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Organic arugula production in greenhouse using high seedlings from different volumes of substrates

Geazí Penha Pinto[1], Denis Borges Tomio[1], Regina Lúcia Felix Ferreira[2], Sebastião Elviro de Araújo Neto[2], Luís Gustavo de Souza e Souza[2]*, Nilciléia Mendes da Silva[2]

[1]Federal Institute of Acre, Rio Branco, Brazil
[2]Federal University of Acre, Rio Branco, Brazil
*Corresponding author, e-mail: gustavo_souza_fj@hotmail.com

Abstract

The objective of this study was to evaluate the productivity and economic profitability the cultivation of organic arugula in greenhouse, in function of substrate volume at seedling production. The high seedling planting evaluation occurred over different substrate volumes: 50, 100, 200, 300, and 400 cm³, in two plastic-cover protected environments, with and without anti-insect screen mech 50, using randomized blocks as experiment design with four replications and 16 plants per plot. For economic evaluation was checked the agricultural production costs, to determine profitability index (PI), net profitability (NP), total cost (TC), and average total cost (ATC), considering fixed and variable costs per treatment. The highest fresh weight and productivity were obtained when the seedlings are produced on substrate with a volume of 280.3 cm³. While the substrate with 316.5 cm³ of volume provided greater dry mass of the aerial part. The environment without side screens is the most suitable for cultivation of arugula, by presenting lower production total cost (R$ 6.63 m²), the higher net revenue (R$ 6.70 m²), and the highest profitability index 117%. The use of 200 cm³ (R$ 0.37 m² day^{-1}) and 100 cm³ (R$ 0.36 m² day^{-1}) containers produce greatest profits daily per m² for the environment with and without anti-insect screen, respectively. With the increase in the volume of the substrate, there is anticipation in the harvest.

Keywords: seedling production, organic substrate, anti-insect screen, *Eruca sativa*

Introduction

The arugula is a leafy vegetable with great potential in the Brazilian market since their production and consumption in salads, pizzas, sauces and soups for its spicy flavor and because it contains a wide range of phytonutrients such as vitamin A, vitamin C and flavonoids, glycosinolates, potassium, sulfur, iron and fiber (Min et al., 2018; Schiattone et al., 2018; Dantas & Torres, 2010; Oliveira et al., 2010).

Despite the arugula has low susceptibility to pests (aphids, great southern white and black cutworm and diseases (like leaf white rust, alternaria leaf spot and *damping-off*). As alternatives, the protected cultivation and the organic system can reduce the phytosanitary problems and produce without pesticides (Ferreira et al., 2014; Solino et al., 2010). In this cultivation system increased the diversity of plants that are shelter for natural enemies. With practices such as crop rotation, polycultures, green manure, companion plants and increased organic matter content (Sediyama et al., 2014).

The culture with anti-insect screnn mechanically controls insects and disease vectors, but increases the temperature up to 2 °C (Duarte et al., 2011), reduces wind speed, and photosynthetically active radiation in almost 30% (Reisser Júnior et al., 2003); however, increases the efficiency in the use of such radiation that is higher than in a greenhouse without side nets (Radin et al., 2004) and contributes to nitrogen metabolism and reduced nitrate content in arugula (Schiattone et al., 2018). Therefore, the lower evaporative demand of the internal environment increases leaf area and plant biomass (Reisser Júnior et al., 2003).

This higher photosynthetic efficiency in protected cultures combined with high (more developed) seedlings produced with larger volumes of substrate can anticipate crop cycles as in cucumber (Seabra Júnior et al., 2004),

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reducing the production cost.

The use of high seedlings is possible better quality indicators, such as stem diameter, root and aerial part mass (Santos et al., 2015).

The increase in the substrate volume is also a strategy to improve the seedlings quality and increase the productive performance of cucumber (Seabra Júnior et al., 2004) and lettuce (Ortiz et al., 2015). This performance is due to the greater seedling development caused by the greater availability of nutrients and water to the root system (Costa et al., 2011; Maggione et al., 2014).

The quality of the seedling in the nursery is not a definitive condition of performance in the field because in field condition it is possible to recover growth and development of seedlings with different qualities (Magro et al., 2011; Simões et al., 2015).

For the adoption of an agricultural technology, additional costs and revenue must be analyzed (Araújo Neto et al., 2012; Machado Neto et al., 2018).

The objective of this study was to evaluate the productivity and economic profitability the cultivation of organic arugula in greenhouse, in function of substrate volume at seedling production.

Material and Methods

Two experiments were carried out from April to September 2014 on Sítio Ecológico Seridó, located at Rodovia AC-10, km 04, Rio Branco (AC), coordinates (09°53'10.6'' S; 67°49'08.6'' W; 170 m altitude). The local climate is equatorial varying to tropical hot and humid with a well-defined dry season with annual rainfall ranging from 1600 to 2750 mm, Am type according to Köppen classification.

The experimental design was randomized blocks with four replicates and five treatments, with 16 plants per plot, and 0.30 m x 0.30 m of spacing. In each environment, as treatment, seedlings of different qualities index (IQM) (Dickson, 1960), produced in different volumes of substrate: 50 cm³, 100 cm³, 200 cm³, 300 cm³, and 400 cm³, were tested. In a pre-test, these volumes of substrates produced seedlings with IQM of 0.015; 0.017; 0.021; 0.025 and 0.028, respectively.

The two protected cultivation environments, used for the experiments, were covered with an additive plastic film of 150 μm, one with anti-insect net mesh 50 on the sides, and the other without.

The substrate was composed of organic layer soil (30%), organic compost (30%), rice husk ash (30%), coal dust (10%), natural thermal phosphate (1.5 kg m^{-3}), dolomitic limestone (1.0 kg m^{-3}), and potassium sulphate (1.0 kg m^{-3}) and was analyzed related to chemical and physical characteristics (Table 1).

Table 1. Chemical composition and physical characteristics of substrate in seedling production. Sítio Ecológico Seridó, Rio Branco, Acre, Brazil, 2014.

pH	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Na
					---------- mg L^{-1} ----------					
7.43	2.74	340.00	57.40	38.80	139.00	0.14	0.02	7.05	0.30	47.00
					Physical characteristics					
		AD	PD	PS	SP	W.H.C.	EC	O.M.		
		----- kg m^{-3} ------			------------ % ------------		mS cm^{-1}	g 100 g^{-1}		
		862.67	2,344.38	73.14	26.86	97.00	0.763	18.37		

AD = apparent density; PD = particles density; PS = porous space; SP = solid particles; W.H.C.= water holding capacity; EC = electrical conductivity; O.M.= organic matter

In the nursery, while conducting the experiment, the temperature ranged between 18.1 and 46.8 °C, with a daily average of 30.9 °C, and relative humidity ranges from 50.0% to 97.8%, with an average of 69.9%.

The sowing was performed in plastic cups reusable, using three to four seeds per container and at the tenth day a thinning was carried out leaving only one seedling.

The soil preparation consisted of plowing and harrowing through animal traction, followed by the incorporation of an organic compound (21 t ha^{-1} dry base), produced from *Brachiaria* grass, unclogging and lifting of the job site (0.2 m height) with a hoe.

The soil of the vegetables organic cultivation, was on a six months fallow with spontaneous plants, in a light-undulated topography, classified as YELLOW Plinthic ACRISOL, without apparent erosion, moderate drainage, with the following chemical characteristics: pH 6.4 ; MO: 30 g dm^{-3}; P: 15 mg dm^{-3}; K: 1.5 mmolc dm^{-3}; Ca 62 mmolc dm^{-3}; Al: 1 mmolc dm^{-3}; H+Al: 20 mmolc dm^{-3}; CTC: 82 mmolc dm$^{-3,}$ and V: 102.5% for 0-20 cm layer. And physical characteristics: apparent density (Da) = 983 kg m^{-3}; particles density (Dp) = 2476.7 kg m^{-3}; porous space (EP) = 65.6%; solid particles (PS) = 34.4%; soil holding capacity (CRA) = 62.7%; C.E. = 0.546 mS.cm^{-1}; and O. M. = 9.86%.

The irrigation, by micro sprinklers, was performed daily applying a water depth of 6 mm day^{-1}.

The temperature in protected environments ranged between 18 °C and 35 °C and 21°C and 44 °C in open and closed environment, respectively.

The arugula harvests were carried out according to the maximum vegetative development. Plants from seedlings produced on large containers were harvested early, considering that visually the plants already had the commercial standard.

The analyzed variables were fresh commercial matter (FCM), and dry matter mass of leaves (DMML) both expressed as g plant^{-1} measured through electronic scale, and productivity, expressed in kg ha^{-1}, estimated considering the plant fresh weight average, planting density, and floor space index per hectare of 70%. The dry mass was determined using an oven with air forced circulation at 65 °C until the samples reach a constant weight.

The experiments economic analysis was performed according to the agricultural production costs, to determine profitability index (PI), net profitability (NP), total cost (TC), and average total cost (ATC) per treatment. The calculations were performed to determine the index per m² and considering the price of R$ 1.20 per pack with a mass greater than or equal to 200 g.

The daily work was calculated considering expenses equivalent to monthly salary remuneration (R$ 937.00), added of 51.56% referring to charges, vacations, 13th salary, accident insurance, FGTs (severance pay fund), which results in R$ 61.74 day^{-1} (CONAB, 2010).

Depreciation (D), which is the necessary cost for the substitution of capital goods when they become useless, was calculated using the linear method for each crop, which can be calculated by equation:

$$D = \frac{Cv - Rv}{Ul} P$$

where:

D - depreciation, R$ / crop; Va - current resource value, R$;

Rv - residual value (resale value or final value of the good after rational use in the activity), R$;

Ul - useful life (period in cycles that the good is used in the activity);

P - Production cycle.

In this work, the following depreciations were considered 25 years for masonry structures, 20 years for wood, with final value corresponding to 20%; 18 months for plastic film, 10 years for PVC tubes and 5 years for micro sprinkler with 5% final value (CONAB, 2010).

Fixed and variable costs were added to the opportunity cost of 6%, adding the value of land that could be rented to another activity, considered in this work to be of beef cattle, corresponding to R$ 15.00 / month, equivalent to 0.92 U.A. (1.5 head per hectare) (INCRA, 2003) at the average price of R$ 12.5 / head / month. Were added to the administration costs of 3% of working capital refer to office expenses (electricity, telephone, printer, notepad, consumables, computer, internet), accounting and training services, all linked to the production process (CONAB, 2010).

As it refers to organic cultivation, it considered as variable cost, in addition to labor, seeds, substrate, electricity and organic compost, neem oil 1% (two applications) and *Baccilus thuringiensis* (1 application) for insect pest control, Bordeaux mixture - 1% (2 applications) and sulfocalic mixture - 4% for disease control, inputs permitted by the Brazilian legislation on organic agriculture.

The total cost represents the sum of all costs with capital service flows (depreciation) and inputs. Its calculation was based on the formula: TC = FC + VC; where: TC - total cost; FC - fixed cost; VC - variable cost.

The calculation of the profitability index (PI) was obtained by the formula: PI = NR / (I + WC) x 100, where: PI - profitability index; NR - net revenue; I - fixed investment; WC - working capital.

The average total cost was obtained by the ratio between total cost and productivity ATC = TC / productivity).

Net revenue corresponds to the difference between total revenue and total cost: NR = TR - TC; where: NR - net revenue; TR - total revenue; TC - total cost.

The data were submitted for verification of discrepant data (outliers) by Grubbs's test, error normality by Shapiro-Wilk test, and homogeneity of variances by Cochran's test. Subsequently, an analysis of variance was performed by the F test. After identified the minimum variation (< 7) between the mean square of the experiments residues in environments with and without a net, a combined analysis of experiments were carried out.

For the quantitative factor regression analysis were performed for all variables, except days of harvest, which did not meet the assumptions of normality and homogeneity, so the non-parametric Friedman test was applied.

The economic indicators were not analyzed statistically because they did not show normality and homogeneity, as there was no difference in commercial productivity between treatments (pack / m²).

Results and Discussion

The factors of substrate volume and protected cultivation, responded in isolation to all production and economic variables. The productivity and the fresh commercial mass of plants were influenced by the substrate volume, responding in quadratic function with maximum productivity of 20,707.6 kg ha^{-1} and 266.22 g plant^{-1}, respectively, both with a volume of 280.3 cm³ (Figure 1).

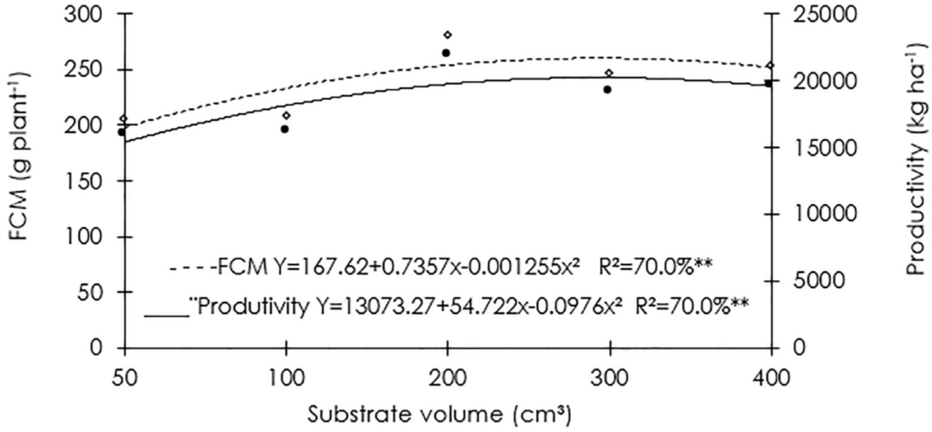

Figure 1. Argula productivity and fresh commercial mass (FCM) from seedlings grown in different substrate volumes. Sítio Ecológico Seridó, Rio Branco, Acre, Brazil, 2014.

Despite the different quality, nursery seedlings do not ensure an increased production in the field (Magro et al., 2011; Simões et al., 2015), seedlings produced with a greater volume of substrate can increase the yield of cucumber (Seabra Júnior et al., 2004), lettuce (Leal et al., 2011; Ortiz et al., 2015), and cauliflower (Godoy & Cardoso, 2005). Because they have more space for root development and consequently leaf biomass, ensuring according to Seabra Júnior et al. (2004), greater productivity and to the absence of stress in transplantation and in developing post-transplant.

However, the maximum productivity was not achieved in the highest volume, also confirming that the highest accumulation of dry matter of 16.5 g plant^{-1} (Figure 2) occurred on plants derived seedlings developed on a substrate with 326.3 cm³ of volume. This was characterized as a limiting volume for high productivity, as the seedlings on this volume, provide lower productivity in the field due to nutrient depletion of the substrate, and consequent nutritional deficiencies in the seedlings as in cauliflower (Godoy & Cardoso, 2005). Therefore, it is recommended that seedlings in smaller volumes of substrates when reaching maximum size should be transplanted.

The productivity and the masses of fresh commercial matter and dry aerial part, in protected cultivation, were higher than in open environment (Table 2).

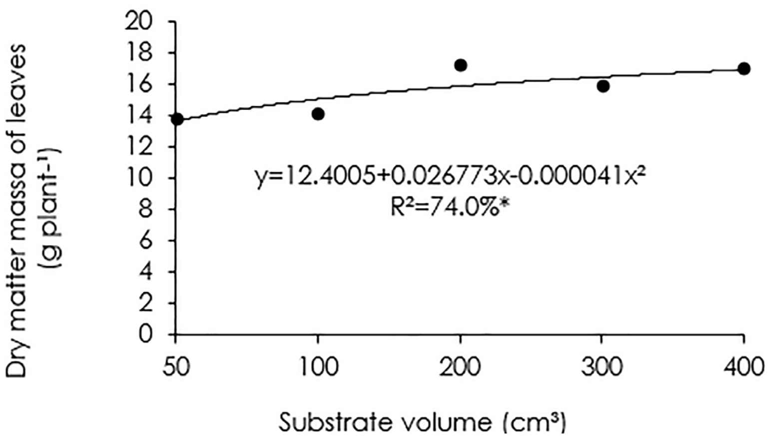

Figure 2. Argula productivity and fresh commercial mass from seedlings grown in different substrate volumes. Sítio Ecológico Seridó, Rio Branco, Acre, Brazil, 2014.

Table 2. Arugula productivity, fresh commercial mass (FCM) and dry matter mass of leaves (DMML), net profitability (NP), total cost (TC), and profitability index (PI) in different environments of organic cultivation system. Sítio Ecológico Seridó, Rio Branco, Acre, Brazil, 2014.

Protected cultivation	Productivity		FCM		DMML		NP	TC	PI
	kg ha^{-1}		---------- g planta^{-1} -------				------- R$ m² --------		%
Screened	19,541.70	a	251.30	a	16.50	a	6.52	6.81	110
Unscreened	17,702.30	b	227.60	b	14.70	b	6.70	6.63	117
C.V. (%)	6.64		9.10		7.82				

Averages followed by the same letter do not differ (p>0.05) between them by Tukey test.

The net profitability and rate of return had small differences among environments, with an advantage for the unscreened environment. Despite the difference in productivity between the screened and unscreened cultivation, it had no impact on the total return of the system which was R$13.33 m^{-2}. This happens because the average mass of plants for both was greater than 200 g, so, a pack was composed of only one plant, and in both types of environments there was an average production equal to 11.11 packs per m². This production was the same for all substrate volumes, with no difference between them in the economic variables (Table 3).

In this case, productivity was fundamental to guarantee profitability in the activity, since the price of organic products in direct sales has little variation. According to Machado Neto et al. (2018), that the productivity and price of the organic tomato, followed by packaging and labour costs, had the greatest influence on the profitability of the activity.

The profitability index, which is the activity payback due to net profitability by operational costs, points out that it is a profitable activity (Table 3).

Table 3. Cultivation days until harvest (DUT), net profitability (NP), average total cost (ATC), daily profit (DP), and profitability index (PI) of the arugula culture after transplantation for two cultivation rooms. Sítio Ecológico Seridó, Rio Branco, Acre, Brazil, 2014.

Substrate volume	Environment											
	------------- Unscreened -------------						--------------- Screened --------------					
	DUT		NP	ATC	DP	PI	DUT		NP	ATC	DP	PI
cm³			--------- R$ m² ----------			%			---------- R$ m² ----------			%
400	18	a	4.88	0.76	0.27	63	18	a	4.73	0.77	0.26	60
300	18	a	6.16	0.65	0.34	93	18	a	6.02	0.66	0.33	89
200	19	b	7.10	0.56	0.37	124	20	b	6.93	0.58	0.35	118
100	22	c	7.68	0.51	0.35	148	21	c	7.54	0.52	0.36	142
50	26	d	8.13	0.47	0.31	170	26	d	7.95	0.48	0.31	160

Number of days until harvest (DUT) followed by the same letter do not differ by Friedman test.

Furthermore, for each real invested there is payback of R$ 1.17 for cultivation without an anti-insect screen and R$ 1.10 with the screen. This payback rate is considered high for the agricultural sector, where those rates vary from 9% to 54% as in castor bean (Araújo et al., 2016).

The higher arugula productivity in a greenhouse with the sides closed with an anti-insect screen is a consequence of the photosynthetic efficiency of these plants under these conditions. A greenhouse with an anti-insect screen on the sides reduces the wind speed, and the incident photosynthetically active radiation in approximately 30% (Reisser Júnior et al., 2003), and increases the temperature up to 2 °C (Duarte et al., 2011), and the efficiency in the use of such radiation, which for lettuce reaches 0.44 g mol^{-1} and 0.60 g mol^{-1} of dry matter, higher than in greenhouse without side screen (0.45 and 0.53 g mol^{-1}) (Radin et al., 2004). In tomatoes, the reduction in energy input reduces the evaporative demand of the internal environment causing morphological and physiological changes, increasing leaf area and leaf maintenance, increasing the production of dry matter (Reisser Júnior et al., 2003).

The economic indicators suffer a linear drop-off according to the increase in the volume of the container, mainly due to the costs increase related to the container, substrate volume, and labor for filling and planting of seedlings, inversely proportional to days of cultivation until harvesting. In this case, the additional technology, such as increase of supplies, did not provide enough productivity to significantly reduce the production cost and increase the economic profitability of the business (Araújo Neto et al., 2012).

Therefore, the daily profit, which is the amount earned per day per square meter minus the production costs, can be used to designate the most cost-effective treatment due to the use of resources and area, in this case the maximum value was found in the treatment in the 200 cm³ container except in unscreened greenhouse, and 100 cm³ in screened greenhouse.

The profitability index also follows this negative linear trend with the increase in the substrate volume, almost 3 times lower when it is 400 cm³ when compared to the container of 50 cm³, regardless of the use of anti-insect screen.

The harvest was anticipated in eight days for the plants derived from seedlings developed in substrates with 300 cm³ and 400 cm³ (Table 3). This precocity in the production was also observed in cucumbers by Seabra Júnior et al. (2004), because cucumber plants originating from seedlings produced in containers with a larger volume of substrate (121.2 cm³) were harvested before those produced in a smaller volume (34.6 cm³). This precocity is attributed to the quality of the seedling, since they presented a higher balance between aerial part and root system, and lower post-transplant stress. This shorter time using the environment reduces fixed and variable production costs, a key point to reduce the average cost of the product (Araújo Neto et al., 2012).

Conclusions

The environment without side screens is the most suitable for cultivation of arugula, by presenting lower production total cost (R$ 6.63 m²), the higher net revenue (R$ 6.70 m²), and the highest profitability index 117%. Although the environment covered with plastic film and anti-insect screen on the sides increase productivity of arugula.

The use of 200 cm³ (R$ 0.37 m² day^{-1}) and 100 cm³ (R$ 0.36 m² day^{-1}) containers produce greatest profits daily per m² for the environment with and without anti-insect screen, respectively.

With the increase in the volume of the substrate, there is anticipation in the harvest.

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