horticultura brasileira

Pesquisa / *Research*

CALORI AH; FACTOR TL; LIMA JÚNIOR S; MORAES LAS; BARBOSA PJR; TIVELLI SW; PURQUERIO LFV. 2014. Electrical conductivity and plant spacing on baby leaf table beet and lettuce production. *Horticultura Brasileira* 32: 426-433. DOI - http://dx.doi.org/10.1590/S0102-053620140000400009

Electrical conductivity and plant spacing on baby leaf table beet and lettuce production

Alex H Calori[1]; Thiago L Factor[2]; Sebastião Lima Júnior[2]; Lívia AS Moraes[1]; Paulo JR Barbosa[3]; Sebastião W Tivelli[4]; Luís FV Purquerio[1]

[1]Instituto Agronômico, Centro de Horticultura, C. Postal 28, 13012-970 Campinas-SP; ahcalori@gmail.com; felipe@iac.sp.gov.br; livia_sumam@yahoo.com.br; [2]Polo Regional de Desenvolvimento Tecnológico dos Agronegócios do Nordeste Paulista, C. Postal 58, 13730-970 Mococa-SP; factor@apta.sp.gov.br; slimajr@apta.sp.gov.br; [3]Faculdade de Tecnologia de Mococa, 13730-000 Mococa-SP; paulobiker@hotmail.com; [4] APTA, UPD AE, Av. 3 de maio 900, 18133-445 São Roque-SP; tivelli@apta.sp.gov.br

ABSTRACT

Baby leaf market and production systems are beginning in Brazil. Some of the few hydroponically growers are adapting the nutrient film technique (NFT) system in their farms, however without the necessary knowledge, provided by research, for that. Thus, the aim of this research work was to evaluate the effect of electrical conductivity of nutrient solution and space between plants on table beet and lettuce for baby leaf production in NFT hydroponic system. Two independent experiments were carried out, from December 2011 to March 2012, with table beet and lettuce in a greenhouse of 126 m^2, at Northeast Paulista field station of Paulista Agency of Agribusiness Technology in Mococa, São Paulo state, Brazil. The experimental design was a split plot with randomized blocks replicated four times. The main treatment was composed of different electrical conductivities of the nutrient solution (0.4, 0.8, 1.2 and 1.6 dS/m) and the secondary treatment consisted of different spacings between plants (2.5, 5.0 and 10.0 cm) for both species. Harvest was carried out when leaves of each specie reached length of approximate 15.0 cm. Higher yields of 5.5 and 3.1 kg/m^2 were obtained with 1.6 and 1.4 dS/m for table beet and lettuce, respectively. The space between plants of 2.5 cm promoted greater yields of 4.2 and 4.9 kg/m^2 for table beet and lettuce, respectively.

Keywords: *Beta vulgaris*, *Lactuca sativa*, greenhouse, soilless cultivation, young leaves, hydroponics.

RESUMO

Condutividade elétrica e espaçamento sobre a produção de *baby leaf* de beterraba e alface

O mercado de *baby leaf* é novo no Brasil, bem como os sistemas de produção desta modalidade. Alguns dos poucos produtores hidropônicos existentes estão iniciando a atividade com adaptações no sistema de cultivo, tipo NFT, existente em suas propriedades, porém sem o necessário conhecimento técnico. Assim, objetivou-se com o trabalho avaliar o efeito da condutividade elétrica da solução nutritiva e do espaçamento entre plantas sobre a produção de beterraba e de alface para baby leaf em sistema hidropônico do tipo NFT. Foram realizados dois experimentos independentes, com beterraba e alface, no período de dezembro de 2011 a março de 2012. Os ensaios foram conduzidos em ambiente protegido de 126 m^2, localizado no Polo Nordeste Paulista da Agencia Paulista de Tecnologia dos Agronegócios em Mococa-SP. O delineamento experimental foi de blocos casualizados, em esquema de parcelas subdivididas, com quatro repetições. O tratamento principal foi composto de diferentes condutividades elétricas da solução nutritiva (0,4; 0,8; 1,2 e 1,6 dS/m). O tratamento secundário consistiu de diferentes espaçamentos entre plantas (2,5; 5,0 e 10,0 cm) para ambas as espécies estudadas. A colheita foi realizada quando as maiores folhas, de cada espécie, apresentaram comprimento aproximado de 15,0 cm. Não houve interação estatisticamente significativa entre os tratamentos estudados. Para beterraba e alface as maiores produtividades de 5,5 e 3,1 kg/m^2 foram obtidas com CE's de 1,6 e 1,4 dS/m, respectivamente. O espaçamento entre plantas de 2,5 cm favoreceu a maior produtividade, independente da espécie utilizada, com médias de 4,2 e 4,9 kg/m^2 para beterraba e alface, respectivamente.

Palavras-chave: *Beta vulgaris*, *Lactuca Sativa*, ambiente protegido, cultivo sem solo, folhas jovens, hidroponia.

(Recebido para publicação em 14 de agosto de 2013; aceito em 6 de agosto de 2014)
(*Received on August 14, 2013; accepted on August 6, 2014*)

In Brazil, consumption of vegetables and fruit is still small compared to some countries in Europe and North America. The average consumption in these countries is more than 400.0 grams per inhabitant a day (Faostat, 2009), whereas in Brazil the consumption is of 73.9 grams per inhabitant a day, according to the Family Budget Survey (IBGE, 2008).

Innovations in the horticulture chain, such as mini-vegetables and baby leaf, may help in the increase of vegetable consumption by Brazilian people, including children, who are attracted by products of small size and diverse colorations, thereby assisting in the prevention of diseases and childhood obesity (Purquerio & Melo, 2011).

Baby leaf vegetables are obtained through early harvest of leaves in relation to the period of time they are traditionally harvested for consumption, however these leaves are still young and they are not fully expanded (Purquerio & Melo, 2011).

In European, American and Japanese countries, the baby leaf product has already conquered consumers and has been widely commercialized. In Italy, about 26% of the production of leafy vegetables is designed for baby leaf market (Castoldi *et al*., 2010).

In Brazil, this product is brand-new, and it can be found, mainly, in supermarkets of large consumer centers.

Baby leaf cultivation can be performed in several ways: in soil, inside and outside greenhouses, in trays used for seedling production and in hydroponic cultivation.

In some regions of Europe and the United States, with semi-arid climate, soil cultivation is performed, in open field, using increased mechanization, from planting to harvest, due to the great number of seeds used per hectare.

In Brazil, soil cultivation is not used yet due to lack of machines adapted to sowing and harvesting this product and also to the high production cost.

Of the few baby leaf growers in Brazil, some are beginning their activity adapting the NFT system in their farms. However, without the necessary knowledge provided by a research.

Technical improvements in several aspects of hydroponic system for baby leaf production need to be studied. Among these aspects, the authors highlight the electrical conductivity (EC) of the nutrient solution and the spacing between plants.

In the nutrient solution, high amounts of nutrients can induce osmotic stress, ion toxicity and lack of nutritional balance. In contrast, small amounts of nutrients often lead to nutritional deficiency.

Nationwide, much information on EC on the production of vegetables carried out until the end of the crop cycle in NFT hydroponic system can be found, mainly on lettuce crop. Evaluating different nutrient solutions, Cometti *et al.* (2008) verified higher yield of lettuce 'Vera' at 1.5 dS/m. Helbel Júnior *et al*. (2008) and Andriolo *et al*. (2005) observed higher productivity, for this cultivar, at 1.2 and 2.0 dS/m, respectively.

However, for table beet and lettuce grown as baby leaf, abroad and in Brazil, no information regarding an optimal range of nutrient concentration of the nutrient solution can be found, because these plants are early-harvested (Fallovo *et al*., 2009). In Brazil, the nearest recommendation is that proposed by Furlani *et al*. (1999) for leafy vegetables growing in the seedling phase. The authors recommend the use of nutrient solution at EC from 1.0 to 1.2 dS/m. For baby leaf, the crop cycle and nutritional requirements may be higher than the ones used for the seedlings, though.

The spacing between plants is also an important factor that contributes for the increase of the crop productivity, enabling lower production cost, by more efficient use of solar radiation, water and nutrients. However, when the population per area is increased, each plant starts to compete for resources, such as sunlight, nutrients and water, reaching a point which is called competition point (Choairy & Fernandes, 1983). Nevertheless, for baby leaf production in NFT hydroponic system, information published in Brazil and abroad, regarding to spacing between lines and plants to be adopted was not found. The information verified is only about vegetables grown until the end of the cycle, in which Gualberto *et al*. (1999), Silva *et al.* (2000) and Purquerio *et al.* (2007), for leaves such as lettuce and rocket salad, the authors observed a yield increase with a reduction in spacing.

For baby leaf, the best crop spacing between plants and lines should be smaller due to the reduced size of the plant that is harvested before the maximum development.

Thus, this work aimed to evaluate the effect of electrical conductivity (EC) of the nutrient solution (0.4; 0.8; 1.2 and 1.6 dS/m) and the spacing between plants (2.5; 5.0 and 10.0 cm) on table beet and lettuce production as baby leaf in NFT hydroponic system.

MATERIAL AND METHODS

Two independent experiments, with table beet and lettuce, were carried out in order to evaluate the effect of electrical conductivity (EC) of nutrient solution and spacing between plants.

The tests were carried out in a greenhouse with dimensions of 7x18 m (126 m^2) and 3.0 m height (ceiling height), arch type, made of galvanized steel and covered with plastic (PEBD, anti-UV) thickness of 150 µm. On the sides, shading screen coverage with 30% was used, and gravel stone number two was placed on the floor. The experiment was carried out at Northeast Paulista field station of Paulista Agency of Agribusiness Technology, in Mococa, São Paulo state, Brazil (21°28'S, 47°01'W, 665 m altitude). The regional climate, according to Köppen's classification, is Cwa, humid hot summer and mild dry winter (Camargo *et al*., 2005).

The hydroponic system used was NFT (Nutrient Film Technique) with reuse of the nutrient solution. The structure was composed of four reservoirs, with a capacity of 1,000 L, each one containing, separately, the four nutrient solutions evaluated. Four motor pumps, responsible for pumping the nutrient solution to the growing channels, were linked to the reservoirs. These channels consisted of 5.8 cm polypropylene profiles; 5 cm wide and 6 m long, white color and the trapezoidal shape. Drilling was carried out in the gutters in spacings of 2.5; 5.0 and 10.0 cm, as secondary treatments. The diameter of the holes, for the placement of the plants, was 3 cm.

Forty-eight growing channels were placed on four countertops, which means, twelve channels for each countertop. Each countertop presented dimension of 1x6 m (6 m^2), with slope of 5% in order to allow the return of the nutrient solution, using gravity, to the reservoirs.

In table beet cultivation, sowing

was performed on December 28, 2011, the transplant to the growing channels was done 9 days after sowing (DAS) and harvesting was carried out at 30 DAS. For lettuce, sowing was done on February 23, 2012, transplant to the growing channels at 7 DAS and harvesting at 22 DAS.

For the seedling production, 288-cell polypropylene trays (JT Agro), 57x23 cm, in a volume of 5 mL per cell, were used. The cells were filled with coconut fiber substrate, GoldenMix n.11 (Amafibra). For each species studied, a fixed number of seeds per cell was set, in order to allow the standardization of the number of plants. Four glomeruli for table beet and three seeds for lettuce were placed. After sowing, the trays were placed on the countertops in a greenhouse.

Seedlings were irrigated by sprinkler irrigation system, according to the physiological needs of the different crops. The seedling fertilization was not done, the only nutrients available for plants being those already present in the substrate (68.2; 21.6; 32.2; 234.0; 8.0; 4.9; 0.3; $8.0x10^{-2}$; 0.28; $7.0x10^{-2}$; $3.2x10^{-1}$ mg/L $N-NO_3$, $N-NH_4$, P, K, Ca, Mg, B, Cu, Fe, Mn, Mo and Zn, respectively, EC 1.1 dS/m and pH 6.2). For the two species, when the seedlings started issuing the first true leaf, they were placed in the growing channels.

Collecting meteorological data was carried out, measuring air temperature (°C) and relative humidity (%), using a data logger (Campbell CR10X model). During the test with table beet, the maximum, average and minimum air temperatures were 29, 24 and 19°C, respectively and relative humidity was 95%. For the lettuce crop, the maximum temperature in the greenhouse was 36°C, the average was 26°C and the minimum was 20°C. The relative humidity of the air was 63%.

The experimental design was in randomized blocks, in split plots, with four replications. The main treatment consisted of different electrical conductivity of the nutrient solution (0.4; 0.8; 1.2 and 1.6 dS/m). The secondary treatment consisted of different spacing between plants (2.5; 5.0 and 10.0 cm).

The table beet cultivar (*Beta vulgaris*) used was Tall Top Wonder (Agristar) and the lettuce cutivar (*Lactuca sativa*) used was Vera (Sakata).

In Brazil, the most commonly used nutrient solution for growing several leafy vegetables, up to adult stage, is the one suggested by Furlani *et al.* (1999). This nutrient solution presents the following concentration: 174.0; 24.0; 39.0; 183.0; 142.0; 38.0; 52.0; 0.3; $2.0x10^2$; 2.0; 0.4; $6.0x10^{-2}$; and $6.0x10^{-2}$ mg $N-NO_3$, $N-NH_4$, P, K, Ca, Mg, S, B, Cu, Fe, Mn, Mo and Zn per liter of water, respectively, and EC between 2.0 to 2.2 dS/m.

To grow baby leaf, dilutions and concentrations of two units above and two below the EC of the nutrient solution recommended by Furlani *et al.* (1999) for growing seedlings were done. This nutrient solution presents the following concentration: 87.0; 12.0; 19.5; 91.5; 71.0; 19.0; 26.0; $1.5x10^{-1}$; $1.0x10^2$; 1.0; 0.2; $3.0x10^{-2}$; and $3.0x10^{-2}$ mg $N-NO_3$, $N-NH_4$, P, K, Ca, Mg, S, B, Cu, Fe, Mn, Mo and Zn per liter of water, respectively, and EC between 1.0 to 1.1 dS/m. The values were 40, 80, 120 and 160% in relation to the recommended solution for seedlings and the corresponding EC's were 0.4; 0.8; 1.2 and 1.6 dS/m, respectively.

The pH of the nutrient solution was maintained in the range of 5.5 to 6.5, using 6 N sulfuric acid and sodium hydroxide for correction and, for reading a combo pH and conductivity digital meter, portable (Hanna, Model HL98129) was used.

The corrections of the nutrient concentrations in the nutrient solutions were made daily, after the plants (seedlings) were placed in the hydroponic system, according to the EC monitoring. The EC was restored to its initial value whenever a decrease or an increase of 50.0 hundredths in the value of EC was observed. For this purpose, a stock nutrient solution of the same concentration of the corresponding initial nutrient solution was used.

The flow of nutrient solution was controlled by an electromechanical timer, 15 minutes on and 15 minutes off, from 6 am to 6 pm. Three circulations of nutrient solution were made for 15 minutes in the evening, at 9, 12, and at 3 am. The flow of the nutrient solution through the growing channel was established between 1.5 to 2.0 L per minute as recommended by Furlani *et al.* (1999) for short-cycle plants.

For the harvest, independent on the cultivated species, Purquerio *et al.* (2010) suggest the maximum leaf length of 15.0 cm, measured from the beginning of the petiole to the end of the leaf blade, as the most interesting method to classify a leaf as baby leaf. Thus, the harvest, for both species studied, was performed when the length was close to 15.0 cm.

In the harvest, six plants were collected and the following traits were evaluated: a) plant height (cm); b) number of leaves per plant; c) length of the largest leaf (cm), measured from the beginning to the end of the leaf blade; d) width of the largest leaf (cm), measured from one end to the other of the leaf blade; e) shoot fresh mass of the plants (g/plant); f) shoot dry mass of the plants (g/plant); and g) yield (kg/m²).

The data obtained in the experiments were subjected to the analysis of variance. For the electrical conductivity data, the regression analysis was done, to select the best fit according to the combination of significance and greater coefficient of determination. For the spacing between plants, Tukey test 5% was used, in order to compare the means of the treatments. The statistical software used to analysis of variance was the 'Project R' version 2.15. To draw the regression graphs 'Origin Pro' version 8 software was used.

RESULTS AND DISCUSSION

Experiment with table beet – In the harvest (at 30 DAS) no significant interaction between electrical conductivity and spacing between plants was noticed. However, an isolated effect of treatments on traits evaluated was observed. The electrical conductivity (EC) of the nutrient solution had a significant effect on all traits evaluated, so that with its increase, a linear increase on the traits evaluated was observed (Figures 1 and 2).

The increase in the EC of the nutrient

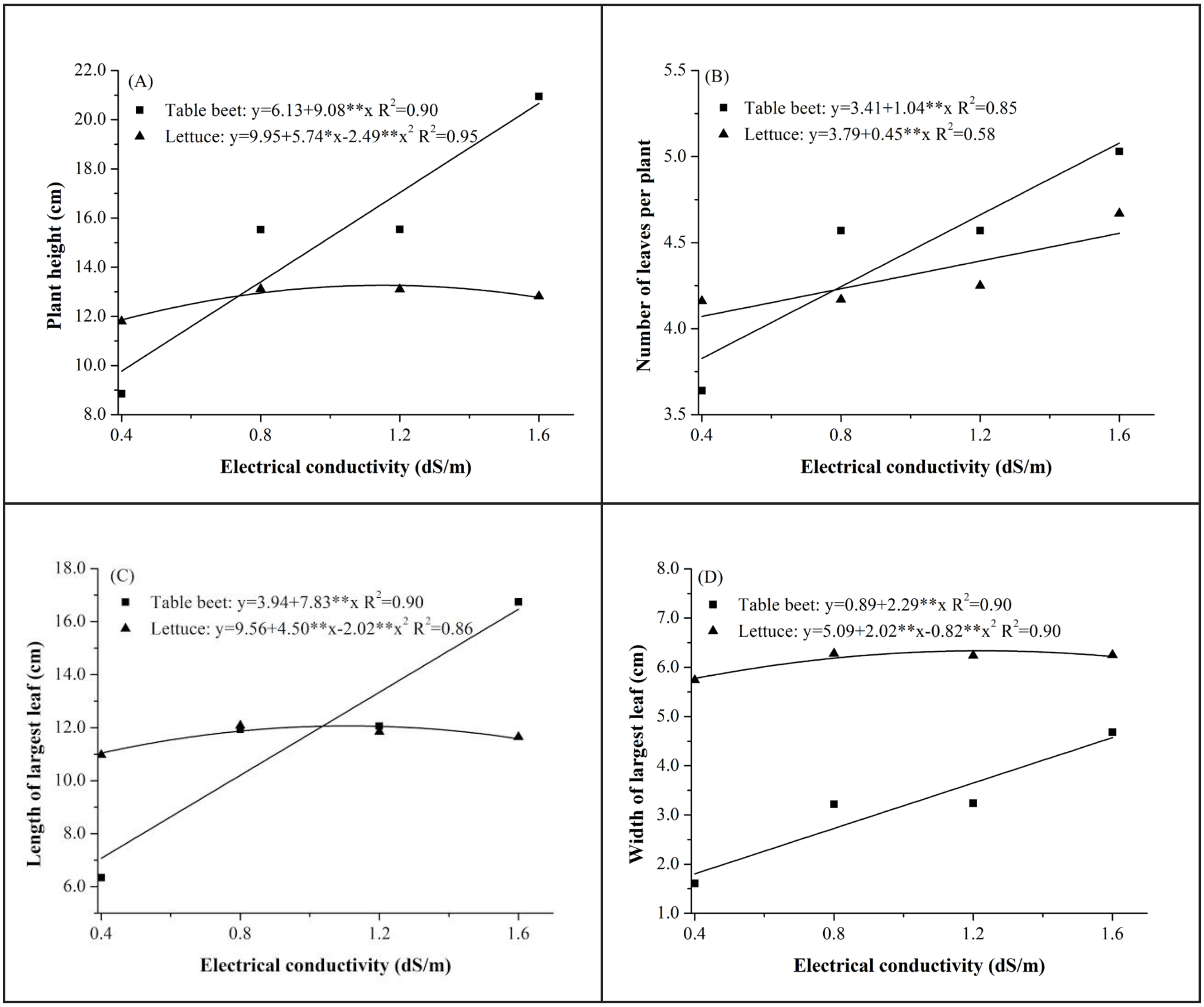

Figure 1. Plant height (A), number of leaves per plant (B), length (C) and width (D) of largest leaf of table beet and lettuce grown for baby leaf in NFT hydroponic system [altura da planta (A), número de folhas por planta (B), comprimento (C) e largura (D) da maior folha de beterraba e alface cultivadas para *baby leaf* em sistema hidropônico NFT]. Mococa, IAC/APTA, 2012.

solution provided a linear increase in plant height up to 1.6 dS/m, and an average of 21.0 cm was observed (Figure 1A). The average observed in this EC, 21.0 cm, was higher than the 15.0 cm recommended by Purquerio *et al.* (2010). Thus, the authors believe that the harvest could be anticipated, for obtaining leaves with height within the suggested value.

Information, on plant height for table beet grown for the purpose of baby leaf, has not been verified in literature. In the usual table beet cultivation, the plant can reach higher height than the maximum height observed in this study, due to the longer growing cycle. In the hydroponic system, Alves *et al*. (2008) and Gondim *et al*. (2011) verified plant height of table beet from 40.0 to 50.0 cm.

For number of leaves per plant, the highest estimated value observed was 5.0 leaves in higher EC of 1.6 dS/m (Figure 1B). For plants grown by the end of the crop cycle, to produce root, Alves *et al*. (2008) and Gondim *et al*. (2011) observed plants with 10.0 to 13.0 leaves. To produce any leafy vegetables, with the purpose of baby leaf, Mou *et al*. (2008) mention that the presence of 4.0 to 5.0 leaves per plant is interesting. Values of 3.8; 4.2 and 4.7 leaves per plant were observed for EC's of 0.4; 0.8 and 1.2 dS/m, respectively, these values being within the range mentioned as interesting.

In the production system in trays, Baqueiro *et al.* (2009) working with different cell volumes, for baby leaf table beet production, also verified 5.0 leaves per plant in a volume of 31 cm^3, at 56 DAS, though.

In relation to the length and width of the largest leaf, highest averages of 16.5 and 4.6 cm, respectively, were also observed in the EC of 1.6 dS/m (Figures 1C and D).

The highest average length of the largest leaf of 16.5 cm was little higher than the value of 15.0 cm, recommended by Purquerio *et al*. (2010) and over the range of 6.0 to 10.0 cm, recommended by Clarkson *et al*. (2005) for the marketing of baby leaves. The authors highlight

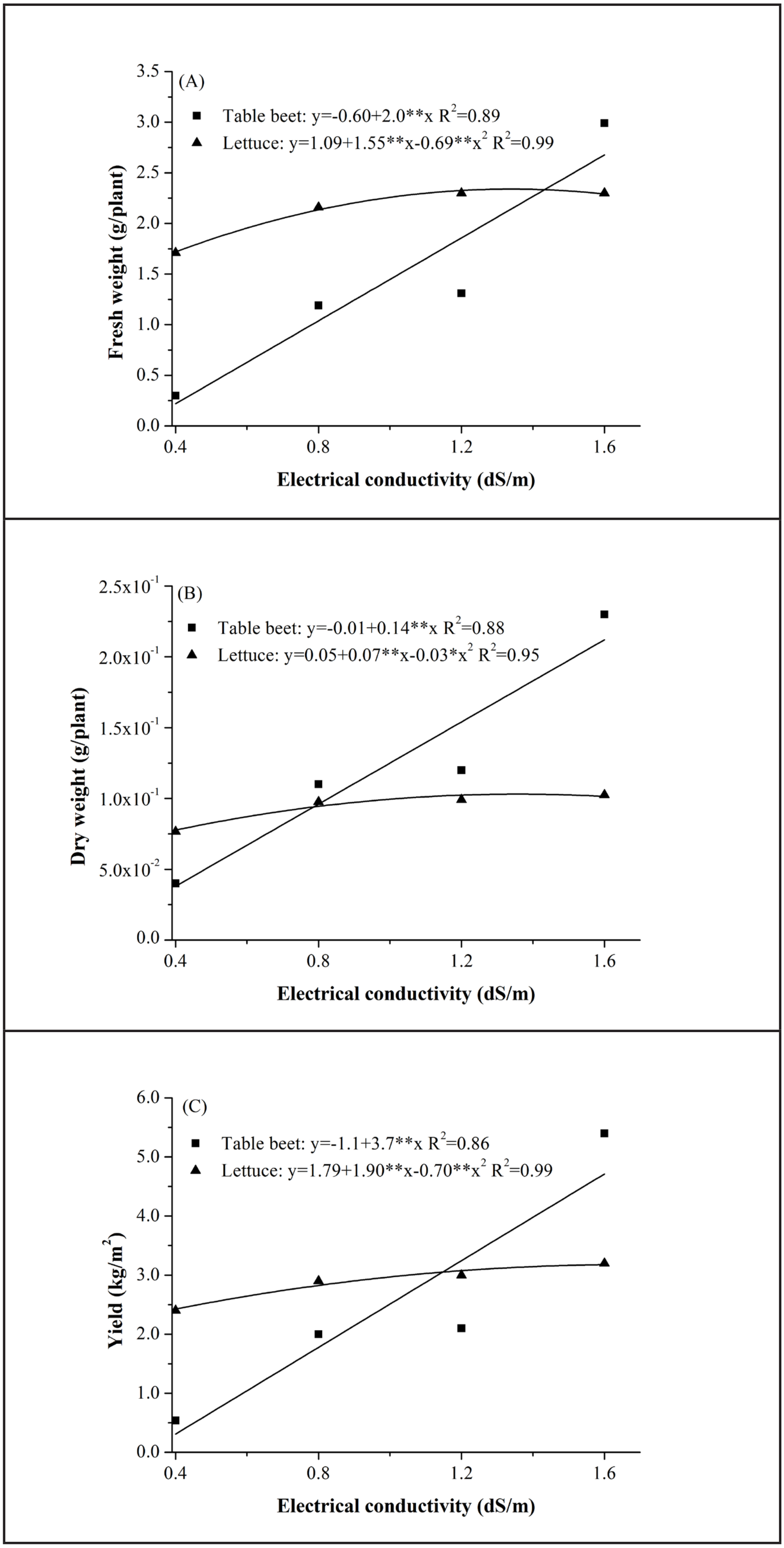

Figure 2. Fresh (A) and dry (B) weight and yield (C) of beet and lettuce grown for baby leaf in NFT hydroponic system [massa de matéria fresca (A) e seca (B) e produtividade (C) de beterraba e alface cultivadas para *baby leaf* em sistema hidropônico NFT]. Mococa, IAC/APTA, 2012.

that the other leaves of the plant showed lower value of length compared to the ones mentioned in this work. Baqueiro *et al.* (2009), growing table beet for baby leaf in tray system, verified the width of the largest leaf of 4.7 cm, value close to the one observed in this study (4.6 cm), with a growing cycle of 56 days, though.

The higher values for fresh and dry matter mass and yield of 2.6 and $2.1x10^{-1}$ g/plant and 5.5 kg/m^2, respectively, were observed in higher EC (1.6 dS/m).

No published articles were found for producing baby leaf table beet, only the research by Baqueiro *et al*. (2009), in which the authors studied the tray production system. In this research, the authors observed averages of 2.1 g/plant and 4.7 kg/m for fresh matter mass and productivity, respectively. These values were lower than the ones observed in this study, possibly, due to the differences in the production system, mainly related to the nutrients and water availability.

With the increase of the nutrient solution concentration, an increase in all evaluated traits was observed, mainly, due to the higher amount of available nutrients for the plant growth. The EC recommended by Furlani *et al.* (1999), from 1.0 to 1.2 dS/m, to grow leafy vegetables in seedling phase, is not enough for growing baby leaf table beet. This fact was evidenced in this study, as the plants grown in the EC's lower than 1.6 dS/m did not show interesting visual aspect to marketing, that means, the plants showed clear visual symptoms of nutritional deficiency. According to Marques *et al*. (2010), table beet is a nutritionally demanding crop, EC's lower than 1.6 dS/m were not enough to supply nutritional deficiencies of the table beet leaves up to 30 DAS.

The spacing between plants, regardless of the EC, had a significant effect on the plant height, width of the largest leaf, fresh and dry matter mass traits and productivity. The number of leaves per plant and length of the largest leaf traits were not affected, the averages observed being 4.0 leaves per plant and 11.7 cm, respectively (Table 1).

The greatest plant height, 16.2 cm, was observed in the widest spacing of 10.0 cm. This value differed statistically

Table 1. Means for plant height (H), number of leaves per plant (NF), length (L) and width (W) of the largest leaf, fresh (FM) and dry (DM) weight and yield of table beet and lettuce grown as baby leaf depending on space between plants in NFT hydroponic system [médias para altura da planta (H), número de folhas por planta (NF), comprimento (L) e largura (W) da maior folha, massa de matéria fresca (FM) e seca (DM), e produtividade de beterraba e alface cultivadas como *baby leaf* em função do espaçamento entre plantas em sistema hidropônico NFT]. Mococa, IAC/APTA, 2012.

Space between plants (cm)	H (cm)	NF	L (cm)	W	FM (g/plant)	DM (g/plant)	Yield (kg/m^2)
Table beet							
2.5	14.4 b[1]	4.0	10.9	2.8 b	1.3 b	1.1x10^{-1}b	4.2 a
5.0	15.0 ab	4.0	11.9	3.2 ab	1.3 b	1.1x10^{-1}b	2.1 b
10.0	16.2 a	4.0	12.4	3.5 a	1.7 a	1.5x10^{-1}a	1.4 c
DMS[2]	1.4	-	-	0.5	0.3	2.0x10^{-2}	0.5
CV (%)	10.2	10.7	14.7	17.1	23.3	26.6	24.0
Lettuce							
2.5	13.0 a	4.0	12.0 a	6.0	1.9	9.0x10^{-2}	4.9 a
5.0	13.0 a	4.0	12.0 a	6.3	2.0	1.0x10^{-1}	2.7 b
10.0	12.1 b	4.0	11.0 b	6.1	2.1	1.0x10^{-1}	1.3 c
DMS	0.5	-	0.6	-	-	-	0.1
CV (%)	4.1	8.9	5.5	6.3	14.7	14.4	18.4

[1]Averages followed by the same letter in the column do not differ statistically by Tukey test (5%); [2]DMS= average significant distance. (médias seguidas de mesma letra na coluna não diferem estatisticamente, Tukey 5%; DMS= distancia média significativa).

only in comparison to the 14.4 cm verified in plants grown in the smallest spacing between plants, 2.5 cm (Table 1). For the width of the largest leaf, the highest average, 3.5 cm, was verified in the at the 10.0 cm spacing between plants. The lowest average of 2.8 cm was observed in the spacing of 2.5 cm (Table 1).

Under increased planting density, competition for resources production, such as water, light and nutrients is greater. In this situation plant etiolation may occur, mainly due to the competition for light which, generally, results in greater height of plants. In this research, a greater plant height due to the reduction of plant spacing was not observed, but a smaller width of the leaves was observed.

The highest averages of fresh and dry matter mass, 1.7 and 1.5x10^{-1} g/plant were verified in the wider spacing (10.0 cm), differing from the average of 1.3 and 1.1x10^{-1} g/plant verified in spacing between plants of 2.5 and 5.0 cm (Table 1). The decrease of the spacing between plants promoted an increase of the yield, values of 4.3; 2.1 and 1.4 kg/m^2 were observed in spacing of 2.5; 5.0 and 10.0 cm, respectively (Table 1).

No information, in literature, on growing table beet for baby leaf according to spacing was verified. However, for lettuce and rocket salad crops in soil and hydroponics, without purpose of baby leaf, Silva *et al.* (2000) and Purquerio *et al.* (2007) verified that in smaller spacing, a decrease in mass for each plant was observed, with higher yield, though. This trend was also observed in table beet for baby leaf, and competition between the plants is due to production limiting factor such as water, light and nutrients. Nevertheless, the increase in productivity achieved by adopting the spacing between plants of 2.5 cm over the spacing 10.0 cm was approximately 300%, compensating the observed decrease in mass per plant. The authors highlight that although plants were smaller at 2.5 cm spacing, their visual aspect was suitable for commercialization.

Experiment with lettuce – In the harvest (at 22 DAS), no significant interaction between electrical conductivity and spacing between plants was noticed. However, an isolated effect of treatments on traits evaluated was observed. With the increase in EC, an increase in all traits which fitted the quadratic polynomial model was noticed, with the exception of number of leaves per plant which showed a linear response.

For plant height, an increase up to 13.3 cm was verified in the EC 1.1 dS/m, above this EC value, a decrease in plant height was noticed, wherein 1.6 dS/m, 12.8 cm was observed (Figure 1).

For lettuce growing for baby leaf, no information, in literature, on the plant height according to the EC of the nutrient solution was verified. Costa *et al.* (2001), growing lettuce 'Ryder', in NFT hydroponic system, with no purpose for baby leaf, did not verify any significant effect of EC (1.5; 2.5 and 4.0 dS/m) for plant height. Results of an absence of differentiation in height according to the EC (1.0; 1.5; 2.0 and 2.5 dS/m), for lettuce 'Ryder', was also observed by Fagundes *et al*. (2006).

For the number of leaves per plant the higher value observed was 5.0 leaves, estimated at 1.6 dS/m (Figure 1B). In production system in trays, Purquerio *et al*. (2010) observed for lettuce 'Elisa', grown for baby leaf, average of 7.0 leaves per plants at 49 DAS. However, Mou *et al*. (2008) mention that for baby leaf, an interesting number of leaves ranges from 4.0 to 5.0.

Regarding the length of the largest leaf, the highest value of 12.0 cm was observed in EC at 1.1 dS/m. From that point on, a length reduction, up to 11.6 cm, was observed in higher EC (1.6 dS/m). Purquerio *et al.* (2010) observed for lettuce 'Elisa', grown for baby leaf, in tray system of production, at 49 DAS, average of 14.6 cm for the length of the largest leaf, which was the maximum observed length in this study. The average length observed for the largest leaf was higher than the values suggested by Clarkson *et al*. (2005) and below the suggested value by Purquerio *et al*. (2010), to classify a leaf as baby leaf.

The width of the largest leaf increased from 5.8 cm at EC of 0.4 dS/m to 6.3 cm at EC of 1.2 dS/m (Figure 1D). Purquerio *et al.* (2010), in tray system production, observed an average of 5.3 cm for lettuce 'Elisa' at 49 DAS. The value observed in this work was higher than the value observed by the cited authors and obtained at 22 DAS.

The highest averages estimated of 2.0 and $9.1x10^{-2}$ g/plant and 3.1 kg/m^2 for fresh and dry matter mass and yield were observed at EC's of 1.1; 1.2 and 1.4 dS/m, respectively (Figure 2).

No information was found, in literature, on EC for lettuce growing for baby leaf in NFT hydroponic system. For growing in the usual way, Helbel Júnior *et al*. (2008) found higher values of fresh matter mass (413.4 g/plant) at EC of 1.2 dS/m for lettuce 'Vera' at 35 days of cultivation. Using 75% of the solution proposed by Furlani *et al*. (1999), or approximately 1.5 dS/m, Cometti *et al*. (2008) verified the highest value of dry matter mass (13.0 g/plant) for lettuce 'Vera'. Andriolo *et al*. (2005), in hydroponic cultivation, for lettuce 'Vera', verified that the EC of 2.0 dS/m provided the best productive output (170.7 g/plant). In Italy, Fallovo *et al*. (2009), growing baby leaf lettuce 'Green Salad Bowl', in floating system, observed productivity close to the one obtained in this study, about 3.5 kg/m^2, at EC of 2.0 dS/m, though.

The results, in this present study, for plant height, length of the largest leaf, width of the largest leaf, fresh and dry matter mass were similar to the information on EC recommended by Furlani *et al*. (1999) approximately 1.0 to 1.2 dS/m for seedling growing, since the EC's which provided the best results in the mentioned traits ranged from 1.0 to 1.2 dS/m. However, the highest yield (3.1 kg/m^2) was observed at EC of 1.4 dS/m (Figure 2C). The EC which provided the highest productivity in this study was higher than the one suggested by Furlani *et al*. (1999) for growing seedlings. This is due, possibly, to the longest baby leaf crop cycle in relation to the seedlings.

The decrease observed in all evaluated traits, due to the increase in EC was probably as a result of the increase of osmotic pressure of the solution. Solutions with high concentrations of nutrients have high osmotic pressure. According to Taiz & Zeiger (2009), environments of high osmotic pressure may hamper water uptake by the plant, being not enough to replace losses through transpiration. In this case, the most notable response, generally, is the productivity loss.

The spacing between plants, independent on the EC, had statistically significant influences on plant height, length of the largest leaf and productivity. For the number of leaves per plant, width of the largest leaf, fresh and dry matter mass no effect of spacing between plants was noticed, the observed means being 4.0 leaves, 6.1 cm, 2.0 and $1.0x10^{-1}$ g/plant, respectively (Table 1).

For plant height and length of the largest leaf, the lowest average values of 12.1 and 11.0 cm were verified at spacing of 10.0 cm. These averages differed statistically from the values of 13.0 and 12.0 cm, found in the spacing of 2.5 and 5.0 cm, respectively (Table 1).

Plant height and length of the largest leaf data observed showed that in smaller spacing (2.5 and 5.0 cm), greater etiolation of the plants was noticed, probably due to the competition for light and space, when compared to the 10.0 cm spacing. However, this etiolation did not affect plant growth.

Purquerio *et al.* (2010), in tray production system, verified for lettuce 'Elisa' plant height and length of the largest leaf of 14.0 and 14.6 cm, respectively, at 49 DAS. In Italy, Gonnella *et al*. (2003), in floating system, observed for baby leaf, in 40 days of cultivation, differences in plant heights of lettuce (20 and 19 cm) due to the densification in planting (316 and 620 plants/m^2).

For yield, the highest average, 4.9 kg/m^2, was verified in denser spacing, 2.5 cm. This value differed significantly from the averages of 2.7 and 1.3 kg/m^2 verified at spacing of 5 and 10 cm, respectively (Table 1).

In floating system, Gonnella *et al*. (2003) observed two densities of cultivation (316 and 620 plants/m^2) for baby leaf lettuce 'Ronda' and 'Amadeus', similar values to the ones obtained in this research, 6 kg/m^2 and 5.5 kg/m^2 for 'Ronda' and 'Amadeus', respectively for the highest density.

The great advantage of dense crops is the yield gain, due to, mainly, the greatest number of plants per unit area (Purquerio *et al*., 2007). Nevertheless, Mondim (1988) highlights that although an increase of production can be noticed, the densification of plants is beneficial to certain limits, so that it can promote high competition between plants and result in a lower mass per plant. In this work, mass reduction of each plant due to the spacing between them was not observed, possibly due to the small crop cycle observed (22 DAS).

Under this research conditions, the authors concluded that for table beet crop the EC of 1.6 dS/m, independently of the spacing, provided the best productive results. For lettuce crop, the EC of 1.4 dS/m showed the highest yield. For both crops studied, the spacing between plants of 2.5 cm resulted in the highest yield.

ACKNOWLEDGEMENTS

To the National Council for Scientific and Technological Development (CNPq), for their support (process number 477615/2011-2), to the Coordination of Improvement of Higher Education Personnel (CAPES), by granting the Master's scholarship to the first author and to Hidrogood company.

REFERENCES

ALVES AU; PRADO RM; GONDIM ARO; FONSECA IM; CECÍLIO FILHO A.B. 2008. Desenvolvimento e estado nutricional da beterraba em função da omissão de nutrientes. *Horticultura Brasileira* 26: 292-295.

ANDRIOLO JL; LUZ GL; WITTER MH; GODOI RS; BARROS GT; BORTOLOTTO OC. 2005. Growth and yield of lettuce plants under salinity. *Horticultura Brasileira* 23: 931-934.

BAQUEIRO LHR; OLIVEIRA F; ROCHA MAV; TIVELLI SW; PURQUERIO LFV. 2009. Produção de *baby leaf* de beterraba em bandejas com diferentes volumes de células. In: CONGRESSO BRASILEIRO DE OLERICULTURA, 49, Águas de Lindóia. *Anais eletrônicos*... Águas de Lindóia: Associação Brasileira de Horticultura, 2009. Disponível em: http://www.abhorticultura.com.br/eventosx/trabalhos/ev_3/A2057_T3410_Comp.pdf. Acessado em 10 janeiro de 2011.

CAMARGO MBP; BRUNINI O; PEDRO JUNIOR

MJ; BARDIN L. 2005. Variabilidade espacial e temporal de dados termopluviométricos diários da rede de estações agrometeorológicas do instituto agronômico (IAC). *Bragantia* 64: 473-483.

CASTOLDI N; BECHINI L; FERRANTE A. 2010. Fossil energy usage for the production of baby leaves. *Energy* 36:86-93.

CHOAIRY SA; FERNANDES PD. 1983. Densidade de plantio na cultura do abacaxi. *Pesquisa Agropecuária Brasileira* 18: 985-988.

CLARKSON GJJ; ROTHWELL SD; TAYLOR G. 2005. End of day harvest extends shelf life. *HortScience* 40: 1431-1435.

COMETTI NN; MATIAS GCS; ZONTA E; MARY W; FERNANDES MS. 2008. Efeito da concentração da solução nutritiva no crescimento da alface em cultivo hidropônico, sistema NFT. *Horticultura Brasileira* 26: 252-257.

COSTA PC; DIDONE EB; SESSO TM; CANIZARES KAL; GOTO R. 2001. Condutividade elétrica da solução nutritiva e produção de alface em hidroponia. *Scientia Agrícola* 58: 595-597.

FAGUNDES NS; LUZ JMQ; SANTOS VB; SODRÉ ACB; DIAS PAA. 2006. Produção hidropônica de alface (*Lactuca sativa*), do tipo Mimosa, em diferentes concentrações de solução nutritiva. In: CONGRESSO BRASILEIRO DE OLERICULTURA, 46, Goiânia. *Anais eletrônicos*... Goiânia: Associação Brasileira de Horticultura, 2006. Disponível em: http://www.abhorticultura.com.br/Eventos/Default.asp?id=4800. Acessado em 12 de março de 2012.

FALLOVO C; ROUPHAEL Y; REA E; BATTISTELLI A; COLLA G. 2009. Nutrient solution concentration and growing season affect yield and quality of Lactuca sativa var. acephala in floating raft culture. *Journal of the Science of Food and Agriculture* 89: 1682-1689.

FAO - Food and Agricultere Organization of the United Nations. 2009, 17 de maio. *Database.* Disponível em http://faostat3.fao.org/faostat-gateway/go/to/home/E.

FURLANI PR; SILVEIRA LCP; BOLONHEZI D; FAQUIM V. 1999. *Cultivo hidropônico de plantas*. Campinas: IAC (Boletim Técnico 180). 52p.

GONDIM ARO; CORREIA MAR; ALVES AU; PRADO RM; CECÍLIO FILHO AB. 2011. Crescimento e marcha de acúmulo de nutrientes em plantas de beterraba cultivadas em sistema hidropônico. *Bioscience Journal* 27: 526-535.

GONNELLA M; SERIO F; CONVERSA G; SANTAMARÍA P. 2003. Yield and quality of lettuce grown in floating system using different sowing density and plant spatial arrangements. *Acta Horticulturae* 614: 687-692.

GUALBERTO R; RESENDE FV; BRAZ LT.1999. Competição de cultivares de alface sob cultivo hidropônico 'NFT' em três diferentes espaçamentos. *Horticultura Brasileira* 17: 155-158.

HELBEL JUNIOR C; REZENDE R; LOUTENÇO DE FREITAS S; GONÇALVES AC; FRIZZONE JA. 2008. Influência da condutividade elétrica, concentração iônica e vazão de soluções nutritivas na produção de alface hidropônica. *Ciência e Agrotecnologia* 32: 1142-1147.

IBGE – Instituto Brasileiro de Geografia e Estatística. 2009. 07 de janeiro. *Pesquisa de orçamentos familiares 2008-2009*. Disponível em http://www.ibge.gov.br/home/estatistica/populacao/condicaodevida/pof/2008_2009_analise_consumo/default.shtm

MARQUES LF; MEDEIROS DC; COUTINHO OL; MARQUES LF; MEDEIROS CM; VALE LS. 2010. Produção e qualidade de beterraba em função da adubação com esterco bovino. *Revista Brasileira de Agroecologia* 5: 24-31.

MONDIM M. 1988. *Influência de espaçamentos, métodos de plantio e de sementes nuas e peletizadas na produção de duas cultivares de alface*. Lavras: UFLA. 52p (Dissertação mestrado).

MOU B; KOIKE ST; TOIT LJ. 2008. Screening for resistance to leaf spot diseases of spinach. *HortScience* 43: 1706-1710.

PURQUERIO LFV; BAQUEIRO LHR; SANCHES J; TIVELLI SW; CIA P. 2010. Produção de *baby leaf* de alface Elisa em diferentes volumes de células. In: CONGRESSO BRASILEIRO DE OLERICULTURA, 50, Guarapari. *Anais eletrônicos*... Guarapari: Associação Brasileira de Horticultura, 2010. Disponível em: http://www.abhorticultura.com.br/eventosx/trabalhos/ev_4/A3065_T4529_Comp.pdf. Acessado em 10 de janeiro de 2011.

PURQUERIO LFV; DEMANT LAR; GOTO R; VILLAS BOAS RL. 2007. Efeito da adubação nitrogenada de cobertura e do espaçamento sobre a produção de rúcula. *Horticultura Brasileira* 25: 464-470.

PURQUERIO LFV; MELO PCT. 2011. Hortaliças Pequenas e saborosas. *Horticultura Brasileira* 29: 1-1.

SILVA VF; BEZERRA NETO F; NEGREIROS MZ; PEDROSA JF. 2000. Comportamento de cultivares de alface em diferentes espaçamentos sob temperatura e luminosidade elevadas. *Horticultura Brasileira* 18: 183-187.

TAIZ L; ZEIGER E. 2009. *Fisiologia vegetal*. Porto Alegre: Artmed. 819p.