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Production and quality of *Cinnamomum zeylanicum* Blume seedlings cultivated in nutrient solution

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ABSTRACT

Brazil imports great amounts of *C. zeylanicum* from different countries, both barks and essential oil, given the absence of commercial cultivation of this spice in the country. Hence, due to the need of studying and indicating adequate mineral fertilizers in the production of *C. zeylanicum* seedlings, this work intended to investigate the effect of adding different concentrations of the complete nutrient solution in the production of high-quality seedlings with potential for commercial purposes. The experimental design used was completely randomized in the split-plot scheme and ten evaluations. In the plots, we evaluated the effect of the concentrations (T1 - 0%, T2 - 25%; T3 - 50%; T4 - 75%; T5 - 100%) of the nutrient solution during the growth period and in the subplots, the evaluation periods was evaluated monthly. Both growth characteristics (height, stem diameter and dry matter of shoots and roots) and quality parameters of the seedlings (Dickson index) was assessed. The nutrient solution at the concentration of 75% provides height and stem diameter growth and increased indices of Dickson quality, shoot dry matter, root dry matter and total dry matter, being suitable for the production of *C. zeylanicum* seedlings. *C. zeylanicum* seedlings have low nutrient requirements; thus, the concentration of 100% of the nutrient solution characterizes luxury consumption.

Key words: Dickson index, Lauraceae, plant nutrition

Produção e qualidade de mudas de Cinnamomum zeylanicum Blume cultivada em solução nutritiva

RESUMO

O Brasil importa de diferentes países grandes quantidades de *Cinnamomum zeylanicum* Blume (sin. *C. verum*) conhecida como canela do Ceilão tanto cascas quanto óleo essencial, dada à ausência de cultivo comercial desta especiaria no País. Assim, em razão da necessidade de estudar e indicar fertilizantes minerais adequados na produção de mudas *C. zeylanicum*, objetivou-se verificar o efeito da adição de diferentes concentrações de solução nutritiva completa na produção de mudas de alta qualidade com potencial para exploração comercial. O delineamento experimental utilizado foi o inteiramente casualizado em esquema de parcelas subdivididas e dez avaliações. Avaliou-se nas parcelas o efeito das concentrações T1 - 0%; T2 - 25%; T3 - 50%; T4 - 75%; T5 - 100% da solução nutritiva (macro e micronutrientes), durante a fase de crescimento e nas sub parcelas, dez avaliações mensais. Foram avaliadas características de crescimento (altura, diâmetro de caule e massa seca da parte aérea e radicular) e parâmetros de qualidade de mudas (relação massa seca da parte aérea/massa seca de raiz, massa seca total e índice de Dickson). A solução nutritiva nas concentrações de 50 e 75% proporcionam crescimento em altura, diâmetro do caule e maiores índice de qualidade de Dickson, massa seca da parte aérea, massa seca do sistema radicular e massa seca total, sendo indicado para a produção de mudas de *C. zeylanicum*. As mudas de *C. zeylanicum* tem baixo requerimento nutricional, sendo que a concentração de 100% da solução nutritiva não é indicada para produção de mudas de *C. zeylanicum*.

Palavras-chave: índice de Dickson, Lauraceae, nutrição de plantas

Introduction

The species *Cinnamomum zeylanicum* (sin. *C. verum*), known as Ceylon cinnamon, the true commercial cinnamon, belongs to the family Lauraceae and it is native of Sri Lanka (former Ceylon), main exporter and producer, followed by Seychelles, Madagascar and India (Koketsu et al., 1997; Lima et al., 2005; Ranasinghe et al., 2013). The tree of *C. zeylanicum* reaches of 8-17 m height and its barks and leaves are generally used in perfume-making, beverage and culinary manufacture due to their aromatic and seasoning properties, and their essential oils are used as flavoring agents for industrialized foods and medicines (Deus et al., 2011; Silva et al., 2012).

The essential oil of this plant is one of the most important on the world market and presents a great diversity in its composition (Lima et al., 2005). *C. zeylanicum* is much used in folk medicine for presenting medicinal properties, such as antispasmodic, carminative, stimulating, tonic, digestive, astringent, aphrodisiacal, antiseptic, antioxidant, aperient, aromatic, hypertensive, sedative and vasodilator (Lima et al., 2005). Brazil imports regularly significant amounts both of barks and essential from different countries, given the absence of commercial cultivation of that spice in the country (Koketsu et al., 1997). *C. zeylanicum* develops well on Brazilian soil, where it was cultivated in the past, having been introduced by the Jesuits (Silva et al., 2012). Related agronomic studies, whether as an association of crops or aiming at the increase production, have been conducted mainly in India, but specific works on the production of *C. zeylanicum* seedlings submitted to different kinds of mineral fertilization was not found in the literature.

In that way**,** studies that provide silvicultural information about the species, inclusive as far as the production of seedlings is concerned is of fundamental importance. The characterization of the quality of seedlings is one of the greatest concerns found in the plant nurseries due to the high production cost of seedlings. That is due, in part, to the development time of plants and hence, the greater expense on inputs (defensives and fertilizers), labor and equipment (Souza et al., 2014; Uliana et al., 2014).

In this context, mineral fertilization, in addition to being an essential factor to the seedling development, speeds up considerably its growth, reducing production costs (Souza et al., 2011a). The practice of mineral fertilization has been efficient in providing nutrients to several crops, with a series of advantages over the traditional method (Souza et al., 2013a).

That technique used the same items of irrigation equipment**,** enabling to dose and split the application of mineral fertilizers in the desired manner, reducing labor and leaching, with better distribution of nutrients (Souza et al., 2015). Nevertheless, this technique is still little spread in the production processes of forest seedlings.

Thus, owing to the need to study and indicate adequate mineral fertilizers for the production of *C. zeylanicum* seedlings, this work aimed to determine the effect of adding different concentrations of nutrient solution upon the production of high-quality seedlings with potential for commercial exploration.

Material and Methods

The study was conducted at Embrapa Roraima, using the dependences of the Laboratory of Seed Analysis and the seedling nursery of the Fruit Growing Sector located on BR 174, Km 8, Industrial District, under geographical coordinates 02º45’28”N and 60º43’54”W, and 90 m of altitude. Boa Vista lies in the Tropical Climate Zone. The climate in the region is, according to Köppen, of the Aw type: rainy tropical with a drought period with average annual rainfall of 1700-2000 mm (Araújo et al., 2001). The rainy period occurs with the greatest frequency from April to August with monthly totals higher than 100 mm (Smiderle et al., 2015). From September on, a marked reduction takes place, with characteristic dry period occurring more frequently from November to March (Tonini, 2011). The average annual temperature is 25.5 ^{o}C (Smiderle et al., 2015).

The species used was *C. zeylanicum* which seeds for the formation of seedlings are originally from the city of Mucajaí, in the state of Roraima (obtained from the isolated plant on a farm). The seeds were sown in the seed nursery and were daily irrigated with water. At 26 days after sowing, the seedlings, with five centimeters tall on average, were transferred to black polyethylene bags, 17 cm tall and 12 cm in diameter, containing two litters of the mixture substrate (Table 1).

The seedlings were spaced and kept in nursery with 50% of shading, with sprinkling irrigation scheduled at each six hours during the daytime, each irrigation lasting five minutes, with two weekly waterings of nutrient solution proposed by Furlani et al. (1999), after the last daily irrigation, avoiding nutrient leaching (Table 2).

The fertigation management was based on the weighing method, in which three black polyethylene bags with plants of each treatment, drains at the bottom, were initially saturated with distilled water to start draining. After ceasing drain, the pots were weighted to obtain the initial wet weight (Ui) corresponding to the capacity of the pot. Therefore, we obtained the value of the container + moist substrate + plant for each treatment that was used as a reference for subsequent irrigations until the end of the experiment. To replace the amount of solution (AS) consumed (evapotranspired) on the previous day, we proceeded to re-weighing the containers, thus obtaining the average final moisture content (U*f*); by the equation $AS = Ui - Uf$, the volumes of water to be applied in each treatment were obtained. The weighing of vessels was done daily, and at the same time.

The experimental design used was the completely randomized in split-plot scheme. The factors under study were five concentrations of nutrient solution and nine evaluation times (months) with six replications. Each plot was made up of three seedlings (one seedling in each container). The effect of the nutrient solution concentrations T1 - 0%; T2 - 25%; T3 - 50%; T4 - 75%; T5 - 100% (Table 2) proposed by Furlani et al. (1999) was evaluated during the growth period and monthly, evaluations were carried out until the seedlings reached the average height of 45 cm and average diameter of 5.0 mm.

Table 1. Chemical analysis, macro and micronutrients and particle size of the substrate used in the growth of *Cinnamomum zeylanicum*

Sub[(1)]	pH	Exchangeable complex[(2)]								V	P	MO
		Ca^{2+}	Mg^{2+}	K^+	Al^{3+}	H+Al	SB	t	T	%	mg dm^{-3}	dag kg^{-1}
		$cmol_c\ dm^{-3}$										
0%Test	6.3	2.3	0.50	24	0.0	1.33	2.86	2.9	4.2	68.3	40.54	1.18
25%Fert	6.2	2.4	0.50	65	0.0	1.36	3.06	3.1	4.4	68.9	56.68	1.30
50%Fert	6.1	2.5	0.45	103	0.0	1.41	3.27	3.3	4.7	69.4	71.82	1.43
75%Fert	6.0	2.6	0.40	147	0.0	1.46	3.52	3.4	4.9	69.7	86.96	1.54
Fert	5.9	2.7	0.4	186	0.0	1.49	3.6	3.6	5.1	70.5	101.1	1.64

	Micronutrients[(3)]					
	Zn	Fe	Mn	Cu	B	S
	mg dm^{-3}					
0%Test	19.4	35.52	81.6	2.6	0.13	3.7
25%Fert	19.2	45.10	83.5	2.6	0.17	6.5
50%Fert	18.9	53.61	86.4	2.6	0.19	9.3
75%Fert	18.6	64.55	91.3	2.6	0.25	12.8
Fert	18.3	73.7	93.2	2.6	0.26	14.5

(1) Substrate: sand: soil. (2) pH in water (1:2,5); Ca^{2+}, Mg^{2+} e Al^{3+}: extractant KCl 1 mol L^{-1}; K^+ e P: extractant mehlich-1; H+Al: extractant SMP; M.O.: organic matter - oxidation $Na_2Cr_2O_7$ 4N + H_2SO_4 10N; SB: sum of exchangeable bases; t: cation exchangeable capacity (CEC) effective; T: CTC a pH 7,0; V: base saturation index; m: aluminum saturation index. (3)Zn, Fe, Mn e Cu: extractant mehlich-1; B: hot water extractant; S: monocalcium phosphate extractant in acetic acid.

Table 2. Nutrient solution composition of the treatments used in the trial

Treat.	$N-NO_3$-	$N-NH_4$+	P	K	Ca	Mg	S	CE	[Íons]	Ionic strength
	mg L^{-1}							Ds m^{-1}	mmol L^{-1}	
100%	174.0	24	39	183	142	38	52	1.84	26.92	21.94
75%	130.5	18	29.25	137.25	106.5	28.5	39	1.38	20.19	16.45
50%	87.0	12	19.5	91.5	71	19	26	0.98	13.52	11.22
25%	43.5	6	9.8	45.8	35.5	9.5	13	0.54	6.81	5.73

The values of the height of the seedlings were obtained by measuring with a millimeter ruler from ground level to the apical meristem, while for the stem diameter, the measures were taken with a digital pachymeter at 1 cm from ground level.

At 300 days after transplanting (DAT), each seedling was split into the shoot and root and each part of the plant were washed in running water and packed into paper bags, remaining in drying oven at 60 - 65°C with air circulation until reaching constant mass (72 h). After dried, they were weighted on analytical scale with precision of 0.01 g for determination of the dry matter of the shoot (SDM) and roots (RDM); and by the sum of these, the total dry matter (TDM) of the plant was calculated and the Dickson quality index (DQI) was established (Dickson et al., 1960) using the formula:

$$DQI = \frac{TDM(g)}{\frac{H(cm)}{SD(mm)} + \frac{SDM(g)}{RDM(g)}}$$

where:

TDM - total dry matter;
H - shoot height;
SD - stem diameter;
SDM - shoot dry matter;
RDM - root dry matter.

The data obtained for the different variables were submitted to the analysis of variance and the means were compared by the Tukey test at 5% of probability, using the statistical software Sisvar (Ferreira, 2011).

Results

For the traits evaluated, height, stem diameter and number of leaves, we verified the significant interaction between the concentrations of nutrient solution and the evaluation in time (Figures 1, 2 and 3). The regression equation (Figure 1) adjusted to the quadratic model, which explained the maximum height of plants (45.3 cm) in T4 (75% of the nutrient solution concentration). The results found in the present study confirmed that the addition of nutrient solution contributed to the growth of the shoot of the seedlings; nevertheless, the ideal range of the concentrations of nutrient solution for the cultivation of *C. zeylanicum* lies between 50% and 100%, leading to more expressive results. The seedlings of the control treatment (T1) presented an average height (26.5 cm) inferior to the other treatments, which contained different concentrations of nutrient solution, thus demonstrating the positive effect of the concentrations formulated with a complete nutrient solution (Figure 1).

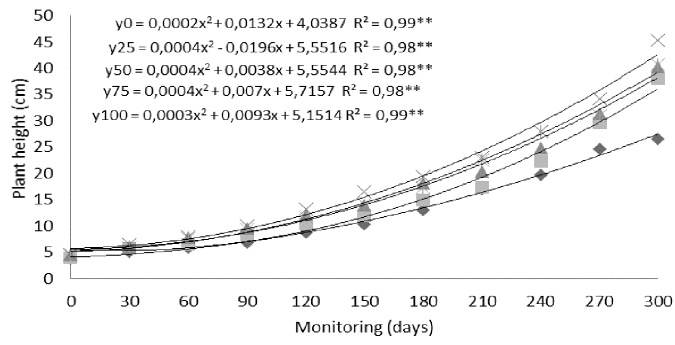

Figure 1. Height of *Cinnamomum zeylanicum* seedlings grown at different concentrations of nutrient solution for 300 DAT

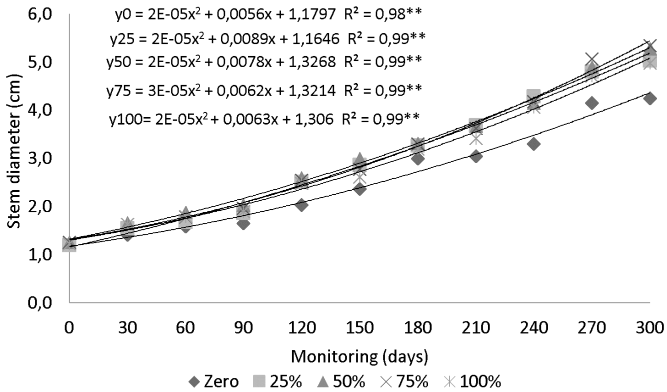

Figure 2. Stem diameter in *Cinnamomum zeylanicum* seedlings grown at different concentrations of nutrient solution for 300 DAT

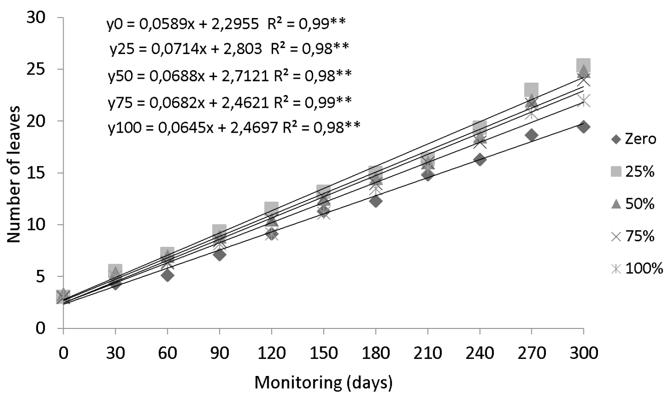

Figure 3. Number of leaves in *Cinnamomum zeylanicum* seedlings grown at different concentrations of nutrient solution for DAT 300

In this study, the means of the stem diameter ranged between 4.35 and 5.45 mm. Similar to the results obtained for height, the lowest mean of the stem diameter was found in the seedlings produced in treatment T1 (control). However, the effects represented by the adjusted models presented biological coherence. Therefore, it was possible to define the best concentrations for the species *C. zeylanicum*. The greatest mean (5.45 mm) was found in the treatment constituted of 75% of the nutrient solution concentration (T4), followed by the concentration of 50% with 5.40 mm (Figure 2). The smallest diameter (4.35 mm) was obtained in the control (Figure 2) differing significantly from other.

As far as the number of leaves is concerned, the regression equation adjusted to a growing linear model in the monitoring period. The smallest average number of leaves (19.5 leaves) was obtained with the control at 300 (DAT), followed by the concentration of 100% (22.0 leaves) of the nutrient solution used. In the concentrations of 25, 50 and 75%, there was an increase in the number of leaves at 300 DAT (Figure 3). Seedlings produced at the different concentrations of the nutrient solution presented higher average values for a number of upper leaves. Then, the concentrations in the range of 25 to 75% should be preferable as alternative components in the production of *C. zeylanicum* seedlings.

Regarding the results obtained for shoot dry matter (SDM), the treatments T3 (50% concentration of the nutrient solution) and T4 (75% concentration of the nutrient solution) presented higher values as compared with the other treatments (Table 1), according to the Tukey test ($p > 0.05$). However, the T1 without the addition of nutrient solution caused the minimal point for shoot dry matter (SDM), root dry matter (RDM) and total dry matter (TDM) and Dickson Quality Index (DQI). However, concentrations of 50 and 75% of the nutrient solution had the highest averages of SDM, RDM, TDM and DQI (Table 3) compared to other treatments.

The positive results of the use of the nutrient solution in the production of *C. zeylanicum* seedlings can be observed when the Dickson quality index is analyzed. For that index, the treatments T3 (50% of the nutrient solution) and T4 (75% of the nutrient solution) presented higher means, whereas seedlings of the treatment T1 (control) provided DQI below that (Table 3). The highest value found for this index (1.11) was with the concentration of 50% of the nutrient solution (Table 3), pointing out the importance of the nutrient solution for the balanced growth of C. *zeylanicum* during the seedling period. The Dickson quality index is a good indicator of seedling quality.

Table 3. Average values observed for shoot dry matter (SDM, g), root dry matter (RDM, g), total dry matter (TDM, g) and Dickson Quality Index (DQI) in *Cinnamomum zeylanicum* seedlings at different concentrations of nutrient solution at DAT 300

Nutrient solution	SDM	RDM	TDM	DQI
T1 (water)	3.07 c*	1.09 c	4.16 c	0.66 b
T2 25%	4.49 b	1.34 b	5.83 b	0.79 b
T3 50%	6.60 a	1.90 a	8.60 a	1.11 a
T4 75%	6.12 a	1.86 a	7.88 a	0.96 a
T5 100%	4.66 b	1.05 c	5.70 bc	0.70 b
CV.%	11.1	17.2	11.2	16.9

*In the column, means followed by distinct letters differ from one another by the Tukey test at the level of 5% of probability. ((T1)= addition of water; (T2)= concentration of 25% nutrient solution; (T3) concentration of 50% nutrient solution; (T4)= concentration of 75% nutrient solution); (T5)= concentration of 100% nutrient solution).

Discussion

In the literature, there are no studies evaluating the effect of nutrient solution, neither with mineral fertilization in the production of *C. zeylanicum* seedlings, which makes the comparison with the results obtained in this study difficult.

The growth of the morphological characteristics evaluated showed the greatest shoot height when using the nutrient solution concentration (75%), along with the concentration 50%, better reflecting on the growth and development of seedlings, as well as the absorption of nutrients from the nutrient solution.

According to Table 1, the results justify the non addition of more than 75% of the nutrient solution concentrations used, due to the high accumulated concentration of nutrients in the T5 contained in the substrate. Thus, the time for obtaining seedling and economy of fertilizers allows at least 25% to 50% in the final cost using basic nutrient solution, without compromising the improvements in growth. Furthermore, the concentration of 25% and 100% of the nutrient solution used in the present study had the lowest values of the characteristics SDM, RDM, the TDM of *C. zeylanicum* seedlings when compared to concentrations of 50% and 100%, showing that both the smaller and the greater concentrations resulted in lower growth and development of seedlings.

Added to this, the species studied have a low nutritional requirement for seedling production, indicating that the concentration of the nutrient solution of 25% was not enough to meet the nutritional requirements, while the concentration of 100% was probably luxury consumption, resulting in wastage of fertilizer.

Results found in the literature using this same nutrient solution at the concentration of 100% on rootstocks of *Citrus limonia* L. Osbeck, by Souza et al. (2013a) showed better growth when compared with the traditional system in seedling production. It explains the importance of nutrient solution application for the development of seedlings even if the gains vary at the concentrations of the nutrient solution in different plant species.

Therefore, Souza et al. (2011a) and Souza et al. (2011b) evidenced that the nutrient solution used in the present study was excellent in the production of rootstock of 'Taiwan Naschi-C' and Okinawa. In these works, the authors obtained linear growth in seedling production, with average height and diameter at 10 cm from ground level of 45.16 cm, 5.0 mm and 78.67 cm, 6.0 mm, respectively, at the concentration of 100% of the nutrient solution. That shows the importance of studying the availability of nutrients at different concentrations of nutrient solution for different species, genera, and family.

According to Souza et al. (2013a) that growth and vigor in the formation of the seedlings is possibly allied to the more favorable environment obtained inside the greenhouse due to the availability of water and nutrients, allowing the seedlings to have faster growth, reducing the production cycle, increasing yield, even if the gains vary among different crops.

Silva et al. (2013) studied the growth of cedro doce seedlings (*Bombacopsis quinata*), grown under nursery conditions in conical polyethylene tubes of 180 cm^3 in volume, under two levels of amendment of the substrate with dolomitic limestone and five doses of potassium topdressed by foliar means. They found, at 57 days after planting, that the best treatment was the control with the average growth of 10.9 cm and 3.73 mm diameter. Nevertheless, the values of these variables were below the ideal limit proposed by Gomes et al. (2002), for native forest species, which is 20 and 35 cm high and 5 to 10 mm in stem diameter. In that way, the nutrient solution used in the present study can be considered an effective strategy to improve the production of seedlings of forest species, mainly of *C. zeylanicum* seedlings with high quality and in a short period.

Souza et al. (2013b), evaluating the early growth and the quality of canafístula seedlings (*Peltophorum dubium* (Sprengel) Taubert) by combined doses of nitrogen and phosphorus (N and P), obtained higher values of DQI (1.98) when they used 125.16 mg kg^{-1} of P_2O_5. However, Freitas et al. (2013) verified greater DQI (3.1) in sugar apple seedlings (*Annona squamosa* L.) at the estimated dose of 10.5 mL dm^{-3} (143.16 mg P $seedlings^{-1}$) of the commercial product Cosmofert®. Gomes et al. (2002) observed in *E. grandis* that, the greater the value of that index, the better the quality standard of the seedlings. Bernardino et al. (2005) evaluating the quality of *Anadenanthera macrocarpa* (Benth.) seedlings, also stated that the seedlings with greatest DQI are classified as of best quality**,** corroborating the present work. Caldeira et al. (2013) established the minimum value of 0.20 for that index; all the treatments presented no satisfactory treatments, 0.14 being the greatest mean, with 20% sewage sludge + 40% carbonized rice hulls + 40% in natura coffee. On the basis of some studies, it is possible to observe that the DQI can vary according to the species, management of the seedlings in the nursery, type and proportion of the substrate, container volume and mainly, the age of the seedling evaluated (Gomes et al., 2002; Caldeira et al., 2008; Brachtvogel& Malavasi, 2010; Caldeira et al., 2012; Vieira et al., 2015).

The Dickson quality index (DQI) is a good indicator of seedling quality for considering the robustness and the equilibrium of the biomass distribution in the calculation, pondering several important characteristics (Souza et al., 2013b). The greater the DQI, the better the quality of the seedling produced. Therefore, the positive increments reached with the addition of different concentrations of nutrient solution demonstrated that the nutrition in *C. zeylanicum* seedlings affects directly and positively their quality. In general, the control limited the growth, but not the nutrient absorption by the *C. zeylanicum* seedlings. Based on the morphological characteristics, the concentrations formulated of nutrient solutions provided greater growth of the *C. zeylanicum* seedlings.

Conclusions

The *C. zeylanicum* seedlings respond to the addition of nutrient solution at concentrations of 50 and 75%, and the mineral fertilizer is important for growth and quality of this species seedlings.

The nutrient solution in the concentrations 50% and 75% provides growth in height, stem diameter and higher levels of Dickson quality index, shoot dry matter, root dry matter and total dry matter, being suitable for the production of *C. zeylanicum* seedlings.

The *C. zeylanicum* seedlings have a low nutritional requirement, and the 100% concentration of the nutrient solution is not suitable for their production.

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