Universidade Federal Rural do Semi-Árido
Pró-Reitoria de Pesquisa e Pós-Graduação
https://periodicos.ufersa.edu.br/index.php/caatinga

ISSN 0100-316X (impresso)
ISSN 1983-2125 (online)
http://dx.doi.org/10.1590/1983-21252018v31n402rc

PHYSIOLOGICAL INDICES AND GROWTH OF 'PALUMA' GUAVA UNDER SALINE WATER IRRIGATION AND NITROGEN FERTIGATION[1]

IDELFONSO LEANDRO BEZERRA[2]*, REGINALDO GOMES NOBRE[3], HANS RAJ GHEYI[4], GEOVANI SOARES DE LIMA[5], JOICY LIMA BARBOSA[5]

ABSTRACT - The cultivation of irrigated guava in semi-arid areas highlights the need for information regarding its responses to irrigation water quality and the fertilization management that enables its exploitation. Thus, this study aimed to evaluate the effect of water salinity and nitrogen (N) doses on the growth and physiology of the guava cv. 'Paluma'. The experiments was conducted in drainage lysimeters under field conditions in an experimental area at the Center of Sciences and Agri-Food Technology of the Federal University of Campina Grande (CCTA/UFCG), Campus II, in Pombal, PB, Brazil. The experiment had a randomized block design, and treatments consisted of a 5 x 4 factorial arrangement corresponding to five levels of irrigation water electrical conductivity, ECw (0.3, 1.1, 1.9, 2.7, and 3.5 dS m^{-1}), and four N doses (70, 100, 130, and 160% of the recommended N dose). The 100% dose corresponded to 541.1 mg of N dm^{-3} of soil. Increments in irrigation water salinity from 0.3 dS m^{-1} led to a reduction in stomatal conductance, internal CO_2 concentration, CO_2 assimilation rate, transpiration, instantaneous water use efficiency, the number of leaves and branches, stem diameter, and absolute and relative growth rates. Nitrogen doses ranging from 378.7 to 865.7 mg of N dm^{-3} of soil did not affect gas exchange and plant growth. Although 'Paluma' guava growth was affected by increases in water salinity, these plants can be irrigated using water of up to 1.42 dS m^{-1} with an acceptable reduction of 10% in growth variables. The interaction between irrigation water salinity and N fertilization had no significant effect on any of the variables studied.

Keywords: *Psidium guajava* L.. Salinity. Nitrogen. Physiology.

ÍNDICES FISIOLÓGICOS E CRESCIMENTO DE GOIABEIRA 'PALUMA' IRRIGADA COM ÁGUA SALINA E ADUBAÇÃO NITROGENADA

RESUMO - O cultivo da goiabeira irrigada nas áreas semiáridas evidencia a necessidade de informações a respeito de suas respostas à qualidade da água de irrigação e ao manejo da adubação que possibilite sua exploração. Assim, objetivou-se estudar o efeito da salinidade da água combinada com doses de nitrogênio no crescimento e fisiologia da goiabeira cv. 'Paluma', em experimento conduzido em lisímetros de drenagem sob condições de campo em uma área experimental no Centro de Ciência e Tecnologia Agroalimentar da Universidade Federal de Campina Grande (CCTA/UFCG), Campus II de Pombal, PB. O delineamento experimental utilizado foi de blocos casualizados, com tratamentos arranjados em esquema fatorial 5 x 4, relativos a cinco níveis de condutividade elétrica da água de irrigação – CEa (0,3; 1,1; 1,9; 2,7 e 3,5 dS m^{-1}) e quatro doses de nitrogênio (70, 100, 130 e 160% de N recomendada), sendo a dose referente a 100% correspondeu a 541,1 mg de N dm^{-3} de solo. O aumento da salinidade da água de irrigação a partir de 0,3 dS m^{-1} promoveu redução na condutância estomática, concentração interna de CO_2, taxa de assimilação de CO_2, transpiração, eficiência instantânea no uso da água, número de folhas e ramos, diâmetro de caule, taxa de crescimento absoluto e relativo. Doses de nitrogênio variando de 378,7 a 865,7 mg de N dm^{-3} de solo não afetaram as trocas gasosas e o crescimento das plantas. Apesar do crescimento da goiabeira cv. Paluma ser afetado com o aumento da salinidade, é possível irrigar com água de até 1,42 dS m^{-1} ocorrendo redução aceitável de 10% nas variáveis de crescimento. Não houve efeito significativo da interação entre salinidade da água de irrigação e doses de adubação nitrogenada em nenhuma variável estudada.

Palavras-chave: *Psidium guajava* L.. Salinidade. Nitrogênio. Fisiologia.

*Corresponding author
[1]Received for publication in 06/22/2017; accepted in 01/22/2018.
Paper extracted from the doctoral thesis of the first author.
[2]Department of Agronomy, Fundação Universidade Federal de Rondônia, Rolim de Moura, RO, Brazil; idelfonsobezerra@gmail.com – ORCID: 0000-0002-1883-8093.
[3]Department of Science and Technology, Universidade Federal Rural do Semi-Árido, Caraúbas, RN, Brazil; rgomesnobre@yahoo.com.br – ORCID: 0000-0002-6429-1527.
[4]Nucleus of Soil and Water Engineering, Universidade Federal do Recôncavo da Bahia, Cruz das Almas, BA, Brazil; hans@pq.cnpq.br – ORCID: 0000-0002-1066-0315.
[5]Academic Unit of Agricultural Sciences, Universidade Federal de Campina Grande, Pombal, PB, Brazil; geovani.soares@ufcg.edu.br – ORCID: 0000-0001-9960-1858 joicy.barbosa0@gmail.com – ORCID: 0000-0003-0422-5728.

INTRODUCTION

The guava (*Psidium guajava* L.) belongs to the Myrtaceae family and is native to Tropical America, possibly somewhere between Mexico and Peru, where it can be found in the wild stage. It is found nationwide in Brazil, where the fruit is much appreciated. As a result, in recent years there has been an increase in the area cultivated for commercial purposes, either for fresh consumption or industrialization (OLIVEIRA et al., 2015). The 'Paluma' cultivar is the most widespread in Brazil, and has the most varied consumer market (RAMOS et al., 2010).

Northeast Brazil is one of the main guava producing regions. The region is characterized by high evaporation rates, irregular rainfall, and deficient drainage in the soil. Its waters often exhibit electrical conductivities greater than 1.5 dS m^{-1}, which may limit agricultural production causing morphological, physiological, and biochemical alterations in plants that compromise their development, production, and fruit quality (NEVES et al., 2009; DIAS et al., 2011; FREIRE et al., 2014). The effects of high salt concentrations in the soil manifest themselves through alterations to physical and chemical properties, which reduce the osmotic potential of the soil solution, and affect the mineral nutrition of the plants through the direct action of specific ions (CAVALCANTE et al., 2009; DIAS et al., 2011).

Nitrogen is one of the most important nutrients for plants as it has structural function, and comprises various organic compounds that are vital to plants (such as amino acids, proteins, and proline), increases the capacity for osmotic adjustment to salinity, and increases crop resistance to water and salt stresses (PARIDA; DAS, 2005). Thus, efficient management of N fertilization can be an alternative to attenuate the effects of salinity on plants.

Growth analysis has been employed as a tool to evaluate the effects of environmental and management factors in plants, and to infer the contributions from different physiological processes involved in plant behavior, as the variables required are easily measured (BENINCASA, 2003). Using open-flow gas exchange systems such as an IRGA (Infrared Gas Analyzer) may enhance the evaluation, resulting in faster and more accurate individual measurement of these processes (HUNT, 2003).

In this context, this study aimed to evaluate the effects of irrigation water salinity and nitrogen (N) fertilization on leaf gas exchange and the growth of guavas, cv. 'Paluma'.

MATERIAL AND METHODS

The study was carried out from October 2015 to August 2016 in 150 L pots that were converted into lysimeters under field conditions. The experiment was set up at the Center of Sciences and Agri-Food Technology (CCTA) at the Federal University of Campina Grande (UFCG), in the municipality of Pombal, PB, Brazil (6º48'16'' S; 37º49'15'' W; 144 m). The climate of the region, according to Köppen's classification, is hot and semi-arid (BSh), with a mean annual temperature of 28 ºC and rainfalls around 750 mm. Mean monthly rainfall and temperatures in the municipality are shown in Figure 1.

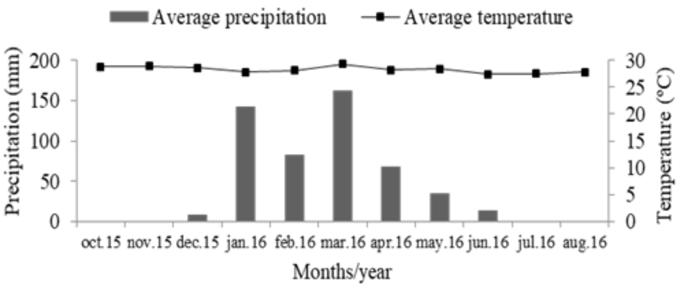

Figure 1. Climatic data of Pombal, PB, during the experimental period.

The experiment had a randomized block design, with a 5 x 4 factorial arrangement, corresponding to five levels of irrigation water salinity, ECw (0.3, 1.1, 1.9, 2.7, and 3.5 dS m^{-1}), and four N doses (70, 100, 130, and 160% of the dose recommended for greenhouse experiments (SOUZA et al., 2016)) that corresponded, respectively, to 378.7, 541.1, 703.4, and 865.7 mg of N dm^{-3} of soil. Each pot had three replicates with one plant per plot.

Solutions with different ECw levels were obtained by dissolving NaCl in water from the local supply system (ECw=0.3 dS m^{-1}), and the quantity (C) was determined based on the empirical equation proposed by Rhoades, Kandiah and Mashali (2000): C (mg L^{-1})=640 x ECw (dS m^{-1}), where ECw represents the pre-established ECw value minus the EC of the water used in the preparation.

Rootstocks were grown from 'Crioula' guava seeds from a commercial orchard at the *Mocó Agropecuário* Farm, in the municipality of Aparecida, PB. The 'Paluma' cultivar was used as a scion because it is a vigorous genotype, with easy propagation, high tolerance to pests and diseases, especially rust (*Puccinia psidii Wint.*) (MANICA et al., 2001), and is readily available in Brazil. In addition, there is a lack of studies evaluating its tolerance to salinity and doses of N (DIAS et al., 2012).

The soil had the following characteristics: pH (soil:water, 1:2.5)=7.41; ECse (dS m^{-1})=1.21; P (mg dm^{-3})=17; exchangeable Ca, Mg, Na, K ($cmol_c$ dm^{-3})=5.4, 4.1, 2.21, and 0.28, respectively. Organic matter, OM (g kg^{-1})=32; base saturation, V (%)=27; apparent density, Da (kg dm^{-3})=1.3; and total porosity, Pt (%)=47. Cultivation practices involved weeding, ridging, scarification, pruning, training, and phytosanitary treatment (sprayings to prevent and control fruit flies (*Anastrepha* spp. and *Ceratitis capitate*), bugs (*Monalonion annulipes*, *Leptoglossus gonagra*, *L. stigma*, *L. zonatus*, *L. fasciatus*, and *Holhymenia clavigera*), and guava psyllids (*Triozoida limbata*)) were conducted according to necessities.

The lysimeters were plastic polyethylene boxes with a top diameter of 0.87 m, a height of 0.43 m, and a 150 L capacity, perforated at the bottom to allow free drainage. They were filled with a substrate composed of Fluvic Neosol (85%) and sand (15%). The soil material was irrigated to field capacity using water with an ECw of 0.3 dS m^{-1}. Once the grafted seedlings of guava, cv. ‘Paluma’, had four pairs of true leaves, they were transplanted to the lysimeters.

Treatment application began at 15 days after transplantation (DAT) and irrigation with the saline solutions was performed according to each treatment. Irrigation in each treatment was based on plant water requirement that was determined by the difference between the applied volume and the volume drained in the previous irrigation, estimated by drainage lysimetry, maintaining soil moisture close to field capacity. Irrigations were carried out twice a day, in the early morning and late afternoon. The water volume applied by irrigation from 40 DAT on, was adjusted to provide the soil with a leaching fraction of 0.15 to avoid excessive accumulation of salts in the soil.

The fertilizer was applied manually at planting to each lysimeter, and contained 189.5 g of single superphosphate (a single dose at planting) and 17.28 g of potassium chloride, split as follows: 1/3 of the recommended dose applied at planting and 2/3 divided into two equal applications at 30 and 60 DAT.

Nitrogen fertilization began at 25 DAT, with 28 weekly applications. 1/5 of the dose was applied in the first 8 weeks as the root system occupied a small volume inside the lysimeter, The rest of the N was equally applied over the following 20 weeks. Urea (45% N) was used as the N source, and was applied via fertigation using 0.3 dS m^{-1} water for all treatments.

Plant growth was evaluated at 255 and 300 DAT based on the number of leaves (NL), number of branches (NB), stem diameter (SD), and absolute (AGR_{SD}) and relative (RGR_{SD}) growth rates of the stem diameter (from 255 to 300 DAT).

Number of leaves was determined by counting the leaves, considering only those with a fully expanded leaf blade, and NB was counted simultaneously. SD was measured with a digital caliper at 5 cm from the base.

AGR_{SD} and RGR_{SD} growth rates of SD were calculated using the methodology proposed by Taiz and Zeiger (2013), as described in Equations 1 and 2:

$$\mathrm{AGR}_{SD} = \frac{(\mathrm{A}_2 - \mathrm{A}_1)}{(\mathrm{t}_2 - \mathrm{t}_1)} (mm\ day^{-1} \tag{1}$$

where AGR_{SD}=absolute growth rate, A_2=plant growth at time t_2, A_1=plant growth at time t_1, and $t_2 - t_1$=time difference between measurements.

RGR_{SD} values were obtained using Equation 2, which allowed determination of plant growth according to the pre-existing biomass, adapting it to plant diameter.

$$\mathrm{RGR}_{SD} = \frac{(\ln \mathrm{A}_2 - \ln \mathrm{A}_1)}{(\mathrm{t}_2 - \mathrm{t}_1)} \ (mm\ mm^{-1} day^{-1}) \tag{2}$$

where RGR_{SD}=relative growth rate, A_2=plant growth at time t_2, A_1=plant growth at time t_1, $t_2 - t_1$=time difference between measurements, and ln=natural logarithm.

At 255 and 300 DAT, leaf gas exchanges (stomatal conductance (*gs*), internal CO_2 concentration (*Ci*), transpiration (*E*), and CO_2 assimilation rate (*A*) were measured using a portable IRGA, model LCPro+, manufactured by ADC BioScientific. All measurements were taken in fully expanded mature leaves (the third leaf from the apex). Readings were taken between 08:00 and 10:00, using an artificial radiation source with 1200 μmol m^{-2} s^{-1} intensity, at room temperature and CO_2 concentration. Photosynthesis and transpiration data were used to calculate the instantaneous water use efficiency, WUEi (SILVA et al., 2014).

The obtained data were subjected to analysis of variance using the F test at 0.05 and 0.01 probability levels. In cases of significance, a polynomial regression analysis was carried out using the SISVAR software program (FERREIRA, 2011).

RESULTS AND DISCUSSION

According to the results of the F test (Table 1), irrigation water salinity levels (S) had a significant effect on *gs*, *Ci*, *A*, *E*, and instantaneous water use efficiency of the guava plants. Nitrogen doses (ND) and the interaction between water salinity and nitrogen doses (S x ND) had no significant effect on any of the variables studied.

Table 1. Summary of the F test for stomatal conductance (*gs*), internal CO_2 concentration (*Ci*), CO_2 assimilation rate (*A*), transpiration (*E*), and instantaneous water use efficiency (WUEi), at 255 and 300 days after transplanting (DAT), of the guava cv. ‘Paluma’ under different levels of irrigation water salinity and nitrogen doses.

Source of variation	F Test									
	gs		*Ci*		*A*		*E*		WUEi	
	Days after transplanting - DAT									
	255	300	255	300	255	300[2]	255[1]	300	255	300[2]
Salinity (S)	**	**	**	**	**	**	**	**	*	**
Linear Reg.	**	**	**	**	**	**	**	**	*	**
Quadratic Reg.	ns	ns	ns	**	ns	**	ns	ns	ns	ns
N dose (ND)	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Linear Reg.	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Quadratic Reg.	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Interaction (SxND)	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Blocks	ns	ns	ns	ns	*	ns	ns	ns	ns	ns
CV(%)	27.37	25.75	14.34	17.39	24.43	15.82	12.74	5.56	24.11	16.71

** and * indicate significance at 0.01 and 0.05 probability levels using the F test; [ns] indicates no significance using the F test; and [1,2] statistical analysis performed after data were transformed to $\sqrt{x+1}$ and $\sqrt{x}$, respectively.

Increasing the electrical conductivity of the irrigation water, led to a linear reduction in the *gs* of guava plants (Figure 2A), equal to a 17.43% per unit increase in ECw at 255 DAT. According to the regression equation, plants subjected to irrigation with an ECw of 3.5 dS m^{-1} showed a reduction in *gs* of 0.033 mol H_2O m^{-2} s^{-1}, compared with those with an ECw of less than 0.3 dS m^{-1}. At 300 DAT, a quadratic response was observed (Figure 2A), and the maximum estimated value (0.152 mol H_2O m^{-2} s^{-1}) was found at a salinity level of 0.3 dS m^{-1}. Silva et al. (2013) claim that plants close their stomata to reduce water loss through transpiration, resulting in a lower photosynthetic rate, which is one of the main causes of reduced growth in species subjected to saline stress.

According to the regression equations, *Ci* linearly decreases with the increment in irrigation water salinity (10.76 and 13.46% per unit increases in ECw (Figure 2B), at 255 and 300 DAT, respectively). Maximum values of 240.53 mmol m^{-2} s^{-1} and 347.54 mmol m^{-2} s^{-1} were observed in plants irrigated with 0.3 dS m^{-1} water. These values represent reductions of 35.60% (255 DAT) and 44.91% (300 DAT) in the *Ci* of plants irrigated with the highest levels of salinity, compared with those subjected to the lowest level of salinity. Such relative reductions in *Ci* may be attributed to the lower *gs*, a common response of plants to saline stress (PRAXEDES et al., 2010; SILVA et al., 2011).

For *A* at 255 DAT, gradual increments in irrigation water salinity led to a reduction of 18.35% per unit increase in ECw (Figure 2C), reaching a reduction of 62.15% (2.70 µmol m^{-2} s^{-1}) in the *A* of plants irrigated with maximum water salinity (3.5 dS m^{-1}) compared with the minimum ECw level (0.3 dS m^{-1}). At 300 DAT, the data fitted best to a quadratic equation (Figure 2C), and *A* reached its highest value of 3.69 µmol m^{-2} s^{-1} at the ECw level of 0.3 dS m^{-1}. Amorim et al. (2010) found that cashew plants under saline stress had lower values of *A* and verified that this was caused by the reduction in stomatal opening, which was also observed in this study. Therefore, it can be inferred that the saline treatments caused stress to the plants, and may have stimulated stomatal closure. However, prolonged exposure to salts led to alterations in plant water status, inducing stomatal closure, and consequently limiting CO_2 entry. Additionally, high concentrations of ions such as Na^+ and Cl^- are the main causes of damage to the structures of enzymes and membranes, indirectly interfering with *A* (SILVA et al., 2011).

Based on Figure 2D, transpiration at 255 and 300 DAT was negatively affected by the increase in irrigation water salinity, with reductions of 14.80 and 3.62% per unit increase in ECw. In other words, plants irrigated with 3.5 dS m^{-1} water showed a reduction in *E* of 49.57% (0.696 mol m^{-2} s^{-1}) and 11.72% (0.179 mol m^{-2} s^{-1}), respectively, in comparison to plants that received 0.3 dS m^{-1} water. The reduction in plant transpiration observed as water salinity increased, was due to the osmotic effect of the salts around the roots and the possible accumulation of potentially toxic ions (Na^+ and Cl^-) in the leaf tissues. Consequently, the plant began to exert greater control over stomatal opening to avoid excessive water loss through transpiration (SOUZA et al., 2011).

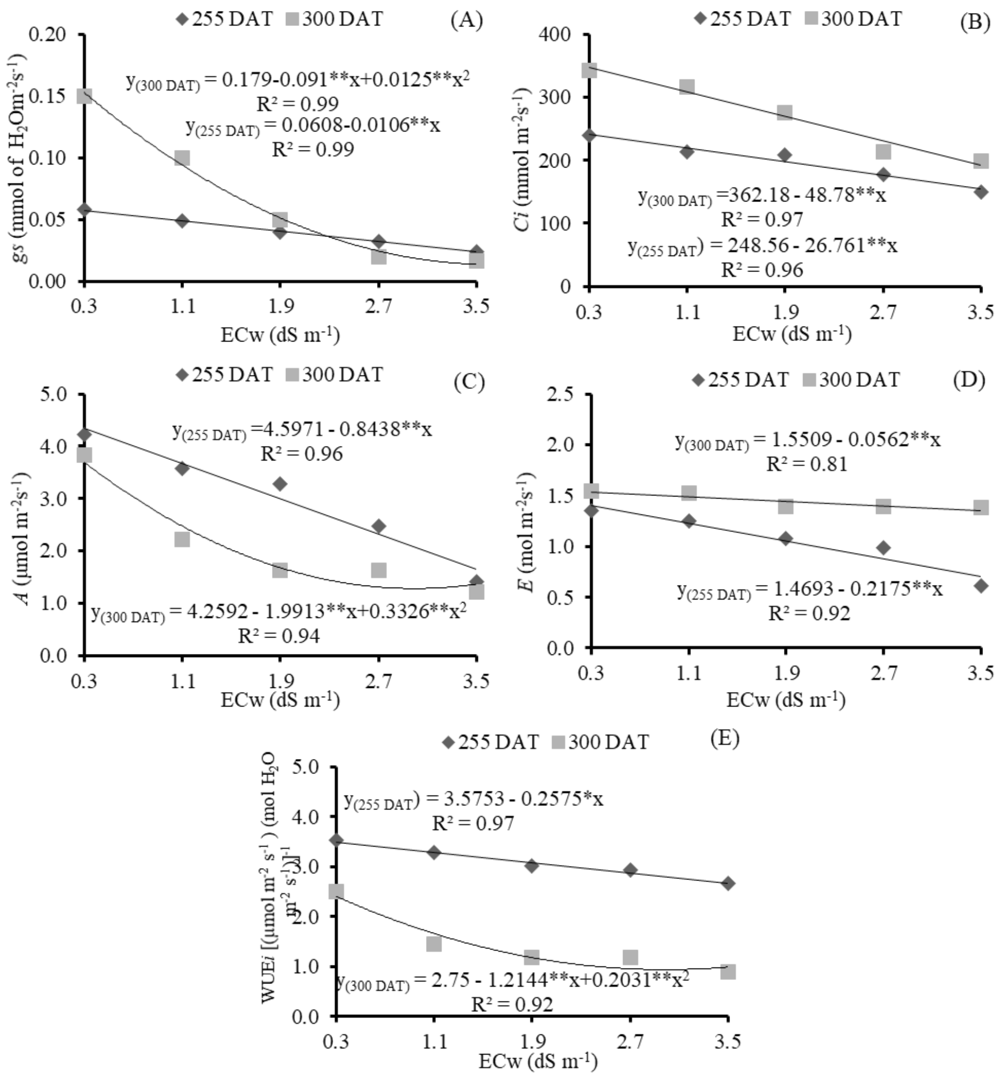

Figure 2. Stomatal conductance - *gs* (A), internal CO_2 concentration - *Ci* (B), CO_2 assimilation rate - *A* (C), transpiration - *E* (D) and instantaneous water use efficiency - WUEi (E), at 255 and 300 days after transplanting (DAT), of the guava cv. ‘Paluma’, cultivated under different levels of irrigation water electrical conductivity (ECw).

Instantaneous water use efficiency (WUEi) was also negatively and linearly affected by irrigation water salinity at 255 DAT and, according to the regression equation (Figure 2E), WUEi linearly decreased by 7.20% per unit increase in ECw. Plants irrigated with 3.5 dS m^{-1} water showed a reduction in WUEi of 23.55% [(0.824 µmol m^{-2} s^{-1}) (mol H_2O m^{-2} $s^{-1})^{-1}$] in comparison to those irrigated with 0.3 dS m^{-1} water. In addition, at 300 DAT (Figure 1), WUEi was also negatively affected by ECw and, according to the regression equation, the quadratic model indicated that plants subjected to irrigation with ECw of 0.3 dS m^{-1} exhibited the highest values for WUEi [(2.40 µmol m^{-2} s^{-1}) (mol H_2O m^{-2} $s^{-1})^{-1}$], whereas plants irrigated with 3.5 dS m^{-1} water showed the lowest values for WUEi [(0.98 µmol m^{-2} s^{-1}) (mol H_2O m^{-2} $s^{-1})^{-1}$]. There was a reduction in WUEi [(1.42 µmol m^{-2} s^{-1}) (mol H_2O m^{-2} $s^{-1})^{-1}$] between the highest (3.5 dS m^{-1}) and lowest (0.3 dS m^{-1}) levels of irrigation water salinity. These results may be associated with osmotic adjustment, i.e., a reduction in cell osmotic potential caused by the accumulation of organic solutes, which contributes to maintaining water absorption and cell turgor that allows the interruption of physiological processes, such as stomatal opening, photosynthesis and cell expansion (SERRAJ; SINCLAIR, 2002).

According to the results of the F test (Table 2), irrigation water salinity levels (S) had a significant effect on all variables studied at 255 and 300 DAT. Nitrogen doses (ND) and the interaction S x ND had no significant effect on any of the variables analyzed.

Table 2. Summary of the results of the F test for number of leaves (NL), number of branches (NB), stem diameter (SD), and absolute (AGR_{SD}) and relative (RGR_{SD}) growth rates of stem diameter, at 255 and 300 days after transplanting of the guava cv. ‘Paluma’, under different levels of irrigation water salinity and nitrogen doses.

Source of variation	F Test							
	NL		NB		SD		AGR_{SD}	RGR_{SD}
	Days after transplanting - DAT							
	255	300	255	300	255	300	255-300	255-300
Salinity (S)	**	**	**	**	**	**	**	*
Linear Reg.	**	**	**	**	**	**	**	**
Quadratic Reg.	ns	ns	ns	ns	ns	ns	ns	ns
N dose (ND)	ns	ns	ns	ns	ns	ns	ns	ns
Linear Reg.	ns	ns	ns	ns	ns	ns	ns	ns
Quadratic Reg.	ns	ns	ns	ns	ns	ns	ns	ns
Interaction (SxND)	ns	ns	ns	ns	ns	ns	ns	ns
Blocks	ns	ns	ns	n	ns	ns	ns	ns
CV (%)	26.97	17.20	31.02	32.25	12.43	9.82	29.73	33.53

ns, **, * denote not significant, significant at $p<0.01$, and significant at $p<0.05$, respectively.

The number of leaves was linearly and negatively affected by water salinity (Figure 3A), with relative reductions of 10.68% (255 DAT) and 15.26% (300 DAT) per unit increase in ECw. Plants irrigated with water with an ECw of 3.5 dS m^{-1} showed reductions of 35.31% (165.98 leaves) and 51.18% (415.96 leaves) , respectively, in comparison to those subjected to water with an ECw of 0.3 dS m^{-1}. When subjected to saline stress, plants commonly exhibit morphological and anatomical alterations such as reduction in the number of leaves, which lead to reductions in transpiration to maintain the low rate of saline water absorption (OLIVEIRA et al., 2013).

Similar behavior was observed for the number of branches of the guava cv. ‘Paluma’, which decreased linearly as irrigation water salinity increased. According to the regression equations (Figure 3B), there were relative reductions in the NB of 12.87 (255 DAT) and 10.83% (300 DAT) per unit increase in ECw, leading to decreases of 42.86 and 35.82%, respectively, in plants irrigated with the highest ECw level (3.5 dS m^{-1}), in comparison to those with ECw of 0.3 dS m^{-1}. With regards to the effects of salinity on stem diameter at 255 and 300 DAT (Figure 3C), increments in water salinity led to linear reductions of 5.54 and 6.06% per unit increase in ECw, i.e., reductions of 4.60 mm (18.05%) and 5.35 mm (19.75%) in the SD of guava plants subjected to the highest level of salinity (3.5 dS m^{-1}) compared with those irrigated with 0.3 dS m^{-1} water, respectively.

Irrigation water salinity negatively affects plant growth, due to the specific effects of the ions and the osmotic effect that delay cell expansion and division, leading to negative consequences for photosynthetic rate, and damaging the plants’ physiological and biochemical processes (GOMES et al., 2011; NUNES et al., 2012). Consequently, it causes a reduction in SD.

Increase in irrigation water salinity had a negative effect (Figure 3D) on the absolute growth rate of the stem diameter from 255 to 300 DAT, with a relative reduction of 13.72% per unit increase in ECw, corresponding to a reduction of 45.85% (0.0156 mm day^{-1}) in the AGR_{SD} of plants irrigated using water with an ECw of 3.5 dS m^{-1}, in comparison to those subjected to water with an ECw of 0.3 dS m^{-1}. The reduction in AGR_{SD} due to saline stress, is probably related to the use of energy substrates responsible for plant growth in the synthesis of organic solutes, to allow for osmotic adjustment (MUNNS, 2005).

Like the trend observed for AGR_{SD}, RGR_{SD} was also affected by saline stress ($p<0.01$) from 255 to 300 DAT (Table 2). RGR_{SD} decreased linearly by 7.69% per unit increase in ECw (Figure 3E), a reduction of 0.00032 mm mm^{-1} day^{-1} (25.19%) in the RGR_{SD} of plants irrigated with 3.5 dS m^{-1} water in comparison to those irrigated with 0.3 dS m^{-1} water. According to Sousa, Bezerra and Farias (2011), these reductions are related to the decrease in water availability or excessive accumulation of Na^{+} and Cl^{-} in plant tissues, which affect physiological processes that are essential to plants.

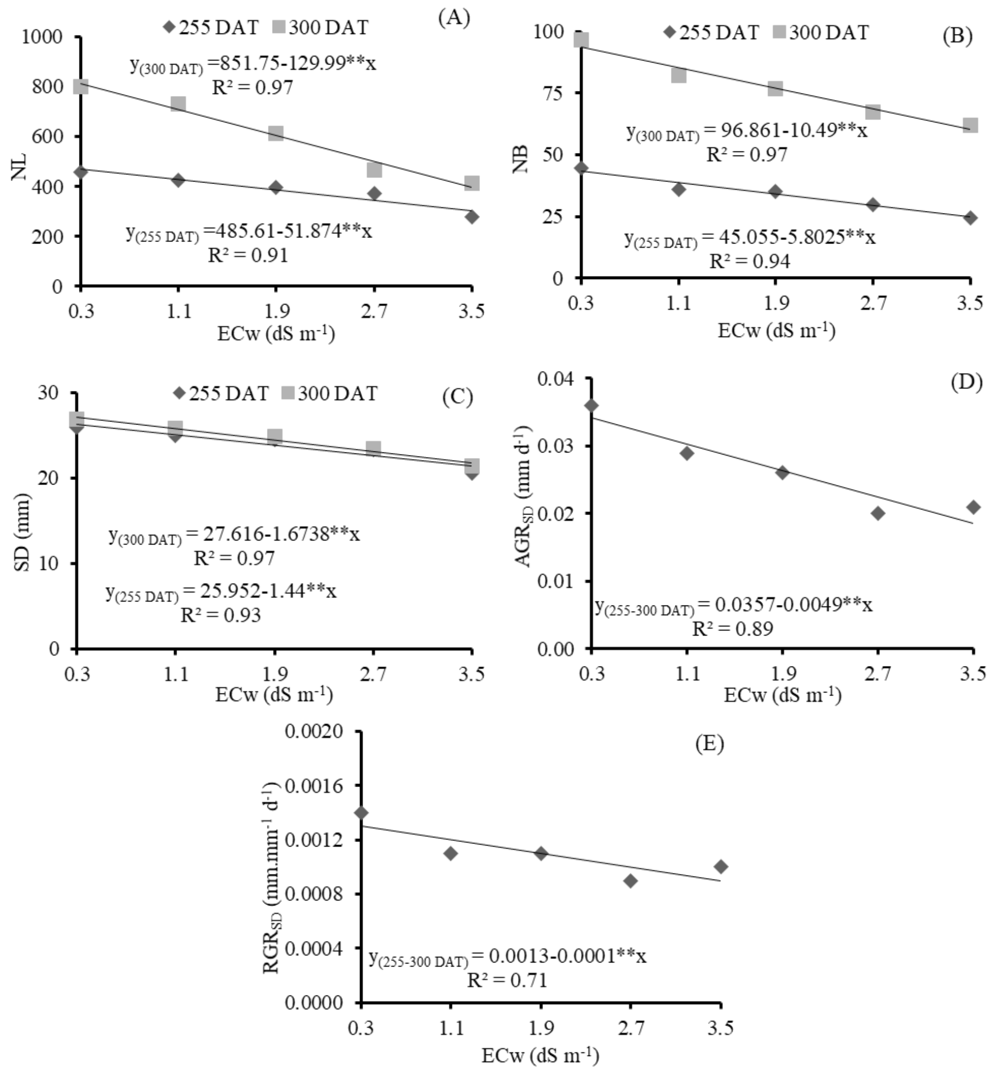

Figure 3. Number of leaves - NL (A), number of branches - NB (B), and stem diameter - SD (C), at 255 and 300 days after transplanting (DAT); and absolute growth rate – AGR_{SD} (D), and relative growth rate - RGR_{SD} (E), from 255 to 300 DAT in the guava cv. ‘Paluma’, cultivated under different levels of irrigation water salinity.

CONCLUSIONS

Irrigation using water with an ECw above 0.3 dS m^{-1}, negatively affects the internal CO_2 concentration, stomatal conductance, CO_2 assimilation rate, transpiration, and instantaneous water use efficiency, as well as number of leaves and branches, stem diameter and absolute and relative growth rates of guava, cv. ‘Paluma’, at 255 and 300 DAT. Guava plants, cv. ‘Paluma’, can be irrigated using water with an ECw of up to 1.42 dS m^{-1}, with an acceptable reduction of 10% in its growth variables. Nitrogen doses neither mitigated the effects of irrigation water salinity nor had significant effects on the studied variables. Guava plants were not significantly affected by the interaction between irrigation water salinity and nitrogen doses.

ACKNOWLEDGMENTS

The authors thank the National Council for Scientific and Technological Development (CNPq) for the financial support to the research and the Coordination for the Improvement of Higher Education Personnel (CAPES/FAPERO) for granting the scholarship to the first author.

REFERENCES

AMORIM, A. V. et al. Respostas fisiológicas de plantas adultas de cajueiro anão precoce à salinidade. **Revista Ciência Agronômica**, Fortaleza, v. 41, n. 1, p. 113-121, 2010.

BENINCASA, M. M. P. **Análise de crescimento de plantas**: noções básicas. 2. ed. Jaboticabal, SP: FUNEP, 2003. 42 p.

CAVALCANTE, L. F. et al. Crescimento de mudas de maracujazeiro amarelo em solo salino com esterco bovino líquido fermentado. **Revista Brasileira de Ciências Agrárias**, Recife, v. 4, n. 4, p. 414-420, 2009.

DIAS, M. J. T. et al. Adubação com nitrogênio e potássio em mudas de goiabeira em viveiro comercial. **Ciências Agrárias**, Londrina, v. 33, Sup., p. 2837-2848, 2012.

DIAS, T. J. et al. Produção do maracujazeiro e resistência mecânica do solo com biofertilizante sob irrigação com águas salinas. **Revista Ciência Agronômica**, Fortaleza, v. 42, n. 3, p. 644-651, 2011.

FERREIRA, D. F. Sisvar: um sistema computacional de análise estatística. **Ciência e Agrotecnologia**, Lavras, v. 35, n. 6, p. 1039-1042, 2011.

FREIRE, J. L. O. et al. Rendimento quântico e trocas gasosas em maracujazeiro amarelo sob salinidade hídrica, biofertilização e cobertura morta. **Revista Ciência Agronômica**, Fortaleza, v. 45, n. 1, p. 1-10, 2014.

GOMES, K. R. et al. Respostas de crescimento e fisiologia do milho submetido a estresse salino com diferentes espaçamentos de cultivo. **Revista Brasileira de Engenharia Agrícola e Ambiental**, Campina Grande, v. 15, n. 4, p. 365-370, 2011.

HUNT, D. F. Measurements of photosynthesis and respiration in plants. **Physiologia Plantarum**, Copenhagen, v. 117, n. 3, p. 314-325, 2003.

MANICA, I. et al. **Goiaba: do plantio ao consumidor. Tecnologia de produção, pós-colheita, comercialização**. 1. ed. Porto Alegre, RS: Cinco Continentes, 2001. 119 p.

MUNNS, R. Genes and salt tolerance: Bringing them together. **New Phytologist**, Cambridge, v. 167, n. 3, p. 645-663, 2005.

NEVES, A. L. R. et al. Trocas gasosas e teores de minerais no feijão-de-corda irrigado com água salina em diferentes estádios. **Revista Brasileira de Engenharia Agrícola e Ambiental**, Campina Grande, v. 13, Sup., p. 873-881, 2009.

NUNES, J. C. et al. Comportamento de mudas de nim à salinidade da água em solo não salino com biofertilizante. **Revista Brasileira de Engenharia Agrícola e Ambiental**, Campina Grande, v. 16, n. 11, p. 1152-1158, 2012.

OLIVEIRA, F. A. et al. Interação entre salinidade e bioestimulante na cultura do feijão caupi. **Revista Brasileira de Engenharia Agrícola e Ambiental**, Campina Grande, v. 17, n. 5, p. 465-471, 2013.

OLIVEIRA, F. T. et al. Respostas de porta-enxertos de goiabeira sob diferentes fontes e proporções de materiais orgânicos. **Comunicata Scientiae**, Bom Jesus, v. 6, n. 1, p. 17-25, 2015.

PARIDA, A. K.; DAS, A. B. Salt tolerance and salinity effects on plants: A review. **Ecotoxicology and Environmental Safety**, New York, v. 60, n. 3, p. 324-349, 2005.

PRAXEDES, S. C. et al. Salt tolerance is associated with differences in ion accumulation, biomass allocation and photosynthesis in cowpea cultivars. **Journal of Agronomy and Crop Science**, Madison, v. 196, n. 3, p. 193-204, 2010.

RAMOS, D. P. et al. Produção e qualidade de frutos da goiabeira 'Paluma', submetida à diferentes épocas de poda em clima subtropical. **Revista Ceres**, Viçosa, v. 57, n. 5, p. 659-664, 2010.

RHOADES, J. D.; KANDIAH, A.; MASHALI, A. M. **Uso de águas salinas para produção agrícola**. 1. ed. Campina Grande: UFPB, 2000. 117 p. (Estudos da FAO. Irrigação e Drenagem, 48).

SERRAJ, R.; SINCLAIR, T. R. Osmolyte accumulation: Can it really help increase crop yield under drought conditions? **Plant Cell and Environment**, Oxford, v. 25, n. 2, p. 333-341. 2002.

SILVA, F. L. B. et al. Interação entre salinidade e biofertilizante bovino na cultura do feijão-de-corda. **Revista Brasileira de Engenharia Agrícola e Ambiental**, Campina Grande, v. 15, n. 4, p. 383–389, 2011.

SILVA, F. L. B. et al. Irrigação com águas salinas e uso de biofertilizante bovino nas trocas gasosas e produtividade de feijão-de-corda. **Irriga**, Botucatu, v. 18, n. 2, p. 304-317, 2013.

SILVA, M. A. et al. Pigmentos fotossintéticos e índice Spad como descritores de intensidade do estresse por deficiência hídrica em cana-de-açúcar. **Bioscience Journal**, Uberlândia, v. 30, n. 1, p. 173-181. 2014.

SOUSA, A. B. O.; BEZERRA, M. A.; FARIAS, F. C. Desenvolvimento inicial do clone BRS 275 de cajueiro sob irrigação com diferentes níveis salinos. **Revista Brasileira de Agricultura Irrigada**, Fortaleza, v. 4, n. 3, p. 166-171, 2011.

SOUZA, L. P. et al. Formation of 'Crioula' guava rootstock under saline water irrigation and nitrogen doses. **Revista Brasileira de Engenharia Agrícola**

e Ambiental, Campina Grande, v. 20, n. 8, p. 739-745, 2016.

SOUZA, R. P. et al. Fotossíntese e acúmulo de solutos em feijoeiro caupi submetido à salinidade. **Pesquisa Agropecuária Brasileira**, Brasília, v. 46, n. 6, p. 587-592, 2011.

TAIZ, L.; ZEIGER, E. **Fisiologia vegetal**. 5. ed. Porto Alegre, RS: Artmed. 2013. 954 p.