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Physiology and growth of cashew 'anão precoce' (*Anacardium occidentale* L.) subjected to salt stress and organic fertilization

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Abstract

Cultivation of cashew in the semi-arid region of Northeast Brazil is pivotal for the generation of jobs and income. However, agricultural production in this region has been compromised by water and soil salinity. Therefore, it is necessary to look for alternatives that minimize the effects of salt stress on cashew cultivation in this region. In this context, this study aimed to evaluate gas exchanges, photochemical efficiency and growth of cashew 'anão precoce' cv. BRS 226 Planalto' irrigated with water containing different salinity levels and under organic fertilizer doses. The experiment was carried out in drainage lysimeters in a greenhouse, using a randomized block design in 5 x 4 factorial scheme with three replicates. Treatments corresponded to five levels of irrigation water electrical conductivity – ECw (0.7, 1.4, 2.1, 2.8 and 3.5 dS m^{-1}) and four doses of organic fertilization (2.5, 3.5, 4.5 and 5.5%). Organic fertilizer doses were determined on the basis of soil volume. Bovine manure was used as source of organic fertilizer. The fertilizer was decomposed and applied in the soil before planting. Irrigation water salinity from 0.7 dS m^{-1} caused increase in the internal CO_2 concentration and reduction in CO_2 assimilation rate, transpiration and stomatal conductance of cashew 'anão precoce' plants, 126 days after transplantation. The results showed that chlorophyll *a* fluorescence and the absolute and relative growth rates were influenced by the increase of salinity in irrigation water. Organic fertilization had negative influence on gas exchanges, chlorophyll *a* fluorescence and growth of cashew 'anão precoce' in the post-grafting stage.

Keywords: *Anacardium occidentale* L., salt stress, bovine manure.
Abbreviations: *gs*_stomatal conductance; *E*_transpiration; *A*_CO_2 assimilation rate, *Ci*_internal CO_2 concentration; EICI_ instantaneous carboxylation efficiency; WUE_instantaneous water use efficiency; Fo_initial fluorescence; Fm_maximum fluorescence; Fv_ variable fluorescence; Fv/Fm_maximum quantum efficiency of photosystem II; ECw_electrical conductivity of the irrigation water.

Introduction

Cashew (*Anacardium occidentale* L.) is considered as one of the most important cultivated species of the tropical regions, occupying an estimated area of 3.39 million hectares in the world. Its main products of economic importance are the edible nut and liquid from the nutshell (Oliveira, 2008). In this context, global cashew nut production is approximately 3.7 million tons and the main producers are: Vietnam, India, Nigeria, Ivory Coast and Brazil (FAO, 2009). Brazil is considered as the largest cashew producer in the world but its yield is low, approximately 300 kg ha^{-1} (IBGE, 2013). The cashew 'anão precoce' is characterized by low plant size, mean height of 2.11 m and mean diameter of the crown of 4.52 m in the sixth year of age. These characteristics are peculiar to the type of cashew 'anão precoce'. The agro-industrial indicators are weight of the nut of 6.4 g, degummed almond with average of 1.6 g with natural humidity, the ratio almond/bark of 25.5%. For the peduncle, the agro-industrial indicators are average weight of 76.5 g and yellow coloration (Paiva and Barros, 2004). According to Véras et al. (2014), cashew is native to Northeast Brazil and its cultivation is a source of income for farmers in the states of Ceará, Rio Grande do Norte and Piauí due to its adaptation to the edaphoclimatic conditions of this region. However, the producing states are located in areas subject to saline soils and water (Ferreira-Silva et al., 2009). According to Viégas et al. (2001), salinity can be aggravated by other environmental stress factors in semi-arid regions, including low water availability, high temperatures and high evapotranspiration. As an aggravating factor, the excess of salts may disturb plant physiological and biochemical functions, causing osmotic stress, which leads to disorders in water relationships, alterations in the absorption and use of essential nutrients, besides the accumulation of toxic ions (Torres et al., 2014). However, the degree of severity, with which these components influence plant development, depends on many factors, such as species, cultivar, phenological stage, saline composition of the medium, stress intensity and duration, edaphoclimatic conditions and irrigation management (Gheyi et al., 2005).

Ferreira-Silva et al. (2009) reported that, although cashew is cultivated under semi-arid conditions and exhibits moderate resistance to salinity, various studies demonstrate that salt stress severely affects the stages of germination (Voigt et al., 2009), initial growth (Ferreira-Silva et al., 2008), grafting (Bezerra et al., 2002) and pre-flowering (Carneiro et al., 2007), besides inducing metabolic disorders related to the mobilization of reserves (Voigt et al., 2009), photosynthesis (Bezerra et al., 2007), nitrogen metabolism (Viégas et al., 2004) and ionic homeostasis (Viégas et al., 2001). However, there are no studies reporting the effects of salt stress on photosynthesis, photochemical efficiency of cashew plants yet. In addition, there are also no reports on the use of technologies that increase plant tolerance to salinity or decrease its effects on the cashew crop.

There is also the importance of organic fertilization as an essential factor for crop development in soils with low fertility, especially in commercial production, because of the need to improve product's quality and meet consumers demands (Abreu et al., 2005). Organic fertilizers also mitigate the deleterious effects of salts on plants due to the positive action on soil physical characteristics and plant root environment. Some studies conducted on other crops such as sweet passion fruit (Damatto Junior et al., 2005), watermelon (Cavalcante et al., 2010), sugar apple (Cavalcante et al., 2012), guava (Oliveira et al. (2014), melon (Ribeiro et al., 2014) and cashew (Melo Filho et al., 2015). These authors have already reported the beneficial effects of organic application on plant growth and development.

Given the above and considering the socioeconomic importance of peanut in the Northeast Brazil, it is of great relevance to conduct studies that enable cashew 'anão precoce' cultivation under saline conditions, through the identification of irrigation water salinity levels can be tolerated by the crop and amount of organic matter to be supplied to meet its nutritional needs and act as attenuator of the stress caused by salts in excess. Therefore, this study aimed to evaluate gas exchanges, photochemical efficiency and growth of cashew 'anão precoce' cv. BRS 226 Planalto' irrigated with water with different salinity levels and under organic fertilizer doses.

Results and Discussion

Effect of saline stress and organic fertilization on cashew 'anão precoce' gas exchanges

According to the summary of analysis of variance (Table 1), irrigation with saline water and organic fertilizer doses had significant influence on gas exchange variables at 126 DAT. Significant interaction between the factors "Salinity levels x Organic fertilizer doses" occurred only for stomatal conductance.

Irrigation with water of increasing salinity levels influenced the analyzed variables of gas exchange (Table 1). According to the regression equation for *Ci* (Fig 1A), there was an increasing linear response with increments of 10.47% per unit increase in irrigation water electrical conductivity. For example, plants irrigated with water of 3.5 dS m^{-1} showed increase of 26.46 μmol m^{-2} s^{-1} in *Ci* compared with those receiving 0.7 dS m^{-1} water. Pereira et al. (2004) pointed out that this type of behavior demonstrates the occurrence of not only damage to the photosynthetic apparatus in the carboxylation stage, but also increase in the photorespiration process, since the Ribulose-1,5-bisphosphate carboxylase oxygenase (RuBisCO) catalyzes the first step of this route. Grassi and Magnani (2005) attribute such increment to non-stomatal factors such as reduction in RuBisCO activity and concentration, photo-inhibition, electron transfer rate and reduction in the photochemical efficiency of PSII, which may compromise photosynthesis.

In study with cashew 'anão precoce' seedlings subjected to salt stress, Silva (2016) found 45.26% increase of *Ci* in the clone CCP 76 at the NaCl concentration of 100 mmol and 7.14% increase in CCP 09, at the same concentration, compared with the respective controls (0 mmol of NaCl in nutrient solution). In studies on yellow passion fruit, Freire et al. (2014) also found increment in *Ci* with progressive increase in water salinity, which was equal to 13.2%, with values of 229.4 μmol mol^{-1} in plants irrigated with 0.5 dS m^{-1} water and 259.7 μmol mol^{-1} in plants under salt stress. According to these authors, that was a consequence of the negative effects of excessive salinity on plant carbon metabolism.

Using water with increasing salinity levels also negatively affected the CO_2 assimilation rate (*A*), transpiration (*E*) and stomatal conductance (*gs*) of cashew 'anão precoce. According to the regression equations (Fig 1B, 1C and 1D), there was a decreasing linear response per unit increase in irrigation water electrical conductivity, with reductions of 12.61, 7.88 and 9.35%, respectively. Reductions of 38.73, 23.35 and 28.0% were found between plants irrigated with 3.5 dS m^{-1} water and those irrigated with 0.7 dS m^{-1} water. Such reduction in the CO_2 assimilation rate, transpiration and stomatal conductance (g*s*) found in the present study may have been resulted from the osmotic effect caused by irrigation water salinity, because the high concentration of salts in the soil compromises water absorption by plant roots, causing reduction in stomatal opening to avoid water loss, consequently, decreasing transpiration and photosynthetic rate.

Neves et al. (2009) claimed that stomatal conductance may result from the osmotic effect, associated with the accumulation of salts in the soil, and also from the reduction in the root system hydraulic conductivity due to the increase of suberization and lignification of vascular tissues in the roots of plants under salt stress. Silva et al. (2011) reported that the decrease in transpiration can be partially caused by the toxic effects of the salts absorbed by plants, low capacity of osmotic adjustment by the crop and reduction of total water potential caused by the increase in saline concentration.

Bezerra et al. (2005), studied young cashew 'anão precoce' plants under salt stress and found linear reduction in the net photosynthesis, while irrigation water salinity levels increased. In a study of adult cashew 'anão precoce' plants irrigated with saline water, Guilherme et al. (2005) found that saline water irrigation did not affect gas exchanges and favored the vegetative growth of the adult plants. Similar results were also found by Bezerra et al. (2002), evaluating the photosynthesis of cashew 'anão precoce' irrigated with saline water. These authors found that salt stress did not alter net photosynthetic rate, stomatal conductance or transpiration and did not significantly affect the internal CO_2 concentration of cashew 'anão precoce' seedlings at any of the studied levels (ECw: 0.5, 1.0, 1.5, 2.0, 2.5 and 3.0 dS m^{-1}).
Application of increasing doses of organic fertilizer negatively affected CO_2 assimilation rate, transpiration and stomatal conductance (Table 2). According to the regression equations (Fig 2A, 2B and 2C), there was a decreasing linear response with reductions of 8.24, 8.49 and 9.99%, respectively, per unit increase in organic fertilizer doses, in which plants fertilized with 5.5% organic matter showed reductions of 31.09, 32.32 and 39.95%, respectively, compared to those fertilized with 2.5% organic matter. Different results were reported by Freire et al. (2014), who observed higher photosynthetic efficiency in yellow passion fruit, in the association of mulch, bovine biofertilizer and irrigation with low-salinity water.

These reductions in gas exchange variables (*A*, *E* and *gs*) may also have been caused by the quantity of manure applied to meet the doses of organic fertilizer. According to Freire and Freire (2007), addition of manure in inadequate amount may cause negative effect on plants due to the possibility of increase in salinity, and consequently, promoting nutritional imbalance in the crops.

Effect of saline stress and organic fertilization on cashew 'anão precoce' chlorophyll a fluorescence

According to Table 2, levels of salinity in irrigation water did not significantly influence the chlorophyll *a* fluorescence variables in cashew 'anão precoce'. However, the organic fertilizer doses had significant influence on maximum fluorescence (Fm), variable fluorescence (Fv) and quantum yield of photosystem II (Fv/Fm). The interaction between factors (SL x OM) did not affect any of the studied variables.
Increment in organic fertilizer doses negatively affected maximum fluorescence, variable fluorescence and quantum yield of photosystem II in cashew 'anão precoce' plants (Table 2). According to the regression equations (Fig 3A, 3B and 3C), there was a decreasing linear response per unit increase in organic fertilizer doses with reductions of 1.88, 2.96 and 1.27%, respectively. This means plants fertilized with 5.5% organic matter showed reductions of 5.91, 9.5 and 3.96% in maximum fluorescence, variable fluorescence and quantum yield of photosystem II, respectively, compared to plants fertilized with 2.5% organic matter. Different results were reported for yellow passion fruit by Freire et al. (2014), who found increase in quantum yield of photosystem II with the increment in organic fertilization, using bovine biofertilizer.

Effect of saline stress and organic fertilization on cashew 'anão precoce' growth

According to the summary of analysis of variance (Table 3), there was no significant effect of salinity levels on the growth rates evaluated in the period from 61 to 126 days after transplantation (DAT). The factor organic fertilizer doses had significant effect on all analyzed growth rates in this period. On the other hand, there was no significant interaction between the factors "Saline levels x Organic fertilizer doses" for any variable.

Application of increasing doses of organic fertilizer negatively influenced the analyzed growth rates (Table 3). According to the regression equation (Fig 4A), AGR-RSD showed a decreasing linear response, in which reduction of approximately 8.98% per unit increase in organic fertilizer doses was observed. This means that plants subjected to fertilization with 5.5% organic matter showed reduction of 34.76% in AGR-RSD, compared to those fertilized with 2.5% organic matter.

For the RGR-RSD, the regression equation (Fig 4B) showed a decreasing linear response, with reductions of 1.21% per unit increase in organic fertilizer doses. This means that plants fertilized with 5.5% organic matter showed reduction of 3.74% in RGR-RSD, compared with those fertilized with 2.5% organic matter. For AGR-SSD and RGR-SSD, the regression equations (Fig 4C and 4D) evidenced decreasing linear response, with reductions of approximately 10.08% and 2.15%, respectively, per unit increase in organic fertilizer doses, in which plants fertilized with 5.5% organic matter showed reductions of 40.4% and 6.81% in AGR-SSD and RGR-SSD, respectively, compared to plants fertilized with 2.5% organic matter.

For plant height, the regression equations (Fig 4E and 4F) evidenced decreasing linear responses in AGR-PH and RGR-PH with respective reductions of the order of 13.76 and 1.95% per unit increase in organic fertilizer doses, in which plants fertilized with 5.5% organic matter showed reductions of 41.25% and 6.13% in AGR-PH and RGR-PH, respectively, compared to those fertilized with 2.5% organic matter. Different results were found by Dias et al. (2013), who studied yellow passion fruit and observed beneficial action of bovine biofertilizer on plant vegetative growth. Similarly, Cavalcante et al. (2009), studied the guava cultivar 'Paluma', and found attenuating action of liquid bovine manure on the degenerative effects of salinity on plants. Bovine manure promoted increment in the analyzed growth variables.

As observed for gas exchange variables (*A*, *E* and *gs*) and chlorophyll *a* fluorescence variables (Fm, Fv, Fv/Fm), reduction in cashew 'anão precoce' growth due to the increase in organic fertilizer doses in both absolute and relative terms may be related to nutritional imbalance as explained by Freire and Freire (2007), since the reductions followed the same trend as in the previously cited variables.
According to Freire and Freire (2007) the addition of manure in inadequate amount may cause negative effect on plants, due to the possibility of increase in salinity and, consequently, promoting nutritional imbalance in the crop.

Table 1. Summary of analysis of variance for the variables internal CO_2 concentration (*Ci*), CO_2 assimilation rate (*A*), transpiration (*E*) and stomatal conductance (*gs*) of cashew 'anão precoce' irrigated with saline water and fertilized with organic matter, at 126 days after transplantation.

Source of Variation	DF	Mean square			
		Ci	*A*	*E*	*gs*
Saline levels (SL)	4	3939.316667*	9.622286**	0.387533*	0.001764**
OM doses (OM)	3	369.444444^{ns}	9.044667**	0.633404**	0.002624**
Interaction (SL) x (OM)	12	3166.027778^{ns}	3.474107^{ns}	0.084638^{ns}	0.000290^{ns}
Block	2	7891.216667^{ns}	0.461555^{ns}	1.160172^{ns}	0.000582^{ns}
Residual	38	1365.146491	0.956595	0.100684	0.000340
CV (%)		15.44	21.87	27.20	31.95

*Significant at 0.05 and at ** 0.01 probability levels; ^{ns} not significant, ^{a} data transformed to √x.

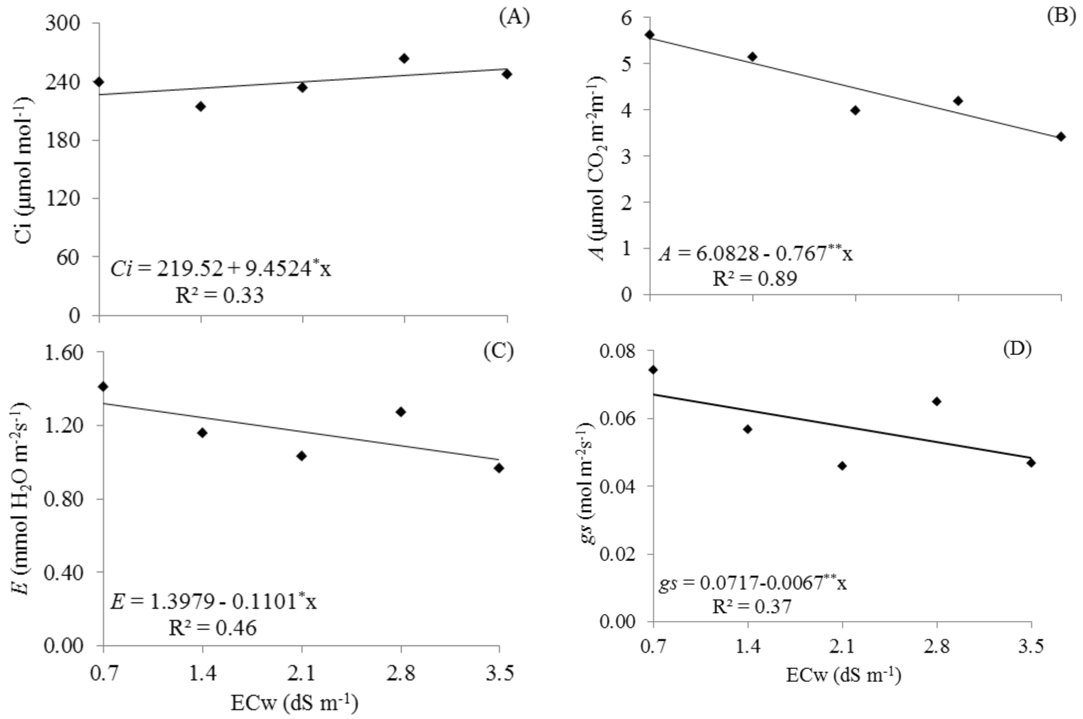

Fig 1. Internal CO_2 concentration - *Ci* (A), CO_2 assimilation rate - *A* (B), transpiration - *E* (C) and stomatal conductance - *gs* (D) of cashew 'anão precoce', as a function of irrigation water salinity – ECw, at 126 days after transplantation.

Table 2. Summary of analysis of variance for initial fluorescence (Fo), maximum fluorescence (Fm), variable fluorescence (Fv) and maximum quantum efficiency of photosystem II (Fv/Fm) in cashew 'anão precoce' irrigated with saline water and fertilized with organic matter, at 126 days after transplantation.

Source of Variation	DF	Mean Square			
		Fo	Fm	Fv	Fv/Fm
Saline levels (SL)	4	339.973108^{ns}	1254.027936^{ns}	1145.659187^{ns}	0.000675^{ns}
OM doses (OM)	3	664.521846^{ns}	11257.128571*	13379.850417*	0.003972*
Interaction (SL) x (OM)	12	753.261742^{ns}	5382.889101^{ns}	3412.548128^{ns}	0.000873^{ns}
Block	2	1475.184194	5070.270724	2531.497681	0.001702
Residual	38	713.931485	3212.480862	2136.707333	0.001013
CV (%)		15.67	8.48	9.28	4.28

*Significant at 0.05 and at ** 0.01 probability levels; ^{ns} not significant, ^{a} data transformed to √x.

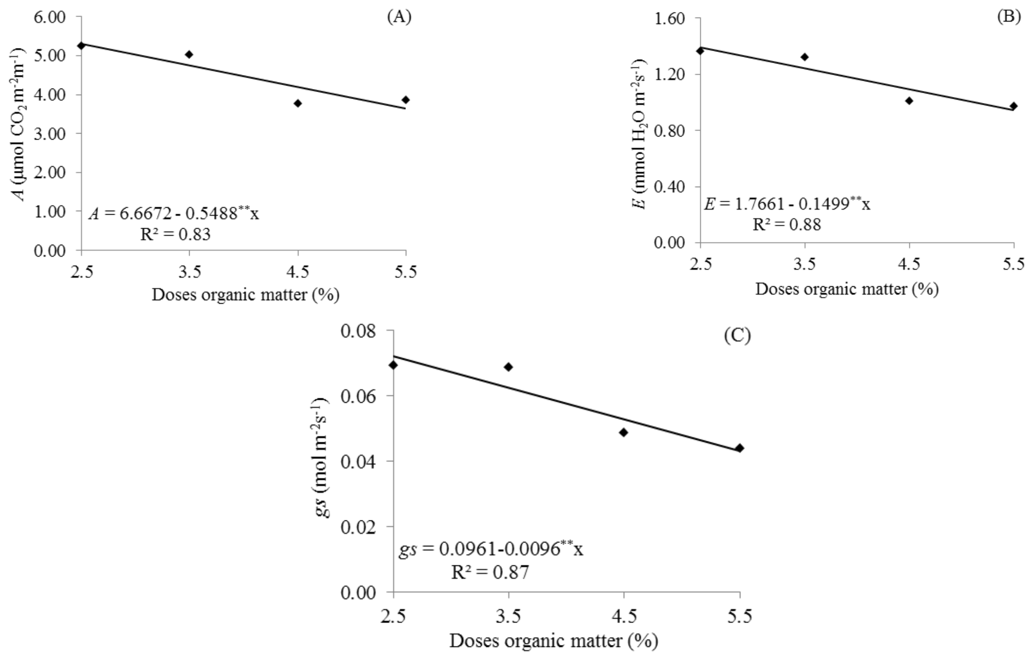

Fig 2. CO_2 assimilation rate - *A* (A), transpiration – *E* (B) and stomatal conductance - *gs* (C) of cashew 'anão precoce', as a function of dose of organic matter, at 126 days after transplantation.

Table 3. Summary of analysis of variance for absolute (AGR-RSD) and relative (RGR-RSD) growth rates of rootstock stem diameter, absolute (AGR-SSD) and relative (RGR-SSD) growth rates of scion stem diameter, absolute (AGR-PH) and relative (RGR-PH) growth rates of plant height in cashew 'anão precoce' irrigated with saline water and fertilized with organic matter, from 61 to 126 days after transplantation.

Source of Variation	DF	Mean Square					
		AGR-RSD	RGR-RSD	AGR-SSD	RGR-SSD	AGR-PH	RGR-PH
Saline levels (SL)	4	0.000530ns	0.006357ns	0.000197ns	0.011182ns	0.003962ns	0.020195ns
OM doses (OM)	3	0.005318**	0.024191*	0.003164**	0.059838**	0.182105*	0.164102**
Interaction (SL) x (OM)	12	0.000620ns	0.004284ns	0.000345ns	0.007396ns	0.040518ns	0.041936ns
Block	2	0.004534	0.001933	0.000547	0.013048	0.040559	0.013604
Residual	38	0.001093	0.007238	0.000474	0.007175	0.047043	0.036942
CV (%)		33.43	3.53	33.51	4.10	92.74	5.81

*Significant at 0.05 and at ** 0.01 probability levels; [ns] not significant, [a] data transformed to √x.

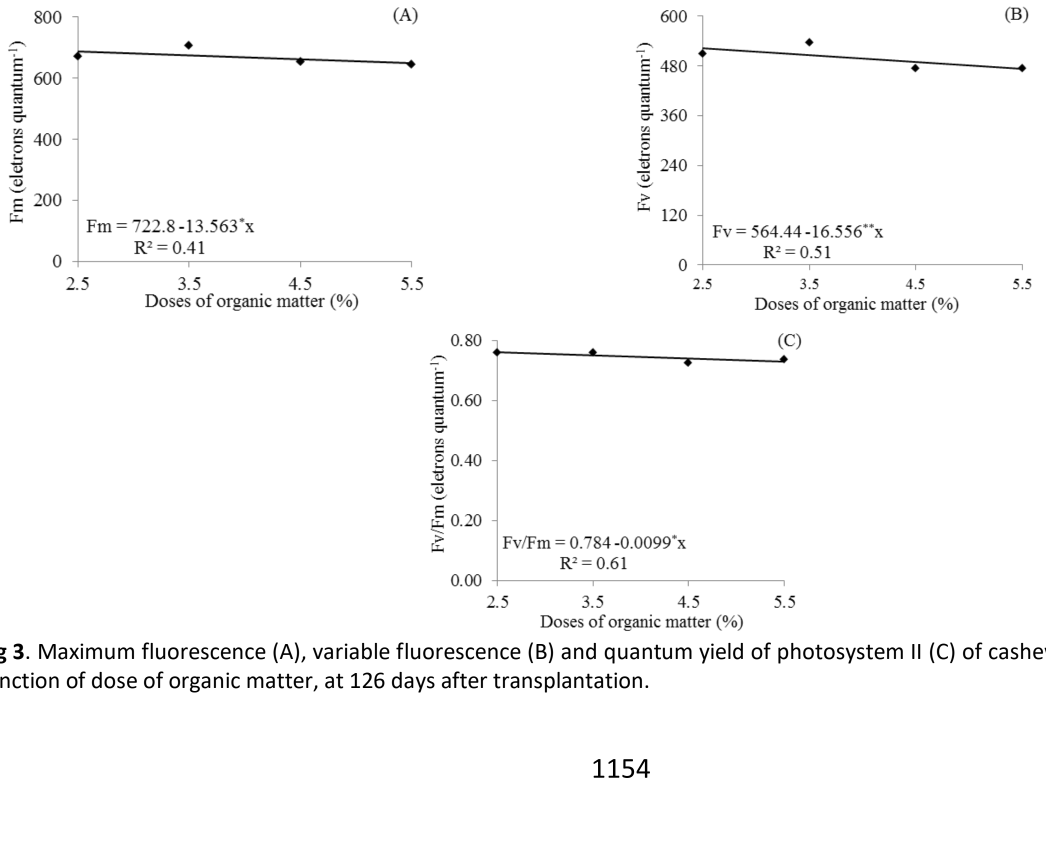

Fig 3. Maximum fluorescence (A), variable fluorescence (B) and quantum yield of photosystem II (C) of cashew 'anão precoce', as a function of dose of organic matter, at 126 days after transplantation.

Table 4. Chemical and physical characteristics of the soil used in the experiment.

Chemical characteristics								
pH_{SP}	OM dag kg^{-1}	P (mg kg^{-1})	K^+	Na^+	Ca^{2+}	Mg^{2+}	Al^{3+}	H^+
			....($cmol_c$ kg^{-1})..					
5.63	1.83	18.2	0.21	0.17	3.49	2.99	0.00	5.81
Physical characteristics								
Granulometric fraction (g kg^{-1})			Textural Class	Moisture (kPa)		AW	Total porosity m^3 m^{-3}	Density (kg dm^{-3})
Sand	Silt	Clay		33.42	1519.5 dag kg^{-1}	....		
572.3	100.8	326.9	CL	12.68	4.98	7.70	0.57	1.31

pH_{SP} - pH of saturation paste; OM – Organic matter: Walkley-Black Wet Digestion; Ca^{2+} and Mg^{2+} extracted with 1 mol L^{-1} KCl at pH 7.0; Na^+ and K^+ extracted with 1 mol L^{-1} NH_4OAc at pH 7.0; H^+ extracted with 1 mol L^{-1} Ca Acetate at pH 7; CL – Clay Loam; AW – Available water.

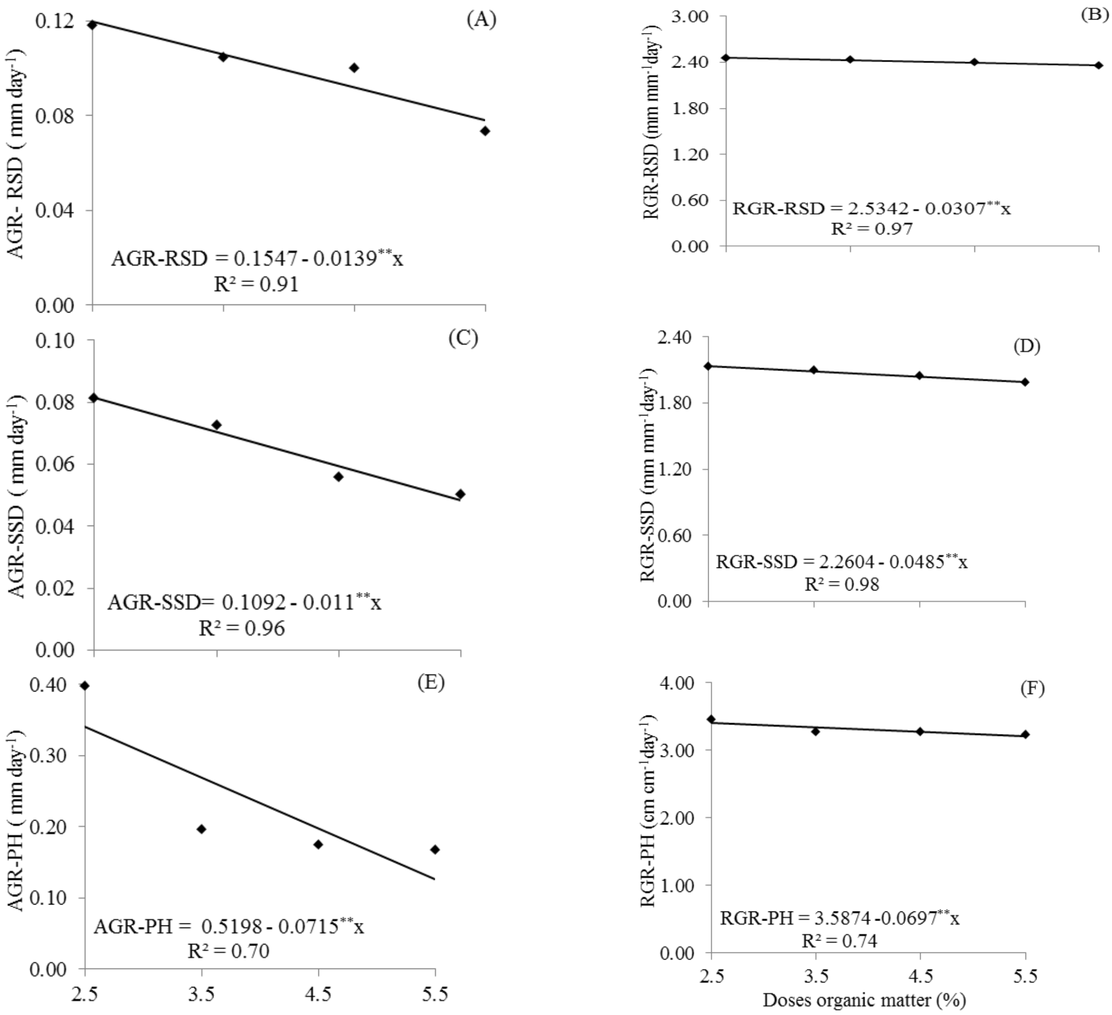

Fig 4. Absolute – AGR-RSD (A) and relative – RGR-RSD (B) growth rates of rootstock stem diameter, absolute – AGR-SSD (A) and relative – RGR-SSD (B) growth rates of scion stem diameter, absolute – AGR-PH (A) and relative – RGR-PH (B) growth rates of plant height of cashew ‘anão precoce’, as a function of dose of organic matter, from 61 to 126 days after transplantation.

Materials and methods

Localization, experimental procedure, treatments and plant material

The experiment was carried out from June to December 2016, in drainage lysimeters, under greenhouse conditions, at the Center of Technology and Natural Resources of the Federal University of Campina Grande (CTRN/UFCG), located in the municipality of Campina Grande-PB, Brazil, at local geographic coordinates 7°15’’18’’’’S, 35°52’’28’’’’W and mean altitude of 550 m. Treatments resulted from the combination between two factors: five levels saline water electrical conductivity (0.7, 1.4, 2.1, 2.8 and 3.5 dS m^{-1}) associated with four doses of organic fertilizer (2.5, 3.5, 4.5 and 5.5%). The experimental design was completely randomized blocks in 5 x 4 factorial scheme, with three replicates, totalling 60 experimental units. Organic fertilizer doses were determined on the basis of soil volume. Bovine manure was used as source of organic fertilizer. The manure was well decomposed, contained 45% organic matter and applied in the soil before planting.

Seedlings obtained from Embrapa Tropical Agroindustry, Fortaleza-CE, whose rootstock was the clone CCP 06 and scion was 'BRS 226 Planalto'. Regarding the rootstock, this genetic material has as characteristics of short plants, mean height of 2.11 m and mean crown diameter of 4.52 m, in the sixth year of age. These characteristics are peculiar to the early type of dwarf cashew. Agroindustrial indicators are nut weight of 6.4 g, peeled kernel with average weight of 1.6 g with natural moisture and the kernel/shell ratio. For the peduncle, agroindustrial indicators are mean weight of 76.5 g and yellow color (Paiva and Barros, 2004).

For the scion, the cashew clone 'BRS 226 Planalto' results from the phenotypical selection of the matrix plant and dwarf cashew number 42 (MAP – 42), at the Caucaia Agroindustrial S/A – CAPISA farm, located in the municipality of Pio IX, Piauí state, followed by clonal evaluation of the genotypes selected in the same region. Its characteristics were: small size, mean height of 124 cm in the third year of age, mean crown diameter of 779 cm, nut weight of 10.4 g; kernel/shell ratio of 25.5%, kernel weight of 2.6 g; 1.3% of broken kernels in the cut and 85% of whole kernels after shell removal, besides peduncle with mean weight of 104.0 g, red color, pyriform shape and mean yield of 1,255.6 kg ha^{-1} of nut (Paiva et al., 2002).

Establishment and management of the experiment

Plants were grown in plastic containers adapted and used as drainage lysimeters with capacity for 200 L. Each lysimeter was perforated at the bottom to allow drainage and connected to a 4-mm-diameter drain (black color). On tip of the drain inside the lysimeter a nonwoven geotextile (Bidim OP 30) was placed to avoid obstruction by soil material. A plastic bottle was placed below each drain to collect drained water and to estimate crop water consumption.

The lysimeters were filled with a 0.5-kg layer of crushed stone followed by 250 kg of soil material representative of the semi-arid region of the Paraíba state (properly pounded to break up clods and homogenized). The soil was collected in the 0-30 cm layer (A horizon). Prior to the experiment, the soil was sampled to determine chemical and physical-hydraulic parameters at the Laboratory of Irrigation and Salinity (LIS) of the CTRN/UFCG, according to the methodology proposed by Claessen (1997). Soil chemical and physical-hydraulic characteristics are presented in Table 4.

Nitrogen (N), phosphorus (P) and potassium (K) fertilization was based on the methodology presented by Ramos et al. (1992). Urea was used as N source and potassium chloride as K source. Phosphorus was applied as single superphosphate, because it is a source of sulfur, an important element for the cashew crop. Total phosphorus was applied as basal dose, whereas N and K were split into three equal applications. The first dose was applied along with basal dose of phosphorus and rest in vegetative and flowering stage.

Water salinity levels (0.7; 1.4; 2.1; 2.8 and 3.5 dS m^{-1}) were prepared in such a way to obtain equivalent proportion of 7:2:1 between Na:Ca:Mg, respectively, using NaCl, $CaCl_2.2H_2O$ and $MgCl_2.6H_2O$ salts, a ratio that prevails in water sources used for irrigation in small properties of the Northeast region (Medeiros, 1992), by adjusting their concentration in the available public-supply water. Irrigation waters were prepared considering the relationship between ECw and concentration of salts (10*$mmol_c$ L^{-1}=ECw dS m^{-1}), according to Richards (1954).

Prior to transplantation, the water volume necessary to bring the soil to field capacity was determined using the capillary saturation method followed by free drainage, in which water was applied according to the treatments. After transplantation, irrigation was performed in each lysimeter by applying water according to the treatments to maintain soil moisture close to field capacity and the amount to be applied was determined based on crop water requirement, estimated through water balance: applied water volume minus volume drained in the previous irrigation, plus a leaching fraction of 0.15.

Traits measured

Cashew 'anão precoce' growth was assessed along the period from 61 to 126 days after transplantation (DAT), based on the determination of plant height (PH), rootstock stem diameter (RSD) and scion stem diameter (SSD). PH was measured as the distance from the base to the insertion of the youngest leaf and SD was determined using a digital caliper. Absolute and relative growth rates of stem diameter and plant height (AGR-SD, AGR-PH, RGR-SD, RGR-PH) were obtained based on data of two evaluations, at 61 and 126 DAT, performed according to the methodology described by Benincasa (2003), using Eqs. 1, 2, 3 and 4:

$$AGR\text{-}SD = (SD_2\text{-}SD_1)/(t_2\text{-}t_1) \quad (1)$$

$$AGR\text{-}PH = (PH_2\text{-}PH_1)/(t_2\text{-}t_1) \quad (2)$$

Where; AGR-SD = absolute growth rate of stem diameter (mm day^{-1}), SD_1 = stem diameter (mm) at time t_1, SD_2 = stem diameter (mm) at time t_2; AGR-PH = absolute growth rate of plant height (cm day^{-1}), PH_1 = plant height (cm) at time t_1, PH_2 = plant height (cm) at time t_2.

$$RGR\text{-}SD = (\ln SD_2\text{-}\ln SD_1)/(t_2\text{-}t_1) \quad (3)$$

$$RGR\text{-}PH = (\ln PH_2\text{-}\ln PH_1)/(t_2\text{-}t_1) \quad (4)$$

Where; RGR-SD = relative growth rate of stem diameter (mm $mm^{-1}day^{-1}$), SD_1 = stem diameter (mm) at time t_1, SD_2 = stem diameter (mm) at time t_2, ln = natural logarithm; RGR-PH = relative growth rate of plant height (cm $cm^{-1}day^{-1}$), PH_1 = plant height (cm) at time t_1, PH_2 = plant height (cm) at time t_2.

Gas exchanges were evaluated at 126 DAT, based on the determination of stomatal conductance (*gs*), transpiration (*E*), CO_2 assimilation rate (*A*) and internal CO_2 concentration (*Ci*). Stomatal conductance (mol of H_2O m^{-2} s^{-1}), transpiration (mmol of H_2O m^{-2} s^{-1}), CO_2 assimilation rate (μmol m^{-2} s^{-1}) and internal CO_2 concentration (μmol m^{-2} s^{-1}) were evaluated in the third leaf counted from the apex, using the portable photosynthesis meter "LCPro+", by ADC BioScientific Ltda.

Chlorophyll fluorescence was also determined at 126 DAT, with a pulse-modulated fluorimeter (model OS5p - Opti Science) using the Fv/Fm protocol, to determine fluorescence induction parameters: initial fluorescence (Fo), maximum fluorescence (Fm) and variable fluorescence (Fv)

(Fv = Fm-Fo), besides the quantum efficiency of photosystem II (Fv/Fm). This protocol was carried out after dark adaptation of the leaves for a 30-min period, using a clip of the device to guarantee that all early electron acceptors are oxidized, i.e., reaction centers are open.

Statistical analysis

Collected data were subjected to analysis of variance by F test at 0.05 probability level, and when significant, linear and quadratic polynomial regression analysis was performed using the statistical software SISVAR - ESAL (Ferreira, 2011). In cases of data heterogeneity verified through the coefficients of variation, an exploratory analysis was performed with data transformed to $\sqrt{x}$.

Conclusion

Irrigation water electrical conductivity from 0.7 dS m^{-1} led to increment in internal CO_2 concentration and reduction in CO_2 assimilation rate, transpiration and stomatal conductance in cashew 'anão precoce' plants, at 126 days after transplantation. Chlorophyll *a* fluorescence and the absolute and relative growth rates were not influenced by the increase in the irrigation water salinity levels. Organic fertilization had negative influence on gas exchanges, chlorophyll *a* fluorescence and growth of cashew 'anão precoce' plants in the post-grafting stage.

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