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Electrical conductivity of complete and commercial nutrient solutions in tube-based passion fruit seedling production

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ABSTRACT: Fertigation is widely used in seedling production for different crops, including passion fruit. There is no consensus on the ideal nutrient solution, and as such, nurseries have used fertigation empirically. This study assessed the electrical conductivity of nutrient solution containing macro and micronutrients in passion fruit seedling production and compared it with commercially used fertigation. A completely randomized design was used, with five treatments and six repetitions. Four electrical conductivities (0.5, 1.0, 2.0 and 4.0 dS m^{-1}) of a complete nutrient solution and an additional treatment (commercial nutrient solution) were analyzed. Daily fertigation with a complete nutrient solution (macro and micronutrients) at electrical conductivities between 2.6 and 3.3 dS m^{-1} followed by two daily irrigations are efficient at producing FB 300 "Araguari" passion fruit seedlings in coconut fiber substrate, with benefits such as greater biomass and better Dickson quality index when compared to commercial nutrient solution.
Key words: *Passiflora edulis*, Dickson quality index, fertigation.

Condutividades elétricas de solução nutritiva completa em comparação com solução nutritiva usada comercialmente na produção de mudas

RESUMO: A fertirrigação é amplamente utilizada na produção de mudas de várias culturas, inclusive o maracujazeiro. Não existe consenso sobre qual solução nutritiva deve ser adotada na produção de mudas de maracujazeiro, mas por causa disso, viveiristas têm usado a fertirrigação empiricamente. O objetivo deste trabalho foi avaliar condutividades elétricas de solução nutritiva com macros e micronutrientes na produção de mudas de maracujazeiro e compará-las com uma fertirrigação adotada comercialmente. Foi utilizado delineamento experimental inteiramente casualizado, com cinco tratamentos e seis repetições. Foram estudadas quatro condutividades elétricas (0,5; 1,0; 2,0 e 4,0 dS m^{-1}) de solução nutritiva completa e um tratamento adicional (solução nutritiva adotada comercialmente). Em substrato à base de fibra de coco, fertirrigações diárias com solução nutritiva completa (macro e micronutrientes), com condutividades elétricas entre 2,6 a 3,3 dS m^{-1}, seguidas de duas irrigações diárias são eficientes na produção de mudas de maracujazeiro FB 300 "Araguari", inclusive com vantagens, como maior biomassa e índice de qualidade de Dickson em relação à solução nutritiva comercial.
Palavras-chave: *Passiflora edulis*, índice de qualidade de Dickson, fertirrigação.

Seedling production is a key stage of the passion fruit production cycle, since it can influence early plant development and fruit yield. As such, high quality seedlings are important in achieving a productive orchard because they make it possible to obtain a rapidly developing, homogeneous and early-maturing crop (NATALE et al., 2004).

Complementary fertilization is vital in tube-based passion fruit seedling production, since the substrate used does not provide the necessary amount and proportion of nutrients for satisfactory seedling development. In passion fruit, slow-release fertilizers (i.e. Osmocote) produce seedlings with 25% more biomass than that of their fertigated counterparts, but at a 2-3 times higher cost (DA SILVA et al., 2020). Additionally, fertigation allows greater control over nutrient application during the seedling cycle, facilitating daily seedling management in nurseries.

Given the lack of consensus on the ideal nutrient solution and electrical conductivity (EC) for passion fruit seedling production, and the fact that nurseries use fertigation empirically, often by applying only N, P and K, our aim was to determine the best electrical conductivity for a nutrient solution containing macro and micronutrients in passion fruit seedling production and compare it with a commercial solution.

The experiment was conducted in a greenhouse at Viveiro Flora Brasil Ltda. in Araguari.

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Minas Gerais State (MG), Brazil, from May to July 2019, using the FB 300 "Araguari" passion fruit cultivar. The seedlings were grown in 50 cm³ polypropylene tubes (30 x 120 mm) filled with Golden Mix® coconut fiber substrate.

A completely randomized design was used, with five treatments and six repetitions. The treatments consisted of four complete nutrient solutions adapted from FURLANI et al. (1999), with ECs of 0.5, 1.0, 2.0 and 4.0 dS m^{-1}, and a reference treatment of a commercial nutrient solution used by Viveiro Flora Brasil, containing only the primary macronutrients N, P and K (Table 1). The solution described by Furlani et al. (1999) was adapted by using ConMicros Standard® (Allplant) to supply micronutrients.

The seedlings were irrigated three times a day until they developed their first true leaf (about 10 days after emergence). This marked the onset of fertigation, which was carried out early every morning, using enough nutrient solution for the tubes to reach minimum drainage. Complementary irrigation was also performed twice a day (at 11 a.m. and 2 p.m.).

In all the treatments, four seedlings from each plot were assessed to determine shoot, root and total dry weight (SDW, RDW and TDW, g); shoot length (SL, cm) measured from the base to the apical meristem of the shoot; number of leaves (NL); stem diameter (SD, mm); shoot/root dry weight ratio (S:R) and leaf area (LA, cm^2) obtained with a leaf area meter (CID Bio-science® CI-203). The Dickson quality index (DQI) was also calculated, according to Eq1. (DICKSON et al., 1960):

$$DQI = \frac{TDW}{\frac{SL}{SD} + \frac{SDW}{RDW}}$$

The EC data for the complete nutrient solution were submitted to analysis of variance and polynomial regression. The means of the variables for seedlings grown using commercial nutrient solution were submitted to analysis of variance and included in the regression graphs for comparison purposes (dotted line). R software was used for all the analyses and significance was set at 5%.

The nutrient solutions with different ECs influenced the growth of the passion fruit seedlings

Table 1 - Electrical conductivity, concentration of the nutrients supplied, and pH of the nutrient solutions used to fertigate passion fruit seedlings.

Fertilizer	Nutrient	----------Electrical conductivity (dS m^{-1}) [1,2]--------				Reference treatment[3]
		0.50	1.0	2.0	4.0	2.4
		---------- g m^{-3} de água ----------				
Ammonium nitrate	$N\text{-}NH_4^+$	0	0	0	0	82.5
	$N\text{-}NO_3^-$	0	0	0	0	82.5
Calcium nitrate Hydro	Ca	38.0	76.0	152.0	304.0	0
	$N\text{-}NO_3^-$	29.0	58.0	116.0	232.0	0
	$N\text{-}NH_4^+$	2.0	4.0	8.0	16.0	0
Potassium nitrate	K	44.8	89.6	179.2	358.4	349.4
	$N\text{-}NO_3^-$	15.0	30.0	60.0	120.0	117.0
MAP	P	23.2	46.4	92.8	185.6	112.7
	$N\text{-}NH_4^+$	10.5	21.0	42.0	84.0	51.0
Magnesium sulfate	Mg	2.5	5.0	10.0	20.0	0
	S	3.3	6.5	13.0	26.0	0
ConMicros®[4]	B	0.455	0.455	0.455	0.455	0
	Cu	0.455	0.455	0.455	0.455	0
	Fe	1.815	1.815	1.815	1.815	0
	Mn	0.455	0.455	0.455	0.455	0
	Mo	0.090	0.090	0.090	0.090	0
	Ni	0.084	0.084	0.084	0.084	0
	Zn	0.183	0.183	0.183	0.183	0
----------pH[5]----------		6.8	6.7	6.5	6.1	6.4

[1]measured with a portable Akso® AK52 electrical conductivity meter; [2]values based on Furlani et al. (1999); [3]Fertigation used by Viveiro Flora Brasil; [4]ConMicros Standard® - mixture of micronutrients (Allplant®); [5]measured with an Akso® AK90 portable pH meter.

for all the variables investigated (SL, SD, SDW, RDW, TDW, NL, LA, S:R and DQI).

The ECs promoted a linear response for SL, NL and S:R. The estimated ECs and maximum values for SD (EC 2.64; 3.83 mm), SDW (EC 3.34; 2.32 g), RDW (EC 2.82; 0.43 g), TDW (EC 3.27; 2.75 g), LA (EC 3.18; 361.1 cm^2) and DQI (EC 2.72; 0.24), were obtained between 2.64 and 3.34 dS m^{-1}. In this range, fertigation with a complete nutrient solution (macro and micronutrients) produced SD, SDW, RDW, TDW, LA AND DQI results 2, 24, 16, 22, 22 and 19% higher, respectively, than those obtained in the reference treatment (nutrient solution used in a commercial nursery (Figure 1)).

Most studies that characterize the number of leaves and shoot size of passion fruit seedlings used smaller containers, such as polyethylene bags (CAVICHIOLI et al., 2016), and disregarded issues related to managing seedlings in the field. This makes it difficult to establish a standard or ideal range for these traits in seedlings produced in 50 cm^3 tubes. In commercial nurseries, good quality seedlings exhibit the following characteristics: height of 20-30 cm, 5 to 8 fully expanded leaves, and a root system completely adhered to the substrate that allows the seedling to be easily removed from the tube without loosening the substrate (information provided by José Rafael da Silva – owner of Viveiro Flora Brasil).

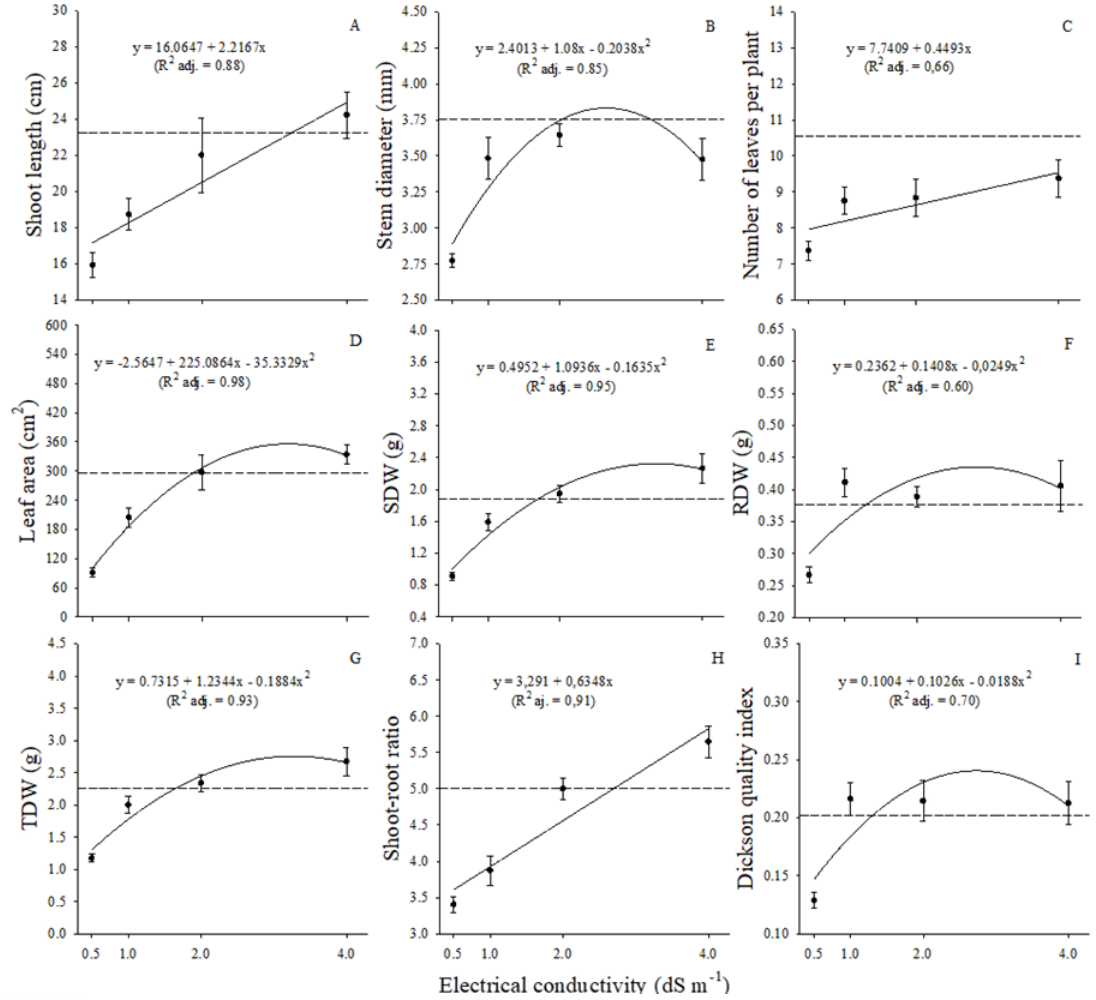

Figure 1 - Shoot length, stem diameter, number of leaves, leaf area, shoot (SDW), root (RDW) and total dry weight (TDW), shoot to root ratio and Dickson quality index of passion fruit seedlings as a function of nutrient solution electrical conductivity at 70 days after emergence. The dotted line represents the average for the additional treatment. Bars indicate the standard error of the mean (n = 6).

In the present study, the maximum DQIs for seedlings fertigated with a commercial nutrient solution (additional treatment) and complete solution were 0.20 and 0.24, respectively. In both cases, plants met the quality seedling criteria established by commercial nurseries, making it possible to establish a DQI range of 0.20 to 0.24 for high quality passion fruit seedlings produced in 50 cm^3 tubes using coconut fiber substrate. For passion fruit seedlings grown in larger containers, DQI values of 0.18 to 0.39 were identified (BERILLI et. al., 2018).

In general, seedling growth increased with a rise in nutrient solution electrical conductivity up to 3.3 dS m^{-1} (Figure 1). However, negative growth responses were observed from ECs above 3.3 dS m^{-1}, likely due to the increased ionic concentration of the substrate solution and resulting decline in the pH of the culture medium. This can compromise water and nutrient absorption by the plant, thereby affecting growth (TAIZ et al., 2017).

Passion fruit seedlings require around 60 days of fertilization and as such, using fertilized substrates can lead to nutrient shortages over time. Although, slow-release fertilizers (SRFs) are widely used, they are costly, and important quality traits such as stem diameter, root mass, number of leaves, leaf area and Dickson quality index were similar between fertigated seedlings and those treated with SRFs (DA SILVA et al., 2020).

Thus, daily fertigation with a complete nutrient solution (macro and micronutrients) at electrical conductivities between 2.6 and 3.3 dS m^{-1} followed by two daily irrigations are efficient at producing FB 300 “Araguari” passion fruit seedlings in coconut fiber substrate, with benefits such as greater biomass and better Dickson quality index when compared to seedlings grown using commercial nutrient solution containing only N, P and K.

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DECLARATION OF CONFLICT OF INTEREST

The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

AUTHORS’ CONTRIBUTIONS

The authors contributed equally to the manuscript.

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