



Research article

Photosynthetic pigments and photochemical efficiency of precocious dwarf cashew (*Anacardium occidentale* L.) under salt stress and potassium fertilization

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Abstract: Cashew cultivation is an activity of great socioeconomic relevance, especially for agriculture in the semi-arid region of Northeast Brazil, standing out as an option to generate jobs and income. Thus, the present study aimed to evaluate the photosynthetic pigments and photochemical efficiency of precocious dwarf cashew under salt stress and potassium fertilization. The study was conducted using a Regolithic Neosol with sandy loam texture, adopting a randomized block design in 5 × 2 factorial arrangement, which corresponded to five levels of electrical conductivity of irrigation water—EC_w (0.4; 1.2; 2.0; 2.8 and 3.6 dS m⁻¹) associated with two doses of potassium fertilization—KD (100 and 150% of recommendation), with three replicates and two plants per plot. Increasing water salinity inhibited chlorophyll synthesis and decreased electron transport rate and quantum yield of non-regulated energy dissipation in precocious dwarf cashew, at 50 days after sowing. There was significant interaction for chlorophyll *a* and *b* contents and the effects of salt stress were intensified by potassium doses on the chlorophyll *b* content of precocious dwarf cashew. Potassium doses of 100 and 150% of recommendation (150 and 225 mg K₂O kg⁻¹ of soil) do not

mitigate the effect of salt stress on photosynthetic pigment synthesis and photochemical efficiency of cashew plants in the rootstock formation phase.

Keywords: *Anacardium occidentale* L.; water salinity; attenuating agent; water scarcity; semi-arid

Abbreviations: EC_w: water electrical conductivity; Chl *a*: chlorophyll *a*; Chl *b*: chlorophyll *b*; Car: carotenoids; F_o: initial fluorescence; F_m: maximum fluorescence; F_v: variable fluorescence; DAS: days after sowing; F_s: initial fluorescence before the saturating pulse; F_{ms}: maximum fluorescence after adaptation to the saturating light; ETR: electron transport rate; Y_{NO}: quantum yield of non-regulated energy dissipation; PAR: photosynthetically active radiation; KD: doses of K fertilization; pH: hydrogen potential; OM: organic matter; EC_{se}: electrical conductivity of the saturation extract of soil; CEC: cation exchange capacity; SAR: sodium adsorption ratio of the saturation extract; ESP: exchangeable sodium percentage

1. Introduction

Belonging to the *Anacardiaceae* family, cashew (*Anacardium occidentale* L.) is an important fruit crop for agriculture in the semi-arid region of Northeast Brazil, both because it is consumed fresh and because of the industrialization [1] and [2], presenting itself as an option to generate employment and income. Its fruit has high nutritive value, obtained in the form of vitamins, tannins, mineral salts and organic acids, with vitamin C contents almost five times higher than those found in oranges, besides the presence of calcium, iron and phosphorus, among others [3].

The semi-arid region of Northeast Brazil provides adequate edaphoclimatic conditions for cashew cultivation, but commonly has problems of water scarcity associated with the availability of water with excess salts [1]. Thus, due to the increase in water demand by both the agricultural activity and the urban and industrial supply, the use of saline water in agriculture must be considered as an important alternative to expand irrigated areas [4].

Accumulation of salts in the soil, especially of Na⁺ and Cl⁻, leads to alterations in the photosynthetic capacity of plants, because of the reduction in the osmotic potential of the soil solution, which influences the synthesis of compatible osmolytes and the inactivation of enzymatic and non-enzymatic antioxidant systems, making it difficult for plants to survive in environments with high salt concentrations, because of the ionic imbalances in the soil, leading to reduction in the absorption of water and mineral nutrients [5] and [6]. Saline stress-induced decline in plant growth and development is a result of cumulative effects on major physiological processes, such as disruption in ionic homeostasis, oxidative stress, and increased lipid peroxidation, thereby promoting changes in water balance and inhibition of photosynthesis and other biochemical processes, including enzymatic activity [7].

Due to the excess of salts in the water, plants exhibit modifications in the functional status of the thylakoid membranes of their chloroplasts, resulting in alterations in the characteristics of chlorophyll fluorescence signals [8]. Thus, chlorophyll fluorescence parameters have been widely used, especially in the diagnosis of photosynthetic apparatus integrity under environmental adversities, allowing for a qualitative and quantitative analysis of light energy absorption and use by the photosynthetic apparatus, standing out as an indicator of the use efficiency of photosynthetically

active radiation and, consequently, quantum efficiency of photosystem II [9], allowing the identification of characteristics related to the capacity of light energy absorption and transfer in the electron transport chain [10].

Potassium (K) fertilization is among the alternatives which can minimize the impacts of irrigation with saline water on the photosynthetic pigments and photochemical efficiency of precocious dwarf cashew. The use of K as a stress-attenuating mechanism is related to the participation of this macronutrient in the activation of many enzymes involved in respiration and photosynthesis (about 46 enzymes require K for activity), maintenance of cell ionic balance and turgor, control of stomatal opening and closure, synthesis and degradation of starch, translocation of carbohydrates in the phloem, and plant resistance to soil salinity [11]. In cells, K helps to maintain transmembrane stress gradients, cytoplasmic pH, and transport of inorganic ions and metabolites [12].

In this context, the photosynthetic pigments, growth and production of West Indian cherry cv. BRS 366 Jaburu were evaluated [13], under irrigation with waters of different levels of salinity (EC_w of 0.8 and 3.8 dS m⁻¹) and K fertilization, concluding that the harmful effects of salinity on the total number and fresh weight of fruits were minimized by K fertilization. Studying the growth and physiological responses of two cowpea cultivars (CE 790 and CE 104), irrigated with saline water (EC_w from 0.8 to 5.0 dS m⁻¹) and subjected to different levels of K, under protected environment conditions, it was observed that the optimal dose of this nutrient depends on the salinity level in the root zone [14].

Despite its importance for the semi-arid region of Northeast Brazil, there are few studies aiming to understand the effects of salt stress on the contents of photosynthetic pigments and photochemical efficiency of precocious dwarf cashew. Given the above, this study aimed to evaluate the photosynthetic pigments and photochemical efficiency of precocious dwarf cashew, as a function of irrigation with saline waters and K fertilization, during the rootstock initial growth stage.

2. Material and methods

The study was conducted in plastic containers under greenhouse conditions, at the Center of Sciences and Agrifood Technology of the Federal University of Campina Grande (CCTA/UFCG), located in the municipality of Pombal, PB, Brazil, situated by the local geographic coordinates 6°48'16" latitude S, 37°49'15" longitude W, and mean altitude of 175 m. During the experimental period the mean temperature and relative humidity inside the greenhouse was 42.75 °C and 41.4%, respectively.

Treatments resulted from the combination of five levels of irrigation water electrical conductivity—EC_w (0.4; 1.2; 2.0; 2.8 and 3.6 dS m⁻¹) associated with two doses of K fertilization—KD (100 and 150% of K₂O recommendation) according to [15]. The doses of 100 and 150% corresponded to 150 and 225 mg of K₂O kg⁻¹ of soil, respectively. The experimental design was randomized blocks in 5 × 2 factorial arrangement, with two plants per plot and three replicates, with a total of sixty experimental units.

The containers were filled with a 2:1:1 proportion of Entisol, sand and organic matter (well-decomposed bovine manure), from the rural area of the municipality of de São Domingos, PB, whose chemical and physical characteristics (Table 1) were obtained according to the methodologies proposed by [16].

Table 1. Chemical and physical characteristics of the soil used in the experiment.

Chemical characteristics								
pH (H ₂ O)	O.M.	P	K ⁺	Na ⁺	Ca ²⁺	Mg ²⁺	Al ³⁺	H ⁺
(1:2.5)	g kg ⁻¹	(mg kg ⁻¹)	cmol _c kg ⁻¹					
7.00	0.38	11.99	0.21	0.09	2.42	5.84	0.00	0.00
Chemical characteristics				Physical characteristics				
EC _{se}	CEC	SAR	ESP	Size fraction (g kg ⁻¹)			Water content (dag kg ⁻¹)	
(dS m ⁻¹)	cmol _c kg ⁻¹	(mmol L ⁻¹) ^{0.5}	%	Sand	Silt	Clay	33.42 kPa	1519.5 kPa
0.75	8.56	0.94	1.05	853.00	130.70	16.30	11.16	4.23

Note: pH: Hydrogen potential; OM: Organic matter; Walkley-Black Wet Digestion; Ca²⁺ and Mg²⁺ extracted 1 M KCl at pH 7.0; Na⁺ and K⁺ extracted with 1 M NH₄ OAc at pH 7.0; Al³⁺ + H⁺ extracted with 0.5 M CaOAc at pH 7.0; EC_{se}—Electrical conductivity of the saturation extract of soil; CEC—Cation exchange capacity; SAR—Sodium adsorption ratio in the saturation extract; ESP—Exchangeable sodium percentage.

Prior to sowing, the soil was brought to field capacity using the respective water of each treatment. After transplanting, irrigation was performed daily, applying in each container a water volume sufficient to maintain the soil close to field capacity. The applied volume was determined according to plant water needs, estimated by water balance: volume applied minus volume drained in the previous irrigation, plus a leaching fraction of 0.10.

Irrigation waters with the respective levels of electrical conductivity (0.4; 1.2; 2.0; 2.8 and 3.6 dS m⁻¹) were prepared by dissolving NaCl in supply water (EC_w = 0.30 dS m⁻¹) from the municipality of Pombal-PB, based on the relationship between EC_w and the concentration of salts (mmol_c L⁻¹ = 10*EC_w dS m⁻¹) according to [17].

This study used seeds of precocious dwarf cashew, 'Faga 11' clone, which were sown at 3 cm depth, by placing one seed per container, in the vertical position, that is, with the thinner tip facing down and peduncle attachment scar facing up.

Fertilization with phosphorus and nitrogen was performed as recommended by [15], applying the equivalent to 300 mg of P₂O₅ kg⁻¹ of soil and 100 mg of N kg⁻¹ of soil, respectively. Mono ammonium phosphate was used as source of phosphorus, whereas urea was used to complement nitrogen. Phosphorus and nitrogen were applied weekly. Micronutrient needs of cashew were met with fortnightly applications of a solution of Ubyfol [(N (15%); P₂O₅ (15%); K₂O (15%); Ca (1%); Mg (1.4%); S (2.7%); Zn (0.5%); B (0.05%); Fe (0.5%); Mn (0.05%); Cu (0.5%); Mo (0.02%)] containing 1.0 g L⁻¹, sprayed on the adaxial and abaxial sides of the leaves.

Photosynthetic pigments of precocious dwarf cashew, at 50 days after sowing, were evaluated by determining the contents of chlorophyll *a* (Chl *a*), chlorophyll *b* (Chl *b*) and carotenoids (Car). Chlorophyll *a* and *b* contents (mg g⁻¹ of fresh matter-FM) were determined according to the methodology of [18], using samples composed of 5 discs of the third mature leaf blade from the apex. The extracts were used to determine the contents of chlorophylls and carotenoids in the solutions through a spectrophotometer at the absorbance (ABS) wavelengths (470, 646, and 663 nm), according to the following equations 1, 2 and 3:

$$\text{Chlorophyll } a \text{ (Chl } a) = 12.21 \text{ ABS}_{663} - 2.81 \text{ ABS}_{646} \quad (1)$$

$$\text{Chlorophyll } b \text{ (Chl } b) = 20.13 \text{ A}_{646} - 5.03 \text{ ABS}_{663} \quad (2)$$

$$\text{Carotenoids (Car)} = (1000 \text{ ABS}_{470} - 1.82 \text{ Chl } a - 85.02 \text{ Chl } b)/198 \quad (3)$$

Photochemical efficiency was measured by the initial fluorescence (Fo), variable fluorescence (Fv), maximum fluorescence (Fm), photosynthetically active radiation (PAR-Clip), initial fluorescence before the saturating pulse (Fs), maximum fluorescence after adaptation to the saturating light (Fms), electron transport rate (ETR), quantum efficiency of photosystem II (Y) and leaf temperature (LTemp, in °C) were determined. Chlorophyll *a* fluorescence was quantified in fully expanded leaves (mature) using a portable Plant Efficiency Analyser - PEA II® (Hansatech Instruments Co., UK). Leaves selected for the analysis were pre-adapted to the dark using specific clips and, after a 30-min period, the readings were taken in the morning between 07.00 and 10.00 h, at 50 DAS. Then, evaluations were carried out under conditions of light, using an acting light with multi-flash saturating pulse, attached to a clip to determine the photosynthetically active radiation (PAR-Clip), initial fluorescence before the saturating pulse (Fs), maximum fluorescence after adaptation to the saturating light (Fms), electron transport rate (ETR), quantum efficiency of photosystem II (Y), photosynthetically active radiation (PAR, $\mu\text{mol m}^{-2} \text{s}^{-1}$) and leaf temperature (LTemp, in °C).

After checking the homogeneity of variances, the obtained data were subjected to analysis of variance by F test at 0.05 and 0.01 probability levels and, in case of significance, linear and quadratic polynomial regression analysis were conducted for the water salinity levels and means comparison test (Tukey) was performed for the potassium doses. When the interaction between factors (SL \times KD) was significant, the salinity levels were further analyzed considering each K dose, using the statistical program SISVAR-ESAL [19].

3. Results and discussion

The summary of analysis of variance (Table 2) showed that the levels of irrigation water salinity caused a significant effect on the initial, maximum and variable fluorescence of precocious dwarf cashew plants, whereas K doses had significant influence only on the initial fluorescence. On the other hand, the interaction between factors (SL \times KD) had a significant effect on the chlorophyll *a* and *b* contents of precocious dwarf cashew, at 50 days after sowing.

Table 2. Summary of analysis of variance for the contents of chlorophyll *a* (Chl *a*), chlorophyll *b* (Chl *b*), carotenoids (Car), initial fluorescence (Fo), maximum fluorescence (Fm) and variable fluorescence (Fv) of precocious dwarf cashew plants under saline water irrigation and potassium fertilization, at 50 days after sowing.

Source of variation	Mean squares					
	Chl <i>a</i>	Chl <i>b</i>	Car	Fo	Fm	Fv
Saline levels (SL)	9.54**	35.45**	0.22 ^{ns}	26469.57*	52142.50*	137619.30*
Linear Regression	35.02**	141.04**	0.82*	96761.50**	206829.45**	510585.30**
Quadratic Regression	2.68*	0.04 ^{ns}	0.03 ^{ns}	3275.00 ^{ns}	1506.64 ^{ns}	210.26 ^{ns}
K dose (KD)	5.58*	1.56 ^{ns}	0.02 ^{ns}	25813.33*	14740.83 ^{ns}	1435.90 ^{ns}
Interaction (SL \times KD)	4.00**	4.69*	0.17 ^{ns}	9690.66 ^{ns}	78240.58 ^{ns}	44570.18 ^{ns}
Blocks	0.13 ^{ns}	0.85 ^{ns}	0.06 ^{ns}	4371.32 ^{ns}	108483.02 ^{ns}	41740.21 ^{ns}
Res \bar{u} uo	0.26	0.81	0.14	2868.40	18289.40	48923.51
CV (%)	5.97	8.40	27.06	7.28	4.83	9.87

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

The chlorophyll *a* content in precocious dwarf cashew decreased significantly due to the interaction between water salinity levels and K doses. According to the regression equation (Figure 1A), plants fertilized with 100% K₂O recommendation showed a linear reduction in chlorophyll *a* content of 12.62% per unit increase in irrigation water salinity. Comparatively, the chlorophyll *a* content in plants under EC_w of 3.6 dS m⁻¹ decreased by 42.55% (4.41 mg g⁻¹ FM) relative to those grown using water with the lowest level of salinity (0.4 dS m⁻¹). A similar trend was observed in plants subjected to the highest K₂O dose (150% of recommendation), i.e., as the EC_w levels increased there was a linear reduction in Chl *a*, equal to 7.56% per unit increase in EC_w. According to the regression equation (Figure 1A), Chl *a* content decreased by 24.96% in plants under EC_w of 3.6 dS m⁻¹ compared to those irrigated with 0.4 dS m⁻¹ water.

Despite the reduction observed in chlorophyll *a* content, precocious dwarf cashew plants subjected to the highest K₂O dose (150% of recommendation) had the lowest reduction when EC_w levels increased. Reduction of chlorophyll *a* in plant exposed to water salinity occurs due to degradation of molecules of this photosynthesizing pigment, possibly resulting in structural destruction of chloroplasts, leading to imbalance and loss of activity of pigmentation proteins [20] and [21]. Quantifying the contents of photosynthesizing pigments in West Indian cherry as a function of irrigation with water of different salinity levels (EC_w of 0.8 and 3.8 dS m⁻¹), [13] concluded that chlorophyll *a* content was reduced by the increasing water salinity.

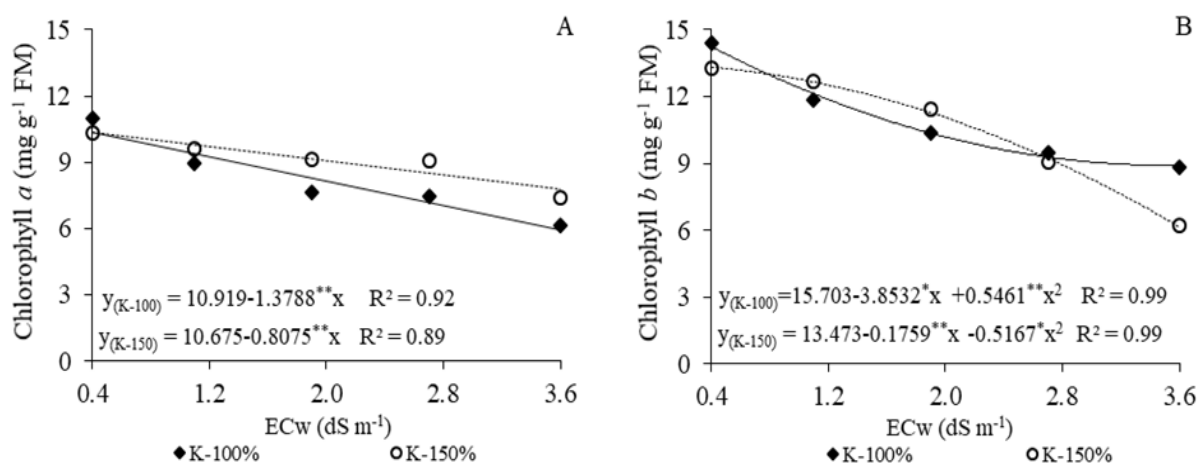


Figure 1. Contents of chlorophyll *a* (A) and chlorophyll *b* (B) of ‘Faga 11’ precocious dwarf cashew plants as a function of the interaction between water salinity levels—EC_w and potassium fertilization doses, at 50 days after sowing.

The chlorophyll *b* content of precocious dwarf cashew was also significantly influenced by the interaction between water salinity levels and K fertilization doses. According to the regression equations (Figure 1B), for plants fertilized with 100 and 150% K₂O recommendation the data fitted best to a quadratic model. Plants grown under fertilization with 100% K₂O recommendation had highest Chl *b* content (14.24 mg g⁻¹ FM) when irrigated with the lowest EC_w level (0.4 dS m⁻¹), with a sharp decrease from this level on, reaching the minimum estimated value (8.90 mg g⁻¹ FM) under EC_w of 3.6 dS m⁻¹. For plants subjected to the highest K₂O dose (150% of recommendation), the highest Chl *b* content (13.31 mg g⁻¹ FM) was found under EC_w of 0.4 dS m⁻¹, decreasing from

this level on and reaching a minimum estimated value of 6.14 mg g^{-1} FM at the highest level of salinity (3.6 dS m^{-1}).

In contrast to the result for chlorophyll *a* content (Figure 1A), increasing K dose intensified the deleterious effect of salt stress on the biosynthesis of Chl *b* (Figure 1B), and the highest reduction was observed in plants under 150% K_2O recommendation. Reduction in chlorophyll biosynthesis may be a response of acclimation to the salt stress, leading to energy saving due to lower capture of light energy and, consequently, reduction of photo-oxidative stress [22]. Evaluating chlorophyll contents in citrus scion-rootstock combinations as a function of irrigation with water of different levels of salinity (EC_w from 0.6 to 3.0 dS m^{-1}) [23], it was concluded that salt stress reduces the contents of chlorophyll pigments in citrus plants.

Water salinity levels had no significant influence ($p > 0.05$) on the carotenoid contents of ‘Faga 11’ precocious dwarf cashew (Table 2). However, based on the regression equation ($y = 1.0617 + 0.1456 \cdot x$, $R^2 = 0.91$), Car contents tended to increase and plants grown under EC_w of 3.6 dS m^{-1} obtained an increment of 0.46 mg g^{-1} FM in comparison to those subjected to the lowest level of water salinity (0.4 dS m^{-1}). In a study on yellow passion fruit [24], it was observed that Car contents were not affected by the increase in irrigation water salinity.

The initial fluorescence of the chlorophyll of precocious dwarf cashew increased linearly as a function of the irrigation with saline water and, according to the regression equation (Figure 2A), F_o increased by 7.90% per unit increase in EC_w , i.e., cashew plants subjected to EC_w of 3.6 dS m^{-1} had a 19.68% (160.63) increase compared to those cultivated under the lowest level of water salinity (0.4 dS m^{-1}). The initial fluorescence of chlorophyll occurs when fluorescence emission is minimal, when quinone (primary acceptor of electrons from photosystem II–PSII) is fully oxidized and the PSII reaction center is open, a situation favorable to the activation of photochemical reactions [25]. Thus, the increase in F_o values under salt stress conditions may be a consequence of damage to the PSII reaction center or reduction in the capacity of excitation energy transfer from the antenna to the reaction center [26]. Differently from the results obtained in the present study, [27] studied the influence of K fertilization as an attenuating agent of salt stress on the gas exchanges and photochemical efficiency of West Indian cherry cv. ‘BRS 366 Jaburu’ and concluded that irrigation with 3.8 dS m^{-1} water compromised the photochemical efficiency of West Indian cherry plants, with reduction in F_o .

In contrast to the initial fluorescence (Figure 2A), the maximum fluorescence of cashew plants decreased significantly with the increasing salinity of irrigation water. Based on the regression equation (Figure 2B), there was a reduction in F_m of 2.94% per unit increase in electrical conductivity of irrigation water. By comparing plants subjected to water salinity levels of 3.6 and 0.4 dS m^{-1} , it is possible to note a reduction of 600 (8.05%). Reduction in the maximum fluorescence of cashew plants with the increase in water salinity may be an indication that there was low efficiency in quinone A photoreduction and in electron flow between the photosystems [28], which results in low activity of PSII in the thylakoid membrane, directly influencing the flow of electrons between the photosystems [29]. Evaluating the photochemical efficiency of yellow passion fruit under irrigation with low (0.5 dS m^{-1}) and high-salinity (4.5 dS m^{-1}) waters, [8] also observed that the latter negatively influenced F_m , with reduction from 2,256.7 to 2,048.1 between plants treated with 0.5 and 4.5 dS m^{-1} water.

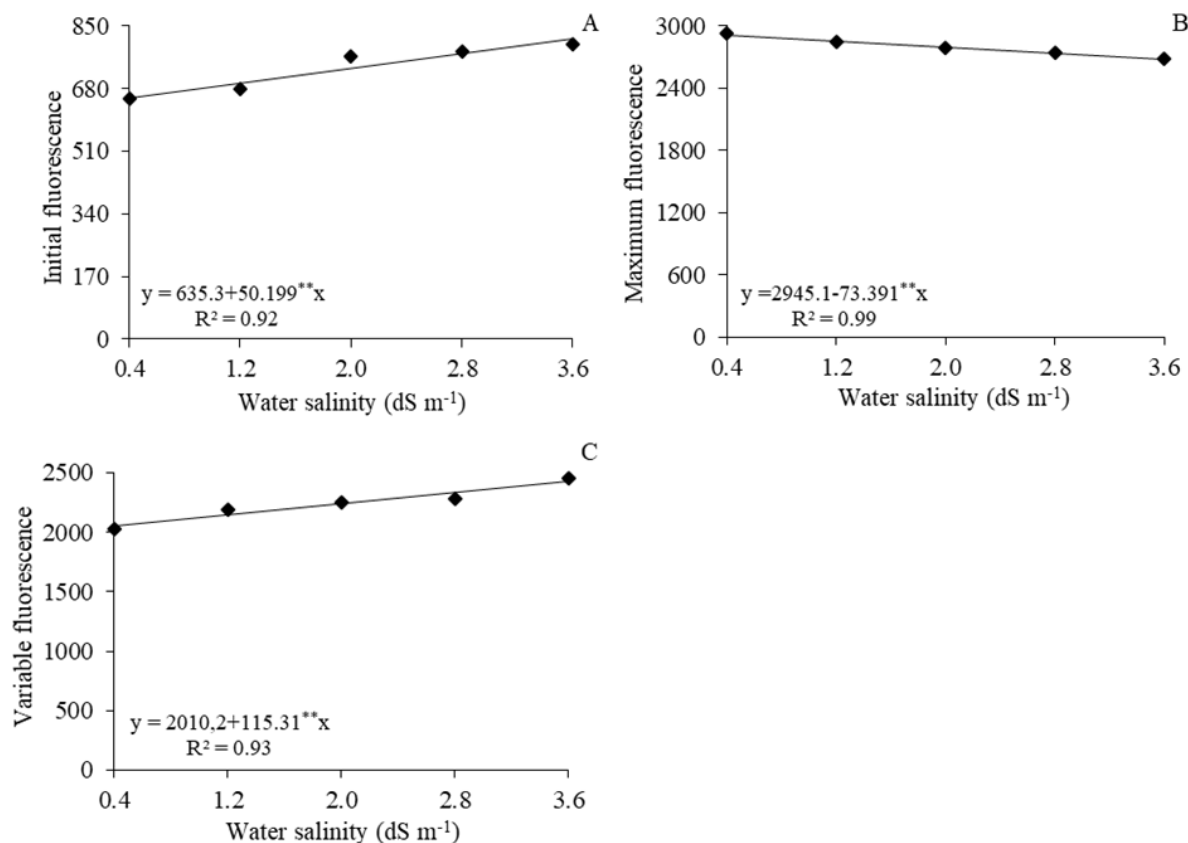


Figure 2. Initial fluorescence (A), maximum fluorescence (B) and variable fluorescence (C) of ‘Faga 11’ precocious dwarf cashew plants as a function of irrigation with saline waters, at 50 days after sowing.

The levels of irrigation water salinity caused increase in the variable fluorescence of cashew plants and, based on the regression equation (Figure 2C), there was a linear increment of 5.37% per unit increase in EC_w. Under EC_w of 3.6 dS m⁻¹, F_v increased by 369.11 (17.90%) in comparison to plants subjected to irrigation with EC_w of 0.4 dS m⁻¹. The increment of F_v in precocious dwarf cashew plants under water salinity conditions is a reflex of their higher capacity to transfer energy from the electrons ejected from pigment molecules to the formation of the reducing agent NADPH, ATP and reduced ferredoxin (F_{dr}) and, consequently, higher capacity of CO₂ assimilation in the biochemical phase of photosynthesis [26]. Evaluating the photosynthetic efficiency of citrus hybrids under salt stress conditions (EC_w of 0.3 and 4.0 dS m⁻¹), report [30] found that the hybrid TSKC × (LCR × TR) was not influenced by water salinity of 4.0 dS m⁻¹. The authors attributed this result to the higher tolerance of this genetic material to the effects of salinity.

According to the summary of analysis of variance (Table 3), the levels of water salinity significantly influenced fluorescence after adaptation to the saturating light (F_{ms}), electron transport rate (ETR) and quantum yield of non-regulated energy dissipation (Y_{NO}) in precocious dwarf cashew. K doses and the interaction between factors (SL × KD) did not significantly influence ($p > 0.05$) any of the variables analyzed, at 50 days after sowing.

Table 3. Summary of analysis of variance for initial fluorescence before the saturating pulse (Fs), maximum fluorescence after adaptation to the saturating light (Fms), electron transport rate (ETR), quantum yield of non-regulated energy dissipation (Y_{NO}) and photosynthetically active radiation (PAR) of ‘Faga 11’ precocious dwarf cashew plants under saline water irrigation and potassium fertilization, at 50 days after sowing.

Source of variation	Mean squares				
	Fs	Fms	ETR	Y_{NO}	PAR
Saline levels (SL)	1191.18 ^{ns}	8114.35*	2592.81*	0.031**	20721.43 ^{ns}
Linear Regression	3792.15*	30532.70*	9610.46*	0.120**	81125.65*
Quadratic Regression	753.00 ^{ns}	923.36 ^{ns}	321.91 ^{ns}	0.001 ^{ns}	989.14 ^{ns}
K dose (KD)	653.33 ^{ns}	874.80 ^{ns}	274.33 ^{ns}	0.0002 ^{ns}	26122.25 ^{ns}
Interaction (SL × KD)	2976.35 ^{ns}	1085.52 ^{ns}	542.53 ^{ns}	0.004 ^{ns}	12778.02 ^{ns}
Blocks	1270.60 ^{ns}	2071.97 ^{ns}	1369.44 ^{ns}	0.006 ^{ns}	108602.38 ^{ns}
Res fluo	614.17	3100.62	680.20	0.002	23078.62
CV (%)	15.44	14.37	27.70	12.08	33.24

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

The maximum fluorescence after adaptation to the saturating light increased linearly as the levels of irrigation water salinity increased. According to the regression equation (Figure 3A), Fs increased by 8.51% per unit increase in EC_w, i.e., cashew plants grown under the highest level of salinity (3.6 dS m⁻¹) had an increase in Fms of 29.38% compared to those under the lowest level of water salinity (0.4 dS m⁻¹). Under conditions of salt stress and high irradiance, a situation commonly found in the semi-arid region of Northeast Brazil, leaves frequently absorb more energy than what can be used by photosynthesis and, to avoid photo-damage, they dissipate excess energy in the form of heat or fluorescence, with consequent loss of photosynthetic productivity [31], which may result in reduction of CO₂ incorporation and, consequently, of plant growth and production [32]. According to [33], during the application of the saturating light pulse and after the tissue has been kept in the dark, the quantum yield of the photochemical process decreases to zero while fluorescence emission and heat dissipation become maximal.

The electron transport rate of precocious dwarf cashew plants was significantly reduced by the increase in the levels of irrigation water salinity. Based on the regression equation (Figure 3B), ETR decreased by 12.57% per unit increase in EC_w. By comparing the data of plants cultivated under EC_w levels of 3.6 and 0.3 dS m⁻¹, it is possible to observe a reduction of 42.36% in ETR. Excess salts in the water may reduce the transport of electrons used in photosynthesis due to the inactivation of both photosynthetic and respiratory electron transporters [34], possibly leading to irreversible inactivation of the photosynthetic electron transport through proteins [35]. Furthermore, reduction in electron transport may have occurred due to the damage to PSII and photo-inhibitory processes, as well as low electron flow rate for the production of ATP and NADPH [36]. Evaluating chlorophyll *a* fluorescence parameter in tomato plants subjected to increasing salt concentrations (0, 50, 100 and 150 mmol_c L⁻¹ of NaCl), [28] also found that water salinity reduced the transport of electrons, by 9, 18 and 49% in plants subjected to NaCl concentrations of 50, 100 and 150 mmol_c L⁻¹, respectively, compared to control plants (0 mmol_c L⁻¹ of NaCl).

The quantum yield of non-regulated energy dissipation (Y_{NO}) is an indication of the amount of energy absorbed by chlorophyll associated with PSII which was used in photochemical activity and, as such, informs the quantity of electrons transported, being an indicator of photosynthesis [25,37]. Thus, the regression equation (Figure 3C) shows that irrigation water salinity led to a reduction in Y_{NO} of 10.05% per unit increase in EC_w . Cashew plants under water salinity of 3.6 dSm^{-1} had a reduction in Y_{NO} of 33.52% compared to those irrigated with EC_w of 0.3 dS m^{-1} , i.e., these plants obtained lower dissipation in the form of thermal energy during the transfer of excitation and fluorescence, which results in reduction of energy available for the next processes of photosynthesis.

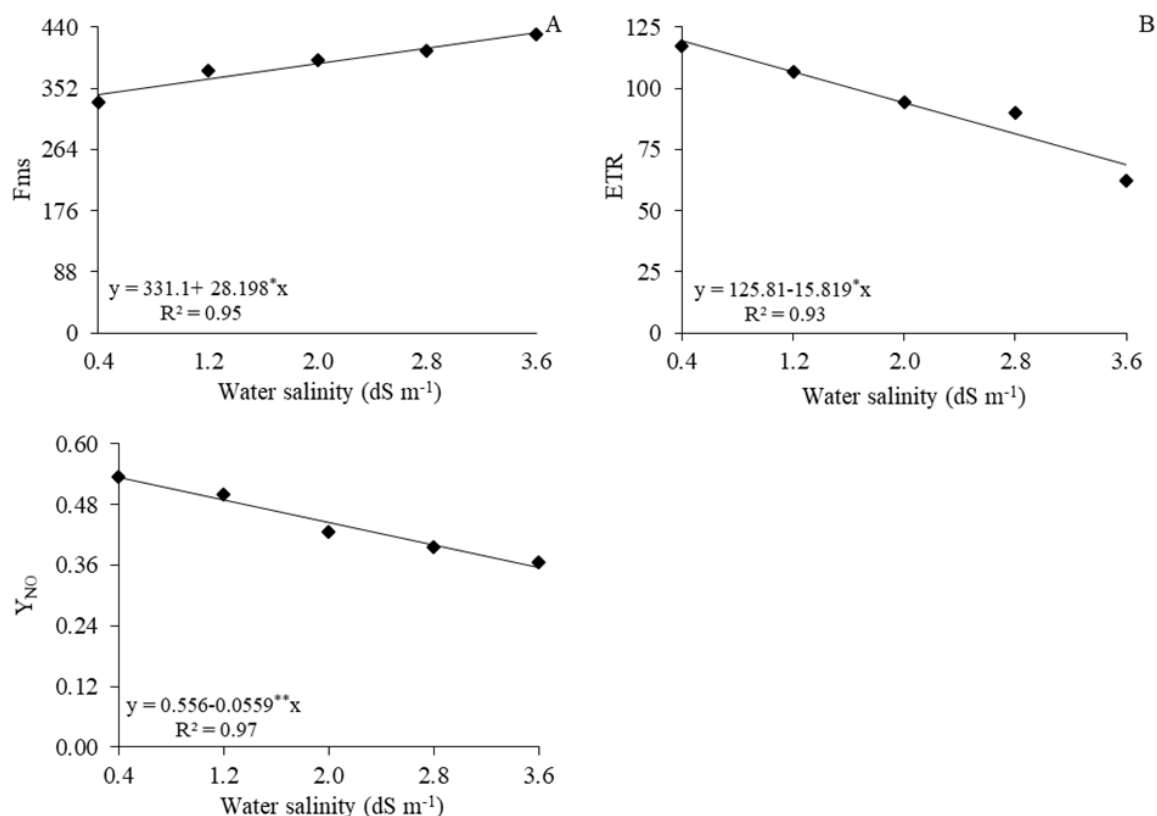


Figure 3. Maximum fluorescence after adaptation to the saturating light—Fms (A), electron transport rate—ETR (B) and quantum yield of non-regulated energy dissipation— Y_{NO} (C) of 'Faga 11' precocious dwarf cashew plants, as a function of saline water irrigation— EC_w , at 50 days after sowing.

4. Conclusions

1. Increasing irrigation water salinity inhibits chlorophyll synthesis and reduces the electron transport rate and quantum yield of non-regulated energy dissipation in precocious dwarf cashew, at 50 days after sowing;
2. Photochemical efficiency in precocious dwarf cashew is changed by irrigation with saline water;
3. There is a significant interaction for chlorophyll *a* and *b* contents and the effects of salt stress are intensified by potassium doses on chlorophyll *b* content in precocious dwarf cashew;

4. Potassium doses of 100 and 150% of recommendation (150 and 225 mg K₂O kg⁻¹ of soil) do not mitigate the effect of salt stress on photosynthetic pigment synthesis and photochemical efficiency of cashew plants in the rootstock formation phase.

Conflicts of interest

No competing conflicts of interest expressed among authors.

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