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Volume of cells on trays influences hydroponic lettuce production

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ABSTRACT

Lettuce seedlings used on hydroponic cultivation (NFT) are usually produced in trays with small volume, requiring two transplants: from tray to nursery and then to the definitive place. The aim of this study was to verify lettuce performance under NFT system, using seedlings produced in trays with several cell volumes (50, 40, 35, 31, 30, 29, 27, 20 and 10 cm^3 $cell^{-1}$). The tray volumes are considered treatments. The experimental design was completely randomized blocks, with four replicates. Seedlings were transplanted directly to the definitive profile, except those ones produced in 10 cm^3 $cell^{-1}$. Two harvests were performed, at 22 and 29 days after transplant (DAT). We evaluated number of senescent leaves, total number of leaves, shoot fresh mass, root fresh mass, shoot dry mass, stem length and productivity. The best performance was obtained using seedlings produced in trays with higher volume per cell. The nursery phase was not necessary and it was possible to obtain reduction from two to one transplant, corresponding to trays of 20 to 50 cm^3 $cell^{-1}$. Seedlings produced in trays with 40 and 50 cm^3 $cell^{-1}$ made the early harvest possible, at 22 DAT of cultivation under hydroponic NFT system.

Keywords: *Lactuca sativa*, seedlings, tray, soilless cultivation, hidroponic.

RESUMO

Volume das células em bandejas influencia produção da alface hidropônica

Tem-se produzido mudas de alface em bandejas cujas células são de pequeno volume para posterior utilização na produção hidropônica. Dessa forma, dois transplantes são necessários, da bandeja para o berçário e posteriormente ao definitivo. O objetivo desta pesquisa foi verificar o desempenho de alface em NFT utilizando mudas produzidas em diversos volumes de células de bandejas (50, 40, 35, 31, 30, 29, 27, 20 e 10 cm^3 $célula^{-1}$), constituindo os tratamentos. O delineamento experimental foi blocos inteiramente casualizados com quatro repetições. As mudas foram transplantadas diretamente na fase definitiva, exceto as de 10 cm^3 $célula^{-1}$. Foram realizadas duas colheitas, aos 22 e aos 29 dias após o transplante (DAT). Avaliaram-se número de folhas em senescência, total de folhas, massa fresca da parte aérea, massa fresca da raiz, massa seca da parte aérea, comprimento do caule e produtividade. O melhor desempenho foi das mudas produzidas em bandejas com maior volume por célula. Dispensou-se a fase de berçário e foi possível obter a redução de transplante de dois para um nos tratamentos correspondentes às bandejas de 20 a 50 cm^3 $célula^{-1}$. A produção de mudas em bandejas com 40 e 50 cm^3 $célula^{-1}$ possibilitou colheita precoce aos 22 DAT de cultivo no sistema hidropônico NFT.

Palavras chave: *Lactuca sativa*, muda, bandeja, cultivo sem solo, hidroponia.

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In Brazil, around 2,000 hectares of food crops are grown under hydroponic systems, and the state of São Paulo stands out as the leading producer. One in five Brazilian municipalities practices hydroponic cultivation (APTA, 2014), considering lettuce the predominant vegetable grown under hydroponic NFT system: Grand Rapids type, followed by crisphead lettuce, looseleaf type and other varieties (Sala & Costa, 2012).

Hydroponic cultivation has boosted several sectors, such as seedling production. Good quality seedlings can influence the final success of the crop, improving sanitary aspect, operational efficiency, earliness and quality of harvested products (Minami, 2010). Seedlings should have suitable physiological characteristics for different production processes which will be submitted after transplanting.

Vegetable seedling production is characterized by numerous models of existing trays, with quantity, volume, depth and different cell shape (Filgueira, 2008).

In Brazil, lettuce cultivation under NFT system commonly uses seedlings produced in trays of 200 cells (10 to 12 cm^3 $cell^{-1}$), containing less volume of substrate in its cell and consequent lower seedling development (Menezes Junior *et al.*, 2000). Seedlings of this kind of tray normally need two transplants under hydroponic system, from tray to intermediate phase, in which they will spend about 7 to 12 days on benches consisting of smaller profiles. Then, from intermediate phase to definitive phase, which consists of bigger profiles; where they will develop until reaching harvest time. The small size of seedlings produced in 10 cm^3 $cell^{-1}$ trays makes impossible the direct transplant for definitive phase. The definitive phase is characterized by profiles of bigger size, which will not remain adequately at the transplant site.

Higher number of transplants under NFT system results in damage to roots and shoots, causing stress in plants and consequently an increase in production costs due to losses and developmental delay, as well as greater use of labor, longer crop cycle and greater space occupied by the intermediate phase benches.

Seedlings produced in trays with larger volume cell may provide more developed lettuce adult plants, eliminating the intermediate phase. When roots have free development, they double its length, considering that the explored space will be eight times larger (Primavesi, 2002). Seedlings could be transplanted directly to the definitive phase of the hydroponic system, considering that plants from trays can show good adaptation to the new environment, higher resistance to mechanic damage during transplant, growing time reduction and, consequently, cost reduction (Reghin *et al.*, 2007, Maggioni, 2014). The aim of this study was to evaluate the performance of lettuce grown under NFT system using seedlings produced under different cell volumes.

MATERIAL AND METHODS

Seedlings were produced in a commercial nursery (IBS Mudas), located in Piracicaba, from February 3 to March 13, 2016 (22º37'46''S 47º36'07''W, 547 m altitude). Nine volumes differentiated per tray cell for seedling production were used (50, 40, 35, 31, 30, 29, 27, 20 and 10 cm^3 $cell^{-1}$) (Table 1). The experimental design was completely randomized blocks, with four replicates, 45 plants each. Pelleted lettuce seeds, cv. Vanda (Sakata) were sown, each cell receiving one seed. Coconut fiber was used as substrate (Amafibra). After sowing, trays were kept in a germination room with controlled environment (25^{0}C and 80% relative humidity) for 48 hours. Right after, for seedling development, trays were allocated in an arch type greenhouse (100 m length, 10 m wide and 4 m ceiling height). Trays were placed on 0.50 m benches. Lateral and front walls were made of anti-aphid screens, using polyethylene film, 150 µm and concrete floor. Irrigation and fertigation were done using sprinkler irrigation system with mobile bars. Seedlings were kept in a protected environment for 40 days, being transplanted after this period.

Seedlings were transplanted into NFT system, 39 days after sowing (DAS) in an experimental area of Universidade Federal de São Carlos, in Araras-SP (22º21'25"S, 47º23'03"W, 646 m altitude). Seedlings were transplanted directly to definitive phase, except of volume 10 cm^3 $cell^{-1}$. These seedlings remained in intermediate phase for 10 days until appropriate size for transplant to definitive phase. The structure of the definitive phase consisted of a self-priming pump (1 hp engine, maximum flow of 3600 L $hour^{-1}$), 5000 liter capacity reservoir, red screen covering (30% shading), 40 m long lateral walls covered with red roof (40 m long, 48 m wide, 1.95 m height ceiling). On the definitive phase we used four benches with seven 75 mm profiles (7.5 cm height, 10 cm wide) with 15 m in length and spacing of 0.30 m between profiles and 0.25 m between plants. Bench slope of 6% and intermediate phase corresponded to a pump and a 500 L capacity reservoir, profiles of 35 mm (5 cm height, 7 cm width), spacing 0.10 m between plants and 0.15 m between profiles, width of 15 m, slope of 6%, red screen covering (30% shading) and lateral walls also composed of the same material.

Nutrient solution (Furlani, 1999) was used both for plants in intermediate and in definitive phase. The circulation scheme of nutrient solution was every 15 minutes during the day (from 6 a.m. to 6 p.m.) and 15 minutes every 4 hours during night. Nutrient solution flow in the hydroponic system was adjusted to 1.8 L per minute per profile in the definitive system and, in the intermediate phase, to 0.5 L per minute per profile. The values of pH and electrical conductivity were controlled daily, from 5.5 to 6.5 and from 1.6 to 1.7, respectively, from transplant to harvest, both for intermediate and definitive phase.

Pests and diseases were controlled preventively, applying Benevia (Dupont, Cyantraniliprole) at a dose of 1 g L^{-1} and Serenade (2.8 mL L^{-1}) (Basf, *Bacillus subtilis* lineage QST 713) at 13 days.

Two harvests were performed, eight plants at each harvest. The first harvest, at 22 days after transplant (DAT), and the second, at 29 DAT. The following traits were evaluated: total number of leaves per plant, shoot fresh mass, root fresh mass, shoot dry mass, stem length, productivity, number of leaves during senescence (leaves which are not commercially acceptable and present yellow color). Leaves during senescence were evaluated only at the 29 DAT harvest, since no leaf was senescent at 22 DAT.

Two harvest seasons were analyzed, using split-plot model. However, aiming to study the relation existing between volume and other traits studied for each of the seasons, the authors adopted the following hierarchical model:

$$Y_{ijk} = \mu + C_k + CV_{ik} + e_{ijk}$$

in which, Y_{ijk} corresponds to the observed variable; µ is the overall average; C_k is the harvest effect; CV_{ik} is the nested effect of volume i within each of the cuts; e_{ijk} is the experimental mistake (Gomes, 2009). When effect of volume within harvest seasons was significant, the authors searched to identify the best polynomial regression model in order to interpret the phenomenon. To make the interpretation easier, first, second and third degree models were considered and tested sequentially. Analyses were done using the statistical software R (R Core Team, 2015), especially the ExpDes package (Ferreira *et al.,* 2013).

RESULTS AND DISCUSSION

We observed an increase of 0.75 senescent leaves with an increase of 10 g of cell volume. Using the smallest cell volume (10 cm^3), lettuce produced 1.9 senescent leaves $plant^{-1}$ at 29 DAT whereas, in the trays from 29 to 50 cm³ cell^{-1}, lettuce produced from 3.18 to 4.65 senescent plant^{-1} (Figure 1A). Senescent leaves are removed from the plant (toilet) before wrapping them in plastic bags for commercialization. The greater the number of these leaves the greater the time required for this activity. Lettuce obtained in trays with larger cell volume need more toilet, compared with lettuce growing in trays with 10 cm³ cell^{-1}. The leaves at the base of the plants from larger cell volumes were shaded by the upper ones which interrupted most of the incident solar energy; thus, according to Campos-Vargas & SaltVeit (2002), favoring the accumulation of phenolic compounds responsible for the induction of yellowing and subsequent death of lower leaves, probably due to spacing which became denser by the development of these lettuces at 29 DAT. Similar situation was found in lettuce seedlings produced in trays with 128 cells and transplanted into soil at different ages, in which older plants tended to an increase of senescent leaves in relation to their better growth (Andriolo *et al*., 2003).

Table 1. Volume per cell (VPC), number of cells (NC), depth (P), tray area (AB), and cell shape (CS) on styrofoam trays. Araras, UFSCar, 2016.

VPC (cm³)	NC	P (cm)	AB (cm²)	CS
50	72	6.0	13.7	Conical
40	64	5.0	22.7	Cube
35	84	4.0	15.6	Cube
31	162	5.5	22.7	Pyramidal
30	98	5.5	13.5	Conical
29	64	6.0	11.5	Pyramidal
27	128	4.0	13.5	Cube
20	128	4.5	13.5	Pyramidal
10	200	4.0	13.5	Pyramidal

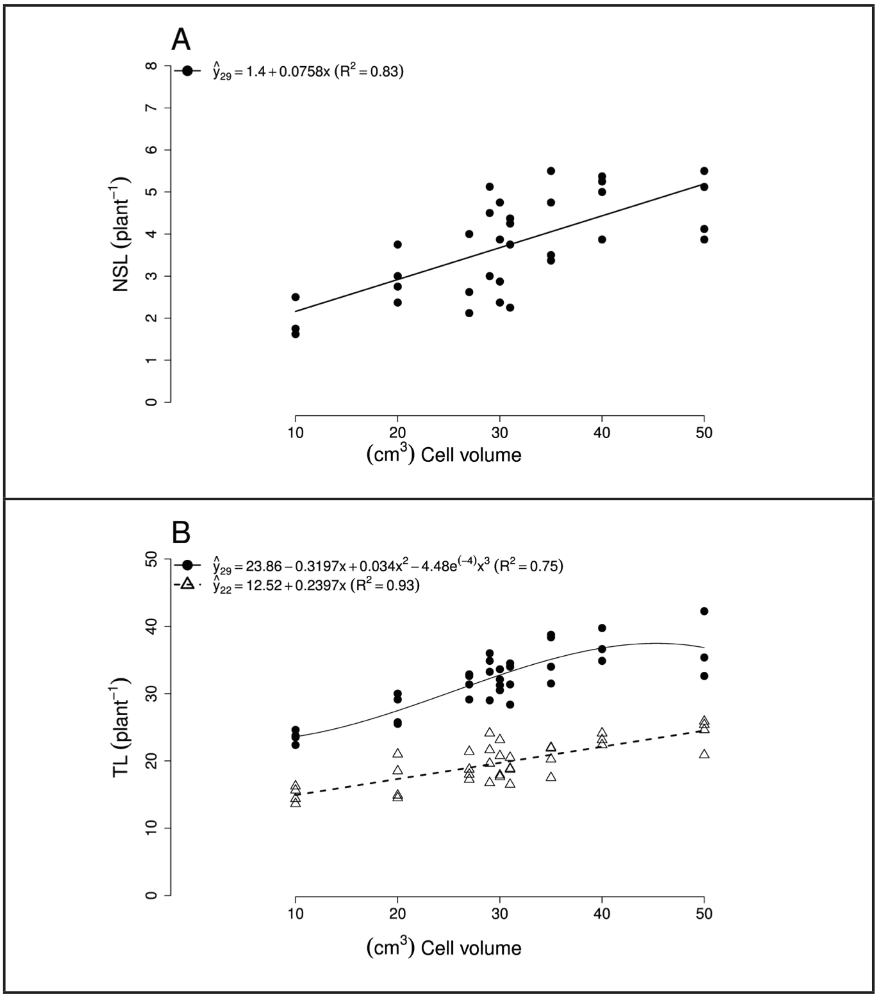

Figure 1. A= Number of senescent leaves (NSL plant^{-1}) and B= Total leaves (TL plant^{-1}) of lettuce plants harvested at 22 and 29 DAT, grown in NFT hydroponic system using seedlings produced in trays with different volumes per cell. Araras, UFSCar, 2016.

Total number of leaves increased constantly according to the range of cell volume variation. At 29 DAT, total number of leaves increased considerably on lettuce produced in trays with cells of up to 30 cm³, being the maximum in trays with volumes of 40 and 50 cm³. In the two harvests, smaller quantities of leaves per plant were found in plants produced in trays with volumes of 20 and 10 cm³ cell^{-1}. In the first harvest, we noticed 61.9% more leaves in plants produced from the greater (50 cm³ cell^{-1}) to the lower volume (10 cm³ cell^{-1}) and 62.8% in the second harvest, showing similar plant growth in the two harvests (Figure 1B). Growing several lettuce cultivars under NFT system using seedlings produced in phenolic foam trays (8 cm³ cell^{-1}) were found 27 leaves plant^{-1} for all the studied varieties at 30 DAT (Magalhães *et al*., 2010). Using the same cell volume and harvest season at 39 DAT for Grand Rapids type lettuce, the authors observed 26.4 leaves plant^{-1} (Casaroli *et al*., 2003).

In the first harvest, fresh matter of aerial part was 96 g plant^{-1} (10 cm³ cell^{-1}) and 237 g plant^{-1} (50 cm³ cell^{-1}), a difference of 59.5%, whereas at 29 DAT the difference between the smaller and larger cell volume was 194 g plant^{-1} (an increase of 56%) (Figure 2A). Ortiz *et al.* (2015), growing lettuce in soil, from seedlings produced in trays with 10, 12 and 14 cm³ cell^{-1}, verified an increase of fresh matter of aerial part according to an increase of cell volume. The fresh matter of lettuce to be commercialized may vary according to the cultivar, spacing used for cultivation, techniques and growing time. Santi *et al*. (2013) stated an average of fresh matter from 156.5 to 399.4 g plant^{-1} for cripshead lettuce.

Production of lettuce in trays with 40 and 50 cm³ cell^{-1} allowed an early harvest (7 days) compared to the lettuce produced in volumes of 10 to 20 cm³ cell^{-1}(Figure 2A). A decrease of fresh matter of aerial part at 29 DAT in volumes of 40 and 50 cm³ cell^{-1} was noticed, probably caused by a higher number of senescent leaves, since they presented dehydration and did not contribute to an increase in fresh matter of aerial part. Blat *et al*. (2011) found fresh matter of aerial part of 130.6 g plant^{-1} in lettuce grown in trays with 8 cm³ cell^{-1} at 28 DAT. Comparing the two harvests, the seedling production in larger volume (50 cm³ cell^{-1}) allowed harvest of approximately 16 cycles year^{-1}; on the other hand, with the volume of 10 cm³ cell^{-1}, harvest decreased to 12 cycles year^{-1}. Besides an increase of annual production, the seedling production with larger cell volume^{-1} reduces the number of transplant from two to one, makes the intermediate phase unnecessary, reduces production costs, increases profitability and quality of harvested plants due to fewer injuries to root system at the time of transplant into NFT system.

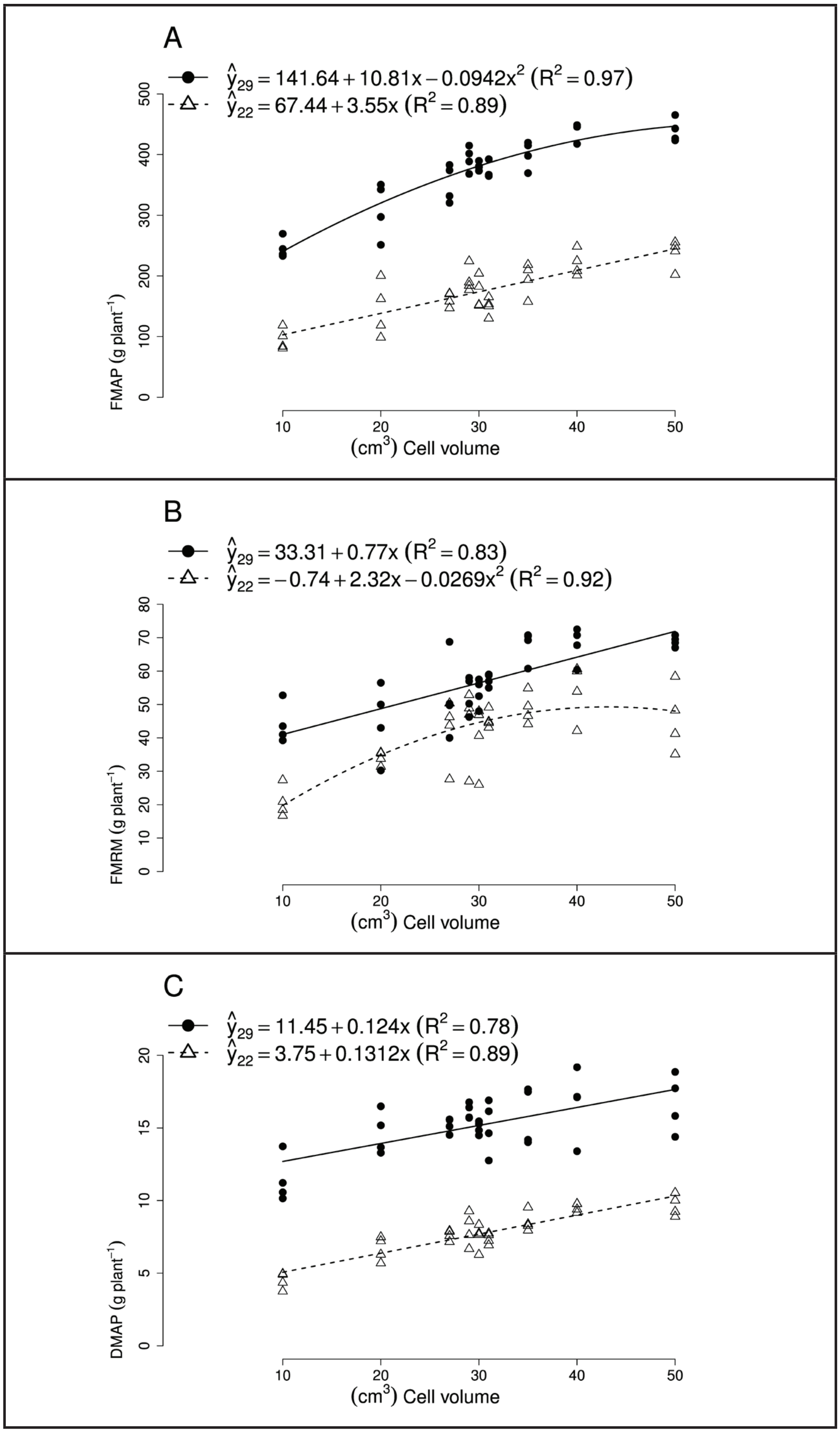

Figure 2. A= Fresh matter of aerial part (FMAP g plant^{-1}); B= Fresh matter of root mass (FMR g plant^{-1}) and C= Dry matter of aerial part (DMAP g plant^{-1}) of lettuce plants harvested at 22 and 29 DAT grown in NFT hydroponic system using seedlings produced in trays with different volumes per cell. Araras, UFSCar, 2016.

Fresh matter of root was found in lettuce grown in trays with 10 and 20 cm³ cell^{-1}, with 44.12 and 44.94 g plant^{-1}, respectively, and greatest mass of 67.81, 67.84 and 67.25 g plant^{-1} of plant roots produced in trays with 35, 40 and 50 cm³ cell^{-1}, respectively (Figure 2B). Casaroli *et al*. (2003), using trays with 8 cm³ cell^{-1} and growing several Grand Rapids type lettuce varieties under NFT which remained 9 days in intermediate phase, observed root fresh matter of 50.94 g at 30 DAT.

Comparing fresh matter of aerial part and dry matter of aerial part at 22 DAT, lettuce plants produced in trays with 50, 40, 35, 31, 30, 29, 27, 20 and 10 cm³ cell^{-1} were composed of dry matter of aerial part 4.0, 4.3, 4.3, 4.9, 4.3, 4.1, 4.7, 4.6 and 4.6%, respectively. A decrease in shoot dry mass accumulation at 22 to 29 DAT was noticed. For the harvest at 29 DAT spacing 0.25 m between profiles and 0.30 m between plants, was not sufficient to increase the shoot dry mass. Evaluating the harvest seasons (35 and 42 DAT) for chicory, a decrease was verified in the transformation from the fresh matter of aerial part to dry matter of aerial part in the second harvest (42 DAT), regardless of the tray used for cultivation (40, 16 and 12 cm³ cell^{-1}) (Reghin *et al*., 2007). Ortiz *et al.* (2015)

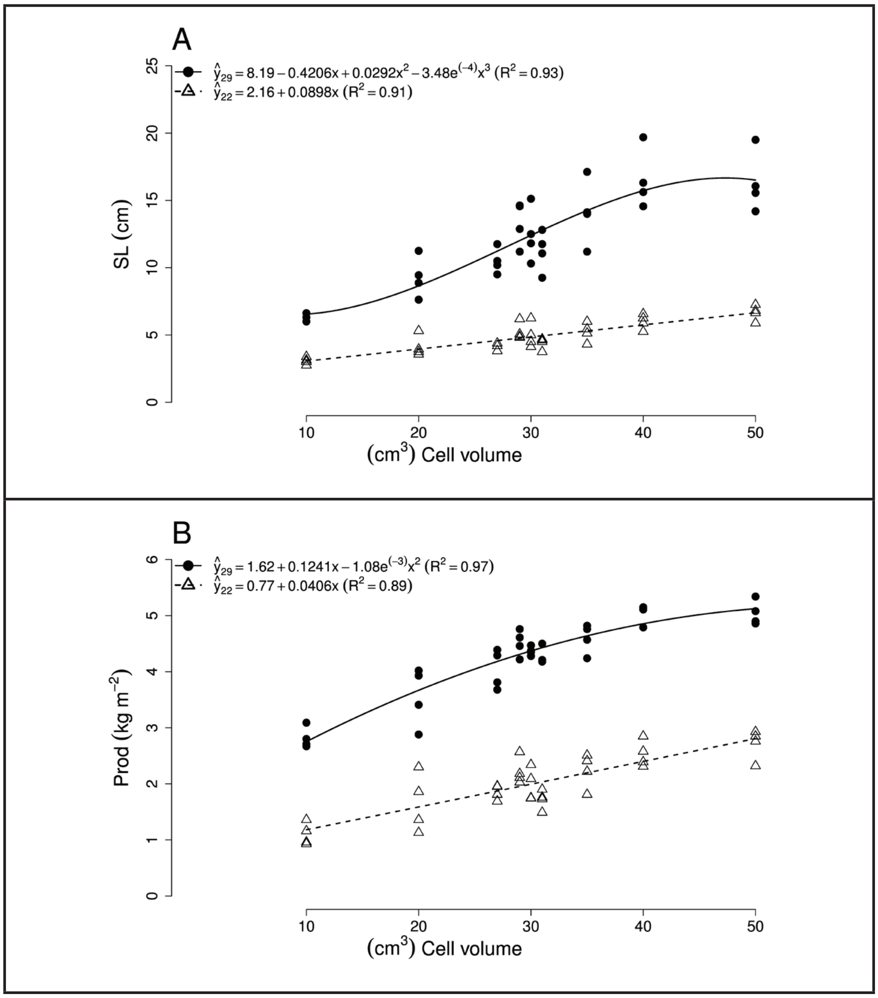

Figure 3. A= Stem length (SL cm plant^{-1}) and B= Productivity (kg m^{-2}) of lettuce plants harvested at 22 and 29 DAT grown in NFT hydroponic system using seedlings produced in trays with different volumes per cell. Araras, UFSCar, 2016.

reported that, in lettuce cultivation, an increase in shoot dry mass according to an increase of cell volume (volume of cell), using trays with 14, 12 and 10 cm³ cell^{-1} was observed. Using cells of 18.75 cm³ cell^{-1} in phenolic foam, Luz *et al.* (2006) observed, for lettuce, shoot dry mass of 11.95 g plant^{-1}, similar to shoot dry mass of the treatments with volumes of 10 cm³ cell^{-1} (11.42 g plant^{-1}) and 20 cm³ cell^{-1} (12.42 g plant^{-1}), found in this study at 29 DAT (Figure 2C).

In the first evaluation, shorter stem length (3.06 cm plant^{-1}) was found in plants produced in cells with 10 cm³ cell^{-1} volume and longer stem with 50 cm³ cell^{-1} (6.64 cm plant^{-1}), without bolting. However, at 29 DAT, the lettuce produced in trays with volume of 40 and 50 cm³ cell^{-1} showed stem measuring 16.54 and 16.32 cm, respectively (Figure 3A), already bolted due to elongation of the stem with the beginning of the floral primordium formation (Silva *et al*., 1999). Early lettuce bolting hinders commercialization due to bitter taste of the leaves (Filgueira, 2008). Gualberto *et al*. (1999), using looseleaf type seedlings produced in trays with 288 cells (without mentioning cell volume) transplanted into NFT in spacing 25x30 cm, found stem of 9.82 cm plant^{-1} at 24 DAT, differing from the result, 3.06 cm plant^{-1}, found for the smallest volume of this study (10 cm³ cell^{-1}). In crisphead lettuce cultivation under NFT system, using seedlings produced in phenolic foam and transplanted into spacing 25x25 cm, Sediyama *et al*. (2009) found stem of 8.35 cm plant^{-1} at 27 DAT, similar to the result found at 29 DAT in this study, 8.12 cm plant^{-1}. Stem with 15.34 cm plant^{-1} was obtained in lettuce 'Elisa' using seedlings produced in trays with 128 cells and transplanted into spacing of 25x30 cm, harvested at 32 DAT cultivated in soil under thermo-reflective screen 30% (Diamante *et al*., 2013).

Lettuce productivity in volume of 10 cm³ cell^{-1} was 1.49 kg m² and 3.82 kg m² for harvests at 22 and 29 DAT, respectively, differing from the largest volume tray (50 cm³ cell^{-1}) in 42.8%, in the first harvest and 55.85% in the second harvest (Figure 3B). The productivity of plants grown in trays with 27 cm³ cell^{-1} (2.51 kg m^{-2}) was exceeded by those recipients of upper volumes. Increasing substrate volume did not influence baby leaf lettuce productivity during four harvest seasons (18, 21, 28, 35 and 42 days) (Oliveira *et al*., 2009), unlike the productivity obtained in this study, which gradual increase, up to 29 DAT. The productivity at 22 DAT of plants produced in volumes of 29 to 50 cm³ cell^{-1} exceeded the productivity found in cultivation of Grand Rapids type lettuce 'Vera' in soil, which reaches 2.58 kg m^{-2} at 42 DAT (Meneses *et al*., 2016).

For most of the evaluated traits, the best lettuce development was obtained when seedlings were grown in trays with larger cell volume, being the better growth related to an increase of substrate volume. Intermediate phase was unnecessary and the reduction of transplant, from two to one, in treatments of 20 to 50 cm³ cell^{-1}, resulting in lower labor costs and shorter cycle. Using seedlings grown in trays with 40 and 50 cm³ cell^{-1} made early harvest possible (in one week). Considering economic terms, the authors highlight that further studies should be carried out aiming to quantify this difference, mainly concerning early cultivation, purchasing trays and seedling production.

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ERRATA

We apologize for the wrong registration of author's names, on the article cited below, published in volume 36 number 3, July to September 2018, page 408-413:

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The following author's names associated to DOI http://dx.doi.org/10.1590/S0102-053620180320 were incorrectly grouped.

Where the names were registered as: Luana Marchi; Marcela Martinez
And grouped as: Camila G Ferreira; Fernando C Sala

The author's names must be individualized.