Revista Ciência Agronômica
ISSN: 0045-6888
ISSN: 1806-6690
Universidade Federal do Ceará

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Revista Ciência Agronômica, vol. 49, no. 2, April-June, 2018, pp. 239-248
Universidade Federal do Ceará

DOI: 10.5935/1806-6690.20180027

Available in: http://www.redalyc.org/articulo.oa?id=195358123007

Revista Ciência Agronômica, v. 49, n. 2, p. 239-248, abr-jun, 2018
Centro de Ciências Agrárias - Universidade Federal do Ceará, Fortaleza, CE
www.ccarevista.ufc.br

Scientific Article
ISSN 1806-6690

Gas exchanges and production of colored cotton irrigated with saline water at different phenological stages[1]

Trocas gasosas e produção do algodoeiro colorido irrigado com água salina em diferentes estádios fenológicos

Lauriane Almeida dos Anjos Soares[2]*, Pedro Dantas Fernandes[2], Geovani Soares de Lima[2], Janivan Fernandes Suassuna[3] and Rennan Fernandes Pereira[4]

ABSTRACT - Scarcity of good-quality water is a limiting factor for irrigated agriculture, especially in semi-arid regions, which leads to the use of water with high salt content to irrigate crops. Therefore, this study aimed to evaluate physiological aspects and production of colored cotton genotypes under saline stress, during the different development stages and under conditions of low and high salinity. The experiment was conducted using a randomized block design, with a 3 × 7 factorial scheme and three replicates. Treatments corresponded to three colored cotton genotypes irrigated with low-salinity water (0.8 dS m^{-1}) and high-salinity water (9.0 dS m^{-1}): T1-$A_1B_1C_1$, T2-$A_2B_1C_1$, T3-$A_1B_2C_1$, T4-$A_1B_1C_2$, T5-$A_2B_1C_2$, T6-$A_2B_2C_1$ and T7-$A_1B_2C_2$ (A_1, B_1 and C_1: without salinity and A_2, B_2 and C_2: with salinity; in the vegetative, flowering and fruiting stages, respectively). Among the genotypes, BRS Rubi was the most sensitive to irrigation water salinity, regardless of development stage. Successive application of saline water at the flowering and boll formation stages led to drastic reduction in physiological aspects of the crop, with recovery of the plants after the stress was interrupted. Saline water irrigation at initial development stages can be used in the cotton crop for reducing the average time to the beginning of flowering. Seed cotton production was more affected by application of saline water at the flowering and boll formation stages.

Key words: *Gossypium hirsutum* L.. Water scarcity. Salinity.

RESUMO - A escassez de água de boa qualidade é um fator limitante para a agricultura irrigada, principalmente na região semiárida, o que induz a utilização de águas com elevados teores de sais na irrigação das culturas. Diante do exposto, objetivou-se avaliar os aspectos fisiológicos e a produção de genótipos de algodoeiro colorido sob estresse salino, durante os diferentes estádios de desenvolvimento das plantas, em condições de baixa e alta salinidade. Adotou-se o delineamento estatístico em blocos ao acaso, em esquema fatorial 3 x 7, com três repetições. Sendo três genótipos de algodoeiro colorido irrigados com águas de baixa (0,8 dS m^{-1}) e alta salinidade (9,0 dS m^{-1}); sendo estas aplicadas sob diferentes estratégias de manejo: T1-$A_1B_1C_1$, T2-$A_2B_1C_1$, T3-$A_1B_2C_1$, T4-$A_1B_1C_2$, T5-$A_2B_1C_2$, T6-$A_2B_2C_1$ e T7-$A_1B_2C_2$ (A_1, B_1 e C_1: sem salinidade e A_2, B_2 e C_2: com salinidade; nas fases vegetativa, floração e frutificação, respectivamente). Dentre os genótipos, o BRS Rubi foi o mais sensível à salinidade da água de irrigação, independente do estádio de desenvolvimento. A aplicação sucessiva da água salina na floração e na formação da produção ocasionou uma drástica redução nos aspectos fisiológicos da cultura, com recuperação das plantas após suspensão do estresse. A irrigação com água salina nas fases iniciais do desenvolvimento pode ser utilizada no cultivo do algodoeiro por proporcionar reduções no tempo médio para o inicio da floração A produção do algodão em caroço foi mais afetada pela salinidade aplicada na fase de floração e formação dos capulhos.

Palavras-chave: *Gossypium hirsutum* L.. Escassez hídrica. Salinidade.

DOI: 10.5935/1806-6690.20180027
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Received for publication on 22/04/2016; approved 07/06/2017
[1]Parte de Dissertação de Mestrado da primeira autora apresentada no Programa de Pós-Graduação em Engenharia Agrícola CTRN/UFCG.
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INTRODUCTION

With the increase in human population and fast economic growth, fresh water scarcity has become a fundamental and chronic problem for the sustainable development of agriculture in arid and semi-arid regions. At the same time, irrigation water quality has deteriorated, mostly due to increased concentrations of salts (AREF; RAD, 2012; JIANG *et al*., 2012).

In general, salinity is one of the main factors that limit plant physiological mechanisms, such as chlorophyll fluorescence and gas exchange attributes, because it restricts water availability to plants by reducing the osmotic potential of the soil solution (AYDIN; KANT; TURAN, 2012; ASHRAF; ASHRAF, 2012). In addition, salinization leads to nutritional imbalance, because excessive sodium in the soil solution causes disruption of the absorption of nutrients, mainly affecting the concentrations of Ca, Mg and K in the plant (ROSALES *et al*., 2012).

Nevertheless, saline water can be used to irrigate crops during a certain period of growth, with slight or no reduction in yield (CHAUHAN; SINGH, 2008). Nonetheless, its utilization requires improvements in water management, soil maintenance and cultivation of salinity-tolerant crops (LACERDA *et al*., 2009). Thus, the economic production of salinity-tolerant crops, such as cotton, under saline conditions depends on suitable cultivation practices, the duration of exposure to salinity and the stages of plant development (CHAVES; FLEXAS; PINHEIRO, 2009; IQBAL *et al*., 2011).

Maas and Hoffman (1977) determined salinity tolerance in the root zone based on agronomic aspects of crops. However, the use of this classification cannot be generalized because tolerance to salinity varies between plant development stages, which may enable cultivation in areas with water of differential salinities, or in areas where water saline content increases during the production cycle of the crops or during the most tolerant stages to salinity (NAWAZ *et al*., 2010). For these reasons, sensitivity or tolerance to saline stress must be evaluated at different stages of plant development (GUIMARÃES *et al*., 2013).

Considering these aspects, this study aimed to evaluate physiological aspects and production of colored cotton genotypes under saline stress, during the different development stages and under conditions of low and high salinity.

MATERIAL AND METHODS

The experiment was carried out in a protected environment (greenhouse) at the Center of Technology and Natural Resources - CTRN of the Federal University of Campina Grande - UFCG, located in the municipality of Campina Grande, Paraíba, Brazil, at geographic coordinates 07°15'18'' S, 35°52'28'' W and mean altitude of 550 m (COELHO; SONCIN, 1982).

The statistical design was in randomized blocks with a factorial scheme (3 × 7), which corresponded to three cotton genotypes (G1 - BRS Rubi; G2 - BRS Topázio; G3 - BRS Safira) and seven management strategies relating to saline water application during the crop development stages. Combining the factors resulted in 21 treatments with three replicates and three plants per plot, totaling 189 plants.

Cotton plants were irrigated with low-salinity water (0.8 dS m^{-1} - index 1) and high-salinity water (9.0 dS m^{-1} - index 2) using different management strategies: T1-$A_1B_1C_1$ - plants irrigated with non-saline water (0.8 dS m^{-1}) for the entire cycle - identified by the index 1 in the phenological stages; T2-$A_2B_1C_1$ - plants under saline stress at the vegetative stage (index 2 in stage A), irrigated using high-salinity water (ECw = 9.0 dS m^{-1}) until the beginning of flowering, and then using low-salinity water until the end of the cycle; T3-$A_1B_2C_1$ - plants under saline stress during the flowering stage (index 2 in stage B) and low-salinity water during the other stages; T4-$A_1B_1C_2$ - plants irrigated with good-quality water at vegetative and flowering stages and high-salinity water at the boll formation stage (index 2 in stage C); T5-$A_2B_1C_2$ - plants irrigated with saline water at vegetative and boll formation stages, and low-salinity water at the flowering stage; T6-$A_2B_2C_1$ - plants under saline water successively in the vegetative and flowering stages, and low-salinity water in the boll formation stage; and T7-$A_1B_2C_2$ - plants under saline stress at flowering and boll formation stages.

Vegetative (A), flowering (B) and boll formation (C) stages corresponded to the periods from appearance of the first true leaf to first flower opening (16 - 37 days after sowing - DAS), from first flower opening to first boll opening (37 - 59 DAS), and from first boll opening to harvest (59 - 113 DAS), respectively.

Plants were grown in plastic pots with a capacity of approximately 20 L, perforated at the bottom, and connected to drains and a container to collect the drained water, which allowed monitoring of the drained volume and crop water consumption. The pots contained a 0.3-kg layer of crushed stone, which covered the bottom, and 24.5 kg of non-saline, non-sodic soil material (loamy sand) (Table 1). The experimental units were arranged in single rows spaced at 1 m and plants were spaced at 0.6 m along each row.

Basal fertilization with NPK was applied as recommended for pot experiments by Novais, Neves

Table 1 - Physical and chemical characteristics of the soil used in the experiment

Density	Total Porosity	OM	Moisture (kPa)		Available water	Sorption Complex				pHsp	EC_{se}
			33.42	1519.5		K^+	Na^+	Ca^{+2}	Mg^{+2}		
(kg dm^{-3})	(%)	dag kg^{-1}	dag kg^{-1}		(%)	($cmol_c$ kg^{-1})				-	dS m^{-1}
1.67	38.59	21.20	11.48	2.41	9.07	0.18	0.37	2.37	3.09	5.80	0.20

Ca^{2+} and Mg^{2+} extracted with 1 mol L^{-1} KCl pH 7.0; Na^+ and K^+ extracted using 1 mol L^{-1} NH_4OAc; P – extracted by Mehlich 1; pH_{sp} – pH of the saturation paste, and ECse – electrical conductivity of the saturation extract

and Barros (1991). Concentrations of 100, 300 and 150 mg kg^{-1} of nitrogen (N), phosphorus (P) and potassium (K), respectively, were applied in the form of ammonium sulfate, single superphosphate and potassium chloride. Basal fertilization consisted of the entire P recommended quantity and only 1/3 of the N and K recommended quantity; the two remaining thirds were applied via irrigation water from 45 to 65 days after sowing (DAS).

The low-salinity water (0.8 dS m^{-1}) used for irrigation was obtained by diluting water from the public supply system of Campina Grande-PB with rainwater, whereas the level corresponding to the highest ECw (9.0 dS m^{-1}) was prepared in such a way to obtain an equivalent proportion of 7:2:1, between Na:Ca:Mg, respectively. The amount was determined as described in the equation of Richards (1954), taking into consideration the relationship between ECw and concentration of salts (10*$mmol_c$ L^{-1} = 1 dS m^{-1}). Soil moisture was adjusted to a level corresponding to field capacity in all experimental units using low-salinity water (0.8 dS m^{-1}), through capillary saturation followed by free drainage. After that, five seeds were planted in each lysimeter, 3 cm deep and equidistant from each other. Thirty days after sowing, thinning was performed to maintain one plant per pot.

At 37, 59 and 113 DAS, physiological variables were determined in the third leaf from the apex, using a portable infrared gas analyzer (IRGA), called LCpro-SD (ADC Bioscientific, UK). The physiological variables were: internal CO_2 concentration (Ci) (µmol m^{-2} s^{-1}), transpiration (E) (mmol H_2O m^{-2} s^{-1}), stomatal conductance (gs) (mol H_2O m^{-2} s^{-1}) and CO_2 assimilation rate (photosynthesis) (A) (µmol m^{-2} s^{-1}). After data collection, instantaneous water use efficiency (WUEi) (A/E) [(µmol m^{-2} s^{-1}) (mol H_2O m^{-2} s^{-1})$^{-1}$] and instantaneous carboxylation efficiency (CEi) (A/Ci) [(µmol m^{-2} s^{-1})/(µmol m^{-2} s^{-1})] were quantified (KONRAD *et al*., 2005).

In the evaluation performed at 37 DAS, only two salinity management strategies were considered in the statistical analysis (T1 - $A_1B_1C_1$ and T2 - $A_2B_1C_1$), whereas four strategies were considered at 59 DAS (T1 - $A_1B_1C_1$, T2 - $A_2B_1C_1$, T3 - $A_1B_2C_1$ and T6 - $A_2B_2C_1$), because in these evaluations the salinity treatments had not yet started in the other strategies. At 113 DAS, the number of days to anthesis (NDANT) and seed cotton weight were determined. NDANT was determined by daily monitoring of flower bud appearance, while seed cotton weight (SCW) was determined based on the total weight of bolls from each plot.

The obtained data were subjected to analysis of variance using the F test. In cases of significance, Scott-Knott means grouping test ($p<0.05$) was applied to management strategies, and Tukey test ($p<0.05$) to cotton genotypes (FERREIRA, 2003).

RESULTS AND DISCUSSION

Significant differences occurred between salinity management strategies for stomatal conductance at 37, 59 and 113 DAS, for transpiration, CO_2 assimilation rate and internal CO_2 concentration at 59 and 113 DAS and for instantaneous carboxylation efficiency and water use efficiency only at 113 DAS. Differences between cotton genotypes were observed only for internal CO_2 concentration and carboxylation efficiency at 113 DAS. There was no effect of interaction between factors on (MS × G), indicating that the adopted management strategies did not interfere with gas exchange in the cotton genotypes (Table 2).

With the beginning of the cotton flowering stage at 37 DAS, saline stress in the strategy T2 - $A_2B_1C_1$ reduced stomatal conductance compared with plants under no stress; in this period, plants obtained gs values of around 0.1829 mol m^{-2} s^{-1} (Figure 1A). Kusvuran (2012) claims that high irrigation water salinity has a harmful effect on stomatal opening, due to increased resistance to CO_2 diffusion, which was observed in plants irrigated using 9.0 dS m^{-1} water. In contrast, at 59 DAS, plants irrigated with saline water in the vegetative stage (T2) showed an increment of 0.2488 mol m^{-2} s^{-1} in stomatal conductance at the end of flowering, superior

Table 2 - Analysis of variance summary for stomatal conductance (gs), transpiration (E), CO_2 assimilation rate (A), instantaneous water use efficiency (WUEi), internal CO_2 concentration (Ci) and instantaneous carboxylation efficiency (CEi) at 37, 59 and 113 days after sowing as a function of different salinity management strategies and cotton genotypes

Variables	DAS	DF	MSq	DF	MSq	DF	MSq	CV%	Overall Mean
			Management Strategies (MS)		Genotypes (G)		MS x G		
gs	37	1	0.0055*	2	0.0003^{ns}	2	0.0013^{ns}	16.58	0.2005
E		1	0.2787^{ns}	2	0.0559^{ns}	2	0.0306^{ns}	9.79	2.6085
A		1	0.0896^{ns}	2	0.6536^{ns}	2	5.1551^{ns}	13.51	15.3675
WUEi		1	1.5922^{ns}	2	0.1155^{ns}	2	0.2954^{ns}	13.95	5.9311
Ci		1	1867.2853^{ns}	2	75.7842^{ns}	2	129.3021^{ns}	12.09	192.4814
CEi		1	0.0006^{ns}	2	0.00002^{ns}	2	0.0001^{ns}	23.68	0.0844
gs	59	3	0.0339**	2	0.0005^{ns}	6	0.0022^{ns}	28.66	0.1678
E		3	5.1323**	2	0.4068^{ns}	6	0.3811^{ns}	18.84	3.5056
A		3	97.1252**	2	11.1883^{ns}	6	6.7393^{ns}	19.33	16.0259
WUEi		3	0.4168^{ns}	2	0.4094^{ns}	6	0.0175^{ns}	10.49	4.7861
Ci		3	1970.1478*	2	622.1321^{ns}	6	323.9594^{ns}	16.18	143.4074
CEi		3	0.0017^{ns}	2	0.0016^{ns}	6	0.0003^{ns}	24.22	0.1179
gs	113	6	0.0337**	2	0.0004^{ns}	12	0.0002^{ns}	21.16	0.1293
E		6	10.4424**	2	0.0724^{ns}	12	0.0846^{ns}	22.11	2.9974
A		6	109.0878**	2	6.4652^{ns}	12	2.2722^{ns}	13.93	11.8575
WUEi		6	1.8826**	2	0.8686^{ns}	12	0.2304^{ns}	14.45	4.3776
Ci		6	6642.7695**	2	1652.9949*	12	378.7082^{ns}	13.51	163.9153
CEi		6	0.0014**	2	0.0015**	12	0.0004^{ns}	24.06	0.0761

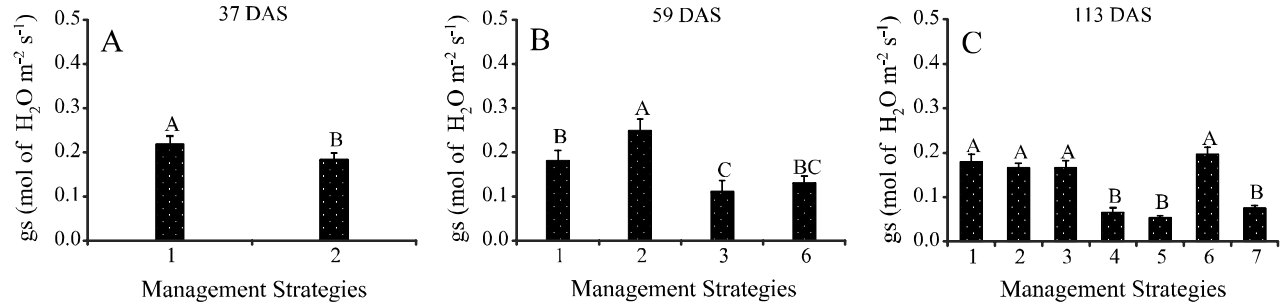
$^{ns, **, *:}$ not significant and significant at p<0.01 and p<0.05; respectively, by F test; DAS = days after sowing and MS = Mean square

to the values of plants under no saline stress (T1), on average equal to 0.1807 mol m^{-2} s^{-1} (Figure 1B).

At the end of the crop cycle (113 DAS), there were no differences between the strategies T1, T2, T3 and T6 for stomatal conductance; values were 0.1800, 0.1655, 0.1666 and 0.1974 mol m^{-2} s^{-1}, respectively. Plants cultivated under these management strategies, immediately after application of saline water ended, experienced improvements in soil hydraulic conditions, which allowed gas exchange between plants and the environment (Figure 1C). Bybordi (2010), studying the effect of saline stress on germination, vegetative growth and concentration of elements and proline in five canola cultivars, also observed significant variations between the cultivars regarding the tolerance to salinity at different stages of development.

As shown in Figure 2A, at the end of flowering (59 DAS), the transpiration rate of plants irrigated under the management strategies T3 and T6, compared to

Figure 1 - Means test for stomatal conductance (gs) of cotton under different salinity management strategies at 37, 59 and 113 DAS. Management strategies with the same letter do not differ by Tukey test, p<0.05; Bars represent the standard error of the mean (n = 9)



plants irrigated with low-salinity water (T1), decreased by 26.61 and 16.66%, from 3.72 mmol m^{-2} s^{-1} to 2.73 and to 3.10 mmol m^{-2} s^{-1}, respectively. Reduction in leaf transpiration under conditions of saline stress is usually attributed to partial stomatal closure, associated with osmotic effects and ion toxicities which affect plant metabolism (NEVES *et al*., 2009). Similar results, with decrease in transpiration rate caused by increase in irrigation water salinity, have also been found in jatropha plants (SILVA *et al*., 2011).

Conversely, plants under the management strategy T2 resumed transpiration rate at 59 DAS (Figure 2A) and 113 DAS (Figure 2B), which increased to 4.45 and 3.66 mmol m^{-2} s^{-1}, respectively, similar to the values with management strategy T1 (3.72 and 3.90 mmol m^{-2} s^{-1}). This behavior confirms the data obtained for gs, ratifying the importance of different salinity management strategies in cotton development. This situation probably led to improvement in the hydraulic conditions of the soil and, consequently, of the plants, allowing gas exchange between plants and the environment.

Due to the reduction in stomatal conductance and transpiration rate in the leaves, CO_2 assimilation rate was compromised when plants were irrigated with high-salinity water at 59 DAS (Figure 3A). This was particularly evident with the strategies T3 and T6, which had the lowest net photosynthetic rates (12.78 and 14.56 µmol m^{-2} s^{-1}, respectively) in comparison to plants irrigated with low-salinity water during the entire cycle – T1 (16.28 µmol m^{-2} s^{-1}); the reductions were 21.49 and 10.56%, respectively. Assis Júnior *et al.* (2007) also observed that water salinity caused a reduction in stomatal conductance, transpiration rate and net

Figure 2 - Means test for transpiration (E) of cotton under different salinity management strategies at 59 and 113 DAS. Management strategies with the same letter do not differ by Tukey test, p<0.05; Bars represent the standard error of the mean (n = 9)

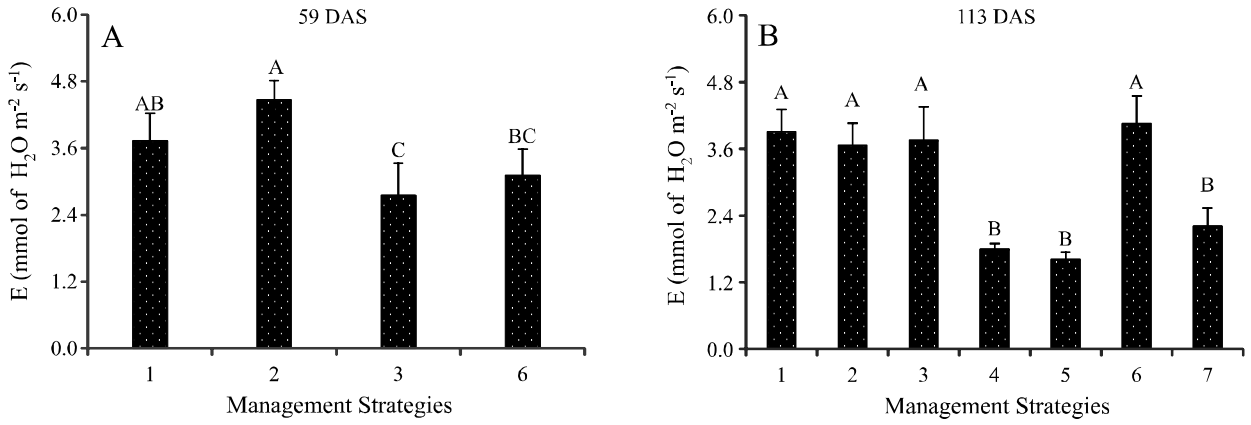
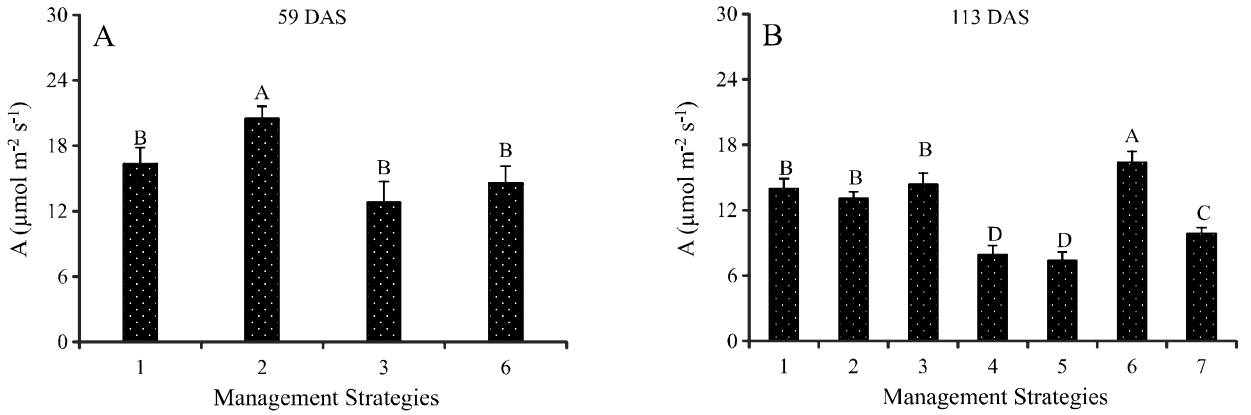


Figure 3 - Means test for CO_2 assimilation rate (A) of cotton under different salinity management strategies at 59 and 113 DAS. Management strategies with the same letter do not differ by Tukey test, p<0.05; Bars represent the standard error of the mean (n = 9)

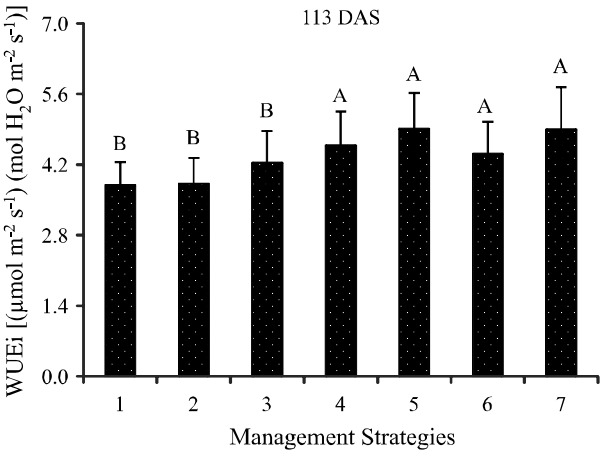


photosynthetic rate during the flowering and fruiting stages of the cowpea cv. EPACE 10, and associated these reductions to partial stomatal closure, besides the osmotic effects and effects of ionic toxicity on the metabolism of plants subjected to saline conditions.

At 113 days after sowing (Figure 3B), successive saline stress - $A_2B_2C_1$ (vegetative and flowering) caused an increment of 85.31% in CO_2 assimilation rates, in comparison to plants irrigated with low-salinity water (0.8 dS m^{-1}). Higbie *et al*. (2010), evaluating physiological aspects of five cultivars of herbaceous cotton (*G. hirsutum* L.) and one strain of Pima cotton (*G. barbadense* L.) under saline conditions (0.57 and 20.0 dS m^{-1}), found no significant morphological differences, due to the short time of exposure to saline stress (0, 7, 14 and 21 days after stress), but all plants recovered after exposure to saline stress and survived until maturity.

In agreement with the results for stomatal conductance, transpiration and CO_2 assimilation rate, there was higher instantaneous water use efficiency (WUEi) at 113 DAS (Figure 4) in plants irrigated using the management strategies T4, T5, T6 and T7, with an average WUE of 4.69 [(μmol m^{-2} s^{-1}) (mmol H_2O m^{-2} $s^{-1})^{-1}$], especially with T5 and T7, in which cotton plants started using photosynthesis more efficiently in response to irrigation water salinity (Figure 4). According to Machado Filho *et al*. (2006), stomatal closure increases the instantaneous water use efficiency, a situation that can be demonstrated at the beginning of water deficit caused by saline stress.

Figure 4 - Means test for instantaneous water use efficiency (WUEi) of cotton under different salinity management strategies at 113 DAS. Management strategies with the same letter do not differ by Tukey test, p<0.05; Bars represent the standard error of the mean (n = 9)



Highest mean values of internal CO_2 concentration (Ci) occurred with the strategies T1 and T2 (151.48 and 159.92 μmol mol^{-1}, respectively); however, values obtained with these strategies did not differ from the value with T6 at 59 DAS (Figure 5A). In this same period, plants under T3 conditions, at the end of flowering, showed reductions of 15.33% in internal CO_2 concentration compared to those under the strategy of no saline stress for the entire cycle.

Nevertheless, plants irrigated using the strategies T2, T3 and T6 resumed the accumulation of internal CO_2 at the end of the cycle (113 DAS). Higher Ci means that carbon was being metabolized by the photosynthetic apparatus, which may be caused by conditions of saline stress in the vegetative and flowering stages. It is worth highlighting that plants under management strategies T4 and T5 exhibited the lowest Ci values (Figure 5B). Under saline conditions, there have been reductions in photosynthesis, transpiration and stomatal conductance, and increments in intercellular CO_2 concentration, depending on the stress level to which the plant was subjected (STEPIEN; KLOBUS, 2006).

With regard to internal CO_2 concentration (Ci) as a function of the cotton genotypes studied, highest mean values were observed in the genotype BRS Topázio, but this did not differ significantly from BRS Rubi (Figure 5C); values were 172.39 and 164.65 μmol mol^{-1}, respectively. The lowest internal CO_2 concentration, at 113 DAS, was recorded for the genotype BRS Safira (154.69 μmol mol^{-1}); this represented a reduction of 10.26% and 6.04% in comparison to the other cotton genotypes. These results were inferior to those found by Ferraz (2012) with the same genotypes, but under field conditions; mean values were 182.9, 210.2 and 223.7 μmol mol^{-1} for BRS Rubi, BRS Topázio and BRS Safira, respectively.

As with most physiological variables, higher mean values occurred with the strategies T3, T6 and T7 (Figure 6A), most notably when plants were irrigated with saline water consecutively in the vegetative and flowering stages (T6), with a mean value of 0.098 [(μmol m^{-2} s^{-1}) (μmol $mol^{-1})^{-1}$]. The management strategies T3 and T7 also stood out with mean values of 0.085 and 0.080 [(μmol m^{-2} s^{-1}) (μmol $mol^{-1})^{-1}$], respectively, whereas lowest CEi value was observed in plants grown under strategies T1, T2, T4 and T5.

The mean CEi values observed in BRS Rubi and BRS Safira were 0.085 and 0.072 [(μmol m^{-2} s^{-1}) (μmol mol^{-1} $s^{-1})^{-1}$]. These values were 7.62 and 2.76% higher, respectively, than the 0.070 [(μmol m^{-2} s^{-1}) (μmol mol^{-1} $s^{-1})^{-1}$] observed in BRS Topázio (Figure 6C), because higher Ci levels were found in plants of this genotype. This result is probably a consequence of the low CO_2 assimilation rate,

Figure 5 - Means test for internal CO_2 concentration (Ci) of cotton under different salinity management strategies at 59 and 113 DAS, and genotypes at 113 DAS. Equal uppercase letters indicate no significant difference between management strategies (Scott-Knott, $p<0.05$) and between genotypes (Tukey, $p<0.05$); Bars represent the standard error of the mean for management strategies (n = 9) and genotypes (n = 21)

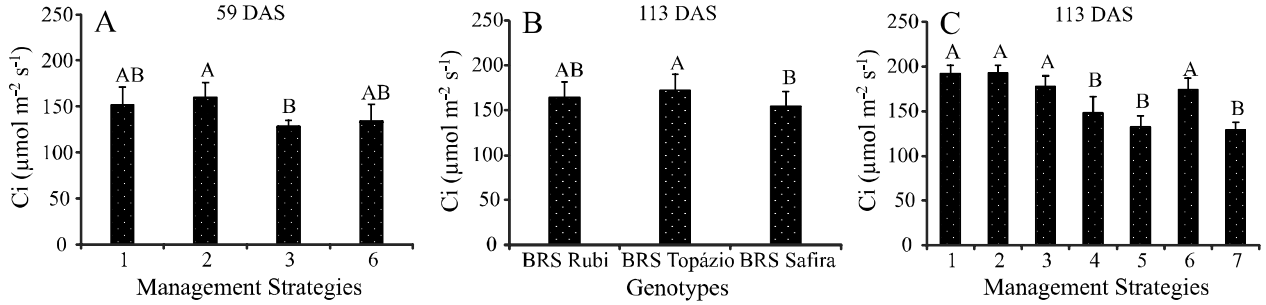
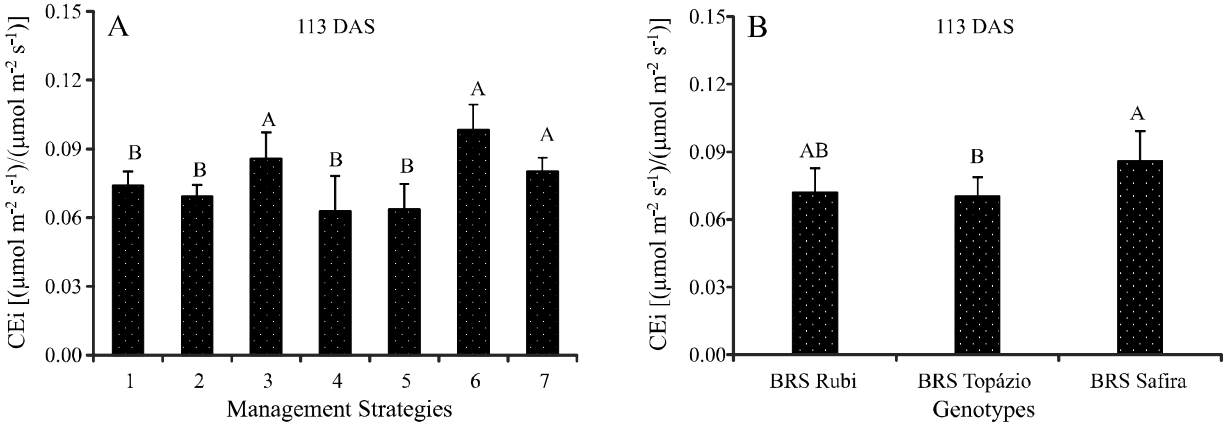


Figura 6 - Means test for instantaneous carboxylation efficiency (CEi) of cotton under different salinity management strategies and genotypes at 113 DAS. Equal uppercase letters indicate no significant difference between management strategies (Scott-Knott, $p<0.05$) and between genotypes (Tukey, $p<0.05$); Bars represent the standard error of the mean for management strategies (n = 9) and genotypes (n = 21)



compared with CO_2 found in the substomatal chamber of this genotype, because if Ci increases and there is a reduction in CO_2 consumption in the chloroplasts due to the reduction in photosynthetic activity, the A/Ci ratio will also decrease.

Salinity management strategies and colored cotton genotypes had a significant effect on seed cotton weight (Table 3). With regard to the interaction between factors (salinity management strategies and cotton genotypes), a significant effect only occurred for the number of days to anthesis, denoting that the salinity management strategies had similar influence on the different cotton genotypes studied.

According to the follow-up analysis of the isolated effect of genotypes for each salinity management strategy on the number of days to anthesis at 113 DAS, the genotypes did not differ in the strategies T1, T2, T3, T5 and T6 (Table 4). On the other hand, differences were observed between the genotypes in the strategies T4 and T7. With these strategies, the genotypes with the highest number of days to anthesis (52.55 and 55.66 days), respectively, were BRS Rubi and BRS Topázio, which showed 49.88 and 48.88 days, respectively. Differences between salinity management strategies were reported only for the genotype BRS Rubi, with reductions in the number of days to flower bud opening with the strategies T1, T3 and T6. Costa *et al*. (2008) found that the increase in irrigation water salinity up to 4.5 dS m^{-1} contributed to retarding the average time for the beginning of amaranth flowering.

Based on the results of the means test for the management strategies of saline water application relative to seed cotton weight (Figure 7A), the strategy T1 ($A_1B_1C_1$)

Table 3 - Analysis of variance summary for number of days to anthesis (NDANT) and seed cotton weight (SCW) at 113 days after sowing, as a function of different salinity management strategies and cotton genotypes

Variation sources	DF	Mean Square	
		NDANT	SCW
Management Strategies (MS)	6	4.932^{ns}	29205.163**
Genotypes (G)	2	4.608^{ns}	5389.677**
MS x G	12	5.170*	406.921^{ns}
Blocks	2	16.513**	44.154^{ns}
Residual	40	2.346	308.221
CV (%)		3.03	10.33
Overall Mean		50.619	169.874

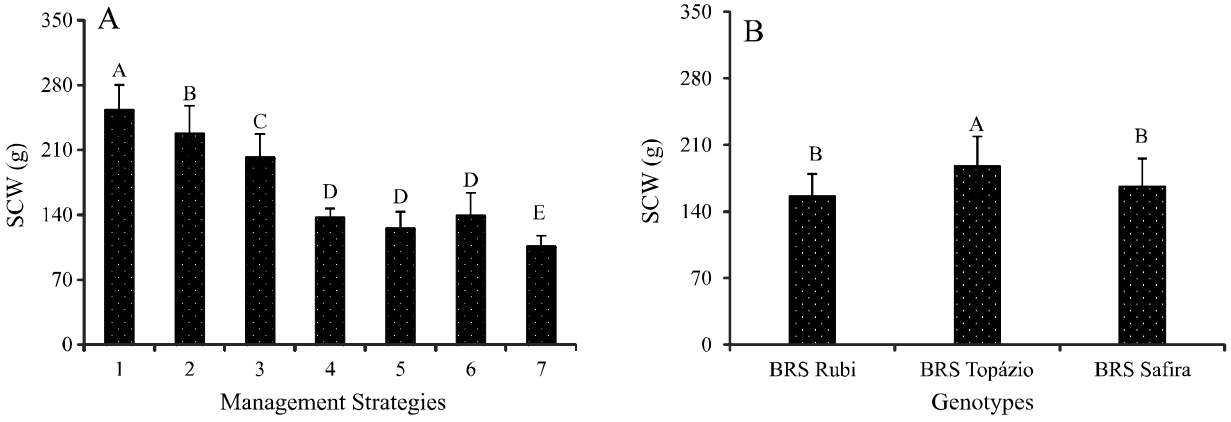
$^{ns, **, *}$: not significant and significant at p<0.01 and p<0.05; respectively, by F test and DAS = days after sowing

Table 4 - Means for the follow-up analysis of the interaction between genotypes and salinity management strategies for the number of days to anthesis at 113 days after sowing

Management Strategies	Genotypes		
	BRS Rubi	BRS Topázio	BRS Safira
T1- A1B1C1	49.222 bA	49.777 aA	51.444 aA
T2- A2B1C1	51.111 aA	49.666 aA	52.444 aA
T3- A1B2C1	48.888 bA	49.444 aA	49.222 aA
T4- A1B1C2	52.555 aA	49.444 aB	50.111 aAB
T5- A2B1C2	52.000 aA	51.000 aA	51.111 aA
T6- A2B2C1	49.555 bA	52.333 aA	51.333 aA
T7- A1B2C2	52.666 aA	48.888 aB	50.777 aAB

Lowercase letters in the column and uppercase letters in the row indicate no significant difference between salinity management strategies (Scott-Knott, p<0.05) and between genotypes (Tukey, p<0.05), respectively; Management strategies: A1, B1, C1: Without salinity and A2, B2, C2: With salinity at the stages

Figure 7 - Means test for seed cotton weight as a function of different salinity management strategies (A) and cotton genotypes (B). Equal uppercase letters indicate no significant difference between management strategies (Scott-Knott, p<0.05) and between genotypes (Tukey, p<0.05); bars represent the standard error of the mean (n = 7)



was superior, with a mean value of 253.09 g per plant. The lowest production values were obtained with the strategies T4, T5, T6 and T7, with reductions of 45.92, 50.53, 45.26 and 58.24%, respectively, compared with the management with low-salinity water. The strategy T7 led to lower seed cotton weight, demonstrating higher sensitivity of the cotton crop when successively subjected to saline stress at flowering and boll formation stages. Oliveira *et al*. (2012) evaluated different levels of irrigation water salinity (0.5, 2.0, 3.5, 5.0 and 6.5 dS m^{-1}) on seed cotton production, using seeds treated with growth regulator and untreated seeds. A deleterious effect 3.5 dS m^{-1} was observed, with loss of seed cotton production of 52.23% between the saline levels of 3.5 and 6.5 dS m^{-1}, regardless of growth regulator application.

With regard to seed cotton weight as a function of the different cotton genotypes (Figure 7B), BRS Topázio showed the highest accumulation (187.36 g per plant), which was 16.78 and 11.22% higher than the values of 155.91 and 166.34 g per plant obtained with BRS Rubi and BRS Safira, respectively. These values differ from those found by Ferraz (2012), who evaluated the behavior of herbaceous cotton genotypes under silicon foliar application and found lower seed cotton weights with BRS Rubi, BRS Topázio and BRS Safira (116.6, 131.7 and 98.5 g per plant, respectively). In treatments without silicon application, this difference may be associated with this experiment being conducted under field conditions.

CONCLUSIONS

1. Among the genotypes, BRS Rubi is the most sensitive to irrigation water salinity (ECw = 9.0 dS m^{-1}), regardless of development stage;
2. Successive application of saline water at the flowering and boll formation stages leads to a drastic reduction in physiological aspects of the crop, with recovery of the plants after stress is interrupted;
3. Saline water irrigation at the initial development stages can be used in the cotton crop to reduce the average time to the beginning of flowering;
4. Seed cotton production is more affected by the salinity applied at the flowering and boll formation stages.

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