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Efficiency of the floating system in the production of lettuce seedlings using different trays and concentrations of nutrient solution

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ABSTRACT

The quality of seedlings is a determining factor to guarantee the greatest potential crop productivity. The aim of this study was to evaluate the quality of lettuce seedlings grown in floating system, in relation to cell volume and electrical conductivity of the nutrient solution. The experiment was carried out in a completely randomized design, in a 3 x 2 x 4 factorial scheme, with three replicates. Seedlings of three lettuce cultivars (Great Lakes 659, Elba and Creta) were produced in two types of trays (128 and 200 cells) and fertigated with nutrient solutions (four electrical conductivities of 1.0; 1.5; 2.0 and 2.5 dS/m). The variables evaluated were: height, number of leaves, length of the main root, stem diameter, leaf area, total dry mass and shoot dry mass/roots dry mass (MSPA/MSR) ratio. Great Lakes 659 showed more vigorous seedlings for most of the evaluated variables. The three cultivars produced higher quality seedlings when cultivated in trays with 128 cells, with the EC of the nutrient solution ranging from 1.8 to 2.0 dS/m.

Keywords: *Lactuca sativa*, seedlings production, floating system, soilless cultivation, mineral nutrition.

RESUMO

Eficiência do sistema floating na produção de mudas de alface utilizando diferentes bandejas e concentrações de solução nutritiva

A qualidade das mudas é fator determinante para garantir o maior potencial produtivo das culturas. Objetivou-se avaliar a qualidade das mudas de alface produzidas em sistema floating, em função do volume das células e da condutividade elétrica da solução nutritiva. O experimento foi realizado no delineamento inteiramente casualizado, em esquema fatorial 3 x 2 x 4, com três repetições. Foram produzidas mudas de três cultivares de alface (Great Lakes 659, Elba e Creta), em dois tipos de bandejas (128 e 200 células), e fertirrigadas com soluções nutritivas de quatro condutividades elétricas (1,0; 1,5; 2,0 e 2,5 dS/m). As mudas foram avaliadas quanto a altura, número de folhas, comprimento da raiz principal, diâmetro de coleto, área foliar, massa seca total e razão entre massa seca de parte aérea e massa seca de raízes (MSPA/MSR). A cultivar Great Lakes 659 apresentou mudas mais vigorosas para a maioria das variáveis analisadas. As três cultivares produziram mudas mais vigorosas quando cultivadas em bandejas de 128 células, com solução nutritiva com CE variando entre 1,8 e 2,0 dS/m.

Palavras-chave: *Lactuca sativa*, produção de mudas, sistema flutuante, cultivo sem solo, nutrição mineral.

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Lettuce (*Lactuca sativa*) is one of the most consumed and grown green leafy vegetables in Brazil and worldwide, being the most cultivated crop using hydroponic system. It is a good source of fiber, iron, folate and vitamin C. This crop is also a good supply of bioactive compounds, which are beneficial to human health, such as flavonoids, glycosylates, phenolic acids, carotenoids, vitamin B groups, ascorbic acid, tocopherols and sesquiterpene lactones, showing anti-inflammatory, cholesterol reducing as well as

The green leaf lettuce is the most common variety in Brazilian market, followed by the head lettuce (Santos *et al*., 2021). However, the demand for other types of lettuce varieties has been growing, mainly the demand for purple and red-leaf color ones. The green leaf lettuce presents flabelled, tender, consistent and flexible leaves, showing wavy edges, predominance of light green color, with an early cycle and no head formation (Santos *et al*., 2021).

Head lettuce has been a widely consumed variety lately (Sala & Costa, 2012). This is due, mainly, to those presented attributes: crispy texture, flavor and resistance to heat of the sandwich, according to Henz & Suinaga (2009). Lettuce with red or purple leaves catches the consumer's attention due its color as they are also rich in anthocyanins and other plant pigments, such as chlorophyll and carotenoids, showing strong antioxidant properties (Zhang *et al*., 2016; Lopes *et al*., 2017).

Seedling production is one of the most important steps in the vegetable growing, since it depends on the productive performance of the plants in the field and the quality of the product for the market (Ceccherini *et al*., 2018).

In hydroponic system cultivation, the seedlings are produced using an inert substrate or a substrate with low chemical activity, such as coconut fiber (Martinez, 2021). Nevertheless, since this fiber is considered a substrate with low ionic activity and nutrients, the use of this substrate requires appropriate nutritional supply in order to obtain more vigorous seedlings (Oliveira *et al*., 2014; Santos *et al*., 2016).

The quality of the seedlings produced in trays is directly affected by the volume of the substrate of each cell. Nurserymen show preference to use trays with smaller cells, since the smaller is the cell volume, the greater is the number of seedlings and the lower is the need to use substrate, with a consequent reduction of production cost (Godoy & Cardoso, 2005).

Using trays with greater cell volume provides more vigorous seedlings, which shall result in more developed plants and in an early harvest, both in leafy plants (Cardoso *et al*., 2017; Ceccherini *et al*., 2018; Lima *et al*., 2018), and vegetables (Machado *et al*., 2018). Cells with greater volume provided more vigorous seedlings due to a greater capacity to store water and nutrients for the plant, favoring the development of well-distributed and strong roots (Jorge *et al*., 2019).

In the conventional system to produce vegetable seedlings, the nutrient availability is related to the substrate used, and no supplemental fertilizer is added. Thus, nutrient availability was limited to the volume of substrate according to cell size. On the other hand, the floating system, in which the tray with the seedlings floats on the nutrient solution, ascending by capillarity into the substrate, has the advantage of keeping constant availability of water and nutrients for plants (Duyar & Kiliç, 2016). Thus, producing good quality seedlings is possible, even using trays with smaller-volume cells, as long as the nutrient availability for the seedlings is constant.

This system has been used by many authors for producing vegetable seedlings, such as peppers (Oliveira *et al*., 2014), green peppers (Costa *et al*., 2015) and cherry tomatoes (Santos *et al*., 2016). However, studies on lettuce seedling production in this growing system are rare.

Given the above, this study aims to evaluate the quality of lettuce cultivar seedlings in relation to the volume of cells and electrical conductivity of the nutrient solution.

MATERIAL AND METHODS

GeographIcal location and characterization of the experimental area

The experiment was carried out from September to October, 2021, in a greenhouse, at the experimental sector of Departamento de Ciências Agronômicas e Florestais, at Universidade Federal Rural do Semi-Árido (UFERSA), Oeste Campus, in Mossoró-RN (5°11'31"S, 37°20'40"W, 18 m altitude). According to Köppen classification, the climate in the region is ‘BSWh’, hot and dry, with quite irregular rainfall, annual average is 673.9 mm, at 27°C and average relative humidity of 68.9% (Alvares *et al*., 2014).

The seedlings were grown in a greenhouse, 18 m long x 7 m wide, galvanized steel structure, arched-tunnel type, covered with low density, transparent polyethylene film, 150 μm thickness and anti-ultraviolet additive. The side and front walls were covered with 50% shading black screens.

Experimental design and treatments

The experimental design used was randomized block, in a factorial scheme 3 x 2 x 4, with three replicates. Three lettuce cultivars, head lettuce ‘Great Lakes 659’ (Topseed®), crispy ‘Elba’ (Topseed®) and purple ‘Creta’ (Isla®), were used; two types of trays with 128 cells (25.1 cm^3/cell) and 200 cells (12.4 cm^3/cells) and four concentrations of nutrient solution (1.0; 1.5; 2.0 and 2.5 dS/m). Each replicate consisted of four rows in the tray, 32 seedlings in the tray of 128 cells per plot, and 40 seedlings in the trays with 200 cells. Ten seedlings per plot were evaluated in order to verify the quality of the material.

The solutions were prepared according to the recommendation of Furlani *et al*. (1999), with the following fertilizer concentrations (g/1000 L): calcium nitrate, 750; potassium nitrate, 500; monoammonium phosphate, 150; magnesium sulfate, 400. The micronutrients were supplied using the commercial products Dripsol Micro Rexene Equilíbrio: magnesium, 1.1%; boron, 0.85%; copper (Cu-EDTA) 0.5%; iron (Fe-EDTA), 3.4%; manganese (Mn-EDTA), 3.2%; molybdenum, 0.05% and zinc, 4.2%, and Dripsol Micro Ferro Q48, Iron chelate (Q48 EDDHA) 6% and, Dripsol (SQM Vitas®). For both, Dripsol Micro Rexene Equilíbrio and Dripsol Micro Ferro Q48, the authors used the dose of 30 g/1000 L for the standard nutrient solution (100%).

The water used to prepare the nutrient solutions was collected from the supply system of the UFERSA Campus. The physical-chemical properties determined the following characteristics: pH = 7.30, CE = 0.50 dS/m, Ca^{2+} = 3.10, Mg^{2+} = 1.10, K^+ = 0.30, Na^+ = 2.30, Cl^- = 1.80, HCO_3 = 3.00 and CO_3^{2-} = 0.20 ($mmol_c$/L). In order to adjust the pH of the nutrient solutions, from 6.0 to 6.5, 0.1 mol/L of HCl was applied.

Conducting the experiment

The seedlings were sown in expanded polystyrene trays, 67.4 cm long X 34.3 cm wide. The authors used coconut mesocarp fiber as substrate (Golden Mix®). Four seeds per cell were sown, 1.0 cm deep.

Nine days after sowing, thinning was performed, leaving the most vigorous seedling in each cell. From sowing to thinning, two daily irrigations were performed (8 a.m. and 5 p.m.) using a fine sieve watering can, applying enough water to cause drainage in trays.

After thinning, the trays were placed to float in tanks to start the applications of different nutrient solutions. These trays were kept there until the evaluation day. The floating system was built on a 1.0 m-high wooden bench, using pine boards (*Pinus elliottii*), 3.0 m long X 0.30 m wide, forming the side walls and the bottom of the container. Then, we inserted wooden partitions, previously covered with plastic film, 150 μm thickness. The system consisted of four reservoirs (0.70 m long X 0.70 wide X 0.20 m deep). Each reservoir was filled with 70 liters of nutrient solution, leaving 0.05 m of edge border.

The trays were kept in the floating system for 21 days. The nutrient solution was not changed during this period and the evapotranspirated solution was replaced daily, adding enough amount to increase the volume of nutrient solution to the initial level. Electrical conductivity and pH were monitored daily, in order to adjust the treatments applied, using a conductivity meter and a peagameter, respectively.

Evaluated variables

Thirty days after sowing, 10 seedlings per plot were collected, considering the most representative ones. The authors evaluated the following variables: seedling height (ALT), measured with the aid of a millimeter ruler, from the stem up to the apex of the greatest leaf; number of leaves (NF), evaluated by counting the leaves larger than 2.0 cm; stem diameter (DC), evaluated with the use of a digital caliper accurate to 0.01 mm, measuring the middle region of the seedling stem; main root length (CRP), measuring the plant stem up to the lower end of the root, with a graduated ruler, in cm; leaf area (AF), determined by the disc method, using a hole punch with an area of 6.26 mm^2, removing ten leaf discs per plant. The total dry mass (MST) was obtained by weighing the plants (shoot dry mass and root dry mass) on an analytical scale (0.01 g), after having the samples dried in an oven, following the same procedure used to weigh the leaf disks. We determined MSPA/MSR ratio using the values obtained for shoot dry mass (MSPA) and root dry mass (MSR).

Statistical analysis

The assumptions of normality and homogeneity of residual variances were verified by Shapiro-Wilk & Barlett tests, respectively. Then, the obtained data were submitted to the variance analysis by F test. The average relating to cultivars were analyzed using the analysis of average comparison by Tukey's test ($p \leq 0.05$), whereas the effect of the concentrations of the nutrient solution was evaluated using the regression analysis, through polynomial models, when significant. The statistical analyses were performed using the statistical software SISVAR 5.7 (Ferreira, 2019).

RESULTS AND DISCUSSION

The cultivars differed in relation to seedling height, in nutrient solutions with ECs of 1.5; 2.0 and 2.5 dS/m. Considering that Great Lakes 659, was superior in the three nutrient solutions, did not differ from Creta in EC of 1.5 dS/m, and Elba in EC of 2.0 dS/m (Table 1). The greatest height of Great Lakes 659, observed for most ECs, can be attributed to traits related to the cultivar itself, since this cultivar showed the largest leaves, and as the height was measured based on the leaf size, it was clearly possible to highlight the superiority of this cultivar.

Table 1. Heights of lettuce cultivars seedlings grown in different types of trays and electrical conductivities of nutrient solutions. Mossoró, UFERSA, 2022.

Cultivars	Electrical conductivity (dS/m)				Regression equations	R^2
	1.0	1.5	2.0	2.5		
Great Lakes 659	13.27 a	13.83 a	18.16 a	16.26 a	$y = -3.79x^2 + 16.411 – 0.685$	0.837
Elba	14.74 a	10.17 b	12.78 b	15.59 a	$y = 3.43x + 7.435$	0.901
Creta	15.64 a	11.55 ab	14.77 b	12.22 b	$y = -6.64x^2 + 23.468x – 5.114$	0.954

Averages followed by the same letters, in the columns, do not differ significantly by Tukey test, 5%.

The authors also verified that an increase in EC of the nutrient solution showed a quadratic response in Great Lakes 659 and Creta cultivars, in which greater heights of the seedlings occurred in ECs 2.16 and 1.77 dS/m, with maximum values of 17.08 and 15.62 cm, respectively. These values are related to increases of 43.10 and 33.36%, comparing to the heights observed in the lowest EC (1.0 dS/m): heights of 11.93 cm for Great Lakes 659 and 11.71 cm for Creta cultivars. For Elba, we verified a linear response in relation to an increase in EC, showing heights ranging from 10.86 to 16.01 cm, in ECs of 1.0 and 2.5 dS/m, equivalent to an increase of 47.35% (Table 1).

These results showed that an appropriate mineral nutrition favors the elongation of leaves and consequently the growth of seedlings. The evaluation of the seedling quality of leafy vegetables using height has to be very criterious, since smaller seedlings are difficult to be taken out of the tray; on the other hand, very high seedlings are quite sensible and can be damaged during transplanting (Henz & Alcântara, 2009).

In relation to type of tray, other authors also verified influence of cell volume of trays on leaf emission in lettuce seedlings (Monteiro *et al*., 2013; Lima *et. al*., 2017). These authors related this behavior to greater availability of nutrients according to the substrate used. In this study, the nutrients were constantly supplied via nutrient solution, so that, cells with greater volume provided greater aeration, space for root development and a larger root capture area for nutrient uptake.

For number of leaves, the cultivars differed in all the nutrient solutions used, considering Elba superior to the others in ECs of 1.0; 1.5 and 2.0 dS/m, whereas in EC of 2.5 dS/m, the highest values occurred in Great Lakes 659 and Elba (Table 2). The authors also verified (Table 2) that no effect of EC on number of leaves in Great Lakes 659 was noticed, showing an average of 5.48 leaves per seedling. In Elba and Creta quadratic responses according to an increase in EC occurred and higher values occurred in ECs of 1.79 and 1.54 dS/m, being 6.19 and 5.24 leaves per seedling, respectively.

Taking into account that the number of leaves is an important trait during seedling transplanting to the final production phase, this result is important due to the fact that the number of leaves in a seedling shall reflect directly in the number of leaves at harvest time (Ceccherini *et al*., 2018). Considering this, the results showed above confirm the need of nutritional management for obtaining good quality seedlings, based on the difference in nutritional demand among cultivars.

According to what is presented in Table 2, the authors verified that Creta, in addition to naturally having a lower number of leaves, this cultivar showed a significant reduction in leaf emission when irrigated with the nutrient solution with the highest EC; it may be an indicative that this cultivar shall be more sensitive to saline stress caused by high concentration of nutrients.

The reduction on the number of leaves under saline stress conditions is one of the alternatives for plants to keep water uptake, reflected in the loss of transpiration as an alternative to maintain water uptake (Silva *et al*., 2008).

The types of trays affected the number of leaves when the seedlings were fertigated with a nutrient solution of EC of 1.0 dS/m, in which the tray with 128 cells provided greater number of leaves (Table 2). The seedlings produced in a tray with 200 cells showed quadratic response with an increase of EC, being the highest value verified with EC of 1.77 dS/m (5.72 leaves), representing an increase of 17.01% comparing with the value obtained in EC of 1.0 dS/m (4.88 leaves). For the tray with 128 cells, we verified a decreasing linear response in which the number of leaves reduced from 5.86 (1.0 dS/m) to 5.32 (2.5 dS/m), resulting in loss of 9.12% (Table 2).

Table 2. Number of leaves in seedlings of lettuce cultivars grown in different types of trays and electrical conductivities of nutrient solutions. Mossoró, UFERSA, 2022.

Cultivars	Electrical conductivity (dS/m)				Regression equations	R^2
	1.0	1.5	2.0	2.5		
Great Lakes 659	5.21 b	5.48 b	5.56 b	5.67 a	y = ns = 5.48	----
Elba	5.83 a	6.23 a	6.37 a	5.62 a	$y = -1.01x^2 + 3.621x + 2.944$	0.704
Creta	4.92 b	5.31 b	4.95 c	4.36 b	$y = -0.98x^2 + 3.026x + 2.902$	0.965
Trays						
200 cells	4.85 b	5.72 a	5.54 a	5.03 b	$y = -1.38x^2 + 4.902x + 1.364$	0.949
128 cells	5.82 a	5.63 a	5.71 a	5.40 a	$y = -0.356x + 6.213$	0.716

Averages followed by the same letters, in the columns for the same factor, do not differ significantly by Tukey test ($p \leq 0.05$).

The reduction of number of leaves with an increase of EC in the seedlings of the trays with 128 cells (greater cell volume) is due to a greater available space for roots and, consequently, contained the highest amount of salts in the clod, which may have intensified the effect of EC on leaf emission. This response corroborates the results showed below for MSPA/MSR ratio, in which the highest EC of nutrient solution reduced the leaf growth more than the root system (Figure 1B). The opposite occurred with the tray with the smallest cell volume, considering that the increase in EC up to a certain level favored leaf emission.

The cultivars differed in relation to the main root length only when the seedlings were fertigated with a solution with higher EC (2.5 dS/m), in which Great Lakes 659 produced greater roots, whereas Creta produced smaller roots. Evaluating the EC effect on the length of the main root for each cultivar, no significant response was verified for Elba and Creta, verifying values of 3.05 and 3.37 cm, respectively. For Great Lakes 659, increasing linear response was noticed, ranging from 2.91 cm (1.0 dS/m) to 3.66 cm (2.5 dS/m), representing a total gain of 25.91% (Table 3).

Table 3. Length of the main root (mm) in seedlings of lettuce cultivars grown in different types of trays and electrical conductivities of nutrient solutions. Mossoró, UFERSA, 2022.

Cultivars	Electrical conductivity (dS/m)				Regression equations	R^2
	1.0	1.5	2.0	2.5		
Great Lakes 659	3.15 a	2.97 a	3.23 a	3.79 a	$y = 0.502x + 2.404$	0.862
Elba	3.05 a	3.03 a	3.18 a	2.76 b	y = ns = 3.05	----
Creta	3.32 a	3.35 a	3.55 a	3.01 b	y = ns = 3.37	----
Trays						
200 cells	3.12 a	3.65 a	3.71 a	3.45 a	$y = -0.79x^2 + 2.975x + 0.942$	0.995
128 cells	3.01 a	2.95 b	3.08 a	2.97 b	y = ns = 2.95	----

Averages followed by the same letters, in the columns for the same factor, do not differ significantly by Tukey test ($p \leq 0.05$).

These results shall indicate that Great Lakes 659 is a more nutritionally demanding cultivar when compared with the others, also showing that more dilute solutions met necessary nutrient requirement to promote main root growth. Some studies, with other vegetables, showed that in some bell pepper cultivars (Costa *et al*., 2015) and cherry tomato cultivars (Santos *et al*., 2016) different responses were verified according to each studied genotype.

The types of trays did not differ statistically when the seedlings were irrigated with a solution of 1.0 dS/m, whereas in the other EC, the trays with 128 cells provided longer main roots. Evaluating the effect of the nutrient solution on the main root length in relation to the type of tray, a significant response was observed in the tray with 200 cells, occurring a quadratic response in which the highest value in EC of 1.88 dS/m (3.74 cm), provided an increase in

19.69% when compared with the value obtained in EC of 1.0 dS/m (3.13 cm). On the other hand, no significant response was noticed for the tray with 200 cells, obtaining an average length of 2.95 cm (Table 3).

The significant response verified in seedlings produced in trays with higher volume shall be attributed to a greater capacity of water and nutrient storage in the clod, changing the seedling root development. These results confirm the results obtained by Lima *et al*. (2017), who also observed greater root growth in trays with great cell volume.

The stem diameter of the lettuce seedlings differed among the cultivars only when the seedlings were produced in trays of 128 cells. In ECs of 1.0 and 1.5 dS/m, higher values were obtained in Creta and Elba, whereas in ECs of 2.0 and 2.5 dS/m, higher values occurred in Great Lakes 659 and Elba. In relation to the effect of the types of trays on stem diameter, significant response was observed in ECs of 1.0; 1.5 and 2.0 dS/m. In EC of 1.0 dS/m, the trays differed for Elba and Creta, being the highest values obtained in trays with 128 cells for both cultivars. In EC of 1.5 dS/m, the authors noticed significant difference in the tray types, for cultivar Elba, where the tray of 128 cells provides greater value. On the other hand, on EC of 2.0 dS/m, significant response was observed only for Great Lakes 659, being the highest stem diameters verified in trays with 200 cells (Table 4).

Table 4. Stem diameter in seedlings of lettuce cultivars grown in different types of trays and electrical conductivities of nutrient solutions. Mossoró, UFERSA, 2022.

Trays	Cultivars	Electrical conductivity (dS/m)				Regression equations	R^2
		1,0	1,5	2,0	2,5		
				Stem diameter (mm)			
200 cells	Great Lakes 659	4.84 Aa	3.80 Aa	3.52 Aa	3.47 Aa	$y = 1.027x^2 - 4.424x + 7.964$	0.86
	Elba	4.22 Ba	3.50 Ba	3.69 Aa	3.49 Aa	$y = -0.947x + 6.216$	0.94
	Creta	4.40 Ba	3.75 Aa	3.25 Aa	2.86 Aa	$y = 2.463x^2 - 10.865x + 14.675$	0.988
128 cells	Great Lakes 659	4.47 Ac	3.92 Ab	2.93 Bab	3.41 Aab	$y = 0.988x^2 - 4.339x + 8.172$	0.987
	Elba	5.30 Ab	4.85 Aa	3.44 Aa	3.97 Aa	$y = 0.918x^2 - 3.693x + 6.993$	0.998
	Creta	6.20 Aa	4.12 Aab	2.61 Ab	2.97 Ab	$y = -1.026x + 5.632$	0.988
				Leaf area (cm² seedling⁻¹)			
200 cells	Great Lakes 659	46.56 Bab	72.09 Ba	55.54 Ba	30.45 Ba	$y = -54.21x^2 + 205.36x - 84.159$	0.839
	Elba	54.25 Aa	42.24 Bb	54.43 Aa	21.91 Aab	$y = -89.31x^2 + 314.31x - 203.36$	0.996
	Creta	23.24 Ab	32.39 Ab	39.47 Bb	15.74 Bb	$y = 39.66x^2 + 161.20x - 107.89$	0.863
128 cells	Great Lakes 659	70.14 Aa	92.45 Aa	119.17 Aa	87.27 Aa	$y = -50.62x^2 + 164.19x - 65.337$	0.938
	Elba	22.28 Bb	65.26 Ab	69.93 Ab	23.60 Ac	$y = -19.964x + 74.402$	0.931
	Creta	16.50 Ab	36.13 Ac	64.42 Ab	44.39 Ab	$y = -47.84x^2 + 167.35x - 99.949$	0.678
				Total dry mass (g seedling¹)			
200 cells	Great Lakes 659	0.32 Ba	0.38 Aa	0.48 Aa	0.46 Aa	y = -0.12x2 + 0.476x + 0.043	0.885
	Elba	0.28 Bab	0.41 Aa	0.37 Bab	0.32 Bb	y = -0.13x2 + 0.473x - 0.076	0.846
	Creta	0.26 Bb	0.36 Aa	0.33 Bb	0.31 Bb	y = -0.09x2 + 0.329x + 0.105	0.789
128 cells	Great Lakes 659	0.39 Aa	0.38 Aa	0.43 Aa	0.44 Aa	y = -0.08x2 + 0.384x + 0.008	0.922
	Elba	0.32 Ab	0.39 Aa	0.45 Aa	0.39 Aab	y = ns = 0.415	
	Creta	0.35 Aab	0.37 Aa	0.42 Aa	0.36 Ab	y = -0.18x2 + 0.646x - 0.178	0.868

Averages followed by the same letters, uppercase in the columns for the same factor and lowercase in the lines, do not differ significantly by Tukey test ($p \leq 0.05$).

Evaluating the effect of the ECs on the stem diameter of each cultivar and for each type of tray, we verified quadratic responses for Great Lakes 659 (200 and 128 cells), Elba (200 cells) and Creta (128 cells). In these combinations the highest values for stem diameter occurred in the lowest EC and reduced with the increase of EC up to certain levels, according to each combination between cultivar and tray. The lowest values of stem diameter were noticed in ECs of 2.19; 2.16; 2.01 and 2.20 dS/m, for the combinations G-B200, G-B128, E-B200 and C-B128, which showed reductions of 29.32; 29.93; 22.21 and 57.04%, respectively, in comparison with the values obtained with the lowest

EC. Moreover, linear response in Elba (128 cells) and Creta (200 cells) was noticed, and the highest stem diameter was verified, in the smallest EC and reduced linearly until the largest EC, with a total loss of 26.95 and 35.48%, for the combinations E-B128 and C-B200, respectively (Table 4).

In general, the use of a nutrient solution with a higher EC provided less development of the stem diameter for all cultivars and tray types. The reduction of the stem diameter, in plants submitted to higher concentrations of nutrient solution, is related to an increase of EC (Santos *et al*., 2016). This result occurred due, possibly, to a hormonal imbalance led by a saline stress in relation to a high concentration of fertilizers, which affected the synthesis of cytokinins in plants, considering that this hormone act on the stem development (Taiz *et al*., 2017).

The leaf area of the lettuce seedlings differed among the cultivar differently, according to the type of the tray and the nutrient solution used. In the tray with 200 cells, Great Lakes 659 showed highest values for most nutrient solutions, not differing from Elba in ECs of 1.0; 2.0 and 2.5 dS/m, whereas Creta showed the smallest leaf area in most solutions. In the tray with 200 cells, Great Lakes 659 was superior to the others, regardless the EC used (Table 4).

Evaluating the leaf area in relation to the type of tray, Great Lakes 659 showed the greatest leaf area in a tray with 128 cells in all nutrient solutions. For Elba, the tray with 200 cells provided the greatest leaf area in ECs of 1.0; 2.0 and 2.5 dS/m, whereas the tray with 128 cells was superior in the nutrient solution of 1.5 dS/m. In Creta, the tray with 200 cells provided the greatest leaf area in ECs of 1.0 and 1.5 dS/m, being inferior in ECs of 2.0 and 2.5 dS/m (Table 3), though.

In general, the greatest leaf area of the seedlings was obtained in a tray with the greatest cell volume. Probably, this was due to a greater area explored by the root system in these larger volumes, according to the observed by other authors (Silva & Queiroz, 2014; Lima *et al.,* 2017).

In relation to the effect of nutrient solutions on the leaf area, the authors verified that the responses of the cultivars varied according to the type of tray used. For cultivars Great Lakes 659 in the two trays, Elba in the tray with 128 cells and Creta in the two trays, the authors observed quadratic response, being the highest values obtained in ECs of 1.62; 1.89; 1.76; 1.75 and 2.03 dS/m. For these levels, we obtained maximum values of 67.80; 110.33; 73.18; 46.40 and 55.91 cm^2/plant, respectively. Comparing these values in the lowest EC, the authors verified that the highest percentage gains occurred in Elba for the tray with 128 cells (238.16%) and Creta for both trays, being 137.22 and 309.61% in trays with 200 and 128 cells, respectively. For Elba in the tray with 200 cells, a decreasing linear response was noticed, so that the leaf area reduced from 54.44 to 24.49 cm^2/plant, at ECs of 1.0 and 1.5 dS/m, and resulted in a total of approximately 55.00% (Table 4).

These results showed that a great difference occurred for cultivars due to an increase of EC of the nutrient solution. An increase in EC of the nutrient solution can positively affect, the leaf growth, whereas in other species can reduce (Carballo-Méndez *et al*., 2023). These responses are related to the degree of tolerance of the cultivar to salinity, according to the difference of the optimal level of EC among the plants studied in this experiment.

The leaf area is an important variable when studying nutrition and plant growth, since the leaf assumes very important functions in the plant, such as intercepting and absorbing light and carries out photosynthesis, gas exchange and transpiration (Taiz *et al*., 2017). Thus, theoretically, plants with greater leaf area have greater capacity for photoassimilate production. The leaf development is considered of the most important attributes in leafy vegetables, since the leaves consist in the commercial part of these crops.

The total dry mass of the lettuce seedlings differed among the cultivars according to the type of tray and nutrient solution used. In the tray with 200 cells, Great Lakes 659 produced more total dry mass, when compared with other cultivars fertigated with the nutrient solution at 2.5 dS/m. In ECs of 1.0 and 2.0 dS/m, the highest values occurred in Great Lakes 659 and Elba, considering that Elba did not differ from Creta in these ECs. For the tray with 128 cells, Great Lakes 659 and Creta showed higher total dry mass, whereas in the EC of 2.0 dS/m, higher values were found in Great Lakes 659 and Elba. No difference among the cultivars in EC of 1.5 dS/m was noticed, as well as in the tray with 128 cells for ECs of 1.5 and 2.0 dS/m (Table 4).

Evaluating the effect of the trays on the MST, the authors verified that the cultivars responded differently according to the evaluated nutrient solution. Significant difference was notice in Great Lakes 659 only in EC of 1.0 dS/m, in which the tray with 128 cells was superior, except in EC of 1.5 dS/m (Table 4).

In relation to the effect of the nutrient solutions on MST, we observed no significant response of Great Lakes 659 for the tray with 128 cells, obtaining an average MST of 0.415 g/plant. For the other combinations of cultivars and trays, the data were adjusted for the quadratic model. The highest values of MST were obtained in ECs of 2.40; 1.79; 1.98; 1.82 and 1.83 dS/m for the following combinations: cv. Great Lakes 659 in the tray with 200 cells, cv. Elba in the two trays (128 and 200 cells) and cv. Creta also in the two trays (128 and 200 cells), being the maximum values of 0.47; 0.40; 0.43; 0.35 and 0.41 g/plant, respectively. Comparing these values obtained in the lowest EC, the authors noticed gains ranging from 17.90% in cv Creta for the tray with 128 cells, to 50.25% in cv, Great Lakes 659 in the tray with 200 cells (Table 4).

These results showed the importance of using a nutrient solution with an appropriate nutrient concentration, since a low EC limits plant growth due to nutrient deficiency. On the other hand, a high EC inhibits plant growth due to a decreased assimilation and distribution of nutrients in the plant, as a result of reduced osmotic potential in the root environment due to excessive salts which causes saline stress (Carballo-Méndez *et al*., 2023). Particularly in the roots, salinity can cause a decrease in elongation and suberization, which can lead to morphological and anatomical changes and, consequently, reduce transpiration and plant growth. A reduction in dry mass accumulation observed in the highest concentration was verified, probably, due to a high salinity of the nutrient solution, reflecting the effect of reducing the osmotic potential of the soil solution, inhibiting water uptake by the plant and, consequently, reducing its growth (Munns *et al*., 2002).

The shoot dry mass and root dry mass (MSPA/MSR) ratio differed among the cultivars studied in this experiment, being Great Lakes 659 superior to the others (Figure 1A). These results showed that Great Lakes 659 showed greater development of the shoot part compared to the root system, in comparison to the other cultivars. The authors highlight that the seedlings with lower MSPA/MSR ratio, may indicate higher quality due to the more vigorous root system, crucial for the acclimatization of seedlings after transplanting.

MSPA/MSR ratio was influenced by the type of the tray, only in the solution with higher EC (2.5 dS/m), in which the tray with 200 cells was superior. In relation to the effect of the nutrient solutions on MSPA/MSR ratio, we verified a linear response in the seedlings in the tray with 200 cells, leading to an increase from 1.55 (1.0 dS/m) to 2.21 (2.5 dS/m), corresponding to an increase of 42.44%. For the trays with 128 cells, we observed a quadratic response, in which the highest MSPA/MSR ratio occurred in the EC of 1.91 dS/m (2.02), being 48.82% higher in comparison to the value obtained in the lowest EC (1.0 dS/m), in which MSPA/MSR of 1.40 was obtained (Figure 1B).

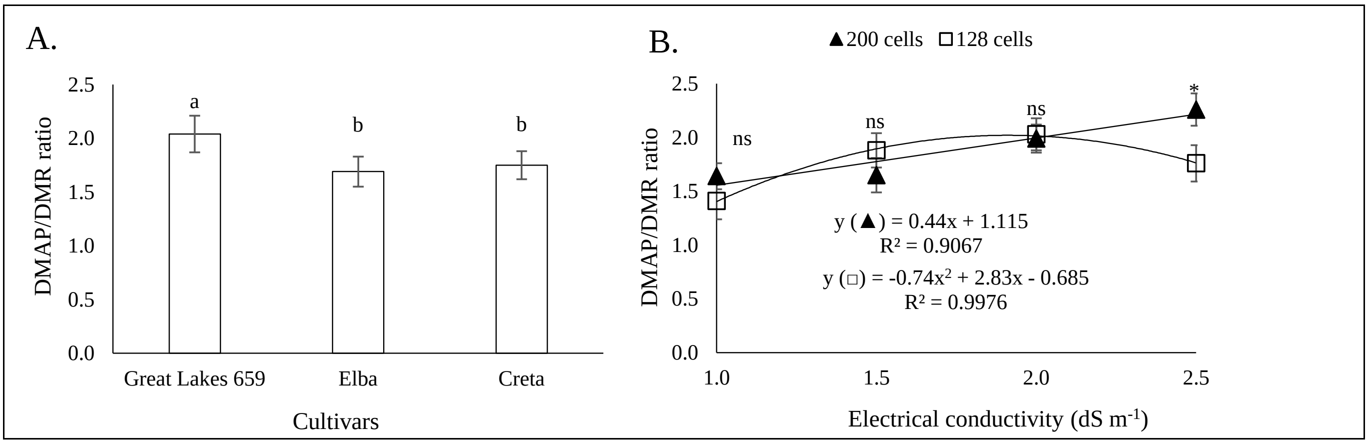

Figure 1. MSPA/MSR ratio in seedlings of lettuce cultivars (A) grown in different types of trays and electrical conductivities of nutrient solutions (B). (Columns with the same letter do not differ by Tukey test (p≤0.05) (A). ns = the trays do not differ by Tukey test (p≤0.05) (B); * = differ by Tukey test (p≤0.05). Mossoró, UFERSA, 2022.

The increase of MSPA/MSR ratio in response to an increase of EC of the nutrient solution showed that the effect of the mineral nutrition was more expressed in the shoot development than in root system. Moreover, we noticed that MSPA/MSR ratio was reduced in the highest EC for plants grown in the tray with 128 cells. This behavior can be due, indirectly, to an increase of the root system provided by the tray with the largest volume cell. An increase in root volume can favor greater exploration and contact of the plant with the substrate soil, favoring the water and nutrient uptake (Machineski *et al*., 2009), giving the plant greater resistance to water stress and nutritional deficiency.

In general, the results obtained in this study allowed to conclude that Great Lakes 659 showed more vigorous seedlings for the most evaluated variables. Lettuce seedlings showing greater quality were obtained using trays with 128 cells for the three studied cultivars. Growing lettuce seedlings under floating system with nutrient solution with electrical conductivity ranging from 1.8 to 2.0 dS/m produced more vigorous seedlings for all the cultivars.

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