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EFFECT OF INTERCROPPING ON THE GROWTH AND YIELD OF COWPEA AND MAIZE CROPS IRRIGATED WITH BRACKISH WATER

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ABSTRACT

The aim of this study was to evaluate the effect of the salinity of irrigation water on the growth, productivity and land-use efficiency in mono- and intercropping systems, using maize and cowpea plants. The experiment was carried out in a randomized-block design in split plots. The plots consisted of the crop year (2012 and 2013), the irrigation water salinity treatments (0.9, 2.5 and 5.0 dS m^{-1}) made up the sub-plots, and the sub-sub-plots included the cropping system tested (cowpea, maize, and maize intercropped with cowpea). The accumulation of salts in the soil increased in proportion to the electrical conductivity of the irrigation water, the highest values being observed in the maize, explained by the longer cycle and greater irrigation depth employed. The total rainfall recorded for the rainy seasons of 2013 and 2014 were sufficient to promote leaching of the excess salts below the root zone of the crops. The effect of salts on total plant biomass and productivity was highly significant in the monocropped systems, especially the cowpea. The microclimate conditions of the intercropping system may have contributed to the reduced effect of salinity on productivity, mainly in the cowpea, resulting in higher values for land-use efficiency.

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INTRODUÇÃO

The use of saline water sources, the reuse of drainage water and desalination reject brine for irrigation, and the exploitation of saline areas for agricultural systems depend on long-term strategies for ensuring socio-economic and environmental sustainability. These strategies should contribute to improving the chemical, physical and biological conditions of the soil, with a reduction in the concentration and presence of salts in the root environment. Consequently, this reduces the impact on the plant, increases land-use and water-use efficiency, and leads to greater exploitation of areas of high salinity, as well as the use of high salinity water for irrigation (Murtaza *et al*., 2006; Al Khamisi *et al*., 2013; Neves *et al*., 2015). Many of the strategies aimed at reducing salinity problems are similar to those used by farmers for other farming conditions, which can increase productivity and land use under both saline and non-saline conditions (Lacerda *et al*., 2011).

These strategies include the application of organic matter, liquid bio-fertilizers and mycorrhiza, the foliar application of organic and inorganic substances, the use of chemical enhancers (fertilizers and amendments), crop rotation, increased planting density, and the use of cover crops and intercropping systems (Lacerda *et al*., 2011; Estrada *et al*., 2013; Tanwar *et al*., 2014; Devkota *et al*., 2015). The practice of cultivating two or more crops in the same area during the same period in order to meet the basic needs of all crops is widespread among farmers in tropical regions of the world. Intercropping systems have higher levels of land productivity and higher production stability compared to monocropping systems, in addition to reducing the risk of rainfed agriculture (Rusinamhodzi *et al*., 2012; Albuquerque *et al*., 2015). These advantages are only present in intercropping systems (Mucheru-Muna *et al*., 2010) or when combined with other management practices such as crop rotation (Miriti *et al*., 2012; Thierfelder *et al*., 2012). Furthermore, there are some reports of the economic advantages of intercropping systems (Souza *et al*., 2011), in addition to improvements in the physical, chemical and microbiological conditions of the soil (Sousa *et al*., 2012; Chieza *et al*., 2013). On the other hand, under irrigation, water demand in an intercropping system may be greater compared to a monocropping system, as previously demonstrated in maize intercropped with cowpea (Ferreira *et al*., 2010). Furthermore, an intercropping system may alter the microclimate and the physiological responses of the plants involved (Lima Filho, 2000), with the magnitude of the microclimate changes depending on the density, shading, leaf area, season, time and location of sampling point of the microclimate elements (Pezzopane etal., 2007). Changes in the microclimate of an intercropping system may also alter the response to abiotic factors, such as salinity and water stress, and depending on the response, may result in greater sustainability and land-use efficiency under these stress conditions compared to monocropping systems. Although studies have evaluated the response of halophytes grown intercropped with fruit trees in saline environments (Kilic, *et al*., 2008), and the intercropping of sorghum and cowpea irrigated with water of moderate salinity (Tanwar *et al*., 2014), almost all studies of the response of plants to salinity have been carried out using monocrops, both in the field and in greenhouse (Neves *et al*., 2010; Lacerda *et al*., 2011). As a result, there is limited information on the effect of salt stress under intercropping system. Therefore, this type of study represents a new approach to research in the literature. In this context, the aim of this study was to evaluate the effect of the salinity of irrigation water on growth, productivity and land-use efficiency in mono- and intercropping systems, using cowpea and maize crops.

MATERIALS AND METHODS

This study was carried out during October 2012 and June 2014 in the experimental area of the Department of Agricultural Engineering (DENA) at the Federal University of Ceará (UFC; Pici Campus) in Fortaleza Ceará State, Brazil, located at 3°44'45" S and 38°34'55" W, at an altitude of 19.5 m a.s.l. The climate in the region is Aw type, characterized as a rainy tropical climate, which is very hot and has predominant rains in the summer and autumn. The total rainfall for the rainy seasons of 2013 and 2014 was 655 and 800 mm, respectively. For the cultivation periods during the dry seasons of 2012 and 2013 the total precipitation was 35 and 80 mm, respectively. The soil in the experimental area is classified as Red-Yellow Argisol, displaying the following characteristics at the start of the study: sandy-loam texture, bulk density of 1.48 kg dm^{-3}, electrical conductivity of 1:1 extract ($EC_{1:1}$) 0.51 dS m^{-1}, exchangeable sodium percentage (ESP) 2% and pH 5.5. The soil contained 1.7, 1.1, 0.3 and 0.2 $cmol_c$ dm^{-3} exchangeable Ca, Mg, K and Na, respectively. The experimental design consisted of randomized blocks, with split plots and three replicates. The plots included the different crop years (2012 and 2013), and the sub-plots consisted of the different irrigation water salinity treatments (0.9, 2.5 and 5.0 dS m^{-1}) and the split-plots of the cropping system (cowpea, maize, and maize intercropped with cowpea). Each split-plot (cropping system) was 4 × 4 m in size, giving a total area of 16 m^2.

To prepare the water, the salts NaCl, $CaCl_2.2H_2O$ and $MgCl_2.6H_2O$ were added to low-salinity water (well water, EC_W = 0.9 dS m^{-1}), maintaining an equivalent ratio of 7:2:1 for Na, Ca and Mg, and following the empirical relationship between EC_W and salt concentration ($mmol_c$ L^{-1} = EC × 10), as described by Rhoades *et al*. (2000). Cowpea (*Vigna unguiculata* Walp L.) seeds from the "EPACE 10" cultivar, and maize (*Zea mays* L.) seeds of the "BRS 4103" cultivar were used. Each of the crops was spaced 0.80 × 0.20 m apart in alternate rows, with one plant per hole for both crops. The crops were sown on the same date, at planting densities of 62,500 plants for maize and cowpea as monocrops, and 31,250 plants from each crop for the intercropping system. Irrigation was carried out every two days using a drip system, and the irrigation depth was defined based on the values of evapotranspiration (ETo), as estimated by the Class A pan method, and the crop coefficients (Kc) recommended for the different growth stages of the crops. For maize, crop coefficients of 0.61, 1.12, 1.11 and 0.91 were used for the early stage, growth, flowering and fruiting, and maturation stages, respectively (DOORENBOS; KASSAM, 1979). For cowpea, the crop coefficients used were 0.70, 0.81, 1.2 and 0.77 for the same stages, respectively, as per Souza *et al*. (2005). The total amount of water applied to the cowpea crop was 401.9 and 408.6 mm in 2012 and 2013, respectively. For the maize crop, the respective values were 620.1 and 606.2 mm. For maize, fertilization consisted of the application of 100, 100 and 60 kg ha^{-1} of N, P_2O_5 and K_2O, respectively, while 20, 60 and 30 kg ha^{-1} of the same nutrients were applied to cowpea, supplied by urea, simple superphosphate and potassium chloride, respectively. To meet the micronutrient requirements of the crops, 30 kg $ha^{-1}$of FTE BR-12 (9% Zn, 1.8% B, 0.85% Cu, 3% Fe, 2.1% Mn and 0.10% Mo) were applied in the form of commercial mineral fertilizer. Both before beginning (July 2012) and after (January 2013 and 2014) harvest of each crop, as well as after the rainy seasons (May 2013 and 2014), soil samples were collected from the 0–30 cm layer of each plot for chemical analysis. All mature pods or ears were collected from plants in the observation area of each plot (central rows). At the end of the cycles of the corn (110 days after planting, DAP) and cowpea (71 DAP) crops, a group of six plants from the central rows were collected, and the leaves (leaf blades), stems (branches and petioles) and pods were separated. The samples were stored in paper bags, dried in an oven at 60 °C, then weighed to obtain the total production of dry biomass and seed yield per hectare (PROD). The land-use efficiency index (LUE) was calculated as described by Souza *et al*. (2004) as LUE = (YIM/YMM) + (YIC/YMC), where YIM is the yield of intercropped maize, YMM is the yield of monocropped maize, YIC is the yield intercropped cowpea and YMC is the yield of monocropped cowpea. The results were submitted to analysis of variance (ANOVA) and the means compared by Tukey's test at the 0.05 probability level, using the ASSISTAT 7.7 beta software (Silva e Azevedo, 2009).

RESULTS AND DISCUSSION

Variations in salt accumulation in the soil: The values for $EC_{1:1}$ increased at the end of the cycle of crops irrigated during the dry seasons of 2012 and 2013, and these increases were proportional to the electrical conductivity of the irrigation water for both years (Table 1). The total rainfall recorded between January and May of 2013 and 2014, although well below the historical average for the municipality of Fortaleza, was sufficient to promote leaching of excess salts below the root zone of the crops. This washing effect due to the rainy season is similar to that observed in other studies (Murtaza *et al*., 2006; Neves *et al*., 2010; Lacerda *et al*., 2011). The $EC_{1:1}$values were higher in the maize crop than in the cowpea crop, which can be explained by the longer crop cycle and greater irrigation depth used for maize. When the cropping systems were compared, differences in $EC_{1:1}$ were only found in the maize crop, with the highest values observed for the intercropping system. It is possible that this difference is associated with the removal of the cowpea crop, which has a shorter cycle.

Productivity and land-use efficiency: The results presented in Table 2 show the efficiency of dry matter production of the mono- and intercropping systems with different levels of salinity and years of cultivation. The differences between 2012 and 2013 were not very significant, and this small difference or lack of a difference can be explained, in part, by small variations in the accumulation of salts in the soil over the two years, as previously mentioned (Table 1). The effects of salinity and the cropping system on total biomass production, expressed in kg ha^{-1} (Table 2A), were found to be more significant in the monocropping system. When the different cropping systems were compared for the same level of salinity, the productivity of each crop was found to vary according to the number of plants per hectare, which was less for the intercropped plants. However, the greatest variations between the productivity of each crop, under the monocropping and intercropping systems, were observed for crops irrigated with water of lower salinity. By comparing the grain yield between the 2.5 dS m^{-1} saline treatment with the lowest saline level (0.9 dS m^{-1}; Table 2A), significant

Table 1. Electrical conductivity of 1:1 (soil:water) extract in the 0-30 cm layer of soil in cultivated area for two years with cowpea and maize under mono and intercropping systems and irrigated with water of different salt concentrations (ECw)

ECw dS m^{-1}	Monocropping		Intercropping	
	Cowpea	Maize	Cowpea	Maize
	July 2012			
	0.51	0.51	0.51	0.51
	December 2012			
0.9	0.56 ± 0.04	1.02 ± 0.03	0.55 ± 0.03	1.22 ± 0.13
2.5	1.00 ± 0.16	2.00 ± 0.26	1.01 ± 0.10	2.70 ± 0.19
5.0	1.34 ± 0.04	3.24 ± 0.44	1.38 ± 0.09	4.25 ± 0.49
	June 2013			
0.9	0.40 ± 0.02	0.44 ± 0.04	0.39 ± 0.03	0.43 ± 0.04
2.5	0.37 ± 0.04	0.39 ± 0.01	0.33 ± 0.01	0.37 ± 0.04
5.0	0.32 ± 0.04	0.40 ± 0.07	0.44 ± 0.05	0.44 ± 0.04
	December 2013			
0.9	0.46 ± 0.03	0.93 ± 0.03	0.51 ± 0.03	1.11 ± 0.12
2.5	0.95 ± 0.15	1.90 ± 0.25	0.96 ± 0.09	2.57 ± 0.16
5.0	1.27 ± 0.04	3.07 ± 0.42	1.31 ± 0.08	4.03 ± 0.46
	June 2014			
0.9	0.21 ± 0.01	0.22 ± 0.03	0.23 ± 0.03	0.22 ± 0.04
2.5	0.23 ± 0.01	0.27 ± 0.01	0.25 ± 0.02	0.25 ± 0.02
5.0	0.24 ± 0.02	0.25 ± 0.01	0.23 ± 0.01	0.27 ± 0.05

Mean ± standard error of mean (n = 3).

Table 2. Total dry mass and productivity (A) and land use efficiency (B) of cowpea and maize crops under different cropping systems, salinity of irrigation water and year of cultivation

A.

	Monocrops		Intercropping	
	Cowpea	Maize	Cowpea	Maize
ECw (dS m^{-1})	Total dry mass (kg ha^{-1})			
0.9	2865.7 aC	17138.4 aA	1275.7 aD	8206.9 aB
2.5	2277.4 abC	14390.4 bA	1166.1 aD	8218.4 aB
5.0	1534.2 bC	12586.6 cA	833.7 bD	6200.0 bB
Year				
2012	2247.77 aC	15184.75 aA	1031.58 aD	8030.66 aB
2013	2203.74 aC	14225.53 bA	1151.75 aD	7052.90 bB
	Productivity (kg ha^{-1})			
0.9	1103.51 aC	4782.15 aA	465.39 aD	2843.66 aB
2.5	1016.37 aC	4224.94 bA	462.14 aD	2525.34 aB
5.0	523.36 bC	3680.31 cA	404.21 aD	2158.00 bB
Year				
2012	914.8 aC	4286.3 aA	407.7 aD	2625.7 aB
2013	847.4 aC	4171.9 aA	480.2 aD	2392.4 aB

B.

ECw (dS m^{-1})	YIM/YMM[1]	YIC/YMC	LUE
0.9	0.594	0.421	1.016
2.5	0.597	0.454	1.052
5.0	0.586	0.772	1.359

Means followed by the same lower case letter in the column and upper case in the line, do not differ by Tukey test (p>0.05).
[1] YIM: yield intercropped maize; YMM: yield monocropped maize; YIC: yield intercropped cowpea; YMC: yield monocropped cowpea.

reductions were only found for the monocropped maize, which showed a mean yield reduction of 12%. For treatments with the highest salinity level, the grain yield for the monocropped and intercropped cowpea crops was reduced by 52 and 14%, respectively, and reduced by 23 and 24%, respectively, for the maize crops. Studies conducted under monocropping systems (Neves *et al*., 2010; Silva *et al*., 2013; Neves *et al*., 2015; Tong et al., 2015) have demonstrated that the salinity-inhibition of biomass production for maize and cowpea are related to the osmotic, toxic and nutritional effects of salt stress. These effects alter the liquid assimilation of CO_2, inhibit leaf expansion, and accelerate the senescence of mature leaves, thereby reducing the area for photosynthesis and the total production of photoassimilates, and consequently, decreasing grain production (Amorim, *et al*., 2010). The lesser effects of salinity on the growth of the maize and cowpea plants, observed in the intercropping system (Table 2A), may be related, at least in part, to the microclimate conditions created in that system (Pezzopane *et al*., 2007). This included reduced radiation in the cowpea crop (Lima Filho, 2000), which may alleviate the osmotic effects of the salts.

The results presented in Table 2B show the land-use efficiency, calculated from the crop productivity dataobtained from the mono- and intercropping systems. There was no difference in land-use efficiency for the treatments in which water with salinity levels of 0.9 and 2.5 dS m^{-1} was used for irrigation, with LUE values of 1.016 and 1.052, respectively. However, at the highest level of salinity, intercropping proved to be the more efficient system for land use, with LUE values reaching 1.359. Many studies have shown that intercropping systems have higher levels of land productivity and greater production stability compared to monocropping systems, as well as reducing the risks for rainfed agriculture (Rusinamhodzi *et al*., 2012; Albuquerque *et al*., 2015). In addition, intercropping systems may change the microclimate and the physiological responses of the plants involved (Lima Filho, 2000), with the magnitude of the changes in microclimate depending on planting density, shading, leaf area, season, and the time and sampling point of the microclimate elements (Pezzopane *et al*., 2007). Microclimatechanges in an intercropping system may also alter the response to some abiotic factors, including salinity and water stress, and depending on the response, may increase sustainability and land-

use efficiency under conditions that restrict plant development compared to a monocropping system. The results obtained in the present study show that the microclimate conditions of the intercropping system may have contributed, at least in part, to reducing the effect of salinity on productivity, especially in the cowpea crop (Table 2A), resulting in higher LUE values (Table 2B).
The effect of the salts on total plant biomass and productivity was more significant in the monocropped plants, particularly for the cowpea crop. The microclimate conditions of the intercropping system contribute to the reduced effect of salinity on productivity, mainly in the cowpea crop, resulting in higher values for land-use efficiency.

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