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Effects of potassium fertilization and commercial substrates on development of passion fruit seedlings under greenhouse condition

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The aim of this work was to evaluate commercially available substrates and levels of potassium on the development of passion fruit seedlings in protected conditions. The experiment was conducted at the city of Presidente Prudente, São Paulo within the period from April to September of 2010. The treatments were made with three different substrates (Bioplant®, Coconut fiber and Vivatto®) and four levels of potassium (0, 150, 300 and 600 mg^{-1} of K dm^{-3}), arranged in a 3 × 4 factorial design with five repetitions. The following parameters were analyzed 120 days after seedlings transplanting: Plant height, number of leaves, length of root, dry matter of shoot, root, total matter and chlorophyll content. The dose of 600 mg dm^{-3} of K provided the highest seedling height, 85.83 cm independent of the substrate. The commercial substrates Bioplant® and Coconut fiber with a dose of 150 mg dm^{-3} of K influenced the maximum accumulation of total dry matter of seedlings. However, Vivatto® substrate provided the highest accumulation of total dry matter with application dose of 600 mg dm^{-3} of K. Mineral potassium fertilization in the substrate Bioplant® and Coconut fiber with a dose of 150 mg dm^{-3} reduced the length of passion fruit's roots.

Key words: *Passiflora edulis Sims*., mineral nutrition, protected cultivation.

INTRODUCTION

The passion fruit (*Passiflora edulis* Sims.) is a widespread culture in all Brazilian regions, both due to the highly favorable soil and weather conditions. Besides, this fruit is largely commercialized *in nature* at public markets and for juice pulp industry (Pires et al., 2008). It is estimated that Brazil currently is the world's largest

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producer of this fruit crop with a production of around 838,000 tons (IBGE, 2016).

In general, the low productivity of passion fruit fields may be related to several factors, including disease, especially viruses and inadequate fertilization practices. Some scientific studies showed that the use of low genetic quality seedlings/plants combined with malnourishment compromise yield production and culture longevity (Silva et al., 2010; Souza et al., 2016). Little has been reported about research analyses of seedlings production in a protected environment, specifically evaluating efficiency of nutrient levels such as potassium and different substrate types.

Traditionally passion fruit seedlings are transplanted to the field during March/April when they are about 30 cm high, coinciding with previous harvest time. Such overlapping period, enhance chances of early infection of passion fruit by virus causing lower productivity and fruit quality. The strategy of producing seedling in protected nurseries and holding their transference to the field until they are about 1.0 m high (at August) can, therefore avoid the previous crop, then bringing important advantages as breaking disease cycle and increasing fruit yields from December to March.

Potassium deficiency in passion fruit is involved with delay of flowering process and reduced production, including fruit size. Thus, interfering negatively with fruit and juice quality (Borges et al., 2002). It has been described, that cultivation of passion fruit requires more potassium than nitrogen (Borges et al., 2003). Moreover, it was shown that high doses of K and Cl can cause plants toxicity, when using potassium.

The growth of seedlings using substrate aims to ensure their development into maturity with higher quality in a short period of time, reducing cost production. However, the substrate must present physical and chemical characteristics to promote, respectively, moisture retention and nutrient availability, thus meeting the nourishment requirements of this plant crop (Cunha et al., 2005).

Silva et al. (2010) reported the effect of different types of substrates in the production of yellow passion fruit seedlings. They found that the substrate Plantmax® favored all growth parameters tested. Santos et al. (2012) studied the early development of *Passiflora-cincinnata* seedlings, and concluded that the substrate Vivatto® provided greater accumulation of fresh and dry root production.

Almeida et al. (2006) evaluated the effects of nitrogen and potassic fertilization on the development and nutrition of yellow passion fruit seedlings, cultivated in dystrophic Red Latosol. After 84 days, the plant height, diameter of the stem, number of leaves and leaf area showed best development of seedlings at the levels of 150 mg of N dm^{-3} and 300 mg of K dm^{-3}. Dias et al. (2012) studied the effects of potassium on the growth of guava seedlings in Red-Yellow Argisol. At 120 days, the fertilization with potassium did not influence the biometric parameters the height, stem diameter, number of leaves, SPAD index, dry weight of leaves. However, the doses of K of 1.452 mg dm^{-3} and K aids in the efficiency of 84.9% of absorption and utilization of N and K for seedlings.

Given the facts above, the aim of this work was to evaluate, in protected conditions, the effects of potassium levels in the development of yellow passion fruit seedlings using 3 commercially available substrates.

MATERIALS AND METHODS

The scientific work was conducted in a greenhouse located in a field area belonging to Agency Paulista for Technology of Agribusiness (APTA) located at the city of Presidente Prudente in the western region of São Paulo, in the period from April to September 2010, whose geographical coordinates are: Latitude 22° 07 '04 "S and longitude 51° 23' 01"O.

The roof of the greenhouse was made of transparent plastic film while the sides were with anti-aphid screen. From inside, bellow roof, a 50% shade fabric was used for protection while the countertops were disposed 80 cm above the ground.

The experiments were conducted in randomized blocks in a factorial 3 × 4 with five repetitions. For treatments were used three commercial substrates (Bioplant®, Coconut Fiber and Vivatto®) and four potassium doses (0, 150, 300 and 600 mg K dm^{-3}) supplied by potassium chloride (60% K_2O). The experimental plots were composed of 5 plant (1 per plastic bag). The substrates were subjected to chemical analysis (UNOESTE, at Soil Laboratory) and physical characteristics are presented in Table 1.

The yellow passion fruit seeds (*P. edulis* Sims.) cultivar 'South Brazil Afruvec' were germinated in trays with 200 divisions. After germination, they were transplanted into 2 L plastic bags with different substrates. The seedlings were monitored and conducted by stakes. During early development seedlings were irrigated until they reached field capacity point at each substrate tested.

In each analyzed experimental unit it was employed 2 L of substrate per bag. When transplanting, each bag received fertilization with P (450 mg dm^{-3}), N (300 mg dm^{-3}), B (0.5 mg dm^{-3}) and Zn (5 mg dm^{-3}) as Lopes (2000). As a source of N, P, B and Zn were used as urea (45% N), triple superphosphate (42% P_2O_5), boric acid (17% B) and zinc sulfate (21% Zn), respectively. The total phosphorus was mixed with the substrate at the time of filling plastic bags. Nitrogen and potassium were applied by fertigation in five applications 20 days apart from transplanting, 20% applied at transplanting and four applications of 20% every 20 days.

After 120 days the assessment was performed by collecting treatments of following parameters: Plant height (PW), number of leaves (NL) per plant; dry weight of shoot (DWS), dry weight of roots (DWR), and total dry weight (TDW), length of root (LR) and the leaf chlorophyll content (LCC) (SPAD value).

The plants' height was evaluated considering the distance between the plant laps until the apex of seedlings, using graduated ruler (mm). For leaves number it was considered only the fully expanded ones. The dry matter content of plants was quantified after collection and drying of material in an oven (with forced air circulation at 65°C for 72 h to reach constant weight). Biomass of root and shoot were determined using analytical precise scale, 0.0001. The chlorophyll content was determined directly by a digital chlorophyll (Chlorophyll Content Meter, CCM-200). The reading of three expanded middle leaves for each plant was considered obtaining the chlorophyll results in SPAD values.

All data were submitted to analysis of variance by F test ($p < 0.05$) and the significant effect of each factor or interaction was compared by the Tukey test ($p < 0.05$). For substrate types and through the

Table 1. Chemistry composition and physical characteristics of substrates.

Substrate	pH	MO	Ca	Mg	K	P	S	SB	CTC	V	B	Zn
	$CaCl_2$	mg dm^{-3}	mmolcdm^{-3}			mg dm^{-3}				%	mg dm^{-3}	
Bioplant®	5.0	218	22	12	16.3	230	193	50	87	58	2.7	28
Coc. fiber	5.0	213	12	4	23.4	104	154	40	59	69	6.4	29
Vivatto®	4.8	211	19	22	12.0	230	234	52	89	59	6.3	8

Substrate	WRC	Density (Kg/m³)	EC (mScm^{-1})	H (%)	TP
Bioplant®	38%	288	1.7	65	85
Coc. fiber	30%	92	0.2	95	90
Vivatto®	40%	267	0.5	48	91

Obs. WRC- water retention capacity; CE- eletric conductivity; U-percentage of humidity; PT- total porosity.

regression analysis of variance in the case of potassium doses it was applied computationally SISVAR 5.6 program (Ferreira, 2011).

RESULTS

The physical characteristics and chemical composition of each substrate are shown in Table 1. With regard of leaf variables analyzed DWS, DWR and TDW; significant correlation between potassium levels and substrate types studied were not observed (Figures 2 and 3).

Effect of substrate types on seedlings height

Table 2 shows that the type of substrate utilized did not influenced significantly the plants' height 120 days after transplanting. The average size obtained was 67.43, 61.96 and 61.34 cm for Bioplant® substrate, Coconut fiber and Vivatto® respectively.

Effect of potassium levels on seedlings height

The plant height obtained for passion fruit seedlings correlated directly to the potassium doses applied, as observed in Figure 1. The maximum response of seedlings occurred at the maximum dose of K (600 mg dm^{-3}), while height average reached 85.83 cm.

Influence of substrate types and potassium levels on seedlings development

It was observed that potassium levels provided gains in leave numbers with a dose of 300 mg dm^{-3} K when plants were grown in Bioplant® and Vivatto® substrate (Figure 2). However, when Coconut fiber was used a positive effect was already achieved with a dose of 150 mg dm^{-3} of K.

The variables of DWS, DWR and TDW of seedlings are shown in Figure 3A to C, respectively. The results of DWS were influenced by the interaction between the type of substrate and potassium doses (Figure 3A). The dry roots weight of yellow passion fruit seedlings showed highest value when applied 300 mg dm^{-3} of K on substrates Bioplant® and Vivatto® (Figure 3B). In the Coconut fiber substrate the potassium application reduced the dry matter of the roots of seedlings.

The responses evaluated in the TDW seedlings differ significantly between the substrates, combined with the dose of K (Figure 3C). In the substrate Bioplant® the best response in the TDW was verified with the use of 300 mg dm^{-3} of K and Coconut fiber the maximum dry matter yield was obtained at a dose of 150 mg dm^{-3} of K. However, when it was used the substrate Vivatto®, the largest dry mass was obtained by applying 600 mg dm^{-3} of K.

The response related to root length varied according to the types of substrates analysed and the potassium doses applied (Figure 4). It can be seen that the substrate Bioplant® and Coconut fiber showed the best results for development of seedlings roots without potassium application. The seedlings which were planted in Vivatto® substrate showed the best average root length without potassium application and maximum dose of 600 mg dm^{-3} of K.

The commercial substrates were accepted statistically for chlorophyll content values (SPAD value) evaluated in yellow passion fruit seedlings (Figure 5). It was observed SPAD values obtained with a dose of 300 mg dm^{-3} of K was higher on Coconut fiber, followed by Bioplant® respectively at 120 days. While development of seedlings sown in Vivatto® presented lower SPAD index for chlorophyll content.

DISCUSSION

For plant height parameters the averages in the three commercial substrates showed not difference statistic (Table 2). Nevertheless, it was found that average were

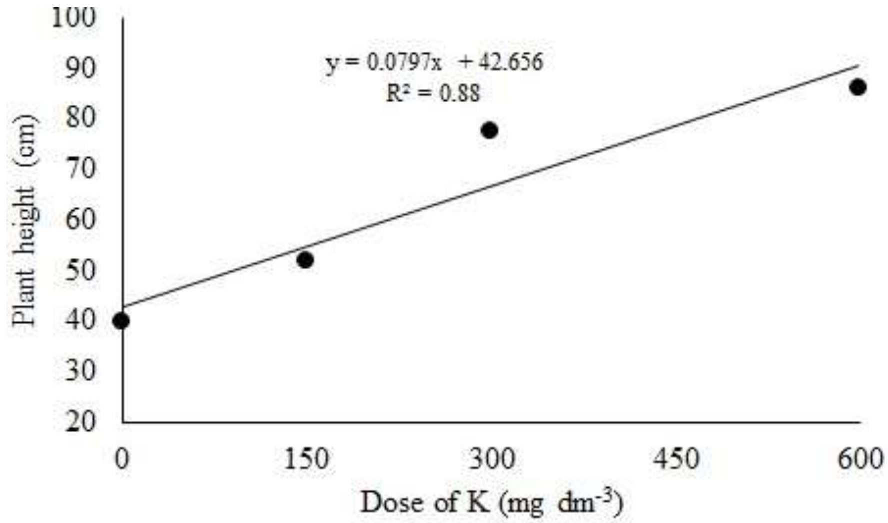

Figure 1. Plant height of yellow passion fruit in fuction of dose of potassium and substrate, after 120 days.

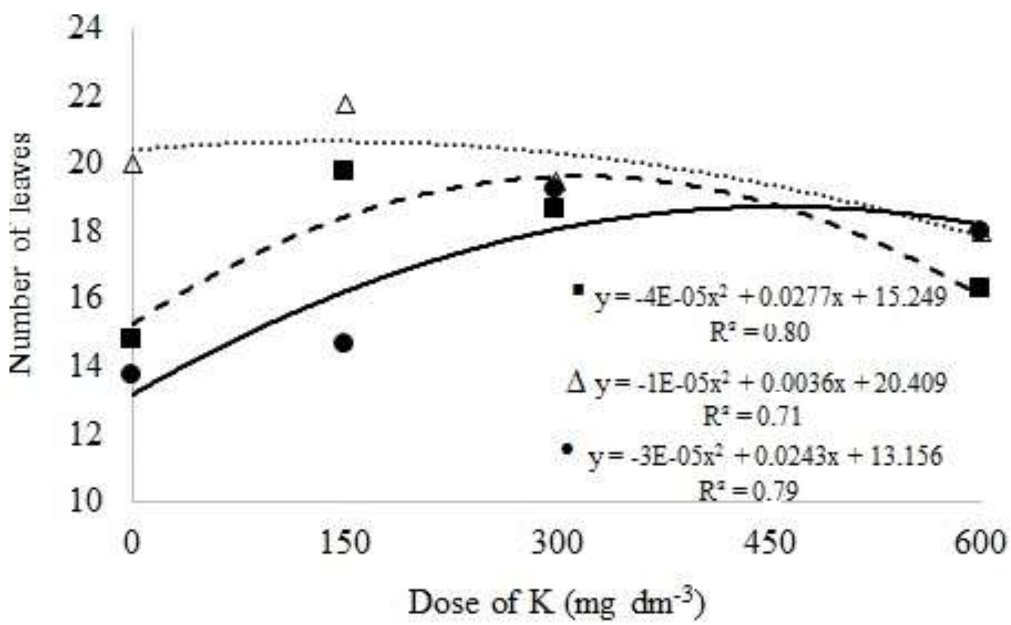

Figure 2. Number of leaves in function of dose of potassium and substrate, at 120 days [(▪) Bioplant; (∆) Coconut fiber and (•) Vivatto].

higher than that of traditional seedlings that are 25 to 40 cm. The substrates with high porosity physical characteristics offers less resistance to root growth and also has the ability to maintain the temperature and humidity of the substrate that influence of growing of plants (Ristow et al.; 2012). These physicals characteristic were verified in the substrates used in this experiment (Table 1).

The positive effect of increase in K levels in the height of passion fruit presenting increasing linear. The potassium effects the main functions in plants such as enzyme activation, protein synthesis, absorption, transport and ion balance, and is also involved in photosynthesis, respiration, transportation and long distance distribution of assimilates (Hawkesford et al., 2012). Prado et al. (2004) evaluating application of potassium doses at 60 days, verified that the development of yellow passion fruit seedlings reached maximum development in height with a dose of 220 mg K dm^{-3}.

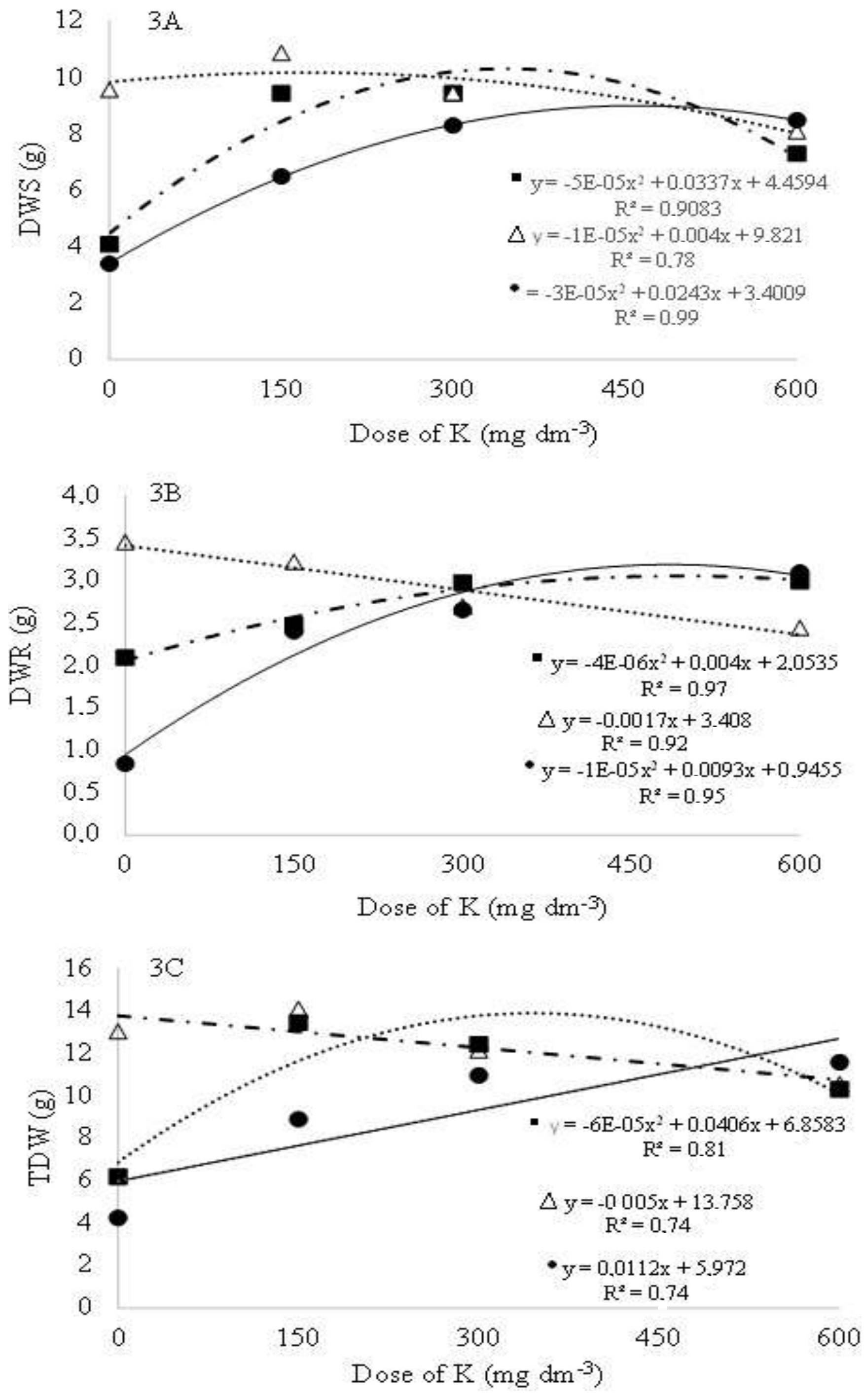

Figure 3. Dry weight of shoot (3A), dry weight of root (3B) and total dry weight (3C) of passion fruit seedlings in function of the applied potassium dose and substrate, at 120 days [(▪) Bioplant; (∆) Coconut fiber and (•) Vivatto].

The potassium dose difference ideal for maximum response varied according with type of substrate due to the difference in the humidity content (H) between the substrates (Table 1) which can be interfered in the nutrient absorption which may have required greater nutrition of seedlings. Almeida et al. (2006) when producing passion fruit seedlings verified maximum of 14 leaves, but the dose of 218 mg dm^{-3} of K grown in Oxisol as a substrate, which shows the seedlings showed good numbers of leaves.

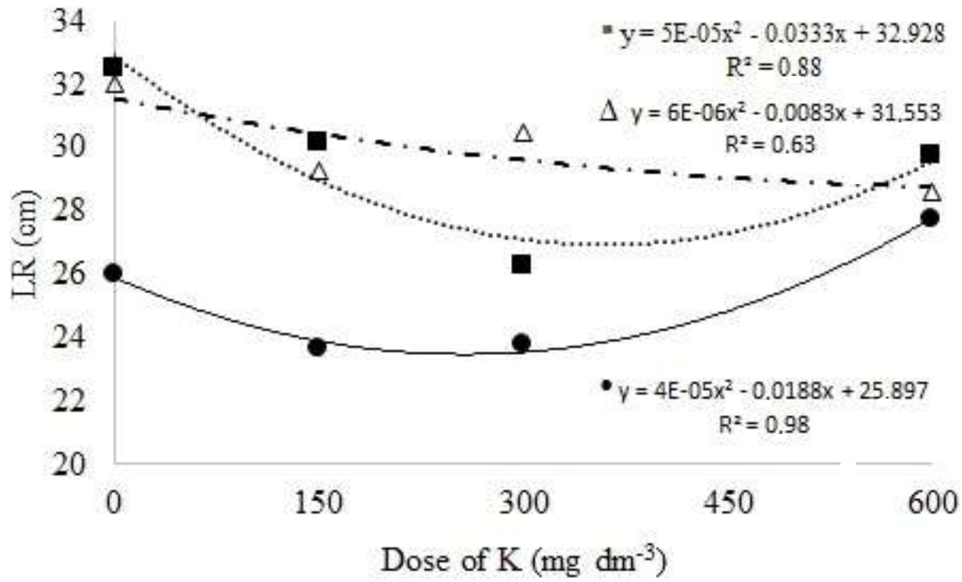

Figure 4. Length of root of passion fruit seedlings in function of the applied potassium dose and substrate, at 120 days [(▪) Bioplant; (∆) Coconut fiber and (•) Vivatto].

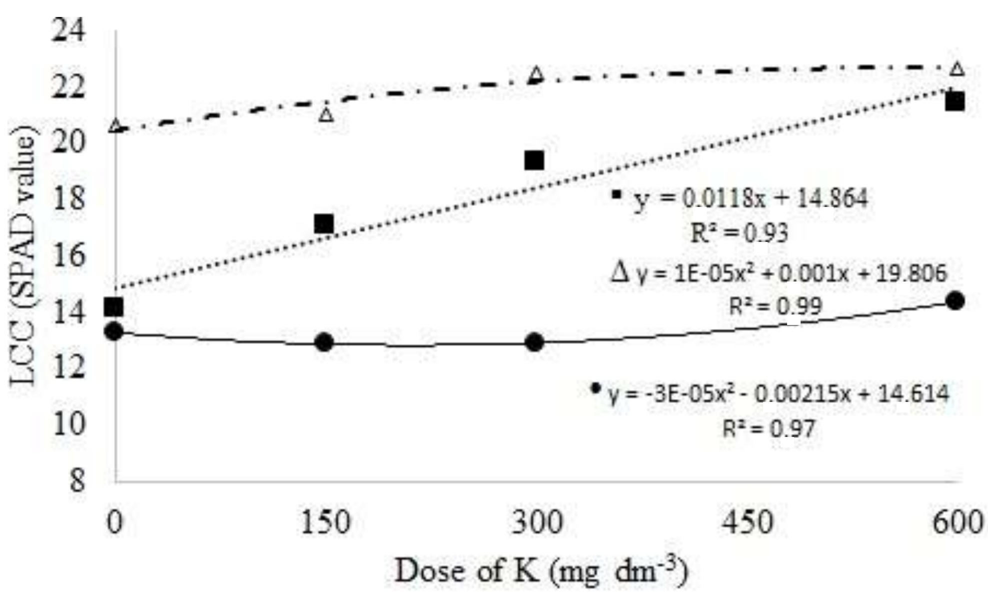

Figure 5. Leaf chlorophyll content of passion fruit seedlings in fuction of the applied potassium dose and substrate, at 120 days [(▪), Bioplant; ∆, coconut fiber; •, Vivatto].

Table 2. Plant height (cm) of passion fruit in fuction of substrate, after 120 days of transplanting.

Substrate	Plant height (cm)
Bioplant®	67.43[a]
Coconut fiber	61.96[a]
Vivatto®	61.34[a]
C.V. (%)	19.90

Mean of same letter have no difference statistic.

In DWS significant difference occurred varying responses on dry matter in accordance with the interaction between potassium dose and type of substrate (Figure 3A). The different results showed can be explained by different chemical characteristics of three substrates (Table 1), which influenced the accumulation of dry matter of seedlings of yellow passion fruit. The effects of increasing doses of K depend on the decrease in the accumulation of Ca and Mg in the substrate. The increase of available K in the soil enhances the competitive effect on the absorption of Ca and Mg, during the root absorption process, these nutrients used the same loading sites (Radane-Malvi, 2011). Prado et al. (2004) found a decrease in dry matter of passion fruit seedlings using a higher dose of 225 mg dm^{-3} of K.

Substrate Coconut fiber was presented as the better in roots accumulation of seedlings, presenting best values than substrate Bioplant® and Vivatto® in the gain of dry matter was without application of potassium (Figure 3B). Probably, the content of substrate of 23.4 $mmol_c dm^{-3}$ (Table 1) was sufficient to express the maximum result in DWR. The difference in accumulation of DWR occurred due to interaction between K: Ca/Mg with application of potassium doses, principality high relation Ca/Mg in the substrate could have hampered K absorption by the plant due to competition for the same absorption site (Radane-Malvi, 2011).

In variable of TDW accumulation of seedlings, significant difference and interaction between types of substrates and doses of K was observed (Figure 3C). This difference to the ideal dose for maximum dry matter accumulation were probably due to differences in chemical composition and physicals of commercial substrates (Table 1), where the interaction between chemical and physical of substrates influenced on responses of TDW. Almeida et al. (2006) studied the mineral nutrition of passion fruit seedlings recommended dose of 300 mg K dm^{-3} to obtain the maximum accumulation 16 g of dry matter of seedlings, but this value was obtained by the sum of total dry matter of two plants that were sown in the same vessel. Boechat et al. (2010) observed that substrates with manure + soil and Plantmax® showed higher values total dry matter in passion fruit seedlings compared the Coconut fiber and presenting 0.80 to 1.20 g dry matter $plant^{-1}$ at 60 days in the dose of 6.4 g K_2O.

In general, it was observed that the increased application of K doses caused reduced growth of the roots of plants yellow passion fruit in the three substrates, this response may be due to two factors combined (Figure 4). This response may be due to two factors combined. First, the salt effect caused by Cl to the fertilization potassium, when using chloride potassium as a fertilizer added to the nitrogen supply of plants in the form that increases the salinity of the substrate, may cause toxicity micronutrient plants (Malavolta, 1997).

The use of potassium chloride as a K source may have caused a toxic salinity roots of seedlings that inhibited growth in excess salts with three commercial substrates. Furthermore, there substrates contains Mg and K in the composition. The omission of plant growth under saline conditions may either be due to osmotic reduction in water availability or to excessive ion levels (Marschner, 1995).

The chlorophyll content (SPAD) in passion fruit seedlings showed difference according to the substrate and potassium doses used (Figure 5). There was an increase in the SPAD values until the dose of 300 mg dm^{-3} using Coconut fiber.

Potassium participates in the onset of metabolic processes of nitrogen, the absorption of mineral nitrogen, and in particular the nitrate reductase and the efficiency of N is reduced in plants that are deficient K (Ruan et al., 2015). Photosynthesis constitute the basis for the production of a culture and using the absorption of light energy by the plant can be estimated by chlorophyll fluorescence analysis (Freire et al., 2013).

The amount of Ca, Mg substrate Vivatto® (Table 1) plus potassium fertilization resulted nutritional unbalance the changes which explains the low content of chlorophyll passion fruit sheet. Authors have reported the feasibility of measurement of chlorophyll as indicators of the nutritional status and quality of passion fruit plants in relation to nutrient (Freire et al., 2013; Cavalcante et al., 2011). Santos et al. (2011) in the study of initial growth of yellow passion fruit seedlings found SPAD value of 57 to 127 days after sowing the seedlings. However, this work were evaluated sources of N being that results better were with bovine + urea manure. The use of salts in the soil, including potassium in high concentrations reduces the nutritional balance of passion fruit seedlings by decreased total chlorophyll levels (Freire et al., 2013).

Conclusion

The doses of potassium that provided the maximum accumulation of total dry matter of seedlings of yellow passion fruit was the dose of 600 mg of K dm^{-3} for substrate Vivatto® and 300 mg of K dm^{-3} for substrate Bioplant®. For substrate, Coconut fiber the potassium dose not reflected in increased dry matter accumulation of seedlings. The types of commercial substrates Bioplant®, Coconut fiber and Vivatto® provoked differences during seedlings development in protected conditions. The response varied among substrate tested and potassium doses, affecting leaves features, dry weight, root length and chlorophyll content of seedlings of yellow passion fruit.

Conflict of Interests

The authors have not declared any conflict of interests.

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