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Okra salt stress reduction under potassium fertigation

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ABSTRACT

Potassium fertigation may be a strategy to reduce saline stress in okra. The objective of this study was to analyze the effect of potassium supplementation as a salinity-attenuating agent in okra. The experiment was conducted in a greenhouse at the Federal Rural University of the Semi-Arid Region, in Mossoró-RN, Brazil. The experimental design was completely randomized, in 2x5 factorial scheme with 4 replicates. Two okra cultivars (Santa Cruz 47 and Valença) fertigated with five fertigation managements [F1= irrigation with non-saline water (0.55 dS/m) and fertigation with a standard dose of potassium (6 g/plant); F2= irrigation with saline water (3.5 dS/m) and fertigation with 6 g/plant of K, F3= irrigation with saline water (3.5 dS/m) and fertigation with 9 g/plant of K, F4= irrigation with saline water (3.5 dS/m) and fertigation with 12 g/plant of K, and F5= irrigation with saline water (3.5 dS/m) and fertigation with 15 g/plant of K]. Plants were collected 110 days after emergence and evaluated for growth variables (leaf number, leaf area, leaf dry mass, stem dry mass, total dry mass) and yield (fruit number, average fruit mass and fruit production). Potassium influenced the growth and yield characteristics of okra irrigated with saline water. The highest yields of fruits occurred at 9.56 and 10.23 g/plant of K, being 330.24 and 733.36 g/plant obtained from cultivars Santa Cruz 47 and Valença, respectively. Okra irrigated with saline water is more demanding in potassium.

Keywords: *Abelmoschus esculentus*, salinity, mineral nutrition.

RESUMO

Redução do estresse salino em quiabeiro sob fertirrigação potássica

A fertirrigação potássica pode ser uma estratégia para reduzir o estresse salino em quiabeiro. O objetivo deste trabalho foi analisar o efeito da suplementação potássica como agente amenizador da salinidade em quiabeiro. O experimento foi conduzido em casa de vegetação na Universidade Federal Rural do Semi-Árido, em Mossoró, utilizando o delineamento experimental inteiramente casualizado, em esquema fatorial 2x5, com quatro repetições. Em duas cultivares de quiabeiro (Santa Cruz 47 e Valença) foram aplicados cinco tratamentos de fertirrigação [F1= Irrigação com água não salina (0,55 dS/m) e fertirrigação com dose padrão de K (6 g/planta), F2= irrigação com água salina (3,5 dS/m) e fertirrigação com 6 g/planta de K, F3= irrigação com água salina (3,5 dS/m) e fertirrigação com 9 g/planta de K, F4= irrigação com água salina (3,5 dS/m) e fertirrigação com 12 g/planta de K, e F5= irrigação com água salina (3,5 dS/m) e fertirrigação com 15 g/planta de K]. As plantas foram coletadas após 110 dias da emergência e avaliadas quanto aos fatores de crescimento (número de folhas, área foliar, massa seca de folhas, massa seca de caule e massa seca total) e rendimento (número de frutos, massa média de frutos e produção). O potássio afetou as características de crescimento e rendimento do quiabo irrigado com água salina. As maiores produções de frutos ocorreram nas doses de 9,56 e 10,23 g/planta de K, sendo 330,24 e 733,36 g/planta das cultivares Santa Cruz 47 e Valença, respectivamente. O quiabeiro irrigado com água salina é mais exigente em potássio.

Palavras-chave: *Abelmoschus esculentus*, salinidade, nutrição mineral.

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Okra (*Abelmoschus esculentus*) is a vegetable belonging to the Malvaceae family. Its fruits are edible and rich in nutrients and minerals, especially in zinc, a mineral important for the proper function of all body tissues. It has antioxidant activity that prevents free radicals, besides antidiabetic properties. So, its consumption should be stimulated (Lima *et al*., 2015).

The okra crop is classified as sensitive to salinity, whose salinity threshold is below 1.3 dS/m in the saturation extract (Maas, 1984). Under salt stress shows significant changes in physiology, growth and yield (Azeem *et al*., 2017; Abbas *et al*., 2018; Sousa *et al*., 2020). Thus, in order to succeed with the use of saline water, some strategies should be adopted to reduce the deleterious effect of salinity.

Plants grown under saline conditions, high concentrations of Na^+ and Cl^- ions can exceed the concentrations of other essential nutrients, which may result in disturbances to the uptake of Ca^{2+} and K^+, modifying the absorption regime of these nutrients through the root system and its translocation to the shoots, thus increasing the Na^+/K^+ ratio (Cova *et al*., 2017; Hu *et al.*, 2020). The reduction in K^+ concentrations caused by excess NaCl are mainly due to the increase in the efflux of K^+ because the membrane is damaged decreasing the influx (Alves *et al.*, 2009).

Potassium, although not being a constituent of any molecule or plant structure, is a vital nutrient for plant growth, influencing yield and quality, as it plays a role in the regulation of stomatal conductance and photosynthesis, enzymatic activation, turgescence and tolerance to stress (Marschner, 2012).

Adequate nutritional management is fundamental. Nutritional imbalance is one of the main effects of salinity, especially in terms of potassium, since the absorption of this nutrient is greatly affected by high concentration of sodium in the water (Soares *et al.*, 2016). Thus, the deleterious effect of salinity on the yield of this crop is possibly directly related to the nutritional imbalance of plants.

As an essential macronutrient for plant growth, potassium (K) has abundant physiological functions, including maintenance of cell osmotic pressure. Potassium uptake and efflux control cell water potential and turgor during osmotic regulation (Hu *et al.*, 2020). Potassium is the most extracted nutrient by the okra crop (Galati *et al.*, 2013) and, at appropriate doses, promotes an increase in the number and size of fruits, consequently increasing okra yield (Santos *et al.*, 2019; Maduagwuna *et al.*, 2021; Silva *et al.*, 2021).

However, there is little research evaluating the response of okra to K fertilization when subjected to salt stress (Saheed & Qader, 2020; Soares *et al.*, 2020). In view of the above, the present study was conducted to analyze the effect of K supplementation as a salt stress-attenuating agent in okra.

MATERIAL AND METHODS

Experimental area

The experiment was carried out from October 2018 to January 2019, in a greenhouse in the Department of Agronomic and Forestry Sciences, at the Center for Agrarian Sciences of the Federal Rural University of the Semi-Arid Region, in Mossoró-RN, Brazil (5º12’04”S, 37º19’39”W, 18 m altitude). The greenhouse covered 126 m^2, 18-m length, 7-m width, top cover of transparent low-density polyethylene film, transparent light diffuser (low density polyethylene film, LDPF), 150 microns thick and anti-UV additive.

During the experiment, daily data on maximum (Tmax), average (Tmed) and minimum temperature (Tmin), maximum (URmax), average (URmed) and minimum (URmin) relative humidity were collected using an automatic weather station (Campbell Scientific Inc. model CR1000), installed inside the greenhouse. There were variations from 25.0 to 28.0ºC for Tmin; 26.0 to 29.0°C for Tmed; 27.0 to 30.0 for Tmax; 44 to 68% for URmin; 48 to 72% for URmed; 51 to 76% for URmax.

Experimental design

The experimental design was completely randomized, in 2x5 factorial scheme, with 4 replicates (2 cultivars x 5 doses of K), and the experimental unit was represented by one 25 L-pot containing one plant.

The soil was an Argisol, presenting the following chemical characteristics: pH= 7.30, $CE_{(1:2.5)}$= 0.41 dS/m, MO= 3.31%, P, K^+, Na^+ and Ca^{2+}= 1.9, 26.9, 4.7 and 1.1 mg/dm^3, respectively; Mg^{2+}, H+Al, SB, t and CTC= 0.7 1.49, 1.89, 1.89 and 3.37 $cmol_c/dm^3$, V(%)= 56 and PST(%)= 1.21.

Fifteen days before sowing, four liters of aged bovine manure and 20 g of NPK (06-24-12) were added in each pot, and the mixture was then homogenized and irrigated until it reached field capacity.

Treatments

The efficiency of potassium fertigation to reduce salt stress was evaluated in two okra cultivars using five fertigation managements, being one without saline water (0.55 dS/m) and the other treatments using saline water (3.5 dS/m). The experimental design was completely randomized, in 2x5 factorial scheme with 4 replicates. Two okra cultivars (Santa Cruz 47 and Valença) fertigated with five fertigation managements [F1= irrigation with non-saline water and fertigation with a standard dose of potassium (6 g/plant); F2 = irrigation with saline water and fertigation with 6 g/plant of K; F3 = irrigation with saline water and fertigation with 9 g/plant of K; F4 = irrigation with saline water and fertigation with 12 g/plant of K; F5 = irrigation with saline water and fertigation with 15 g/plant of K].

For a lower salinity (F1), we used water from a deep well located in UFERSA campus, showing the following chemical attributes: pH= 7.30; CE= 0.55 dS/m; (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 $mmol_c/L$). To obtain the saline water (3.5 dS/m), we used sodium chloride (NaCl) dissolved in lower salinity water (F1). We adjusted salinity with the aid of a bench conductivity meter.

Five seeds were sown directly onto the soil, in each pot, at 2.0 cm depth. Seedlings were thinned 10 days after emergence (DAE), leaving just the most vigorous one in each pot. The pots were kept in the greenhouse, spacing 1.2 m between lines and 0.5 m between plants. From sowing to thinning, the pots were irrigated twice a day, in the morning and in the afternoon, using a fine-sived watering can.

The authors adopted a drip irrigation system previously evaluated under normal operating conditions. Microtube emitters, also called “spaghetti” tubes were used, internal diameter 1.5 mm, length 0.5 m, with 4.5 L/h average flow, with an emitter installed in each pot.

Two independent systems were installed, one for the lower salinity water (F1) and another for salinity waters (F2, F3, F4 and F5), using a circulating pump Metalcorte/Eberle, self-ventilated, model EBD250076, driven by a single-phase motor, 210 V voltage, 60 Hz frequency, a reservoir (310-L water tank), 16 mm diameter hoses and microtubes.

Six daily irrigations were carried out, at 2-hour intervals, beginning at 7 a.m., for five minutes. During the experiment, each irrigation period became longer according to the plant development (Table 1).

Fertigations were done weekly, according to each treatment. The pace of macronutrient uptake of okra crop used was obtained by Galati *et al*. (2013), with the following nutrient quantities: N= 2.9 g/plant; P= 0.47 g/plant; K= 6 g/plant; Ca= 4.7 g/plant; Mg= 1.2 g/plant; S= 0.44 g/plant. Thus, according to the nutritive solutions, the following potassium quantities provided by potassium chloride fertilizer were applied: F1 and F2 = 6 g/plant, F3 = 9 g/plant, F4 = 12 g/plant and F5 = 15 g/plant.

During the experiment, phytosanitary control was carried out. We used the insecticide with active ingredient Imidacloprid 700 g/kg, belonging to the chemical group Neonicotinoid, IV toxicology, at a dose of 20 g/100 L.

Studied factors

Plants were harvested manually, as the fruits reached a minimum length of 12 cm, identifying the ideal harvest point by breaking the tip of the fruits. The number of harvests differed between cultivars due to the greater earliness of cv. Valença. There were 16 and 6 harvests for the cultivars Valença and Santa Cruz 47, respectively. In each harvest, the obtained fruits were counted and weighed to determine the number of fruits per plant (NFR) and the average fruit weight, in g/fruit (AFW). Fruit yield, in g/plant, was determined from the product of NFR x AFW.

Fruit length was not evaluated because it is a criterion to determine the harvest point, thus, it could interfere in data analysis and interpretation.

Plants were collected at 110 days after sowing and evaluated for the variables: number of leaves (NL), determined by counting all leaves longer than 1.0 cm; leaf area (LA), determined by the leaf disc method (Souza *et al*., 2012); leaf dry mass (LDM), stem dry mass (SDM), fruit dry mass (FDM) and total dry mass (TDM), determined after drying each material in a forced air circulation oven at 65ºC, until reaching constant weight.

The obtained data were subjected to analysis of variance (F test), with further analysis of the factors whenever significant interaction between them was detected. The data of number of leaves were transformed into $\sqrt{x}$. The means obtained in each cultivar were compared by Tukey test ($p<0.05$). The effect of potassium doses was analyzed using polynomial regression. Statistical analyses were performed using the statistical program Sisvar (Ferreira, 2014).

RESULTS AND DISCUSSION

Growth

According to the statistical analysis, there was a significant effect of the interaction between the factors cultivars and fertigation on number of leaves (NL), leaf area (LA), leaf dry mass (LDM) and stem dry mass (SDM) as well as on the fruit dry mass (FDM) and total dry mass (TDM).

The number of leaves (NL) was affected by the salinity of the irrigation water (F2) only for cv. Santa Cruz 47, causing a reduction of 47.11%. However, the salinity effect was altered by potassium fertilization. As for the effect of K doses, there was a significant response only for cv. Santa Cruz 47, in which there was a quadratic response, with the highest NL occurring at 11.7 g/plant of K (6.77 leaves), equivalent to an increase of 29.12%, compared to the NL obtained at the lowest dose of K (5.25 leaves). There was no effect of salinity or K doses on NL in cv. Valença, with an average of 6.52 leaves/plant. There was a significant difference between cultivars only on the lowest dose of K, in which cv. Valença was superior by 66.47% (Figure 1A).

In general, effect of salinity (F2) was observed on the number of leaves, no corroborating the results presented by Nascimento *et al*. (2017), who observed no effect of irrigation with saline water (from 0.26 to 5.0 dS/m) on the number of leaves of okra. Besides the reduction in the production of new leaves, the reduction in leaf area occurred due to the acceleration of leaf senescence, which may cause the death of the leaves (Mahmoud & Mohamed, 2008).

The increase in the number of leaves in response to potassium fertilization may have occurred as an indirect response to the increase in K availability, causing a reduction in Na absorption, whereas excess in the plant tissue causes a reduction in leaf emission.

The use of saline water (F2) caused a reduction in leaf area (LA) in both cultivars, with losses of 44.85 and 9.48% of cultivars Santa Cruz 47 and Valença, respectively. The LA was affected by the doses of K, in a quadratic way for the two cultivars, with higher values occurring in the doses 11.23 and 10.29 g/plant, obtaining maximum values of 13,548.08 and 16,615.32 cm^2/plant of cultivars Santa Cruz 47 and Valença, respectively. Comparing these values with those obtained at the lowest dose of K, there were increases of 74.34% for cv. Santa Cruz 47, and 45.32% for cv. Valença. There was a significant difference between cultivars for the doses 6 and 9 g/plant of K, where cv. Valença was superior by 22.64 and 29.20%, respectively (Figure 1B).

It can also be observed that 12 g/plant of K (F4) was efficient in minimizing the effect of salinity on the LA of cv. Santa Cruz 47. For cv. Valença, the dose of 9 g/plant of K provided superior LA than that obtained with plants irrigated with non-saline water (F1) (Figure 1B).

Table 1. Detailing irrigation management and water applied in the experiment. Mossoró, UFERSA, 2019.

Irrigation management	Crop stages (days after emergence)		
	0-40	41-80	81-120
Time/event (min)	5	7	9
Daily irrigation time (min)	30	42	54
Water applied daily (L/plant)	2.25	3.15	4.05
Development stages (L/plant)	90	126	162

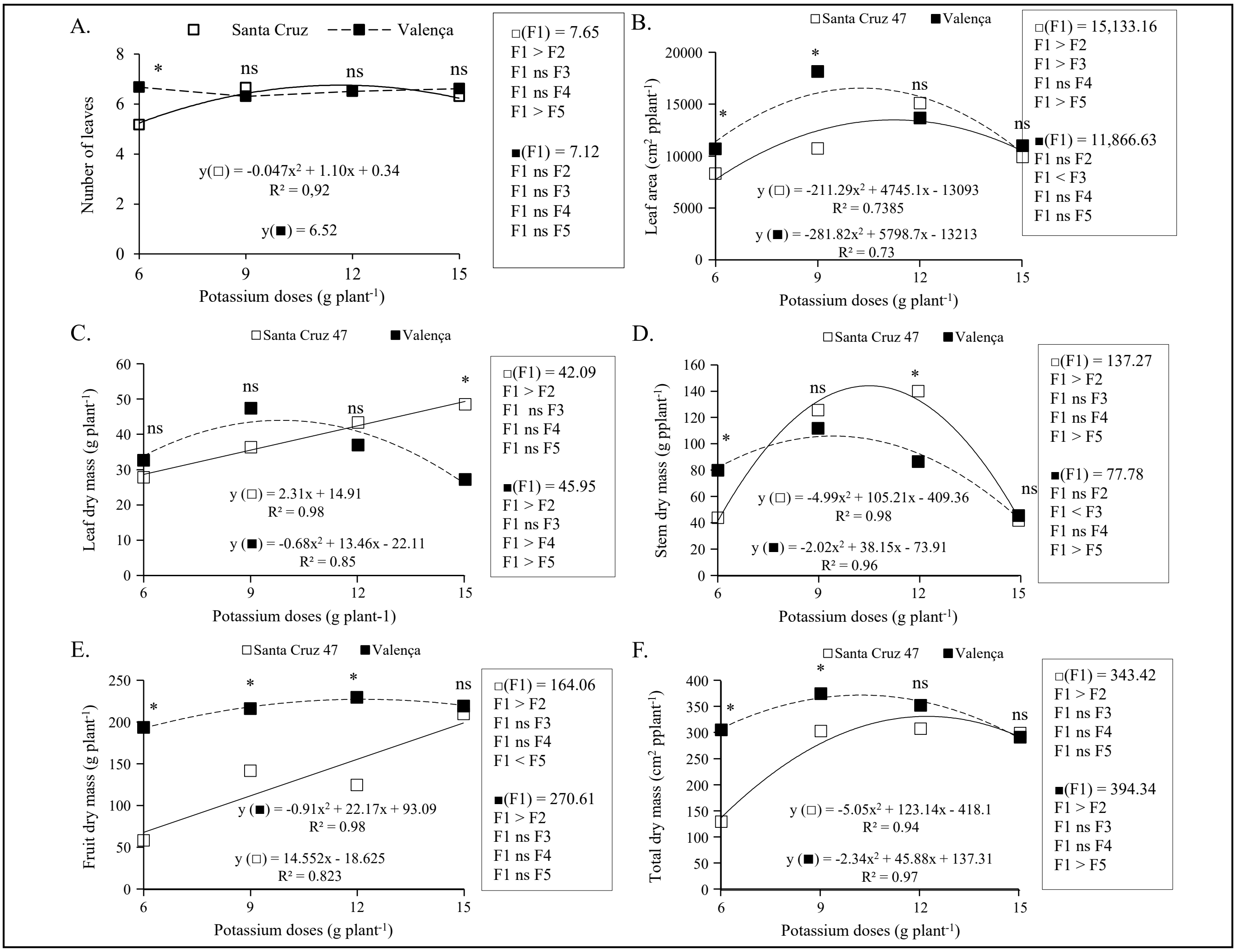

Figure 1. Number of leaves (A#), leaf area (B), leaf dry mass (C), stem dry mass (D), fruit dry mass (E) and total dry mass (F) of okra cultivars fertigated with nutrient solutions salinized and enriched with potassium. F1= irrigation with no-saline water (0.55 dS/m) and fertigation with standard dose of potassium (6 g/plant); F2, F3, F4 and F5= irrigation with saline water (3.5 dS/m) and fertigation applications with increasing doses of potassium (6, 9, 12 and 15 g/plant, respectively). **, * = significant at 0.01 and 0.05 probability levels, respectively; #, ns = significant and non-significant differences between the cultivars for each potassium dose by the F test (0.05). #Transformed data in $\sqrt{x}$. >, < and ns = higher, lower or not significantly different between control treatments and potassium doses, by Dunnett test (0.05). Mossoró, UFERSA, 2019.

Several authors observed reduction in the leaf area of okra subjected to salt stress (Modesto *et al*., 2019; Saheed & Qader, 2020; Motamedi *et al*., 2021), because its leaves are salinity-sensitive organs, and there may be reduction both in the production of new leaves, leaf area size and in the senescence of older leaves, under salt stress conditions.

Considering that the leaf area of a plant is directly related to the number of leaves and the size of the leaf blade, in the present study we found that the effect of treatments using extra potassium was more evident on leaf size than on the production of new leaves, since the number of leaves per plant was not significantly affected by the increase in potassium doses.

Under salt stress conditions, there are morphological and anatomic alterations in the plants, resulting in the loss of transpiration as an alternative to maintain the absorption of water (Taiz *et al*., 2017).

Potassium increases photosynthesis by increasing the leaf area of the plant through controlling the water balance process by regulating the opening and closing of stomata as well as its importance in the cell's division and expansion (Taiz *et al*., 2017). According to Hu *et al*. (2020), K regulates mesophyll cell expansion and proliferation to affect leaf area.

The dry mass of leaves (LDM) was affected by the salinity of the irrigation water (F2) for both okra cultivars, with reductions of 33.57 and 2.73%, on cultivars Santa Cruz and Valença, respectively, compared to the LDM obtained at the lowest salinity (F1). Cv. Santa Cruz 47, increased linearly with increasing K dose, so that the highest LDM (49.56 g/plant) was obtained with 15 g/plant of K, equivalent to an increase of 72.26%, compared to LDM obtained at the lowest dose of K (28.77 g/plant). Cv. Valença showed a quadratic response and the highest LDM (44.49 g/plant) was obtained with 9.89 g/plant of

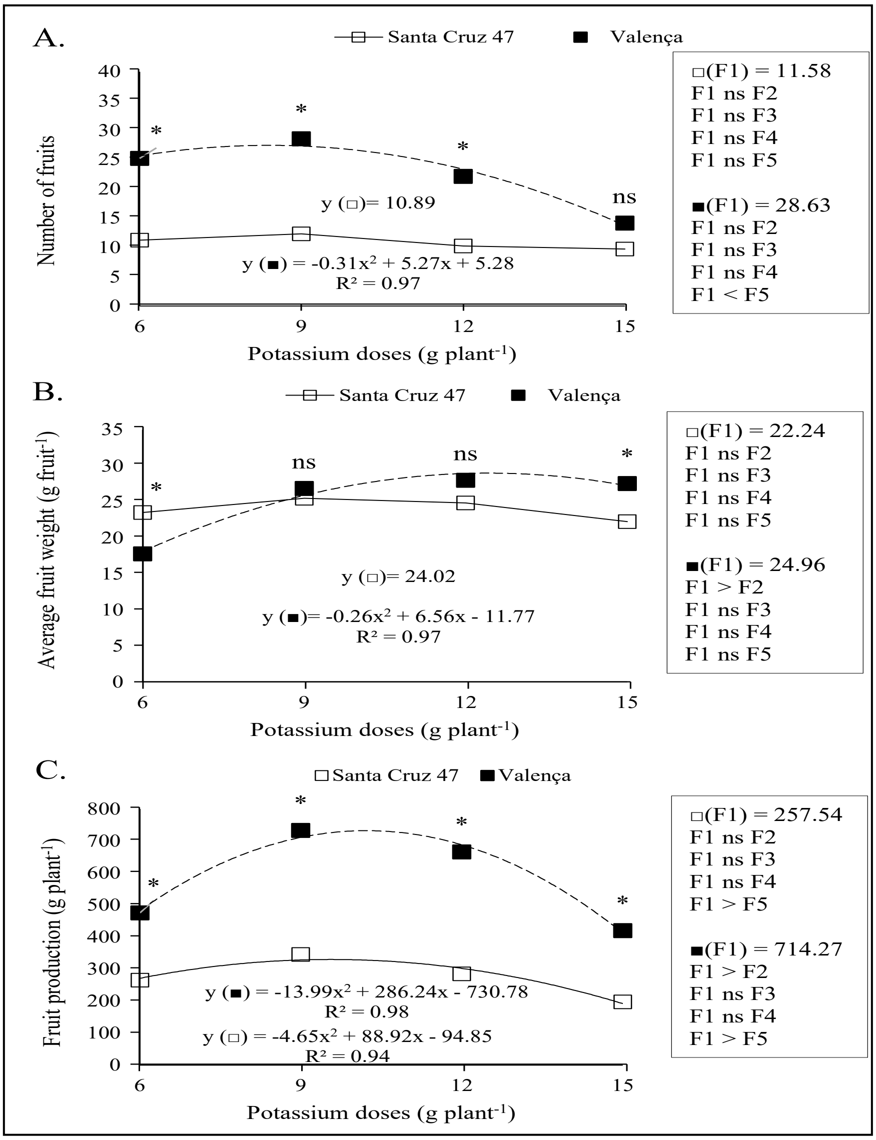

Figure 2. Mean values of number of fruits, average fruit weight and fruit production of okra cultivars fertigated with nutrient solutions salinized and enriched with potassium. F1= irrigation with no-saline water (0.55 dS/m) and fertigation with standard dose of potassium (6 g/plant); F2, F3, F4 and F5= irrigation with saline water (3.5 dS/m) and fertigation applications with increasing doses of potassium (6, 9, 12 and 15 g/plant, respectively). **, * = significant at 0.01 and 0.05 probability levels, respectively; #, ns = significant and non-significant differences between the cultivars for each potassium dose by the F test (0.05). >, < and ns = higher, lower or not significantly different between control treatments and potassium doses, by Dunnett test (0.05). Mossoró, UFERSA, 2019.

K. This value corresponds to an increase of 30.22%, compared to the LDM of this cultivar obtained at the lowest dose of K (34.17 g/plant). Furthermore, it appears that there was a significant difference between cultivars only in the highest dose of K, in which cv. Santa Cruz 47 was 84.99% higher (Figure 1C).

Analyzing the effect of fertigation strategies, it appears that, for cv. Santa Cruz 47, K doses of 9 g/plant was efficient to reduce the salinity effect. For cv. Valença, 9 g/plant of K was effective in cancelling the effect of salt stress on the leaf area (Figure 1C).

The salinity of the irrigation water negatively affected stem dry mass (SDM) only on cv. Santa Cruz 47, showing a reduction of 67.76%, comparing the F1 and F2 fertigations. Analyzing the effect of potassium fertilization, we verified that the increase in K doses affected the SDM in a quadratic way for the two okra cultivars, with higher values occurring with 10.54 and 9.44 g/plant of K, obtaining maximum SDM of 145.21 and 106.21 g/plant, for cultivars Santa Cruz 47 and Valença, respectively. Comparing the cultivars at different doses of K, it appears that cv. Valença was 94.67% higher in SDM for the dose of 6 g/plant, while for the dose of 12 g/plant of K, cv. Santa Cruz 47 was superior by 44.71% (Figure 1D).

The application of K at 9 and 12 g/plant was efficient to inhibit the deleterious effect of salinity on SDM in cv. Santa Cruz 47. For cv. Valença, the dose of 9 g/plant provided SDM superior to that obtained with the use of non-saline water. For both cultivars, the use of the highest dose of K reduced the SDM (Figure 1D).

The use of saline water caused a reduction of fruits' dry mass (FDM) on both cultivars, with losses of 64.07 and 28.31% of cultivars Santa Cruz 47 and Valença, respectively. Both cultivars have different responses to K doses for fruit dry mass (FDM). Cv. Santa Cruz 47 showed a linear and positive response, with the highest FDM (199.66 g/plant) obtained at 15 g/plant of K, equivalent to an increase of 190.66%, compared to the FDM obtained with lowest K dose (68.68 g/plant). Cv. Valença showed a quadratic response, with the highest value being obtained at 12.18 g/plant of K (228.12 g/plant). We also verified that, except for the highest dose of K, the cultivars differed in the doses, in which cv. Valença was superior, with greater difference in the dose of 65.92 g/plant of K (226.26%) (Figure 1E). Also, in Figure 1E, it can be seen that 9 g/plant of K was efficient to reduce the effect of salt stress on FDM in both cultivars.

For total dry mass (TDM), both cultivars responded quadratically to the increase of K doses. The highest values were obtained with 12.19 and 9.80 g/plant of K, with maximum values of 332.36 and 362.20 g/plant, for cultivars Santa Cruz 47 and Valença, respectively. Comparing these values with those obtained at the lowest dose of K, the greatest gain was observed in cv. Santa Cruz 47 (139.36%). Comparing the cultivars, it appears that cv. Valença was superior in doses of 6 and 9 g/plant of K, being superior in 53.63 and 29.76%, respectively. Furthermore, for both cultivars, K dose of 9 g/plant was efficient to reduce the effect of salt stress on TDM (Figure 1F).

The reduction in the LDM, SDM, FDM and TDM of okra in response to irrigation water salinity is consistent with the results presented by other authors (Sousa *et al*., 2020; Motamedi *et al*., 2021). The salinity reduces growth via water potential in the root zone, specific ion toxicity, and nutritional imbalance rises with the elevated internal concentration of Na^{+} ions. Several authors have suggested that low uptake of Na^{+} and high uptake of K^{+} signifies salinity tolerance in higher plants (Cova *et al*., 2017).

In a study with soybean, Hashi *et al.* (2015) found that the additional application of potassium could be helpful to reduce harmful effect of salinity in relation to dry matter production in different plant parts and as such K played an important role in improving salinity tolerance. The results presented in this study show that adequate potassium nutrition is essential to reduce the salt stress effect. However, it must be viewed with reservations. Excess K can reduce the efficiency of radiation use in leaves, causing a reduction in biomass production (Pan *et al*., 2019)

Cv. Valença had higher tolerance to salinity in terms of biomass accumulation, evidencing the variability of okra genotypes regarding response to stress (Azeem *et al*., 2017). Cv. Santa Cruz 47 was more responsive to the extra addition of K, which is consistent with the results reported by Santos *et al*. (2019), who also evaluated cv. Santa Cruz 47 and demonstrated that okra is very demanding with respect to this nutrient.

Fruit yield

According to the analysis of variance, there was a significant effect of the interaction between the cultivars and fertigation on the number of fruits per plants (NFR), average fruit weight (AFW) and production (PROD) ($p<0.01$).

The number of fruits per plant (NFR) was not affected using saline water (F2) for any of the cultivars. There was no effect of potassium doses on the number of fruits per plant (Figure 2A) and average fruit weight (AFW) for cv. Santa Cruz 47 (Figure 2B), obtaining mean values of 10.89 fruits/plant and 24.02 g/fruit, respectively. For cv. Valença, there was a quadratic response for both variables, with higher values occurring in the doses 8.5 and 12.06 g/plant, with maximum values of 27.7 fruits per plant, and 24.02 g/fruit. Comparing these values with those obtained at the lowest dose of K, there were increases of 7.5% for the NFR and 62.4% for the AFW.

Cv. Valença was superior to cv. Santa Cruz 47 regarding NFR for most K doses (Figure 2A), with the greatest difference occurring in the 15 g/plant dose (57.8%). As there was no effect of salinity on the number of fruits, there was no effect of the fertigation strategies to relieve salt stress. However, the highest dose of K caused a reduction in NFR (Figure 2A).

For AFW, cv. Valença was 32.3% higher at 6 g/plant of K, but 19.2% lower at 15 g/plant. AFW was affected by salinity only on cv. Valença, with a loss of 28.81% fruit mass, compared to the doses that provided the highest values. However, the application of K at 9 g/plant was efficient in inhibiting the effect of salt stress (Figure 2B).

Several authors observed reduction in the number of okra fruits in response to increased salinity of irrigation water (Abbas *et al*., 2018; Modesto *et al*., 2019; Sousa *et al*., 2020; Motamedi *et al*., 2021), probably due to the increase in the rate of flower and fruit abortion. According to Soares *et al*. (2020), potassium doses cause increases in the size of okra fruits, minimizing the harmful effects of the salinity of the irrigation water.

Cv. Valença was superior to cv. Santa Cruz 47 with respect to the number of fruits/plant. This occurred because cv. Valença is earlier (Feltrin®), which promotes greater number of harvests along the experimental period, as occurred in this experiment.

In a study conducted with okra in hydroponic cultivation, Modesto *et al*. (2019) also found no effect of salinity on fruit fresh weight. The absence of response to salinity in this variable can be attributed to the fact that fruit size was the criterion for harvesting.

The use of saline water (F2) affected fruit yield only in cv. Valença, causing a reduction of 33.45%, compared to the yield obtained in the absence of salinity (F1). Analyzing the effect of K doses on plants irrigated with saline water, the yield was affected in a quadratic way on both cultivars, with higher values occurring in the doses of 9.6 and 10.2 g/plant, obtaining maximum yield of 271.27 and 733.36 g/plant, for cultivars Santa Cruz 47 and Valença, respectively. Comparing these values with those obtained at the lowest dose of K, the greatest gain occurred on cv. Valença (51.93%), while cv. Santa Cruz registered an increase of 21.74%. Furthermore, cv. Valença was superior in all doses of K, with the greatest difference occurring on the dose of 12 g/plant of K (57.18%).

As there was no effect of salinity on the yield of cv. Santa Cruz 47 it was not possible to analyze the efficiency of K doses to reduce salt stress. On the other hand, 9 g/plant of K was sufficient to provide high yield. However, it appears that, for both cultivars, the highest dose of K (15 g/plant) reduced fruit yield, compared to the doses that provided the highest yields (Figure 2C).

There are several studies in the literature reporting reduction in okra yield due to salt stress (Abbas *et al*., 2018; Modesto *et al*., 2019; Soares *et al*., 2020; Sousa *et al*., 2020; Motamedi *et al*., 2021). The results presented in this study corroborate those presented by Modesto *et al*. (2019), who obtained similar results, working with okra in salinity threshold of 5.43 dS/m produced in hydroponic cultivation. Ifediora *et al*. (2014), evaluating the effect of NaCl (0-200 mM) in the nutrient solution, found that fresh fruit weight was affected only by electrical conductivity above 5,0 dS/m (50 mM).

Both okra cultivars responded significantly to K doses, showing the importance of this nutrient on crop yield (Silva *et al*., 2021), especially when the plants are subjected to salt stress (Saheed & Qader, 2020; Soares *et al*., 2020). For Soares *et al*. (2020), potassium doses cause increments in the average diameter of okra fruits, minimizing the deleterious effects of irrigation water salinity. According to Hu *et al*. (2020), adequate K nutrition increases the leaf area and photosynthetic rate simultaneously, thus enhancing crop yield.

Thus, the authors concluded that extra addition of potassium influence the growth and yield characteristics of okra irrigated with saline water. The highest yields of fruits occurred at 9.56 and 10.23 g/plant of K, being 330.24 and 733.36 g/plant, the productivity of cultivars Santa Cruz 47 and Valença, respectively.

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