Effects of different nutrient concentrations and reuse of substrate in tomato production

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Abstract

Reusing the substrate in subsequent crops has been proposed due to several advantages, especially economic and environmental ones. Furthermore, the electrical conductivity of the nutrient solution can directly influence the nutrient content present in the substrate, especially when it is reused, thus interfering with absorption by plants. In this way, the present study aimed to determine the feasibility of reusing the substrate and determine the optimal concentration of the nutrient solution in tomato cultivation. The experiment was conducted in a greenhouse at the Department of Vegetable Crops and Aromatic Medicinal Plants, belonging to FCAV-UNESP. The 'Paronset' hybrid was cultivated in pots containing coconut husk fiber as substrate. The nutrient solution was evaluated at five concentrations, namely 25, 50, 100 (original solution), 150 and 200% of recommended solution, and the substrate at two usage levels (new and reused). Fertigation was performed by dripping with nutrient solution as recommended. The characteristics evaluated were: production per plant, yield, number of fruits per plant, average fruit weight, soluble solids, and transverse and longitudinal fruit diameter. There was no interaction between the reuse of the substrate and nutrient solution concentration; moreover, there was no difference between the characteristics evaluated for all treatments. Under the conditions of this study, the reuse of the substrate is recommended, at least once, and the use of nutrient solution at a concentration of 25% of the original for the cultivation of 'Paronset' tomato hybrid.

Keywords: *Solanum lycopersicum*, greenhouse cultivation, coconut husk fiber, fertigation, nutrient solution

INTRODUCTION

Among the vegetables produced in Brazil, tomatoes stand out as one of the main ones, from both an economic and social aspect. Data from the Food and Agriculture Organization in reference to 2012, features the tomato crop as the eighth most cultivated in the world, with production estimated at 161.8 million tons (FAO, 2014).

Various vegetables have been produced under greenhouse conditions, which allow continuous supply and harvests in periods of low availability of the product on the market, thereby providing more competitive prices. However, currently, one of the greatest problems confronted by greenhouse growers is soil degradation, resulting from inadequate management of fertilizing and intensive cultivation, which causes salinization. As an alternative measure to this problem, some growers have adopted hydroponics, with the use of substrate, for example, coconut husk fiber.

The reuse of substrates has been the purpose of many studies, since it helps to reduce costs. Fernandes et al. (2007) and Cardoso (2009) found excessive increase in electrical conductivity of reused substrates, demonstrating the possibility of reduction in fertilizer levels applied in the course of cultivation. However, the effects on the production and quality of fruits of tomato plants cultivated in reutilized substrates have not been established in the literature. The study of the reuse of these materials depending on concentration of nutrients in the nutrient solution can provide valuable information in regard to the management of fertigation.

Therefore, the aim of the present work was to compare the performance of plants in new and reused substrates, under the influence of different concentrations of nutrient solution.

MATERALS AND METHODS

The study was conducted in a greenhouse, at the Department of Vegetable Crops and Aromatic Medicinal Plants, School of Agricultural and Veterinary Sciences (UNESP-FCAV), Jaboticabal Campus-SP. The location is at an altitude of 614 m, with coordinates 21°14’05”S and 48°17’09”W.

The experimental design was randomized blocks, in a 2×5 factorial scheme, with four repetitions. The treatments consisted of two levels of substrate utilization (new and reused) and five concentrations of nutrient solution 25, 50, 100 (original solution), 150 and 200% of recommended solution, with 12 plants plot^{-1}, with six plants being evaluated.

Seedlings were grown using the hybrid F_1 ‘Paronset’ (SYNGENTA®), the salad type cultivar, with indeterminate type growth, vigorous growth, short internodes (medium-sized), good foliar cover (protection of fruits), rounded fruits, slightly flattened, multilocular, long-lived (more than 15 days as red fruit), mean weight of 200-220 g, resistance to *Fusarium* 1 and 2, *Verticilium* 1, *Tobacco mosaic virus* (TMV), *Cladosporium* 1-5, *Tomato spotted wilt virus* (TSWV), harvest starting within 100 to 105 days after planting. Seeds were sowed in styrofoam trays containing 128 cells filled with commercial substrate, Bioplant®.

The seedlings were transplanted, when they showed 4 to 6 definitive leaves, to plastic pots with a total capacity of 9.8 dm^3, containing substrate composted of Golden Mix coconut husk fiber, which has the following physical characteristics: total porosity of 94%, aeration capacity of 35% and water retention capacity of 40% (AMAFIBRA, s.d.). The spacing utilized was 1.0 m between double rows, 0.8 m between single rows, and 0.5 m between plants. The plant density m^{-2} was equal to 2.22.

The fertigation method utilized was drip, where two drippers were set up per pot. The nutrient solution used was according to the recommendation of Moraes (1997) for tomatoes. The irrigation system was open type and triggered ten times day^{-1} by keeping it active on 15 min each time. The ratio of leaching was 30%.

The plants were staked with plastic ribbons, up to a height of 2.0 m from the ground, when apical pruning was done. The plants were pruned to one stem per plant, with sprout thinning and tied once a week.

The corresponding to tomato cultivation period was between January 19 to May 13, 2013. Harvest was started when at least 60% of the epicarp of the fruits was red, eight crops being conducted in total. The following characteristics were evaluated: productivity (t ha^{-1}), number of fruits per plant, mean fruit weight (g), level of soluble solids (°Brix); and longitudinal and transverse diameter of fruits (mm). The harvested fruits were counted and weighed to obtain the productivity and number of fruit per plant and average fruit weight. Fruits were cut in half to obtain the longitudinal and transverse diameters with a caliper. Following fruits were crushed, the juice obtained was sieved and a small portion was placed in a hand refractometer to obtain the soluble solids.

To assess the physical characteristics of the substrate in the center of each pot, a volumetric PVC ring 285 cm^3 (7.2 cm in diameter and 7.0 cm height) was placed, 1 L of the substrate was placed at the bottom of the vessel and the volume was positioned in the center of the vessel ring; substrate was added slowly to fill the volumetric ring and the vessel, with the goal of determining density (D), and total porosity (P), aeration space (AE) available water (AW), easily available water (EAW), buffering water (BW) and retained water (RW). This characterization was obtained following the methodology described by de Boodt and Verdonck (1972), two undisturbed samples were collected per plot at the end of the experiment.

The data obtained were then subjected to analysis of variance and the means were compared by the Tukey test at 5% probability, utilizing the program AGROESTAT version 1.1 (Barbosa and Maldonado, 2011).

RESULTS AND DISCUSSION

According to the summary of analysis of variance, there was no significant interaction with any of the factors evaluated. Thus, the factors are discussed separately. For all traits there were no significant differences (Table 1).

Table 1. Analysis of variance for total production (TP), number of fruits per plant (NFP), mean weight of fruit (MWF), soluble solids (SS), longitudinal diameter of fruits (LDF) and transverse diameter of fruits (TDF) according to reuse of substrate and concentration of nutrient solution.

Causes of variation	TP ($t\ ha^{-1}$)	NFP	MWF (g)	SS (°Brix)	LDF (mm)	TDF (mm)
Use of substrate (US)						
New	74.83 a	23.63 a	125.07 a	4.85 a	58.12 a	71.41 a
Used once	69.00 a	22.90 a	123.35 a	4.85 a	55.84 b	68.76 a
Concentration of nutrient solution (CS)						
25%	69.33 a	22.73 a	120.14 a	4.75 a	57.27 a	68.24 a
50%	74.55 a	23.57 a	123.27 a	4.75 a	58.05 a	70.16 a
100%	78.09 a	23.27 a	131.21 a	5.00 a	56.25 a	70.17 a
150%	65.10 a	23.14 a	125.27 a	5.00 a	55.49 a	70.01 a
200%	72.51 a	23.61 a	121.19 a	4.75 a	57.83 a	71.83 a
Interaction US×CS	0.62^{ns}	0.69^{ns}	1.19^{ns}	1.98^{ns}	0.35^{ns}	0.59^{ns}
CV %	15.15	9.99	6.43	7.32	5.77	7.38

The fertigation, when well-managed, fosters increased productivity and quality of vegetables. However, as with all technical practices, inadequate management in supplying fertilizer can cause salinization of the substrate and excessive absorption of nutrients by the plants, resulting in toxicity and decline in productivity and quality of fruits, besides unnecessary loss of nutrients and possibility of contamination of the environment (Kawakami et al., 2006).

The high concentration of the nutrient solution made it difficult for the plants to absorb water, aggravating the negative effects of water stress on growth and productivity. On the other hand, low concentrations of nutrient solution, combined with environmental conditions of reduced evaporative demand of the atmosphere, reduce dry weight as well as the quality of production (Lorenzo et al., 2003).

Kawakami et al. (2006) assessed the management of fertigation according to electrical conductivity of the drained nutrient solution in cherry tomatoes under greenhouse cultivation, and observed that as electrical conductivity (EC) increased (from 1.3 to 3.8 dS m^{-1}), there was a decrease in mean fruit weight, but without differences in the number of fruits per plant and productivity between the EC studied Torres et al. (2004) found that in recirculating hydroponic cultivation of tomatoes, a reduction in the concentration of nutrient solution to a EC below that of solutions commonly used did not decrease productivity. Genúncio et al. (2006) evaluated the growth and productivity of tomatoes grown under NFT hydroponics, according to ionic concentration of nutrient solution and observed that dilution of the original solution by 50% (1.4 dS m^{-1}) did not influence the influence the total number of fruits per plant and the accumulation of mass of the salad tomato cultivars.

In view of the studies cited, it is noted that variations in levels of electrical conductivity of the nutrient solution may or may not influence the performance of plants. The present work provided proof of the second notion, by not demonstrating significant quali-quantitative differences (Table 1) in the performance of tomato plants subjected to five different concentrations of nutrient solution, under the conditions in which the study was conducted. Therefore, low electrical conductivity can be used in the cultivation of tomatoes, because in this way, there would be lower costs for fertilizer, which would be reflected in the market price of the product, besides mitigating waste and environmental impacts.

One probable explanation for this can be related to the physical characteristics of the substrate. Coconut husk fiber has been one of the most utilized commercial substrates, because this material has a long durability without alterations in its physical characteristics and can be sterilized, and because its raw material is renewable and abundant, besides being sold at low cost (Carrijo et al., 2004). A large percentage of lignin (35-45%) and cellulose (23-43%) and small quantity of hemicellulose (3-12%), which is a fraction readily attacked by microorganisms, confer great durability to coconut husk fiber substrate, making this material suitable for the cultivation of long cycle plants (Noguera et al., 2000).

The reuse of substrates in the cultivation of vegetables has been the subject of many studies. It is extremely advantageous to the grower the possibility of utilizing it with various crops, and besides, the longer the time of utilization of these residues, the less environmental impact there will be. However, to reutilize the substrate, it is necessary to understand the alterations that occur over time, so as not to hamper productivity. Some authors studied the reuse of substrates and found out that there was no decrease in productivity in two or more subsequent cultivations (Andriolo et al., 1999; Çelikel and Caglar, 1999; Reis et al., 2001; Fernandes et al., 2007). Urrestarazu et al. (2008), in studying the productivity of melons and tomatoes, in reused substrates consisting of almond husk and plant waste compost, in Almeria, Spain, found that there were no negative effects up to 265 and 530 days, respectively, from reuse.

In evaluating the physical characteristics, there was no significant interaction between "utilization of substrate" and "concentration of nutrient solution" for all characteristics examined. There were also no significant differences for all physical characteristics analyzed (Table 2).

Table 2. Means of physical characteristics of coconut husk fiber substrate according to utilization of substrate and concentration of nutrient solution. Density (D), aeration space (AE), total porosity (P), available water (AW), easily available water (EAW), buffering water (BW) and retained water (RW).

	D	AE	P	AW	EAW	BW	RW
						(%)	
Use of substrate (US)							
New	0.08 a	21.0 a	72.5 a	22.3 a	16.9 a	5.3 a	29.12 a
Used once	0.07 a	23.9 a	75.4 a	20.8 a	15.7 a	5.1 a	30.67 a
Concentration of nutrient solution (NS)							
25	0.07 a	21.7 a	69.5 a	18.7 a	13.7 a	4.9 a	28.97 ab
50	0.07 a	23.4 a	77.3 a	21.8 a	16.4 a	5.4 a	32.00 a
100	0.07 a	21.6 a	70.8 a	20.8 a	15.4 a	5.4 a	28.29 ab
150	0.07 a	23.8 a	70.5 a	19.0 a	14.6 a	5.4 a	27.68 ab
200	0.07 a	24.7 a	71.4 a	20.1 a	14.7 a	5.7 a	26.54 b
Interaction US×CS	2.87^{ns}	1.03^{ns}	1.27^{ns}	2.01^{ns}	1.79^{ns}	1.53^{ns}	1.07^{ns}
CV%	14.50	20.21	10.71	19.45	19.45	34.18	13.58

Fernandes et al. (2006) analyzed the alterations in physical properties in reutilized substrates in the cultivation of cherry tomato plants and observed a decrease in porosity of the substrate with its decomposition, through the reduction in particle size of these components. Coupled with this factor, there was also an increase in density, decreased aeration and increased volume of water retained by the substrate, since the presence of small particles in the substrate implies an increase in contact surface of the substrate particles, thereby facilitating water retention. However, this chain of events was not noted in the current experiments, indicating the reuse of substrate for subsequent crops. It is extremely advantageous for the grower, allowing reuse of the substrate in various crops, since the more these materials are used, the less environmental impact they will have by their discard.

With regard to the concentration of nutrient solution, there was a difference only in relation to remaining water, which decreased with supply of fertilizer (Table 2). The remaining water corresponds to the volume of water that remains in the substrate after the application of 100 hPa tension. Therefore, in situations of water stress, the use of higher concentrations can limit water availability for the plants.

CONCLUSIONS

According to the conditions in which the work was carried out, the reuse of substrate, coconut husk fiber is recommended at least once and the use of a less concentrated nutrient solution, 25% of recommended, for the cultivation of the hybrid 'Paronset'.

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