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Nitrogen as a mitigator of salt stress in yellow passion fruit seedlings

O nitrogênio como mitigador do estresse salino nas mudas de maracujazeiro amarelo

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Abstract

The poor chemical quality of water, especially in arid and semiarid regions, almost always precludes the practice of irrigated agriculture, thus demanding the adoption of techniques that mitigate the deleterious effects of excess salt on soil and plants. The aim of this research was to evaluate the effectiveness of nitrogen fertilization in mitigating the negative effects of excess salt in irrigation water on the growth of yellow passion fruit seedlings grown in a greenhouse in plastic tubes containing 0.65 dm^3 of substrate. The treatments were organized in randomized blocks, in accordance with a 5 × 3 factorial scheme – five electrical conductivities of irrigation water (0.3, 1.0, 2.0, 3.0, and 4.0 dS m^{-1}) combined with three levels of nitrogen fertilizer (no nitrogen fertilization and 150 mg dm^{-3} of N derived from either ammonium sulfate or urea). Evaluations were performed 80 days after sowing and consisted of measuring the seedling height, stem diameter, number of leaves, leaf area, leaf nitrogen content, leaf concentration of chlorophyll *a* and *b* and total chlorophyll, specific leaf area, leaf area ratio, and Dickson quality index. An increase in the electrical conductivity of irrigation water hindered the production of yellow passion fruit seedlings. Nitrogen fertilization, with urea or ammonium sulfate, mitigated the effects of irrigation water salinity and favored the growth and quality of yellow passion fruit seedlings. Yellow passion fruit seedlings with a minimum quality standard (DQI) can be produced with irrigation water with salinity of 1.8 dS m^{-1}, which means they can be considered as moderately sensitive. The higher quality provided by nitrogen to the yellow passion fruit seedlings made them more tolerant to salinity, allowing the use of water with salinity of 2.1 and 2.5 dS m^{-1} under fertilization with ammonium sulfate and urea, respectively.

Key words: Nitrogen sources. *Passiflora edulis* Sims. Water salinity.

Resumo

A baixa qualidade química da água, especialmente nas regiões áridas e semiáridas, quase sempre impede a prática da agricultura irrigada, exigindo a adoção de técnicas que atenuem os efeitos deletérios do excesso de sal no solo e nas plantas. O objetivo desta pesquisa foi avaliar a eficiência da adubação nitrogenada na mitigação dos efeitos negativos do excesso de sal na água de irrigação, sobre o crescimento de mudas de maracujazeiro amarelo, produzidas em tubetes contendo 0,65 dm^3 de

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substrato em uma estufa telada. Os tratamentos, distribuídos em blocos ao acaso, obedeceu um esquema fatorial de 5 × 3 – cinco condutividade elétrica da água de irrigação (0,3; 1,0; 2,0; 3,0; e 4,0 dS m^{-1}) combinadas níveis de adubação nitrogenada (sem adubação nitrogenada e com aplicação 150 mg dm^{-3} de N utilizando sulfato de amônio ou ureia). As avaliações foram realizadas aos 80 dias após a semeadura e consistiram em medir a altura da muda, o diâmetro do caule, o número de folhas, a área foliar, o teor foliar de nitrogênio, os índices foliares de clorofila "a" e "b" e clorofila total, a área foliar específica, a razão de área foliar e o Índice de qualidade de Dickson. O aumento na condutividade elétrica da água de irrigação reduziu a qualidade das mudas de maracujazeiro amarelo. A adubação nitrogenada, com ureia ou sulfato de amônio, atenuou os efeitos da salinidade da água de irrigação e aumentou o crescimento e a qualidade das mudas de maracujazeiro amarelo. As mudas de maracujazeiro amarelo com padrão de qualidade mínima (IQD) podem ser produzidas com água de irrigação de 1,8 dS m^{-1}, considerando-a moderadamente sensível. A maior qualidade proporcionada pelo nitrogênio às mudas de maracujazeiro amarelo as tornaram mais tolerantes a salinidade, possibilitando utilizar água com 2,1 e 2,5 dS m^{-1} sob adubação com sulfato de amônio e ureia, respectivamente.

Palavras-chave: Água salina. Fontes nitrogenadas. *Passiflora edulis* Sims.

Introduction

The chemical quality of water available for irrigated agriculture is a decisive factor in plantation establishment because of the risks that excess dissolved salts can pose to soils and plants (AYERS; WESTCOT, 1994). The major limitations for plants under a salinized environment are a reduction in water absorption, toxicity, and nutritional imbalance (MARSCHNER, 2012; TAIZ et al., 2017). Excess salts alter the hormonal balance and increase the production of reactive oxygen species, affecting cell expansion and division and vegetative and productive growth, and may lead to plant senescence (PRISCO et al., 2016; TAIZ et al., 2017). These effects lower seedling quality and generally reduce crop yield.

Considering that nutritionally balanced plants are more tolerant of salinity than those subjected to nutrient deficiency, the adoption of appropriate organic and mineral fertilization management becomes necessary to enhance plant adaptation to salts. The mitigating effect of nitrogen on salinity can be related to, among other factors, its participation in the amino acid proline; and its action as an osmoregulator that also contributes to the redox state of cells under stress (VERBRUGGEN; HERMANS, 2008). However, the intensity of the nitrogen effect is associated with the nutrient source used (DEBOUBA et al., 2006; HESSINI et al., 2013; OLIVEIRA et al., 2017) and with the concentration of dissolved salts in the irrigation water or in the soil.

Nitrogen can be absorbed as a cation (NH_4^+) or anion (NO_3^-), nitrate predominating (TAIZ et al., 2017). However, of the metabolic processes performed by plants, nitrogen assimilation is among those demanding more energy (MARSCHNER, 2012; MASCLAUX-DAUBRESSE et al., 2010), which varies depending on the source. For example, ammonium sulfate requires less energy consumption for nitrogen (NH_4^+) assimilation, which can lead to advantages in situations of stress (MARSCHNER, 2012).

Passion fruit (*Passiflora edulis*) is an important crop for Brazil (POMMER; BARBOSA, 2009) which is the world's largest producer of fresh fruits (FAO, 2011), particularly in the northeast region. The yellow passion fruit is a crop that is considered to be sensitive to salinity; that is, it does not tolerate an electrical conductivity of saturated soil extract higher than 1.3 dS m^{-1} (AYERS; WESTCOT, 1994). Water with an electrical conductivity greater than 1.0 dS m^{-1} is unsuitable for the irrigation of yellow passion fruit seedlings (CAVALCANTE et al., 2009).

Thus, this study's objective was to evaluate the efficiency of nitrogen sources in mitigating the negative effects of excess salts in the water used to irrigate yellow passion fruit during seedling development.

Materials and Methods

Treatments and experimental design

The experiment was conducted under greenhouse conditions (6° 57’ 58.2” S and 35° 42’ 56.6” W, altitude 518 m) in the city of Areia, Paraíba State, Brazil. The treatments were arranged in a 5 × 3 factorial scheme, corresponding to five electrical conductivities of the irrigation water (0.3, 1.0, 2.0, 3.0, and 4.0 dS m^{-1}) and three levels of nitrogen fertilizer (no nitrogen fertilization and nitrogen applied as urea or ammonium sulfate). The nitrogen was applied by way of the irrigation water at a dose of 150 mg dm^{-3} divided into three applications of 50 mg dm^{-3}: 48 h before sowing and 42 and 57 days after sowing.

The treatments were distributed in a randomized block design with four replicates. The experimental unit consisted of three seedlings, each grown individually in a 0.65 dm^3 tube.

Substrate collection and characterization

The material used as substrate was collected from the 0 to 20 cm deep layer of an Oxisol Ustox. After collection, the material was ground, homogenized, air- and shade-dried, and then passed through a 2 mm sieve. The substrate was then characterized regarding its chemical (fertility and salinity) and physical properties (TEIXEIRA et al., 2017).

The following chemical measurements relating to fertility were performed: the hydrogen potential (pH) in a sample of fine, air-dried soil diluted with 2.5 times its mass of distilled water; calcium, magnesium, and aluminum employing 1 mol L^{-1} KCl as extractor, with Ca^{2+} and Mg^{2+} titrated using EDTA (disodium salt), and Al^{3+} titrated using 1 mol L^{-1} NaOH; potassium, sodium, and phosphorous using Mehlich 1 solution (0.0125 mol L^{-1} H_2SO_4 + 0.05 mol L^{-1} HCl) as extractor, with K^+ and Na^+ determined in a flame photometer, and P determined in a photocolorimeter; exchangeable acidity (H^+ + Al^{3+}) by the 1 mol L^{-1} KCl method and titrated with 0.0606 mol L^{-1} NaOH using phenolphthalein as an indicator; and organic carbon with a 0.0667 mol L^{-1} solution of potassium dichromate titrated with 0.1 mol L^{-1} ammonium ferrous sulfate.

The following chemical measurements relating to salinity were conducted on a saturated extract of substrate removed with a vacuum pump: hydrogen potential (pH); electrical conductivity (EC); calcium and magnesium in an atomic absorption spectrophotometer; sodium and potassium in a flame photometer; carbonate and bicarbonate by acidimetry with 0.0125 mol L^{-1} H_2SO_4, using phenolphthalein as indicator for CO_3^{2-} and methyl red for HCO_3^-; and chlorides by volumetric determination with 0.05 mol L^{-1} $AgNO_3$ in the presence of $K_2Cr_2O_4$ as indicator.

The physical analyses evaluated the following features: the texture, by analyzing the grain size distribution of the mineral fractions using the hydrometer method and the chemical dispersant 1 mol L^{-1} NaOH; the soil density, by the volumetric flask method; and the particle density, by the volume displaced by a known mass of soil in a volumetric container. The total porosity (Equation 1) was calculated as the difference between the moisture and the quotient of the soil density divided by the particle density. For the natural moisture, a pressure cooker was used at pressures of 0.033 MPa (field capacity) and 1.5 MPa (permanent wilting point). The available water was calculated as the difference between the water at field capacity and the water at the permanent wilting point. The results of the chemical and physical analyses are shown in Table 1.

$$Total\ porosity = \left(1 - \frac{Soil\ density\ (m^3\ m^{-3})}{Particle\ density\ (m^3 m^{-3})}\right) \times 100 \quad (1)$$

Table 1. Chemical (fertility and salinity) and physical attributes of the material from the 0- to 20-cm layer of the Oxisol Ustox used as substrate.

Chemical attributes*				Physical attributes**	
Fertility		Salinity			
pH (1:2.5)	4.90	pH	6.41	Sand (g kg^{-1})	552
EC (dS m^{-1})	0.05	EC (dS m^{-1})	1.05	Silt (g kg^{-1})	101
Ca^{2+} ($cmol_c$ kg^{-1})	1.58	Ca^{2+} ($mmol_c$ L^{-1})	3.58	Clay (g kg^{-1})	347
Mg^{2+} ($cmol_c$ kg^{-1})	2.36	Mg^{2+} ($mmol_c$ L^{-1})	3.54	Ds (kg dm^{-3})	1.11
K^+ ($cmol_c$ kg^{-1})	0.03	K^+ ($mmol_c$ L^{-1})	1.13	Dp (kg dm^{-3})	2.67
Na^+ ($cmol_c$ kg^{-1})	0.09	Na^+ ($mmol_c$ L^{-1})	2.18	Porosity (m^3 m^{-3})	0.59
SB ($cmol_c$ kg^{-1})	4.06	SO_4^{2-} ($mmol_c$ L^{-1})	0.72	Natural moisture (%)	
Al^{3+} ($cmol_c$ kg^{-1})	0.80	CO_3^{2-} ($mmol_c$ L^{-1})	0.00	0.033 MPa	23.00
$H^+ + Al^{3+}$ ($cmol_c$ kg^{-1})	7.83	HCO_3^- ($mmol_c$ L^{-1})	0.50	1.5 MPa	14.65
CEC ($cmol_c$ kg^{-1})	11.89	Cl^- ($mmol_c$ L^{-1})	9.17	Available water	8.35
V (%)	34.1	SAR ($mmol_c$ $L^{-1})^{1/2}$	1.16	Textural class	Loam
P (mg dm^{-3})	13.5	ESP (%)	0.75		Clay
SOM (g kg^{-1})	17.0	---	---		Sandy

*pH: hydrogen potential; EC: electrical conductivity; SB: sum of bases; CEC: cation exchange capacity; V: base saturation; SOM: soil organic matter; OM: organic carbon; SAR: sodium adsorption ratio; ESP: exchangeable sodium percentage.
**Ds: density of soil; Dp: density of particles.

Experiment

Fruit of the local yellow passion fruit cultivar known as "*Guinezinho*" was obtained during the 2013 harvest from a commercial orchard in Nova Floresta municipality, Paraíba State, Brazil. After collecting the fruit, the pulp was manually removed; the seeds were extracted, then washed with deionized water, and dried in a well-ventilated and shaded location.

Basic fertilization of the substrate was conducted by applying 1.5 g dm^{-3} of simple superphosphate and 0.25 g dm^{-3} of potassium chloride, corresponding to doses of 300 mg dm^{-3} of P_2O_5 and 150 mg dm^{-3} of K_2O, respectively (NOVAIS et al., 1991). Four seeds were sown directly into each tube at a depth of 2 cm. Thinning was conducted after the seedlings emerged (35 days after sowing), and only the most vigorous seedling in each tube was retained.

Irrigation was performed daily, observing the surface moisture and preventing drainage. The salt levels were obtained from dilution in the water supplied of sodium, calcium, and magnesium ions, provided in a 7:2:1 ratio, as sodium chloride (NaCl), calcium chloride ($CaCl_2{\cdot}H_2O$), and magnesium chloride ($MgCl_2{\cdot}6H_2O$), respectively.

Evaluations

Evaluations were performed 80 days after sowing (DAS), by which time the plants were ready for transplantation to the field. The following variables were evaluated: height, measured with a millimeter ruler from the root collar to the apical meristem of the plant; stem diameter, measured at the root collar with a digital caliper; the number of leaves; leaf area, measured through photographs and estimated with the assistance of SigmaScan® Pro 5.0 Demo software; leaf nitrogen content, determined by titration with 0.025 mol L^{-1} H_2SO_4 after digesting the ground leaf in 0.025 mol L^{-1} H_2SO_4 and adding 10 mol L^{-1} NaOH; leaf levels of chlorophyll *a* and *b* and total chlorophyll, determined using a Falker ClorofiLOG® CFL 1030; specific leaf area (SLA, Equation 2), which is the ratio between the leaf area and leaf dry mass (HUNT, 1990b); leaf area ratio (LAR, Equation 3), which is the ratio between the leaf area and total dry mass (HUNT, 1990b); and the Dickson quality index (DQI, Equation 4), which is the ratio between the total dry biomass and the sum of the quotients of both the height divided by the stem diameter and the shoot dry biomass divided by the root dry biomass (DICKSON et al., 1960).

$$SLA = \frac{Leaf\ area\ (cm^2)}{Leaf\ dry\ mass\ (g)} \tag{2}$$

$$LAR = \frac{Leaf\ area\ (cm^2)}{Total\ dry\ mass\ (g)} \tag{3}$$

$$DQI = \frac{Total\ dry\ mass\ (g)}{\frac{Height\ (cm)}{Stem\ diameter\ (mm)} + \frac{Dry\ masss\ of\ the\ shoot\ (g)}{Dry\ mass\ of\ the\ roots\ (g)}} \tag{4}$$

Statistical analysis

The data were subjected to analysis of variance to assess the effects of the main factors and their interactions using the F-test ($p \leq 0.05$). The differences in response to the nitrogen levels were assessed using Tukey's test. The effects attributable to the electrical conductivity of the irrigation water were fitted by regression analysis, using the F-test ($p \leq 0.05$) with SAS® University Edition software using PROC GLM to determine the significance of the coefficients.

Results

Growth

An increase in the electrical conductivity of the irrigation water from 0.3 to 4.0 dS m^{-1} reduced the seedling height from 9.8 to 4.1 cm (58%) when the seedlings were unfertilized, from 19.2 to 3.7 cm (81%) when they were fertilized with urea, and from 17.9 to 4.6 cm (74%) when they were fertilized with ammonium sulfate (Figure 1A). For the stem diameter, the reductions caused by the increase in electrical conductivity of the water from 0.3 to 4.0 dS m^{-1} were 26% (2.9 to 2.1 mm), 50% (3.7 to 1.9 mm), and 39% (3.6 to 2.2 mm) when the seedlings were unfertilized, fertilized with urea, and fertilized with ammonium sulfate, respectively (Figure 1B).

The number of leaves and leaf area of the yellow passion fruit seedlings decreased with an increase in the electrical conductivity of the water. When increasing the electrical conductivity of the irrigation water from 0.3 to 4.0 dS m^{-1}, the average decrease in the number of leaves was 1.3 (19%), 5.0 (49%), and 3.8 (40%) for unfertilized seedlings, those fertilized with urea, and those fertilized with ammonium sulfate, respectively (Figure 2A). For the salt levels of 0.3 and 4.0 dS m^{-1}, the respective leaf areas were 459.2 and 48.8 cm^2 (−89%) for the yellow passion fruit seedlings fertilized with urea, and 393.1 and 59.0 cm^2 (−85%) for those fertilized with ammonium sulfate (Figure 2B). In the absence of nitrogen fertilizer, the average leaf area of the seedlings was 99.6 cm^2.

Figure 1. Height (A) and stem diameter (B) of yellow passion fruit seedlings under the effects of nitrogen and the electrical conductivity of the irrigation water. Results are expressed as means ± standard errors. $^{**}p \leq 0.01$ and $^{*}p \leq 0.05$ by the F-test.

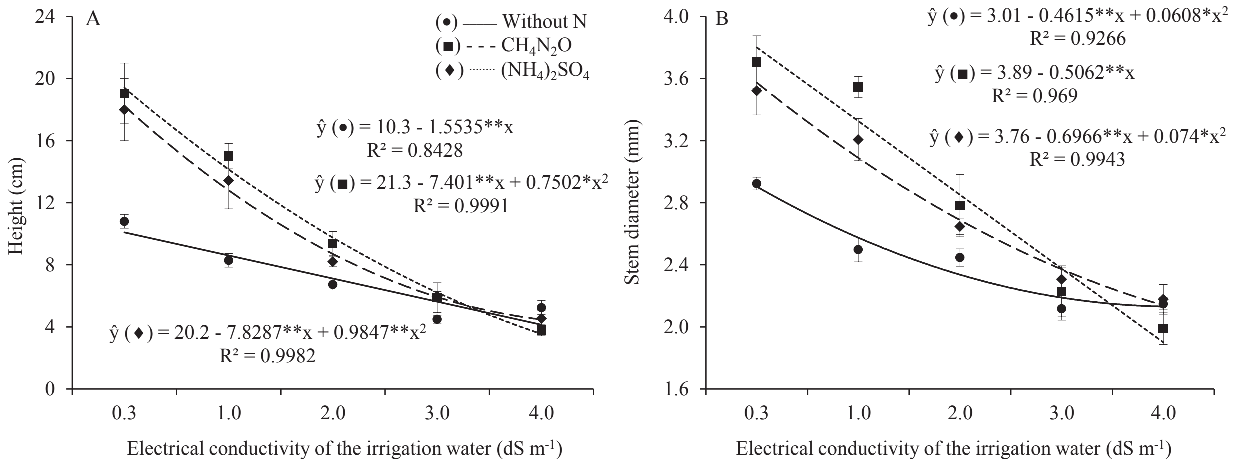
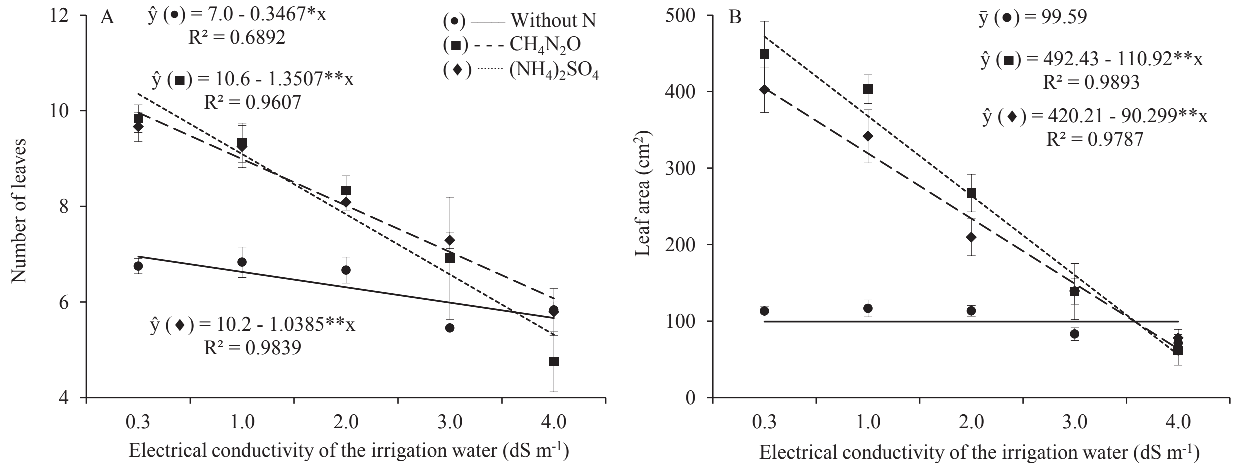


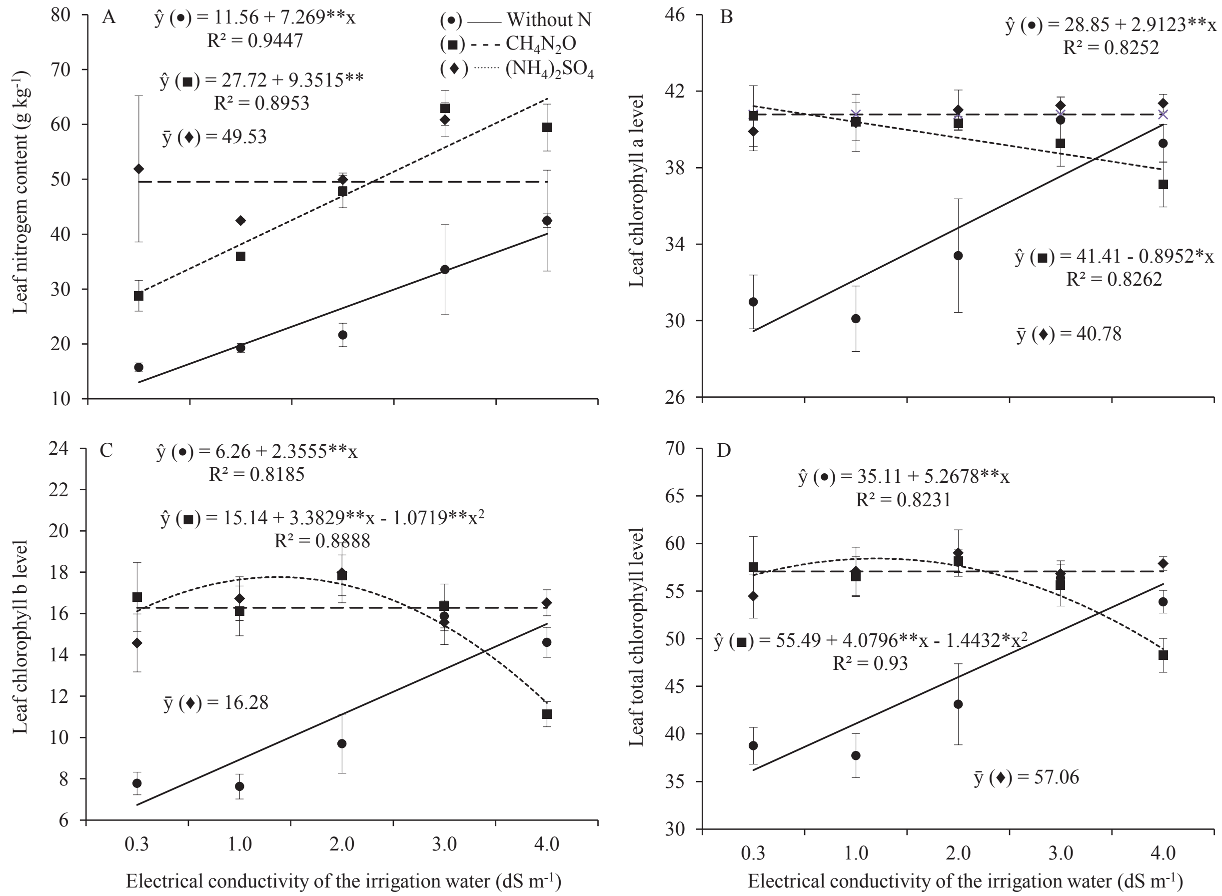
Figure 2. Number of leaves (A) and leaf area (B) of yellow passion fruit seedlings under the effects of nitrogen and the electrical conductivity of the irrigation water. Results are expressed as means ± standard errors. $^{**}p \leq 0.01$ and $^{*}p \leq 0.05$ by the F-test.



Leaf nitrogen concentration and leaf chlorophyll indices

An increase in the electrical conductivity of the irrigation water from 0.3 to 4.0 dS m^{-1} led to increases in the leaf nitrogen content of 196% for unfertilized seedlings and 113% for those fertilized with urea (Figure 3A). A similar, but less pronounced, trend was also recorded for the leaf chlorophyll content; when comparing plants irrigated in the absence of nitrogen fertilizer with water having the lowest and highest salinity, the increases were 36% for chlorophyll *a* (Figure 3B), 125% for chlorophyll *b* (Figure 3C), and 53% for total chlorophyll (Figure 3D). With the application of urea, the use of water with conductivity up to 1.6 and 1.4 dS m^{-1} was estimated to result in gains in the leaf levels of chlorophyll *b* (Figure 3C) and total chlorophyll (Figure 3D), respectively. When raising the electrical conductivity of the irrigation water from 0.3 to 4.0 dS m^{-1} and fertilizing with ammonium sulfate, the leaf levels of chlorophyll *a*, chlorophyll *b*, and total chlorophyll decreased by 9%, 28%, and 14%, respectively, resulting in mean values at the highest salinity level that were lower than those obtained for the unfertilized plants.

Figure 3. Leaf nitrogen content (A) and leaf index of chlorophyll *a* (B), chlorophyll *b* (C), and total chlorophyll (D) in yellow passion fruit seedlings under the effects of nitrogen and the electrical conductivity of the irrigation water. Results are expressed as means ± standard errors. **p ≤ 0.01 and *p ≤ 0.05.



Morphophysiological indices

The application of urea increased the SLA by 16% compared with the SLA obtained without nitrogen application (Table 2). For the LAR, the application of urea and ammonium sulfate led to increases of 38% and 29%, respectively, compared with the LAR of seedlings receiving no nitrogen fertilization. There were no verified effects of the electrical conductivity of the irrigation water for both variables.

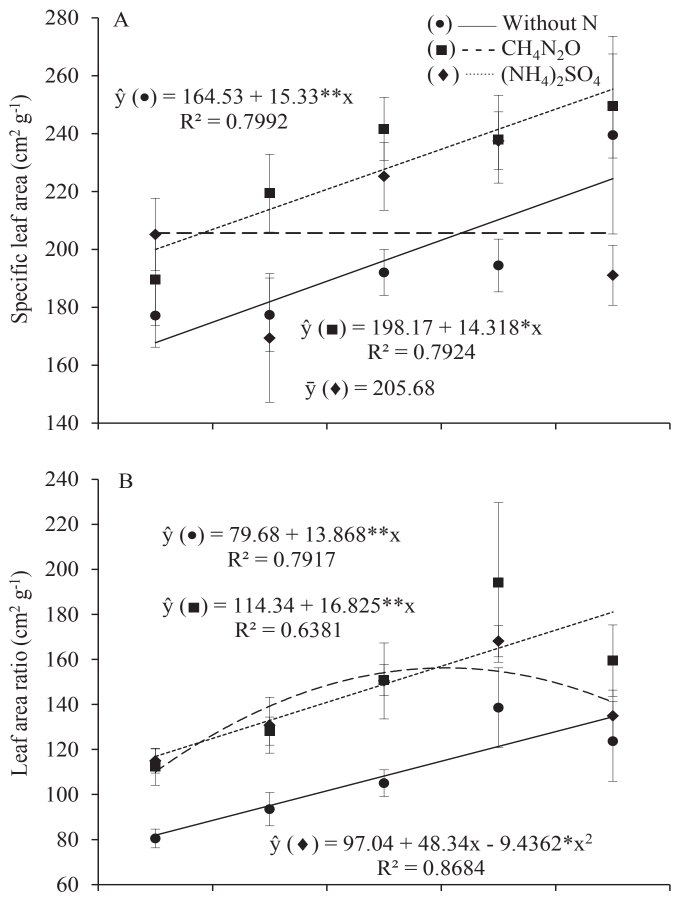
Table 2. Specific leaf area and leaf area ratio in yellow passion fruit seedlings under the effects of nitrogen.

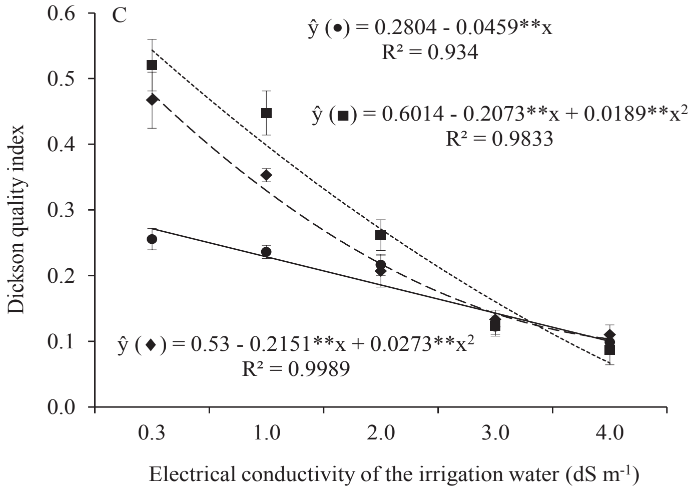
Variables[1]	Nitrogen fertilizer			CV^3 (%)
	Absent	Urea	Ammonium sulfate	
SLA ($cm^2\ g^{-1}$)	196.1 b[2]	227.7 a	205.7 ab	15.3
LAR ($cm^2\ g^{-1}$)	108.2 b	149.0 a	139.8 a	20.8

[1] SLA: specific leaf area; LAR: leaf area ratio;
[2] Means with the same letter in a row do not differ by Tukey's test ($p \leq 0.05$);
[3] CV: coefficient of variation.

An increase in the electrical conductivity of the irrigation water from 0.3 to 4.0 dS m^{-1} resulted in increases in the SLA of 34% and 26% for the unfertilized and urea-fertilized yellow passion fruit seedlings, respectively (Figure 4A). For the LAR, the increases were 61%, 52%, and 26% in the seedlings without nitrogen fertilization, in those fertilized with urea, and in those fertilized with ammonium sulfate, respectively (Figure 4B). However, under fertilization with ammonium sulfate, the steepest increases were obtained with water conductivity up to 2.6 dS m^{-1}.

Figure 4. Specific leaf area (A), leaf area ratio (B), and Dickson quality index (C) of yellow passion fruit seedlings under the effects of nitrogen and the electrical conductivity of the irrigation water. Results are expressed as means ± standard errors. **p ≤ 0.01 and *p ≤ 0.05.





Regarding the DQI, when raising the electrical conductivity of the irrigation water from 0.3 to 4.0 dS m^{-1}, the following reductions were observed: from 0.27 to 0.10 in the unfertilized seedlings, from 0.54 to 0.07 in those fertilized with urea, and from 0.47 to 0.11 in those fertilized with ammonium sulfate, which correspond to losses of 63%, 87%, and 77%, respectively (Figure 4C). Under water with salinity of 0.3 dS m^{-1}, nitrogen application increased the quality index of 0.28 (without nitrogen) to 0.47 (with ammonium sulfate) and 0.54 (with urea), increments of 68% and 93%, respectively.

Discussion

Growth and leaf production

An increase in the electrical conductivity of the irrigation water, regardless of nitrogen application, hindered growth (Figure 1) and leaf production (Figure 2) in yellow passion fruit seedlings. The use of urea or ammonium sulfate as the nitrogen fertilizer favored the development of seedlings and mitigated the effects of excess salts. However, the beneficial effects of the nitrogen were reduced as the electrical conductivity of the irrigation water increased and were totally nullified when using water with an electrical conductivity exceeding 2.0 dS m^{-1} for the seedling height, 3.0 dS m^{-1} for stem diameter and leaf area, and 4.0 dS m^{-1} for the number of leaves.

The extent of plant growth reduction is one of the main biometric indicators of the degree of plant tolerance to salinity. Cavalcante et al. (2009) and Nascimento et al. (2017) confirmed the sensitivity of yellow passion fruit seedlings to salinity. When the salt concentration is increased, reducing the osmotic potential of the solution, water absorption is compromised (MARSCHNER, 2012), thus interfering with plant water relationships and negatively affecting the nutrient balance (BHATT et al., 2008; MUNNS; TESTER, 2008).

Nitrogen stimulates the production of leaf biomass and leaf area as well as the photosynthetic rate in passion fruit plants (FREITAS et al., 2012), thus exerting a positive effect on their growth and on the quality of their seedlings. Aref and Shetta (2013) observed that the application of ammonium sulfate or calcium nitrate not only favored the growth of seedlings of *Ziziphus spina-christi* (L.) Willd. and *Acacia tortilis* subsp. *tortilis* (Forssk.) but also conditioned the plants to tolerate salinity. The form of the available nitrogen can also influence plant responses to salinity. Accordingly, Hessini et al. (2013) observed that compared with the use of nitrate, the use of ammonium provided greater biomass, leaf area, and number of leaves in *Spartina alterniflora* that were subjected to a salinity of 500 mM NaCl. Debouba et al. (2006) concluded that tomato seedlings are more sensitive to the specific salinity of NaCl when fertilized with nitrate. Thus, the intensity of the response required for nitrogen fertilization to mitigate the effects of excessive salts on plants depends not only on the type and concentration of the salts but also on the nitrogen source and dose.

Leaf nitrogen concentration and leaf chlorophyll indices

The leaf nitrogen content and the leaf levels of chlorophyll *a* and *b* and total chlorophyll in yellow passion fruit seedlings increased with the application of nitrogen (Figure 3), with larger increases observed when using water with lower electrical conductivity. The chlorophyll levels were closely related to the leaf nitrogen content, as shown by the positive and significant Pearson correlation (ρ) between the leaf nitrogen content and the leaf levels of chlorophyll *a* ($\rho = 0.56$, $p < 0.0001$), chlorophyll *b* ($\rho = 0.50$, $p = 0.0004$), and total chlorophyll ($\rho = 0.55$, $p < 0.0001$) in yellow passion fruit seedlings.

In tomato plants, Flores et al. (2001) observed that the application of nitrogen increased the chlorophyll content. Evaluating combinations of nitrate and ammonium, these authors found that an increase in the proportion of ammonium increased the chlorophyll content and that this effect was more significant when the concentration of sodium chloride was increased. In general, the leaf nitrogen content and leaf chlorophyll levels in passion fruit seedlings increased with an increase in the electrical conductivity of the irrigation water (Figure 3).

In many cases, anion absorption is reduced by an increase in salinity because of competition with chlorine (MARSCHNER, 2012). However, there are literature reports of increases in the nitrogen (FEIJÃO et al., 2011) and chlorophyll (KAMALULDEEN et al., 2014) content of leaves from salt-stressed plants. Under fertilization with ammonium sulfate, the relationship between leaf chlorophyll levels and salinity did not fit the regression models tested; however, the levels were high and could therefore be related to the lower energy expenditure required to assimilate ammonium (KANT et al., 2007; MARSCHNER, 2012).

Morphophysiological indices

The application of nitrogen, regardless of the source, and an increase in the electrical conductivity of the irrigation water resulted in an increase in both the SLA and LAR in yellow passion fruit seedlings (Table 2, Figure 4). The increase in SLA indirectly resulted in a reduction of the leaf tissues. This pattern is corroborated by Freitas et al. (2012), who observed a reduction in leaf tissues caused by nitrogen. Regarding excess salts, Munns and Tester (2008) reported that salt stress induces adjustments in leaf morphology, chlorophyll content, and biochemical processes. In that sense, Bezerra et al. (2016) also observed a reduction in SLA in genotypes of yellow passion fruit seedlings on increasing the salinity of irrigation water.

The LAR is a morphophysiological component that results from the functional leaf area available for photosynthesis; that is, the leaf area that the plant uses to produce one gram of dry biomass (HUNT, 1990b). In yellow passion fruit seedlings, the salinity of the irrigation water led to a greater LAR (Figure 4B), suggesting a greater allocation of photoassimilates to the production of leaves than to the production of other organs or else a lesser photosynthetic efficiency, resulting in lower biomass accumulation. According to Munns and Tester (2008), salt stress reduces both the opening of stomata and photosynthetic activity, and the reduction of photosynthesis leads to the formation of reactive oxygen species. To protect against reactive oxygen species, plant leaves are induced to undergo morphophysiological changes (MUNNS; TESTER, 2008). Qados (2011) observed a reduction in the osmotic potential of *Vicia faba* (L.) plants subjected to salt stress. Kamaluldeen et al. (2014) observed that an increase in the salinity of either the soil or irrigation water reduces water use efficiency and dry biomass accumulation in tomato and okra plants.

Regarding the DQI, an increase in the electrical conductivity of the irrigation water resulted in lower quality of the yellow passion fruit seedlings (Figure 4C). This index is based on shoot and root biometrics resulting from the physiological relationships of these structures, which are reflected in the plant architecture, with the minimum value for a quality seedling at 0.20 (HUNT, 1990a). Accordingly, Diniz Neto et al. (2014) showed that water salinity reduces the dry matter of *Licania rigida* seedlings and increases the ratio of shoot dry biomass to root dry biomass and/or the ratio of height to stem diameter, which results in a lower DQI. Considering the minimum limit of 0.2 for the quality index (HUNT, 1990a), it was observed that nitrogen potentiated the quality of the seedlings irrigated with non-saline water and raised the salinity tolerance limit (Figure 4). Without nitrogen or with the application of ammonium sulfate or urea under water with salinity of 0.3 dS m^{-1}, the indices were 0.27, 0.47 and 0.54, respectively. As for the limits of tolerance, the absence of nitrogen fertilization or application of ammonium sulfate or urea allowed reductions of 26%, 57% and 63%, tolerating irrigation with water with salinity of 1.8, 2.1, and 2.5 dS m^{-1}, respectively.

Conclusions

Yellow passion fruit seedlings with a minimum quality standard (DQI) can be produced with irrigation water with salinity of 1.8 dS m^{-1}, which means they can be considered as moderately sensitive. Nitrogen fertilization, with urea or ammonium sulfate, favors the growth and quality of yellow passion fruit seedlings. The higher quality provided by nitrogen to the yellow passion fruit seedlings made them more tolerant to salinity, allowing the use of water with salinity of 2.1 and 2.5 dS m^{-1} under fertilization with ammonium sulfate and urea, respectively.

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