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Cultivation of green onion (*Allium fistulosum* L.) with support channels and nutrient solution in hydroponic

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Abstract

Hydroponics is an efficient cultivation system and brings benefits to the environment. In hydroponic systems, to improve plant performance grown is necessary to understand which management conditions are more appropriate to the particular requirements of each species. This study evaluated the growth of green onion plants (*Allium fistulosum*, L.), cultivar Tokio Kuro, under completely randomized blocks, contrasting nutrient solution concentrations (I - 50%, II - 75%, III - 100%, IV - 125%) and different positions on hydroponic channels (I - initial, II - intermediary, III - final). At the end of the growing cycle, the height, number of leaves, fresh leaf weight, and the tillering number of green onion plants were analyzed using univariate, multivariate analysis, and Pearson correlation. Results demonstrated that green onion plants presented better height, number of leaves, fresh leaf weight, and tillering number using nutrient solution concentrations between 50 and 100%. In the 125 % of nutrient solution concentration, occurred a decrease in the number of leaves and fresh leaf weight. There are no significant differences between plants' positions on hydroponic channels for height, number of leaves, fresh leaf weight, and tillering number of green onion plants. Our finding suggests hydroponic cultivation of green onion is a great cultivation system associated with the optimal concentration of 68.8%, promoting a higher plant development and earlier harvest. Plant positions in the hydroponic channels do not interfere green onion.

Keywords: hydroponic channels, fertilizer efficiency, food quality, plant nutrition

Introduction

Hydroponic is presented as an efficient cultivation system with positive benefits to the environment due to adequate racial water use, rapid plant development, and high productivity (Zhou et al., 2020). There is an interest of consumers for friendly food with high quality and preservation of the environmental (Wang et al., 2020a). Both conditions turn hydroponic a great system for food production (Sambo et al., 2019). Studies of Borges et al. (2016) and Leite et al. (2016) with the cultivation of lettuce (*Lactuca sativa* sp.) showed that hydroponic systems are viable economic alternatives with a rapid return rate (□ 2-3 years). There is a dependence on natural resources such as water and nutrients in the hydropic system (Khudoyberdiev et al., 2020). The concentration of nutrients in solution is considered a vital aspect of hydroponic cultivation and directly impacts production cost and productivity (Araujo et al., 2016). The extension of the hydroponic channel is another relevant factor due to alterations that can be generated in the nutrient solution when traversing the channels with the plants. Even in short channels (4 m), some species may be sensitive to small changes, as found by Luz et al. (2012) testing the production of cilantro (Verdão cultivar) and curly parsley (Folha Crespa cultivar). Furlani et al. (1999) using diluted concentration (50%) noticed that in the initial position of the hydroponic profile there was a better development for the crepe chicory plants.

The green onion plant (*Allium fistulosum* L.) is an important seasoning worldwide (Wang et al. 2020b) with high nutritional value (Gao et al., 2021). Generally, the green onion is produced by local production in family farming (Santos et al., 2019;). Rouphael et al. (2012) showed that condiment plants as green onion presents a high concentration of minerals and bioactive ingredients. The green onion is indicated as food with antifungal

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properties, antioxidants, antihypertensive, and recently discovered, the anti-obesity effect (Singh et al., 2020). In hydroponic systems, the production of green onion is considered low compared to conventional production in soil (Backes et al., 2004). There are few studies of green onion production in hydroponic systems compared to a conventional system. Kane et al. (2006) and Araujo et al. (2016) testing nutrients solution showed a mean production of 5.2 and 16.1 g plant^{-1} of dry matter, and Furlani et al. (1999) recommend a nutritive solution to lettuce planting. Luz et al. (2018), Araujo et al. (2016) showed that the nutrient absorption curve of nutrients is different for each pant and can negatively impact productivity. Therefore, studies demonstrating the adequate nutrient solution to green onion in hydroponic systems, and justifying this study.

We hypothesized that hydroponic systems are a viable and profitable alternative to cultivate green onion. Our goal here was to find an optimal combination of nutrients to improve the green onion yield and check the influence of the positions on hydroponic channels.

Material and Methods

Study characterization

The study was monitored in a greenhouse in the University of Uberlândia (UFU), Brazil, using nutrient solutions and plant positions on the channels. The experimental design involved completely randomized blocks in a split-plot, using the concentrations of nutrient solution (Plot: I - 50%, II - 75%, III - 100%, IV - 125%), associated with plant positions on the channels (Sub-plot: I - initial, II - intermediary, III - final), with three replications (Figure 1).

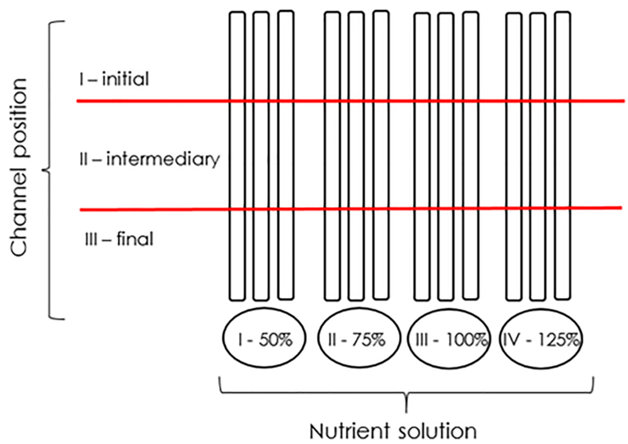

Figure 1. Concentrations of nutrient solution (Plot: I - 50%, II - 75%, III - 100%, IV - 125%), associated with plant positions on the channels (Sub-plot: I - initial, II - intermediary, III - final).

The nutrient solution was composed of macronutrients (rate: 750; 500; 150; 400 g of calcium nitrate, potassium nitrate, monoammonium phosphate, and magnesium sulfate, respectively) and micronutrients (0.15; 0.5; 1.5; 0.15; 0.30 g of copper sulfate, zinc sulfate, boric acid, sodium molybdate, and ferrilene, respectively). The nutrient solution was prepared, according to Furlani et al. (1999). This nutrient solution is commonly used in the study of hydroponic systems with lettuce, parsley (*Petroselinum crispum* sp.), and coriander (*Coriandrum sativum* sp.) (Luz et al., 2006; Backes et al., 2004).

Set installations

Seeds of green onion (variety: Tokio Kuro) were sowed in hydroponics foam (2.5 x 2.5 x 3 cm each cell), using a rate of 3 seeds per cell. After sowing, the hydroponic foam sheets were completed with vermiculite and disposed of in the greenhouse with a 40% shading screen covered. Daily, foam with seeds was irrigated until achieving the germination of the seeds. After 14 days of sowing (DAS), the plants were transferred to initial growth channels fueled with a nutrient solution concentration (50%). Application of nutrient solution with the concentrations I (50%), II (75%), III (100%), and IV (125%) were performed on the 25th DAS. Temperature, pH, electric conductivity, and nutrient solution volume were monitored and corrected daily. The pH was maintained in the range between 5.5 and 6.5 (solutions: NaOH or HCl), the electric conductivity of nutrient solution was maintained in 0.25 mScm^{-1}.

One hydroponic bench was used for plants in initial growth and four benches for plants in final growth. The initial growth bench was composed of 15 propylene channels measured about 5 cm in diameter, 10 cm spaced between channels, and 10 cm spaced between plants. The four final growth benches were composed of 9 propylene channels measured about 10 cm in diameter, 18 cm spaced between channels, and 25 cm spaced between plants. All channels measured about 4.5 m in length. Every three hydroponic channels formed one treatment, fueled by an independent 100 liters reservoir, powered by a 32-watt power pump. The reservoirs were externally painted with white rubber ink to avoid heating at the nutrient solution temperature. The hydroponic technique adopted was the Nutrient film technique (NFT).

Analyzed variables and data processing

The number of leaves, height leaf weight of onion green was measured at 48 days after sowing, when the plants reached optimum length for commercialization (Filgueira, 2008). The ratio of leaves per height and leaves per tillering were monitored to understand the plant development profile.

Data was studied using mean, standard deviation, minimum and maximum values. The data were submitted to tests of normality (Shapiro-Wilk Test, SPSS Inc., USA), homogeneity of variances (Bartlett Test, SPSS Inc., USA), and analysis of variance (ANOVA) based on the F-test ($p < 0.05$). When the F-test was significant ($p < 0.05$), the mean was compared by the Tukey test ($p < 0.05$; channel positions) and Regression test (nutrient solution concentrations). The variables were correlated by Pearson's correlation test ($p < 0.05$).

A multivariate exploratory analysis was run using the hierarchical method. A similarity matrix was constructed with Euclidean distance, and Ward's method was performed (Sneath & Sokal, 1973). The distances between the two groups were defined as squares between the two groups across all variables (Hair Junior et al., 2009). The Euclidean distance between the accessions for variables was determined by the difference between the factors studied (Nutrient solution concentrations: 50; 75; 100 and 125%). Statistical analyses were performed in R (version 4.0.0; R Foundation for Statistical Computing); and Python (version 3.8.3; Python Software Foundation), and results graphed in the Sigmaplot (version 11.0; Systat Software, Inc.).

Results

Concentrations and channel position

The plants' height and the number of leaves fitted a linear model with the concentration of nutritive solutions ($p < 0.05$; Table 1). The plants' height was positively impacted, represented by an increase from 31.9 to 33.1 cm with nutritive concentration (50 to 125%). In opposite, the impact was negative on the number of leaves with a reduction of 13% (Figure 2). These results indicate that the increase of nutritive concentration promoted plants' height with a reduction of the pre-leaves.

Both fresh leaf weight and the number of tillers fitted a quadratic model with the optimal concentration of nutritive solution at 85 and 68.8% ($p < 0.05$; Table 1; Figure 2). Indicate a reduction of nutrients to cultivate green onion in a hydroponic system. Using the optimal rate of 85%, there was a production of 36.5 g $plant^{-1}$ of the fresh leaf with a height and number of tillering of 35 cm and 14 tillers, respectively (Figure 2).

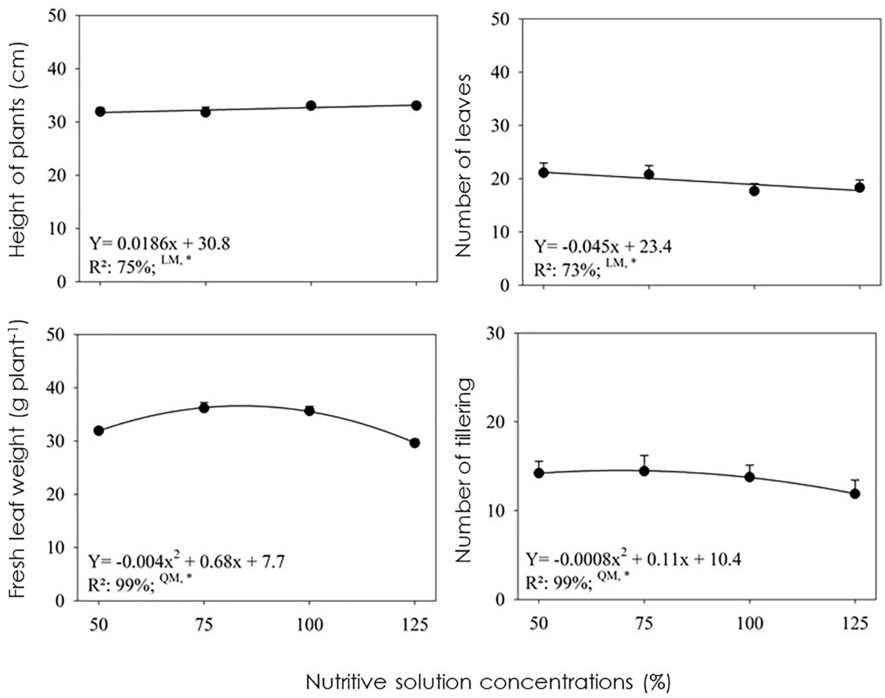

Figure 2. Height (cm), number of leaves, fresh leaf weight (g $plant^{-1}$), and tillering number of green onion plants (*Allium fistulosum*) with nutritive solution concentrations (50; 75; 100; 125%). ^{QM} and ^{LM} represent a quadratic and linear model, respectively. * Significant model.

The concentration of 125% was indicated as a prejudicial rate to green onion development in the hydroponic system to all agronomics variables (Figure 3). In the hierarchical analysis, two groups were distinguished, Group 1, formed by 125% concentration, and Group 2 formed by 50, 75 e 100% concentrations. There is a similarity concerning the groups' evaluated characteristics, corresponding to homogeneity between 50, 75, and 100% concentrations, and heterogeneity between Group 1 and 2 (Figure 3).

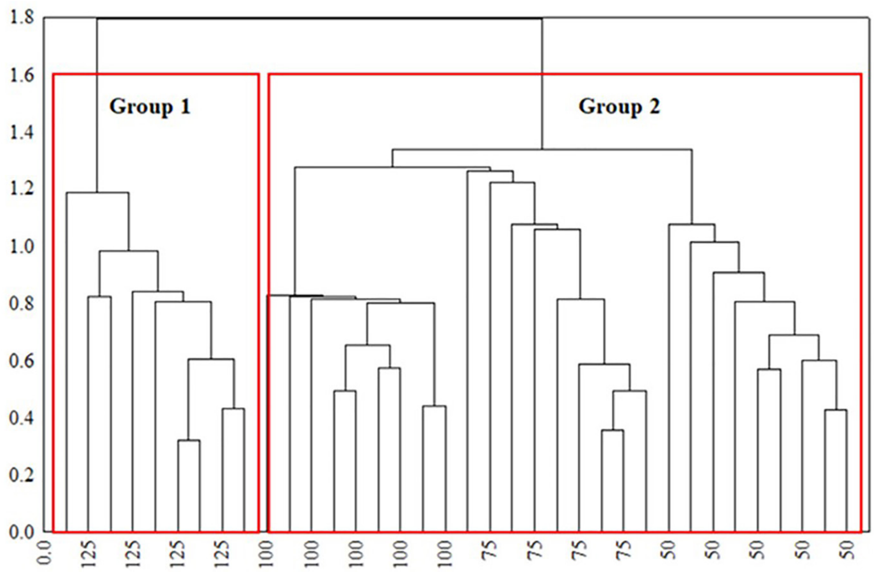

Figure 3. Hierarchical analysis for green onion plants (*Allium fistulosum*) is cultivated in hydroponic systems under nutrient solution concentrations (50, 75, 100 e 125%).

There was no interaction with different concentrations and channel positions using a p of 0.05 (Table 1). The channel's position did not affect the green onion development with a general mean of 32.4 cm; 19.4; 33.3 g plant^{-1} and 13.5, respectively to height, number of leaves, fresh leaf weight, and tillering number of green onion (Table 1). The variation of data was low with the coefficient of variation lower than 10%, indicating that the green onion was not affected by channel positions.

Table 1. Height (cm), number of leaves, fresh leaf weight (g plant^{-1}), and tillering number of green onion plants (*Allium fistulosum*) with nutritive solution concentrations (50; 75; 100; 125%) and channel positions (Initial; Intermediate and Final).

Position	Height	Number of leaves	Fresh leaf	Tillering
		Concentration: 50%		
Initial	32.03	21.00	32.03	14.33
Intermediate	31.93	21.33	31.90	14.33
Final	31.83	21.00	31.80	14.00
		Concentration: 75%		
Initial	31.30	21.00	36.27	15.00
Intermediate	32.13	20.33	36.20	14.33
Final	31.93	21.00	36.00	14.00
		Concentration: 100%		
Initial	33.17	18.00	35.57	13.67
Intermediate	33.07	17.33	35.63	13.67
Final	32.87	17.67	35.67	14.00
		Concentration: 125%		
Initial	32.93	18.00	29.80	11.67
Intermediate	33.23	18.33	29.60	12.00
Final	33.03	18.67	29.43	12.00
		ANOVA		
$P_{concetration}$	<0.001	<0.001	<0.001	<0.001
$P_{position}$	0.27	0.76	0.63	0.88
$P_{conc*pos}$	0.24	0.82	0.98	0.81
CV (%)	2.15	8.87	9.33	8.58

The mean was compared by LSD (position; P<0.05) and Regression test (Concentration solution; P<0.05). CV: coefficient of variation.

The green onion's fresh matter presented a positive correlation with the number of tillers ($p < 0.05$). However, there was no correlation of fresh matter with plants' height and the number of leaves with an r of -0.28 and -0.07, respectively (Figure 4).

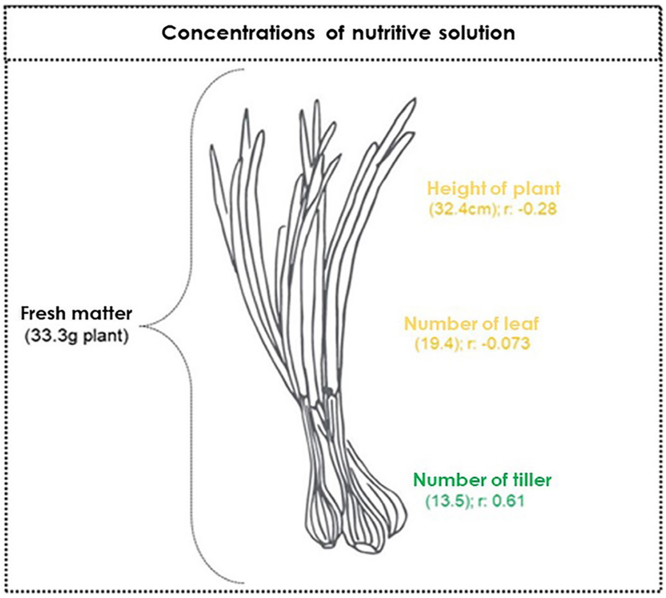

Figure 4. Correlation of fresh leaf weight with height, number of leaves, and tillering number of green onions. Green and yellow correlations mean null and positive correlation (Pearson correlation; P<0.05).

Discussion

The plants' height and the number of leaves linear increased with the concentration of nutritive solutions with increasing from 31.9 to 33.1 cm. According to Santos et al. (2005), green onions cultivated in hydroponics systems have a tumbling tendency since the favorable conditions of the cultivation system propelled the plants' growth. The higher growth of plants is not desirable and must be avoided when the fresh leaf weight does not increase to avoid plants tumbling. The number of leaves presents a mean of 19.47, with minimum and maximum values of 17.0 and 22.0, respectively. Lower averages for the number of leaves were observed under the 100 and 125% nutrient solution concentrations. For some crops, it is perceptible that the nutrient solution concentration influences some agronomic traits. Luz et al. (2012) observed that curly parsley cultivated in hydroponic systems had better performance under 100% concentration, with a higher number of leaves. These different results for agronomic traits under different nutrient concentrations occur because the presence of nutrients and their concentration guides the biochemical reactions in plants, in turn causing significant changes in the number of leaves and fresh leaf weight, amongst others (Santos et al., 2005). Each horticultural crop has its specific water and nutrient supply needs that arise from specific physiological responses, phenological stage of the plants, sources of nutrients, environmental factors, and season cultivation (Pignata et al., 2017; Martins et al. 2020).

The recirculation systems in hydroponic greenhouses are efficient water and nutrient absorption and avoidance of diseases caused by soil-borne pathogens (Mishra et al., 2018). In our study, the nutrient solution was composed of macronutrients (calcium nitrate, potassium nitrate, monoammonium phosphate, and magnesium sulfate) and micronutrients (copper sulfate, zinc sulfate, boric acid, sodium molybdate, and ferrilene). The high supply of nutrients can also harm plant growth (Caruso et al., 2011). The present work observed that a higher nutrient supply reduced the number of leaves, fresh leaf weight, and tillering capacity.

Sublett et al. (2018) evaluating lettuce, also observed that mineral nutrient concentrations increased with increasing solution EC, which reached a saturation point and decreased in plants exposed to the highest solution concentration. Deleterious effects in crop yields from excessive applications of nutrients in green onions were found to Zhao et al. (2020). Luz et al. (2012) verified that for hydroponic cultivation of cilantro, 125% concentration, the nutrient solution is more harmful than sub-rates, such as 75% concentration.

The tillering number presented a mean of 13.58 units and a maximum value of 16.0 units (Table 1). This variable presented itself in a quadratic function in which the higher tillering number (14.18) occurred under an application of 68.8% nutrient solution concentration. Furlani et al. (1999), who verified higher tillering capacity and higher fresh weight of leaves using 75% concentration, found similar results. The absence of channels position effects is probably because of the channels' small length (4 m). Similar results were found by Luz et al. (2011), who verified that the channels' small length prevented the differences to occur. However, for cilantro and curly parsley, differences in growth occurred even using small-length channels (Luz et al., 2012).

For all nutrient solution concentrations, plants reached a mean of 45 cm in length at harvest, being considered higher than the indicated height (35 cm) for harvesting, which was reached at 48 DAS. Interestingly, our results demonstrate that hydroponic cultivation of green onions with the management used makes possible an early harvest, and constraining to Filgueira (2008), who highlighted that harvest should be done when plants reach 35 cm in length, which is what would happen at 85 DAS using seed propagation.

According to Krause et al. (2018), the ideal harvest time in the green onion crop should be well defined by the farmer, meeting the maximum potential of the plant (productivity) with quality and commercial value. These authors found the highest mass values of fresh and dry commercial green onion cultivated in the field (soil) when they harvested at 100 DAS, compared to 73 DAS. It is important to highlight that hydroponic cultivation can significantly reduce the time of harvest provided by meeting market demands in a short period, as in the present work, with harvest at 48 DAS meeting market requirements (size and volume) and saving 52 DAS, compared to the maximum potential found by Krause et al. (2018).

On the other hand, Martins et al. (2020) evaluating the green onions according to planting density cultivated in the field, established the harvest to 64 DAS, with the second harvest 31 days later (95 DAS). The authors found the height of 37 to 41 cm and 39 to 43 cm at the first and second harvest, respectively, and the fresh leaf of 8 to 13 and 15 to 22 g plant^{-1} at the first and second harvest, respectively. In the present study, we observed plants with lower height than Martins et al. (2020), but the fresh leaf was compatible with the sum of the two harvests by Martins et al. (2020), with a 47 DAS savings.

In an economic analysis comparing field cultivation and hydroponics, it is necessary to elucidate that currently, in field cultivation, the producer harvests every 4 weeks after transplantation and may make 3 cuts. While in hydroponics, the producer harvests in 3 weeks and starts a new cycle with new seedlings. Taking into consideration the cost with seedlings, fertilization, and phytosanitary control, the cost per plant on field cultivation is around R$ 0.08, which multiplied by two gives R$ 0.16 per commercial pack of plants. Therefore, the producer will have a total cost of R$ 10.08 for the 63 commercial packs harvested in a 1 m^2, while in hydroponics, considering the cost of seedlings, nutritional solution, and phytosanitary control, the cost per pack is around R$ 0.23. That is, the producer will have a total cost of R$ 20.47 for the 89 packs harvested.

The highest cost in hydroponics refers mainly to the need for new seedlings at each cycle. The market often differentiates a higher price for the hydroponic product, however, in the present analysis, the sales value of R$ 1.50 per pack was considered independent of the cultivation system. Therefore, there was a positive impact of protected cultivation in green onion, with a net return higher than that specified in conventional cultivation.

Besides that Green onion from hydroponic cultivation has a longer shelf life and a better sanitary aspect, which adds value and represents a niche market, still relatively unexplored for species of less importance compared to other leafy vegetables, such as lettuce and arugula that are consumed on a larger scale and already widely cultivated in hydroponics. In this context, the present study, by elucidating nutritional aspects of green onion in hydroponics, helps to clarify and encourage producers, since the advantages and returns of the hydroponic system are encouraging and good management rewards investments.

Conclusions

Green onion plants present better performance to height, the number of leaves, fresh leaf weight, and tillering number using nutrient solution concentration between 50 and 100%, with great development performance in 68.8% and making possible an earlier harvest. At 125% nutrient solution concentration, the number of leaves is reduced, decreasing the fresh leaf weight. Plant positions in the hydroponic channels do not interfere with height, number of leaves, leaf weight, and tillering number of green onion plants.

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