

Commercial substrates and nutrient concentrations in the production of arugula microgreens

Sustratos comerciales y concentraciones de nutrientes en la producción de microvegetales de rúgula

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ABSTRACT

The objective of this study was to evaluate the effects of different substrates and concentrations of nutrient solutions in the production of arugula (*Eruca sativa* Miller) microgreens grown in a protected environment at the campus of the Faculty of Agronomy of the Federal University of Rio Grande do Sul (UFRGS), in Porto Alegre, Brazil. The treatments consisted of the combination of five commercial substrates, CSC[®] vermiculite (S1), Green-Up phenolic foam (S2), S10 Beifiur[®] organic (S3), Carolina Soil[®] seedlings (S4), and Carolina Soil[®] organic (S5) and three concentrations of nutrients in the nutrient solution (0, 50, and 100%). A 5×3 factorial arrangement was used, in a completely randomized experimental design with three replicates. The addition of nutrients in the irrigation solution favored substrates S1, S4, and S5. Substrate S2 showed better performance with the addition of 50% of the total concentration of nutrients. Substrate S3 without the addition of the nutrient solution showed average values very close to the use of the nutrient solution, which can be considered in the evaluation of production costs of microgreens, generating savings to producers.

Key words: *Eruca sativa* Miller, crops, soilless cultivation, protected environment.

RESUMEN

El objetivo de este estudio fue evaluar los efectos de diferentes sustratos y concentraciones de soluciones nutritivas en la producción de microvegetales de rúgula (*Eruca sativa* Miller) cultivados en un ambiente protegido en el campus de la Facultad de Agronomía de la Universidad Federal de Rio Grande do Sul (UFRGS), en Porto Alegre, Brasil. Los tratamientos consistieron en la combinación de cinco sustratos comerciales, CSC[®] vermiculita (S1), espuma fenólica Green-Up (S2), S10 Beifiur[®] orgánico (S3), Carolina Soil[®] plántulas (S4) y Carolina Soil[®] orgánico (S5) y tres concentraciones de nutrientes en la solución nutritiva (0, 50 y 100%). Se utilizó un arreglo factorial 5×3, en un diseño experimental completamente al azar con tres repeticiones. La adición de nutrientes en la solución de riego favoreció a los sustratos S1, S4 y S5. El sustrato S2 mostró un mejor desempeño con la adición del 50% de la concentración total de nutrientes. El sustrato S3 sin la adición de la solución nutritiva mostró valores promedio muy cercanos al uso de la solución nutritiva, lo que se puede tener en cuenta en la evaluación de costos de producción de microvegetales, generando ahorros para los productores.

Palabras clave: *Eruca sativa* Miller, cultivos, cultivo de sustrato, ambiente protegido.

Introduction

With the rapid increase in the world population, humanity is faced with the need to develop sustainable ways of living on earth (Walker & Salt, 2006). Rapid urban growth has created serious concerns regarding food production, transport, and consumption, making sustainable production a matter of interest to all sectors, coupled with the increased demand for organic, fresh, and locally-sourced vegetables. Thus, food production in urban centers becomes an alternative, shortening the distance between production and the consumer, reducing carbon emissions and the consumption of fossil fuels for transportation. Also,

the shorter distance between cultivation and consumption ensures a higher quality food. Considering the global trends, such as climate change and the scarcity of natural resources, new approaches are needed to make cities more sustainable since the growth of urbanization is inevitable.

The cultivation of microgreens is among the alternatives to mitigate this scenario of unavailability of fresh and healthy food. Microgreens are vegetables that are consumed during the seedling phase, when cotyledon leaves are still turgid and true leaves have not fully expanded (Xiao *et al.*, 2012). They can be grown in small spaces by urban dwellers, as well as by commercial producers. Microgreens are a

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category of new and relatively unknown products on the market, are available in a pleasant variety of colors, textures, and flavors (Pfeiffer *et al.*, 2015; Weber, 2017), and have been gaining more and more use in cooking. The main reason for this success is that they are rich in essential elements for the proper functioning of the human body and contain higher concentrations of vitamins and carotenoids when compared to adult vegetables (Xiao *et al.*, 2012).

Arugula (*Eruca sativa* Miller) is a leaf-type vegetable that has increased in production in Brazil and has a slightly spicy taste (Menegaes *et al.*, 2015). Just like broccoli and cauliflower, arugula has great potential benefits for health thanks to its high content of glucosinolates, vitamins, and polyphenols. This species is a good option for microgreen production since in this growth stage it has a concentrated and attractive taste for the palate, contributing positively to the ornamentation and preparation of dishes, adding color, flavor, and texture.

The production of microgreens serves different consumers and markets, and the adaptation of cultivation techniques allows production in non-traditional spaces for plant cultivation. However, technical information about production systems and the handling of microgreens is scarce. Additionally, there are few scientific studies in the world and in Brazil that validate microgreen production technologies. Thus, this study aimed to evaluate the productivity of arugula microgreens in different commercial substrates and concentrations of nutrient solution, in a closed irrigation system.

Materials and methods

The experiment was conducted on the campus of the Faculty of Agronomy at the Federal University of Rio Grande do Sul (UFRGS), in the Department of Horticulture and Silviculture, located in the city of Porto Alegre, Brazil (30°01' S, 51°13' W). The trial was set up in a protected environment or greenhouse covered with plastic film (low-density polyethylene), arranged in an east-west direction with dimensions of 5.0 m x 10.0 m and 3.0 m height.

The experimental design was completely randomized with a factorial arrangement (5x3) formed by five commercial substrates and three concentrations of nutrients in the solution with three replicates per treatment. The commercial substrates were: CSC® vermiculite (S1), Green-Up phenolic foam (S2), S10 Beifiur® organic (composting waste from the wine industry) (S3), Carolina Soil® seedlings (peat +

roasted rice husk + vermiculite) (S4), and Carolina Soil® organic (peat + vermiculite) (S5). The nutrient solution (NS) was prepared according to Santos *et al.* (2004). This solution was suggested for use in hydroponic forage cultivation and had the following composition (100% concentration) of macronutrients (mmol L⁻¹): NO₃⁻ - 13.89; H₂PO₄⁻ - 1.41; SO₄²⁻ - 1.09; NH₄⁺ - 1.41; K⁺ - 6.41; Ca²⁺ - 3.4, and Mg²⁺ - 1.09. Micronutrient composition (mg L⁻¹) was as follows: 5.0 of Fe, 0.05 of Mn, 0.09 of Zn, 0.10 of B, 0.04 of Cu, and 0.02 of Mo. Rainwater was used to prepare the nutrient solution. The initial electrical conductivity (ECi) values were 0 (0% nutrient concentration), 1.20 (50% nutrient concentration), and 2.00 dS m⁻¹ (100% nutrient concentration), with pH values from 5.5 to 6.0.

The tested substrates were characterized in terms of chemical and physical properties in the Substrate analysis laboratory at UFRGS/Porto Alegre. Before use, the substrates were sterilized in an autoclave for 120 min at a temperature of 120°C and pressure of 1.5 atm.

Sowing was performed manually on February 22, 2018, using arugula Folha Larga seeds (Sakata®) with lightly cut leaves and bright green coloring, at a density of 0.10 kg m² in a previously wetted substrate. The substrates were placed in white polystyrene trays of 0.14 m x 0.21 m and 0.015 m deep, without compartmentation and perforated at the base (Fig. 1). Each tray received a layer of approximately 0.01 m of the substrate, on which the seeds were deposited.



FIGURE 1. Microgreens in white polystyrene trays distributed in rectangular pools.

After sowing, the trays were distributed in rectangular pools, a structure proposed for the production of microgreens, with a sub-irrigation system. The nutrient solution was supplied intermittently (15 min/h) according to the

treatments, from 8 a.m. to 6 p.m. plus two irrigations during the nighttime.

The pools were made of wood and covered with a double face film (white/black) and had a depth of 0.07 m and a slope of 2%. The pool contained a drain for the return of the drained solution to the nutrient solution reservoir; thus, the system was closed, without loss of the drain. During the first 3 d after sowing, the trays were maintained in the dark and covered with paper sheets; then, they were uncovered when seeds were already germinated. This technique was used to favor uniform seed germination.

During the experimental period, the average temperature and the relative humidity of the air were monitored daily, using a temperature and humidity Datalogger (model AK174, AKSO®, São Leopoldo, Brazil), installed inside the cultivation environment, next to the production benches. The harvest point was reached between the 8 to 11 d after sowing when 80% of the microgreen seedlings had the primary leaves in early development and the cotyledons were still turgid. Harvest was carried out by cutting with scissors at the level of the substrate. The fresh and dry mass of the shoots were evaluated; these data were extrapolated for productivity, considering the tray area, and the production cycle (precocity).

The daily averages of air temperature, recorded from February 22 to March 3, 2018, inside the protected environment varied between 24.7 and 30.2°C, and the relative humidity was between 68.0 and 74.5% (min. and max.) (Fig. 2).

Results were subjected to a normality test and analysis of variance by the F test and the means were compared with the Tukey's test at 5% probability of error, using the Sisvar program (Ferreira, 2011).

Results and discussion

For the variables average fresh and dry mass productivity of the shoot of arugula microgreens grown in a hydroponic system, the analysis of variance of the results indicated that there was a significant interaction between the substrate factors and concentration of the nutrient solution according to the F test (<0.05).

The average temperature for the period was approximately 27.4°C. Abreu *et al.* (2012) and Regan (2014) evaluated the effect of different temperatures on the germination of arugula seeds and found that temperatures between 25 and 30°C generated seedlings with greater root length. The temperatures recorded during the experimental period may have contributed to the production of arugula microgreens.

The characterization of the substrates (Tab. 1) demonstrated that the Green-Up phenolic foam (S2) and the S10 Beifiur® organic (S3) have high electrical conductivity (EC), of 1.28 and 1.20 dS m^{-1} , respectively. These values are considered outside the ideal range for substrates.

For Green-Up phenolic foam (S2) and S10 Beifiur® organic (S3), the pH values were 4.05 and 4.86 and are considered less than ideal for this variable. The other substrates, CSC® vermiculite (S1), Carolina Soil® seedlings (S4), and Carolina Soil® organic (S5), showed a range of variation for EC between 0.01 and 0.46 dS m^{-1} and for pH between 5.26 and 6.34. On the other hand, these last substrates proved to be suitable for use for plant production, since these values are in the recommended range for cultivation on substrates (Abreu *et al.*, 2012; Regan, 2014).

Regarding dry density (Tab. 1), the values of commercial substrates ranged from 11.50 to 302.74 kg m^{-3} . According

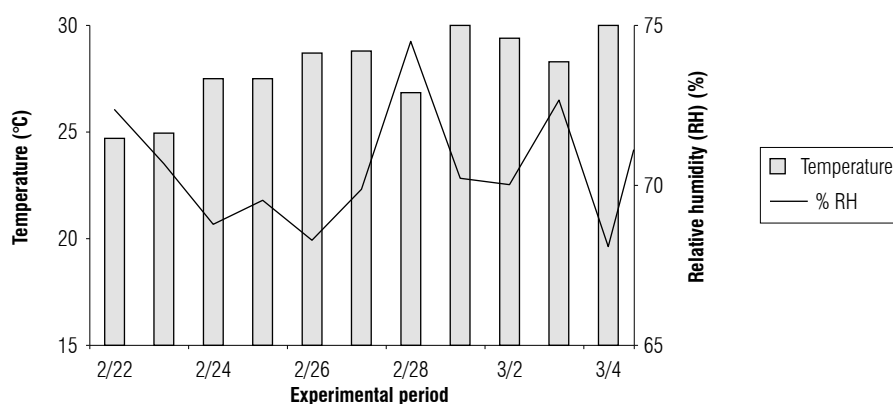


FIGURE 2. Air temperature and relative air humidity during the experimental period. Porto Alegre, UFRGS. 2020.

TABLE 1. Chemical and physical characterization of commercial substrates used in the production of arugula (*Eruca sativa* Miller) microgreens. CSC® vermiculite (S1), Green-Up phenolic foam (S2), S10 Beifiur® organic (S3), Carolina Soil® seedlings (S4), and Carolina Soil® organic (S5).

Chemical characteristics	Substrates				
	S1	S2	S3	S4	S5
EC (dS m ⁻¹)	0.01	1.28	1.20	0.46	0.28
pH (H ₂ O)	6.34	4.50	4.86	5.26	5.98
Physical characteristics					
Wet density (kg m ⁻³)	181.36	13.80	582.85	262.57	313.58
Dry density (kg m ⁻³)	177.90	11.50	302.74	122.41	113.44
TP %	73.23	-	81.33	87.73	91.62
AS %	23.24	-	21.48	38.91	29.32
RAW %	7.21	-	15.50	13.07	21.48
WRC-10 %	49.99	-	59.84	48.82	62.63

EC - electrical conductivity in a 1:5 solution (v/v); pH - in H₂O, dilution of 1:5 (v/v); TP - total porosity; AS - aeration space; RAW - readily available water; WRC-10 - water retention capacity under suction of a 10 cm water column, determined on a volumetric basis (v/v).

to Kämpf (2000), adequate values are between 100-300 kg m⁻³ for cultivation in seedling trays, which are containers with a volume closer to that used for the production of microgreens. The substrate S3, although with a dry density very close to that recommended, showed a higher wet density than the other substrates (Tab. 1). This led to the visual observation of resistance to root penetration, preventing seedling fixation. However, according to Table 2, the average productivity of shoot fresh matter (SFM) and shoot dry matter (SDM) in substrate S3 with concentrations of nutrients C1 and C2 obtained the best responses for these variables.

There is a change in this behavior only in the concentration of 100% of nutrients (C3) in the solution. Thus, the physical characteristic and the density of S3 did not limit the production of arugula microgreens, but the concentration

of the nutrient solution and the chemical characteristics of the substrate influenced the increase of mass. This can be seen by the negative influence on the average productivity of SFM and SDM, with a reduction of 7% and 24%, respectively (Tab. 2), when the concentration of the nutrient solution was increased from 50% to 100%.

Chemical characteristics are not generally considered to be exclusive when choosing a substrate since they can be easily modified during preparation and cultivation (Fermino & Kämpf, 2003). Due to the organic composition of S3 originating from the decomposition of residues from the winemaking process, the use of nutrients in the nutrient solution must be adequate to avoid the reduction in microgreen productivity.

According to Silva *et al.* (2013), arugula cultivation is classified as moderately sensitive to salinity with 2.75 dS m⁻¹ indicated as without loss of relative yield for a cycle of 30 to 40 d. As substrate S3 showed high initial EC, the use of the conductivity of 2.0 dS m⁻¹ in the nutrient solution with 100% of the concentration may have caused an excess of salts for the cultivation. According to Ribeiro *et al.* (2001), the high concentration of nutrients is a stress factor for plants, as it reduces the osmotic potential and provides the action of ions on the protoplasm.

Another substrate that showed high EC was phenolic foam. However, this material is considered inert, and the negative effects of the chemical characteristics were less than that of S3 that accumulates more nutrients with the addition of NS irrigation, and salinization may occur. In this study, the phenolic foam showed a much lower dry density than that recommended for substrates (Tab. 1), but this physical characteristic did not disrupt the response of arugula microgreen productivity in SFM and SDM in this substrate

TABLE 2. Effect of cultivation substrate and nutrient solution concentration on shoot fresh matter (SFM) and shoot dry matter (SDM) of arugula (*Eruca sativa* Miller) microgreens in a recirculating system.

Substrate	SFM (g m ⁻²)			SDM (g m ⁻²)		
	C1**	C2	C3	C1	C2	C3
S1	567.7 c C [*]	1534.4 ab B	1989.8 a A	46.6 b B	65.3 ^{ns}	67.4 a A
S2	641.2 bc B	1545.6 a A	1567.5 b A	39.1 b C	63.6	52.7 b B
S3	1115.9a AB	1564.3 ab A	1034.7 c B	71.1 a A	68.0	53.8 b B
S4	948.0 ab B	1155.8 bc B	1669.0 ab A	61.9 a AB	67.0	55.4 ab B
S5	581.0 bc C	1026.5 c B	2013.9 a A	43.9 b B	60.2	66.3 a A
CV	12.7	11.3	8.4	9.2	8.8	10.1

ns - not significant according to the Tukey test at 5% probability. *Means followed by the same lowercase letter in the column and uppercase in the row do not differ statistically according to the Tukey test at 5% probability ($P < 0.05$). **Initial electrical conductivity (ECi) established for the three evaluated nutrient concentrations (C1 - 0%, C2 - 50%, and C3 - 100%) in the nutrient solution: C1 - 0.0, C2 - 1.20, and C3 - 2.0 dS m⁻¹, respectively. CSC® vermiculite (S1), Green-Up phenolic foam (S2), S10 Beifiur® organic (S3), Carolina Soil® seedlings (S4), and Carolina Soil® organic (S5). CV - coefficient of variation.

(Tab. 2) compared to the other substrates and nutrient concentrations in the nutrient solution. However, a negative point of substrate S2 was the difficulty of accommodating seeds uniformly during sowing when compared to the other substrates. The surface caused an irregular distribution of seed, generating an excess of seeds in some points of the substrate. In these places, seeds showed difficulty in fixing the roots to the substrate. A possible alternative for overcoming this problem in phenolic foam is to use perforated foams for the production of microgreens. However, this visually observed behavior did not negatively affect the productivity of SFM and SDM (Tab. 2) in the phenolic foam since this substrate did not show the lowest results. The sowing density of arugula microgreens used in this study may have not provided seed saturation at the points of accumulation for influencing productivity results.

The average productivity of SFM between all treatments ranged from 567.7 to 2013.9 g m⁻². These results were similar to those that Paradiso *et al.* (2018) found with chicory (*Cichorium intybus*, cultivar Itálico) microgreens, curly lettuce (*Lactuca sativa*, cultivar Bionda da Taglio) and cabbage (*Brassica oleracea*, cultivar Natalino), grown on peat substrate in which fresh mass varied between 659 g m⁻² and 1548 g m⁻². In the study by Paradiso *et al.* (2018), microgreens were grown in a growth chamber with controlled temperature and relative humidity, making production more expensive. It can be inferred that the system proposed in this work, without control of these variables, responded adequately to the production of arugula microgreens without affecting the productivity of SFM. It should be noted that these authors worked with other species; however, in the literature there is still a lack of data on the production of arugula microgreens.

Without the use of fertilizers (C1) for irrigation, substrate S1 obtained the lowest average yield of SFM (567.57 g m⁻²) when compared to those with better results (S3 and S4) (Tab. 2). The results in S1 may be related to the EC value that was much lower than that in the other substrates (Tab. 1). Combined with the low chemical activity of this material (Caldeira *et al.*, 2013), S1 did not contribute nutrients to the increase in the fresh mass of the microgreen shoots. Although it is a short cycle, the seed reserves were not able to supply the demand for seedling growth, so the addition of fertilizers to this substrate is necessary for greater SFM yield.

The nutrient solution with 100% concentration (C3) favored the highest productivity of SFM and SDM (Tab. 2) of arugula microgreens grown on substrates S1 and S5, without differing statistically from S4 (Tab. 2); they were

250%, 246%, and 76% higher than SFM productivity when only pure water (C1) was used for irrigation (Tab. 2). It is important to point out that these substrates (S1, S4, and S5) showed EC values below 0.46 dS m⁻¹ that are much lower than those of S2 and S3 that were close to 1.2 dS m⁻¹ (Tab. 1).

The effect of increasing EC in the tested substrates for the SFM average productivity variable (Tab. 2) showed an increased response for substrates S1, S4, and S5. For S2, the addition of a nutrient solution caused a positive response, but differences were not observed between 50% (C2) and 100% (C3). However, they were higher than C1. Thus, the most concentrated solution (C3) was indicated for substrates S1, S4, and S5, while for S2 and S3 the 50% dilution (C2) was recommended for use.

In the phenolic foam, which also showed a high EC, the addition of 50% of the concentration of nutrient solution provided similar results to the addition of 100% (Tab. 2). From these results, it can be inferred that substrates with higher EC are more successful for the production of microgreens when using lower concentrations of nutrient solution or only water. When compared at different levels of EC in the nutrient solution (Tab. 2), S3 generated similar results between the use of 50% (C2) and 0% (C1). However, when the nutrient solution increased to 100% (C3) there was a reduction in the average productivity of 7.28%. Therefore, for this substrate, we recommend using only water or NS at 50%, because the response becomes negative with a higher concentration.

For the variable average SDM productivity (Tab. 2) using only water for irrigation (C1), substrates S3 and S4 showed statistically equal values that were higher than the other tested substrates. However, when using NS with 50% of the concentration of nutrients (C2), this difference was diluted, and the substrates did not show a statistical difference between them.

When the NS concentration became 100% (C3), there was an inversion in the behavior obtained for C1 (Tab. 2). This was expected mainly for S3 since it showed a reduction in SDM productivity of 21% from C2 to C3 (Tab. 2). The only substrates that responded positively to the addition of nutrient solutions for SDM were S1, S2, and S5. For S1 and S5, the increase in the concentration of nutrients in the nutrient solution from 50% to 100% did not show a statistical difference, and it was not necessary to add 100% nutrients to the NS. The substrate S4 tended to increase the amount of SDM with the addition of the nutrient solution. However, it did not differ statistically when it was worked without

fertilizer applications. Observing the average productivity of SFM (Tab. 2), which is the variable that represents the commercial weight of this product, the answer was different. It showed greater fresh weight when the concentration of 100% of nutrients in the nutrient solution (NS) was used. In this case, the use of 100% NS is indicated for this substrate to obtain fresh weight gain.

An explanation for the decrease in SDM productivity with the increase in the concentration of nutrients in the nutrient solution from C2 to C3 (Tab. 2) in substrates S2, S3 and S4 is due to the chemical characteristics of these materials that had the highest EC values (Tab. 1). This showed the negative effect of increasing the salinity of the root medium on the absorption of water and nutrients by plants since it decreased or canceled the effects of the increase of the nutrient concentration on growth (Rattin *et al.*, 2003).

From the responses obtained in this study, it appears that commercial substrates for the production of arugula microgreens were more dependent on chemical characteristics, while physical characteristics had less influence on productivity. Thus, studies for each cultivation system are justified, as they can directly influence the productive and qualitative responses of arugula microgreens.

Conclusions

The commercial substrates tested in this study provided good productivity of arugula microgreens grown in a sub-irrigation system, inside a protected environment. However, the concentration of nutrients in the nutrient solution influenced the responses of the substrates.

For production without adding nutrients to the nutrient solution, the use of the substrate S10 Beifiur® organic is recommended.

For greater economic yield, given by the average productivity of fresh mass, we recommend the use of a nutrient solution with 100% of the concentration of nutrients for substrates CSC® vermiculite, Carolina Soil® seedlings, and Carolina Soil® organic. For the Green-Up phenolic foam and the S10 Beifiur® organic, we recommend the use of 50% of the nutrient solution.

When seeking greater yield in dry mass, we recommend the use of 50% diluted nutrient solution for the substrates CSC® vermiculite, Green-Up phenolic foam, and Carolina Soil® organic, or the use of pure water for the S10 Beifiur® organic and Carolina Soil® seedlings.

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Author's contributions

ARW formulated the overarching research goals and aims, developed the methodology, validated the overall replication/reproducibility of results/experiments and other research outputs, conducted the research process, performed the experiments and data/evidence collection, provided the study materials, and prepared the presentation of the published work, specifically writing the initial draft, including substantive translation. WDP formulated the overarching research goals and aims, developed the methodology, conducted the research process, performed the experiments and data/evidence collection, and prepared the presentation of the published work, specifically writing the initial draft, including substantive translation. TSD prepared the presentation of the published work and was in charge of the critical review, commentary or revision.

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