ISSN 2316-6886
WRIM
Water Resources and Irrigation Management

Water Resources and Irrigation Management
Universidade Federal do Recôncavo da Bahia, Cruz das Almas, BA
Instituto Federal Baiano, Salvador, BA
v.5, n.1, p.9-14, Jan.-Abr., 2016

Productivity of lettuce under proportions of bovine manure and levels of irrigation water salinity

Francisco José Carvalho Moreira[1], Karla da Fonseca Silva[2], Maria Cristina Barbosa da Silva[2], Beatriz de Abreu Araújo[2], Lívia Sales de Sousa Lima[3], Antonio Evami Cavalcante Sousa[4]

[1] Agronomist, Master in Agronomy/Crop Science. Professor shaft of Natural Resources - IFCE – *Campus* Sobral, Ceará, Brazil; franzecm@gmail.com / franze.moreira@ifce.edu.br
[2] Graduate students in Irrigation and Drainage, Scholarship Program PIBIC-IFCE; CNPq – *Campus* Sobral, Ceará, Brazil; karla236fonseca@hotmail.com; bia10_pjc@hotmail.com
[3] Technologist in Irrigation and Drainage, Specialization in Environmental Management – IFCE – *Campus* Sobral, Ceará, Brazil; liviaejose@yahoo.com.br
[4] Technologist in Water Resources, PhD in Agricultural Engineering; IFGOIANO – *Campus* Rio Verde, Goiás, Brazil; evami.sousa@gmail.com

Abstract: This study aimed to evaluate the effect of irrigation with different levels of water salinity and different levels of bovine manure on the growth and yield of lettuce. The experiment was conducted in randomized blocks in a 5 x 4 factorial design with three replicates and one plant/pot, characterizing the experimental unit. Four levels of salinity (S_1 = 0.27; S_2 = 1.5; S_3 = 3.0; S_4 = 4.5 dS m^{-1}) were used and water from the supply system was adjusted by the addition of NaCl for irrigation, with five levels of bovine manure in the substrate with sand at five proportions (Sm_1 = 0:1; Sm_2 = 1:3; Sm_3 = 1:1; Sm_4 = 3:1 and Sm_5 = 1:0). The variables evaluated were: number of leaves, plant diameter, root length, fresh weight of shoots and roots and dry weight of shoots and roots at 35 days after transplanting. All variables were affected by the studied factors, with isolated effect of salinity levels and manure levels, but without significance in the interaction (S x Sm). The results showed that the development of lettuce was negatively affected by salinity above 3.0 dS m^{-1} and positively affected by increasing proportions of manure levels.

Keywords: *Lactuca sativa*, organic compost, osmotic potential.

Produtividade de alface em proporções de esterco de curral e níveis de salinidade da água de irrigação

Resumo: Objetivou-se avaliar o efeito da irrigação com água de diferentes níveis de salinidade e diferentes teores de esterco bovino no crescimento de alface. O experimento foi conduzido em delineamento inteiramente casualizado, em esquema fatorial 5 x 4, com três repetições e uma planta/vaso, caracterizando a unidade experimental. Quatro níveis de salinidade (S_1 = 0,27; S_2 = 1,5; S_3 = 3,0 e S_4 = 4,5 dS m^{-1}) foram utilizados e a água ajustada proveniente de abastecimento, através da adição de NaCl na água de irrigação e cinco níveis de esterco bovino no substrato com areia nas proporções (Sm_1 = 0:1; Sm_2 = 1:3; Sm_3 = 1:1; Sm_4 = 3:1 and Sm_5 = 1:0). As variáveis avaliadas foram: número de folhas, diâmetro das plantas, comprimento da raiz, massa fresca da parte aérea e raiz e massa seca da parte aérea e raiz aos 35 dias após o transplantio. Todas as variáveis foram afetadas pelos fatores estudados, sendo o efeito isolado dos níveis salinos e dos teores de esterco, sem, contudo, haver significância na interação (S x Sm). Os resultados demostraram que o desenvolvimento de alface foi afetado negativamente pela salinidade da água acima de 3,0 dS m^{-1} e positivamente pelas proporções crescentes de níveis de esterco.

Palavras-chave: *Lactusa sativa*, composto orgânico, potencial osmótico.

Introduction

With growing competition from urban, industrial and agricultural development the availability of fresh water for irrigation is decreasing more and more, making it a challenge to conduct an efficient and rational management using economic and viable alternatives, decreased the risk of soil salinity. Therefore produce with planned and quality.

Lettuce (*Lactuca sativa* L.) is one of the most widespread vegetables currently being cultivated throughout the country, due mainly to large existing genetic divergence among cultivars used by producers (Sousa et al., 2007).

The water quality is an important factor in the productivity of any crop together with the substrate, where they develop through the roots. The production of vegetable seedlings It is one of the most important stages of the productive system (Silva Junior et al., 1995), since it determines the end performance of production plants in plot, both from a nutritional point of view, the time required for the production and, consequently, the possible number of production cycles per annum (Carmello, 1995). Because of this, the exponential growth of production activity and specialized marketing of vegetable seedlings, has been based mainly in search of the best sources and substrate combinations (Giorgetti, 1991).

Salinity stress inhibits plant growth by reducing the osmotic potential of the soil solution, restricting the availability of water and / or excessive accumulation of ions in plant tissues, and may also cause ionic toxicity, nutritional imbalance, or both (Boursier & Läuchli, 1990).

The substrate plays an important role, or to ensure through its solid phase to handling and stability of the root system of the plant, the liquid phase the supply of water and nutrients and the gas phase the oxygen supply and transport carbon dioxide between the roots and the outside air (Lamaire, 1995).

The organic matter acts on several substrates to improve physical and chemical properties. The main benefits provided by its addition substrates are: increased the water retention capacity, of the total porosity and the aeration space and reduction of density, in addition to serving as a source and nutrient reservoir (Bellé, 1990; Carneiro, 1995).

Through quantitative analysis of plant growth technique developed by fitofisiólogos (Magalhães, 1979), it is possible to assess the morphological and physiological conditions of the plant in different cycle intervals to quantify plant development; this technique is therefore valuable tool in the study of plant behavior in salt stress, enabling the assessment of its effects on growth and the degree of tolerance of the plant to salinity.

According to Ayers & Westcot (1999), the lettuce is 'moderately sensitive' to salinity. In Brazil, despite its economic importance (FIBGE, 2001), few research involving salt stress, while the vast majority held in the Southeast (Blanco et al., 1999; Silva et al., 1999; Gervásio et al., 2000) where in addition to different environmental conditions are also different cultivated varieties.

Faced with the lack of research findings related to salt stress in lettuce on different substrates, evaluate the effect of irrigation with different levels of water salinity and different levels of manure bovine on growth and yield of lettuce.

Material and Methods

The experiment was carried out from August 24 to October 8, 2013 in protected environment with agricultural mesh of 50% shade, on the Federal Institute of Education, Science and Technology of Ceará, in the city of Sobral, located in the north of Ceará region under geographic coordinates 3°41'03 "south latitude, 40°20'24" west of Greenwich longitude and altitude of 70 m.

In August 22, 2013, lettuce seeds 'Ruby' were put to germinate in styrofoam tray of 128 cells containing as substrate a mixture of earth and tanned manure bovine at a ratio of 2:1.

The treatments were distributed in randomized blocks in a factorial 4 x 5, four salinity levels (0.27 - control, 1.5, 3.0, 4.5 dS m^{-1}) and five different doses of manure bovine in the substrates referring to (0, 25, 50, 75 and 100%) with three replications each. Water salinity was obtained by adding of sodium chloride to the local water supply. The seedlings were planted in pots made of funnels bottles of mineral water, containing approximately 3.0 kg of each substrate.

In 4 September, 2013, (13 days after transplanting) the seedlings were transplanted to the final vessels, from there, the treatments were applied (according with Figure 1).

Salinity levels was weighed on the analytical balance on Analysis Laboratory Soil and Water for Irrigation, in Sobral, and was added in 5.0 liters of water supply system for each level of sodium chloride, and the irrigations performed daily.

Plants were harvested at 35 days after transplanting, which were measured, the number of leaves (NL),

Figure 1. Stages of the experimental test as a function of the levels of organic material in the substrate and level salinity water. (A) Overview of the test with distribution of vases; (B) overview with vessels filled with the respective substrates (C) detail of the plants grown on the substrate organic matter (D) detail of plants in sand (E) Comparison of the plant growth substrates between organic matter and sand (F)**.** Sobral - CE, IFCE - *Campus* Sobral, 2014.

diameter of the plants (DP), root length (RL), weight of the fresh weight of shoot (WFS) and roots (WFR) plus the weight of the dry mass of shoots (WDMS) and roots (WDMR). The plants collected were taken to the Soil Analysis Laboratory from and Water Irrigation, Technological Axis of Natural Resources, which were weighed and placed in an oven at 75°C. After 24 hours, he removed the material from the oven and proceeded to the realization of the weight of the dry matter in analytical balance, accurate to 0.001 g.

The results were tabulated in Microsoft Excel™ spreadsheet, and the averages subjected to analysis of variance by F test and the averages compared by Tukey test at 5% probability.

Results and Discussion

On Table 1 can observed the data analysis of variance they were submitted to the diameter of the plant data, number of leaves, root length, fresh weight of shoots, fresh weight of roots, dry weight of shoots and dry matter weight of the root of lettuce as a result of the manure bovine levels in substrate and salinity of the irrigation water. It was observed that all variables had significant results ($p \leq 0.01$) for both main effects and for the interaction except for dry weight of root (WDMR), which showed significance only for the isolated salinity ($p \leq 0.01$). Therefore, the vegetative growth variables evaluated were significantly influenced by the increase in salinity levels at different levels of manure bovine in the substrate.

According to the results of analysis of the data noted by the Table 1. The salinity significantly affected all variables, with the highest probability to the diameter of the plant. The substrates were not significant in the dry matter weight of root. In the interaction, substrate by salinity on the weight of fresh root matter was significant at probability levels of 5% and is not significant on the weight of dry matter of root having a greater coefficient of variation.

The Table 2 shows that the plant stem diameter was being affected by saline water according increased, with greater intensity in treatment as salinity levels were increasing the same as the substrate levels were rising. Taiz & Zeiger (2009) point out that the plants with greater stem diameter have higher tendencies to survival, mainly due to increased capacity building and new root growth. The contact of the roots with saline adversely contribute to greater and more rapid absorption of salts depressively cause all the organs of plants including the stem (Araujo et al., 2000). These adverse effects of salinity affected on growth plant development becoming, complex problems by the result of combinations of nutritional factors nature, osmotic and toxic.

The increased substrate volume and increased levels of salinity irrigation water resulted in a marked decrease

Table 1. Summary of variance analysis of plant diameter (DP), number of leaves (NL), root length (RL), fresh weight of shoots (WFS), fresh weight of roots (WFR), dry weight of shoots (WDMS) and dry matter weight of the root (WDMR) of lettuce depending on the levels of manure bovine in the substrate and the salinity of the irrigation water.

Sources of variation	GL	Average square						
		DP	NL	RL	WFS	WFR	WDMS	WDMR
Manure bovine (A)	4	115.024**	49.916**	75.949**	50.151**	0.581**	0.576**	0.017^{ns}
Salinity (B)	3	566.992**	224.844**	332.225**	330.827**	4.447**	1.634**	0.167**
(A x B)	12	48.351**	18.594**	27.000**	29.240**	0.349*	0.197**	0.011^{ns}
Residue	40	6.723	2.716	5.87	8.555	0.139	0.061	0.006
CV (%)	-	57.92	54.94	64.41	100.7	119.29	104.03	133.28

** Significant at 1% probability by F test

* Significant at 5% probability by F test ($0.01 \leq p < 0.05$)

^{ns} – Not significant by F test.

Table 2. Mean values diameter of the plant, number of leaves, root length, the dry weight of shoot and weight of the dry mass of lettuce root depending on the levels of manure bovine in the substrate and irrigation water salinity.

Salinity levels	Levels in manure bovine (%)				
	Zero	25	50	75	100
			Diameter of the plant (mm)		
0.0 (dS m^{-1})	15.66abA	12.66bA	17.00abA	21.66aA	0.00cA
1.5 (dS m^{-1})	2.00bB	3.66bB	1.53bB	11.00aB	0.00bA
3.0 (dS m^{-1})	0.00aB	2.00aB	0.00aB	2.33aC	0.00aA
4.5 (dS m^{-1})	0.00aB	0.00aB	0.00aB	0.00aC	0.00aA
			Number of leaves (leaf.pl^{-1})		
0.0 (dS m^{-1})	10.33 abA	9.00 bA	10.00 abA	13.00aA	0.00cA
1.5 (dS m^{-1})	2.00 bB	3.00 bB	1.66 bB	8.33aB	0.00bA
3.0 (dS m^{-1})	0.00 aB	1.00 aB	0.00 aB	1.66aC	0.00aA
4.5 (dS m^{-1})	0.00 aB	0.00 aB	0.00aB	0.00aC	0.00aA
			Root length (cm)		
0.0 (dS m^{-1})	12.03 aA	11.60 aA	13.43 aA	14.93 aA	0.00bA
1.5 (dS m^{-1})	2.50 bB	4.63 abB	1.70 bB	9.93 aA	0.00bA
3.0 (dS m^{-1})	0.00 aB	1.13 aB	0.00 aB	3.33 aB	0.00 aA
4.5 (dS m^{-1})	0.00 aB	0.00 aB	0.00 aB	0.00 aB	0.00 aA
			Leaves dry mass (g)		
0.0 (dS m^{-1})	0.70 bA	0.58 bA	0.58 bA	1.58 aA	0.00 cA
1.5 (dS m^{-1})	0.20 abAB	0.08 abAB	0.04 abB	0.61 aB	0.00bA
3.0 (dS m^{-1})	0.00 aB	0.02 aB	0.00 aB	0.18 aBC	0.00 aA
4.5 (dS m^{-1})	0.00 aB	0.00 aB	0.00 aB	0.00 aC	0.00 aA
			Dry root mass (g)		
0.0 (dS m^{-1})	0.2660	0.3120	0.2183	0.3027	0.0000
1.5 (dS m^{-1})	0.0133	0.0290	0.0097	0.0757	0.0000
3.0 (dS m^{-1})	0.0000	0.0047	0.0000	0.0087	0.0000
4.5 (dS m^{-1})	0.0000	0.0000	0.0000	0.0000	0.0000

* Lowercase letters: Compare between lines.

* Capital letters: Compare between columns.

of leaf area with greater significant results for plants grown in the substrate at the level of 75% by volume relative to the salinity 1.5 dS m^{-1} being also significant for the other parameters analyzed.

The leaf area reduction, is indicative of stress of root environment and can cause physiological imbalances in plants in general (Lauchi & Epstein, 1984; Ayers & Westcot, 1999). The decrease of leaves expansion results is cause in low photosynthetic efficiency, imbalance in the absorption and translocation of nutrients, damage to the working of the stomata and auxin synthesis for growth.

Studies conducted with other cultures have shown adverse effects of salt stress, causing reduced leaf area with increasing level of salt, as the work done with the cucumber crop (Folegatti & Blanco, 2000) and melon (Medeiros et al., 2007), among other crops of agronomic importance.

Viana et al. (2001), mentions the lettuce be "moderately susceptible" to salinity, suffering the production decreased by 15% per unit increase of electrical conductivity (EC) of the saturation extract above 1.3 dS m^{-1}. Andriolo et al. (2005) studied lettuce 'Vera', observed reduction in growth and fresh mass production plant where salinity levels were above 2.0 and 2.6 dS m^{-1}, respectively.

The reduction in the number of leaves in plants subjected to high salt levels can be attributed to a plant adapted to minimize water loss by transpiration (Taiz & Zeiger, 2009), also occurring according Munns and Tester (2008) in salt conditions, the number of sheets glycophyte plants are reduced due to the lower availability of water, increasing the salt concentration of the solution by toxicity and high salt concentration in the roots environment.

The leaf area of plants grown in saline conditions is one of the most affected variables, and the decrease of leaf area, possibly, is related to decreased availability and water absorption, which affects the division and cell elongation (Tester & Davenport, 2003) so a reduction in the number of leaves in plants under saline irrigation water is important for maintaining high water potential of the plant obtained by reducing transpiration.

Root growth showed significant statistical behavior between the different cultivars in their containers. With the increase in salt levels in the water had a greater reduction of this parameter in conditions of greater volume substrate with manure bovine. While admitting that all variables were statistically lower in the highest volume of manure bovine substrate, it appears that the waters in any salt index are potentially harmful conditions in the levels of higher volume of manure bovine in the substrate.

Due to the limited volume the root growth, the substrates must be able to provide constant supply of water, oxygen and nutrients to plants (Fermino, 2002), thereby ensuring stable development of the plants to environments (Carlile, 1997). Karchi et al., (1992) observed that seedlings with more developed root system more resistant to transplanting than those where the shoot is succulent. According Sturion (1981) the substrate exerts a pronounced influence on the root system mainly attributed to the amount and size of particles and defining the aeration water retention necessary for growth of the roots.

The dry matter production of the aerial part and the roots of the plants were significantly decreased with increasing salt concentration in the water and with the highest level of the manure bovine volume in the substrate. For dry matter accumulation there was no significant difference among cultivars when using water of lower salinity 1.5 dS m^{-1}, averaging 0.025 g $plant^{-1}$, similar to the fresh matter accumulation, dry mass was reduced in all cultivars at the highest level of manure bovine substrates because excess salts acquired by irrigated soil solution from which were modifying metabolic activities of the cells, causing a reduction of cell elongation process, limiting its development.

It was observed that 100% of the substrate manure bovine (Table 2) did not develop lettuce plants. It is considered that it has retained a lot of moisture lethally affecting plant growth. Thus, second (Ferraz et al., 2005), taking into account the distribution of pores is directly related to particle size distribution, it can be inferred that the aforementioned studied substrate has a high water holding capacity (WHC).

It is possible to hypothesize that once with bovine manure substrate high water retention capacity, hence lower ratio of micropores to macropores compared, this has the lowest aeration. This should also be considered to explain the differences in the other parameters. It is worth remembering that the aeration is essential for the respiration of root cells and therefore to the performance of plants in general.

In this context, the smaller development of plants submitted to saline stress should to nutritional imbalance inflict by excess salts, occasioning disturbance in absorption and distribution of nutrients, affecting the metabolic processes of the plant (Munns, 2002).

Conclusions

1. Water salinity negatively affected the development of lettuce 'Ruby';

2. The lowest values of stem diameter, leaf area, root length, dry matter production of roots and shoots of the plants caused by salinity of the water as the salt levels were increasing, they were recorded in the vase of larger volume substrate;

3. The effects of salinity were more aggressive on stem diameter, leaf area and plant biomass between salts levels 3.0 and 4.0 m ds^{-1} and level substrate larger volume of manure bovine.

Acknowledgement

The authors (1, 2, 3 and 4) acknowledge the Federal Institute of Education - IFCE - *Campus* Sobral for the support and encourage research and innovation and Scientific Initiation Program PIBIC/IFCE/CNPq for granting scholarships[(2)].

Literature Cited

Andriolo, J. L.; Luz, G. L.; Witter, M. H.; Godoi, R. S.; Barros, G. T.; Bortolotto, O. C. Growth and yield of lettuce plants under salinity. Horticultura Brasileira. v.23, p.931-934. 2005.

Araújo, D. da C.; Sá, J. R. de; LIMA, E. M. de. Efeito do volume de água e da cobertura morta sobre o crescimento inicial do maracujazeiro- amarelo. Revista Brasileira de Engenharia Agrícola e Ambiental, v.4, p.121-124. 2000.

Ayers, R. S.; Westcot, D. W. A qualidade da água na agricultura. 2ª ed. Campina Grande: UFPB. 1999, 153p.

Bellé, S. "Uso da turfa "Lagoa dos Patos" (Viamão/RS) como substrato hortícola. Porto Alegre: UFRGS, 1990. 142p. Dissertation Master.

Blanco, F. F.; Medeiros, J. F.; Folegatti, M. V. Produção da alface (*Lactuca sativa* L.) em ambiente protegido sob condições salinas. In: Congresso Brasileiro de Engenharia Agrícola, 28, 1999, Pelotas. Anais... Pelotas: Sociedade Brasileira de Engenharia Agrícola, 1999.

Boursier, P.; Lauchli, A. Growth responses and mineral nutrient relations of salt-stressed sorghum. Crop Science. v.30, p.1226-1233, 1990.

Carlile, W. R. The requirements of growing media. Peat in Horticulture. v.2, p. 17-23. 1997.

Carmello, Q. A. de C. Nutrição e adubação de mudas hortícolas. In: MINAMI, Q. (Ed.). Produção de mudas de alta qualidade em horticultura. São Paulo: T. A. Queiroz, p. 7-27. 1995.

Carneiro, J. G. A. Produção e controle de qualidade de mudas florestais. Curitiba: UFPR/ FUPEF, 1995. 451p.

Fermino, M. H. O uso da análise física na avaliação da qualidade de componentes e substratos. In: Furlani AMC. Caracterização, manejo e qualidade de substratos para produção de plantas. Campinas: Instituto Agronômico, p.29-37. 2002.

Ferraz, M. V.; Centurion, J. F.; Beutler, A. N. Caracterização física e química de alguns substratos comerciais. Acta Scientia Agronomica. v.27, p.209-214, 2005.

FIBGE – Fundação Instituto Brasileiro de Geografia e Estatística. Anuário Estatístico do Brasil. Rio de Janeiro: IBGE, 2001. s/p Filgueira, F. A. R. Asteraceaes. In: Novo manual de olericultura. Viçosa: UFV, 2001. p.289-295.

Folegatti, M. V.; Blanco, F. F. Desenvolvimento vegetativo do pepino enxertado irrigado com água salina. Scientia Agrícola, v.57, p.451-457, 2000.

Gervásio, E. S.; Carvalho, J. A.; Santana, M. J. Efeito da salinidade da água de irrigação na produção da alface americana. Revista Brasileira de Engenharia Agrícola e Ambiental, v.4, n.1, p.125-128, 2000.

Giorgetti, J. R. Produção e comercialização de mudas de tomate. In: Encontro Nacional de Produção e Abastecimento de Tomate, 2. 1991, Jaboticabal, São Paulo. *Anais*... Jaboticabal: UNESP, p. 242 - 244. 1991.

Karchi, Z.; Dagan, A.; Cantliffe, D. J. Growth of containerized lettuce transplants supplemented with varying concentrations of nitrogen and phosphorus. Acta Horticulturae, v.319, p.367- 370, 1992.

Lamaire, F. Physical, chemical and biological properties of growing medium. Acta Horticulturae. v.396, p.273-284, 1995.

Lauchi, A.; Epstein, E. Mechanism of salt tolerance for plants. California Agriculture, v.38, n.10, p.12-20. 1984.

Magalhães, A. C. N. Análise quantitativa de crescimento. In: Ferri, M. G., (Ed.) Fisiologia vegetal. São Paulo: EPU / EDUSP, 1979. p.331-350.

Medeiros, J. F. de; Silva, M. C. C.; Sarmento, D. H. A.; Barros, A. D. de. Crescimento do meloeiro cultivado sob diferentes níveis de salinidade, com e sem cobertura do solo. Revista Brasileira de Engenharia Agrícola e Ambiental, v.11, p.248- 255, 2007.

Munns, R. Comparative physiology of salt and water stress. Plant, Cell and Environment, v.25, p 239-250, 2002.

Munns, R.; Tester, M. Mechanisms of salinity tolerance. Annual Review of Plant Biology, v.59, p.651-681, 2008.

Silva Júnior, A. A.; Macedo, S. G.; Stuker, H. Utilização de esterco de peru na produção de mudas de tomateiro. Florianópolis: EPAGRI, 1995. 28 p.

Silva, E. F. F.; Duarte, S. N.; Furlan, R. A.; Ferreira, Y. R. P.; Miranda, J. H. Utilização de águas com diferentes níveis de salinidade na irrigação da alface. Revista de Horticultura Brasileira, v.17, p.327, 1999.

Sousa, C. S.; Bonetti, A. M.; Goulart Filho, L. R.; Machado, J. R. A.; Londe, L. N.; Baffi, M. A.; Ramos, R. G.; Vieira, C. U.; Kerr, W. E. Divergência genética entre genótipos de alface por meio de marcadores AFLP. Bragantia, v.66, p.11-16, 2007.

Sturion, A. A. Produção de mudas de *Mimosa scabrella* Benth. In: Seminário Sobre Atualidades e Perspectivas Florestais, 4., *Bracatinga* uma alternativa para reflorestamento, Curitiba. *Anais*... Curitiba, EMBRAPA URPFCS, 1981. p.39-52.

Taiz, L.; Zeiger, E. Fisiologia vegetal. 4ª ed. Porto Alegre: Artmed, 2009. 848 p.

Tester, M.; Davenport, R. Na^+ tolerance and Na^+ transport in higher plants. Annals of Botany, v.91, p. 503-527, 2003.

Viana, S. B. A.; Fernandes, P. D.; Gheyi, H. R. Germinação e formação de mudas de alface em diferentes níveis de salinidade de água. Revista Brasileira de Engenharia Agrícola e Ambiental. v.5; p.259-264. 2001.