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Production of Arugula Baby-Leaf Type

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Abstract: *Baby leaf is the name adopted for leafy vegetables obtained from early harvesting, in relation to the traditional time for consumption, presenting young leaves that are not completely expanded. Without current legislation in Brazil, production of this type of vegetable is still small and research is needed to determine production standards such as fertilization and the most suitable substrates. Therefore, the objective of this work was to evaluate the influence of types of substrates and doses of slow-release fertilizers on the production of baby-leaf arugula. The work was performed at School of Natural Sciences and Engineering of São Paulo State University (UNESP), Campus of Ilha Solteira, São Paulo state, Brazil, in a greenhouse Pad & Fan type. The experiment was installed in black polyethylene trays with 60 cells filled with different substrates: S1 – Forth Conditioner®, S2 – Tropstrato® and S3 – BioFlora®, with one seed per cell. The fertilization variation factor was performed before sowing with the treatment of substrates with three doses of the tested fertilizer and a control without addition. The fertilizer used was Forth Cote (MiniPrill 18-05-09) 5M® at doses: D1 – control without fertilizer addition, D2 – 2.0 g k^{-1} of substrate, D3 – 4.0 g kg^{-1} and D4 – 6.0 g kg^{-1}. The experimental design used was a 3×4 factorial scheme (substrates x fertilizer doses), totalling 12 treatments, four replicates, with each replicate consisting of five experimental units with one seed each. Every seven days until the end of the experiment, 35 days after seedlings emergence (DAE), the total height and number of leaves were evaluated. The height was measured using a graduated ruler, measuring five plants of each experimental unit close to the substrate until the apex of the highest leaf, the average was calculated to know the mean height per plant. The number of leaves was measured by counting the leaves of five plants in the experimental unit, and then calculating the mean of leaves per plant. At the end of the experiment, fresh mass of shoot and root were evaluated. Data were tabulated and the analysis of variance was performed applying Tukey and regression tests when data was significant according to F test. The statistical software used was Sisvar. According to the data presented, the ideal substrate for the production of arugula baby-leaf is BioFlora with addition of 2.81 g kg^{-1} of slow-release fertilizer (Forth Cote MiniPrill 18-05-09 5M®) with harvest approximately 21 days after the beginning of seedlings emergence.*
Key Word*: Substrate; Slow-release fertilizer; Early harvesting.*

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I. Introduction

With the world population growth at an accelerated rate, food production needs to be done in an accelerated way as well, and this occurs in all areas of vegetable production. In addition to this, there is a growing demand for good quality vegetables on offer throughout the year. Thus, investment in new cropping systems that adapt regions to cultivation has been intensified[1].

One of the most consumed vegetables may be highlighted the arugula (*Eruca sativa*). It is a species of the Brassicaceae family, hardwood, herbaceous, much appreciated in form of salad. Due to its simple planting system, fast vegetative growth and short cycle, it has been gaining more and more space in the consumer market, in addition to having considerable nutritional value as having large amounts of vitamins A and C, potassium, sulphur and iron, being of great importance to prevent inflammation, especially in the intestine and may be used to aid in gingivitis treatment. Studies show that it can be used in folk medicine, as an invigorating, digestive, anti-asthmatic, among others[2,3,4].

Considering this, it is of great importance that the production of the plant is increased in a shorter period and for this, it is necessary to look for alternative ways to speed up the production process. In case of crops with relatively short cycles, the production acceleration process should start with seedlings production, for the time between germination and transplantation to be as short as possible.

In addition to this, nowadays, another form of vegetable production has been gaining space in the consumer market: the baby leaf type.

Baby-leaf type vegetables are attractive due to their small size, tender consistency and differentiated flavour. This type is produced cultivating regular plants, such as watercress, lettuce, beet, chard or arugula, however the production ends with the early harvest, when the leaves do not present fully expanded leaf blade. In Brazil there are no official classification standards to define the harvest time for baby leaf type plants, which means that the product is marketed in different sizes depending on the species and the type of use (only leaves or whole plant)[5].

Just like the traditional production system, in which you must wait for the entire cycle and wait for the plant to grow completely, the environment in which baby leaf vegetables are grown also depends on a good substrate for their development.

One of these limiting factors in seedling production is the substrate. Plant substrate is defined as any porous material, used in mixture or pure, which provides physical and chemical conditions for good plant development[6]. In the production process of vegetable seedlings, the choice of efficient substrates is essential for good development of plants, reflecting both nutritional characteristics and productive capacity[7].

For a substrate to meet the needs of vegetable production, it is necessary to know the morphological and physiological characteristics of the species to be cultivated. Several factors must be observed to choose the best substrate for a given culture, such as its physical and chemical characteristics[8]. The physical properties of substrates, such as porosity, density, water retention capacity, are fundamental to know the ease of oxygen diffusion to the roots and the water storage capacity. While chemical properties, such as pH, organic matter and soluble salts content, and cation exchange capacity (CTC), are essential in the dynamics of nutrient availability[9].

The seedling production market offers a wide range of ready-made substrates, called commercial substrates and precisely due to having large number of types, it is necessary to be careful when choosing, as often the desired substrate characteristics for a plant are not those desired for another. In a research carried out by São José et al.[9], it is possible to conclude what was mention previously, in which two commercial substrates were tested in the emergence of seeds and seedling development of *Dianthus chinensis* and *Limonium sinuatum*, in this case only one of the commercial substrates was recommended for use in both species. This reinforces the idea that it is necessary to test, even ready-made substrates, for the crop of interest.

Having chosen the substrate that best suits the seedlings production of required species, it is important to think about a second point: the fertilization of this substrate, as many commercial materials are free from complementary fertilization, existing only the nutrients of the materials that make up its formulation. In addition, the availability of nutrients in the initial seedlings phase may increase production, as they will be able to go field faster, in addition to being more vigorous.

Fertilization brings important benefits to the plant as it strengthens its nutritional status, which will guarantee seedlings with a more vigorous and better developed root system, greater number of leaves, greater leaf area, which will guarantee higher photosynthetic rates[10].

Thus, the aim of this study was to evaluate the behaviour of arugula seedlings developed on different commercial substrates and fertilizer doses.

II. Material And Methods

The work was performed at the School of Natural Sciences and Engineering of São Paulo State University (UNESP), Campus of Ilha Solteira, São Paulo state, Brazil, in a greenhouse Pad & Fan type, which presented an average ambient temperature of 27.5 ºC and a relative humidity of 77.3%.

The experiment was installed in black polyethylene trays with 60 cells filled with different substrates: S1 – Forth Conditioner®, S2 – Tropstrato® and S3 – BioFlora®, with one seed per cell. Substrate information, according to manufacturers, is shown in Table no 1.

Table no 1. Characteristics and composition of different substrates, according to information from manufacturers.

Substrate	%WRC	pH	EC (dS m^{-1})	%Humidity	Composition
S1 – Forth Condicionador®	168	7.3	1.8	51.6	Naturally decomposed pine bark and ash
S2 – Tropstrato®	130	5,8 ± 0.3	1.5 ± 0.3	60	Pine bark, peat, charcoal, simple superphosphate
S3 – BioFlora®	150	6.0 ± 0.5	0.5 ± 0.3	60	Pinus/Eucalyptus bark, coniferous fibre, rice straw, peat, coconut fibre, vermiculite, limestone, simple superphosphate, ammoniated SFS.

WRC – Water Retention Capacity; EC – Electric conductivity. Source: The manufactures.

The fertilization variation factor was performed before sowing with the treatment of substrates with three doses of the tested fertilizer and a control without addition. The fertilizer used was Forth Cote (MiniPrill 18-05-09) 5M® at doses: D1 – control without fertilizer addition, D2 – 2.0 g k^{-1} of substrate, D3 – 4.0 g kg^{-1} and D4 – 6.0 g kg^{-1}.

The experimental design used was a 3×4 factorial scheme (substrates x fertilizer doses), totalling 12 treatments, four replicates, with each replicate consisting of five experimental units with one seed each.

The treatments were properly homogenized and trays were filled with this mixture. Arugula seeds were sown and subsequently irrigated. This irrigation was performed daily until the substrate container capacity was reached.

Every seven days until the end of the experiment, 35 days after seedlings emergence (DAE), the total height and number of leaves were evaluated. The height was measured using a graduated ruler, measuring five plants of each experimental unit close to the substrate until the apex of the highest leaf, the average was calculated to know the mean height per plant. The number of leaves was measured by counting the leaves of five plants in the experimental unit, and then calculating the mean of leaves per plant.

At the end of the experiment, fresh mass of shoot and root were evaluated. The five plants of each experimental unit were removed from the tray and washed with running water to remove all substrate residue. After this procedure, with aid of scissors, aerial part and roots were separated, weighting the set of five plants separately to obtain the fresh mass shoot and root (in grams), the mean was calculated to obtain the mass per plant.

Data were tabulated and the analysis of variance was performed applying Tukey and regression tests when data was significant according to F test. The statistical software used was Sisvar[11].

III. Result

Figure no 1 shows the regression analysis of the height of baby-leaf arugula plants grown on different substrates and fertilizer doses evaluated for a given period. It is possible to observe that there was a different behaviour comparing the three substrates in the different fertilizer doses.

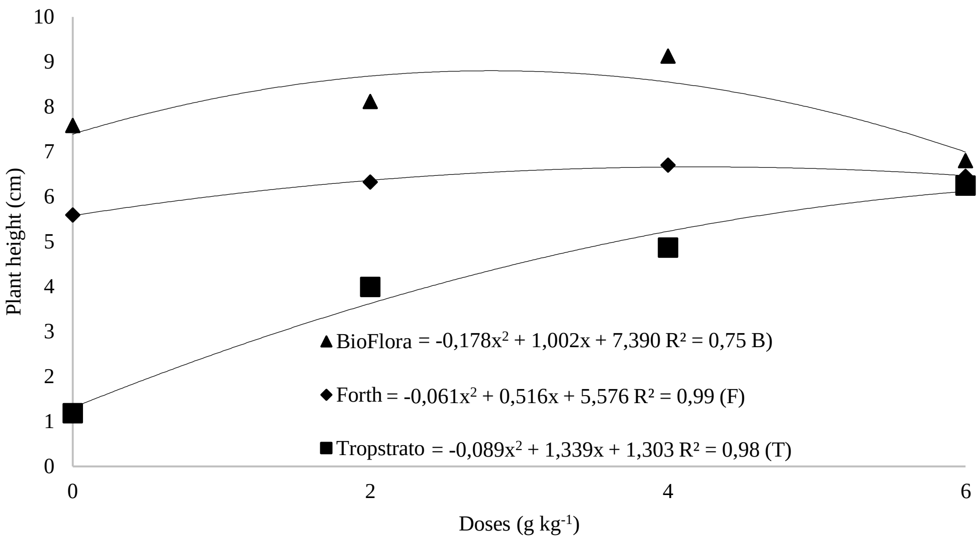

Figure no 1. Height of arugula plants subjected to different doses of slow-release fertilizer in different substrates.

The three substrates evaluated showed quadratic behaviour in relation to the doses of slow-release fertilizer, with a gradual increase in seedling height and subsequent decline. Among the substrates, BioFlora presented the highest plant heights, followed by the Forth substrate and finally the Tropstrato substrate.

Analysing the height of arugula plants subjected to doses of slow-release fertilizers within each level of substrate (Table no 2), it is possible to state that at doses 0, 2 and 4 g kg^{-1} there was statistical difference among treatments. In the three dosages, the substrate that highlighted was BioFlora, followed by Foth and finally Tropstrato. In the control (0 g kg^{-1}), the Tropstrato substrate produced seedlings with a reduction of 84.4% in relation to BioFlora. At dose 2 g kg^{-1}, this difference reduced to 50.8% and at dose 4 g kg^{-1} the difference was 46.7%.

Table no 2. Height of arugula plants subjected to different doses of slow-release fertilizer in different substrates.

Plant height (cm)				
Substrates	Doses (g kg^{-1})			
	0	2	4	6
Forth	5.59 b	6.32 b	6.69 b	6.45 a
BioFlora	7.58 a	8.11 a	9.12 a	6.80 a
Tropstrato	1.18 c	3.99 c	4.86 c	6.24 a
CV(%)	17.82			

Means followed by the same letter in the column do not differ from each other at the 5% level using the Tukey Test.

The evolution of height of arugula baby-leaf type plants in relation to the evaluated period showed linear trend for all substrates and BioFlora substrate presented the highest averages in all evaluations (Figure no 2).

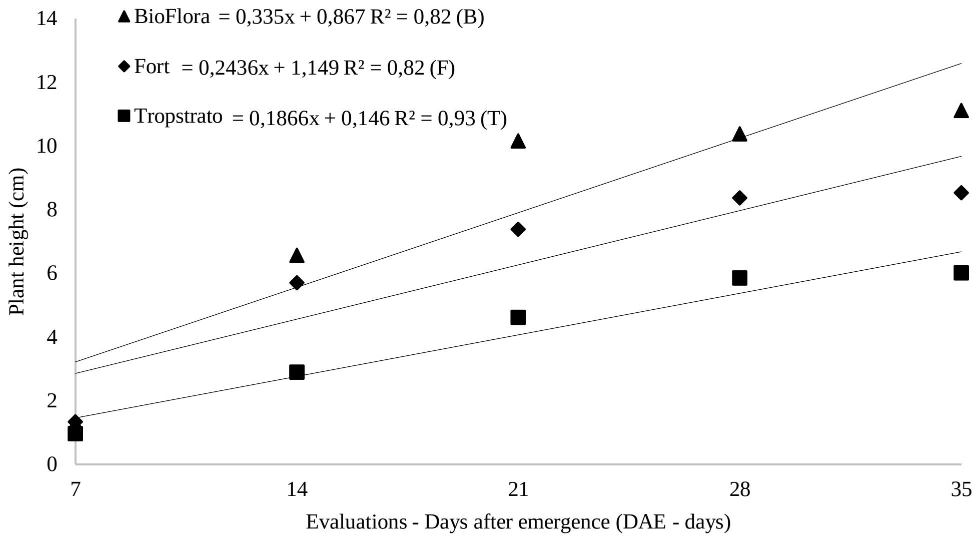

Figure no 2. Plant height (cm) of arugula baby-leaf type developed on different substrates and fertilizer doses.

The number of baby-leaf arugula leaves grown in different substrates and doses of slow-release fertilizer is reported in Figure no 3 and it is possible to observe that there was a linear trend for all substrates. Up to the dose of 4 g kg^{-1} the behaviour of the plants was in the BioFlora, Fort and Tropstrato substrate sequence, while at the dose of 6 g kg^{-1} the Tropstrato substrate outperformed the Forth substrate.

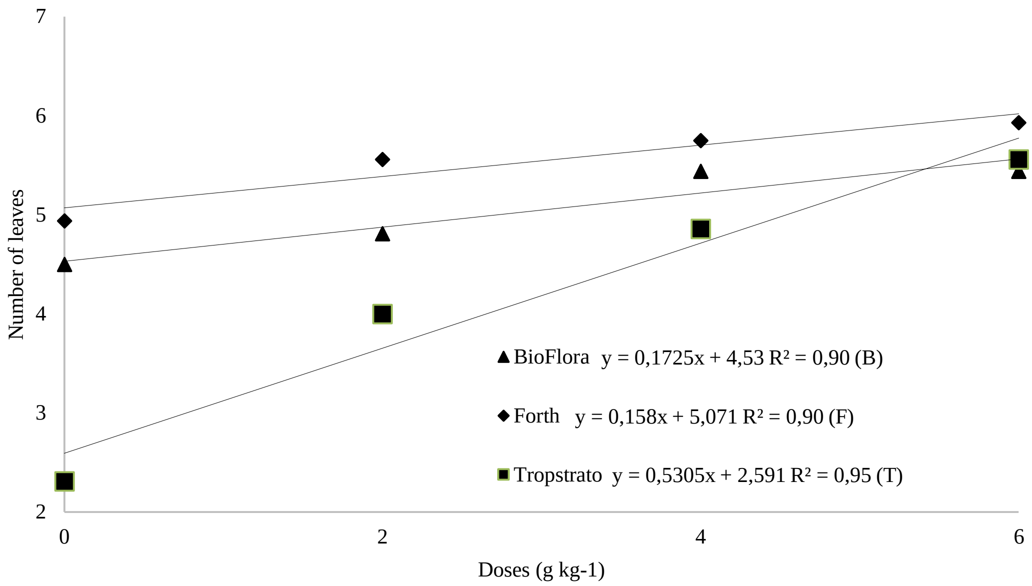

Figure 3. Number of leaves of arugula baby-leaf type developed on different substrates and fertilizer doses.

In a second analysis, when observing the doses of slow fertilization fertilizers within each level of substrate, they were also important factors for the increase in leaves number (Table no 3).

In the control (without fertilizer addition) the Forth and BioFlora substrates did not differ statistically from each other statistically, however, both differed from the Tropstrato substrate. With a dose of 2 g kg^{-1} the three substrates differed and this time Forth substrate produced plants with a greater number of leaves. With dose of 4 g kg^{-1}, the most expressive and statistically significant difference was between substrates Forth and Tropstrato and with dose of 6g kg^{-1} there was no statistical difference for any of substrates.

Table no 3. Number of leaves of arugula baby-leaf type seedlings subjected to different doses of slow-release fertilizer in different substrates.

Number of leaves				
Substrates	Doses (g kg^{-1})			
	0	2	4	6
Forth	4.9 a	5.6 a	5.8 a	5.9 a
BioFlora	4.5 a	4.8 b	5.4 ab	5.4 a
Tropstrato	2.3 b	4.0 c	4.9 b	5.6 a
CV(%)	14.17			

Means followed by the same letter in the column do not differ from each other at the 5% level using the Tukey Test.

The regression analysis of the data collected on the number of leaves on each substrate for a period of 35 days showed a quadratic trend for the BioFlora substrate and a linear trend for the Forth and Tropstrato substrates (Figure 3).

For the BioFlora substrate, this quadratic trend was an increase and subsequent decrease in the number of leaves, while this characteristic was not observed in the other substrates.

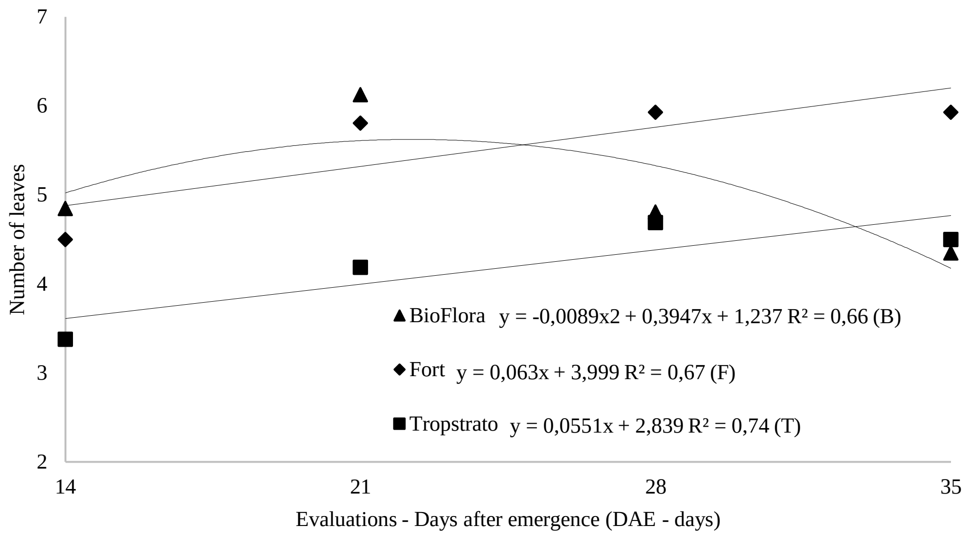

Figure no 3. Number of leaves of arugula baby-leaf type developed on different substrates and fertilizer doses.

The fresh mass of shoot and root only showed statistical differences for the substrate factors and fertilizer doses separately, therefore, the interaction between them did not show statistical differences. For fresh mass of shoot, a quadratic behavior was observed for regression, while for fresh mass of root, it showed a linear trend (Figure no 4).

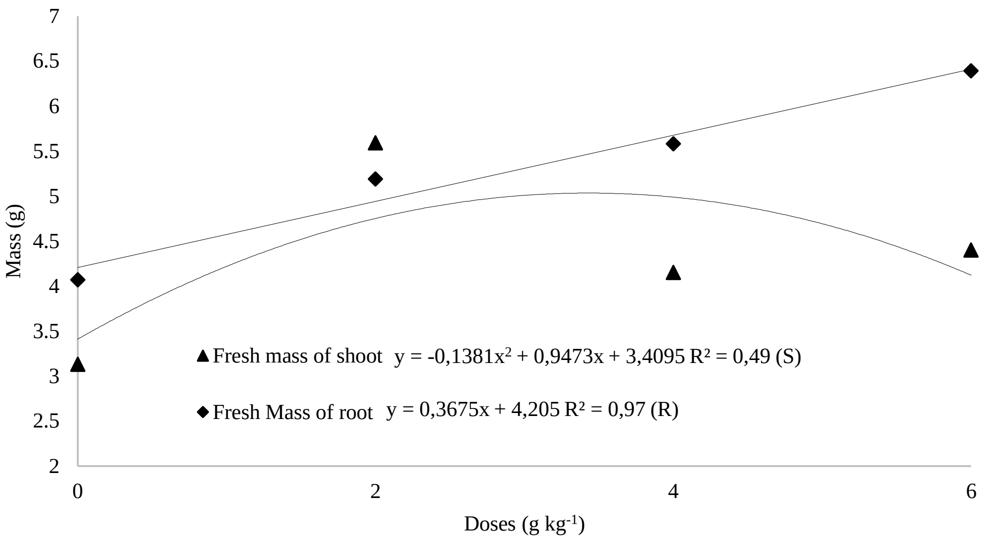

Figure no 4. Fresh mass of shoot and root of arugula baby-leaf type developed on different substrates and fertilizer doses.

In relation to the substrates, for fresh mass of shoot there was only statistical difference between Forth and Tropstrato substrates, with the first having greater accumulation. For fresh mass of root, the statistical difference was between BioFlora substrates, which provide greater accumulation in relation to Tropstrate substrate.

Table no 4. Fresh mass of shoot and root of arugula baby-leaf type seedlings subjected to different doses of slow-release fertilizer in different substrates.

Substrates	FMS	FMR
	-- g --	
Forth	4.14 a	5.54 ab
BioFlora	3.85 ab	5.66 a
Tropstrato	3.43 b	4.72 b
CV(%)	16.77	20.26

Means followed by the same letter in the column do not differ from each other at the 5% level using the Tukey Test.

IV. Discussion

Deriving regression equations of Figure no 1, it was observed that the maximum dose for the maximum height found in the BioFlora substrate is 2.81 g kg^{-1}; for the Forth substrate, this maximum dose was 4.22 g kg^{-1} and in relation to the Tropstrato substrate, it was 7.52 g kg^{-1}.

It is possible to infer that there was greater need for fertilization in substrate that presented smaller plant (Tropstrato) and even so, it was not enough to achieve growth in BioFlora.

One of the explanations for the fact that arugula seedlings are higher in BioFlora substrate may be due to the composition, as this substrate is fertilized with simple superphosphate (Table no 1). Simple superphosphate, called SSP or super simple, is a fertilizer used in agriculture as a source of phosphorus, calcium and sulphur, nutrients of great importance for plant development.

Considering that the slow-release fertilizer formulation was 18-05-09, the simple superphosphate present in the substrate supplied phosphorus necessity.

Considered an essential nutrient, phosphorus acts directly on development of plant roots, enabling them to have good absorption of nutrients and water. This nutrient plays an important role in several metabolic processes, such as ATP synthesis and photosynthesis[12].

In Brazil, there is still no official classification regarding the maximum length that may be used to be classified as baby leaf plant, however, according to Purquerio et al.[13], the suggestion is that plant present 15 cm maximum in leaves length.

Therefore, all dosages of slow-release fertilizer in the evaluated substrates are below 15 cm. However, considering the time to reach greater height, the BioFlora substrate with a dose of 2.81 g kg^{-1} produced highest plants in a shorter time. In this case, it is essential that more plant is produced in a shorter period of time so consumer market may be improved.

As seen in Figure 3, the increment in number of leaves was increasing for all substrates, but at the highest dose (6 g kg^{-1}) the Tropstrato substrate produced more arugula leaves than the Forth substrate, which was the second.

Among substrates evaluated, Tropstrato increased 140.7% in number of leaves in relation to control (0 g kg^{-1}), while making this same comparison with the other substrates, BioFlora increased 20.9% and Forth increased 20%.

With the derivation of equations in Figure no 1, mentioned at the beginning of this section, the maximum dose was calculated to find the greatest plant height. Using these maximum dosages in the equations in Figure no 3 (replacing the x with the dosage found), it is possible to verify that at the maximum dosage for height the BioFlora substrate would produce 5.01 leaves, Forth 5.74 leaves and Tropstrato 6.6 leaves. It is then observed that the Tropstrato substrate would require more slow-release fertilizer to produce more leaves, however, with smaller size.

For the fresh sale of baby-leaf arugula, these two characteristics are important, the height of these plants and the number of leaves, since the leaves are the commercially important parts of this vegetable. Therefore, it is important for the producer to check the costs so that the final product does not increase in price, as baby-leaf vegetables on the market already have an additional value.

The number of leaves presented an interesting fact throughout the evaluation period (Figure no 3) in which there was a decrease in leaves in plants grown in the BioFlora substrate. The only plausible explanation is that these leaves were senescent; they ended up drying out and were not included in the count. This incident is detrimental to producer, as, as seen previously, the arugula leaf is the commercial part.

It is important to remember that the plants were grown in polyethylene trays with 60 cells and this material does not have a significant volume of space for root growth properly, which may have explained the death of leaves in BioFlora substrate (Figure no 3). As the highest plants were produced in this substrate and also reduced the largest fresh root mass (Table 4), it possibly occupied the entire cell volume, making it impossible for the plant to absorb water and nutrients, causing senescence entrance of leaves.

According to Fayad et al.[14], achieving a good relationship between root system and the aerial part has benefits in the production of seedlings, as well as maintaining the original structure of roots, pivoting or fasciculate, with the objective of achieving a plant with high retention capacity, water supply and nutrient absorption, benefiting development throughout its cycle.

If root growth is greater than that supported by the container, the roots become tangled, causing stress to the plant and, even in optimal conditions, the plant will not be able to reach its maximum production potential.

The behaviour of regression trend lines analysis infer that fresh mass of shoots tends to increase while the fresh mass of roots, after an increment, decreases with the highest doses of slow-release fertilizer (Figure no 4). It may be highlighted that the container is a limiting factor even in the production of baby leaf, making it necessary to harvest and process arugula before this decrease occurs, for not losing commercial value.

V. Conclusion

According to the data presented, the ideal substrate for the production of arugula baby-leaf is BioFlora with addition of 2.81 g kg^{-1} of slow-release fertilizer (Forth Cote MiniPrill 18-05-09 5M®) with harvest approximately 21 days after the beginning of seedlings emergence.

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