



Different tray cell volumes for lettuce grown in conventional and hydroponic system

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ABSTRACT: Nowadays, an important economic movement is involved in the improvement of polyethylene trays for the production of seedlings, being developed with different volumes, numbers and cell formats in an each culture-specific manner. The objective of the present study was to evaluate the performance of curly lettuce originated from seedlings from trays with different volumes, through the comparison between conventional and hydroponic-NFT cultivation. Five volumes of trays (10, 20, 30, 40 and 50 cm³ of cell⁻¹) were tested in conventional and hydroponic cultivation, from February to March 2016. For the purpose of comparison, the plants were evaluated through the characteristics of height, circumference, stem diameter, number of leaves, fresh shoot mass and productivity. The use of volumes greater than 10 cm³ showed higher precocity in both cultivation systems, with hydroponic cultivation being more precocious and productive when compared to conventional cultivation.

Key words: *Lactuca sativa* L., seedling, comparative, field, hydroponic.

Diferentes volumes de célula da bandeja para alface cultivada em sistema convencional e hidropônico

RESUMO: Atualmente, um importante movimento econômico está envolvido na aprimoração das bandejas de polietileno para a produção de mudas, sendo desenvolvido com diferentes volumes, números e formatos de células de forma específica para cada cultura. O objetivo do presente estudo foi avaliar o desempenho de alface crespa, oriunda de mudas de bandejas com diferentes volumes, através da comparação entre cultivo convencional e hidropônico-NFT. Cinco volumes de bandejas (10, 20, 30, 40 e 50 cm³ de célula⁻¹) foram testados em cultivo convencional e hidropônico, no período de fevereiro a março de 2016. Para fins de comparação, as plantas foram avaliadas através das características de altura, circunferência, diâmetro do caule, número de folhas, massa fresca da parte aérea e produtividade. O uso de volumes superiores a 10 cm³ apresentou maior precocidade em ambos os sistemas de cultivo, sendo o cultivo hidropônico mais precoce e produtivo quando comparado ao cultivo convencional.

Palavras-chave: *Lactuca sativa* L., mudas, comparativo, campo, hidroponia.

INTRODUCTION

Lettuce (*Lactuca sativa* L.) is the most important leafy vegetable in terms of production area in conventional cultivation and represents 80% of the hydroponic-NFT cultivation in Brazil (FURLANI, 1999; SALA & COSTA, 2012). Having generated under wholesale trading in 2016, a higher amount in R\$ 288 million and production of 105.207 tons (CONAB, 2017), it is still estimated that in retail has reached R\$ 8 billion and production of more than 1.5 million tons (ABCSEM, 2017).

In Brazil in recent years, more and more vegetable producers have been interested in the

adoption of higher technologies in their cultivation system, being a good example of this option, the cultivation in hydroponics-NFT. This technology of soilless cultivation represents a more sustainable alternative to conventional cultivation, since it improves nutrition, water use and phytosanitary control of the plants, allowing the producer to obtain precocity in the cycle, greater productivity per area with higher quality and cleaning of product, besides reducing the manpower due better ergonomics in handling (NETO & BARRETO, 2011; PAULUS et al., 2012). Representing in this way, in a very interesting alternative of cultivation for the producers, mainly of the familiar agriculture, since, besides being able to

be considered like a more sustainable technological investment, generates a good and fast rate of return the initial investment of implantation.

Polyethylene trays are being developed with different volumes for substrate and cell format, in order to establish which new volume and format is better suited in a specific way, to every type of olericultural species (MINAMI, 2010). Where, in practice, nurserymen have used standard trays of 200 cells to produce lettuce seedlings, because they have lower volumes of substrate by cells, providing lower production costs due to less substrate use and more seedlings per square meter.

However, this economy in the stage of production of the seedlings can cause less development and quality of the same, reflecting in lower field potential after transplantation, resulting in losses in production, cycle extension and malformation of plants, because the lower volume of substrate available for root development causes greater competition for water, nutrients and oxygen due to the limitation in the pore space due to the presence of larger root mass. Thus, when transplanted, the seedlings are unable to compensate for evapotranspiration, even if well irrigated (WIEN, 1997; REGHIN et al., 2007).

Faced this new trend in the development of trays with higher volumes of substrate per cell for seedling formation and the growing interest in the adoption of hydroponic-NFT by the producers, the present research had as objective to elucidate how the use of greater volume of tray can influence in the precocity production of curly lettuce, comparing its performance of cultivation in conventional system with hydroponics.

MATERIALS AND METHODS

The experiment was conducted in the experimental field of Horticulture of the University Federal of São Carlos (UFSCar), in Araras-SP campus, in 2016 (22°21'25" south latitude, 47°23'03" west longitude and altitude 646 m). The climate of the region, according to the classification of Köppen, is designated as a Cwa (humid subtropical climate), with average temperatures of 20.3 °C and average annual precipitation of 1.312 mm. To carry out the experiment, in January the seeds were sown in the trays, and when they were ready in February, the seedlings were transplanted and harvest in March for evaluation.

The experimental design was a randomized block (DBC), forming a factorial scheme in 5 x 2, with five tray volumes (10, 20, 30, 40 and 50 cm³ of cell⁻¹) and two cultivation methods (hydroponic

and soil) with 4 replications for both cultivation, composed of field plots with 24 and hydroponics with 45 plants. From the field, four plants were collected at random and eight plants from the hydroponics of the central lines, avoiding the external lines of the borders, for subsequent analysis of the agronomic characteristics of plant height (H cm); circumference (C cm); diameter of stem (DC mm); number of leaves (NF) with a minimum of 5 cm; fresh shoot mass (MFA g) and Productivity (Prod t ha⁻¹).

The seedlings production was carried out by the nursery of vegetable seedlings (IBS Mudás), located in the county of Piracicaba-SP, between January and February 2016 (22°37'46 " south latitude, 47°36'07 " west longitude and altitude 547 m).

For sowing, a pelleted seed per cell was used in the 5 different trays (Table 1) of the cultivar 'Vanda' (Sakata®). The substrate used for sowing was type fine-textured coconut fiber (Amafriba®).

After sowing, the trays were kept in a germination room under 80% relative humidity and 25 °C for 48 hours. Soon after, they were placed in benches with a height of 0.50 m, in an oven with arch structure, 100 m long, 10 m wide and 4 m right foot. The side and front walls were of anti-aphid screen, with 150 µm polyethylene plastic cover and concrete floor. Irrigation and fertigation were by sprinkler on spray boom system, until the final formation of the seedlings for 30 days.

For the transplanting of the seedlings in the field, the soil was prepared with light grating, followed by the harrow for lifting the beds with a height of 30 cm and divided into plots of 2 m². The pre-planting fertilization was performed with fertilizer 4-14-8 (1.2 t/ha of fertilizer), sprinkler irrigation with shift regulated to provide water blade of approximately 8 mm day⁻¹ and weed control by hand, per weeding. Posteriorly, the transplant was performed with spacing of 0.3 m x 0.25 m. The cover fertilizer was made with Calcium Nitrate (0.3 t/ha⁻¹) and Potassium Chloride (0.12 t/ha⁻¹) at 12 days after transplanting.

For transplantation in the NFT system, the nursery phase corresponded to a motor pump and reservoir with a capacity of 500 L, profiles of 35 mm (5 cm high and 7 cm wide), with spacing of 0.10 m between plants and 0.15 m between profiles, with a width of 15 m, slope of 6%, red screen cover 30% and side walls of red screen with length of 40 m, width of 48 m and 1.95 m right foot. The structure of the definitive phase had a one self-priming water pump (1 hp engine, maximum flow of 3600 L hour⁻¹), reservoir with a capacity of 5000 L, screen cover and side walls

Table 1 - Tray specific features. UFSCar (CCA), Araras, SP, 2016.

Number of cells	Volume (cm ³)	Profundity (cm)	Área (cm ²)	Superior cell format	Inferior cell format
72	50	6	13.78	Circle	Conic
64	40	5	22.78	Quadrante	Cube
98	30	5.5	13.52	Quadrante	Triangular conical
128	20	4.5	13.52	Quadrante	Triangular conical
200	10	4	13.52	Quadrante	Triangular conical

equal to the nursery phase, four benches containing seven 75 mm (7.5 cm high and 10 cm width) profiles with 15 m length and 0.30 m spacing between profiles and 0.25 m between plants and 6% of the benches.

The flow of the nutrient solution in the system was adjusted to 0.5 L min⁻¹ in the nursery profile and in the definitive to 1.8 L min⁻¹ per profile. To formulate the nutrient solution, it was prepared the formulated by FURLANI (1999), with the circulation scheme of the solution nutrition regulated every 15 in 15 minutes during the day (06:00 to 18:00) and 15 minutes to every 4 hours during the night time. Electrical conductivity and pH of the nutrient solution were controlled and maintained daily from 1.2 to 1.7 and 5.5 to 6.5, respectively, since transplant until harvest.

Then, the seedlings formed in the 20, 30, 40 and 50 cm³ volumes per cell were transplanted directly to the definitive profiles, as they had adequate sizes to not slip for inside the profiles. While the seedlings formed in the cells of 10 cm³ had to stay 10 days before in the nursery phase until reach size suitable for transplantation to the final phase.

For evaluation, the lettuces were conducted until 30 days after transplantation in both cultivations. However, the lettuces of the hydroponics were evaluated 10 days before the field, because they were transplanted 10 days before.

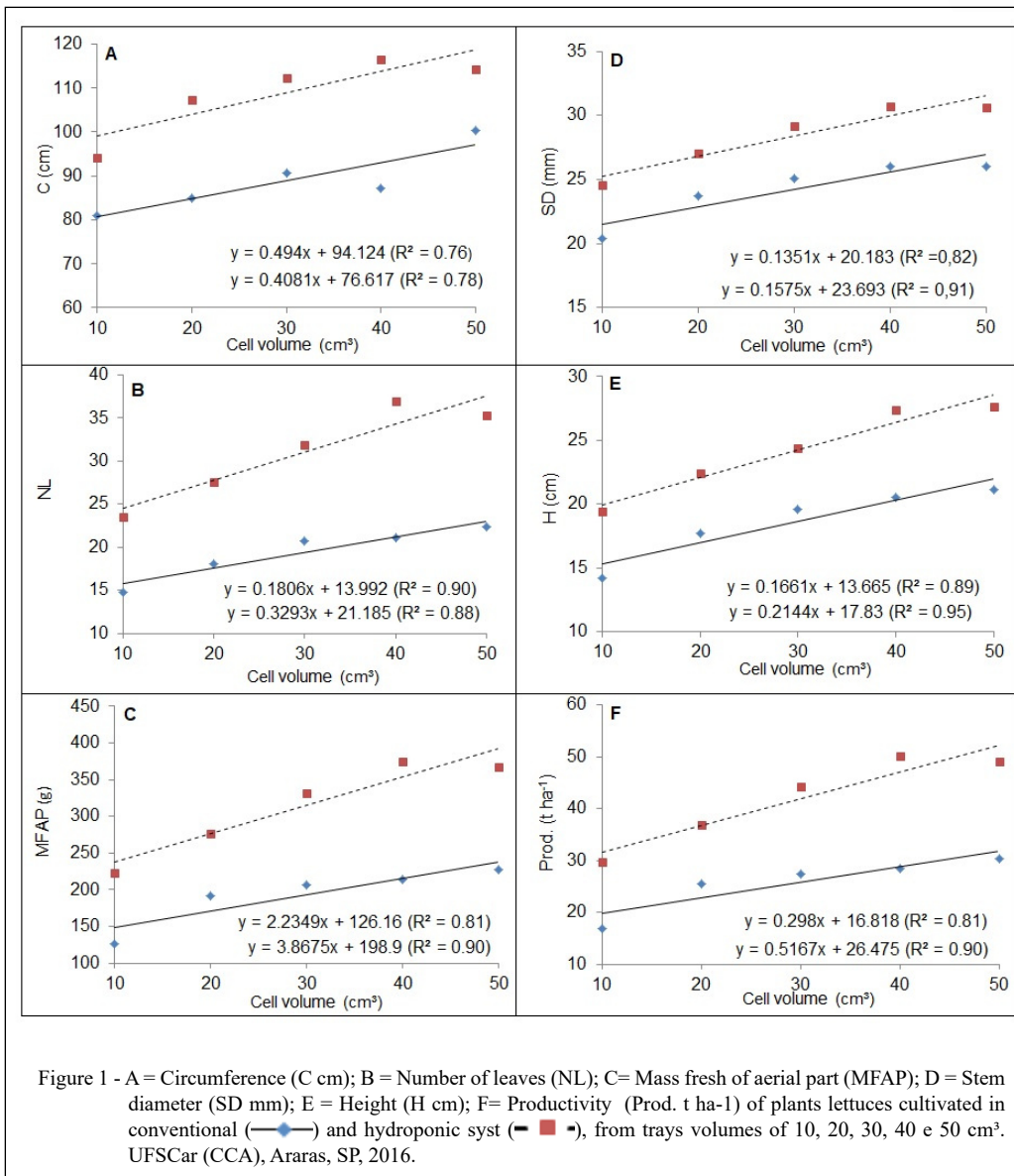
In the analysis of the data, the statistical software "Sisvar 5.6" was used and the Tukey test was applied, at 5% probability. Then, the data were included in scatter plots and applied to the regression lines by the MICROSOFT EXCEL 2010® software.

RESULTS AND DISCUSSION

At harvest, the 200-cell tray seedlings generated lettuce with a circumference of 81 cm in the field and 94.12 cm in hydroponics (Figure 1A), indicating precocity as a function of the cultivation way. That observation is reinforced by FELTRIM et al. (2005) with american lettuce and STEINER et al.

(2009) with crisp lettuce, where the authors reported precocity in the cycle in relation to conventional cultivation, this is because the direct contact of the roots with the nutrient solution, allowed a more efficient nutrition without losses, such as leaching (NETO & BARRETO, 2011). This difference was more evident when we verified that the volume of 10 cm³ in hydroponic was superior to all the volumes in the field, except for the one of 50 cm³ that acquired average circumference of 100,31cm; however, the volume that gave greater circumference was the of 40 cm³ in hydroponics with 116.65 cm. The higher cell volume for substrate gives a more vigorous seedling, allowing lettuce to reach the harvest point early, due to the greater field potential (REGHIN, et al., 2007; COCCO et al., 2015). Agreeing with the results of COCCO et al. (2015) with strawberry (*Fragaria x ananassa* Duch.) and MACHADO et al. (2018) with tomato (*Solanum lycopersicum* L.), the use of seedlings with greater volume of tray is advantageous for the producer, because has greater space for the development of a denser root system, implying in a greater surface of absorption of water and nutrients, promoting better adaptability to the field, generating precocity in the cultivation (REGHIN et al.,2007; LEAL et al.,2011; COCCO et al.,2015).

According to FLÔRES et al. (2016), lettuces with smaller circumference generate a smaller number of leaves; however, the volume of 50 cm³ in the field exhibited a larger circumference than the 10 cm³ in hydroponics (Figure 1A), but obtained 1.25 plant⁻¹ leaves less (Figure 1B), noting influence of the best nutrition of the production system. With the standard volume of 10 cm³ in the field (14.81 leaves plant⁻¹) as a comparative parameter, we reported that the 50 cm³ in the field presented greater differential gain of leaves number with 7.5 plant⁻¹ leaves more, and in relation to 10 cm³ in hydroponics, this difference reached 8.76 plant⁻¹ leaves (59.08% more). In addition, the volume of 40 cm³ in hydroponics was the one that presented the highest number of leaves



(36.96 leaves plant⁻¹), between the volumes and cultivations. This increase in the number of leaves due to the larger tray volume, as which has also described by LEAL et al. (2011) in lettuce and LUZ et al. (2018) in arugula (*Eruca sativa* M.). This higher number of leaves generated by the higher volume and cultivation in hydroponics is favorable, because it promotes greater interception of light energy that will be converted into chemistry and will serve to boost the development of the plants more vigorously, causing precocity in the harvest (TAIZ et al., 2017)

As a result of the increase in the circumference and number of leaves, was verified increase in the weight of fresh mass, according the increase of volume. When used as a parameter

comparative, the volume of 10 cm³ in the field presented an average of 127 g plant⁻¹, different from the volume of 50 cm³ that obtained the greatest highest in the field with 227.56 g plant⁻¹ (79.18% more) (Figure 1 C). This influence of volume on the fresh mass was also reported in tomato (*Solanum lycopersicum* L.) (RODRIGUES et al., 2010), basil (*Ocimum basilicum* L.) (MAGGIONI et al., 2014) and lettuce (ORTIZ et al., 2015). In addition to this, the cultivation system also influenced the weight gain, because while the soil cultivation had showed a maximum of 227.56 g plant⁻¹, in hydroponics the maximum weight obtained was 375.25 g plant⁻¹ (64.90 % more) (Figure 1C), corroborating with described by STEINER et al. (2009).

The volumes of 40 and 50 cm³ presented similar values (26 mm) in the field for characteristic stem diameter, being thicker at 5.63 mm than 10 cm³ (Figure D), also in the field too. And in hydroponics, the volume of 40 cm³ presented stem diameter higher in 6.12 mm in relation to 10 cm³ and was superior to the others for result in plants with stem diameter in 30.71 mm. This characteristic can be exploited by nurseries at the time of commercialization, because; although, the greater use of substrate for the production of seedlings, he will be offering seedlings with greater vigor and; consequently, a higher price. In this way, farmers can obtain a better uniform, early and lower loss of plantation, since the larger seedlings are larger in stem diameter, thus tolerating mechanical stresses and adverse environmental conditions after transplantation (SCHWERTNER et al., 2013), assuring the producer to offer more lettuces. Thereby indicating a possible cost-benefit relationship in the production chain, but it is necessary to carry out a better economic approach.

Using the 10 cm³ volume of the field as a parameter, we observed at the harvesting point, the lettuces showed a height of 14.25 cm (Figure 1 E), being smaller in 7.55 cm for the one of 50 cm³ in field and 5.21 cm smaller than the 10 cm³ in hydroponics, demonstrating greater development and precocity due to the higher volume of cell for substrate and choice of the culture system, because it allowed the lettuces to reach the harvest point quickly. And associated to the hydroponic cultivation makes this precocity more evident, since in the present study the volumes of 40 cm³ and 50 cm³ reached a height of 27.40 cm and 27.68 cm. This happen because the higher cell volume for substrate assures a greater supply of water and nutrients to the root system and due the better nutrition of the plants and effective absorption of nutrients the direct contact of nutritive solution with the root system confers in hydroponic, causing greater development and precocity in the cycle (REGHIN et al., 2007; NETO & BARRETO, 2011). In addition, for being marketed in boxes, how much larger the lettuce size will be necessary smaller number of plants to compose the box and; consequently, the return per area will be higher to the producer.

Among the volumes and systems tested, the volume of 10 cm³ in the field presented the lowest yield stipulated with 16.93 t ha⁻¹, a value close to the national lettuce production in the year of 2017 that reached 18.6 t ha⁻¹, according to data from the Brazilian Confederation of Agriculture and Livestock (CNA, 2017), while the highest stipulated productivity was registered with the volume of 40 cm³ in hydroponics, with 50.03 t ha⁻¹ (Figure 1F). For farmers who always

searched the maximum yield, it is viable invest in the purchase of seedlings in trays with higher volumes, since the high productivity obtained results in more boxes per area, justifying their recommendation. In addition, the higher productivity obtained in hydroponics is mainly due the direct availability of nutrients in the rhizosphere region, which favors the rapid and efficient absorption of nutrients, allowing the species or variety to reach its maximum genetic potential (NETO & BARRETO, 2011; RANAWADE et al., 2017), as already described in the literature on lettuce (STEINER et al., 2009) and spinach (*Spinacia oleraceae*) (RANAWADE et al., 2017). Thus, with the high productivity in a smaller area, shorter cycle and better prices of hydroponics, the producer can obtain a good profit and; therefore, a quick return of the initial invested capital (NETO & BARRETO, 2011).

CONCLUSION

Plants from seedlings produced in trays larger than 10 cm³ reach the harvesting point early, because the larger volume of available substrate did not oppress the maximum capacity of root development and consequently the aerial part, resulting in larger plants. This enables rapid reuse of space and greater box picking per area because the better vigor of seedlings produced in trays with higher volumes. The evaluated characteristics showed us that the volume of 40 cm³ was more satisfactory in hydroponics, while in the soil it was 50 cm³. The high yield in hydroponics outweighs the investment in adopting the cultivation method.

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DECLARATION OF CONFLICT OF INTERESTS

The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

AUTHORS' CONTRIBUTIONS

GJC, TJLL and FCS designed and designed experiments. GJC and TJLL performed the experiments. The FCS supervised the experiments. The GJC performed statistical analyzes of experimental data. GJC prepared the draft manuscript.

All authors critically reviewed the manuscript and approved the final version.

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