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USE OF REJECT BRINE FROM DESALINATION ON DIFFERENT DEVELOPMENT STAGES OF HYDROPONIC LETTUCE[1]

NILDO DA SILVA DIAS[2]*, FRANCISCO AÉCIO DE LIMA[3], CLÁUDIO RICARDO DA SILVA[4], OSVALDO NOGUEIRA DE SOUSA NETO[5], HANS RAJ GHEYI[6]

ABSTRACT - In order to evaluated the impact of the high salinity reject brine from reverse osmosis desalination on hydroponics lettuce cultivated in greenhouse an investigation was carried out in Mossoro, Northeast of Brazil (5º11'S, 37º20'O and 18m above sea). Two lettuce cultivars ('Verônica' and 'Babá de verão') were cultivated with a basic nutrient solution with 1.1 dS m^{-1} (control) during the crop cycle (1-28 days after transplanting – DAT) – T_0 and with basic nutrient solution containing 50% of the reject water from desalinization with 4.8 dS m^{-1} exposed during 1-7, 21-28, 7-14 e 1-28 DAT (T_1, T_2, T_3 and T_4, respectively). The addition of 50% of brine reject from desalination into the hydroponic nutrient solution allows grow only 'Verônica' lettuce with no reduction in fresh biomass. This lettuce cultivar shows to be more tolerant to salinity for all exposure time with reject brine in the nutrition solution, despite the fact that 'Babá de Verão' cultivar is more productive.

Keywords: Salinity. Reverse osmosis. *Lactuca sativa* L. Groundwater

USO DE REJEITO SALINO DA DESSALINIZAÇÃO DA ÁGUA EM DIFERENTES ESTÁDIOS DE DESENVOLVIMENTO DA ALFACE HIDROPÔNICA

RESUMO - Com o objetivo de avaliar os efeitos da utilização do rejeito da dessalinização na solução nutritiva no cultivo de alface hidropônica em ambiente protegido, duas cultivares de alface ('Verônica' e 'Babá de Verão') foram cultivadas com solução nutritiva básica com 1,1 dS m^{-1} (testemunha) durante todo o ciclo (1-28 dias após o transplantio - DAT) – T_0 e com solução nutritiva básica contendo 50% de água de rejeito da dessalinização com 4,8 dS m^{-1} expostas de 1-7, 21-28, 7-14 e 1-28 DAT (T_1, T_2, T_3 e T_4, respectivamente). As plantas dos tratamentos T_1, T_2 e T_3 foram irrigadas com solução nutritiva básica (T_0) nas demais fases do ciclo. A adição de 50% de rejeito do dessalinizador à solução nutritiva permite o cultivo da alface em sistema hidropônico, somente para a cv. 'Verônica', sem haver redução na produção de matéria fresca. A cultivar 'Verônica' foi mais tolerante a salinidade em todos os tempos de exposição da salinidade da solução nutritiva com rejeito salino, embora a cultivar 'Babá de Verão' seja mais produtiva.

Palavras-chave: Salinidade. Osmose reversa. *Lactuca sativa* L. Água subterrânea.

*Autor para correspondência.
[1]Recebido para publicação em 25/06/2010; aceito em 05/10/2010.
[2]DCAT/UFERSA, Caixa Postal 137, 59600-900, Mossoró - RN; nildo@ufersa.edu.br
[3]UFERSA, Caixa Postal 137, 59625-900, Mossoró - RN; aecioagro@hotmail.com
[4]UFU, Campus Umuarama, 38400-902, Uberlândia – MG; claudio@iciag.ufu.br
[5]UFERSA, Caixa Postal 137, 59625-900, Mossoró - RN; neto_ufersa@hotmail.com
[6]UFRB, 13418-900, Cruz das Almas - BA; 44380-000; hans@pq.cnpq.br

INTRODUTION

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 (MEDEIROS et al., 2003; SOUSA et al., 2009). However, groundwater salinity can be decreased by desalinization process (FRITZMANN et al., 2007).

Historically, due to its high cost, desalination was limited to applications as a source for potable water and for high-quality water for industrial uses. However, technological advances in the last years have driven down the cost of desalinated water due to reductions in the price of equipment, reduction in energy demand and know-how on water treatment (TSIOURTIS, 2001; FRITZMANN et al., 2007). In Rio Grande do Norte State, the first desalination plant experience began in 1997 and since then, the numbers of desalination plants have been increased annually.

Reverse osmosis is by far the most widespread type of membrane based desalination process being capable of produce almost pure water. However, it generates also a waste brine with high salinity that may cause salinization of areas where it is dumped (PORTO et al., 2001). Depending on the brine composition and its disposal can lead an adverse effect on soil and groundwater as observed by Mohamed et al. (2005). The major constituents of reject brine are inorganic salts. However, reject brine from industrial plants can also contains small quantities anti-scale additives, corrosion products, and other reaction products (MOHAMED et al., 2005). In fact, desalinization method has been limited by the disposal costs of the brines produced and by the adverse impact of brine compositions on the environment. Thus, researches must be carried to solve or minimize the impact of brine.

In Brazil, in most cases, the reject brine from desalination is not receiving any treatment before being dumped on soil, which has leading high accumulation of salts in superficial layers of soil (PORTO et al. 2001). An option to reduce the problem is use it on nutrient solution in hydroponic cultivation of vegetables, since the plant tolerance to salinity in hydroponic systems is greater than in the conventional system (SOARES et al., 2007). Under hydroponic system the matric potential is keep lower than convention system that facilitate water uptake by plants. Moreover, in the hydroponic the reject brine is already captured and may be re-circulated and diluted to irrigate other crops or even can be easily directed to evaporation pans, preventing its release to the soil.

Studies on the tolerance of various species to salinity in hydroponic system have shown that, through adequate water management and cultivation practices, crops can be produced commercially with saline water (CARUSO; VILLARI, 2004; SAVVAS et al., 2007; AL-KARAKI et al., 2009). Thus, in hydroponic systems, it is expected that crops, particularly fast-cycle, provide a sustainable use for the reject brine and also, a guaranteed food production in the communities where the desalination plants were implanted.

The present study was to evaluate whether the reject brine can be used into hydroponic nutrient solution under different stages of development of lettuce cultivated in greenhouse.

MATERIAL AND METHODS

The present study was carried out in a greenhouse located at Federal University of Semi-Arid – UFERSA, Mossoró, Brazil (5.2°S, 37.3ºO and 18m above sea) from September, 17 to October, 29 of 2008. The climate is BSwh by Thornthwaite classification system with impressive seasonality of monthly precipitation, with a drier regime, generally from June to January and another more wetted from February to May.

The seeds of 'Verônica' and 'Babá de Verão' lettuce cultivars (*Lactuca sativa* L.) were sown on September 17 of 2008 on a 128-cell styrofoam box filled with vermiculite. These cultivars were chosen because they are very common under hydroponic systems.

After the germination, the styrofoam box was placed in a DFT system (FURLANI et al., 1999) and then left to drain 4-5cm depth for keeping the substrate moist and for helping the development of root system. The transplanting for hydroponic cultivation was made at 21 days when the seedlings, uniform in size, had 5 or 6 cm height and 5 definitive leaves.

The reject brine was collected in 'Puxa Boi' desalinization plant community while the fresh water came from the supply system of the university. The chemical characteristics of the reject brine, fresh water and dilutions used in the experiment are described in Table 1.

The hydroponic system was by Nutrient Film Technique (NFT) with PVC tube channel, a reservoir and pumps. The tubes were over a flat wood stand at 1 m above of ground and spaced by 0.3 m. Along the tube, spaced at 0.2 m, there were holes of 0.09 m of diameter to support the seedlings of lettuce plants. The nutrition solution was pumped to channels and then redistribute by gravity for irrigating all plants. The pumping system was managed to keep a constant solution and water status in the root zone by continuously recirculation for 15 minutes, at intervals of 90 minutes during the day, whereas at night, no solution was supplied to the plants.

The lettuce seedlings were transplanted and distributed alternately into the plots. Each parcel unit was composed by a channel tube which was attached to a 150 L reservoir outside the greenhouse and be-

Table 1. Chemical composition of water supply (W), reject brine from desalinization plant (R) and the mixture of water supply and reject brine (M).

	EC[1] (dSm^{-1})	pH	Ca	Mg	Na	Cl	CO_3	HCO_3	SAR[2] (mmol L^{-1})^{0,5}
			.............mmol$_c$ L^{-1}................						
W	0.46	8.0	0.6	0.1	5.1	1.8	0.5	3.8	8.63
R	5.96	7.4	22.4	8.6	30.6	64.6	0.3	8.1	7.77
M	3.80	7.6	11.6	4.2	16.8	26.0	0.4	5.7	5.97

[1] Eletrical condutivity
2 Sodium adsorption ratio

low the soil level to avoid warming. It was used 16 lettuce seedlings by channel but only six of each one were considered as useful. The last two seedlings at the end of tubes were used as border.

The treatments consisted of supplying plants with a basic nutrition solution 1.1 dSm^{-1}(control) throughout their stages of development (1-28 days after transplating, DAT) namely by T_0; with a basic nutrient solution containing 50% volume of brine reject at 4.8 dS m^{-1} supplied in the first week of cultivation (1-7 DAT) - T1; in the last cultivation week (21-28 DAT) – T_2; in the first two cultivation weeks (1-14 DAT), T_3; and throughout all cultivation (1-28 DAT) – T_4. After the time of imposition of treatments, T_1, T_2 and T_3 plants were irrigated with the basic nutrition solution. The five treatments and cultivars were randomized in a factorial blocks design, with four replications. Each treatment had a NFT system, with four channels (replications) and a reservoir.

The basic nutrition solution had the following composition of inorganic macro nutrients (g L^{-1}): 0.5; 0.37; 0.14 e 0.27 of calcium nitrate, potassium nitrate, monoammonium phosphate (MAP), magnesium sulfate, respectively. As source of micro nutrients was applied 0.06 g L^{-1} of commercial EDTA-chelated nutrient form containing 0.28% of Cu, 7.5% of Fe, 3.5% of Mn, 0.7% of Zn, 0.65% of B and 0.3% of Mo. The electric conductivity and pH of solution were monitored daily and each every week the solution was replaced.

The harvest was done at 28 days after transplanting when was measured the number of leaves (NL) by counting all green leaves longer than 3.0 cm length and ignoring yellow and/or dried leaves; fresh biomass weight (FB) was determined with a digital precision balance. After, dry matter (DM) was obtained by drying biomass in a forced-air oven at 70^{o}C until constant weight, expressed in grams. The leaf area (LA) was determined using a leaf area meter (LI-COR, Lincoln, NB, USA).

Data were submitted to variance analysis and means compared by the Tukey test ($P \leq 0.05$). All analyses were performed by the software statistical SISVAR (FERREIRA, 2000).

RESULTS AND DISCUSSION

According to the analysis of variance for growth variables data, the exposure time of the nutrient solution with reject brine, the lettuce cultivar and the interaction were influenced significantly ($P \leq 0.01$).

In relation to response of lettuce plants to reject brine exposure, it can be seen in Table 3 that the fresh biomass weight (FB) and leaf area of T_1 treatment did not differ statistically from the control which can be associated by reduced time to exposure (7 days) and due to lower water requirement of plants. Furthermore, T_2 has the same exposure time that T_1 but differed from the control treatment, indicating that the tolerance of lettuce to salinity depends not only by time of exposure, but also the development phase or water requirement of plants. In this study, although all plants have been exposed to the same duration, those submitted on the initial phase of growth had higher FB (65.258 and 57.686g for T_1 and T_2) and LA (1131.04 and 1065.88 cm^2 for T_1 and T_2) when compared to those exposed at the end phase (Table 2) evidencing that the initial development is more tolerant to the effects of salinity. However, this behavior may vary depending on the species cultivated. Maas (1990) concluded that sweet corn suffered during the initial stage of growth despite tolerated up to 9 dS m^{-1} during the grain filling stage without prejudice yield.

As regards with lettuce cultivar compared to control, 'Veronica' cultivar was not affected to exposure time and stage of application of brine reject for most all growth variables studied, except for DM and LA in T_1 and T_4 (Table 3). However, 'Babá de Verão' cultivar had a significant decrease ($P \leq 0.05$) in all growth variables when exposure time with reject brine was increased (Table 4). Soares et al. (2007) did not found effects of exposure time with saline nutrition solution for 'Elisa' and 'Verônica' cultivars cultivated in hydroponic systems. The discrepancy between the results may be associated with climatic condition where the experiment was developed (Piracicaba, SP), since as reported by Dias et al. (2003), plants grown in cold climate or seasons are more tolerant to salinity than those of warm or

Table 2. Mean values of fresh biomass weight (FB) dry matter (DM), number of leaves (NL) and leaf area (LA) in the treatments.

Treatments	Growth variables (1)			
	FB	DM	NL	LA
	.... g			.... cm^2 ....
T_0	73.44A	4.84A	16.96A	1286.46A
T_1	65.26AB	4.13AB	16.71A	1131.04AB
T_2	57.69BC	4.34A	16.30A	1065.88BC
T_3	52.30BC	3.87AB	14.04B	884.04C
T_4	51.13C	3.26B	14.25B	894.96C

(1) Means followed by the same letter in the columns are not different by Tukey test ($p > 0.05$).

Table 3. Mean values of fresh biomass weight (FB) dry matter (DM), number of leaves (NL) and leaf area (LA) in the treatments with lettuce (cv. 'Verônica').

Treatments	Growth variables (1)			
	FB	DM	NL	LA
	.... g			.... cm^2 ....
T_0	47.19A	3.98A	9.92AB	771.25A
T_1	37.05A	2.34B	9.50AB	639.83A
T_2	37.47A	3.95A	10.92A	763.42A
T_3	35.56A	2.79AB	8.67B	604.92A
T_4	37.38A	2.45B	9.58AB	637.00A
C.V. (%) (3)	38.40	15.79	28.52	40.28

(1) Means followed by the same letter in the columns are not different by Tukey test ($p > 0.05$).
(2) Coefficient of variation

Table 4. Mean values of fresh biomass weight (FB) dry matter (DM), number of leaves (NL) and leaf area (LA) in the treatments with lettuce (cv. 'Babá de verão').

Treatments	Growth variables (1)			
	FB	DM	NL	LA
	.... g			.... cm^2 ....
T_0	99.70A	5.70A	24.00A	1801.7A
T_1	93.47AB	5.93A	23.92A	1622.3AB
T_2	77.90BC	4.74AB	21.67AB	1368.3BC
T_3	69.04C	4.96AB	19.42B	1163.2C
T_4	64.88C	4.09B	18.92B	1152.9C
C.V. (%) (2)	23.150	25.69	14.80	20.37

(1) Means followed by the same letter in the columns are not different by Tukey test ($p > 0.05$).
(2) Coefficient of variation

hot, dry months. In colder months, water demand and evaporation is less and therefore the effect of salinity in decrease water availability or toxicity is little decisive. The degree to which the osmotic potential can influence the plant growth is dependent of many factors, especially species, cultivar, development stage, the composition of saline soil and climatic conditions (SHANNON, 1997). Furthermore, Adams (1991) complements that plant tolerance to salinity is influenced by several factors including the growth stage, time and duration of exposure.

Mittova et al. (2002) and Sultana et al. (2002) concluded that 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 crop adaptation to salinity.

The salinity of 3.8 dS m^{-1} obtained by mixing water and reject brine was used in order to expand the volume of water available for agricultural use, and especially to allocate the reject generated in rural communities where have been installed desalination plants. The knowledge about sensitivity of crops to salinity in its development stages is an important tool for rational exploration of water sources in according to their quality. In this study, the nutrition of the plants with desalination reject brine reduced the fresh biomass weight by 30.38% when compared to control, which allowed production without higher significant losses.

CONCLUSIONS

The addition of 50% of brine reject from desalination into the hydroponic nutrient solution allows grow only ‘Verônica’ lettuce with no reduction in fresh biomass;

This lettuce cultivar shows to be more tolerant to salinity for all exposure time with reject brine in the hydroponic nutrition solution, despite the fact that ‘Babá de Verão’ cultivar is more productive;

The adverse effects were more pronounced when it was increased the time of plant exposure or in the late of development stage, demonstrating that the response of lettuce to use of reject brine in nutrition solution depends on the exposure duration and the stage of plant development.

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