,533.25	1,459.12 a
S4	1,418.09	1,181.48	1,299.79 ab
S5	1,254.61	1,150.67	1,202.64 ab
Mean	1,323.03 A	1,297.08 A	

Means followed by the same uppercase letter in the rows, and lowercase letters in the column, do not differ from each other using the Tukey test ($p \leq 0.05$). S1 - Standard nutrient solution (500 mg L^{-1} of KNO_3); S2 - Saline nutrient solution (500 mg L^{-1} of KNO_3); S3 - Saline nutrient solution (625 mg L^{-1} of KNO_3); S4 - Saline nutrient solution (750 mg L^{-1} of KNO_3); S5 - Saline nutrient solution (1,000 mg L^{-1} of KNO_3).

of salinity on this variable in cv. Manteiga da Geórgia. It is also verified that, for cv. Manteiga da Geórgia, nutrient solutions with higher concentrations of KNO_3 (S4 and S5) favored an increase in LA, despite not differing from solution S2.

Silva et al. (2023), when working with kale cv. Manteiga, using the same cultivation system and standard nutrient solution, obtained LA of 2.78 m^2 per plant. Furthermore, the authors found a 49.28% reduction in LA when using water with EC 6.0 to prepare the nutrient solution.

The addition of NaCl to the nutrient solution (S2) caused a reduction in the production of leaves (PL), regardless of the cultivar studied, obtaining an average loss between cultivars of 31.34%. It was also verified that the extra addition of KNO_3 from 25% was efficient in nullifying the effect of salt stress.

Reduction in commercial production of kale was also observed by other authors working with salinity, whether in soil cultivation (Viana et al., 2021), or in hydroponics (Šamec et al., 2021, Silva et al., 2023a).

In a study conducted by Oliveira et al. (2023) with kale cv. Manteiga, using this same cultivation system, but with water salinity of 6.0 dS m^{-1}, the authors observed reduction of 55.6% in leaf production.

Salt stress causes damage to the plant's metabolic and cellular processes, including disruption of ionic homeostasis due to excess influx of sodium ions (Na^+) and efflux of potassium (K^+). This condition subsequently results in a significant reduction in potassium levels, inhibiting plant growth attributes (Kumari et al., 2021). According to Shahzad et al. (2021), some salinity-tolerant Brassica species experience high salt stress as a result of the higher Na^+/K^+ ratio, better K^+ retention capacity in the leaf mesophyll and osmotic adjustments.

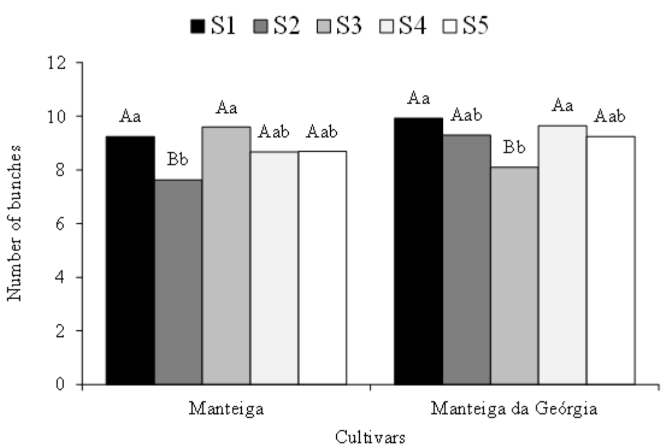
Soares et al. (2020), when studying salinity and flow rate of the nutrient solution in cauliflower in the hydroponic system, found that the decreases in plant growth due to the increase in the salinity of the nutrient solution may be due to the osmotic effect of the higher concentrations of ions in the nutrient solutions on the plants.

High concentrations of Na^+ and Cl^- cause imbalances in the absorption of nutrients by plants, since an excess of these ions in the nutrient solution can cause imbalances in the absorption of essential nutrients, such as nitrogen, calcium, and potassium (Šamec et al., 2021).

Potassium plays a role in carbohydrate metabolism, protein synthesis, and enzyme activation, helping to balance cations and anions and allowing water movement, energy transfer, and regulation of osmotic processes (Taha et al., 2020). For Yan et al. (2021), K^+ availability or deficiency has significant effects on the homeostasis of other essential nutrients, particularly under conditions of abiotic stress, including nutrient deficiency.

The reduction in leaf area is a survival mechanism that plants have when subjected to salt stress, because when plants are exposed to water stress, stomatal closure is induced to retain water in the plant, reducing leaf transpiration (Khalid et al., 2023).

The effect of nutrient solutions on NL was directly reflected in the number of bunches (NB) harvested (Figure 1), as the



S1 - Standard nutrient solution (500 mg L^{-1} of KNO_3); S2 - Saline nutrient solution (500 mg L^{-1} of KNO_3); S3 - Saline nutrient solution (625 mg L^{-1} of KNO_3); S4 - Saline nutrient solution (750 mg L^{-1} of KNO_3); S5 - Saline nutrient solution (1,000 mg L^{-1} of KNO_3). Bars with the same uppercase letter referring to cultivars in the same type of nutrient solution, and lowercase letters referring to nutrient solutions in the same cultivar, do not differ significantly by the Tukey test ($p \leq 0.05$).

Figure 1. Number of bunches in two kale cultivars grown in a semi-hydroponic system subjected to salinized nutrient solutions and potassium concentrations

Table 3. Summary of analysis of variance and mean values for soluble solids content (SS), vitamin C (VIT C), titratable acidity (TA), hydrogen potential (pH), soluble solids/titratable acidity ratio (SS/TA) in two kale cultivars grown in a semi-hydroponic system subjected to salinized nutrient solutions and potassium concentrations

Source of variation	DF	Mean squares				
		SS	VIT C	pH	TA	SS/TA
Nutrient solutions (NS)	4	0.87*	1.33 ns	0.0024 ns	0.0015 ns	88.44 ns
Block	3	0.19 ns	0.18 ns	0.0029 ns	0.00083 ns	12.23 ns
Error 1	12	0.23	0.51	0.0079	0.0012	33.00
Cultivars (C)	1	0.09 ns	0.07 ns	0.0071 ns	0.00028 ns	34.99 ns
NS × C	4	0.24 ns	0.13 ns	0.0031 ns	0.00018 ns	3.74 ns
Error 2	15	0.52	0.31	0.0016	0.00045	20.34
CV 1 (%)		7.84	20.08	1.39	19.79	16.13
CV 2 (%)		11.99	14.4	0.63	12.32	12.66
		Mean comparison test				
Source of variation		SS (°Brix)	VIT C (mg 100 g^{-1})	pH	TA (%)	SS/TA
Nutrient solutions						
S1		5.85 b	4.22 a	6.41 a	0.19 a	30.44 a
S2		6.07 ab	3.21 a	6.42 a	0.17 a	36.54 a
S3		5.93 ab	3.77 a	6.41 a	0.18 a	34.76 a
S4		5.80 b	3.40 a	6.45 a	0.16 a	36.99 a
S5		6.61 a	3.34 a	6.44 a	0.17 a	39.36 a
Cultivars						
Manteiga		6.10 a	3.55 a	6.44 a	0.17 a	36.56 a
Manteiga da Geórgia		6.01 a	3.63 a	6.41 a	0.17 a	34.69 a

ns; *; ** - Not significant, significant at $p \leq 0.05$ and $p \leq 0.01$, respectively by F test; CV 1 - Coefficient of variation of the nutrient solutions factor; CV 2 - Coefficient of variation of the cultivar factor; DF - Degrees of freedom. Means followed by the same letter, in the columns, do not differ significantly using the Tukey test ($p \leq 0.05$). S1 - Standard nutrient solution (500 mg L^{-1} of KNO_3); S2 - Saline nutrient solution (500 mg L^{-1} of KNO_3); S3 - Saline nutrient solution (625 mg L^{-1} of KNO_3); S4 - Saline nutrient solution (750 mg L^{-1} of KNO_3); S5 - Saline nutrient solution (1,000 mg L^{-1} of KNO_3)

nutrient solution S2 led to a 17.51% reduction in NB for cv. Manteiga. However, the extra addition of KNO_3 at 25% (S3) reduced the deleterious effect of salt stress on this variable. For cv. Manteiga da Geórgia, no effect of the addition of NaCl on NB was observed, except that the adoption of nutrient solution S3 caused a reduction of 18.42% in NB (Figure 1).

Regarding post-harvest quality variables, only the soluble solids (SS) content was affected by the nutrient solutions ($p \leq 0.05$). The other variables were not affected by the factors studied (Table 3).

The saline nutrient solution enriched with 100% KNO_3 (S5) promoted higher values for the soluble solids (SS) content, while the lowest values occurred in solutions S1 (standard nutrient solution) and S4 (saline nutrient solution enriched with KNO_3 in 50%). The largest percentage difference occurred between solutions S1 and S5, with solution S5 being 12.99% better (Table 3).

The soluble solids content in kale can vary depending on factors such as genetic material, environmental conditions, and cultivation system, with SS varying from 5.07 to 9.12 °Brix (Verruma-Bernardi et al., 2021). Therefore, the SS values obtained in the present study are within the range observed by these authors, regardless of the nutrient solutions studied.

Although the sugar content is not a determining factor in the purchasing decision of kale consumers, the increase in the soluble solids content is an important variable to be analyzed, as the sugars are organic compounds and represent more than 50% of the total osmotic potential in glycophytes subjected to salt stress, and act in osmoprotection, osmotic adjustment, and carbon storage (Rahman et al., 2021).

The increase in SS observed in nutrient solution S5 can be attributed both to the beneficial effect on this variable and to the effect of NaCl, which caused greater electrical conductivity of the nutrient solution, and due to the concentration effect, promotes a higher content of soluble sugars (Bantis et al., 2020).

As previously presented, the nutrient solutions did not affect the variables VIT C, pH, TA and SS/TA, and the average values obtained were 3.59 mg 100g^{-1} (VIT C), 6.42 (pH), 0.17% citric acid (TA), and 35.62 (SS/TA).

The effects of salt stress on these variables are divergent according to the literature, varying mainly depending on species, genotypes and cultivation conditions. El-Nakhel et al. (2022), working with spinach, did not observe a significant effect on vitamin C content. On the other hand, Giuffrida et al. (2017), in a study with cauliflower, found a positive effect of salt stress on this variable. In a study carried out with broccoli crop, Guo et al. (2014) observed a significant reduction in vitamin C content in response to salt stress.

The fact that most of the post-harvest quality variables were not affected in the treatments is an important finding, as it shows that under the cultivation conditions used in the present study, it is viable to use saline water in the hydroponic cultivation of kale, without loss of quality in the leaves.

Conclusions

1. Among the two cultivars studied, cv. Manteiga da Geórgia was found to be more tolerant to salt stress.

2. The extra addition of KNO_3 at 25% in nutrient solution was efficient in reducing the deleterious effect of salt stress on the variables leaf blade length, leaf area, leaf production, and number of bunches.

3. The saline nutrient solution with the addition of NaCl reduced production of leaves, but did not reduce the post-harvest quality of kale.

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