International Research Journal of Agricultural Science and Soil Science (ISSN: 2251-0044) Vol. 1(5) pp. 163-171 July 2011
Available online http://www.interesjournals.org/IRJAS

Full Length Research Paper

Influence of plant spacing and irrigation water quality on a cowpea-maize cropping system

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Accepted 06 June, 2011

Salt stress can reduce canopy development in most plant species, and in such conditions, decreasing spacing between plants and consequently increasing planting density may result in higher yields and increase in water and radiation use efficiency. The objective of this study was to evaluate the interaction between water quality and plant spacing in a cowpea-maize cropping system. The use of saline water in irrigation reduced the radiation intercepted by apical leaves and consequently, increased the radiation intercepted by the basal leaves, increasing their photosynthetic rates. The increase in spacing between rows resulted in more vigorous plants, with greater dry biomass production, when plants were irrigated with low-salinity water. However, the use of high salinity water resulted in less growth and productivity in plants, with the greatest relative reductions observed in plants with greater spacing. For the minor spacing between rows (0.5 m) the irrigation with saline water caused a reduction of 17% in grain yield and water productivity, while for the larger spacing (0,9 m) this reduction reached almost 40%. On the other hand, the shorter planting distance and the residual effect of saline water used in irrigation of the previous crop had negative impacts on the growth and final yield of maize.

Key words: planting density; photosynthesis; saline water; *Vigna unguiculata*; *Zea mays*

INTRODUCTION

The use of saline water, drainage water, and treated waste water in irrigation depends on long-term strategies that guarantee socio - economic and environmental sustainability of agricultural systems (Qadir and Oster 2004; Sharma and Minhas 2005; Lacerda et al., 2009; Leal et al., 2009; Murtaza et al., 2009). These management strategies for the salinity problem can be divided into two groups, non-specific and specific.

Some of the non-specific strategies that have been used in saline conditions include the addition of organic matter, the application of liquid bio-fertilizers, the use of chemical fertilizers and amendments, mycorrhization, fol-

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iar applications of organic and inorganic substances, crop rotation, and increasing planting density (Mitchell et al., 2000; Ghafoor et al., 2008; Ould Ahmed et al., 2010). On the other hand, specific strategies are those directly related to the salinity problem and that normally do not apply to crops in non-saline conditions. Commonly cited strategies specific to saline conditions include the use of tolerant and moderately tolerant glycophytes, the cultivation of halophytes, mixtures of waters with different salinities, the cyclic use of saline and fresh water, the use of saline water in phases when the crop has greater tolerance, bio-drainage, and the establishment of specific conditions for germination (Glenn et al., 1998; Flowers et al., 2005; Malash et al., 2005; Chauhan et al., 2008; Isla and Aragués, 2010).

Some non-specific strategies, such as the use of bio-fertilizers, organic matter, mycorrhization and mineral fertilization, improve the development and productivity of some crops, although these improvements are smaller than those obtained when such strategies are applied to plants in non-saline environments (Grattan and Grieve 1999). On the other hand, crop rotation studies have shown promising results for annual crops (Sharma and Rao, 1998; Murtaza et al., 2006; Kaur et al., 2007; Bezerra et al., 2010), where the accumulation of salts due to irrigation during the dry season can be completely or partially reversed during the rainy season. This strategy is promising for annual crops, especially for soils that have good drainage or are associated with other strategies that promote salt leaching. To obtain the best results with crop rotation using saline waters, it is necessary to grow more tolerant plant species during the dry season, when water with greater salinity is used. In association with other strategies, such as the use of greater plant density, this strategy can contribute towards increasing land use efficiency and soil conservation.

Although the reduction in leaf area by plants under salt stress is an important mechanism for reducing plant water loss, it is not entirely beneficial because photosynthetic processes depend on the interception of light energy and its conversion into chemical energy, which occurs directly in the leaf and forms carbohydrates that are allocated to vegetative and reproductive parts. Some studies have shown that salinity reduces the vegetative growth of cowpea (Wilson et al., 2006a; Neves et al., 2010), and each plant in this condition occupies a smaller area than a plant irrigated with fresh water. According to Wang et al (2001), the combined osmotic and ion toxicity effect from salt stress often reduces canopy development in most plant species, and one would expect a reduction in radiation absorption and radiation use efficiency. On the other hand, plants under salt stress can have higher average net photosynthetic rates than plants irrigated with low-salinity water as a result of decreased shadowing of these plants. In these conditions, it is possible that a reduction in plant spacing and, consequently, an increase in planting density may increase water and radiation use efficiency, resulting in higher yield. Therefore, this study was conducted to evaluate the interaction effect of water quality and plant spacing in a cowpea-maize cropping system.

MATERIALS AND METHODS

The experiment was conducted on Ultisol of sandy loam texture at the experimental area of the Hydraulic and Irrigation Laboratory (Federal University of Ceará) in Fortaleza, CE, Brazil (3°45'S, 38°33'W, and altitude of 19 m); according to the Köppen classification system, the experimental area is located in a region with an Aw' climate. Two crops were grown using the rotation system, the first from September to December (dry season) during 2008 with cowpea [*Vigna unguiculata* (L) Walp.] cultivar Epace 10 and the second from January to April (rainy season) of 2009 with maize (*Zea mays* L.) hybrid AG 1051. The weather information obtained during the two cropping seasons is shown in Table 1.

The experiment with cowpea was conducted in a randomized block design in a 3x2 factorial scheme (three spacings between rows x two levels of irrigation water salinity) and five repetitions, totaling 30 plots. Each plot unit had a length of 3.0 m with five rows of planting, and only the three central rows were used for data collection. The following plant spacings were used: S1 (0.5 m x 0.3 m), S2 (0.7 m x 0.3 m), and S3 (0.9 m x 0.3 m), with two plants per hole, corresponding to planting densities of 133,333, 95,238 and 74,074 plants ha^{-1}, respectively.

Well water with electrical conductivity (ECw) of 0.8 dS m^{-1} and saline water of ECw of 5.0 dS m^{-1} were used for irrigation, in accordance with the treatment block layouts. To prepare the saline water, NaCl, $CaCl_2.2H_2O$ and $MgCl_2.6H_2O$ were added to the well water in equivalent proportions of 7:2:1, obeying the relation between ECw and salt concentration ($mmol_c$ L^{-1} = ECw x 10), according to Rhoades et al. (1992). The water was applied in leveled closed furrows, and the irrigation water depths were defined based on reference evapotranspiration values (ETo) obtained by the Class A pan method and the crop coefficients (Kc). When calculating the depth of water to be applied, a leaching fraction of 0.15 was added (Ayers and Westcot 1985). Irrigations were applied until 62 days after sowing (DAS) in all treatments. A three-day watering schedule was used, and the total water depth applied in all treatments throughout the cycle was 390 mm. In Northeast Brazil the cowpea requires 300 to 450 mm water depth under irrigated conditions (Andrade et al., 2002). The main characteristics of the well water and the saline water used in the irrigation

Table 1. Mean temperature (T), rainfall (P), wind speed (WS), relative humidity (RH), insolation (INS), and evaporation of the Class A pan (ECA) observed during cultivation of cowpea (dry season, September-December) and maize (rainy season, January-April) crops

Date	T (°C)	P (mm)	WS ($m\ s^{-1}$)	RH (%)	INS (hours)	ECA (mm)
Sep 2008	28.4	0.00	4.67	65.00	307.30	268.40
Oct 2008	28.6	8.50	4.47	65.67	321.10	291.60
Nov 2008	28.6	9.00	4.20	76.00	310.10	258.00
Dec 2008	28.9	14.10	3.33	68.33	304.80	253.00
Jan 2009	28.4	141.10	3.23	74.33	240.70	194.30
Feb 2009	27.73	396.10	2.80	78.67	172.50	122.60
Mar 2009	27.2	450.00	2.16	83.00	125.80	102.30
Apr 2009	27.0	515.30	1.46	83.67	146.90	83.80

Table 2. Characteristics of the well water and saline water used in the irrigation of cowpea plants grown at different spacings

Characteristics	Well water	Saline water
ECw ($dS\ m^{-1}$)	0.8	5.0
pH	7.1	7.0
Ca^{2+} ($mmol_c\ L^{-1}$)	1.0	10.0
Mg^{2+} ($mmol_c\ L^{-1}$)	1.0	5.0
Na^{+} ($mmol_c\ L^{-1}$)	3.9	35.0
HCO_3^{-} ($mmol_c\ L^{-1}$)	2.8	2.8
Cl^{-} ($mmol_c\ L^{-1}$)	3.6	65
SAR* ($(mmol\ L^{-1})^{1/2}$)	3.9	12.8
Richards (1954) Classification[1]	C_3S_1**	C_4S_2
UCCC Classification[1,2]	C_2S_1	C_4S_1

[1]Cited by Gheyi et al. (2010). [2]Electrical conductivity according to the University of California Committee of Consultants and sodicity according to Ayers and Westcot (1985); *SAR - Sodium Absorption Ratio; **C and S - classes of electrical conductivity and sodium absorption ratio, respectively.

are shown in Table 2.

For fertilization, 1.1g of urea, 8g of single superphosphate and 1.5 g of potassium chloride were used per hole. The urea and single superphosphate doses were added before planting, while half of the potassium was applied at planting, and half was applied at 30 DAS. At 36 DAS, the net photosynthetic rates (A), photosynthetically active radiation (PAR) levels and leaf temperatures were measured. These measurements were made on the second leaf from the bottom and on the first completely mature leaf from the apex using a plant gas exchange analyzer (LCi, ADC, Hoddesdon, UK), with readings taken between 9:00 and 11:00 in the morning. Subsequently, four plants from each plot were collected, the leaves were separated from the stems, and total leaf area was determined (LI-3000, LI-COR, Lincoln, NE, USA). The leaf area index (LAI) was measured, relating the leaf areas of four plants and the land area occupied by these plants under the different treatments.

At the end of the cycle, six plants from each plot were collected, and the leaf blades were separated from the stalks (stems plus petioles). After overnight drying in an oven at 60°C, they were weighed to obtain the dry mass. The harvesting was initiated after the first pods reached maturity and extended until 71 DAS in the three central rows. The following agronomic variables were evaluated: the dry biomass production per plant, the estimated productivity ($kg\ ha^{-1}$), the harvest index (HI), and the water productivity (WP, $kg\ DM\ mm^{-1}$).

The radiation use efficiency (RUE), expressed in $g\ MJ^{-1}$, was observed by relating the above-ground biomass ($g\ m^{-2}$) with the cumulative photosynthetically active radiation (PAR). The total PAR during cowpea cultivation ($MJ\ m^{-2}$) was estimated using data from global

Table 3. The electrical conductivity of the soil/water extract ($EC_{1:1}$) and the exchangeable sodium percentage (ESP) in soil samples from different depths of Ultisol collected before planting the cowpea crop, after harvesting the cowpea crop (end of dry season) and after harvesting the maize crop (end of rainy season)

ECw ($dS\ m^{-1}$)	Spacing (m)	$EC_{1:1}$ ($dS\ m^{-1}$)				ESP		
		Depth (m)				Depth (m)		
		0-0.30	0.30-0.60	0.60-0.90		0-0.30	0.30-0.60	0.60-0.90
	August 2008 (before the cowpea crop)							
		0.25	0.25	0.35		2.00	7.00	8.00
	December 2008 (after the harvest of the cowpea crop)							
0.8	0.5	0.77	0.83	0.41		7	6	5
0.8	0.7	0.56	0.62	0.58		6	7	6
0.8	0.9	0.60	0.74	0.55		8	8	7
5.0	0.5	2.08	2.19	1.58		18	12	11
5.0	0.7	1.63	2.04	1.80		16	14	13
5.0	0.9	1.41	2.31	1.99		13	15	16
	May 2009 (after the harvest of the maize crop)							
0.8	0.5	0.27	0.31	0.40		2	8	9
0.8	0.7	0.21	0.30	0.40		2	6	9
0.8	0.9	0.26	0.34	0.38		3	7	8
5.0	0.5	0.23	0.29	0.36		3	8	8
5.0	0.7	0.27	0.28	0.38		4	7	9
5.0	0.9	0.23	0.26	0.37		3	7	10

solar radiation measured with a pyranometer connected to an automatic meteorological station (Campbell Scientific).

Hybrid AG 1051 maize seeds were planted on January 23, 2009, after the first rain of the season. Planting was carried out in the same plots where the cowpea was planted, and the plants grew until May 1, 2009. The following spacings were used: S1 (0.5 m x 0.2 m), S2 (0.7 m x 0.2 m), and S3 (0.9 m x 0.2 m), corresponding to planting densities of 100,000, 71,428 and 55,555 plants ha^{-1}, respectively. The rainfall between the harvesting of cowpea and planting of maize was 88.3 mm and the subsequent rain during maize cropping season was 1430 mm. Thus, there was no need for supplementary irrigations.

The fertilizers applied consisted of 1.5 g of urea, 8.4 g of superphosphate and 1.4 g of potassium chloride per hole. The superphosphate was applied at the time of soil preparation, and the urea and potassium chloride were applied in three phases, one at the time of soil preparation and two as topdressing at 25 and 40 DAS.

At 90 DAS, at random 15 plants were collected from each plot, separating the leaf blades, culms plus sheath, tassel, ears and dry matter. The ears were separated into grain, straw and cob. The vegetative and reproductive dry matter contents, estimated crop productivity and harvest index were measured.

Prior to the experiment (August, 2008) and after the harvest of cowpea (December, 2008) and maize (May 2009), soil samples were collected from different depths (0 to 0.3, 0.3 to 0.6 and 0.6 to 0.9 m) in the five plots for each treatment; these were then homogenized, forming a compound sample for each treatment. The samples were collected between the plants, in the middle third of the central row of each plot, and then analyzed (Silva, 1999).

The data related to the cowpea crop were submitted to analysis of variance, and the means were compared using test of Tukey, employing the SAEG/UFV 9.0 program. This procedure was also used to assess the residual effect of water salinity applied to the first crop on the development of the following maize crop.

RESULTS AND DISCUSSION

Soil characteristics

The electrical conductivity of the soil/water extract ($EC_{1:1}$) and the exchangeable sodium percentage (ESP) of the soil were low before the cowpea crop was grown, but it increased as a result of the irrigations of the crop, particularly in the treatments where water with high salt concentrations was used (Table 3). It was also observed that the maximum accumulation of salt and sodium in each planting row occurred in the surface layer (0 to 0.3 m) for the treatment with smaller spacing between rows, which could affect the initial development of the crops

Table 4. Two-way analysis of variance (F values) of the effects of salt, spacing (S), and the salt x spacing interaction on several parameters of cowpea and maize crops. Levels of significance: *, $P \leq 0.05$; **, $P \leq 0.01$; ns denotes a non-significant effect

Cowpea crop	**Salt**	**Spacing**	**SaltxSpacing**	**CV (%)**
A (old leaf), µmol m^{-2} s^{-1}	125.59**	11.40**	0.81ns	18.1
A (young leaf), µmol m^{-2} s^{-1}	92.65**	4.68*	11.37**	7.2
T_{leaf} (old leaf), °C	6.28*	3.25*	0.03ns	2.5
T_{leaf} (young leaf), °C	0.56ns	0.35ns	0.30ns	2.2
Leaf area (dm^2)	74.03**	0.72ns	0.65ns	23.1
Leaf area index (m^2 m^{-2})	61.99**	15.10**	3.75*	25.3
Vegetative dry mass (g $plant^{-1}$)	27.03**	6.64**	1.10ns	20.9
Reproductive dry mass (g $plant^{-1}$)	17.95**	8.14**	2.90*	20.3
Total dry mass (g $plant^{-1}$)	45.24**	13.96**	2.66ns	14.8
Productivity (kg ha^{-1})	18.77**	3.56**	1.12ns	18.7
Harvest index (%)	1.16ns	0.13ns	0.60ns	16.8
Water productivity (kg DM mm^{-1})	36.14**	6.85**	2.15ns	13.5
Radiation use efficiency (g MJ^{-1})	61.32**	9.46**	0.64ns	12.1
Maize crop				
Vegetative dry mass (g $plant^{-1}$)	9.18**	3.89*	0.12ns	12.3
Reproductive dry mass (g $plant^{-1}$)	6.42**	11.80**	0.36ns	14.7
Total dry mass (g $plant^{-1}$)	10.00**	11.04**	0.31ns	11.7
Productivity (kg ha^{-1})	6.27*	6.75**	0.83ns	18.1
Harvest index (%)	0.69ns	6.45**	0.35ns	7.9

A – Net photosyinthetic note,
T_{eaf} - Leaf temperature

planted during the rainy season. Higher salt accumulation in the surface layer in all treatments may be due to evaporation, while more accumulation in rows with smaller spacings may be as a result of possible lateral water movement due to gradient which does not take place when row spacing is more than 0,5 m due to sandy texture of the soil. The $EC_{1:1}$ and ESP of the soil measured after the harvest of maize crop (at the end of the rainy season) decreased in all treatments as a result of the rains between January and April 2009 (Table 1). Similar leaching was observed in other studies conducted in the same area in previous years (Neves et al., 2010) and in experiments conducted in other countries (Murtaza et al., 2006).

Photosynthesis, growth and productivity of cowpea

The net photosynthetic rates differed as a result of the plant spacing, the salinity of the irrigation water and the age of the plant leaf (Tables 4 and 5). Water salinity reduced the net photosynthetic rates in younger (apical) leaves, and the influence of spacing on these leaves was less than that in basal leaves. In the apical leaves, photosynthesis was limited only by salt stress resulting from the irrigation water because radiation did not vary between treatments. This reduction in the net photosynthetic rate of apical leaves caused by salt stress may result from partial stomatal closure, which is associated with the osmotic effects of salinity, and the effects of ion toxicity on metabolism (Wilson et al., 2006b; Sultana et al., 1999; Praxedes et al., 2010).

In older (basal) leaves, the highest net photosynthetic rates were observed when there were larger spacings between rows and in plants under salt stress (Table 5). According to Távora et al (2000), as planting density increases, the LAI and light interception increase, and the photosynthetic capacities of basal leaves are consequently reduced. However, the use of saline water in irrigation reduced the radiation intercepted by apical leaves and, consequently, increased the radiation intercepted by the basal leaves, increasing their photosynthetic rates and leaf temperatures. This result arises from the fact that plants under salt stress presented less vegetative growth and lower leaf area indexes (Figure 1). In this study, it was observed that leaf growth was significantly reduced only by salt stress, whereas the LAI was reduced by increasing plant spacing and by increased salinity. The increase in planting density could therefore increase the absorption of radiation by plants under salt stress, helping to reduce the impact of salinity on radiation use efficiency (Wang et

Table 5. Net photosynthetic rates (A), leaf temperatures (Tleaf) and photosynthetically active radiation (PAR) levels measured at 36 DAS on cowpea leaves from plants grown with different plant spacing (S) and irrigated with low- and high-salinity water (ECw)*

ECw (dS m^{-1})	Spacing (m)	A (μmol m^{-2} s^{-1})	T_{leaf} (^oC)	PAR (μmol m^{-2} s^{-1})
2nd leaf from the base				
0.8	0.5	5.4 Bb	38.3 Aa	275.5
0.8	0.7	7.8 Bb	38.6 Aa	350.3
0.8	0.9	13.1 Ba	39.5 Aa	471.5
5.0	0.5	18.3 Ab	39.4 Aa	1004.8
5.0	0.7	21.5 Aab	39.5 Aa	1974.0
5.0	0.9	23.4 Aa	40.6 Aa	1939.5
1st mature leaf from the apex				
0.8	0.5	33.7 Aa	40.5 Aa	2061.0
0.8	0.7	31.9 Aa	40.8 Aa	2025.5
0.8	0.9	32.0 Aa	40.8 Aa	1963.0
5.0	0.5	20.5 Bc	40.4 Aa	2020.8
5.0	0.7	27.9 Ba	40.1 Aa	2039.8
5.0	0.9	24.5 Bb	40.8 Aa	1994.0

*Means in the columns followed by the same small letter for the same level of ECw do not differ significantly using Tukey's test ($p \geq 0.05$); means in the columns followed by the same capital letter for the same spacing do not differ significantly using Tukey's test ($p \geq 0.05$)

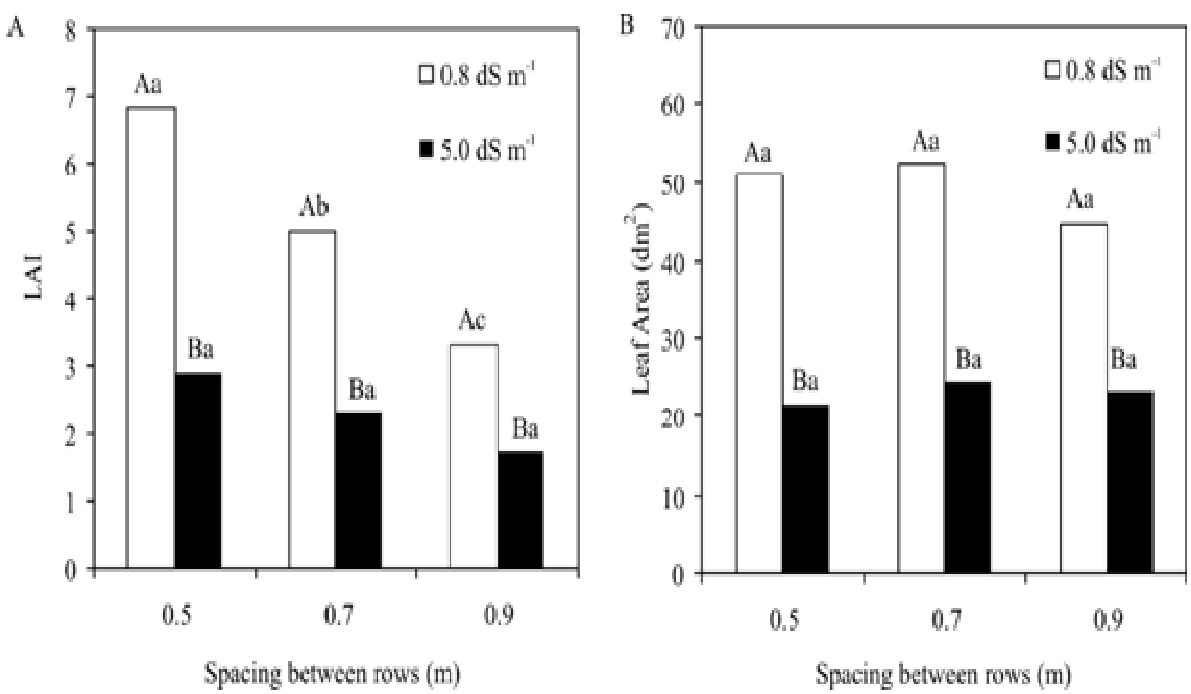

Figure 1. Leaf area index-LAI (A) and leaf area per plant (B), measured at 36 days after sowing in cowpea plants grown at different spacings and irrigated with low and high salinity water. *Means over the bars followed by the same capital letters for ECw within a same spacing and the same small letter for spacing in the same ECw, do not differ between each other, using the Tukey's test ($p \geq 0.05$)

Table 6. Vegetative (VDM), reproductive (RDM) and total (TDM) dry masses, estimated productivity (PROD), harvest index (HI), water productivity (WP), and radiation use efficiency (RUE) of cowpea plants grown at different spacing (S) and irrigated with low- and high-salinity waters*

ECw	S	VDM	RDM	TDM	PROD	HI	WP	RUE
(dS m^{-1})	(m)	-------------- (g $plant^{-1}$) ---------------			(kg ha^{-1})	(%)	(kg DM mm^{-1})	(g MJ^{-1})
0.8	0.5	33.50 Ab	21.89 Ab	55.39 Ab	2307.3 Aa	31.3 Aa	5,92 Aa	1.21 Aa
0.8	0.7	47.44 Aa	28.50 Aab	75.94 Aa	2148.9 Aa	29.9 Aa	5,51 Aa	1.19 Aa
0.8	0.9	49.29 Aa	36.19 Aa	85.47 Aa	2108.0 Aa	32.9 Aa	5,41 Aa	1.04 Aa
5.0	0.5	24.88 Ba	18.22 Ba	43.10 Ba	1925.6 Ba	34.8 Aa	4,94 Ba	0.94 Ba
5.0	0.7	29.61 Ba	22.65 Ba	52.26 Ba	1671.0 Bab	33.7 Aa	4,28 Bab	0.82 Bab
5.0	0.9	32.49 Ba	22.13 Ba	54.62 Ba	1273.6 Bb	32.0 Aa	3,27 Bb	0.66 Bb

*Means in the columns followed by the same small letter for the same level of ECw do not differ significantly using Tukey's test ($p \geq 0.05$); means in the columns followed by the same capital letter for the same spacing do not differ significantly using Tukey's test ($p \geq 0.05$)

al. 2001).

The dry mass production per plant was influenced by spacing, irrigation water salinity and the interaction of these two factors (Tables 4 and 6). The increase in spacing between rows resulted in more vigorous plants, with greater dry mass production in vegetative and reproductive parts, when plants were irrigated with low salinity water. However, the use of high-salinity water resulted in less growth and productivity in plants, with the greatest relative reductions observed in plants with greater spacing. Comparing the effect of the saline water treatment with the control (0.5 dS m-1), at smaller and larger plant spacing, reductions of 26 and 34, 17 and 39, and 22 and 36% were observed in vegetative (leaves and stalks), reproductive (pods) and total dry masses, respectively.

Cowpea grain yield was influenced by plant spacing and ECw (Tables 4 and 6), but neither of these factors influenced the harvest index (HI). Theproductivity in treatments irrigated with fresh water (ECw of 0.8 dS m^{-1}) did not differ significantly among crop spacing (Table 6), even when the population increased from 74,074 to 133,333 plants ha^{-1}, although the denser crop had a higher value. The study conducted by Távora et al. (2000) with ten cowpea cultivars, showed a significant increase in productivity with increased crop density. On the other hand, the use of saline water (ECw of 5.0 dS m^{-1}) reduced productivity by 16.5 and 39.6% with both smaller and larger spacing, respectively (Table 6). Comparing the mean productivity of these two treatments, the increase in density from 74,074 to 133,333 plants ha^{-1} resulted in a 51% increase in crop yield.

The water productivity (WP) and radiation use efficiency (RUE) were significantly influenced by irrigation water salinity and crop density (Tables 4 and 6). Their values were higher in plants irrigated with well water (ECw of 0.8 dS m^{-1}) than in plants irrigated with saline water, with the greatest reduction being observed in the treatment with greater spacing (Table 6). This reduction in WP of cowpea with an increase in irrigation water salinity was also observed by Lacerda et al (2009). According to Wang et al. (2001), salt stress reduced the RUE in soybean plants, and this effect was related to reduce canopy development. On the other hand, plant spacing did not have an influence on the WP or RUE when the plants were irrigated with well water (ECw of 0.8 dS m-1), as a result of either no or little effect of water salinity on plant growth. This is in agreement with the findings of Cardoso et al (1997) in cowpea crops, where no relationship was found between the WP and crop density, and the WP was influenced only by the cultivar's genetic potential. However, in the present study, when saline water was used, WPs and RUEs were decreased with increased plant spacing (Table 6), indicating that the response within one cultivar may be influenced by abiotic factors.

Maize growth and yield

The use of saline water during cowpea crop growth and the increased maize crop density reduced the dry mass production of vegetative and reproductive parts of maize and reduced the productivity of the maize crop (Tables 4 and 7). The increased plant density reduced the reproductive and total dry mass per plant in plots previously irrigated with low- and high-salinity water, indicating that the smallest spacing used (0.5 x 0.2 m) may compromise light distribution and photosynthetic processes in the whole plant. On the other hand, the residual effect of salinity was dependent on the plant density because only the treatment with smaller spacing presented a reduction of approximately 20% in plant

Table 7. Vegetative (VDM), reproductive (RDM) and total (TDM) dry mass, productivity (PROD) and harvest index (HI) of maize plants grown in plots that were previously used for growing cowpea at different spacings (S) and irrigated with low- and high-salinity waters*

ECw	S	VDM	RDM	TDM	PROD	HI
($dS\ m^{-1}$)	(m)	--------------- ($g\ plant^{-1}$) ---------------			($kg\ ha^{-1}$)	(%)
0.8	0.50	62.62 Aa	76.26 Ab	138.88 Ab	5535.13 Aa	39.5Aa
0.8	0.70	69.39 Aa	95.27 Aa	164.66 Aab	5070.86 Aab	43.2 Aa
0.8	0.90	69.67 Aa	97.19 Aa	166.87 Aa	4035.00 Ab	43.5 Aa
5.0	0.50	52.06 Bb	61.08 Bb	113.14 Bb	4266.92 Ba	37.5 Ab
5.0	0.70	61.86 Aa	89.13 Aa	150.99 Aa	4704.04 Aa	43.6 Aa
5.0	0.90	61.99 Aa	84.70 Aa	146.69 Aa	3436.77 Aa	42.0 Aa

*Means in the columns followed by the same small letter for the same level of ECw do not differ significantly using Tukey's test ($p \geq 0.05$); means in the columns followed by the same capital letter for the same spacing do not differ significantly using Tukey's test ($p \geq 0.05$)

growth and productivity compared to the respective watering control. The residual effect in this treatment can be explained in part by a greater accumulation of salts in the planting row (0 to 0.3m layer) during the growth of the cowpea crop (Table 3) as explained earlier, which is associated with a higher sensitivity of maize crop to salts during germination and initial growth (Maas and Hoffman, 1977). It is important to mention that this residual effect may also be associated with total rainfall before maize planting. A study conducted by Bezerra et al (2010) found an approximately 30% greater accumulation of salts in the planting row (0 to 0.3 m layer) than those observed in Table 3, but this accumulation did not have any residual effect on maize crops, and the total rainfall before sowing was three times greater than that observed in this study.

CONCLUSIONS

Our work showed that the use of saline water in irrigation increased the concentration of salts and the percentage of exchangeable sodium in the different soil layers studied, verifying that the greatest accumulation of salts in the 0 to 0.3 m soil layer occurred in the planting rows in treatments with shorter spacing. Under saline conditions, it is possible to grow cowpea with greater planting density, maintaining the leaf area index and the distribution of photosynthetically active radiation at appropriate values for the photosynthetic process, resulting in considerable increases in productivity and in water and radiation use efficiency. However, the reduction in planting density and the residual effect of saline water used in irrigation of the cowpea crop negatively interfered with the vegetative growth and final productivity of the maize crop, with the residual effect of salinity only observed in the treatment with the greatest planting density. High levels of rainfall throughout maize growth caused the leaching of excess salts in the soil at the end of the maize crop, but total rainfall before sowing was not sufficient to completely eliminate the residual effects of salinity on this crop.

ACKNOWLEDGEMENTS

The authors wish to thank the National Council for Scientific and Technological Development (CNPq) for financial support.

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