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Beet cultivation with saline effluent from fish farming

Welson L. Simões[1], Jony E. Yuri[1], Miguel J. M. Guimarães[2], José E. dos Santos[3] & Emanoel F. J. Araújo[3]

[1] Embrapa Semiárido. Petrolina, PE. E-mail: welson.simoes@embrapa.br (Corresponding author); jony.yuri@embrapa.br
[2] Universidade Federal Rural de Pernambuco/Departamento de Engenharia Agrícola. Recife, PE. E-mail: mjmguimaraes@hotmail.com
[3] Universidade de Pernambuco. Petrolina, PE. E-mail: josezequiel95@gmail.com; emanoelfernando_ja@hotmail.com

Key words:
salinity
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A B S T R A C T
This study aimed to evaluate the distribution of salts along the soil profile, the biometric parameters and the yield of beet cultivars under different leaching fractions using saline effluent from fish farming, under the conditions of the Sub-middle São Francisco Valley. An experiment was conducted at the Caatinga Experimental Field of the Embrapa Semi-Arid, in 2013. The treatments were arranged in split plots composed of four leaching fractions (0, 5, 10 and 15%) in the plots, with saline effluent from fish farming, and three table beet cultivars in the subplots: Scarlet Super, Early Wonder 200 and Fortuna. The analysed parameters were: salt distribution along the soil profile, number of leaves, length and width of leaves and petioles, total and commercial yields. The application of leaching fractions of 10 and 15% promoted better salt distribution along the soil profile. The beet cultivar Fortuna showed the highest commercial yield for a lower leaching fraction.

Palavras-chave:
salinidade
distribuição de sais
fração de lixiviação

Cultivo de beterraba com efluente salino da piscicultura

R E S U M O
Realizou-se este trabalho com o objetivo de avaliar a distribuição de sais no perfil do solo, os parâmetros biométricos e a produtividade de cultivares de beterraba submetidas a diferentes frações de lixiviação com efluente salino da piscicultura nas condições do Submédio do Vale do São Francisco. Foi conduzido um experimento no Campo Experimental Caatinga pertencente à Embrapa Semiárido no ano de 2013. Os tratamentos foram dispostos em parcelas subdivididas compostas por quatro frações de lixiviação: 0; 5; 10 e 15%, de efluente salino da piscicultura e as subparcelas por três cultivares de beterraba de mesa: Scarlet Super, Early Wonder 200 e Fortuna. Foram avaliados os parâmetros: distribuição dos sais no perfil do solo, número de folhas, comprimento e largura das folhas e do talo, produtividade total e comercial. A utilização de frações de lixiviação de 10 e 15% proporcionou uma distribuição melhor dos sais no perfil do solo. A cultivar de beterraba Fortuna foi a que apresentou maior produtividade comercial para uma fração menor de lixiviação.

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Introduction

For promoting multiple use of waters, the agriculture-aquaculture integration can be a sustainable strategy for the utilization of water resources, as in the employment of saline water from fish farm effluent for the production of crops moderately tolerant to salinity, in areas where the availability of good-quality water for irrigation is limited.

Many studies have been developed with vegetable (Castellani et al., 2009) and forage crops (Carvalho Júnior et al., 2010; Gurgel et al., 2012) and saline water, in which the correct irrigation management is one of the fundamental parameters for the sustainability of the cultivation, since the increase in salt contents in the soil solution can reduce its osmotic potential and decrease water availability, intensifying the toxicity of certain ions to plants (Silva, 2014).

In this context, the beet crop (*Beta vulgaris* L.) presents itself as an alternative for the production under saline conditions, because it is considered as one of the salt-tolerant vegetable crops (Dias & Blanco, 2010; Silva et al., 2013b). In addition, it stands out for the nutritional quality, especially due to the presence of sugars and betalains, which are important substances in the diet for having nutraceutical properties (Marques et al., 2010; Zabotti & Genena, 2013).

Given the above, this study aimed to evaluate the distribution of salts along the soil profile, the biometric parameters and the yield of beet cultivars subjected to different leaching fractions with saline effluent from fish farming, under the conditions of the Sub-middle São Francisco Valley.

Material and Methods

The experiment was carried out at the Caatinga Experimental Field, which belongs to the Embrapa Semi-arid, in Petrolina-PE, Brazil, in the Sub-middle region of the São Francisco Valley (9° 8′ 8.9′′ S; 40° 18′ 33.6′′ W; 373 m), from April to August 2013. The soil in the experimental area was classified as Red Yellow Argisol (EMBRAPA, 2006) with medium texture, located on a flat relief. The climate in the region is classified as semi-arid, BSwh', with the following mean annual values of the climatological variables: air temperature = 26.5 °C, rainfall = 541.1 mm, relative air humidity = 65.9%, Class-A pan evaporation = 2,500 mm year^{-1} and wind speed = 2.3 m s^{-1}. Rainfalls are irregularly distributed in space and time, concentrating from April to December; the annual insolation is higher than 3,000 h (Azevedo et al., 2006).

During the experiment, the mean relative air humidity was 69.6% and the temperature was around 24.7 °C. The maximum daily evapotranspiration was 6.97 mm, with mean of 5.35 mm. Rainfall events totalized 32.7 mm during the cycle. The electrical conductivity (EC) of the irrigation water, from fish farm effluent, showed stable behavior, with mean of 2.5 dS m^{-1}.

A randomized block design was adopted, with four blocks, in split plots composed of four leaching fractions (LF): 0, 5, 10 and 15% of saline effluent from fish farming, in the plots, and three table beet cultivars in the subplot: Scarlet Super, Early Wonder 200 and Fortuna. Each experimental unit (subplot) consisted of two double rows with length of 1.5 m and width of 1.0 m. The following spacings were adopted: 0.2 between rows, 0.1 m between plants and 0.4 m between double rows, totaling 40 plants m^{-2}.

The experimental area was prepared according to crop needs, with plowing, harrowing and the construction of ridges. Basal fertilization was based on the previously performed soil analysis (Table 1), with the application of 40 kg ha^{-1} of nitrogen, 180 kg ha^{-1} of phosphorus and 30 kg ha^{-1} of potassium. Top-dressing fertilizations were performed at 25 days after planting (DAP), using 20 kg ha^{-1} of nitrogen as urea and 30 kg ha^{-1} of potassium as potassium chloride; at 45 DAP, a top-dressing fertilization was performed using 20 kg ha^{-1} of nitrogen as urea, according to the recommendations for the crop in the state of Pernambuco (Cavalcanti, 2008).

The beet cultivars were sown in polystyrene trays containing 200 cells, which were filled with the commercial substrate Plantmax®. The seedlings were grown in a greenhouse and, after 25 days, were transplanted to the field. Among the cultural practices during the crop cycle, manual weedings and preventive sprayings for phytosanitary control were performed.

Irrigations were daily performed using a surface drip system, consisting of a drip tube with emitters with flow rate of 1.6 L h^{-1}, spaced by 0.3 m. In order to minimize problems with emitter clogging, a disc filter (mesh: 120) was used. The irrigation system was supplied by water from fish farm tanks with capacity for 5 m^3, containing black tilapias at a population density of 40 fish m^{-3}. In the management of the tanks, 50% of the water was daily changed and made available for the irrigation management. The chemical characteristics of the irrigation water from fish farming were determined in weekly evaluations during the experiment, and the mean values are shown in Table 2.

The water depths applied through irrigation were calculated based on the crop evapotranspiration (ETc) measured

Table 1. Chemical and physical characteristics of the soil in the experimental area

Layer (cm)	EC dS m^{-1}	pH	OM g kg^{-1}	P mg dm^{-3}	K	Na	Ca	Mg	Al	H + Al	SB	CEC	V
					cmol$_c$ dm^{-3}								%
0-10	1.64	5.5	7.7	15.65	0.65	0.80	2.8	1.50	0.00	2.1	5.8	7.8	73.4
10-20	1.99	5.7	5.7	14.25	0.55	0.65	1.9	1.30	0.00	2.7	4.4	7.1	61.8
20-40	2.91	7.4	6.3	3.60	2.05	1.50	1.8	1.40	0.00	3.7	6.8	10.4	64.7

Layer (cm)	Density (kg dm^{-3})		Total porosity (%)	Granulometry (g kg^{-1})		
	Bulk	Particle		Sand	Silt	Clay
0-10	1.46	2.59	43.86	729.4	182.9	87.7
10-20	1.46	2.51	41.74	789.8	116.9	93.3
20-40	1.37	2.52	45.58	613.2	178.1	208.7

EC – Electrical conductivity in the saturation extract; OM – Organic matter; P – Available phosphorus extracted with Mehlich; Ca – Exchangeable calcium; Mg – Exchangeable magnesium; Na – Exchangeable sodium; K – Exchangeable potassium; Al – Exchangeable aluminum; H + Al – Potential acidity; SB – Sum of bases; CEC – Cation exchange capacity at pH 7.0; V – Base saturation

Table 2. Chemical characteristics of the irrigation water from fish farming*

Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Cl^{-}	pH	EC 25 °C	Hardness $CaCO_3$	SAR
mmolc L^{-1}						dS m^{-1}	mg L^{-1}	(mmol L^{-1})$^{-1/2}$
12.6	7.7	7.2	0.34	35.2	8.19	2.5	50.75	2.26

*Mean values; EC – Electrical conductivity; Ca - Calcium; Mg - Magnesium; Na - Sodium; K - Potassium; Cl^{-} - Chloride; SAR – Sodium adsorption ratio

between irrigations, according to the tested leaching fractions. Reference evapotranspiration (ETo) was estimated through the FAO-56 Penman-Monteith model (Allen et al., 1998), based on meteorological data collected in an automatic weather station located beside the experimental area. The crop coefficient (Kc) values described by Silva et al. (2014) for beet under saline stress were used.

Harvest was performed at 85 days after transplantation, when the following variables were measured: number of leaves, mean leaf length and width, length and diameter of the leaf petiole and total and commercial yield.

Immediately after harvest, soil samples were collected for the determination of EC at the depths of 0, 0.10, 0.20, 0.30 and 0.40 m, and distances of 0, 0.15, 0.30 and 0.45 m from the center of the ridges outwards. EC was measured through the saturation paste extract of each sample. The Kriging method was used to make the EC distribution maps, in the program Surfer®.

The obtained data were subjected to analysis of variance (ANOVA) using the program Sisvar 5.0. For the comparison between leaching fractions, first- and second-order regression models were evaluated, when significant, at 0.01 or 0.05 probability levels. Tukey test at 0.05 probability level was adopted for the comparison of beet cultivars.

Results and Discussion

Irregular EC distribution along the soil profile can be observed for the treatment with LF of 0% (Figure 1). The salinity level in the layer of 0-0.20 m, in which most of the root system is found (Draycott, 2006), was higher than 3 dS m^{-1}, reaching values above 5 dS m^{-1}.

The increase in LF caused lower EC values in the studied soil profile, promoting better distribution of salts (Figure 1D), thus proving to be an alternative to control the gradual increment of salts in the zone of distribution of the root system (Sharma & Rao, 1998; Ayers & Westcot, 1999).

The highest salt concentrations were observed in the layer of 0-0.1 m and in the center of the ridges. These results agree with those reported by Ferreira et al. (2006), who evaluated the effects of leaching on a salinized soil cultivated with beet and observed higher EC values in the superficial soil layers. The accumulation of salts in the center of the ridges was also expected, due to the irrigation system used in the experiment, which promotes higher salt concentration in this area, corresponding to the edges of the wet bulbs, and the evaporation losses (Hanson & May, 2011).

In addition, the application of leaching fractions of 0, 5 and 10% (Figure 1) promoted poor EC distribution along the soil profile, compared with the treatment with leaching of 15%, since, for this fraction, soil EC was maintained around 3 dS m^{-1} in approximately 70% of the studied profile, with some points of higher values in the central region of the profile, as predicted by Hanson & May (2011).

Irrigation management using leaching fractions is recommended by many authors for the use of waters with high salt contents. Carvalho et al. (2011), evaluating irrigation management in soil cultivated with cabbage irrigated with

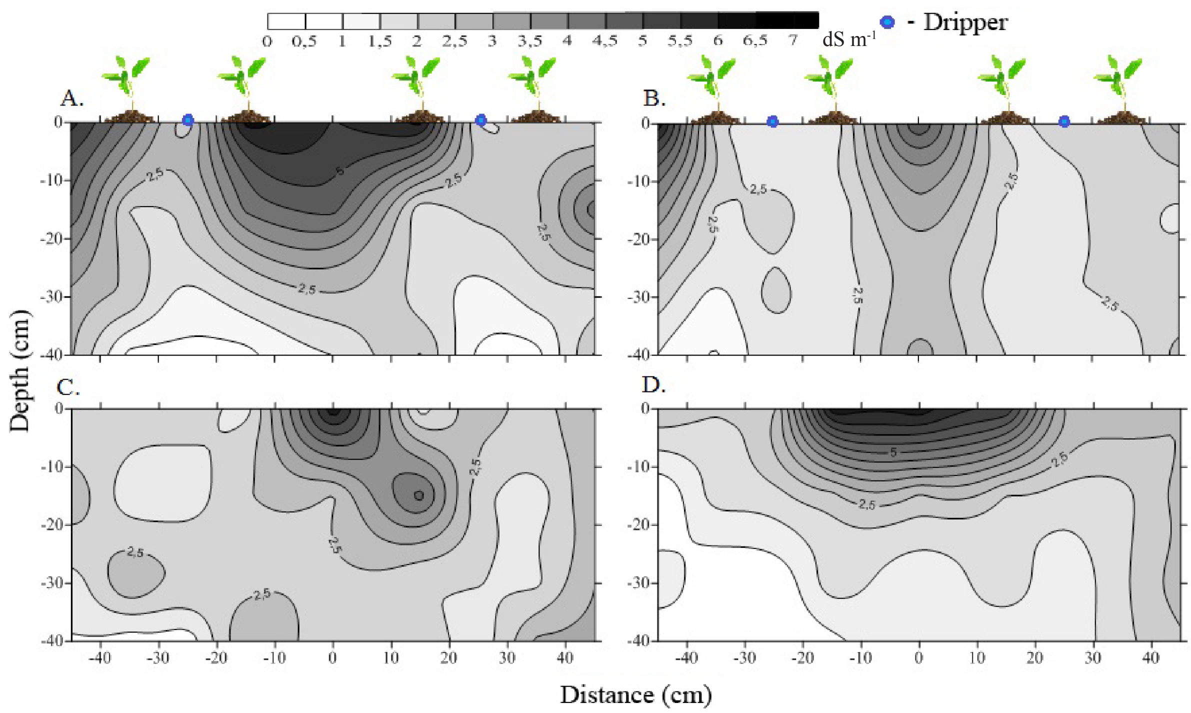

Figure 1. Electrical conductivity of saturation extract (EC) distribution along the profile of a soil cultivated with table beet cultivars subjected to leaching fractions of 0 (A), 5 (B), 10 (C) and 15% (D)

saline water (1.89 dS m^{-1}), observed satisfactory productions for a LF of 20%. Oliveira et al. (2005), evaluating bean cultivation subjected to leaching fractions, also observed that the increase in LF promoted decrease in the mean EC of the soil profile. Assis Júnior et al. (2007), evaluating salinity effects on cowpea yield, observed that the effects of salinity were minimized with the increase in LF.

No significant interactions were observed for the evaluated biometric parameters. LF application did not interfere significantly with the biometric characteristics of the evaluated plants. For the comparison between cultivars, no significant differences were observed for the characteristics of the leaf petiole, which showed mean values of 8.51 and 4.47 cm for length and diameter, respectively. The cultivar Scarlet Super showed the highest number of leaves (12.9); however, the largest leaves were observed in the cultivars Early Wonder 200 and Fortuna (Table 3).

The studied cultivars had different behaviors for total and commercial yields as a function of the tested leaching fractions, which showed significant interaction at 0.01 probability level. There were no significant differences in the yields between the cultivars, for the application of leaching fractions of 0 and 15%. The cultivar Fortuna showed the highest total and commercial yields when subjected to the LF of 5%, 30.12 and 29.4 t ha^{-1}, respectively. For the LF of 10%, there was no significant difference in the total yield of the cultivars; however, higher commercial yields were observed for the cultivars Early Wonder 200 and Fortuna (Table 4).

According to Figure 2, the yield data were represented by linear and quadratic regression models. The total and commercial yields of the cultivar Scarlet Super fitted best to a linear model, with maximum values of 26.77 and 25.52 t ha^{-1}, respectively (Figure 1A). The cultivars Early Wonder 200 and Fortuna fitted best to quadratic models for the commercial

Table 3. Comparison between beet cultivars with respect to shoot biometric variables: number of leaves, length and width of the largest leaf and length and diameter of leaf petiole

Cultivar	NL	Leaf		Petiole	
		L_L	L_W	P_L	P_D
Scarlet Super	12.9 a	12.68 b	6.50 b	7.25 b	4.16 a
Early Wonder 200	10.1 b	14.50 a	8.8 a	8.93 a	4.70 a
Fortuna	9.8 b	14.70 a	8.16 a	9.35 a	4.55 a

Means followed by equal letters in the column do not differ by Tukey test at 0.05 probability level; NL – Number of leaves; L_L – Leaf length; L_W – Leaf width; P_L – Petiole length; P_D – Petiole diameter

Table 4. Total and commercial yields of beet cultivars irrigated with saline water from fish farming, subjected to different leaching fractions

Cultivar	Leaching fraction - %			
	0	5	10	15
	Total yield (t ha^{-1})			
Scarlet Super	17.87 a	19.00 b	22.85 a	26.77 a
Early Wonder 200	20.81 a	24.09 ab	28.82 a	23.44 a
Fortuna	22.63 a	30.12 a	28.53 a	21.94 a
	Commercial yield (t ha^{-1})			
Scarlet Super	14.41 a	11.93 c	19.33 b	25.52 a
Early Wonder 200	17.77 a	21.14 b	27.33 a	21.72 a
Fortuna	17.33 a	29.40 a	28.18 a	20.61 a

Means followed by equal letters in the column do not differ by Tukey test at 0.05 probability level

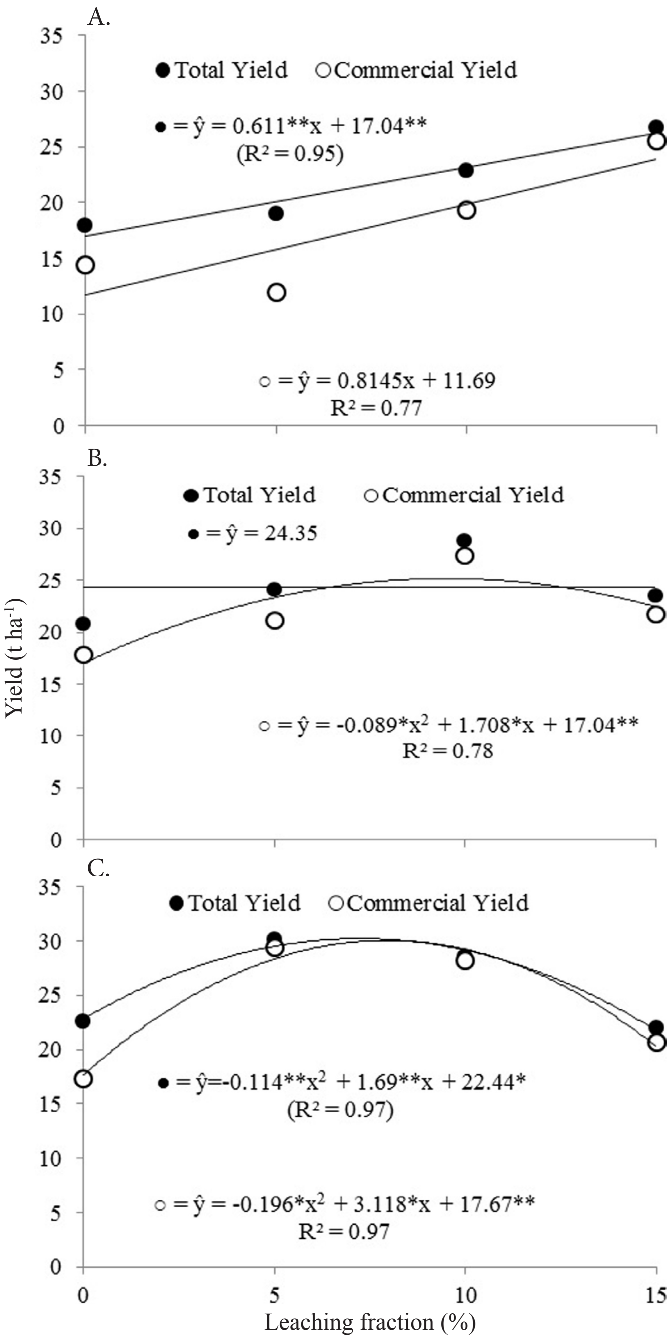

Figure 2. Total and commercial yields of beet cultivars irrigated with saline water from fish farming, subjected to different leaching fractions: Scarlet Super (A), Early Wonder 200 (B) and Fortuna (C)

yield. From these behaviors, it was possible to find the point of maximum commercial yield as a function of the leaching fraction using the derivative of the equation. The maximum commercial yield of the cultivar Fortuna (30.07 t ha^{-1}) was obtained with a LF of 7.9%, followed by Early Wonder 200 (25.23 t ha^{-1}) with a LF of 9.6%.

These results are consistent with those reported by many authors (Assis Júnior et al., 2007; Oliveira et al., 2005; Santos et al., 2012), who evaluated the effects of the application of saline water with leaching fractions, in various crops and in different environments, and observed significant increases in crop yield with the increment in the leaching fractions.

The values of commercial yield corroborate those reported by Resende & Cordeiro (2007), who evaluated the yield of beet plants irrigated with water of different salinity levels and observed commercial yields of about 29 t ha^{-1} when irrigated with salinity of 4 dS m^{-1}, and Silva et al. (2013a), who evaluated the production of beet irrigated with saline water and observed significant reductions in crop yield with the increase in the salinity levels.

Conclusions

1. The use of leaching fractions of 10 and 15% promoted better distribution of salts along the soil profile.

2. Among the studied cultivars, Fortuna showed the highest commercial yield for a lower leaching fraction.

Literature Cited

Allen R. G.; Pereira L. S.; Raes D.; Smith M. Crop evapotranspiration guidelines for computing crop water requirements. Rome: FAO, 1998. 300p. Irrigation and Drainage Paper 56

Assis Júnior, J. O.; Lacerda, C. F. de; Silva, C. F.; Silva, F. L. B.; Bezerra, M. A.; Gheyi, H. R. Produtividade do feijão-de-corda e acúmulo de sais no solo em função da fração de lixiviação e da salinidade da água de Irrigação. Engenharia Agrícola, v.27, p.702-713, 2007. http://dx.doi.org/10.1590/S0100-69162007000400013

Ayers, R. S.; Westcot, D. W. A qualidade da água na agricultura. Campina Grande: UFPB, 1999. 153p.

Azevedo, P. V. de; Sousa I. F.; Silva, B. B. da; Silva V. de P. R. da. Water-use efficiency of dwarf-green coconut (*Cocos nucifera* L.) orchards in Northeast Brazil. Agricultural Water Management, v.84, p.259-264, 2006. http://dx.doi.org/10.1016/j.agwat.2006.03.001

Carvalho, J. F.; Montenegro, A. A. A.; Soares, T. M.; Silva, E. F. F.; Montenegro, S. M. G. L. Produtividade do repolho utilizando cobertura morta e diferentes intervalos de irrigação com água moderadamente salina. Revista Brasileira de Engenharia Agrícola e Ambiental, v.15, p.256-263, 2011. http://dx.doi.org/10.1590/S1415-43662011000300006

Carvalho Júnior, S. B. de; Furtado, D. A.; Silva, V. R. da; Dantas, R. T.; Lima, I. S. P.; Lima, V. L. A. de. Produção e avaliação bromatológica de espécies forrageiras irrigadas com água salina. Revista Brasileira de Engenharia Agrícola e Ambiental, v.14, p.1045-1051, 2010. http://dx.doi.org/10.1590/S1415-43662010001000004

Castellani, D.; Camargo, A. F. M.; Abimorad, E. G. Aquaponia: Aproveitamento do efluente do berçário secundário do Camarão-da-Amazônia (*Macrobrachium amazonicum*) para produção de alface (*Lactuca sativa*) e agrião (R*orippa nasturtium aquaticum*) hidropônicos. Bioikos, v.23, p.67-75, 2009.

Cavalcanti, F. J. de A. Recomendações de adubação para o estado de Pernambuco. 2ª Apr. 3.ed., Recife: IPA, 2008. 212p.

Dias, N.da S.; Blanco, F. F. Efeitos dos sais no solo e na planta. In: Gheyi, H. R.; Dias, N. da S.; Lacerda, C. F. de (ed.). Manejo da salinidade na agricultura: Estudo básico e aplicados. Fortaleza: INCTSal, 2010. p.129-140.

Draycott, A. P. Sugar beet: World agriculture series. Oxford: Blackwell Publishing. 2006. 465p. http://dx.doi.org/10.1002/9780470751114

EMBRAPA – Empresa Brasileira de Pesquisa Agropecuária. Centro Nacional de Pesquisa de Solos. Sistema brasileiro de classificação de solos. 2.ed. Rio de Janeiro: EMBRAPA, 2006. 306p.

Ferreira, P. A.; Moura, R. F.; Santos, D. B.; Fontes, P. C. R.; Melo, R. F. Efeitos da lixiviação e salinidade da água sobre um solo salinizado cultivado com beterraba. Revista Brasileira de Engenharia Agrícola e Ambiental, v.10, p.570-578, 2006. http://dx.doi.org/10.1590/S1415-43662006000300006

Gurgel, G. C. S.; Santos, W. O.; Bezerra, F. G.; Barreto, H. B. F.; Lima, C. B. Produção de milho verde cultivado irrigado por gotejamento com água do efluente de aquicultura. Enciclopédia Biosfera, v.8, p.771-777, 2012.

Hanson, B.; May, D. Drip irrigation salinity management for row crops. Richmond: University of California. 2011. 13p.

Marques, L. F.; Medeiros, D. C.; Coutinho, O. L.; Marques, L. F.; Medeiros, C. B.; Vale, L. S. Produção e qualidade da beterraba em função da adubação com esterco bovino. Revista Brasileira de Agroecologia, v.5, p.24-31, 2010.

Oliveira, F. G.; Ferreira, P. A.; Santos, D. B.; Garcia, G. O. Índice diário de estresse hídrico do feijoeiro irrigado com água salina. Revista Brasileira de Engenharia Agrícola e Ambiental, v.9 (sup), p.6-10, 2005.

Resende, G. M. de; Cordeiro, G. G. Uso da água salina e condicionador de solo na produtividade de beterraba e cenoura no semi-árido do Submédio São Francisco. Petrolina: Embrapa Semiárido. 2007. 4p. Comunicado Técnico, 128.

Santos, D. B. dos; Ferreira, P. A.; Oliveira, F. G.; Batista, R. O.; Costa, A. C.; Cano, M. A. O. Produção e parâmetros fisiológicos do amendoim em função do estresse salino. Idesia, v.30, p.69-74. 2012. http://dx.doi.org/10.4067/S0718-34292012000200009

Sharma, D. P.; Rao, K. V. G. K. Strategy for long term use of saline drainage water for irrigation in semi-arid regions. Soil & Tillage Research, v.48, p.287-295, 1998. http://dx.doi.org/10.1016/S0167-1987(98)00135-4

Silva, A. O. A fertirrigação e o processo de salinização de solos em ambiente protegido. Nativa, v.2, p.180-186, 2014. http://dx.doi.org/10.14583/2318-7670.v02n03a10

Silva, A. O.; Klar, A. E.; Silva, E. F. F. Produção da cultura da beterraba irrigada com água salina. Engenharia na Agricultura, v.21 p.271-279, 2013a. http://dx.doi.org/10.13083/1414-3984.v21n03a06

Silva, A. O.; Klar, A. E.; Silva, E. F. F.; Cunha, A. R. Evapotranspiração e coeficiente de cultivo para a beterraba sob estresse salino em ambiente protegido. Irriga, v.19, p.375-389, 2014. http://dx.doi.org/10.15809/irriga.2014v19n3p375

Silva, A. O.; Klar, A. E.; Silva, E. F. F.; Tanaka, A. A. Silva Júnior, J. F. Relações hídricas em cultivares de beterraba em diferentes níveis de salinidade do solo. Revista Brasileira de Engenharia Agrícola e Ambiental, v.17, p.1143-1151, 2013b. http://dx.doi.org/10.1590/S1415-43662013001100003

Zabotti, C.; Genena, A. K. Avaliação do potencial antioxidante do extrato obtido a partir da beterraba vermelha (*Beta vulgaris* L.) por meio do uso da água como solvente de extração. Cultivando o Saber, v.6, p.195-200, 2013.