Production and quality of strawberry plants produced from different nutrient solutions in soilless cultivation[1]

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ABSTRACT

The production of strawberry seedlings in a soilless cultivation system can be an alternative for the production of seedlings of high physiological and sanitary quality. The objective of this study was to evaluate the influence of the use of different nutrient solutions in mother plants on the production and quality of strawberry seedlings of the Aromas and Camarosa cultivars. The experiment was carried out in two crop cycles: the first cycle in 2016/2017, where four different nutrient solutions (1; 2; 3 and 4) were used for the nutrition of the parent plants of the cultivars under study and the second in 2017/2018, when the most productive solutions (nutrient solution 3 and 4) based on the results of the first cycle were used, together with the two cultivars. The propagules produced were collected, evaluated and rooted in substrate-filled trays, forming plant plugs, which were evaluated for quality. Nutritional solutions influence the propagative potential of the parent plants more than the physiological quality of the plug plant seedlings produced, when they are formed on substrates that provide nutrients. The nutrient solution 4 is the most recommended for the production of strawberry seedlings of the cultivars Aromas and Camarosa, in a soilless system.

Keywords: stolon; *Fragaria* x *ananassa*; plug plant; propagation; substrate

INTRODUCTION

Within the group of small fruits, the strawberry (*Fragaria* x *ananassa* Duch.) is the species that presents the greatest economic importance. Although Brazil is not among the world's largest strawberry producers, national production has doubled in the last fifteen years, making the country the largest producer in South America, with around 4,200 hectares cultivated with the species, producing around 120,000 tons of fruit (Fagherazzi *et al.*, 2017). It is estimated that for the establishment of strawberry producing areas in the country, the annual demand is 300,000,000 seedlings (Fagherazzi *et al.*, 2021).

In Brazil, most strawberry seedlings are produced in open-air nurseries, which use few technological innovations, generating seedlings of low phytosanitary and physiological quality (Fagherazzi *et al.*, 2021). Mainly due to soil diseases, nematodes and larvae, which are controlled through the use of methyl bromide that promotes soil fumigation, however it is not a permitted practice in Brazil. However, is carried out in countries such as Chile and Argentina, from where country imports part of the seedlings used in the areas of strawberry cultivation (Baruzzi *et al.*, 2012; Antunes & Peres, 2013). Rio Grande do Sul is the Brazilian state that has the greatest dependence on the import of seedlings, where approximately 90% of the cultivated area is implanted with imported seedlings (Gonçalves & Antunes, 2016). Usually, delays occur in the delivery of these seedlings, meaning that planting ends late, thus delaying the start of production, and making the producers fail to sell during the off-season when the prices paid for the fruit are highest (Zeist & Resende, 2019).

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Strawberry production in soilless cultivation systems has been growing in Brazil. In this system, substrates and a protected environment are used, making it possible to reduce the incidence of pests and diseases, in addition to facilitating cultural treatments and improving worker ergonomics (Alves *et al.*, 2020; Antunes *et al.*, 2020). This system can be used for the production of fruits and with some adaptations, it can also be used for the production of strawberry seedlings. For this purpose, mother plants from tissue culture are used, which are planted in soilless cultivation beds, nourished with nutrient solution and their propagules rooted in the substrate (Treder *et al.*, 2015), originating plug plants.

One of the main factors that affect plant growth and development is the composition of the nutrient solution, which must be adapted for different cropping systems, production objectives (fruits or seedlings), as well as for cultivars (Mattner *et al.*, 2017; Paulus *et al.*, 2018). The concentration of the mineral elements individually, as well as the maintenance of the balance between them, a correct absorption and assimilation by the plants is very important (Shirko *et al.*, 2018). Different formulations of nutrient solutions are described in the literature for the soilless cultivation of strawberry, in the production of both seedlings and fruits (Lee *et al.*, 2015; Shirko *et al.*, 2018).

According to the concentration of nutrients present in the plant, the plant will have more or less vegetative growth and will produce more or less stolons, a factor that will possibly influence the quality of the seedling produced. According to Mattner *et al.* (2017), the production of stolons from the mother plants is influenced by several factors, among them, the region's climate, the cultivar, the nutrition provided to the mother plants and also the cultivation system used. Among the macronutrients required by plants, nitrogen is required in the largest quantities and also the most limiting for plant development, as it is part of many plant molecules and is directly linked to cell growth (Shirko *et al.*, 2018). According to Neri *et al.* (2012), the production and branching of stolons, as well as the development of strawberry seedlings are influenced by the doses of nitrogen used in the nutrient solutions.

In Brazil, few research results are found on the composition and management of the nutrient solution in the production phase of strawberry seedlings. Therefore, further studies must be carried out using different nutrient solutions, which enable the production of strawberry seedlings of high physiological and phytosanitary quality, leveraging seedling production in Brazil and thus reducing producer dependence on the imported seedling.

In view of the above, the objective of the present work was to evaluate the use of different nutrient solutions, in mother plants, in the production and quality of strawberry seedlings of the Aromas and Camarosa cultivars, in a soilless cultivation system.

MATERIAL AND METHODS

The experiments were conducted in the experimental area belonging to Embrapa Clima Temperado, Pelotas-RS, latitude 31º40' South and longitude 52º26' West, at a 60 m altitude. The climate of the region, according to W. Köppen, is of the "Cfa" type - humid temperate with hot summers (Alvares *et al.*, 2013), with average temperature and annual precipitation of 17.9 °C and 1500 mm, respectively. Two experiments were carried out, the first between November 2016 and May 2017 and the second between October 2017 and May 2018, for which two greenhouses were used, one for the nursery and the other for the establishment and growth of seedlings, both protected at the top with transparent low density polyethylene film (150 μm thick) and laterally with antiaphidic screen.

In the first growing cycle carried out in 2016-2017, two commercial strawberry cultivars, Camarosa, of short days and, Aromas, of neutral days, and four nutritive solutions (Table 1) were studied. Nutritional solution 1 (NS1) was formulated based on the solution proposed by Furlani & Fernandes Junior (2004); Nutritional solution 2 (NS2), was based on solutions used by strawberry producers in a soilless cultivation system in the region of Pelotas-RS; Nutritional solution 3 (NS3) was based on the solution proposed by Sonneveld & Straver (1994) and adapted by Peil *et al.* (2018); Nutritional solution 4 (NS4) was a commercial solution used in the region. The micronutrient content was standardized for nutrient solutions 1, 2 and 3, with the following composition in ($mg.L^{-1}$): 1.44 Fe; 0.5 Mn; 0.68 Zn; 0.42 B; 0.72 Cu; 0.007 Mo; NS4 has the necessary micronutrients in its composition for the development of the crop, however the quantities used for each micronutrient are not specified on the product label.

Based on the preliminary results of seedling production of the 2016-2017 cycle, the two nutrient solutions that presented the best results were selected and together with the two Camarosa and Aromas cultivars, they were studied again during the 2017-2018 growing cycle. All mother plants used in the experiment came from tissue culture acquired from a commercial company. The soilless cultivation system was used, with recirculation of the nutrient solution, which was composed of 2.30m long, 0.80m wide fiber cement tiles and two 0.10m high channels, supported on metal trestles, keeping the tiles at 1.10m above the ground and with a 5% slope to drain the nutrient solution.

The tiles were waterproofed with black polyethylene film (150 μm thick), and the channels were then filled with carbonized rice husk, used as a substrate for the support and growth of plant roots, over which an irrigation tape was placed at 0.10m intervals between drippers, with one drip tape for each tile channel, to supply the nutrient solution. Subsequently, the tiles were covered with white and black double-sided polyethylene film (150µm thick), with the white part facing upwards and the mother plants arranged 0.30m between plants, totaling six plants per cultivation channel. The irrigation system consisted of four motor-pumps and four water tanks of 310 liters each, where each set supplied four tiles, that is, eight cultivation channels, so that the set (motor-pump and reservoir) delimited each nutritive solution.

Fertigation was performed daily at 2-hour intervals, for ten minutes (6:00; 8:00; 10:00; 12:00; 14:00; 16:00; 18:00; 20:00 hours and once during the night at 2:00 hours) totaling nine times a day, all with an average flow per dripper of 1.5 L. $hour^{-1}$. The pH and electrical conductivity were monitored weekly during the production period, with the pH maintained between 5.5 and 6.5 and the electrical conductivity between 1.2 and 1.5 $dS.m^{-1}$.The experimental design was completely randomized, with four replications, in a 4x2 factorial scheme (four nutrient solutions and two cultivars) in the first cycle, and 2x2 (two nutrient solutions and two cultivars) in the second cycle, with the treatments arranged in subdivided plots, with the main plots constituting the nutrient solutions and the cultivars constituting the subplots. Each experimental unit was formed by six parent plants.

The planting of the mother plants in the first cycle of cultivation occurred on November 16, 2016 and in the second cycle on October 10, 2017. All the flowers from the mother plants during cultivation were removed.

The propagules were collected in both cultivation cycles, starting in the second half of February. For rooting the propagules, 72-cell polystyrene trays (internal volume of 124 mL) were filled with commercial substrate Carolina Soil®, a compound based on Sphagnum peat, expanded vermiculite, dolomitic limestone, agricultural plaster, with pH: 5.5 ± 0.5; Electrical conductivity: 0.4 ± 0.3 $mS.cm^{-1}$; Density: 145 $kg.m^{-3}$; Water retention capacity of 55% and maximum humidity of 50%, together with the Osmocote® 15-9-12 fertilizer (nitrogen, phosphorus and potassium), in the proportion of 5 $kg.m^{-3}$. The collected propagules were placed in contact with the substrate and kept in a misting chamber with an irrigation frequency of 12.5 seconds every 10 minutes for the first 7 days, and 12.5 seconds every hour from day 7 to 14, with an average flow of 36 $L.hour^{-1}$ and after this period, the seedlings were transferred to growth benches, being manually irrigated once a day until they were well formed, about 50 days after planting the propagules. The control of pests and diseases was carried out using chemical products registered for the culture at the Ministry of Agriculture, Livestock and Supply (MAPA).

The analyzed variables were divided into two groups: the variables referring to the mother plant and the variables referring to the quality of the seedlings produced. The variables referring to the mother plant were as follows: average number of stolons per mother plant, obtained by directly counting all the stolons that each mother plant emitted, the same being expressed in stolons per plant; Average number of seedlings per plant: obtained by directly counting all propagules produced by the parent plant, expressed in seedlings per plant; Average number of propagules per stolon: obtained by the quotient between the average number of seedlings produced per plant and the average number of stolons produced per plant, the same being expressed in number of propagules per stolon.

The variables referring to the quality of the seedlings were measured approximately 50 days after planting the propagules in the trays, when the seedlings were considered ready for transplantation to the fruit production area. For this purpose, four replications of six plants were used for each treatment, evaluating the following variables: Crown diameter: measured with the aid of a digital caliper and the results expressed in millimeters (mm); Average number of leaves: measured by counting the number of leaves that each seedling

Table 1: Composition of macronutrients of the different nutrient solutions used during the nursery phase, for the production of strawberry seedlings

Nutrient solution	**Composition of nutrients ($mmol.L^{-1}$)**						
	NO_3^-	**$H_2PO_4^-$**	**SO_4^-**	**NH_4^+**	**K^+**	**Ca^{2+}**	**Mg^{2+}**
NS1	9.98	1.50	1.00	0.53	5.66	2.65	1.00
NS2	3.05	2.94	2.36	0.28	5.23	1.38	1.22
NS3	9.99	1.28	2.48	0.75	5.98	2.92	1.83
NS4	7.44	2.97	1.15	1.86	5.43	1.95	0.76

NS1: nutrient solution 1 (proposed by Furlani & Fernandes Junior (2004) NS2: nutrient solution 2 (used by strawberry producers in a soilless cultivation system in the region of Pelotas-RS); NS3: nutrient solution 3 (proposed by Sonneveld & Straver (1994) and adapted by Peil *et al.* (2018); NS4: nutrient solution 4 (commercial solution).

presented at the time of commercialization, results expressed in leaves.seedling^{-1}; Root system length: measured with the aid of a graduated ruler and the results expressed in centimeters (cm); Average petiole length: obtained by measuring the length of the leaf petiole, with the aid of a graduated ruler and the results expressed in centimeters (cm); Dry mass of leaves, crown and roots: the material was separated into leaves (leaf + petiole), crown and root system, and then placed in an oven at 65 °C with forced air circulation until constant mass, with the results being expressed in grams per plant (g.plant^{-1}).

The data were subjected to analysis of variance by the F test, and when significant, the treatment averages were compared with the Tukey test at 5% probability of error. All analyses were performed with the Rbio software (Bhering, 2017).

RESULTS AND DISCUSSION

The variables referring to the number of propagules per stolon, number of stolons and seedlings per mother plant, in the 2016/2017 cycle, showed significant interaction between cultivars and the studied nutrient solutions (Table 2). The use of NS4 for the Camarosa cultivar, provided the largest number of propagules per stolon, number of stolons and seedlings per mother plant, which is associated with the phosphorus content ($H_2PO_4^-$) that is present in greater concentration in NS4, than in other solutions.

Nutrient solutions with low concentrations of phosphorus affect vegetative growth, including the emission of stolons. Once phosphorus is a nutrient that participates in the formation of phosphate sugars, which are intermediates in photosynthesis and respiration, it is also a component of nucleotides, such as adenosine triphosphate (ATP), which acts on the energy metabolism of plants, directly affecting photosynthesis and respiration, as well as energy storage and transfer, cell division and growth (Taiz *et al.*, 2017). The quantity of phosphorus ($H_2PO_4^-$) in NS2 is similar to that of NS4 (Table 1), which produced the lowest number of stolons and seedlings per mother plant compared to the other solutions, however it has a low nitrogen concentration, both in the form of nitrate (NO_3^-) and ammonium (NH_4^+). According to Shirko *et al.* (2018), this mineral nutrient is the most required and limiting by plants, as it is directly linked to cell growth, being part of many plant molecules, including chlorophyll, amino acids and nucleic acids.

Table 2: Number of propagules per stolon, number of stolons per mother plant and number of plants per mother plant, fertigated with different nutrient solutions, in the 2016/2017 and 2017/2018 cycles

Nutrient solution	Number of propagules per stolon		Number of stolons per mother plant		Number of plants per mother plant	
	2016/2017					
	Camarosa	**Aromas**	**Camarosa**	**Aromas**	**Camarosa**	**Aromas**
NS1	3.93 b B	6.75 bc A	23.38 b A	9.46 b B	92.42 c A	63.17 b B
NS2	4.77 b B	5.72 c A	11.96 c A	6.49 b B	57.12 d A	36.67 b A
NS3	4.75 b B	7.28 ab A	26.5 b A	13.92 a B	125.83 b A	101.33 a A
NS4	6.34 a B	8.34 a A	30.54 a A	14.25 a B	193.75 a A	119.17 a B
C.V.a (%)	11.26		9.93		15.93	
C.V.b (%)	8.31		12.02		16.13	
	2017/2018					
	Nutrient solutions					
NS3	5.59 ^{ns}		18.66 ^{ns}		96.19 b	
NS4	6.14		120.75		120.76 a	
Cultivar						
Camarosa	4.73 b		25.57 a		120.49 a	
Aromas	6.7 a		13.84 b		96.47 b	
C.V.a (%)	9.24		12.99		7.88	
C.V.b (%)	16.63		11.51		17.31	

Means followed by the same lower case letters in the columns and upper case in the rows, do not differ by Tukey's test, at 5% probability of error; ^{ns}: not significant; C.V.a: Coefficient of variation; C.V.b: coefficient of variation; NS1: nutrient solution 1 (proposed by Furlani & Fernandes Junior (2004) NS2: nutrient solution 2 (used by strawberry producers in a soilless cultivation system in the region of Pelotas-RS); NS3: nutritient solution 3 (proposed by Sonneveld & Straver (1994) and adapted by Peil *et al.* (2018); NS4: nutrient solution 4 (commercial solution).

Nitrogen dosages can favor the production and branching of stolons during the multiplication phase, in addition to influencing the speed and development of seedlings during their formation period (Neri *et al.*, 2012). The nitrogen absorption process by plants requires energy in the

The nitrogen absorption process by plants is a process that requires energy in the form of ATP (Daneshmand *et al*, 2019), and since phosphorus is part of the composition of these substances, the balance between the ratio of nitrogen and phosphorus is essential for one to favor the absorption of the other. NS1 has an N:P ratio of 7.00, so it has 7 mmol of nitrogen to 1 mmol of phosphorus, NS2 had 1.13, NS3 had 8.39 and NS4 had 3.13, which explains the different responses presented by the plants fed with the different solutions. Phosphorus and nitrogen interact synergistically, so that when both are made available in adequate quantities, one favors the absorption of the other, enabling greater yields of the cultures, than when they are applied separately (Fageria & Baligar, 2014).

The highest number of propagules per stolon, number of stolons and seedlings per mother plant was found with the use of NS3 and NS4, for the Aromas cultivar, with no statistical difference between them. 'Aromas' presented the highest number of propagules per stolon than 'Camarosa', regardless of the nutrient solution used. Similar results were found by Becker (2017), which demonstrates that 'Aromas' tends to have longer length stolons and thus a greater number of seedlings per stolon. However, 'Camarosa' was significantly superior to 'Aromas', in relation to the number of stolons produced per mother plant in all nutrient solutions. According to Guimarães *et al.* (2015), the number of stolons formed per plant varies between cultivars, with short-day cultivars generally producing a greater number of stolons than plants of neutral days.

The Camarosa cultivar, produced a higher number of seedlings per mother plant than 'Aromas', when both were fed with NS1 and NS4 (Table 2). Under conditions of high temperatures and long days, plants from short-day cultivars such as 'Camarosa' tend to emit a large number of stolons, propagating vegetatively, while the emission of flowers is inhibited (Guo *et al.*, 2021). In contrast, neutral day cultivars such as Aromas flower continuously due to insensitivity to the photoperiod and greater tolerance to high temperatures, delaying the emission of stolons (Strassburger *et al.*, 2010). This can explain the difference found between the cultivars in the production of seedlings, since the period of production of the same occurred in the summer, when not only the photoperiod increases, but also the temperature, favoring the emission of stolons, mainly in short-day cultivars like 'Camarosa'.

In the experiment carried out in 2017/2018, there was no significant interaction between the factors, for the number of propagules per stolon, number of stolons and seedlings per mother plant (Table 2). 'Aromas' had a higher number of propagules per stolon and 'Camarosa' a greater number of stolons per mother plant. While the use of NS4 was significantly higher than NS3 in relation to the number of seedlings per mother plant. This variation that is associated with the phosphorus content present each (Table 1), interfering with absorption and assimilation of nitrogen.

Nitrogen can be absorbed by plants in the form of nitrate (NO_3^-) and ammonium (NH_4^+). Nitrate absorption occurs actively, against an electrochemical potential gradient, through a symmetrical system, a process that requires energy, while ammonium is passively absorbed by diffusion, without energy expenditure (Taiz *et al.*, 2017). When ammonium is absorbed, it is readily available to be assimilated by the plant, however in the case of nitrate, there is a greater energy expenditure, since it is necessary to reduce nitrate to nitrite, through nitrate reductase enzymes and later to ammonium, through nitrite reductase enzymes, to then be incorporated into organic compounds, glutamates and glutamines (Liu *et al.*, 2017). Phosphorus deficiencies can thus decrease the absorption, as well as the assimilation of nitrate and ammonium, affecting the entire metabolism of the plant.

The largest number of seedlings per mother plant was produced by 'Camarosa', with an average of 120.49 seedlings per mother plant, differing significantly from 'Aromas', which produced 96.47 seedlings per mother plant. The different rates of propagation of the strawberry can be attributed to the genetic composition of each cultivar, the different crop systems, the environmental conditions and the management of the crop (Oliveira *et al.* 2010).

Theaverage length of the petiole and roots, referring to the quality of the seedlings produced with the different nutrient solutions, in the 2016/2017 cycle, were influenced by the interaction between the factors studied (Table 3). The use of NS2 for the cultivar 'Camarosa', produced seedlings with shortest petiole length and the largest root length, however, this last parameter differed significantly only from NS3.

This lower growth of the aerial part and greater root growth provided with NS2 may be due to the plant having destined its reserves to form the root system first, for the absorption of water and nutrients and then later form the aerial part. For 'Aromas', the nutrient solutions did not influence the average length of the petiole and the roots of the seedlings produced.

The 'Aromas' seedlings showed greater root length than the 'Camarosa' seedlings, when they were produced produced with NS1 and NS3.

The Camarosa cultivar presented seedlings with a longer average petiole than 'Aromas', when NS1 was used. However, when NS2 was used, the reverse occurred, 'Aromas' had leaves with a longer average petiole length, which may be related to the nitrogen content present in the solutions.

The average length of the petiole and roots of the seedlings produced in the 2017/2018 cycle were not influenced by the interaction between nutrient solutions and cultivars (Table 4). The seedlings of Aromas cultivar had a longer root length than those of 'Camarosa', where the nutrient solutions did not influence this variable.

The number of leaves and the crown diameter of the seedlings produced in the 2016/2017 and 2017/2018 cycle did not show any interaction between the factors (Table 4). The isolated effect of the cultivar factor was only observed for the number of leaves per plant, where 'Aromas' was higher than 'Camarosa' in both cultivation cycles.

In the 2016/2017 cycle, seedlings with a larger crown diameter were obtained when NS4 was used, but it only differed significantly from NS2, which had the smallest crown diameter, a fact related to the low nitrogen content present in NS2 (Table 1). According to Silveira *et al.* (2016), nitrogen is part of the synthesis of chlorophyll, thus being directly linked to the photosynthetic metabolism of plants, therefore the deficiency of this nutrient compromises the development of the plant, decreasing the production of dry mass of the aerial part and the root system.

The crown diameter is directly related to the plant's reserves, since the crown contains carbohydrates, mainly

Table 3: Average petiole length and root length of strawberry seedlings produced with different nutrient solutions, in the 2016/2017 cycle

Nutrient solution	Average petiole length (cm)		Root length (cm)	
	Camarosa	Aromas	Camarosa	Aromas
NS1	15.52 a A	13.58 a B	10.52 ab B	11.83 a A
NS2	11.37 b B	14.22 a A	11.25 a A	11.75 a A
NS3	13.82 a A	14.44 a A	10.23 b B	11.67 a A
NS4	15.78 a A	14.22 a A	10.83 ab A	11.33 a A
C.V.a (%)	7.96		4.94	
C.V.b (%)	6.78		3.39	

Means followed by the same letter, lower case in the columns and upper case in the rows, do not differ by Tukey's Test, at 5% probability of error; C.V.a: Coefficient of variation; C.V.b: Coefficient of variation; NS1: nutrient solution 1 (proposed by Furlani & Fernandes Junior (2004) NS2: nutrient solution 2 (used by strawberry producers in a soilless cultivation system in the region of Pelotas-RS); NS3: nutrient solution 3 (proposed by Sonneveld & Straver (1994) and adapted by Peil *et al.* (2018); NS4: nutrient solution 4 (commercial solution).

Table 4: Average length of petiole and root of strawberry seedlings produced with different nutrient solutions in the 2017/2018 cycle and crown diameter and number of leaves of strawberry seedlings produced with different nutrient solutions, in the 2016/2017 and 2017/2018 cycles

Nutrient solution	Average petiole length (cm)	Root length (cm)	Crown diameter (mm)		Number of leaves per plant	
	2017/2018	2017/2018	2016/2017	2017/2018	2016/2017	2017/2018
NS1	-	-	8.76 ab	-	5.42 b	-
NS2	-	-	8.36 b	-	5.81 ab	-
NS3	7.19^{ns}	10.11^{ns}	8.69 ab	9.40 ^{ns}	5.92 ab	6.77 b
NS4	6.61	10.12	9.79 a	9.95	6.29 a	7.65 a
Cultivar						
Camarosa	7.36^{ns}	9.98 b	8.96 ^{ns}	9.78 ^{ns}	5.54 b	6.85 b
Aromas	6.44	10.25 a	8.84	9.57	6.18 a	7.56 a
C.V.a (%)	13.05	5.05	9.44	6.55	8.80	7.77
C.V.b (%)	11.94	2.15	6.38	4.08	9.73	6.52

Means followed by the same letters in the columns, do not differ by the Tukey test, at 5% probability of error; ^{ns}: not significant; C.V.a: Coefficient of variation; C.V.b: Coefficient of variation; NS1: nutrient solution 1 (proposed by Furlani & Fernandes Junior (2004) NS2: nutrient solution 2 (used by strawberry producers in a soilless cultivation system in the Pelotas-RS region); NS3: nutrient solution 3 (proposed by Sonneveld & Straver (1994) and adapted by Peil *et al.* (2018); NS4: nutrient solution 4 (commercial solution).

starch, such that its concentration can be positively correlated with the productive potential of plants (Torres-Quezada *et al.*, 2015).

In the 2017/2018 cycle, when only NS3 and NS4 were studied, these did not influence the crown diameter of the seedlings, similar to the previous cycle (2016/2017). It is worth noting that, regardless of the nutrient solution or cultivar studied, all seedlings produced had an average crown diameter greater than the minimum requirement for a seedling to be marketed in the country, which according to Brazilian legislation is 5 mm (Brasil, 2012).

The higher number of leaves per plant was obtained with the use of NS4, differing significantly from NS1, in the 2016/2017 cycle (Table 4). It is worth mentioning that the NS1 and NS4 solutions have similar amounts of nitrogen (NO_3^- and NH_4^+), but their phosphorus content ($H_2PO_4^-$) varies, with NS4 having a higher content than NS1 (Table 1), a fact that may have limited nitrogen absorption by plants fed with NS1. Similar to the seedlings produced in the 2017/2018 cycle, the largest number of leaves was observed in seedlings in which the stolons were produced with NS4, possibly due to the difference between the phosphorus content ($H_2PO_4^-$) present in NS3 and NS4.

According to Li *et al.*, (2014), the process of nitrogen absorption requires energy, and phosphorus is part of the energy metabolism of plants. Thus, the lower phosphorus content present in NS1 and NS3, may have negatively affected the energy metabolism of the plant and thus compromised the absorption of nitrogen, which caused less growth of the aerial part and as a consequence a smaller number of leaves per plant.

The dry mass of leaves, crowns and roots of seedlings produced in the 2016/2017 cycle, showed significant interaction between the factors studied (Table 5). The seedlings of the Camarosa cultivar, showed the highest dry mass of roots when the stolons were produced with NS4, while the highest dry mass of leaves was verified with the use of NS4 and NS1, For with no differences between them, but both differed significantly from NS2. The lower nitrogen content present in NS2, may have affected the development of the propagules from the nursery stage, as well as in the next stage, when the stolons are placed in substrates to root and form the seedling, and since this propagule has already been formed with nutritional deficiencies, the quality of the seedling ends up being compromised.

For the Aromas cultivar, only the crown dry mass was influenced by the nutrient solutions, where NS4 was statistically superior to NS1. In plug plant seedlings, the main parameters used to evaluate the quality of the seedlings are the crown diameter, the volume and quality of the roots and the dry mass of the aerial part, as they are factors that most influence strawberry production (Menzel & Smith, 2012).

When NS1 was used, the seedlings of the Camarosa cultivar showed a greater dry mass of leaves and crown than those of 'Aromas'. While with the use of NS2 and NS3, there was no difference between cultivars, for any of the variables referring to the dry mass of seedlings (Table 5). However, when NS4 was used, the seedlings of Camarosa cultivar showed a higher dry mass of leaves and roots compared to Aromas cultivar.

The root system of the seedlings is one of the factors that most influences the success after transplanting the seedlings, as they are tissues that have energy stored in the form of starch and are also used to absorb water and nutrients, which are essential for the formation of new leaves and roots. According to Torres-Quezada *et al.* (2015), tissues with high amounts of dry matter, favor the resumption of plant growth after transplantation.

The dry mass referring to the different partitions of leaves, crown and roots of the seedlings produced in the 2017/2018 cycle did not show significant interaction between cultivars and nutrient solutions (Table 5). The nutrient solution factor did not influence the dry mass of leaves, crown and roots of the seedlings produced, while the cultivar factor interfered only in the variable dry mass of leaves, where 'Camarosa' produced greater mass than 'Aromas'.

The cultivars are plants of the same species, which have different genetic characteristics, which gives them different behaviors when they are taken to the field, not only in aspects related to fruit production, resistance to pests and diseases but also in plant architecture, where vigor can be one of the parameters used to differentiate cultivars. According to Oliveira & Antunes (2016), one of the characteristics of the Camarosa cultivar is the high vigor presented by its plants, while 'Aromas' is considered to be a medium vigor cultivar, a characteristic that is mainly noticed in the leaf mass of the plants. in this experiment, it was observed that the 'Camarosa' seedlings presented a higher dry mass of leaves than those of 'Aromas', however, for the other variables, the cultivars showed statistically similar results.

The interest of nurserymen, producers of strawberry seedlings, is the search for management techniques that provide high seedling production per mother plant, so that they can obtain the highest possible profitability, while the interest of fruit producers is the search for seedlings of excellent quality and with high health and productivity.

However, the research fails to meet the demand of the entire production chain through the recommendation of a cultivation technique that encompasses all requirements, because many times when a mother plant produces many

Table 5: Dry mass of leaves, crown and roots of strawberry seedlings produced with different nutrient solutions, in the 2016/2017 and 2017/2018 cycles

Nutrient solution	Dry mass of leaves ($g.plant^{-1}$)		Dry mass of crown ($g.plant^{-1}$)		Dry mass of roots ($g.plant^{-1}$)	
			2016/2017			
	Camarosa	**Aromas**	**Camarosa**	**Aromas**	**Camarosa**	**Aromas**
NS1	1.59 ab A	1.32 a B	0.29 a A	0.19 b B	0.24 b A	0.28 a A
NS2	1.21 c A	1.38 a A	0.24 a A	0.26 ab A	0.29 b A	0.24 a A
NS3	1.31 bc A	1.38 a A	0.25 a A	0.27 ab A	0.26 b A	0.27 a A
NS4	1.74 a A	1.36 a B	0.27 a A	0.30 a A	0.41 a A	0.27 a B
C.V.a (%)	13.95		17.27		20.06	
C.V.b (%)	12.24		17.66		13.6	
			2017/2018			
Nutrient solution						
NS3	1.39 ^{ns}		0.31 ^{ns}		0.28 ^{ns}	
NS4	1.46		0.31		0.27	
Cultivar						
Camarosa	1.62 a		0.34 ^{ns}		0.28 ^{ns}	
Aromas	1.24 b		0.29		0.27	
C.V.a (%)	9.40		19.13		15.78	
C.V.b (%)	10.35		16.03		6.22	

Means followed by the same letters, lower case in the columns and upper case in the rows, do not differ by Tukey's Test, at 5% probability of error; ^{ns}: not significant; C.V.a: Coefficient of variation; C.V.b: Coefficient of variation; NS1: nutrient solution 1 (proposed by Furlani & Fernandes Junior (2004) NS2: nutrient solution 2 (used by strawberry producers in a soilless cultivation system in the Pelotas-RS region); NS3: nutrient solution 3 (proposed by Sonneveld & Straver (1994) and adapted by Peil *et al.* (2018); NS4: nutrient solution 4 (commercial solution).

seedlings, part of them end up being weak, since they have low quantity of reserves and after transplanting, they end up dying or showing low fruit production. Thus, it is necessary to use nutritional solutions that provide an adequate nutrition to the mother plant, so that it produces seedlings in quantity and quality to supply the needs of the country's domestic market.

With the accomplishment of this work, it was observed that the nutrient solutions have more influence on the number of propagules produced per mother plant, than on the quality of the seedlings produced, since plug plant seedlings are formed from the propagules collected from the mother plant and placed to root in substrates. In this experiment, a substrate that had a certain amount of nutrients was used, and together with it the Osmocote® fertilizer was added. Together, these two provided the necessary nutrients for the growth and development of the root system and the aerial part of the seedlings. Through the analysis of the evaluations carried out regarding the quality of the seedlings, it was observed that overall, regardless of the nutrient solution used, they showed satisfactory results, showing little variation between them, and therefore in plug plant seedlings. Growth and development depend not only on the nutrients and reserves provided by the mother plant, during the nursery phase, but also on the next stage, in which the propagules are placed to root in substrates that provide certain amounts of nutrients.

Thus, the nurseryman, producer of strawberry plug plant seedlings, can choose nutrient solutions that enable the production of a greater number of propagules per mother plant, since they do not have a strong influence on the quality of the seedling, but can make the cultivation activity as profitable as possible and also offer the market quality seedlings at a fair price.

CONCLUSIONS

Seedling production is influenced both by the genotype and by the constitution of the nutrient solution used in the nursery phase. The cultivar Camarosa has a greater propagation potential than Aromas in a soilless cultivation system;

Nutritional solutions influence the propagative potential of the parent plants more than the physiological quality of the plug plant seedlings produced, when they are formed on substrates that provide nutrients;

The commercial nutrient solution (NS4) is the most recommended for the production of strawberry seedlings of the cultivars Aromas and Camarosa, in a soilless cultivation system.

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