ISSN 1807-1929
Revista Brasileira de Engenharia Agrícola e Ambiental
Brazilian Journal of Agricultural and Environmental Engineering
v.26, n.2, p.135-141, 2022
agriambi
Campina Grande, PB – http://www.agriambi.com.br – http://www.scielo.br/rbeaa

DOI: http://dx.doi.org/10.1590/1807-1929/agriambi.v26n2p135-141

Gas exchange in yellow passion fruit under irrigation water salinity and nitrogen fertilization[1]

Trocas gasosas em maracujazeiro amarelo sob salinidade da água de irrigação e adubação nitrogenada

José A. C. Wanderley[2*], Carlos A. V. de Azevedo[2], Marcos E. B. Brito[3], Fagner N. Ferreira[4], Mailson A. Cordão[2] & Robson F. de Lima[2]

[1] Research developed at Centro de Ciências e Tecnologia Agroalimentar, Universidade Federal de Campina Grande, Campina Grande, PB, Brazil
[2] Universidade Federal de Campina Grande/Programa de Pós-Graduação em Engenharia Agrícola, Campina Grande, PB, Brazil
[3] Universidade Federal de Sergipe/Centro de Ciências Agrárias do Sertão, Senhora da Glória, SE, Brazil
[4] Universidade Federal Rural do Semiárido/Programa de Pós-Graduação em Fitotecnia, Mossoró, RN, Brazil

HIGHLIGHTS:

Water with a salinity of 3.1 dS m^{-1} negatively affects gas exchange in yellow passion fruit seedlings such as 70 DAS.
Doses of 90 to 100% of N recommendation mitigate the negative effects of saline irrigation water from 1.7 to 2.4 dS m^{-1} at 55 DAS.
The attenuating effect of nitrogen fertilization is directly linked to dose and saline concentration.

ABSTRACT: The objective of this study was to evaluate the gas exchange of 'Redondo Amarelo' passion fruit seedlings under the mitigating action of nitrogen fertilization on the salinity of irrigation water. The experiment was carried out in a greenhouse of the Universidade Federal de Campina Grande (CCTA-UFCG), Campus of Pombal, PB, Brazil, The experimental design was in randomized blocks, split plots, comprising five irrigation water electrical conductivities (plot) (ECw) (0.3; 1.0; 1.7; 2.4 and 3.1 dS m^{-1}) and five doses of nitrogen (subplot) (60; 80; 100; 120 and 140% of 300 mg of N dm^{-3}), in five blocks. Plants were grown in pots (Citropote JKS®) with volume of 3.780 mL, filled with soil, bovine manure, wood shavings in a proportion of 2:1:0.5 (mass basis), respectively. Water with salinity levels was applied in the period from 40 to 85 days after sowing. The internal CO_2 concentration, transpiration, stomatal conductance and photosynthesis were measured at 55 and 70 days after sowing. There was an attenuating effect of nitrogen doses at irrigation water electrical conductivities of 1.7 and 2.4 dS m^{-1} on photosynthesis at 55 DAS. Irrigation water salinity reduces most of the variables evaluated, especially at the highest level studied (3.1 dS m^{-1}).

Key words: *Passiflora edulis* Sims. *f. flavicarpa* Deg., salt stress, photosynthesis

RESUMO: Objetivou-se avaliar as trocas gasosas de mudas de maracujá Redondo Amarelo sob a ação mitigadora da adubação nitrogenada sobre a salinidade da agua de irrigação. O experimento foi conduzido em casa de vegetação da Universidade Federal de Campina Grande, Campus Pombal, PB. O delineamento experimental foi em blocos casualizados, parcelas subdivididas, compreendendo cinco condutividades elétricas da água de irrigação (parcela) (CEa) (0.3; 1.0; 1.7; 2.4 e 3.1 dS m^{-1}) e cinco doses de nitrogênio (subparcela) (60; 80; 100; 120 e 140% de 300 mg de N dm^{-3}), em cinco blocos. As plantas foram cultivadas em citropotes com volume de 3.780 mL, preenchidos com solo, esterco bovino curtido e maravalha na proporção de 2:1:0,5 (base massa), respectivamente. A aplicação dos níveis de salinidade ocorreu no período de 40 a 85 dias após a semeadura. Mensurou-se, aos 55 e 70 dias após a semeadura a concentração interna de CO_2, transpiração, condutância estomática e fotossíntese. Verificou-se efeito atenuante das doses de nitrogênio para as águas de irrigação de 1.7 e 2.4 dS m^{-1} sobre a fotossíntese aos 55 dias. A salinidade da água de irrigação reduz a maioria das variáveis avaliadas, sobretudo no maior nível estudado (3.1 dS m^{-1}).

Palavras-chave: *Passiflora edulis* Sims. *f. flavicarpa* Deg., estresse salino, fotossíntese

• Ref. 248070 – Received 28 Jan, 2021
* Corresponding author - E-mail: alberto_agronomo@hotmail.com
• Accepted 04 Aug, 2021 • Published 01 Sept, 2021
Edited by: Hans Raj Gheyi

Introduction

Among the species with production potential in the Brazilian semi-arid region, yellow passion fruit (*Passiflora edulis* Sims *f. flavicarpa* Deg.) stands out. Brazilian production was 593.429 tons in 2019, the Northeast with 382.739 tons, which represents 64.5% of national production (IBGE, 2019).

The Northeast region faces problems with the excess of salts in the irrigation water, compromising the formation and establishment of seedlings and consequently their production (Moura et al., 2017).

The excess of salts in the soil solution reduces the osmotic potential, compromising growth and production (Islam et al., 2017). High levels of toxic ions interfere with physiological activity by reducing the rates of transpiration, photosynthesis and internal CO_2 concentration (Gong et al., 2018). Yellow passion fruit is sensitive to salinity, with a salinity threshold level of 1.3 dS m^{-1} (Ayers & Westcot, 1999). Silva Neta et al. (2020) observed a reduction in photosynthesis, stomatal conductance and transpiration rates in passion fruit seedlings irrigated using water with salinity above 0.3 dS m^{-1}.

Salinity can be mitigated by the use of nitrogen fertilization in plants, due to the relationship between salinity and nutrition (Figueiredo et al., 2019). The deleterious effects of irrigation with salinity up to 1.3 dS m^{-1} in passion fruit seedlings are mitigated with a dose of 125 mg N kg^{-1} of soil, as it increases the rate of net photosynthesis (Silva Neta et al., 2020). Supplementation of N increases the absorption of NO_3^-, to the detriment of Cl^-, reducing the Cl^-/N ratio in the leaves, restoring ionic homeostasis, and reducing salt stress in plants (Ibrahim et al., 2018).

In this context, the objective of this study was to evaluate the gas exchange of 'Redondo Amarelo' passion fruit seedlings under the mitigating action of nitrogen fertilization on the salinity of irrigation water.

Material and Methods

The experiment was conducted during the months from February to April 2015, under greenhouse (50% shading) of the Centro de Ciências e Tecnologia Agroalimentar of the Universidade Federal de Campina Grande (CCTA-UFCG), Campus of Pombal, PB, Brazil, at the coordinates 6° 48' 16" S and 37° 49' 15" W and 175 m altitude. According to Köppen's classification, the predominant climate of the region is BSh, that is, hot and dry semiarid, with period of irregular rains between the months from February to June (Alvares et al., 2013). The climatic factors - maximum, minimum and average temperatures, reference evapotranspiration and mean irrigation water depth applied in each treatment during the experimental period are shown in Figure 1.

The experimental design used was randomized blocks with treatments distributed in a split-plot scheme, composed of five irrigation water electrical conductivities in the plots (EC_w) (0.3; 1.0; 1.7; 2.4 and 3.1 dS m^{-1}) and five nitrogen doses in the sub-plots (60; 80; 100; 120 and 140% of the recommendation of 300 mg N dm^{-3} of soil of Malavolta (1980), with five replicates, each consisting of 5 plants, totaling 25 treatments and 125 experimental units. The characteristics of the water used for the preparation of saline levels are shown in Table 1.

Passion fruit seeds of the cultivar 'Redondo Amarelo' were sown in a commercial substrate packed in 166-cell polyethylene trays. At 30 days after sowing (DAS), the seedlings were transplanted to pots (Citropote JKS®) with a capacity of 3.780 mL, containing the substrate composed of a mixture of soil, decomposed bovine manure and wood

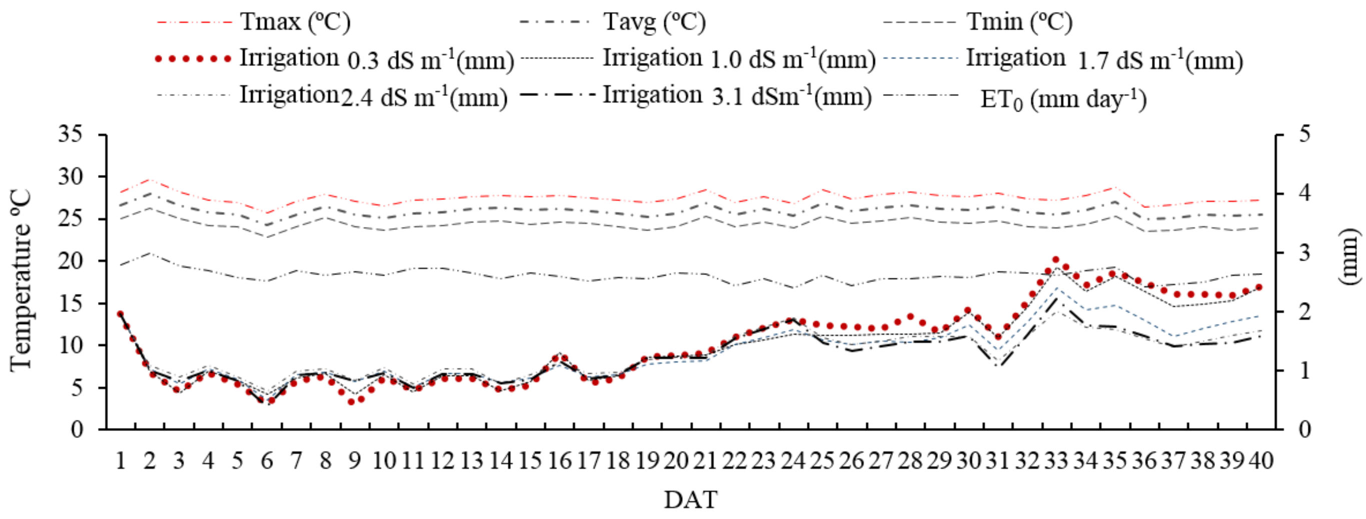


Figure 1. Climatic factors during 40 days of application of treatments (DAT), maximum (Tmax), minimum (Tmin) and average (Tmed) temperatures (°C), reference evapotranspiration (ET_0) (mm) and mean irrigation depths (mm) applied for each level of water salinity studied (0.3; 1.0; 1.7; 2.4 and 3.1 dS m^{-1})

Table 1. Chemical characteristics of the water used to prepare salinity levels

EC (dS m^{-1})	pH	K^+	Ca^{+2}	Mg^{+2}	Na^+	SO_4^{-2}	CO_3^{-2}	HCO_3^-	Cl^-	SAR[1]	$CaCO_3$ (mg L^{-1})
	(mmol$_c$ L^{-1})										
0.3	7.8	0.2	0.6	1.2	0.71	0.0	0.0	2.36	1.8	0.75	99.2

EC - Electrical conductivity; SAR- Sodium absorption ratio - $Na^+/(Ca^{+2} + Mg^{+2}/2)^{0.5}$

shavings in a proportion of 2:1:0.5 (mass basis), respectively. The soil used was an Entisol, of A horizon, whose physical-chemical characteristics are shown in Table 2, collected in the experimental area of the CCTA/UFCG. The soil and the bovine manure were sieved through 2-mm mesh and placed in the containers, leaving about 2.0 cm distance between the soil surface and the upper edge of the pots to facilitate irrigation.

For 10 days after transplantation, the seedlings were irrigated with low-salinity water (0.3 dS m^{-1}) from the local supply system, for the acclimatization of the plants, daily applying irrigation depths equivalent to 80% of the field capacity of the soil; after this period, the application of treatments began, lasting 45 days. Nitrogen application was split into four portions and applied at an interval of five days, dissolved in water via irrigation, using urea as nitrogen source. The basal fertilization followed recommendations proposed by Lima (2002).

Irrigation waters with desired electrical conductivities were obtained by adding sodium chloride (NaCl), calcium chloride ($CaCl_2.H_2O$) and magnesium chloride ($MgCl_2.6H_2O$) salts in an equivalent proportion of 7:2:1, respectively, the predominant ratio of ions in water sources used for irrigation in Northeast Brazil according to Brito et al. (2014).

The five irrigation water electrical conductivities (ECw) under study were prepared considering the empirical relationship between ECw and the salt concentration contained in Rhoades et al. (1992) ($mmol_c$ L^{-1} = 10* ECw), valid for ECw from 0.1 to 5.0 dS m^{-1}, which encompasses the tested values. Thus, the salts were weighed according to treatment, adding water, until the desired value of ECw was reached, checking the values with a portable conductivity meter, whose electrical conductivity was adjusted to a temperature of 25 °C.

Irrigation management was carried out based on daily water consumption, obtained by the water balance method, through drainage lysimetry, adapted as described in Mantovani et al. (2009).

The lysimeters consisted of pots with 3.780 mL capacity, installed with drains to collect the excess volume, at each salinity level, that is, distinct management as a function of the irrigation water electrical conductivity treatment. The volume applied (Va) daily in the pots was obtained by the difference between the total volume applied to the pots on the previous day (V_{ta}) and the volume drained (V_d) on the following day, dividing the result by the number of pots (n) and applying a leaching fraction of 20% (LF), as indicated in Eq. 1.

$$Va = \frac{\left[\frac{V_{ta} - (V_d)}{n}\right]}{1 - 0.2} \tag{1}$$

The evaluations were carried out in the final period of seedling formation at 55 and 70 DAS, relative to 15 and 30 days after stress started. To identify initial physiological changes, a portable infrared gas exchange analyzer (IRGA) was used to determine photosynthesis (A) (μmol m^{-2} s^{-1}), stomatal conductance (gs) (mol H_2O m^{-2} s^{-1}), transpiration (E) (mmol H_2O m^{-2} s^{-1}) and internal CO_2 concentration (Ci) (μmol m^{-2} s^{-1}). These data were then used to estimate instantaneous water use efficiency (WUEi) (A/E) [(μmol m^{-2} s^{-1})(mmol H_2O m^{-2} s^{-1})$^{-1}$) and intrinsic carboxylation efficiency (CEi) (A/Ci) [(μmol m^{-2} s^{-1}) (mmol CO_2 m^{-2})$^{-1}$] (Freire et al., 2014; Melo et al., 2014).

The data obtained were subjected to analysis of variance by F test, followed by regression analysis (linear and quadratic) for irrigation water electrical conductivity at each nitrogen dose when there was interaction, or for the factors, separately, using the program Sisvar 5.6 (Ferreira, 2014).

Results and Discussion

Based on the analysis of variance, there was a significant effect of the interaction between irrigation water salinity and nitrogen doses (Table 3) on the gas exchange variables Ci, A, WUEi and CEi at 55 DAS, whereas transpiration (E) was significantly affected by the individual factors salinity and nitrogen doses, and stomatal conductance was not significantly affected by any of the factors.

For the effect of N doses at each irrigation water electrical conductivity on Ci values (Figure 2A), no significant difference was observed at irrigation water electrical conductivity of 0.3, 1.0, 1.7 and 3.1 dS m^{-1}. Significant effect of N levels on Ci values was observed only under irrigation with 2.4 dS m^{-1} water and a quadratic regression model fitted to the values, with the lowest concentration recorded at 55 DAS, at N dose of 250.58 mg dm^{-3} of soil (105.87% of the recommendation) with 249.00 mmol of CO_2 m^{-2}. This represented a reduction of 10.57% in Ci compared to the N dose of 60%, which is directly linked to the photosynthesis rate (Figure 2B). The reduction of Ci values in plants irrigated with salinity of 2.4 dS m^{-1}, followed by an increment of N levels, is directly related to the behavior of the photosynthesis rate under these conditions (Figure 2B), since the CO_2 in the substomatal chamber is required to perform

Table 2. Physical and chemical characteristics of the soil and bovine manure used in the study

Soil														
pH (H_2O)	EC (dS m^{-1})	P (mg dm^{-3})	K^+	Na^+	Ca^{+2}	Mg^{+2}	Al^{+3}	$H^+ + Al^{+3}$	SB	t	T	V	N	OM (g kg^{-1})
			($cmol_c$ dm^{-3})									(%)		
5.96	0.3	58	1.59	0.85	4.9	7.4	0	1.73	13.89	13.89	15.62	89.48	1.12	18

Density (kg dm^{-1})	Sand	Silt	Clay	Moisture bar – (% weight)					
	(g kg^{-1})			0.1	0.33	1	5	10	15
1.48	800	140.6	59.4	20.33	17.11	7.91	3.97	3.57	3.43

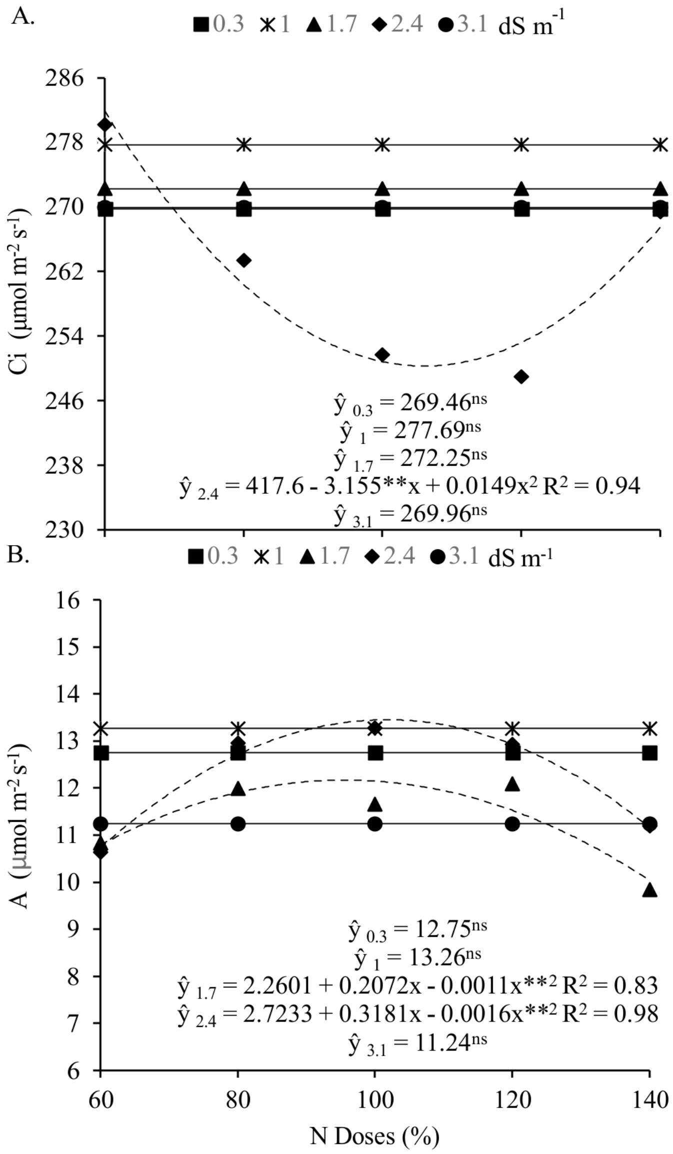
Bovine manure														
pH (H_2O)	EC (dS m^{-1})	P (mg dm^{-3})	K^+	Na^+	Ca^{+2}	Mg^{+2}	Al^{+3}	$H^+ + Al^{+3}$	SB	t	T	V	N	OM (g kg^{-1})
			($cmol_c$ dm^{-3})									(%)		
7.62	1.23	80	2.15	4.4	3.2	10.7	0	0	20.45	20.45	20.45	100	2.49	41

EC - Electrical conductivity; SB - Sum of bases; t - Effective cation-exchange capacity; T - Cation-exchange capacity; V - Percentage of base saturation, OM - Organic matter

Table 3. Summary of the analysis of variance for internal CO_2 concentration (Ci), transpiration (E), stomatal conductance (gs), photosynthesis CO_2 (A), instantaneous water use efficiency (WUEi) and intrinsic carboxylation efficiency (CEi) at 55 days after sowing as a function of irrigation water electrical conductivity and nitrogen doses applied to 'Redondo Amarelo' passion fruit (*Passiflora edulis* Sims. *f. flavicarpa* Deg.)

SV	DF	Mean square					
		Ci	E	gs	A	WUEi	CEi
Blocks	4	21435.03	0.511753	0.098246	3.913376	3.7137	0.001149
Water salinity (S)	4	723.11^{ns}	0.5257*	0.0230^{ns}	19.920*	1.4143^{ns}	0.00022*
Residual 1	16	667.09	0.1073	0.0071	4.9325	0.5921	0.000066
Nitrogen (N)	4	421.07^{ns}	0.2235*	0.0089^{ns}	4.5208*	0.6071*	0.00012*
S x N	16	362.26*	0.0911^{ns}	0.00635^{ns}	3.7854*	0.6554**	0.000091**
Residual 2	80	200.01	0.0527	0.0027	1.7149	0.2383	0.000040
Mean		270.47	2.5485	0.2990	12.148	4.8035	0.0457
CV1 (%)		9.55	12.86	18.33	18.28	16.02	17.69
CV2 (%)		5.23	9.01	17.42	10.78	10.16	13.89

*, **, ^{ns} - Significant at $p \le 0.05$ and $p \le 0.01$ and not significant by F test, respectively; DF - Degrees of freedom; CV - Coefficient of variation; SV - Sources of variation



*, **, ^{ns} - Significant at $p \le 0.05$ and $p \le 0.01$ and not significant by F test, respectively

Figure 2. Internal concentration of CO_2 (Ci) (A) and net photosynthesis - A (B) in passion fruit seedlings of the cultivar 'Redondo Amarelo' as a function of the interaction between electrical conductivity of irrigation water and nitrogen doses, at 55 days after sowing

net photosynthesis (Taiz & Zeiger, 2009). Silva et al. (2019) observed a reduction in Ci values caused by doses higher than 50 mg N kg^{-1} in watermelon plants irrigated with water of salinity of 3.2 dS m^{-1}.

The N doses caused changes in net photosynthesis at 55 DAS, when the plants were irrigated with water of 1.7 and 2.4 dS m^{-1} (Figure 2B), and the data were described by quadratic models, in both situations, with the highest values obtained under the estimated N doses of 94.18 and 99.40% of the recommendation (282.54 and 298.20 mg of N dm^{-3} of soil), respectively, promoting photosynthesis rates of 12.01 and 18.54 µmol CO_2 m^{-2} s^{-1}, results superior to those obtained by Andrade et al. (2019), who verified a reduction at 61 days after transplanting from 7.57 to 3.48 µmol CO_2 m^{-2} s^{-1} due to the increase in ECw from 0.7 to 2.8 dS m^{-1}, in seedlings of yellow passion fruit. Silva Neta et al. (2020) observed values of 21.13 and 23.40 µmol CO_2 m^{-2} s^{-1} CO_2 for photosynthesis, respectively caused by irrigation with water salinity of 0.3 and 1.3 dS m^{-1} in 'BRS Rubi do Cerrado' passion fruit seedlings.

The increments related to the N doses of 94.2 and 99.4% of the recommendation for ECw of 1.7 and 2.4 dS m^{-1}, respectively, were of the order of 12.6 and 25.59% in A, when compared to those obtained at the N dose of 60%. These results suggest stress attenuation by N, since the net photosynthesis observed with these combinations is similar to those observed in plants irrigated using water with salinity below the crop's threshold (0.3 and 1.0 dS m^{-1}) (Figure 2B), i.e., less than 1.3 dS m^{-1} (Cavalcanti et al., 2005), denoting the importance of adequately using N fertilization. The reduction in A values as a function of N doses greater than 282.54 and 298.20 mg N dm^{-3} combined with water salinity levels of 1.7 and 2.4 dS m^{-1}, respectively (Figure 2B), is probably linked to the increase in the source of N used in this research. Concentrations of excess N by means of urea and the action of the enzyme urease transform the amidic N into ammoniacal N, and the absorption of NH_4^+ by the roots controlled by a carrier, when it is transported into the cell, causes an electrical imbalance (Silva et al., 2019). Excess of ammoniacal N lowers intracellular pH, causing osmotic imbalance, favoring oxidative stress and leading to changes in photosynthesis by the plants (Bittsánszky et al., 2015).

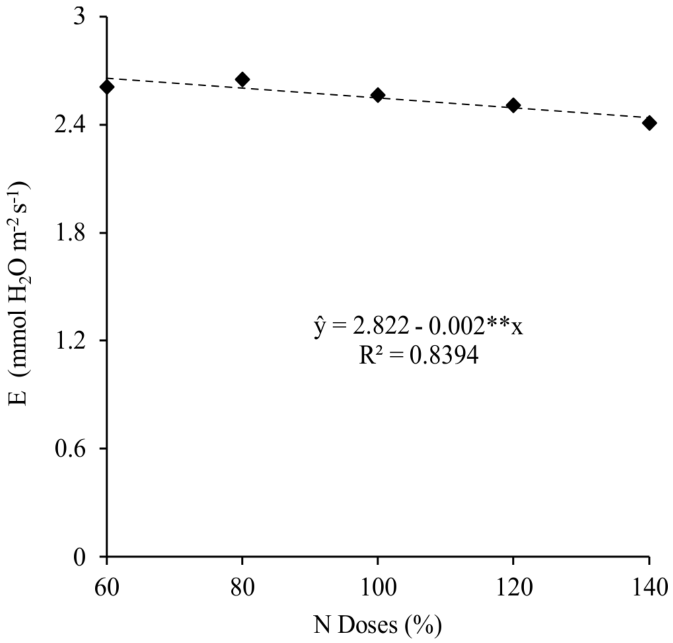
The transpiration (E), at 55 DAS, was reduced by 0.084 mmol H_2O m^{-2} s^{-1} with unit increment in the electrical conductivity of the irrigation water; however, it was not possible to adequately fit the values of transpiration, according to equation $\hat{y} = 2.6923 - 0.0846^{*}x$, though significant at

0.05 probability level, it explains only 41.65% of the variation in transpiration as a function of ECw and hence it should not be used for prognostic purposes. Transpiration was also reduced by 0.002 mmol H_2O m^{-2} s^{-1} with unit increase in the N dose, corresponding to 1.42% reduction with each 20% increase in N dose (Figure 3). Such reductions can be attributed to the osmotic effects caused by the concentrations of salts in the substrate, those related both to saline waters and to salts derived from the N compounds.

By analyzing the effect of interaction on the instantaneous water use efficiency (WUEi) and intrinsic carboxylation efficiency (CEi) (Figure 4), a quadratic fit of the data is observed with the increase in N doses for irrigation water electrical conductivity of 2.4 dS m^{-1}. The highest WUEi was 6.707 [(μ mmol m^{-2} s^{-1}) (mmol H_2O m^{-2} s^{-1})$^{-1}$] at the N dose of 111.8% of the recommendation, and the highest CEi, of the order of 0.05471 [(μmol m^{-2} s^{-1}) (mmol CO_2 m^{-2})$^{-1}$], was obtained with the N dose of 103.7% of the recommendation. The increase in WUEi in passion fruit plants reflects the role of nitrogen in plant metabolism through its structural role in the synthesis of amino acids, proteins, coenzymes, nucleic acids, vitamins and chlorophyll, organic compounds essential for the survival of plants (Lima et al., 2019).

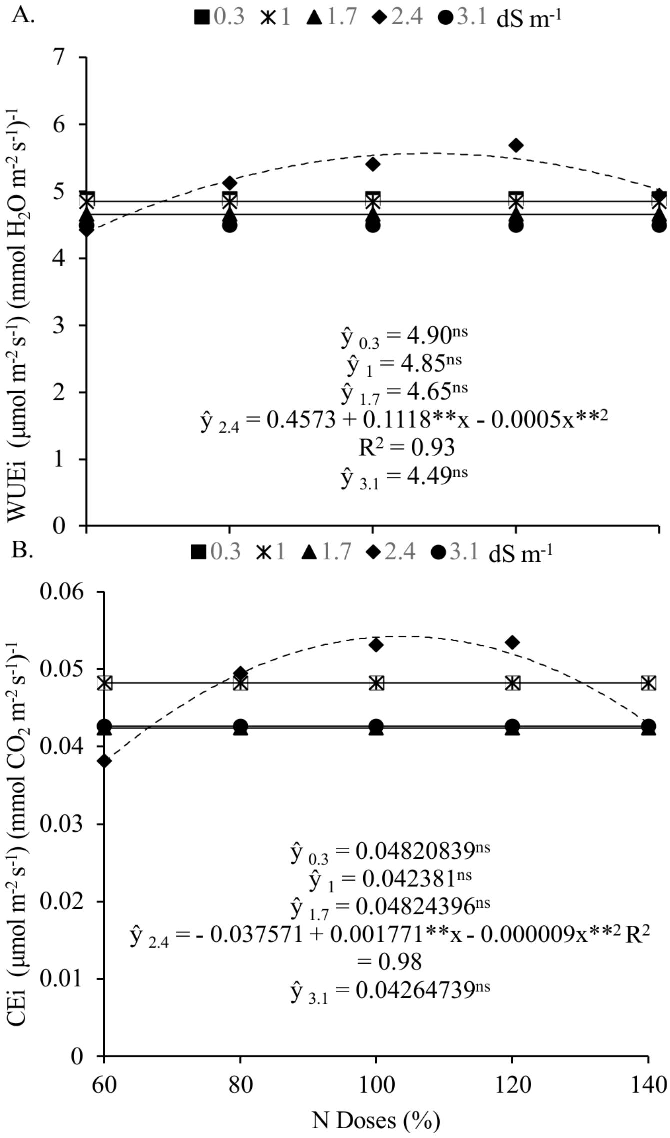
As WUEi is related to water loss by the stomata and carboxylation efficiency is related to the capacity for metabolizing the substrate (Ci) in photosynthesis (Taiz & Zeiger, 2009), the effects of salinity on passion fruit may be related to both the osmotic effect, conditioning the plants to a lower water potential, and the ionic effect, related to the increase in the concentration of toxic ions, or even causing nutritional imbalance, altering the photosynthetic activity through the reduction in water availability or through the absence of essential elements.

At 70 DAS of passion fruit seedlings, there was no effect of the interaction between irrigation water electrical conductivity



*, **, ns - Significant at p ≤ 0.05 and p ≤ 0.01 and not significant by F test, respectively

Figure 3. Transpiration (E) of passion fruit seedlings of the cultivar 'Redondo Amarelo' as a function of nitrogen doses (B) 55 days after sowing



*, **, ns - Significant at p ≤ 0.05 and p ≤ 0.01 and not significant by F test, respectively

Figure 4. Instantaneous water use efficiency (WUEi)) (A) and intrinsic carboxylation efficiency (CEi) (B) in passion fruit seedlings of the cultivar 'Redondo Amarelo' as a function of the interaction between electrical conductivity of irrigation water and nitrogen doses, at 55 days after sowing

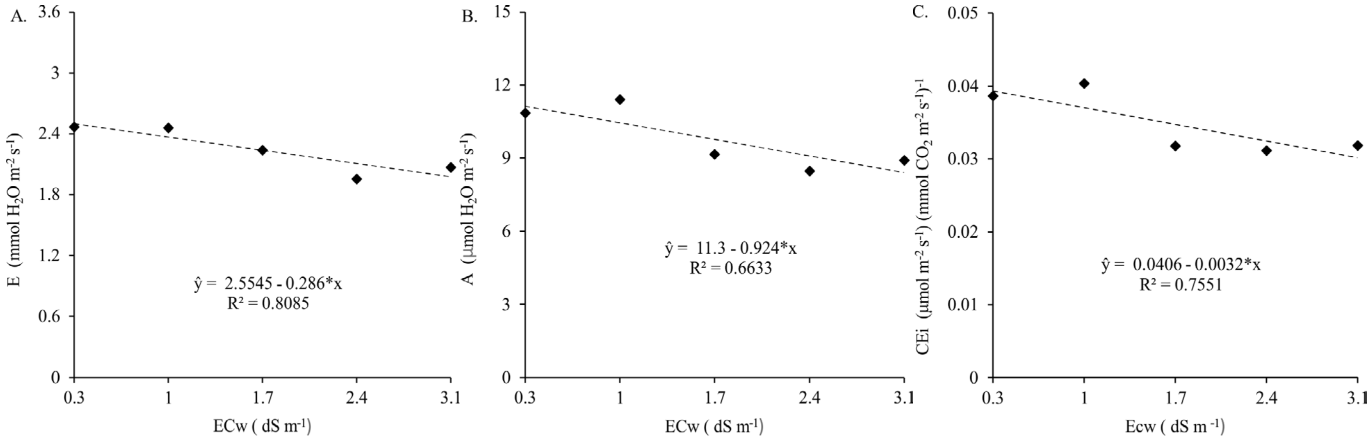
and N doses on gas exchange variables; however, the irrigation water salinity significantly reduced the values of transpiration (E), net photosynthesis (A) and intrinsic carboxylation efficiency (CEi). Reductions in the values of A, E, and CEi are related to the osmotic effect caused by the excess of salts in the irrigation water, increasing the concentration of salts in the soil, decreasing water absorption by the roots, conditioning passion fruit seedlings to reduce stomatal opening to decrease water loss, reducing transpiration and photosynthetic rate (Andrade et al., 2019). Studies conducted by Wanderley et al. (2020) evidenced 64.27% damage to the cell membrane in yellow passion fruit seedlings when subjected to an increase from 0.3 to 3.1 dS m^{-1} in irrigation water salinity.

The values of transpiration (E) ranged from 2.4982 to 1.977 mmol H_2O m^{-2} s^{-1}, when the salt concentration increased from 0.3 to 3.1 dS m^{-1}, respectively, which represented reduction of the order of 0.0286 mmol of H_2O m^{-2} s^{-1} with unit increase in ECw (Figure 5A), and this is directly related

Table 4. Summary of the analysis of variance for internal CO_2 concentration (Ci) (mmol mol^{-1}), transpiration (E), stomatal conductance (gs), net photosynthesis CO_2 (A), instantaneous water use efficiency (WUEi) and intrinsic carboxylation efficiency (CEi) at 70 days after sowing (DAS) as a function of irrigation water electrical conductivity and nitrogen doses

SV	DF	Mean square					
		Ci	E	gs	A	WUEi	CEi
Blocks	4	52890.74	3.933993	0.174747	24.82473	3.762703	0.000213
Water salinity (S)	4	765.37^{ns}	1.3129*	0.0328*	39.441*	0.8374^{ns}	0.000420*
Residual 1	16	670.41	0.3417	0.0328	7.5068	0.4659	0.000092
Nitrogen (N)	4	278.50^{ns}	0.0779^{ns}	0.0015^{ns}	2.8998^{ns}	0.1966^{ns}	0.000052^{ns}
S x N	16	198.48^{ns}	0.1660^{ns}	0.0025^{ns}	6.6664^{ns}	0.2453^{ns}	0.000101^{ns}
Residual 2	80	503.15	0.1584	0.0029	6.1819	0.6438	0.000118
Mean		282.58	2.2379	0.2098	9.7287	4.3988	0.0351
CV1 (%)		9.16	16.12	19.81	18.16	15.52	17.30
CV2 (%)		7.94	17.78	25.68	15.56	18.24	20.98

*, **, ^{ns} - Significant at $p \leq 0.05$ and $p \leq 0.01$ and not significant by F test, respectively; DF- Degrees of freedom; CV - Coefficient of variation; SV - Sources of variation



*, **, ^{ns} - Significant at $p \leq 0.05$ and $p \leq 0.01$ and not significant by F test, respectively

Figure 5. Transpiration - E (A), net photosynthesis -A (B) and intrinsic carboxylation efficiency (CEi) - A/Ci (C) in passion fruit seedlings of the cultivar 'Redondo Amarelo' as a function of the electrical conductivity of irrigation water, at 70 days after sowing

to the stomatal movement, whose values ranged from 0.2421 to 0.1777 mol H_2O m^{-2} s^{-1}. For this variable, although a linear fit was significant at 0.05 level of probability ($\hat{y}$ = 0.2495 - 0.0233*x), the value of R^2 was relatively low (0.507). Thus, the increase in irrigation water electrical conductivity caused an increase in stomatal resistance, which reduced the flow of water to the external environment, hence limiting the influx of CO_2 in the substomatal chamber, resulting in a decrease in photosynthesis (Figure 4B). Reductions observed in A, E and CEi are due to the osmotic effect resulting from the excess of salts in the irrigation water, raising the levels of salts in the soil, compromising the absorption of water by the roots, leading passion fruit plants to increase stomatal resistance to decrease water loss and, consequently, decrease transpiration (Silva Neta et al., 2020), corroborating the results reported by Liu et al. (2014).

Irrigation with saline water reduced net photosynthesis (A) values from 11.0228 to 8.4356 µmol CO_2 m^{-2} s^{-1}; reductions superior to those observed by Andrade et al. (2019), who found a reduction at 61 days after transplanting (121 DAS) from 7.5767 to 4.0947 µmol CO_2 m^{-2} s^{-1}, with increasing salinity from 0.7 to 2.8 dS m^{-1}. Analogous observation was made by Wanderley et al. (2018), when studied the growth and pigments in yellow passion fruit seedlings with an increase in water salinity from 0.3 to 3.1 dS m^{-1}. Silva et al. (2019) verified a decrease in stomatal movement, transpiration and photosynthesis rate in watermelon plants submitted to irrigation with 3.2 dS m^{-1}. Similar results were reported by Freire et al. (2014), evaluating the responses related to photosynthetic efficiency and gas exchange of yellow passion fruit under water salinity, biofertilizer application and soil cover.

With the decrease in photosynthetic activity as a function of salinity, there was a reduction in the mobilization of internal carbon, which increased the internal concentration of CO_2; consequently, the intrinsic carboxylation efficiency was reduced from 0.0391 to 0.0307 (µmol m^{-2} s^{-1}) (mmol CO_2 m^{-2})$^{-1}$ (Figure 5C), since it represents the ratio between photosynthesis and internal CO_2 concentration. The CEi expresses the relationship between the photosynthesis (A) and the internal CO_2 concentration (Ci). The reduction observed at 70 DAS can be justified, since the tendency of increasing Ci to reduce photosynthesis was not significant, as the salinity of the irrigation water increased (Freire et al., 2014).

Salinization is greater with increasing time and concentration; however, the effect is variable with this form of salinization (Barbosa et al., 2017). For example, the abrupt changes in the salt concentration may cause greater problems in plants than in a situation where the increase in salinity is gradual.

Conclusions

1. Nitrogen doses between 90 and 100% of the recommendation attenuated the negative effects of irrigation water electrical conductivity of 1.7 and 2.4 dS m^{-1} at 55 days after sowing (DAS) on net photosynthesis (A), instantaneous

water use efficiency (WUEi) and intrinsic carboxylation efficiency (CEi) of the passion fruit cultivar 'Redondo Amarelo'.

2. The salinity of the irrigation water negatively affected transpiration, net photosynthesis and intrinsic carboxylation efficiency of passion fruit at 70 DAS, mainly at the highest level studied (3.1 dS m^{-1})

3. Nitrogen doses do not mitigate the negative effects of water salinity at 70 DAS on gas exchange in yellow passion fruit seedlings.

Literature Cited

Alvares C. A.; Stape J. L.; Sentelhas P. C.; Gonçalves, J. L. de M.; Sparovek, G. Köppen's climate classification map for Brazil. Meteorol Zeitschrift, v.22, p.711-728 2013. https://doi.org/10.1127/0941-2948/2013/0507

Andrade, E. M. G.; Lima, G. S. de; Lima, V. L. A. de; Silva, S. S. da; Gheyi, H. R.; Silva, A. A. R. da. Gas exchanges and growth of passion fruit under saline water irrigation and H_2O_2 application. Revista Brasileira de Engenharia Agrícola e Ambiental, v.23, p.945-951, 2019. https://doi.org/10.1590/1807-1929/agriambi.v23n12p945-951

Ayers, R. S.; Westcot, D. W. A qualidade de água na agricultura. Campina Grande: Universidade Federal da Paraíba, 1999. 153p.

Barbosa, R. C. A.; Brito, M. E. B.; Sá, F. V. da S.; Soares Filho, W. dos S.; Fernandes, P. D.; Silva, L. A. Gas exchange of citrus rootstocks in response to intensity and duration of saline stress. Semina: Ciencias Agrarias, v.38, p.725-738, 2017. https://doi.org/10.5433/1679-0359.2017v38n2p725

Bittsánszky, A.; Pilinszk, K.; Gyulai, G.; Komives, T. Overcoming ammonium toxicity. Plant Science, v.231, p.184-190, 2015. https://doi.org/10.1016/j.plantsci.2014.12.005

Brito, M. E. B.; Fernandes, P. D.; Gheyi, H. R.; Melo, A. S. de; Soares Filho, W. dos S.; Santos, R, T. dos. Sensibilidade à salinidade de híbridos trifoliados e outros porta-enxertos de citros. Revista Caatinga, v.27, p.17-27, 2014.

Cavalcanti, M. L. F.; Fernandes, P. D.; Gheyi, H. R.; Barros Júnior, G.; Soares, F. A. L.; Siqueira, E. da C. Tolerância da mamoneira BRS 149 à salinidade: Germinação e características de crescimento. Revista Brasileira Engenharia Agrícola e Ambiental, v.9, p.57-61, 2005. https://doi.org/10.1590/1807-1929/agriambi.v9nsupp57-61

Ferreira, D. F. Sisvar: a guide for its bootstrap procedures in multiple comparisons. Ciência e Agrotecnologia, v.38, p.109-112, 2014.

Figueiredo, F. R. A.; Gonçalves, A.; Ribeiro, J. E. da S.; Silva, T. I. da; Nóbrega, J. S.; Dias, T. J.; Albuquerque, M. B. Gas exchanges in sugar apple (*Annona squamosa* L.) subjected to salinity stress and nitrogen fertilization. Australian Journal of Crop Science, v.13, p.1959-1966, 2019. https://doi.org/10.21475/ajcs.19.13.12.p1754

Freire, J. L. de O.; Dias, T. J.; Cavalcante, L. F.; Fernandes, P. D.; Lima Neto, A. J. de. Rendimento quântico e trocas gasosas em maracujazeiro amarelo sob salinidade hídrica, biofertilização e cobertura morta. Revista Ciência Agronômica, v.45, p.82-91, 2014. https://doi.org/10.1590/S1806-66902014000100011

Gong, D. H.; Wang, G. Z.; Si, W. T.; Zhou, Y.; Liu, Z.; Jia, J. Effects of salt stress no photosynthetic pigments and activity of ribulose-1,5-bisphosphate carboxylase/oxygenase in *Kalidium foliatum*. Russian Journal of Plant Physiology, v.65, p.98-103, 2018. https://doi.org/10.1134/S1021443718010144

IBGE - Instituto Brasileiro de Geografia e Estátistica. Produção agrícola municipal. Lavouras permanentes 2019. Available on: <http://www.sidra.ibge.gov.br/bda/tabela/>. Accessed on: Apr. 2021.

Ibrahim, M. E. H.; Zhu, X.; Zhou, G.; Ali, A. Y. A.; Ahmad, I.; Elsiddig, A. M. I. Nitrogen fertilizer reduces the impact of sodium chloride on wheat yield. Agronomy Journal, v.110, p.1731-1737, 2018. https://doi.org/10.2134/agronj2017.12.0742

Islam, M. N.; Islam, A.; Biswas, J. C. Effect of gypsum on electrical conductivity and sodium concentration in salt affected paddy soil. International Journal of Agricultural Papers, v.2, p.19-23, 2017.

Lima, A. A. Maracujá produção: Aspectos técnicos. Brasília: Embrapa Informação Tecnológica, 2002. 103p. Frutas do Brasil, 15

Lima, G. S. de; Pinheiro, F. W. A.; Dias, A. S.; Gheyi, H. R.; Nobre, R. G.; Soares, L. A. A.; Silva, A. A. R. da; Silva, E. M. da. Gas exchanges and production of West Indian cherry cultivated under saline water irrigation and nitrogen fertilization. Semina: Ciências Agrárias, v.40, p.2947-2960, 2019. https://doi.org/10.5433/1679-0359.2019v40n6Supl2p2947

Liu, S.; Dong, Y.; Xu, L.; Kong, J. Effects of foliar applications of nitric oxide and salicylic acid on salt-induced changes in photosynthesis and antioxidative metabolism of cotton seedlings. Plant Growth Regulation. v.73, p.67-78, 2014. https://doi.org/10.1007/s10725-013-9868-6

Malavolta, E. Elementos de nutrição mineral das plantas. Piracicaba: Ceres, 1980. 251p.

Mantovani, E. C.; Bernardo, S; Palaretti, L. F. Irrigação: Princípios e métodos, 2.ed. Viçosa: Editora UFV, 2009, 355p.

Melo, A. S. de; Silva, J. M. da; Fernandes, P. D.; Dutra, A. F.; Brito, M. E. B.; Silva, F. G. da. Gas exchange and fruit yield of yellow passion fruit genotypes irrigated with different rates of ET_0 replacement. Bioscience Journal, v.30, p.293-302, 2014.

Moura, R. S.; Gheyi, H. R.; Coelho Filho, M. A.; Jesus, O. N. de; Lima, L. K. S.; Cruz, C. S. da. Formation of seedlings of species from the genus Passiflora under saline stress. Bioscience Journal, v.33, p.1197-1207, 2017. https://doi.org/10.14393/BJ-v33n5a2017-36957

Rhoades, J. D.; Kandiah, A.; Mashali, A. M. Uso de águas salinas para produção agrícola. Campina Grande: UFPB, 1992. 117p.

Silva, S. S. da; Lima, G. S. de; Lima, V. L. A. de; Gheyi, H. R.; Soares, L. A. dos A.; Lucena, R. C. M. Gas exchanges and production of watermelon plant under salinity management and nitrogen fertilization. Pesquisa Agropecuária Tropical, v.49, p.1-10, 2019. https://doi.org/10.1590/1983-40632019v4954822

Silva Neta, A. M. de S.; Soares, L. A. dos A.; Lima, G. S. de; Silva, L. de A.; Ferreira, F. N.; Fernandes, P. D. Morphophysiology of the passion fruit 'BRS Rubi do Cerrado'irrigated with saline waters and nitrogen fertilization. Comunicata Scientiae, v.11, p.1-9, 2020. https://doi.org/10.14295/cs.v12.3456

Taiz, L.; Zeiger, E. Fisiologia vegetal. Porto Alegre: ArtMed, 2009. 828p.

Wanderley, J. A. C.; Azevedo, C. A. V. de; Brito, M. E. B.; Cordão, M. A.; Lima, R. F. de; Ferreira, F. N. Nitrogen fertilization to attenuate the damages caused by salinity on yellow passion fruit seedlings. Revista Brasileira de Engenharia Agrícola e Ambiental, v.22, p.541-546, 2018. https://doi.org/10.1590/1807-1929/agriambi.v22n8p541-546

Wanderley, J. A. C.; Brito, M. E. B.; Azevedo, C. A. V. de; Silva, F. das C.; Ferreira, F. N.; Lima, R. F. de. Cell damage and biomass of yellow passion fruit under water salinity and nitrogen fertilization. Revista Caatinga, v.33, p.757-765, 2020. https://doi.org/10.1590/1983-21252020v33n319rc