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BELL PEPPER CULTIVATION WITH BRINE FROM BRACKISH WATER DESALINATION[1]

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ABSTRACT - In desalination process, besides the potable water, highly salty and pollutant water (brine) is generated, which can be used for producing crops since it is carefully monitored. In order to test this hypothesis, bell pepper plants, cv. 'Margarita', were grown in coconut fiber substrate under greenhouse and were irrigated with nutrient solutions prepared with tap water, brine from desalination plant, and its dilution with tap water at 75, 50 and 25%, giving a range of electrical conductivities of the nutrient solution (ECs) of 2.6, 3.1, 6.6, 10.0 and 12.2 dS m^{-1} after the dilutions and fertilizers addition. Completely randomized blocks design was used with 5 treatments (salinity levels of the nutrient solutions) and six replications. Leaf area, number of marketable fruit, total and marketable yield were reduced with ECs increase. The marketable yield of bell pepper 'Margarita' reduced 6.3% for each unitary increase of ECs above 2.6 dS m^{-1} (threshold salinity) and the results suggest that in hydroponic system, the reduction of marketable yield with increasing ECs is promoted by reduction of the number of fruits per plant instead of a reduction of fruit mean weight.

Keywords: *Capsicum annuum* L. Hidroponics. Environmental Impact. Salt Tolerance.

CULTIVO DO PIMENTÃO COM REJEITO DA DESSALINIZAÇÃO DE ÁGUA SALINA

RESUMO - No processo de dessalinização se gera, além da água potável, um rejeito altamente salino e de poder poluente elevado, podendo este ser utilizado na produção agrícola deste que seja rigorosamente manejado. Para testar esta hipótese, plantas de pimentão (cv. 'Margarita') foram cultivadas em fibra de coco sob condições protegidas e irrigadas com solução nutritiva preparadas com água de abastecimento, água de rejeito coletada no dessalinizador e da sua diluição com água de abastecimento a 75, 50 e 25%, resultando em condutividades elétricas da solução nutritiva (ECs) de 2.6, 3.1, 6.6, 10.0 e 12.2 dS m^{-1} após as diluições e adição de fertilizantes. O delineamento experimental foi em blocos casualizados, com 5 tratamentos (níveis de salinidade da solução nutritiva) e seis repetições. A área foliar, o número de frutos comerciais e as produtividades total e comercial foram reduzidos com o incremento de ECs. A produtividade comercial do pimentão 'Margarita' foi reduzida em 6,3% para cada aumento de uma unidade de ECs acima de 2,6 dS m^{-1} (salinidade limiar) e os resultados sugerem que, em sistema hidropônico, a redução da produção comercial com o aumento de ECs é promovida pela redução do número de frutos por planta e não pela redução do peso médio dos frutos.

Palavras-chave: *Capsicum annuum* L. Hidroponia, Impacto Ambiental. Tolerância à Salinidade.

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INTRODUCTION

In semi-arid area of Brazil, the use of groundwater is a viable alternative to ensure community access to water, but these water sources have in most cases, restrictions for domestic consumption and irrigation uses because of their high salinity (SOUSA et al., 2009).

Reverse osmosis technology has been widely used for the treatment of brackish water (PORTO et al., 2001), with experiences in most communities on the Northeast region of Brazil. However, this desalination technique produces always drinking water, but also reject water (brine) with concentration of salts higher than the original water (FELL, 1995). Therefore, the great challenge of using the reverse osmosis is the deposition or the reuse of the brine in order to avoid negative impacts on the environment.

Generally brine does not receive any treatment in Brazil; anyway, it has been poured on soil, providing high accumulation of salts in soils (PORTO et al., 2001) causing short term salinisation problems in communities that benefit from the desalination technology.

To overcome this problem, the brine could be used for production of hydroponic vegetables, where the saline effluent at the end of the crop season, containing ions of the nutrient solution and brine, would be stored in the tank to be reused for the next crop. In addition, the hydroponics may constitute an advantage when using saline water reject because there is no soil matric potential or it is minimized, which allow a significant increase of crops tolerance to salinity (SOARES, 2007). Thus, there is no soil contamination with salts and the food production would be closer to the sustainable production, with highest environmental protection.

The objective of the present study was to evaluate the possibility of using brine from the desalination of brackish water, mixed to nutrient solution in different concentrations, for bell pepper under hydroponics. In addition, the crop salinity tolerance was investigated to determine the effects of brine dilutions on crop growth and yield.

MATERIAL AND METHODS

The work was conducted from February to May 2009 in a greenhouse in the irrigation sector of the Department of Environmental Sciences, Universidade Federal Rural do Semi-Árido. The greenhouse was 6.4 m wide, 22.5 m long and 3.0 m height, covered with polyethylene film of 0.15 mm of thickness with additive anti-ultraviolet rays and closed on the sides with black shade cloth (50% shade).

The experimental area consisted of six rows of bell pepper cv. 'Margarita', and the two rows located in the sides were used as borders. Plants were trained through three lines of wire tied to stakes that were installed at the ends of each row. Each plot consisted of two plastic pots of 12 L containing a 2 cm layer of gravel at the bottom, covered with nylon screen and filled with 8 kg of coconut fiber substrate. The pots were placed so that the plants were spaced 0.50x1.00 m between plants and rows of plants, respectively.

Randomized block experimental design was used with five treatments and six replications. Treatments corresponded to five levels of electrical conductivity of nutrient solution (ECs) prepared with: tap water (treatment T1), brine collected after desalination of a saline water by reverse osmosis (treatment T5) and its dilution with tap water at 75, 50 and 25% (T_2, T_3 and T_4). Brine was collected from a brackish water desalination plant of a rural community located in Mossoró, RN and its electrical conductivity (EC) was around 9 dS m^{-1}, while the EC of tap water was 0.52 dS m^{-1}. The ECs of the treatments T1, T2, T3, T4 and T5 were 2.6, 3.1, 6.6, 10.0 and 12.2 dS m^{-1}, respectively, after the addition of the fertilizers.

Seeds of bell pepper cv. 'Margarita' were sown on February 20, 2009, in polystyrene trays with 128 cells filled with vermiculite. After germination, the seedlings were grown under DFT system (FURLANI et. al., 1999), leaving a film of nutrient solution of 5 cm depth that was sufficient enough for the development of seedlings roots and to maintain the substrate moistened to assure good development of seedlings without restriction of water and nutrients. The transplanting of seedlings to pots was carried out at 20 days after sowing (DAS), when plants were about 10 cm tall.

Plants were trained with a single stem along and around a vertical plastic string with branches supported by the three wires, eliminating the excess side shoots by pruning. Some branches and old leaves were removed in order to improve light and ventilation in the plant canopy.

Irrigation was performed manually using a graduated cylinder, keeping the substrate moisture always at field capacity, defined as the amount of water that remains on the substrate after the drainage of excess water. The volume of water applied was calculated from the moisture content of the substrate estimated with tensiometers installed at 20 cm depth and the substrate-water retention curve.

The nutrient concentrations in the nutrient solution were identical in all treatments (Savvas et al., 2007). The amount of each fertilizer added in nutrient solutions (pH=6.0) for 100 L of irrigation water was 18.4 g of calcium nitrate, 9.2 g of potassium chloride, 9.4 g of monoammonium phosphate, 8.6 g of magnesium sulfate and 3.8 g of Quelatec® (solid mixture of EDTA-chelated nutrients containing 0.28% Cu, 7.5% Fe, 3.5% Mn, 0.7% Zn, 0.65% B and 0.3% Mo). The electric conductivity and pH of solution were monitored daily and each every week the solution was replaced.

At 75 days after transplanting (DAT) plant height (distance from soil surface and the top of the highest branch) and stem diameter, at 1 cm above the soil surface, were determined. All plants were collected to determine shoot fresh and dry weight and leaf area, using leaf area meter LI-3100. All fruits harvested were used to determine total and marketable yield, number of fruits per plant and average fruit weight. The marketable fruits were considered those free of mechanical injury, spots and deformities and weighing more than 50 g.

Data was subjected to analysis of variance and F-test. Means of the variables affected by salinity were plotted against ECs and the model of Maas and Hoffman (1977) was adjusted, with model parameters estimated by the program SALT (GENUCHTEN, 1983).

RESULTS AND DISCUSSION

Growth of bell pepper plant cv. 'Margarita' was not affected by the addition of brine to the nutrient solution, except for leaf area (Table 1).

Table 1. Summary of analysis of variance and means of steam diameter (D), plant height (PH), leaf area (LA), total number of fruits (TNF), number of marketable fruits (NMF), shoot fresh weight (FW), shoot dry weight (DW), total (TY) and marketable (MY) yield, mean weight of total (MWTF) and marketable (MWMF) fruits of bell pepper, cv. 'Margarita', irrigated with brine from water desalination.

	(D)	PH	LA	TNF	NMF	FW	DW	TY	MY	MWTF	MWMF
ECs	Cm		cm^2	fruits $plant^{-1}$		g $plant^{-1}$		g $plant^{-1}$		g $fruit^{-1}$	
2.6	10.7	60	4027	7.8	7.2	212	33 9	422	403	55.7	57.7
3.1.	11.2	62	4022	6.7	6.7	230	34.6	383	383	59.0	59.0
6.6.	11.3	62	3108	8.3	6.4	206	31.6	330	295	41.7	48.2
10.0	11.6	65	3421	6.7	4.8	201	29.3	340	273	53.5	58.7
12.2.	12.7	65	2836	6.0	2.2	177	23.7	197	106	40.0	43.1
Test F	1.1	0.6	2.8 *	0.6	5.3 **	0.9	2.1.	4.6**	5.9**	1.0	0.9
Mean	11.5	62.7	3483	7.1	5.5	205.2	30.6	334	292	50.0	53.4
CV	10.8	10.3.	23 6	34.3	27.5	26.4	18.7	21.6	28.4	30.5	29.4

*, ** Significant at 0.05 and 0.01 of probability, respectively, by test F

The lack of response to plant height (PH) corroborates the results observed by Medeiros et al. (2002), which found no effect of soil salinity on height of bell pepper hybrid 'Luiz'. Leaf area (LA) was reduced by 2.8% per unit increase of ECs (Figure 1). The decrease in LA was probably due to decrease in the volume of cells and also as a mechanism of plant tolerance to salinity, once the reductions in LA and photosynthesis contribute in some way to transpiration rate reduction and crop adaptation to salinity (MITTOVA et al., 2002; SULTANA et al., 2002).

The ECs showed a significant effect on the number of marketable fruits (NMF), with an average of 7.1 fruits $plant^{-1}$ (Table 1). The relative NMF (NMFr) decreased linearly from the ECs of 8.77 dS m^{-1} (threshold salinity, TS), with a decrease of 20.7% in NMFr per unit increase of ECs above the TS (Figure 2). Rubio et al. (2009) showed that saline nutrient solution increased the number of fruits with blossom-end rot, with consequent reduction in marketable yield of bell pepper cv. 'Somontano'. Indeed, many investigations have reported an increased occurrence of blossom-end rot with decreasing osmotic potential in the root zone of bell pepper even if this decrease is partly imposed by raising the Ca concentration (Savvas et al., 2007).

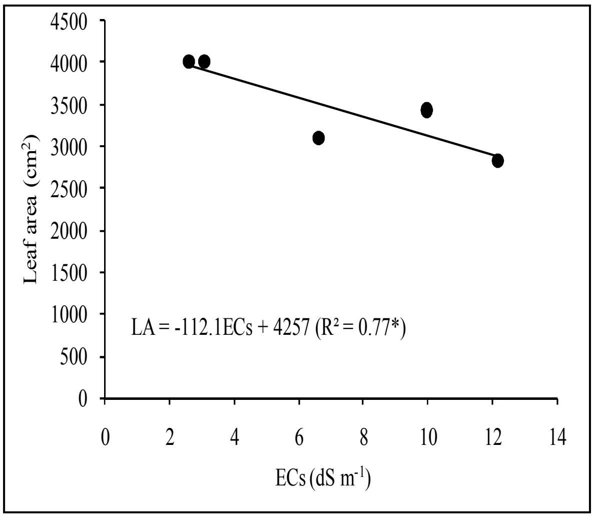

Figure 1. Leaf area (LA) of bell pepper, cv. 'Margarita', as a function of salinity of the nutrient solution (ECs) promoted by the addition of brine from water desalination under soilless system.

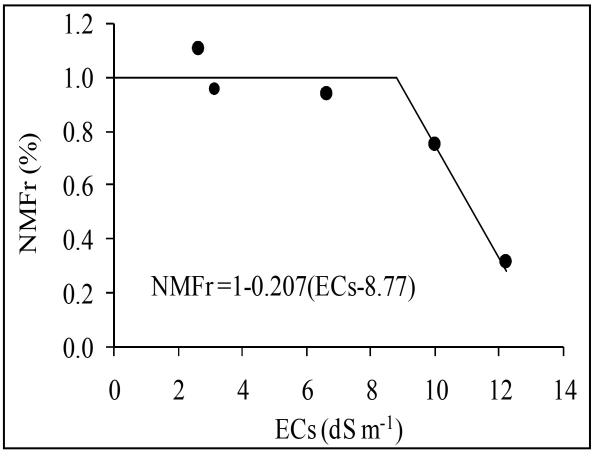

Figure 2. Number of marketable fruits per plant (NMFr) of bell pepper, cv. 'Margarita', as a function of salinity of the nutrient solution (ECs) promoted by the addition of brine from water desalination under soilless system.

Both total yield (TY) and marketable yield (MY) were affected by ECs (Table 1); TY decreased linearly with the increasing ECs, with yield loss from the treatment T1 to the treatment T5 of 53.1% (Figure 3A). Reduction of MY was 6.67% for each unit increase of ECs above 2.8 dS m $^{-1}$ (Figure 3B).

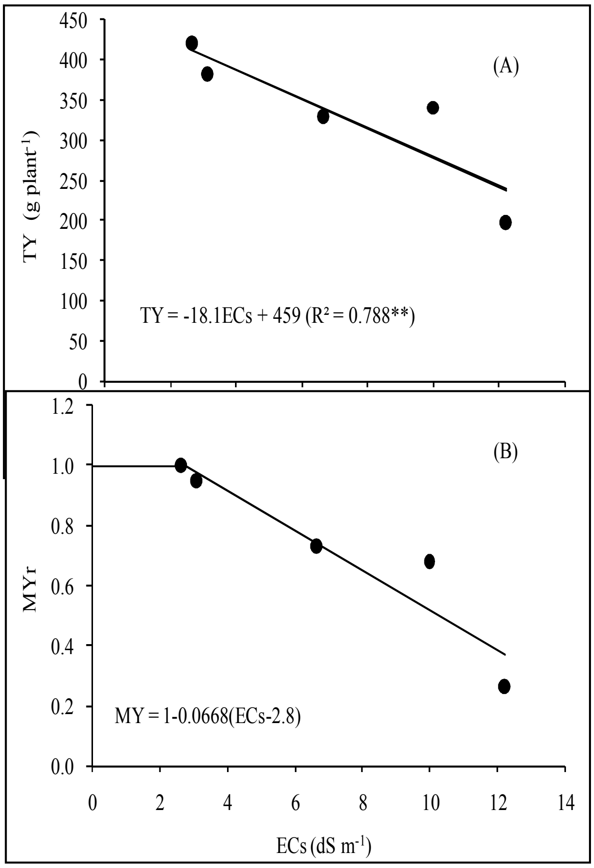

Figure 3. Total yield, TY, (A) and relative marketable yield, MY, (B), of bell pepper cv. 'Margarita', as a function of salinity of the nutrient solution (ECs) promoted by the addition of brine from water desalination under soilless system.

The extrapolation of the linear regression function it could be find that ECs above 18.5 dS m $^{-1}$ results in loss of 100% in TY, well above the yield reduction stated by Maas e Hoffman (1977) of 8.6 dS m $^{-1}$, showing a higher tolerance of bell pepper to salinity when grown in the coconut fiber substrate.

The reduction of TY was 6.3% for each unit increase of ECs above 2.6 dS m $^{-1}$, which was below the decrease of TY stated by Maas and Hoffman (1977), 14%, Medeiros et al. (2002), 11.4% and Silva (2002), 8.56%. In the present study no reduction of the stand population was observed and there was no significant effect of treatments on both the total number of fruits (TNF) and the mean weight of total fruits (MWTF), so it is not possible to identify the main reason of yield decrease. Anyway, the low reduction of TY with increasing salinity indicates a build up of bell pepper tolerance to salts under hydroponics, which makes possible the use of brine in appropriate concentrations.

Decrease of MY was 6.7% for each unit increase of ECs above 2.8 dS m $^{-1}$, which was due to the reduction of number of marketable fruits (NMF), as also observed in hydroponics by Al-Karaki et al. (2009) for bell pepper cvs. 'Flavian', 'Sonar' and 'Alzado', and by Caruso and Villari (2004) for pepper 'Friariello' (*C. annuum* L., var. Longum). Reducing of NMF with increasing ECs and the consequent loss of marketable yield was promoted by the higher occurrence of fruits with blossom-end rot (BER) or deformation. Increasing the Ca^{+2} concentration in nutrient solution could minimize the reduction of NMF by reducing the BER incidence (RUBIO et al., 2009).

Brine addition to the nutrient solution raised the ECs of about 1.22 dS m-1 for each 10% increase in brine concentration. Assuming that a 10% loss on MY could be acceptable, thus brine may be added to the nutrient solution up to a concentration of about 30%.

CONCLUSIONS

The salinity of the nutrient solution reduces the marketable yield of bell pepper, cv. 'Margarita'', of 6.67% for each unitary increase of salinity above 2.8 dS m $^{-1}$;

Brine from brackish water desalination may be used for bell pepper under hydroponics up to concentration of 30% in the nutrient solution, with about 10% reduction of marketable yield.

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