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Growth and yield of cowpea/sunflower crop rotation under different irrigation management strategies with saline water

Crescimento e produtividade da rotação feijão-de-corda/girassol sob diferentes estratégias de manejo de irrigação com água salina

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ABSTRACT

This study aimed to evaluate the effect of management strategies of irrigation with saline water on growth and yield of cowpea and sunflower in a crop rotation. The experiment was conducted in randomized blocks with thirteen treatments and five replications. The treatments consisted of: T1 (control), T2, T3 and T4 using water of 0.5 (A1), 2.2 (A2), 3.6 (A3) and 5.0 (A4) dS m^{-1}, respectively, during the entire crop cycle; T5, T6 and T7, use of A2, A3 and A4 water, respectively, only in the flowering and fructification stage of the crop cycle; using different water in a cyclic way, six irrigations with A1 followed by six irrigations with A2 (T8), A3 (T9) and A4, (T10), respectively; T11, T12 and T13, using water A2, A3 and A4, respectively, starting at 11 days after planting (DAP) and continuing until the end of the crop cycle. These treatments were employed in the first crop (cowpea), during the dry season, and the same plots were used for the cultivation of sunflower as succeeding crop during rainy season. The strategies of use of saline water in the salt tolerant growth stage (treatments T5, T6 and T7) or cyclically (treatments T8, T9 and T10) reduced the amount of good quality water used in the production of cowpea by 34 and 47%, respectively, without negative impacts on crop yield, and did not show the residual effects of salinity on sunflower as a succeeding crop. Thus, these strategies appear promising to be employed in areas with water salinity problems in the semiarid region of Brazil.

Key words: *salt stress, **Vigna unguiculata**, **Helianthus annuus**.*

RESUMO

Este estudo teve como objetivo avaliar o efeito de estratégias de manejo de irrigação com água salina no crescimento e produção de feijão-caupi e do girassol em um sistema de rotação de culturas. O experimento foi conduzido em blocos ao acaso com treze tratamentos e cinco repetições. Os tratamentos consistiram de: T1 (controle), T2, T3 e T4, utilizando água de 0,5 (A1), 2,2 (A2), 3,6 (A3) e 5,0 (A4) dS m^{-1}, respectivamente, ao longo de todo o ciclo da cultura; T5, T6 e T7, utilizando águas salinas A2, A3 e A4, respectivamente, apenas na fase de floração e frutificação; uso de diferentes fontes de água de forma cíclica, com seis irrigações com A1 seguido por seis irrigações com A2 (T8), A3 (T9) e A4 (T10), respectivamente; T11, T12 e T13, usando água A2, A3 e A4, respectivamente, a partir de 11 dias após o plantio (DAP) e continuando até ao final do ciclo da cultura. Estes tratamentos foram empregados na primeira safra com o feijão-caupi, durante a estação seca. As mesmas parcelas foram utilizados para o cultivo de girassol como cultura de sucessão durante a estação chuvosa. O uso de água salina no estádio de maior tolerância à salinidade (tratamentos T5, T6 e T7) ou ciclicamente (tratamentos T8, T9 e T10) reduziu a quantidade de água de boa qualidade usada na produção de feijão-caupi em 34 e 47%, respectivamente, sem impactos negativos na produtividade da cultura, e eliminou os efeitos residuais da salinidade no girassol como uma cultura de sucessão. Assim, essas estratégias parecem promissoras para serem empregadas em áreas com problemas de água salinas na região semiárida do Brasil.

Palavras-chave: *estresse salino, **Vigna unguiculata**, **Helianthus annuus**.*

INTRODUCTION

Farmers in many parts of the world have attempted to use low quality water resources, such as saline and wastewater, however, the use of these water sources, particularly in the case of irrigated agriculture, depends on long-term strategies that ensure socioeconomic and environmental

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sustainability of the agricultural systems (MALASH et al., 2005; MURTAZA et al., 2006; TRAVASSOS et al., 2011; OSTER et al., 2012).

The use of some strategies for irrigation management, such as the use of saline water only during salt-tolerant growth stages, the mixture of water sources and cyclic use of water of different qualities, associated with crop rotations, can contribute to reduce salt accumulation in the soil. This fact limits the negative impacts on the environment and crop development, providing increased efficiency of use of good quality water (MURTAZA et al., 2006; CHOUDHARY et al., 2011; BARBOSA et al., 2012; OSTER et al., 2012; AL KHAMISI et al., 2013).

The alternate application of high and low salinity water may contribute to leach the excess of salts added to the root zone, promoting good development of the crop. In maize, for example, the use of this strategy allowed the substitution of about 50% of low salinity (0.8dS m^{-1}) by water of electrical conductivity (EC) of 4.5dS m^{-1} in irrigation, without negative impacts on crop yield (BARBOSA et al., 2012). According to MURTAZA et al. (2006), the use of suitable management strategies of soil and water allow the economically profitable production of the crops for several years, with little or no impact on the soil. Furthermore, the authors observed that the use of crop rotation could be an additional alternative to semiarid environments, particularly in areas with problems of water salinity.

Another important aspect that should be considered regarding the use of saline water in irrigation is that genotypes of the same species may respond differently to effects of salinity in the different stages of the crop cycle (NEVES et al., 2010). In cowpea, for example, the application of water with an EC of 5.0dS m^{-1} throughout the cycle and during germination and initial growth stage caused significant reductions in the number of pods and seed yield per plant. However, irrigation of the crop with the same water during flowering and pod formation stages did not affect the growth and crop yield, and allowed the replacement of about 40% of good quality water (LACERDA et al., 2011).

Thus, this study aimed to evaluate different management strategies of irrigation with saline water in a cowpea/sunflower crop rotation system, trying to find the strategies that cause minor impact on soil and crop development, as well as higher economy of good quality water.

MATERIAL AND METHODS

The study was conducted during the dry season of 2011 and in the rainy season of 2012 in the municipality of Pentecost, Ceará, Brazil (3º45'S, 39 º15'W and altitude of 47m). According to the classification of KÖPPEN (1948) the region has a BSw'h' type climate, semi-arid, very hot with rains in summer-autumn. The soil is classified as Fluvic Neosol (EMBRAPA, 1999), with loamy sand texture, $EC_{1:1}$=1.26dS m^{-1}, and exchangeable sodium percentage of 6.0%.

During the dry season (September-November 2011) seeds of cowpea (***Vigna unguiculata*** L. Walp.) cultivar EPACE 10, were sown in 0.8x0.3m spacing, with two seeds per hole equivalent to plant density of 83,333 plants ha^{-1}. The experiment was conducted in randomized blocks with thirteen treatments and five replications. Each plot had dimensions of 6.6x4.0m, with five rows, totaling 65 plots.

In the composition of the treatments, four sources of water were used: A1- Canal water with EC of 0.5dS m^{-1}; A2 - Wastewater from the desalination plant installed near to experimental area, with EC of 2.2dS m^{-1}; A3 - Saline water with EC of 3.6dS m^{-1}, obtained by mixing the wastewater from a desalinization plant with NaCl and $CaCl_2.2H_2O$ salts in 7:3 equivalent ratio; and A4 - Saline water with EC of 5.0dS m^{-1}, also obtained by the addition of mentioned salts to wastewater from desalinization plant.

The treatments were as follows: T1 (control), T2, T3 and T4 using water of 0.5 (A1), 2.2 (A2), 3.6 (A3) and 5.0 (A4) dS m^{-1}, respectively, during the entire crop cycle; T5, T6 and T7, using A2, A3 and A4 water, respectively, only in the flowering and fructification stage of the crop cycle; using different types of water in a cyclic way, six irrigations with A1 followed by six irrigations with A2 (T8), A3 (T9) and A4, (T10), respectively**;** T11, T12 and T13, using A2, A3 and A4 water, respectively, starting at 11 days after planting (DAP) and continuing until the end of the crop cycle.

In all treatments, the water was applied using a drip irrigation system, and depth of irrigation water to be applied was based on evapotranspiration (ETo), estimated by Class A Pan method, and crop coefficients (Kc) recommended by SOUZA et al. (2005). The total water applied, the contribution of each type of water and the mean weighted EC were calculated. At the end of the crop cycle, the EC of the topsoil (until 10cm) was determined in all plots, using a portable conductivity sensor model Wet HH2 (AT Delta-T Devices, Cambridge, England).

At the end of the crop cycle (60 DAP), groups of six plants of each plot (in the three central rows) were collected and separated into leaves (leaf blades) and stems (petioles and branches). After drying the materials in an oven at 60°C, the dry mass of each part was determined. The pods were also collected from all plants in the three central rows of each plot, and then weighed. The grain yield and water use efficiency for both primary production (WUEp) and grain yield (WUEy) were also determined.

In the rainy season of 2012 (March to June) sunflower (***Helianthus annuus*** L), cultivar Catissol was cultivated, aiming to evaluate the residual effect of the treatments employed during the dry season. Sowing was done in the same plots that were used for cultivation of the cowpea, which remained marked and identified. The spacing used was 0.8m between rows and 0.3m between plants, with one plant per hole corresponding to planting density of 41,666 plants ha^{-1}.

Due to the low amount of rainfall in 2012 supplemental irrigations with canal water (A1) were necessary. The water depth was calculated based on Class A Pan evaporation and crop coefficient. The same irrigation system employed in the cultivation of cowpea was used.

At 63 DAP the plant height (PH), stem diameter (SD), inner (INCAP) and the outer diameter of the capitulum (OUTCAP), were measured. At the end of the crop cycle (111 DAP), six plants were collected in each plot (three central rows). The plants were divided into leaves, stems and capitulum and dry masses were obtained after drying the materials in an oven at 60°C. The crop yield and weight of 1000 seeds were also determined.

The data were subjected to analysis of variance (F test) and means were compared by Tukey test at $P \leq 0.05$, using as a tool the program ASSISTAT 7.6 beta (SILVA, 2011).

RESULTS AND DISCUSSION

The contribution of saline water in total water depth applied in each treatment ranged from zero (T1) to 100% (Table 1). The treatments T2, T3 and T4 had 100% saline water, while in treatments T11, T12 and T13 irrigation with saline water accounted for about 85% of total depth. However, in treatments where saline water was applied only in the flowering and fructification stage of cowpea (T5, T6, and T7) or alternately (T8, T9 and T10) the contribution of saline water corresponded to 34.1 and 47% of the total water applied, respectively.

Table 1 - Contribution of different types of waters for total water depth of irrigation (mm) applied in different treatments in cowpea crop.

Treatment	---Types of water---				Irrigation depth (mm)
	A1	A2	A3	A4	
T1[1]	375.7 (100)[2]	---	---	---	375.7
T2	---	375.7 (100)	---	---	375.7
T3	---	---	375.7 (100)	---	375.7
T4	---	---	---	375.7 (100)	375.7
T5	247.6 (65.9)	128.1 (34.1)	---	---	375.7
T6	247.6 (65.9)	---	128.1 (34.1)	---	375.7
T7	247.6 (65.9)	---	---	128.1 (34.1)	375.7
T8	198.6 (52.9)	177.1 (47.1)	---	---	375.7
T9	198.6 (52.9)	---	177.1 (47.1)	---	375.7
T10	198.6 (52.9)	---	---	177.1 (47.1)	375.7
T11	56.3 (15)	319.4 (85)	---	---	375.7
T12	56.3 (15)	---	319.4 (85)	---	375.7
T13	56.3 (15)	---	---	319.4 (85)	375.7

[1]T1 (control), T2, T3 and T4 using water of 0.5 (A1), 2.2 (A2), 3.6 (A3) and 5.0 (A4) dS m^{-1}, respectively, during the entire crop cycle; T5, T6 and T7, using saline waters A2, A3 and A4, respectively, only in the flowering and fruiting stage of the crop cycle; T8, T9 and T10, using different water sources in a cyclic way, with six irrigations with A1 followed by six irrigations with A2, A3 and A4, respectively; T11, T12 and T13, using water A2, A3 and A4, respectively, starting at 11 days after planting (DAP) and continuing until the end of the crop cycle.
[2]Values between parentheses represent the percentage in relation to total depth of irrigation water applied.

The results demonstrate the possibility of replacement of good quality water by the high salinity water, with values of 100 (T2, T3 and T4), 85 (T11, T12 and T13), 47 (T8, T9 and T10) and 34% (T5, T6 and T7). However, only the use of saline water with EC of 2.2dS m^{-1} starting at 11 DAP (T11) and the treatments where saline water was applied during the salt tolerant growth stage (T5, T6, and T7) or alternately (T8, T9 and T10) were able to reduce the amount of good quality water used in the production of cowpea, without negative impacts on crop yield (Figure 1). It is important to emphasize that the magnitude of the beneficial result of these strategies seems to depend, at least in part, on salt tolerance of the crop and the salt concentration in irrigation water (MURTAZA et al., 2006; LACERDA et al., 2009; AL-KHAMISI et al., 2013).

For irrigation with saline water, such as with EC of 3.6 to 5.0 dS m^{-1}, the results indicate that there is a limit to replace fresh water by saline water, regardless of management strategy. When this limit is exceeded, the effects of salinity become more pronounced. For example, substitution of 46% of low salinity (0,36dS $m^{-}1$) water by high salinity (4.5dS m^{-1}) water applied in an alternating form did not affect the yield of maize, but when the replacement was 54% a reduction of 16% in crop yield was observed (BARBOSA et al., 2012).

The continuous application of water of high salinity in irrigation resulted in a greater accumulation of salts in soil and reduction in dry matter production and in water use efficiency (Table 2). This trend was observed both in treatments where saline water was applied continuously from planting (T2, T3 and T4) and in the treatments where irrigation with these waters was initiated after germination (T12 and T13). The reduction in the growth of cowpea might be related to osmotic, nutritional, and toxic effects, arising from the accumulation of salts in the root zone of the plant that affect net CO_2 assimilation, inhibit the leaf growth and accelerate senescence of mature leaves, thereby reducing the total production of photoassimilates (MUNNS, 2002; WILSON et al., 2006).

The application of the high salinity water during the flowering and fructification stage (T5, T6 and T7) resulted in growth similar to the control (T1), even when irrigation water had EC of 5.0dS m^{-1} (Table 2). Moreover, the cyclic use of low and high salinity water also showed results similar to the control, but with a slight downward trend. For example, the continued use of water of high salinity (T4) reduced crop yield by approximately 34%, but when the same water source is applied only in the flowering and fructification stage of the crop cycle (T7) or in a cyclic form (T10) reductions were 3 and 17%, respectively, compared to control (T1).

Many experiments have demonstrated that application of saline waters only during salt tolerant growth stage reduces considerably the effect of salinity on plants (PORTO FILHO et al.,

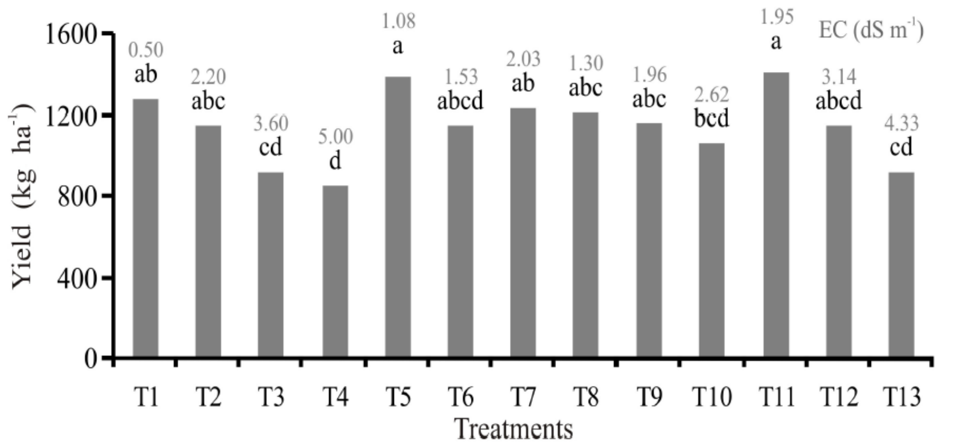

Figure 1 - Yield of cowpea crop under different management strategies of irrigation with saline water. For description of treatments, see the legend of table 1.
Means in bars with the same letter do not differ statistically by Tukey test (P<0.05). Values above the bars signify the mean weighted electrical conductivity (dS m^{-1}) of irrigation water for respective treatment.

Table 2 - Mean weighted electrical conductivity of irrigation water (ECmw), soil electrical conductivity (EC), dry mass of leaves (LDM), stems (SDM), bark (BDM), grain (GDM) and total (TDM), and water use efficiency considering the total dry mass (WUEp) and yield (WUEy) of cowpea crop under different management strategies of irrigation with saline water.

Treatment[1]	ECmw	Soil EC	LDM	SDM	BDM	GDM	TDM	WUEp	WUEy
	------------(dS m^{-1})-------		-------------------------------------(g $plant^{-1}$)-----------------------------------					--------(kg ha^{-1} mm^{-1})-------	
T1	0.50	1.50	12.92a[2]	22.68a	4.79a	15.39ab	55.77a	12.35a	3.40ab
T2	2.20	2.60	10.54abc	17.15abc	3.81abc	13.89abc	45.43ab	10.06ab	3.07abc
T3	3.60	4.19	11.68ab	17.26abc	2.89c	11.05cd	42.89abc	9.50abc	2.44cd
T4	5.00	6.18	6.75c	8.12c	2.98c	10.24d	28.09d	6.22d	2.26d
T5	1.08	2.97	13.04a	21.71a	4.51a	16.80a	56.07a	12.42a	3.72a
T6	1.56	2.90	13.78a	21.87a	3.92abc	13.74abcd	53.32ab	11.81ab	3.04abcd
T7	2.03	2.55	13.59a	21.40a	4.35ab	14.96ab	54.31ab	12.03ab	3.31ab
T8	1.30	2.60	11.79ab	22.99a	4.25abc	14.62abc	53.64ab	11.88ab	3.23abc
T9	1.96	3.37	11.17ab	18.03ab	3.79abc	13.96abc	46.94ab	10.39ab	3.09abc
T10	2.62	3.34	10.41abc	19.09a	3.97abc	12.74bcd	46.24ab	10.24ab	2.82bcd
T11	1.95	3.57	11.69ab	19.01ab	4.78a	17.01a	52.51ab	11.63ab	3.76a
T12	3.14	4.22	8.82bc	14.96abc	3.96abc	13.81abcd	41.62bcd	9.22bcd	3.06abcd
T13	4.33	5.93	7.31c	9.65bc	3.45abc	11.07cd	28.10d	6.97cd	2.45cd

[1] For description of treatments see the legend of table 1;
[2]Means in columns with the same letters do not differ statistically by Tukey test (P<0.05).

2006; LACERDA et al., 2009), a fact confirmed in this study. Moreover, the efficiency of the strategy of cyclic use of low and high salinity water has also been demonstrated in other studies (MURTAZA et al., 2,006; BARBOSA et al., 2012). According to these authors, this strategy results in lower absorption of potentially toxic ions (Na^+ and Cl^-) by plants, and reduces the accumulation of salts in the soil, resulting in smaller effects on plants.

The supplemental irrigation and rainfall occurring during the sunflower cultivation reduced the accumulation of salts (EC) in the soil, with no statistical difference between treatments at the end of the crop cycle (Table 3). Nevertheless, it was observed that continuous application of water of EC 5.0dS m^{-1} (T4) during the whole cycle of cowpea caused residual effect for some growth variables, such as plant height (PH), stem diameter (SD), and the outer diameter of the capitulum (OUTCAP) of sunflower crop. For inner diameter of the capitulum (INCAP), the highest value was found in the treatment that used water with EC of 2dS m^{-1} applied 11 DAP until the end of the crop cycle (T11), with no significant differences in comparison to other treatments. However, the productivity data followed a similar trend that observed for diameter of capitulum, showing a strong relationship between these variables. The other variables (vegetative dry matter and weight of 1000 seeds) did not show the residual influence of salinity.

The occurrence of residual effects of salinity on some growth variables can be justified by the low amount of rainfall between the cultivation of cowpea and sunflower, as well as during the sunflower cultivation. During the sunflower cultivation the monthly rainfalls were 30.4, 86.8, 15.6 and 0mm for March, April, May and June, respectively. Contrary to this, BEZERRA et al. (2010) and LACERDA et al. (2011) did not observe residual effects of salinity on crops of cowpea and maize in crop rotation systems, after the areas had been irrigated with water of EC up to 5.0dS m^{-1} during the dry season. However, the total rainfall during these studies was at least three times higher than that observed in the present study. Therefore, if the total rainfall is not sufficient to promote leaching of salts from the soil, there may be a reduction in growth of the succeeding crop, especially if the salts remain in the soil during the early stages of crop development (CHEN et al., 2009).

The irrigation management strategies used in the cultivation of cowpea, application of saline water only in the salt tolerant growth stage or alternately, eliminated the residual effects of the salts on all variables in the sunflower crop, even when water of higher salinity was used (Table 3). This is a consequence

Table 3 - Soil electrical conductivity (EC), plant height (PH), stem diameter (SD), vegetative dry matter (VDM), outer diameter of the capitulum (OUTCAP), inner diameter of the capitulum (INCAP), weight of 1000 seeds, and yield of sunflower plants in the experimental plots previously cultivated with cowpea under different management strategies of irrigation with saline water.

Treat[1]	Soil EC ($dS\ m^{-1}$)	PH (m)	SD (mm)	VDM ($g\ plant^{-1}$)	OUTCAP (cm)	INCAP (cm)	W1000 (g)	Yield ($kg\ ha^{-1}$)
T1	1.38	1.52a[2]	15.07a	25.53a	21.46ab	10.50c	57.78a	1345.20bc
T2	1.43	1.26cd	13.14a	26.60a	20.37abc	10.06c	56.81a	1589.72abc
T3	1.50	1.28bcd	12.78a	33.62a	20.08abc	9.25c	64.44a	1687.38abc
T4	1.41	1.24a	10.68a	25.62a	19.72abc	9.40c	61.91a	1258.42c
T5	1.35	1.41abcd	15.63a	33.02a	19.46bc	10.30c	60.46a	1319.71bc
T6	1.32	1.35abcd	13.45a	28.62a	20.05abc	10.46c	56.79a	1392.73abc
T7	1.31	1.36abcd	15.27a	39.98a	18.50c	10.26c	62.06a	1611.18abc
T8	1.44	1.36abcd	15.30a	28.47a	20.96abc	10.76bc	61.44a	1358.64bc
T9	1.30	1.46a	15.55a	33.01a	20.54abc	10.84bc	64.55a	1388.46bc
T10	1.25	1.36abcd	14.33a	28.67a	20.29abc	10.22c	62.02a	1323.89bc
T11	1.39	1.45ab	17.69a	32.17a	22.33a	13.75a	64.45a	1925.97a
T12	1.46	1.42abc	16.29a	30.34a	20.90abc	10.59a	61.37a	1779.32abc
T13	1.33	1.35abcd	17.73a	36.21a	21.85ab	12.58ab	66.57a	1831.65ab

[1]Supplementary irrigation with water similar to the control treatment ($EC = 0.5\ dS\ m^{-1}$) in plots previously irrigated using different strategies of irrigation with saline water, as described in table 1;
[2]Means in columns with the same letters do not differ statistically by Tukey test ($P<0.05$).

of lesser accumulation of salts in these treatments during the dry season, and indicates that these strategies can be effective even when there is not enough leaching of salts in the beginning of the succeeding crop.

CONCLUSION

The strategies of use of saline water in the salt tolerant growth stage (flowering and fructification) or cyclically (six irrigations with fresh water followed by six irrigations with saline water) reduced by 34 and 47%, respectively, the amount of good quality water used in the production of cowpea, without negative impact on crop yield, and eliminated the residual effects of salinity on succeeding sunflower crop. Thus, these management strategies appear promising to be employed in the areas with water salinity problems in the semiarid regions of Brazil.

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REFERENCES

AL KHAMISI S.A. et al. Conjunctive use of reclaimed water and groundwater in crop rotations. **Agricultural Water Management**, v.116, p.228-234, 2013. Available from: <http://www.sciencedirect.com/science/article/pii/S0378377412002065>. Acessed: Dez. 06, 2012. doi: 10.1016/j.agwat.2012.07.013.

BARBOSA, F.S. et al. Productivity and íon content in maize irrigated with saline water in a contínuos or alternating system. **Ciência Rural**, v.42, p.1731-1737, 2012. Available from: <http://www.scielo.br/pdf/cr/v42n10/a29112cr5985.pdf>. Acessed: Apr. 30, 2012. doi: 10.1590/S0103-84782012001000003.

BEZERRA, A.K.P. et al. Rotação cultural feijão caupi/milho utilizando-se águas de salinidades diferentes. **Ciência Rural**, v.40, p.1075-1082, 2010. Available from: <http://www.scielo.br/scielo.php?pid=0103-8478&script=sci_serial>. Accessed: Apr. 06, 2012. doi:10.1590/S0103-84782012001000003.

CHEN, M. et al. Drip irrigation with saline water for oleic sunflower (***Helianthus annuus*** L.). **Agricultural Water Management**, v.96, p.1766-1772, 2009. Available from: <http://www.sciencedirect.com/science/article/pii/S0378377409002091>. Accessed: Apr. 06, 2012. doi: 10.1016/j.agwat.2009.07.007.

CHOUDHARY, O.P. et al. Effects of long-term use of sodic water irrigation, amendments and crop residues on soil properties and crop yields in rice–wheat cropping system in a calcareous soil. **Field Crops Research**, v.121, p.363-372, 2011. Available from: <http://www.sciencedirect.com/science/article/pii/S0378429011000244>. Accessed: Apr. 06, 2012. doi: 10.1016/j.fcr.2011.01.004.

EMBRAPA (EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA). Centro Nacional de Pesquisa de Solos. Rio de Janeiro: Sistema brasileiro de classificação de solos. Brasília: Sistema de Produção de Informação, 1999. 412p.

KÖPPEN, N.W. **Climatologia**: con un estudio de los climas de la tierra. México: Fondo de Cultura Econômica, 1948. 478p.

LACERDA, C.F. et al. Eficiência de utilização de água e nutrientes em plantas de feijão-de-corda irrigadas com água salina em diferentes estádios de desenvolvimento. **Engenharia Agrícola**, v.29, p.221-230, 2009. Available from: <http://www.scielo.br/scielo.php?pid=S0100-69162009000200005&script=sci_abstract&tlng=pt>. Accessed: Apr. 06, 2012. doi: 10.1590/S0100-69162009000200005.

LACERDA, C.F. et al. Soil salinization and maize and cowpea yield in the crop rotation system using saline waters. **Engenharia Agrícola**, v.31, p.663-675, 2011. Available from: <http://www.scielo.br/scielo.php?pid=S0100-69162011000400005&script=sci_arttext>. Accessed: Apr. 06, 2012. doi: 10.1590/S0100-69162011000400005.

MALASH, N. et al. Effect of irrigation systems and water management practices using saline and non-saline water on tomato production. **Agricultural Water Management**, v.78, p.25-38, 2005. Available from: <http://www.springerlink.com.w10016.dotlib.com.br/content/0342-7188/26/4/>. Accessed: Apr. 06, 2012. doi: 10.1007/s00271-007-0095-7.

MUNNS, R. Comparative physiology of salt and water stress. **Plant and Cell Environment**, v.25, p.239-250, 2002. Available from: <http://onlinelibrary.wiley.com/doi/10.1046/j.0016-8025.2001.00808.x/full>. Accessed: Apr. 06, 2012. doi: 10.1046/j.0016-8025.2001.00808.x.

MURTAZA, G. et al. Irrigation and soil management strategies for using saline-sodic water in a cotton–wheat rotation. **Agricultural Water Management**, v.81, p.98-114, 2006. Available from: <http://www.sciencedirect.com/science/journal/03783774>. Accessed: Apr. 06, 2012. doi:10.1016/j.agwat.2005.03.003.

NEVES, A.L.R. et al. Monitoring soil coverage and yield of cowpea furrow irrigated with saline water. **Revista Ciência Agronômica**, v.41, p.59-66, 2010. Available from: <http://www. ccarevista.ufc.br/seer/index.php/ccarevista/issue/view/21>. Accessed: Apr. 06, 2012.

OSTER, J.D. et al. Comparison of transient state models that include salinity and matric stress effects on plant yield. **Agricultural Water Management**, v.103, p.167-175, 2012. Available from: <http://www.sciencedirect.com/science/article/pii/S0378377411003167>. Accessed: Apr. 06, 2012. doi: 10.1016/j.agwat.2011.11.011.

PORTO FILHO, F.Q. et al. Viabilidade da irrigação do meloeiro com águas salinas em diferentes fases fenológicas. **Ciência Rural**, v.36, p.453-459, 2006. Available from: <http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0103-84782006000200015>. Accessed: Apr. 06, 2012. doi: 10.1590/S0103-84782006000200015.

SILVA, F. de A.S. e. **ASSISTAT Versão 7.6 beta**. 2011. Disponível em: <http://www.assistat.com>. Accessed: Apr. 06, 2012.

SOUZA, M.S.M. et al. Coeficientes de cultura do feijão caupi na região litorânea do Ceará. **Irriga**, v.10, p.241-248, 2005. Available from: <http://200.145.140.50/ojs1/viewarticle.php?id=189&layout=abstract>. Accessed: Apr. 06, 2012.

TRAVASSOS, K.D. et al. Produção de aquênio de girassol irrigado com água salobra. **Revista Brasileira de Engenharia Agrícola e Ambienta**l, v.15, p.371-376, 2011. Available from: <http://www.scielo.br/scielo.php?pid=S1415-43662011000400007&script=sci_arttext>. Accessed: Apr. 06, 2012. doi: 10.1590/S1415-43662011000400007.

WILSON, C. et al. Growth response of major USA cowpea cultivars. **Plant Science**, v.170, p.1095-1101, 2006. Available from: <http://hortsci.ashspublications.org/content/41/1/225.full.pdf>. Accessed: Apr. 06, 2012.