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Hydroponic nutrient solution to cultivate of parsley and cerbiatta lettuce

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Abstract

Species that provide phytonutrients and bioactive compounds, such as parsley and lettuce, have gained prominence in a scenario of searches and concerns about maintaining health. Cultivation systems that enhance production in quantity and quality are essential. In this context, the objective of this study was to evaluate the development of parsley and lettuce under nutrient solution concentrations and plant position in the hydroponic system. The experiment was carried out in a randomized block design with five replications, in a 4 x 3 factorial scheme using four nutrient solution concentrations (50, 75, 100 and 125%) and three positions of the plants in the hydroponic profiles (initial, intermediate and final). Results showed that rates between 75 and 100% of nutrient solution presented higher production of cerbiatta lettuce and parsley in the hydroponic production. Channel position did not influence the cerbiatta lettuce production, but it influences the production of parsley. Based on results conclude that is necessary different management to production of cerbiatta lettuce and parsley in hydroponic solution.

Keywords: Fertilizer efficiency, hydroponic channels; *Lactuca sativa; Petroselinum crispum,* plant nutrition

Introduction

Lettuce (*Lactuca sativa*) is a basic ingredient in fresh salads and cultivated in the worldwide, providing vitamins and nutrients and many flavors and compounds with medicinal effects (Wiggins et al., 2020). The consumption of parsley (*Petroselinum crispum*) also offers many important health benefits, including neuroprotectivity, anticancer, anti-inflammatory, antibacterial and antifungal activities (Hasan, 2022).

The agronomic practices, especially fertilization and irrigation, determine production of lettuce and parsley and also phyto-compounds biosynthesis and the quality of the vegetables (Alharbi et al., 2019). Nutrient availability and nutritional status are key factors toward cultivation. The nutrient rates lead to the balance of nutrients in plant tissues and this directly affect the development and metabolism of the plants, and the nutrient accumulation (i.e., nitrate accumulation in human body) (Souri et al., 2018).

Hydroponic cultivation stands out among the forms of cultivation due to its estimable benefits with higher yield and quality of production, reductions of pest and diseases, optimization of resources (water and nutrients), and better use of the cultivation area (Batista et al., 2021). The hydroponic is considered a great option to vegetables that can grow in a short time and are periodically planting and harvesting (Saraçoğlu et al., 2020), such as parsley (*Petroselinum crispum*) and cerbiatta lettuce (*Lactuca sativa*).

Based on hypothesis that hydroponic cultivation is great option to parsley and cerbiatta lettuce production with influence of cultivation channels on production, the aim of the present study was to evaluate the effect of the nutrient solution concentrations under cultivation of lettuce and parsley grown in different positions of the hydroponic channels.

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Material and Methods

Study area, experimental design and plant growing conditions

The present study was conducted with lettuce and parsley under hydroponic conditions in a greenhouse at the Universidade de Uberlândia, municipality of Uberlândia, Minas Gerais, Brazil (18°57'30" S e 48°12'0" W).

The experimental design was completely randomized blocks, with three replications. The lettuce and parsley plants were grown using four concentrations of nutrient solutions (50, 75, 100 [control – recommended], and 125%). In addition, the plants were collected at the initial, intermediate and final positions of the hydroponic channel.

The structure for plants final growth consisted of four cultivation benches (one by treatment), each of them, with three hydroponic channels. Each bench was supplied by an independent 100-L capacity reservoir, and an electric pump 32-watt to inject the nutrient solution into the three hydroponic channels. The reservoirs were painted externally with white rubber paint to avoid the heating of the nutrient solution. Nutrient Film Technique (NFT) hydroponic system was used, consisting of 100-mm-diameter propylene channels and 4.5-m long, with a slope of 3%.

The spacing used was 0.18 m × 0.25 m, representing the distance between hydroponic channels and plants, respectively. The system consisted of a bench used for plants in initial growth (production of seedlings) and four benches for plants in final growth (development of the adult plant). The seeds were acquired from the company Isla and sown in phenolic foam (2.5 cm × 2.5 cm × 3.0 cm each cell), using three seeds per cell.

The cells were covered with vermiculite and taken to a greenhouse (covered with 40% shading screen). The phenolic foam was irrigated twice a day until achieve germination of the seeds. At 14 days after sowing, the seedlings were transferred to a nursery (NFT system) built with 50-mm-diameter propylene channels (using spacing of 0.10 m × 0.10 m between channels and plants), where they received a nutrient solution with a 50% concentration according to the recommendations of Furlani et al. (1999) for leafy vegetables.

After 25 days after sowing, the plants were transferred to the definitive cultivation system and received the different concentrations of concentrations of nutrient solution. Each bench contained 18 plants, 6 plants for each position (initial, intermediate and final). The 4 central plants of the two central channel of each plot were evaluated.

The complete nutrient solution (100 % concentration) was composed by following composition (g 1000 L^{-1}): 750 calcium nitrate, 500 potassium nitrate, 150 monoammonium phosphate, 400 magnesium sulfate, 0.15 copper sulfate, 0.5 zinc sulfate, 1.5 boric acid, 0.15 sodium molybdate (Na_2MoO_4 $2H_2O$), and 0.3 iron (FeEDDHA-6%) (Furlani et al., 1999).

During the experiments, the electrical conductivity and pH of the solutions values were measured daily in the reservoirs. The pH values were maintained in the range recommended for hydroponic cultivation (between 5.5 and 6.5) using NaOH or HCl solutions., and the electric conductivity of nutrient solution maintained in 2.5 $mScm^{-1}$.

Analyzed variables and data processing

At 30 days after transplanting (plants reached the commercial standard), the plants were harvested to determination of the plant height, leaves fresh matter, and shoot fresh matter.

The data were submitted to normality using the Shapiro-Wilk test and homogeneity of variances using the Bartlett test (SPSS Inc., USA). Subsequently, the data were subjected to analysis of variance by F-test ($p \leq 0.05$) and the means obtained as a function of the plants positions in the hydroponic channel were compared by Tukey-test ($p \leq 0.05$). The nutrient solution concentrations were evaluated by regression analysis. The variables also were correlated by the Pearson's correlation test considering the significant correlations with $p < 0.05$.

A probability analysis based on naive bayes classifier was tested using the nutrient solution with the rates between 75 and 100% (classified as better rates in Tukey-test). The positive probability was defined when yield of parsley and cerbiatta lettuce were higher than 70 e 200 g $plant^{-1}$, respectively. These values represent the general average of highest yield of parsley and cerbiatta lettuce. A decision tree was used to demonstrate the results of probability analysis in each position on the channel.

Statistical analysis was performed using the programming language in R (version 4.0.0; R Foundation for Statistical Computing, Vienna, Austria); and Python (version 3.8.3; Python Software Foundation, Wilmington, USA), and results were graphed in Sigmaplot (version 11.0; Systat Software, Inc., Palo Alto, USA).

Results and Discussion

Curly parsley

A significant effect of the nutrient solution concentrations was recorded for the plant height, leaves fresh matter, and shoot fresh matter of parsley. As a function of the positions of the plants in the hydroponic channels, plant height and shoot fresh matter were significantly influenced (**Table 1**).

Table 1. Summary of the F-test of analysis of variance for plant height (PH), shoot fresh matter (SFM), and leaves fresh matter (LFM) of parsley (*Petroselinum crispum*) under different nutrient solution concentrations (NSC) and plants grown at the initial, intermediate and final positions of the hydroponic channels

Source of variation	PH cm	SFMg plant^{-1}	LFMg plant^{-1}
NSC	*		
Positions			
NSC x positions	ns	ns	ns
CV (%)			
	Means as a function of positions		
Initial	27.5 A	73.0 B	33.9A
Intermediate	27.3 AB	73.3 AB	33.9 A
Final	27.2 B	73.6A	33.8 A

CV – coefficient of variation; *, **, ns – significant at $p \leq 0.05$, at $p \leq 0.01$, and not significant, respectively; means followed by the same letter are not significantly different by the Tukey-test at $p \leq 0.05$

The highest means of plant height (**Figure 1**A) and leaves fresh matter (Figure 1B) of parsley were estimated with the nutrient solution concentrations at 95.7 and 96.7%, respectively. The shoot fresh matter increased with the increase in nutrient solution concentration, representing an increase of 4.3% (between 50 and 125%) (Figure 1C). Luz et al. (2012) also developed studies with hydroponic systems of parsley with a better performance under 100% concentration, rate close to observed in our study.

The influence of channel position was not clear to parsley development with the highest height obtained in the initial position with an average of 27.5 cm, 2% higher than final position. While, shoot fresh matter was lowest in the final position with an average of 73.6 g, 1% higher than initial position (Table 1). In addition, the leaves fresh matter was not influenced by position in the channel, with a general average of 33.8 g plant^{-1}. The variability and small difference can be associated with the small length of the channels (4.5 m).

Luz et al. (2011) also observed such results and explained that small length of the channels promoted the low differences to occur. However, in other study Luz et al. (2012) testing curly parsley demonstrated a difference in growth in the channels.

Cerbiatta lettuce

Height and shoot fresh matter of lettuce were increased by nutrient concentration with quadratic responses and optimal rates fitted at 56.7 and 91.2%, indicating that nutritive solution higher than these rates promoted a lower lettuce development (**Figure 2**A and B). Interest, the root fresh matter presented a linear development with nutritive concentration ranging from 50 and 125% and representing an increase of 40% (Figure 1B). Genúncio et al. (2012) found a significant decrease in lettuce fresh weight when the EC in the nutrient solution decreased from 1.8 to 0.92 dS m^{-1}.

Dunn et al. (2015) evaluating SPAD were affected by the presence or absence of P and K in leaves of 'Vista Red' salvia. Singh et al. (2019) evaluating fresh weight and dry weight in lettuce, identified an interaction between cultivar and fertilizers, demonstrating that nutrients are not directly available to plants, and plants can influence nutrient availability, specially by releasing root exudates

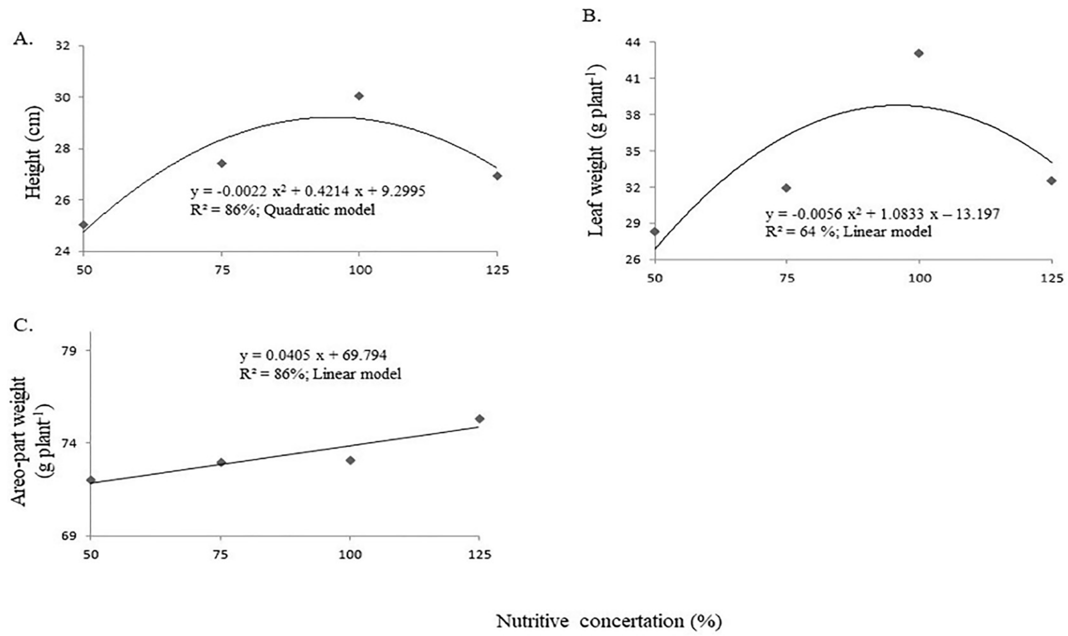

Figure 1. Height (cm), shoot fresh matter (g plant^{-1}) and leaves fresh matter (g plant^{-1}) of curly parsley (*Petroselinum crispum*) with nutritive solution concentrations (50; 75; 100; 125%). The results are of fresh part of plants. Rates were tested by the Regression test (P<0.05).

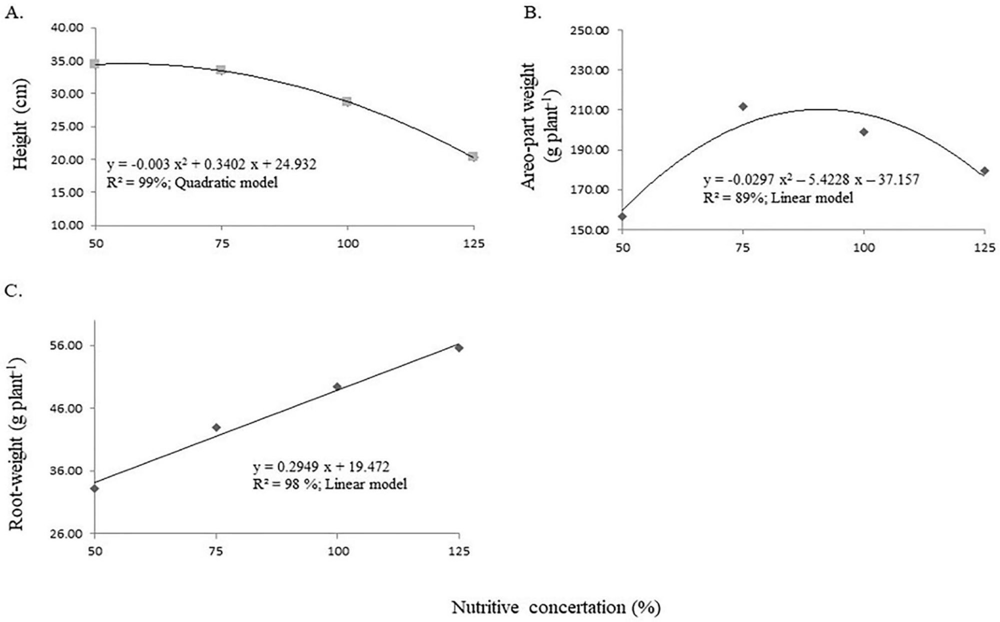

Figure 2. Height (cm), shoot fresh matter (g plant^{-1}) and root fresh matter (g plant^{-1}) of curly parsley (*Petroselinum crispum*) with nutritive solution concentrations (50; 75; 100; 125%). The results are of fresh part of plants. Rates were tested by the Regression test (P<0.05).

or exploring new areas by growing their roots.

El-Nakhel et al. (2019) demonstrated that a 50% decrease of macronutrient input caused a marginal decrease in fresh biomass of lettuce cultivars, that can consider an increase in nutrient use efficiency and modulate secondary metabolisms to improve the functional quality.

There was no influence of channel position in height, shoot fresh matter, and root fresh matter of lettuce with a general average of 29.2 cm, 186.7 g plant^{-1}, 45.2 g plant^{-1}, respectively (**Table 2**).

Correlations and probability

The development of shoot and root matter was positive correlated to cerbiatta lettuce, indicating that the roots were associated with the shoot (r = 0.62; p<0.05). While, shoot fresh matter and leaves fresh matterof parsley was not associated indicating that there was a steam development influencing in the shoot development (r = 0.10; p<0.05), **Figure 3**.

There is 100% of probability to obtain higher production of shoot of cerbiatta lettuce when used the rates between 75 and 100% nutrient solution, independently of position on the channel. The results demonstrate that the nutrient available is equivalent between the channels for the lettuce.

When used the rates between 75 and 100% nutrient solution for the production of parsley, there is a possibility of 66.7% to obtain higher production of aero-part in the intermediary channel, and a higher possibility of 83.3% to obtain higher production of shoot in the final channel (**Figure 4**).

This result indicates that is necessary different management to production of cerbiatta lettuce and parsley in hydroponic solution with rates between 75 and 100% when was not influenced by channel position for cerbiatta lettuce, but it influences the production of parsley. According to (Luz et al., 2009), species can behave differently at the same nutrient concentration, due to their physiological apparatus and nutrient metabolism. Thus, injection of nutrients via stock solutions needs frequent adjustment based on estimations of the nutrient uptake rates (Savvas et al., 2017).

Luz et al. (2009) also found better performance for plants in the intermediate and final positions. The authors attributed the results to the nutrient solution concentration in the initial position, which could possibly be above the required for the plants. At high concentrations, due to the

Table 2. Height (cm), shoot fresh matter (g plant^{-1}) and root fresh matter (g plant^{-1}) of cerbiatta lettuce (*Lactuca sativa*) with channel positions (Initial, Intermediate, and Final).

Position	Height cm	shoot fresh matter g plant^{-1}	root fresh matter g plant^{-1}
Initial	27.6 A	162.6 A	51.2 A
Intermediate	29.4 A	195.7 A	46.2 A
Final	30.4 A	201.7 A	48.3 A
		ANOVA	
$P_{concetration}$	<0.05	<0.05	<0.05
$P_{position}$	0.06	<0.05	0.06
$P_{conc*pos}$	0.38	0.58	0.61

The results are of fresh part of plants. Mean was compared by the Tukey-test (position; P<0.05) and the Regression test (Concentration solution; P<0.05).

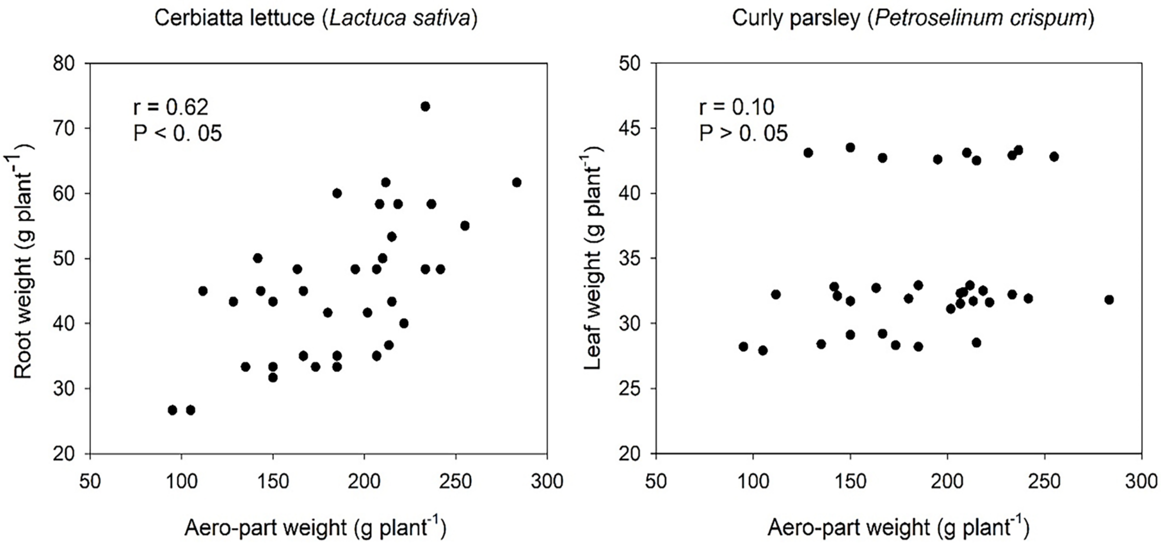

Figure 3. Correlations between shoot fresh matter (g plant^{-1}) and root fresh matter (g plant^{-1}) of cerbiatta lettuce (*Lactuca sativa*), and between shoot fresh matter (g plant^{-1}) and leaves fresh matter (g plant^{-1}) of parsley (*Petroselinum crispum*). The results are of fresh part of plants. Pearson correlation was used with a r-correlation (P<0.05)

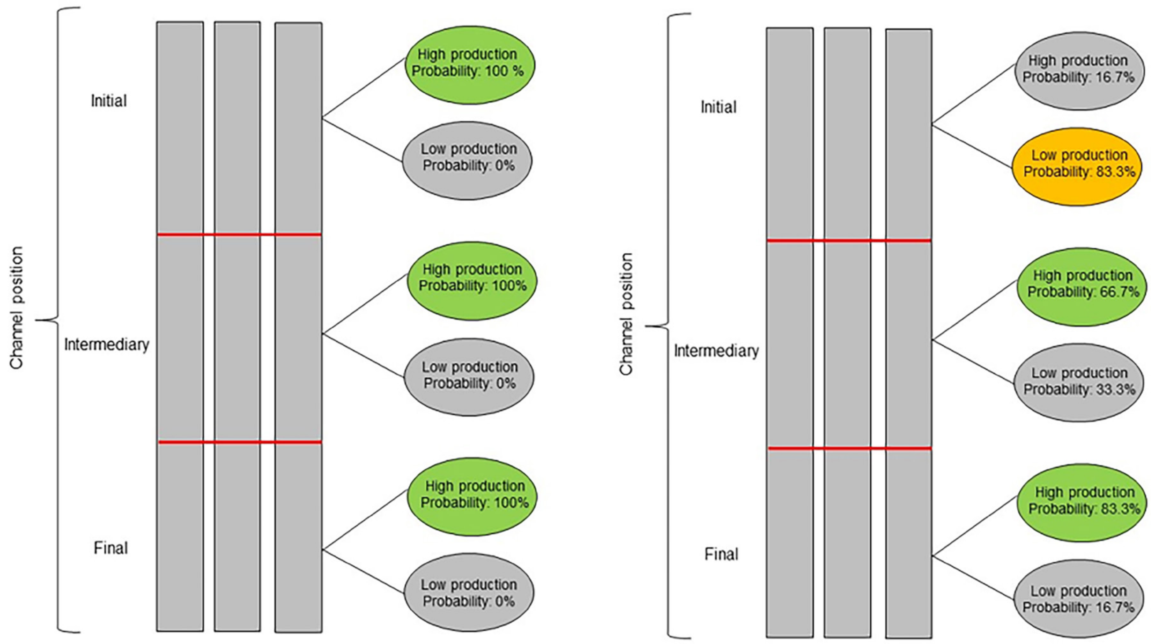

Figure 4. Probability of high production of shoot of cerbiatta lettuce (*Lactuca sativa*) and parsley (*Petroselinum crispum*) using the rates between 75 and 100% (classified as better rates in Tukey-test) in each position on the channel

greater osmotic pressure of the solution, there is less water absorption, which results in less nutrient transport and, consequently, less development and fresh mass gain.

In hottest regions, proposals have been made to reduce the concentration of solutions by reducing the EC to the range 1.0 to 1.5 dS m^{-1}. The decrease in nutrient solution concentration relate to a rationalization of the fertilizers uses and a decrease in production costs in the NFT hydroponic system (Luz et al., 2009). Moreover, high temperature and high nutrient solution depresses water and nutrient uptake through reduced oxygen availability, decreasing physiological processes such as root browning and active transport in membranes, which may ultimately decrease crop growth (Falah et al., 2010; Trejo-Téllez et al., 2012).

The nutrients and oxygen rates also have correlation where the K is the nutrient most sensitive to oxygen deprivation while NO_3^- uptake is the least affected by oxygen levels. The level of nutrients and oxygen in the solution can cause alteration on water consumption and in the flow of K, Mg^{+2}, P and sulfate from the root into the nutrient solution (Othman et al., 2019). The accumulation of solutes will inevitably occur in the root zone and this can provide a disturbance in electrical conductivity (EC) and plant nutrient imbalances in the growing system (Massa et al., 2020).

According to Massa et al. (2019) vegetable crops can be grown at low nutrient concentrations in the root zone if they are replaced at concentrations close to the actual uptake concentrations, knowing that nutrient needs of a plant species may change at different developmental stages (Savvas & Gruda, 2018). To achieve these possibilities, it is necessary to know the absorption behavior of different species, in different regions, and the present study is an information to be considered by producers for cerbiata lettuce and parsley.

Fine roots and root hair zone are essential for nutrient uptake and high nutrient solution can damage these roots, especially at early growth stages in plant development (Othman et al., 2019). Therefore, the nutrient concentrations may be frequently modified during the cropping cycle, with the aim to provide the gentlest and most suitable concentration to the root zone (Savvas & Gruda, 2018).

Soilless system is considered a promise to contribute to sustainability, feeding the world's growing population (Michelon et al., 2020), being hydroponic system easily to growers check the amounts of nutrients plants are receiving, providing 100% control of the nutrients that plants need (Waiba et al., 2020).

This system is essential to supply species with high health benefits, especially due to increasing discoveries about lettuce and parsley, being parsley uses also been expanded for other useful purposes in the ecosystem (Estelle et al., 2021), therefore is a growing demand in the next years. Our study brings the incentive to expand new studies and new efforts to bring information about hydroponics cultivation and the dynamics of nutrient solutions, especially with wide variation in climatic conditions that Brazil presents.

Conclusions

The rates between 75 and 100% of nutrient solution is necessary to production of cerbiatta lettuce and parsley in the hydroponic production.

Channel position did not influence the cerbiatta lettuce production, but it influences the production of parsley.

For higher parsley shoot fresh matter production, it is 66.7% possible in the intermediary channel and 83.3% possible in the final channel.

References

Alharbi, B.M., Mahmoud, A.A., Astatkie, T., Said-Al Ahl, H.A.H. 2019. Growth and essential oil composition responses of parsley cultivars to phosphorus fertilization and harvest date. *Journal of Plant Nutrition* 42:2395–2405.

Batista, M.C., Nascimento, R., Maia Júnior, S.O., Nascimento, E.C.S., Bezerra, C.V.C., Lima, R.F. 2021. Physiology and production of cherry tomato cultivars in a hydroponic system using brackish water. *Revista Brasileira de Engenharia Agrícola e Ambiental* 25:219-227.

Dunn, B.L., Goad, C. 2015. Effect of foliar nitrogen and optical sensor sampling method and location for determining ornamental cabbage fertility status. *HortScience* 50:74–77.

Estelle, L.Y.L., Reine, B.G.S., Joelle, T., Parfait, K., Kobi, D.K.O., Daniel, C.C. 2021. Repellent and insecticidal effects of essential oils of *Petroselinum crispum* (Mill.) Fuss and *Pimenta racemosa* var. racemosa (Mill.) J.W. Moore leaves on *Dinoderus porcellus* Lesne (Coleoptera: Bostrichidae). *Journal of Stored Products and Postharvest Research*1:8-19.

El-Nakhel, C., Pannico, A., Kyriacou, M.C., Giordano, M., Pascale, S., Rouphael, Y. 2019. Macronutrient deprivation eustress elicits differential secondary metabolites in red and green-pigmented butterhead lettuce grown in a closed soilless system. *Journal of the Science of Food and Agriculture* 99:6962-6972.

Falah, M.A.F., Wajima, T., Yasutake, D., Sago, Y., Kitano, M. 2010. Responses of root uptake to high temperature of tomato plants (*Lycopersicon esculentum* Mill.) in soil-less culture. *Journal of Agricultural Science and Technology* 6:543–558.

Furlani, P.R., Silveira, L.C.P., Bolonhezi, D., Faquim, V. 1999. Cultivo hidropônico de plantas. Campinas: Instituto Agronômico. Boletim Técnico IAC, 180. 52p.

Genunio, G.C., Gomes, M., Ferrari, A.C., Majerowicz, N., Zonta, E. 2012. Hydroponic lettuce production in different concentrations and flow rates of nutrient solution. *Horticultura Brasileira* 30:526–530.

Hasan, H.M. 2022. Study the effect of different polar extracts of parsley seeds (Petroselinum Crispum) and its phenolic compounds as antioxidants. *Annals of the Romanian Society for Cell Biology* 26:1898-1905.

Luz, J.M.Q., Andrade, L.V., Dias, F.F., Silva, M.A.D., Haber, L.L., Oliveira, R.C. 2012. Produção hidropônica de coentro e salsa crespa sob concentrações de solução nutritiva e posições das plantas nos perfis hidropônicos. *Bioscience Journal* 28:589-597.

Luz, J.M.Q., Costa, C.C., Guerra, G.M.P., Silva, M.A.D., Haber, L.L. 2011. Efeito da variação da solução nutritiva no cultivo hidropônico de rúcula. *Revista Verde* 6:76-82.

Luz, J.M.Q., Silva, M.A.D., Haber, L.L., Pirolla, A.C., Doro, L.F.A. 2009. Cultivo hidropônico de chicórias lisa e crespa e almeirão em diferentes concentrações de solução nutritiva. *Revista Ciência Agronômica* 40:610-616.

Massa, D., Germano, R., Carmassi, G., Incrocci, L., Montesano, F., Parente, A., Burchi, G., Pardossi, A. 2019. Increased phosphorus use efficiency in basil grown hydroponically with low phosphorus concentration and saline water. *Acta Horticulturae* 1242:327–334.

Massa, D., Magán, J.J., Montesano, F.F., Tzortzakis, N. 2020. Minimizing water and nutrient losses from soilless cropping in Southern. *Agricultural Water Management* 241:1-14.

Michelon, N., Pennisi, G., Myint, N.O., Dall'Olio, G., Batista, L.P., Salviano, A.A.C., Gruda, N.S., Orsini, F., Gianquinto, G. 2020. Strategies for Improved yield and water use efficiency of Lettuce (*Lactuca sativa* L.) through simplified soilless cultivation under semi-arid climate. *Agronomy* 10:1-14.

Othman, Y., Bataineh, K., Al-Ajlouni, M., Alsmairat, N., Ayad, J., Shiyab, S., Al-Qarallah, B., Hilaire, R.S. 2019. Soilless culture: management of growing Substrate, water, nutrient, salinity. Microorganism and product quality. *Fresenius Environmental Bulletin* 28:3249-3260.

Saraçoğlu, Ö.A., Kılıç, C.C., Duyar, H. 2020. The effects of different salinity levels (NaCl) on yield and plant growth in soilless culture head lettuce (*Lactuca Sativa* L.). *Journal of the Institute of Science and Technology* 10:1370-1381.

Savvas, D., Öztekin, G.B., Tepecik, M., Ropokis, A., Tüzel, Y., Ntatsi, G., Schwarz, D. 2017. Impact of grafting and rootstock on nutrient to water uptake ratios during the first month after planting of hydroponically grown tomato. *Journal of Horticultural Science and Biotechnology 92:* 294–302.

Savvas, D., Gruda, N. 2018. Application of soilless culture technologies in the modern greenhouse industry – A review. *European Journal of Horticultural Science 83:*280–293.

Singh, H., Dunn, B., Payton, M., Brandenberger, L. 2019. Fertilizer and cultivar selection of lettuce, basil, and swiss chard for hydroponic production. *Hortscience Technology* 29:1-7.

Souri, M.K., Rashidi, M., Kianmehr, M.H. 2018. Effects of manure-based urea pellets on growth, yield, and nitrate content in coriander, garden cress, and parsley plants. *Journal of Plant Nutrition* 1-10.

Trejo-Téllez, L.I., Gómez-Merino, F.C. 2012. Nutrient solutions for hydroponic systems. In Hydroponics-A Standard Methodology for Plant Biological Researches. Martinez-Mate, M.A., Martin-Gorriz, B., Eds.; InTechOpen: Rijeka, Croatia, 22p.

Waiba, K.M., Sharma, P., Sharma, A., Chadha, S., Kaur, M. 2020. Soil-less vegetable cultivation: A review. *Journal of Pharmacognosy and Phytochemistry* 9:631-636.

Wiggins, Z.D., Akaeze, O., Nandwani, D., Witcher, A. 2020. Substrate properties and fertilizer rates on yield responses of lettuce in a vertical growth system. *Sustainability* 12:1-8.

Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.