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Reuse of substrate and nutritive solution concentration on the cultivation of salad tomato

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Abstract

Among the most modern techniques of vegetables production cultivation in substrate is highlighted. In this method the substrate and the nutritive solution are main components that deliver nutrients to the crop and directly influence the performance of the plants. The objective of this study was to evaluate the reuse of substrate with several concentration of the nutritive solution in cultivation of tomato plants of the salad group 'Paronset'. The experimental design was a randomized blocks in a factorial scheme 3x5, with four replicates. The plants were grown in coconut husk fiber, in three substrate reuse levels (new substrate, reused once and reused twice) and five concentrations of the nutritive solution recommended for the culture [25%; 50%; 100% (original solution); 150% and 200%]. The chemical and physical characterization of the substrate after cultivation was done such as fruit productivity and quality and nutritional status of the plants. Physical characteristics were only influenced when substrate was reutilized. Chemical characteristics of the substrate were influenced by both the reuse of the substrate and the concentration of the nutritive solution. It was observed that the nutritional status of the plants was influenced only by the concentration of the nutritive solution. It was also noted that the productivity and fruit mass decreased after the second reuse of the substrate. The use of the original solution (100%) allowed the highest productivity; however, the largest fruit mass was obtained with the most dilute solution (25%).

Keywords: *Solanum lycopersicum* L., coconut husk fiber, soilless cultivation, fertigation, production.
Abbreviations: AS_Aeration space; AW_Avaible water; D_Density; P_Porosity; RAW_Readily available water.

Introduction

The use of substrates in the cultivation of vegetables has been stimulated by providing advantages such as better sanitary conditions of plants, higher use efficiency of irrigation and fertigation, elimination of the costs with soil management, and others. Like majority of the cropping on substrates, fertilization of plants is provided by a fertigation system, when well-managed, promotes increase in productivity and the quality of vegetables.

The high concentration of nutrients in the nutritive solution makes the absorption of water by the plants difficult, what might aggravate the negative effects of drought stress on growth and yield. Conversely, low nutritive solution concentrations, combined with environmental conditions of reduced evaporative demand by the atmosphere, diminish the dry mass content as well as the quality (Lorenzo et al., 2003). Another important characteristic, that should be considered in cultivation in vases for vegetables cropping, is the reuse of substrates, since it is extremely advantageous for the producers to have the option to utilize it for many times. Besides, the longer the time utilizing the substrate, the lower the environmental impact due to the discard of this material. Some authors studied the reuse of substrates and verified that there was a decrease on yield in two or more consecutive cropping (Reis et al., 2001; Fernandes et al., 2007; Urrestarazu et al., 2008).

In Brazil, coconut husk fiber has been the most utilized substrate in vegetables production with great yield results and quality of the products. However, there is not enough research that evaluates the possibility of reutilization of substrates, as well as the nutritive solution concentration in this system (Charlo et al. 2010).

Therefore, evaluation of the nutritive solution concentration in consonance with the reuse of coconut husk fiber allows verifying possible chemical and physical alterations in this substrate during the cultivations. Furthermore, their influences on plant performance can be assessed which defines the amount of fertilizers that might be applied due to the reuse of the substrate.

Thus, the objective of this work was to evaluate the performance of tomato plants ‘Paronset’, group salad, cultivated in coconut husk fiber, under reuse of substrate and several concentrations of nutritive solution.

Results and Discussion

Physical analysis of substrate

Regarding the physical characterization of the substrate, there was an interaction between "substrate utilization" and "nutritive solution concentration", only for density (D). Amongst levels of utilization, there was a significant difference for porosity (P), available water (AW) and readily available water (RAW). Nutritive solution concentration did not cause any difference on physical characteristics (Table 1). Analyzing the interaction between levels of substrate utilization and nutritive solution concentration, it was verified that in the concentrations of 25% and 50% higher density values were noted when substrate was utilized twice, when compared to the new one. At the concentration of 100%, there was difference among new and once reutilized substrate, in which the latter did not differ from the twice-utilized substrate. At the 150% and 200% concentration, there was no difference between levels of substrate utilization (Table 2).

The trend in increasing density due to time of substrate use is a common characteristic the occurred as a result of coconut husk fiber decomposition and the movement of particles in the container promoting a higher accommodation in the available space.

Density is a characteristic that influences the development of plant root system, where there are several recommendations for the substrate. Yeager et al. (2007) recommended that the ideal media density for growing vegetables is lower than 900 kg m^{-3} and may be as low as 80-120 kg m^3 in light peat, rockwool and perlite. Thereby, the verified density in the majority of the treatments, in which substrate was reutilized is above the recommended by these authors. A larger porosity was verified in the new substrate compared to the one utilized twice. According to Fernandes (2007), irrigation and decomposition of the organic matter and the movement of the particles by root growth decrease porosity and an increase of the density on the substrate. The decomposition of organic substrates causes a reduction on the size of particles. Consequently, there is a reduction on the size of porous created by them. Fernandes et al. (2004), suggested that in vegetables cropping the substrates with total porosity higher than 85% of the volume provides a good performance for yield production in pots. Available water (AW) and readily available water (RAW) were lower in the new substrate. Among the reutilized substrates, there was no difference for this characteristic. The decrease of porosity and the increase of density in the reused substrates tend to higher water retention (Fernandes, 2006). A good substrate shall have, among other characteristics, 10 to 30% of aeration space and a readily available water range from 20 to 30% (Fernandes et al., 2004, Fernandes et al., 2007). Fernandes (2007) evaluated the reuse of seven substrates (blend of sand base materials, peanut shell and sugarcane bagasse), in cherry tomato (Sindy) crop and verified alteration of physical properties only in the treatment that simultaneously utilized the combination of some of them. Furthermore, the increase in density and readily available water and reduction of porosity, aeration space and remaining water were noted.

According to Pardossi et al. (2011) the decrease on aeration space and the increase of water retention capacity in reutilized substrates can be controlled by revolving the substrate and the adequacy of a fertigation regime. According to the same authors, increase in electric conductivity values and other toxic ions in the substrate can be re-adjusted by its rinse or a fertigation management.

Chemical analysis of substrate

There was no significant interaction between substrate utilization and nutritive solution concentration for the chemical characteristics of the substrate (Table 3). Regarding the factor "substrate utilization", it was verified that electric conductivity (EC) was higher on the substrate reused twice, and pH was lower only in the new substrate. The Ca, Mg, S, Fe, Mn and Zn content, were higher in the substrate utilized twice. N-nitrate (N-N) and P content differed only among treatments with the new substrate and the reutilized twice, in which this last one accumulated the highest quantities (Table 3).

The C/N ration decreased due to the reuse of the substrate, in which new substrate possesses higher values, followed by the one reutilized once and then reutilized twice. The decrease of the C/N ratio demonstrates that, despite the coconut husk fiber possess a good durability, the material trends to enter in considerable level of decomposition during the growing period (Table 3). Urrestarazu et al. (2008) verified alteration from 172 for 15 at the 695 days of reuse of almond shells as substrate in tomato cropping, at Almeria, Spain. The decomposition of organic matter results in physical and chemical alteration in the substrate. It may influence plant performance throughout cropping. The reduction of the C/N ratio indicates organic matter degradation by microorganisms, reducing the inert characteristic over time, influencing plant nourishment. The C/N ratio also diminished with the increase of the nutritive solution concentration (Fig. 1), indicating that the substrate tends to degrade more rapidly with the increment of fertilization. This occurs due to a larger quantity of available nutrients for microbial degradation of organic matter, mainly nitrogen. The highest quantities of nutrient found in the twice reutilized substrate occurred due to the accumulation of fertilizers throughout the crops. Fernandes et al. (2007) reported accumulation of nutrient after reuse when reutilized substrate in cherry tomato culture, which accumulated quantities varied as the management of the nutritive solution, specie, substrate type, climatic conditions and other factors.

However, despite the accumulation of some nutrients in the substrate, low electric conductivity values verified, even when reutilizing the substrate twice (Table 3). The values on electric conductivity of the substrate may vary due to the frequency and the volume of nutritive solution applied, promoting leaching or nutrient accumulation. The drainage adopted in this experiment, associated to the rapid absorption of the nutrients by the plants, which might have contributed to no excessive values in the substrates. Other authors also reported different results for chemical analysis of substrates. Urrestarazul et al. (2008) reutilized a composed substrate by almond shell residues in melon and tomato cropping and verified alterations in the electric conductivity (dS m^{-1}) of 2.47, 2.24, 2.03, 3.90, 3.15 and 2.99 at the 0, 165, 265, 430, 530 and 695 days of reuse, respectively. In the work performed by Urrestarazu et al. (2008), the fertigation management was adopted due to plant growth, substrate physical and chemical properties, real time climatic conditions (specially radiation) and drainage parameters.

Table 1. Physical characteristics of coconut husk fiber substrate due to its use (A) and nutritive solution concentration (B). Jaboticabal, UNESP-FCAV, 2016.

	D	AS	P	AW	RAW
	kg m^{-3}	-----------------	-----------------%	-----------------	-----------------
Substrate Use (A)					
New	649.0	21.0 a	75.4 a	17.1 b	12.0 b
Reused	778.0	23.9 a	72.5 ab	20.8 a	15.7 a
Reused twice	836.0	24.4 a	67.8 b	22.3 a	16.9 a
Nutritive Solution Concentration (%) (B)					
25	763.6	21.7	69.5	18.7	13.7
50	782.5	23.4	77.3	21.8	16.4
100	779.1	21.6	70.8	20.8	15.4
150	717.8	23.8	70.5	19.0	14.6
200	723.5	24.7	71.4	20.1	14.7
F (linear)	2.11 ^{ns}	2.24 ^{ns}	0.16 ^{ns}	0.00 ^{ns}	0.00 ^{ns}
F (quadratic)	0.50 ^{ns}	0.24 ^{ns}	0.83 ^{ns}	1.30 ^{ns}	2.15 ^{ns}
Interaction A x B	2.87*	1.03^{ns}	1.27^{ns}	2.01^{ns}	1.79^{ns}
CV (%)	14.50	20.21	10.71	19.45	19.45

Means followed by the same letter do not differ among them by the F test at 5% of significance. * significant at 5% of probability ($0.1 \leq p < 0.05$).
D – Density; AS – Aeration Space; P – Porosity; AW – Available Water; RAW – Readily Available Water.

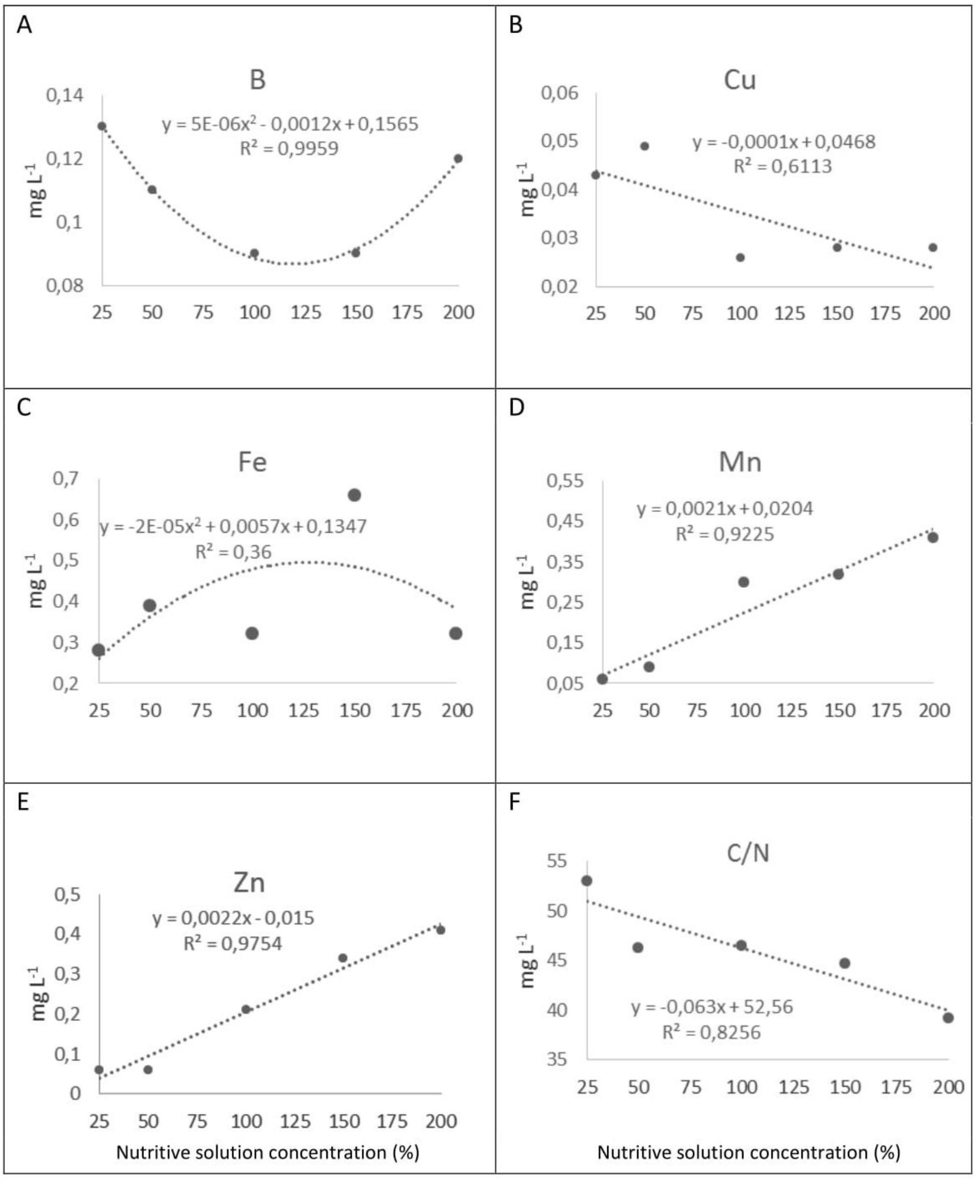

Fig 1. Boron (A), Cu (B); Fe (C); Mn (D); Zn (E) content and C/N ratio (F), characterized in coconut husk fiber substrate (extraction ratio 1:1.5), due to nutritive solution concentration. Jaboticabal, UNESP-FCAV, 2016.

Table 2. ANOVA analysis between substrate utilization and nutritive solution concentration on substrate density (kg m^{-3}), Jaboticabal, UNESP-FCAV, 2016.

Substrate utilization/ Nutritive solution concentration	25%	50%	100%	150%	200%
New	589 Ba*	598 Ba	650 Ba	688 Aa	720 Aa
One use	774 ABa	910 Aa	881 Aa	667 Aa	659 Aa
Two use	927 Aa	839 Aa	807 ABa	798 Aa	791 Aa

*Means followed by the same letter do not differ among them by the F test at 5% of significance.

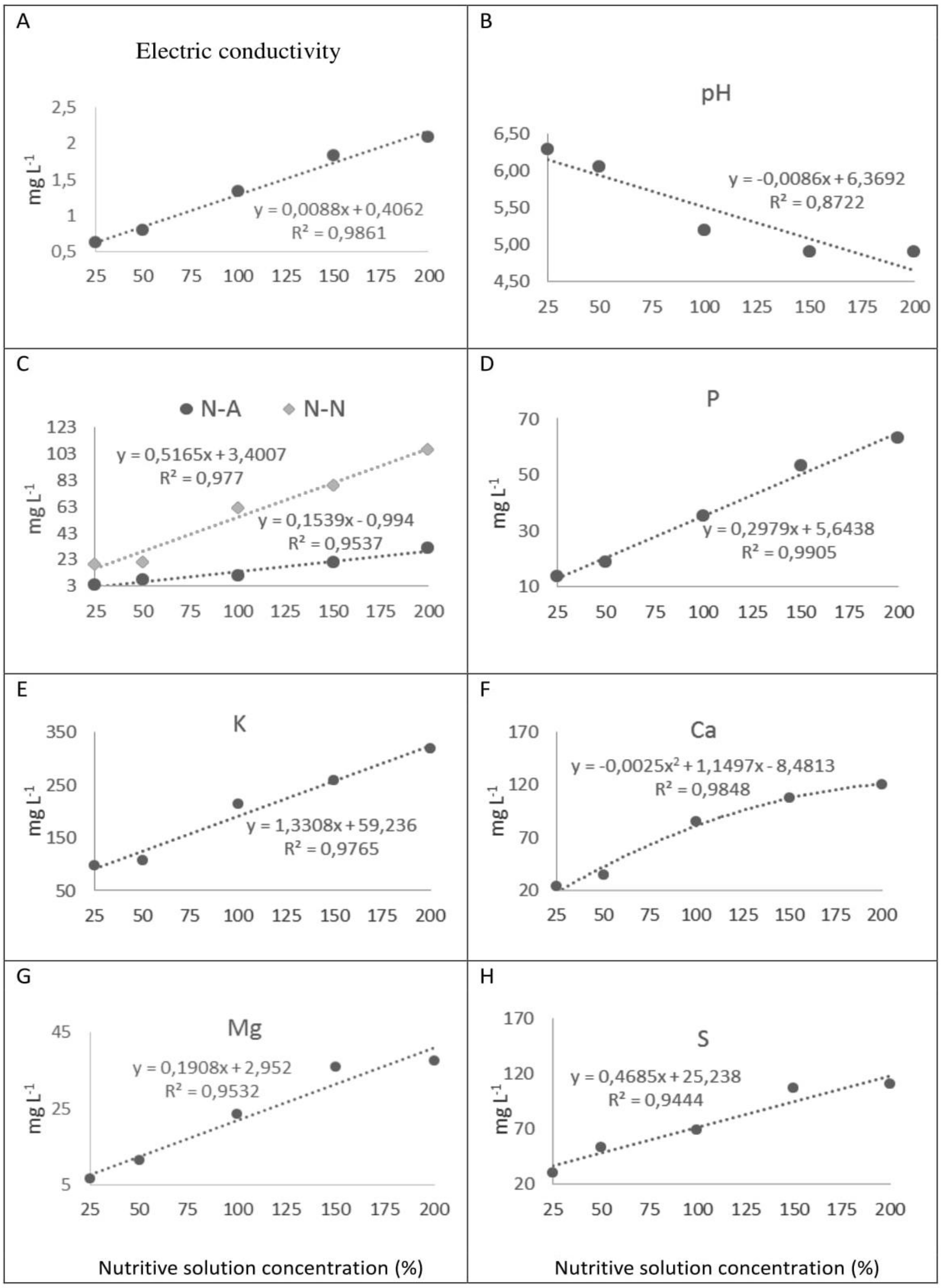

Fig 2. Electric conductivity (A), pH (B), N-N and N-A (C), P (D), K (E), Ca (F), Mg (G) and S (H) content, characterized in coconut husk fiber substrate (extraction ratio 1:1.5), due to nutritive solution concentration. Jaboticabal, UNESP-FCAV, 2016.

Table 3. Chemical characteristics of coconut husk fiber (extraction ratio 1:1.5), and nutritional status of tomato plants 'Paronset', due to the substrate use (A) and nutritive solution concentration (B). Jaboticabal, UNESP-FCAV, 2016.

	Substrate use (A)			Nutritive solution concentration (B)		Interaction A x B	CV%
	New	Reused	Reused Twice	F Linear	F Quadratic		
Substrate analysis							
EC	1.14 b	1.25 b	1.61 a	88.57**	0.66^{ns}	0.37^{ns}	34.77
pH	5.26 b	5.59 a	5.56 a	342.3**	44.54**	3.62^{ns}	4.19
N-N	47.09 b	55.39 ab	70.42 a	120.23**	0.02^{ns}	0.27^{ns}	40.36
N-A	17.70 a	14.54 a	13.24 a	109.77**	4.54*	0.70^{ns}	48.02
P	31.97 b	34.07 ab	44.72 a	106.36**	0.23^{ns}	0.55^{ns}	38.80
K	199.75 a	185.71 a	211.05 a	116.71**	0.50^{ns}	0.85^{ns}	30.77
Ca	51.56 b	74.12 b	97.22 a	95.59**	4.10*	0.26^{ns}	40.06
Mg	15.28 b	20.49 b	33.20 a	42.53**	1.45^{ns}	0.74^{ns}	63.11
S	57.86 b	67.29 b	98.13 a	39.66**	0.99^{ns}	0.35^{ns}	49.56
B	0.11 a	0.09 a	0.12 a	1.05^{ns}	8.57**	2.04^{ns}	29.61
Cu	0.02 a	0.02 a	0.05 a	4.78*	0.93^{ns}	0.71^{ns}	73.67
Fe	0.31 b	0.34 b	0.55 a	11.40**	11.95**	4.33^{ns}	32.54
Mn	0.19 b	0.21 b	0.31 a	75.13**	3.23^{ns}	0.56^{ns}	48.16
Zn	0.11 b	0.18 b	0.36 a	65.02**	0.08^{ns}	2.05^{ns}	60.75
Ratio C/N	53.96 a	47.04 b	36.83 c	25.04**	0.00^{ns}	2.49^{ns}	13.58
Nutritional Status							
N	42.07 a	43.40 a	42.97 a	57.62**	0.20^{ns}	1.61^{ns}	10.12
P	4.37 a	4.61 a	4.61 a	23.01**	10.59**	0.65^{ns}	14.37
K	29.49 a	28.81 a	27.57 a	42.15**	2.24^{ns}	0.58^{ns}	16.07
Ca	12.46 a	12.67 a	12.24 a	16.78**	1.42^{ns}	0.76^{ns}	20.08
Mg	3.66 a	3.63 a	3.61 a	6.69*	0.23^{ns}	0.25^{ns}	11.38
S	5.45 a	5.35 a	5.35 a	0.19^{ns}	0.20^{ns}	0.68^{ns}	11.66
B	49.35 a	46.70 a	49.70 a	1.84^{ns}	14.34**	0.98^{ns}	27.29
Cu	9.75 a	10.45 a	11.05 a	7.97**	4.90*	1.69^{ns}	26.04
Fe	93.60 a	94.25 a	92.50 a	12.21*	0.01^{ns}	1.29^{ns}	17.60
Mn	81.95 a	87.55 a	91.55 a	28.93**	6.79*	0.90^{ns}	26.47
Zn	35.90 a	38.00 a	33.30 a	40.46**	3.73^{ns}	0.35^{ns}	28.03

Means followed by the same letter do not differ among them by the F test at 5% of significance, ** significant at 1% of probability (p <0.01), * significant at 5% of probability (0.1≤ p <0.05), ^{ns} non-significant, EC – Electric conductibility; N-N: Nitrate-Nitrogen; A-N; Ammonium-Nitrogen.

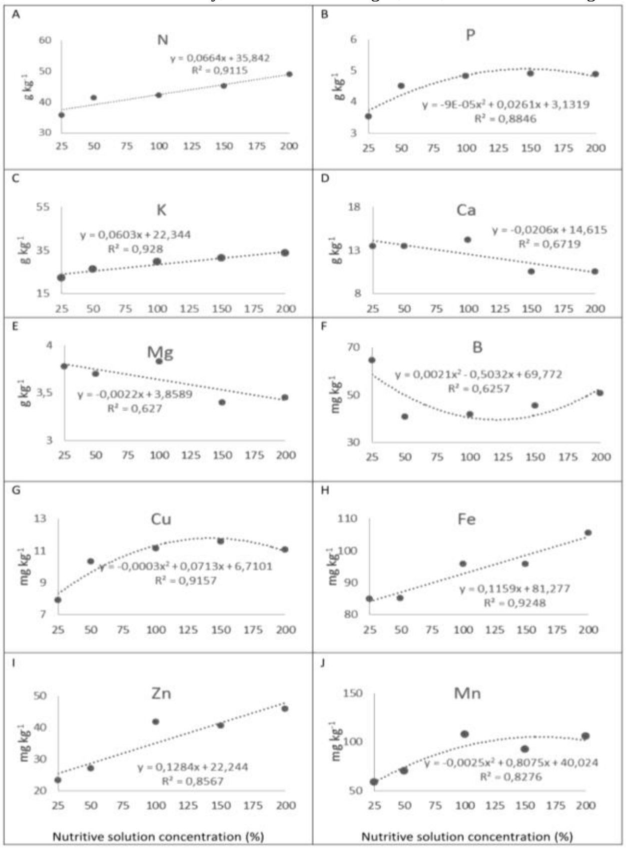

Fig. 3. N (A), P (B), K (C), Ca (D), Mg (E), B (F), Cu (G), Fe (H), Zn (I) and Mn (J) content of tomato plant 'Paronset' due to nutritive solution concentration. Jaboticabal, UNESP-FCAV, 2016.

Table 4. Summary of the variance analysis and average, in factorial scheme, between substrate use (A) and nutritive solution concentration (B), for each characteristic of tomato plant 'Paronset'. Jaboticabal, UNESP-FCAV, 2016.

	TY	NFP	FTD	FLD	AFW	SS	pH	TA
Substrate use (A)								
New	87.77 a	29.73 a	53.11 a	65.11 ab	120.62 a	4.98 a	4.22 a	0.21 a
Reused	84.56 a	30.70 a	53.28 a	66.36 a	120.25 a	5.08 a	4.19 ab	0.20 a
Reused twice	78.15 b	27.86 a	51.79 a	62.53 b	112.44 b	5.21 a	4.16 b	0.40 a
Nutritive solution concentration (B)								
F linear	5.04*	18.90 **	36.06**	21.95**	111.70**	37.76**	34.30**	2.23^{ns}
F quadratic	13.42**	21.88**	0.82^{ns}	0.34^{ns}	1.65^{ns}	7.17*	4.22*	3.08^{ns}
interaction A x B	1.95^{ns}	1.15^{ns}	0.43^{ns}	0.85^{ns}	0.92^{ns}	0.68^{ns}	0.37^{ns}	1.06^{ns}
CV%	9.35	9.22	5.54	5.24	6.53	6.92	1.66	17.7

Means followed by the same letter do not differ among them by the F test at 5% of significance. ** significant at 1% of probability (p <0.01), * significant at 5% of probability (0.1≤ p <0.05), ^{ns} non-significant, TY – Total yield (t ha^{-1}); NFP – Number of fruits per plant; FTD – Fruit transversal diameter (mm); FLD – Fruit longitudinal diameter (mm); AFW – Average fruit weight (g); SS – Soluble solids (°Brix); TA – titratable acidity (% citric acid).

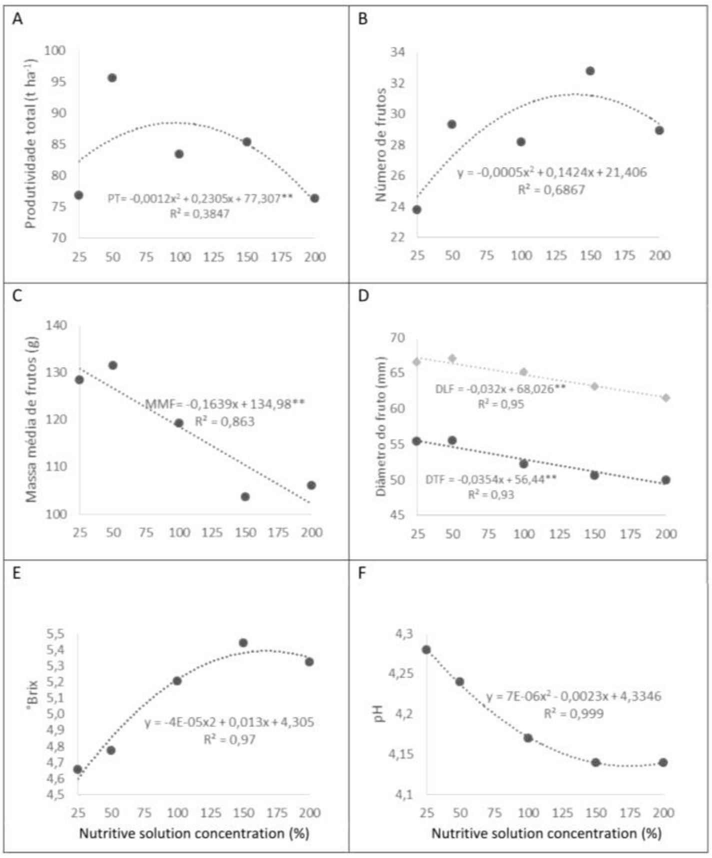

Fig 4. Total yield (A), number of fruits (B), average fruit weight (C), Longitudinal diameter of fruits (LDF) and transversal diameter of fruits (TDF) (D), soluble solids content (°Brix) (E) and pH (F) due to nutritive solution concentration. Jaboticabal, UNESP-FCAV, 2016.

The substrate analysis was performed by the method of extraction by saturation, described by Warneck (1896).

Pardossi et al. (2011) explained a reference for chemical analysis (method 1:1.5) in organic substrates, utilized in controlled conditions. The values were as follows: 5.5-6.0 (pH); 0.6-1.5 (EC); 40 – 80 mg L^{-1} (NO_3^-); 25-35 mg L^{-1} (NH_4^+); 12-45 mg L^{-1} (K); 20-30 mg L^{-1} (P); 40-80 mg L^{-1} (Ca); 25-45 mg L^{-1} (Mg); 115-150 mg L^{-1} (SO_4^-); 0.1-0.4 mg L^{-1} (Fe); 0.01-0.3 mg L^{-1} (Mn); 0.01-0.06 mg L^{-1} (Cu); 0.01-0.3 mg L^{-1} (Zn) and 0.01-0.3 mg L^{-1} (B). Comparing the abovementioned values with the present work, only K and all micronutrients, in the most diluted treatment (25%) were superior to those reported by those authors (Table 3). For the other nutrients, values verified in the substrate only reached similar or superior (Pardossi et al., 2011) from the use of the 100% nutritive solution. Sulfur was the only nutrient that in any concentration of the nutritive solution reached the minimum recommended by these authors.

Fernandes et al. (2007) reutilized seven composed substrates by mixture of sand, peanut shell and sugarcane bagasse, in a tomato crop from the group 'Sindy' and concluded the average value of 3.0 dS m^{-1} after a second cropping, compared to 0.3 dS m^{-1} before the first crop (extraction method 1:1.5).

Analyzing the factor "nutritive solution concentration", it was verified that the N-nitrate, N-ammonium, P, K, S, Mg and Zn contents, increased linearly due to treatments, and polynomially for Ca. Contents of B and Fe obtained quadratic polynomial dynamic, and Cu content decreased linearly as nutritive solution concentration was increased (Fig. 1, 2).

The values of K in the substrate for the most diluted solution (Fig. 2-E) were above the ideal (Pardossi et al., 2011). However, with its higher concentrations no visual symptoms of toxicity were observed in the plants. Some papers reported the direct influence of K on fruit development. Charlo et al. (2012) stated that increasing application rate of K influences weight and size of fruits. Though, excessive rates do not necessarily imply in increment of production, generating higher costs to the farmer.

The increase on nutrient content in the substrate is justifiable as a result of the higher supply of fertilizers, in which excess is considered luxury fertilization. The reduction of the nutrient content in the substrate might be justified by the larger absorption by the plants due to its demand. The reduction of pH may happen when nutritive solution concentrations are increased (Fig 2-B). This is owing to several factors, among them the excessive utilization of ammoniated fertilizers, organic matter oxidation and sulfur, cation with basic character removal (Ca, Mg, K and Na) and consequently the increase of Al and H content (Charlo et al., 2012). The ideal range of pH for tomato is from 6.0 to 6.5 (Incrocci at al. 2006); however, tomato plants present tolerance to moderate acidity, from 5.5 to 6.5.

It obtained higher NO_3^- content than NH_4^+ (Fig. 2-C). The higher NO_3^- content in soil solution or substrate is not desired because the excessive accumulation of this compound in plants might be harmful for human health. It should be taken into consideration that the most absorbed form of nitrogen by tomato plants is either NH_4^+ or NO_3^-. We require evaluation of concentration these compounds in the vegetative organs and mainly fruits that is consumed.

The NO_3^- is absorbed in larger quantities by plants, when there is a higher concentration of this compound in the soil solution. However, in lower concentration or in similar proportions, NH_4^+ is absorbed in larger quantities due to its minor energy use by the plants. Nevertheless, according to these authors, absorption of NO_3^- is necessary for plant growth. Besides, the high absorption of NH_4^+ provokes a soil/substrate acidification.

Nutritional status of plants

There was no interaction between "substrate utilization" and "nutritive solution concentration" for foliar content of all evaluated nutrients. Similarly, there was no difference between nutrient foliar content amongst levels of substrate utilization. The differences were noted among treatments due to nutritive solution concentration except for sulfur (Table 3). Among treatments corresponding to "nutritive solution concentration", it was verified a linear increase on N, K, Fe and Zn content. A linear decrease of Ca and Mg content and quadratic adjust in P, Cu, B and Mn content was also observed (Fig. 3).

The linear increase verified on N, K, Fe and Zn content due to the nutritive solution concentration, indicating that the plants continuously absorb these nutrients as they are supplied in larger quantities.

Conversely, foliar content of Ca and Mg decreased in tissues as the supply was increased. They might possibly have had a competition of these nutrients with one another's cation. For example concentration of K which is more absorbed nutritive solution was increased (Fig. 3-C). Sonnevelde and Welles (1988) reported decrease on foliar content of Ca and Mg when nutritive solution concentration was increased. According to the same authors, the precipitation of these nutrients in the nutritive solution occurs frequently in saline conditions, when there is an unbalance between bicarbonates and bivalent cations, in this case Ca^{+2} and Mg^{+2}.

Besides, the possible unavailability of Ca and Mg to the plants, larger accumulation of these cations in the substrate and the decrease of foliar contents of these nutrients might be due to a dilution factor. In other words, plants are more responsive to the N supply and produce larger foliar weight and provide a decrease on foliar content of Ca and Mg.

Foliar content of $H_2PO_4^-$, Cu^{2+} and Mn^{2+} are similar to the adjustments of the regressions. This dynamic demonstrates that, probably the plant no longer absorbs these nutrients, when the concentration close to the roots increases beyond necessary.

Regarding the B, it was verified that there was a decrease on foliar content until the use of the original concentration (100%), from which there was an increase in foliar content (Fig 3-F). It is possible to verify that this dynamic was similar to the results reported for the substrate and probably this occurred due to the availability of this nutrient in the radicular environment (Fig 1-A).

The decrease of pH values in the substrate (Fig. 2-B) is due to the increase of the nutritive solution concentration which may influence the absorption of nutrients. Practically, it is considered that an ideal pH for the majority of the crops is 6.0 to 6.5.

Yield and fruit quality

There was no significant interaction between reuse of substrate and nutritive solution concentration for all characteristics (Table 4). For the factor "reuse of substrate, there was significant difference for total estimated yield, fruit longitudinal diameter, fruit average weight and pH. Regarding these characteristics, the lowest averages were reported in plants cultivated in substrate reutilized twice, not presenting difference among other treatments. For the factor "nutritive solution concentration", except for titratable acidity, all evaluated characteristics presented differences (Table 4).

Fernandes et al. (2007) evaluated the reuse of substrates composed by a mixture of sand, peanut shell and sugarcane bagasse. They reported that yield of tomato plants were 9.07 kg m^{-2} (90.7 kg ha^{-1}), when cultivated in a new substrate; and 8.44 kg m^{-2} (80.4 kg ha^{-1}), when cultivated in a substrate reutilized once. Similarly, these results corroborate with Urrestarazu et al. (2008), on tomato plants 'Daniela' in a substrate composed by almond shell, where the yield was reduced from 80.1 kg ha^{-1} to 65.2 kg ha^{-1} at 530 days of reuse.

The differences on fruit longitudinal diameter and fresh weight imply that the fruit obtained in substrates reutilized twice were smaller, mainly, in new substrates. Fernandes et al. (2007) also observed an increase in cherry tomato yield of larger size in new substrates. Analyzing the results of "nutritive solution concentration" factor, it was verified that total yield and number of fruits have quadratic adjusts, which from a certain point, decreases with the increase of the nutritive solution concentration (Fig. 4). The highest yield and number of fruits are obtained in the concentration of 96% and 142%, respectively. Bao and Li (2010) also reported diminish of productivity in tomato plants under increased salinity.

In the present work, a limit of 6 to 8 fruits per raceme was determined and thinning was realized when excesses were noted. Therefore, the treatments that obtained the lowest number of fruits occurred due to the non-fixation of the maximum number of fruits established by raceme. Probably, the increase of the nutritive solution's concentration benefits the fixation of fruits only until the 142% concentration, which from that, reductions were noted. According to Dorais et al. (2001), the number of flowers per raceme can be influenced negatively due to high salinity, influencing the fixation, fruit quality and yield.

The average fruit weight presented linear adjust, decreasing with the increase of the nutritive solution concentration (Fig. 4). As verified by the equation, the highest fruit weight can be obtained with the lowest concentration of the nutritive solution. These results might be influenced by the lower number of fixed fruits. As mentioned, the number of fruits increased until the use of 142% concentration.

Zeidan (2005) suggested that the high salinity of the soil promotes deficiency on water intake by the plants as a result of osmotic potential of the soil solution increased. Consequently, there is a decreasing trend on cellular volume, fruit size and tomato yield. Dorais et al. (2001) reported the effect of salinity in tomato cropping and verified that losses in productivity arise mainly from losses of average fruit weight.

Analyzing these last mentioned characteristics, it is possible to comprehend that, even lower concentration promotes a higher fruit weight. The yield was only decreased, when concentration was higher than 96%. The 100% solution was the treatment that enabled the highest fruit yield. Considering the objective of the producers to obtain larger and heavier fruits, the less concentrated nutritive solution can be utilized. However, a smaller quantity of fruits per area will be obtained (Fig. 4).

The fruit's longitudinal and transversal diameters characteristics were decreased after increase in nutritive solution concentration, following a linear adjust for both (Fig. 4). The decrease was approximately 10% for longitudinal diameter and 8% for transversal diameter for concentration of 25 and 200%, respectively. These results might occur due to an osmotic unbalance generated by salinity, when fruit size reduction is consequence of low water in the cell expansion phase in fruits (González-Fernandez and Cuartero, 1993) (Fig. 4).

For soluble solids a quadratic adjust was observed when nutritive solution concentration was increased (Fig. 4). The maximum soluble solids content was verified at the 162% nutritive solution concentration, observing the equation. The reduction from this point on might be related to the negative effect of transport and absorption of nutrients in plants under high saline stress, resulting in a later reduction of soluble solids. The gradual increase of this characteristic in plants subjected to increasing levels of salinity may occur due to accumulation of sugars such as glycose, fructose and saccharose, which is a physiological mechanism for protection and osmotic adjustments in plant (Ashrafe and Harris, 2004). Therefore, increase in soluble solids content of fruits possibly occurres with the objective of osmoregulation up to levels that would tolerate substrate salinity.

A continuous decrease of pH values due to the increase of nutritive solution concentration was verified (Fig. 4). Although this trend was occurred, in practice differences among values are infinitesimal, not being able to influence characteristics sensible to human consumption.

These results demonstrate that the continuous use of substrate and the increase in the concentration of the nutritive solution tend to negatively influence production characteristics and fruit quality. However, due to the low electric conductibility values in the substrate (Table 3), the negative factors that influenced plant growth might not be related to salinization but to the passage of the concentrated solution in root environment, an example that occurs in the hydroponic NFT.

However, in case that salinization becomes a limiting factor, treatments with rinsing might be applied to the substrate with the aim to leach the nutrients. Zeidan (2005) suggested that increase in water salinization or nutritive solution for the improvement of fruit quality might be applied in the soil during cultivation. In this system, the radicular absorption zone can be easily washed when an excessive accumulation of salt is available.

Materials and Methods

Location and installation of the experiment

The experiment was installed and conducted in a greenhouse in Jaboticabal at the Sao Paulo State, Brazil, located at 614 asl; 21°14'05" S, 48°17'09" W. The climate, according to Köppen's classification is Aw with transition to Cwa (VOLPE). The greenhouse that housed the experiment was the arched one, with 51 m long × 14 m wide and 3.5 m height. The side protection screen with shade cloth of 50% and soil covered with black raffia tissue were applied.

Experimental design

The experimental design adopted was randomized blocks, in a factorial scheme of 3x5, with four replicates. The factors evaluated were: three substrate utilization (new substrate, reutilized once, reutilized twice), and five nutritive solution concentration [25% of the recommended concentration (0.8 dS m^{-1}); 50% of the recommended concentration (1.6 dS m^{-1}); 100% of the recommended concentration (original solution: 3.2 dS m^{-1}); 150% of the recommended concentration (4.8 dS m^{-1}) e 200 % of the recommended concentration (6.4 dS m^{-1})]. Each plot was composed of 12 plants, in which the six central plants were evaluated.

In order to obtain the three levels of substrate utilization, two similar experiments to the present were set up. In these experiments, by the end of each tomato harvest cycle, the substrates were held in the pot to be reutilized in the next crop, whereas the experiment was reinstalled, pots with new substrates were added in to the cropping area. Therefore, the first cultivation gave rise to the twice reused substrate (the second originated from the once reused).

Seedling production and description of the growing area

For the formation of the seedlings, the hybrid F_1 Paronset (SYNGENTA®) was sown in expanded polystyrene trays containing 288 cells filled with commercial substrate (BIOPLANT®). Seedlings were transplanted into the vases with substrate, on July 14th of 2014, 26 days after sowing, when they presented three to five definitive leaves.

The plants were cultivated in 1.0 m double interlines, 0.8 m simple interlines, and 0.5 between plants. The plastic black pots with 9.8 dm^3 capacity (ECOVASOS®) were utilized and totally filled with substrate. For substrate, the coconut husk fiber Golden Mix Misto 98, from the same lot (combined with the fibrous portion of the granular coconut mesocarp fiber) was utilized with 0.9 mS/cm, water hold capacity of 400 ml per liter of substrate and total porosity of 95% (AMAFIBRA®).

The filling of pots followed methodology described by Fernandes (2006), in which a portion of substrate was added in the pot and a PVC ring was placed in the center and then completed the pot with the remain substrate with care not to be compacted.

The method of fertigation by drip, and two drippers by pots, flow rate of two L h^{-1} each was utilized. Nutritive solution supplied followed the current values for 1.000 L of water: 285g of monoammonium phosphate; 600g of magnesium sulfate; 1.088g of calcium nitrate; 423g of potassium sulfate; 340g of potassium chloride; 3g of manganese sulfate; 0,45g of zinc sulfate; 2,94g of boric acid; 10g of iron sulfate; 0,41g of cooper chloride and 0,02g of ammonia molybdate. The irrigation was performed by mediate fertigation composed of five reservoirs of fiber glass, one for each nutritive solution concentration, capacity of 1,500 L. The hydraulic system had five independent motor pumps for each reservoir. The nutritive solution was supplied according to the observation of pot drainage, the moment that the pumps were programed to shut-off. This way the operations of the pumps were controlled by timers, wherein the system was turned on ten times a day.

The plants were conducted vertically. The stalking were done with polythene strips up to 2.2 m from the soil, when it was performed the tip pruning, being conducted one stem per plant. The thinning of lateral ramification was carried out every two to three days and plant strapping done when necessary. There were maintained six racemes per plant, in which a thinning was performed, keeping six to eight fruits per raceme.

The phytosanitary control was executed as a preventive way and upon visual exam of the agent, insect or pathogen, adopting technical recommendations for each chemical product.

Harvest and Ratings

The harvest was performed by the identification of fruit maturation point, in which they presented red color or a transition from orange to red.

The ripe fruits were collected, identified and taken to the laboratory of Horticultural Products, where there following characteristics were evaluated: estimated total yield (kg ha^{-1}); number of fruits per plant and average mass of fruit (g). Five fruits per plots were chosen to determine transversal diameter of fruits (cm) and longitudinal diameter of fruits (cm); soluble solids (SS) (^{o}BRIX), obtained by a digital refractometer, obtaining values in %, corrected to 20^{o}C; pH: determined on juice extract, with assistance of a digital pH meter, in five fruits per plots; titratable acidity (TA): obtained by an aliquot of 10 mL of juice, in which 40 mL of distilled water and three drops of the indicator phenolphthalein alcohol at 1% were added to titrated with NaOH 0.1 N solution, until the turning point. The titratable acidity was expressed as % citric acid.

The determination of nutritional status of tomato plants was done by leaf sampling during tomato full blooming, according to the methodology described by Malavolta et al. (1997). The leaf samples were washed with deionized water, and oven dried at 60^{o}C, until constant weight. Then they grounded and submitted to chemical analysis according to methodology described by Bataglia (1983).

By the end of the experiment, it was selected randomly one pot per plot, to realize the chemical analysis of the substrate. The entire substrate from each pot was homogenized on a clean surface, where 2 L per samples were collected to send to the IAC (Agronomic Institute of Campinas) Laboratory for substrate analysis. The values for pH, electric conductivity, soluble content of NH_4^+, N-NO_3^-, P, K, S, Ca, Mg, B, Cu, Fe, Mn, Zn and ration C/N were obtained according to the Dutch method proposed by Sonneveld et al. (1974) (extraction ration 1:1.5).

The physical properties evaluated were: density (D), aeration space (AS), porosity (P), available water (AW) and readily available water (RAW), according the proposed by De Boodt & Verdonck (1972), utilizing volumetric rings of PVC 285 cm^3 (7.2 cm diameter and 7.0 cm height). Pots were disassembled to collect samples, being the PVC rings carefully removed as described by Fernandes (2006).

Climatological data

Climatological data inside the greenhouse were collected daily and monthly average calculated for the months of July, August, September, October and November. Monthly maximum relative air humidity values were 97, 98, 98, 97 e 95%. Monthly minimum relative air humidity values were 32, 31, 37, 38 e 36%. Maximum air temperatures were 30; 34; 33.5 and 37 °C. Minimum air temperatures were 10; 12.5; 11; 15 and 17 °C.

Statistical analysis

The data were submitted to an analysis of variance and means were compared by Tukey test t 5% of probability. Quantitative characteristics were submitted to regression analysis. Analyses were performed utilizing the digital software AgroEstat 1.0.

Conclusion

Considering the results, it is possible to conclude that the substrate is altered chemically and physically due to levels of reuse and for the nutritive solution concentration, which each nutrient is liable to accumulate or diminish owing to nutritional demand by the plants. The reduction of the nutritive solution concentration to 25% grants the highest fruit weight and the highest yield obtained from the original solution. We concluded that the reuse of the substrate twice reduces production characteristics and fruit weight.

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