

Soilless cultivation of cherry tomato with gutter subirrigation and reused substrate

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Abstract: Soilless cultivation systems in horticultural production are modern technologies that involve the supply of water and minerals through the nutrient solution and plant growth on media. The soilless cultivation of vegetables ensures higher yields and better quality than with traditional soil crops. When managed in a closed system with irrigation water of good quality soilless cultivation can significantly reduce the environmental impact of nutrient solutions with respect to crops grown in open systems. Compared with drip irrigation, gutter subirrigation simplifies the management of the closed system because disinfection of recirculated nutrient solution and correction of its chemical composition is not necessary. Gutter subirrigation was developed in previous experiments for the cultivation of tomato on fresh substrate. The objective of this work was to evaluate the use of the same substrate after two consecutive crops of tomato and to study the effect of the presence, if any, of previous radical residues with the same cultivar and rootstock. The experiment was conducted in an unheated iron and polycarbonate greenhouse with forced ventilation. Cherry tomato plants were transplanted into pots containing fresh or reused coconut fiber. The following parameters were considered: biomass, production, product quality (electrical conductivity, pH, titratable acidity, dry residue, dissolved solid content) and chemical analysis of recirculated and radical nutrient solution. The results obtained in this experiment reveal no significant differences in production and fruit quality between plants grown on fresh substrate and those grown on reused substrate (marketable yield was 5.4 kg m⁻² vs 5.3 kg m⁻², respectively).

1. Introduction

Greenhouse soilless horticulture requires a high level of technology, considerable capital investment, and operators with adequate professional skills but it is highly productive, ergonomic, and uses water and space efficiently (Savvas, 2003; Resh, 2012).

Over the last few years research has aimed to achieve the most effective systems able to satisfy restrictions relating to the protection of ground water and soil.

In fact, the conversion of soilless culture to a closed system is associated with environmental policies established to reduce environmental pollution (Voogt *et al.*, 2013). To avoid some of the risks (rapid spread of root pathogens, accumulation of Na and mismanagement of electrical conductivity - EC - and pH), disinfection of recirculated nutrient solution (NS) and amendment of its chemical composition are carried out. However, discharge of part of the recirculated solution is still required since NaCl, from the irrigation water, and organic compounds, from long cultivations, accumulate causing an inhibition of growth (Voogt *et al.*, 2013). The difficulties associated

with managing the recirculated NS hinder the widespread adoption of the closed system, especially in areas where protected agriculture is characterized by a low level of technology.

Subirrigation can simplify the closed loop management of the NS, because unlike the drip-irrigation system, the elements that are not absorbed by the plant do not accumulate in the recirculated solution but rather in the upper part of the substrate, where roots are less present (Venezia *et al.*, 2001; Santamaria *et al.*, 2003; Venezia *et al.*, 2006; Venezia and Piro, 2007; Venezia, 2010). Spatial distribution of salts within the substrate makes it possible to minimize the effects of excessive salinity.

Only a few studies to date about soilless cultivations have assessed the possibility of reusing the substrate (Urrestarazu *et al.*, 2008; Venezia *et al.*, 2008). The use of inert inorganic substrates involves disposal problems that can be avoided by employing organic substrates. Among them, peat has been widely used in the Mediterranean area. In this context, it is necessary to identify ecologically-friendly alternatives, such as renewable organic substrates that can be reused for several crop cycles, which would provide great benefits to vegetable production.

In the case of reusing the substrate, the presence of roots from the previous crop may result in adverse effects on the development of the crop, especially because in soil-

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less cultivation farmers are specialized in and practice monoculture.

The aim of this work was to evaluate the utilization of ecologically-friendly coconut fiber substrate for repeated crops of cherry tomato cultivated in closed loop gutter sub-irrigation.

2. Materials and Methods

The experiment was conducted at CREA Vegetable Crops Research Centre in Pontecagnano, southern Italy (40°38' N, 14°52' E, 28 m asl).

Cherry tomato plants (*Solanum lycopersicum* L., cv Shiren - Cois '94 - rootstock Beaufort - De_Ruiter) were grown in a closed-loop soilless system with gutter sub-irrigation in an iron-type greenhouse with polycarbonate covering under natural light conditions. Air temperature thresholds for ventilation and cooling were 25 and 26°C, respectively.

A fresh bulk coconut fiber substrate was compared with the same medium previously utilized for two cropping cycles of cherry tomato Shiren/Beaufort. The latest cultivation on the reused substrate was terminated 40 days before the experiment started. Plots were composed of one row of 20 pots per trough for the fresh substrate and 17 for the reused one. The pots, which contained 10 L of substrate, were positioned on hydraulically independent gutter with 1% slope.

For each gutter the NS was contained in an independent storage tank of 270 L. The ionic compositions of the NS supplied expressed in meq L⁻¹ were:

- NS T1, used for irrigation before transplant in the fresh substrate: 0.3 Na⁺, 0.4 NH₄⁺, 2.5 K⁺, 4.9 Mg⁺⁺, 8.9 Ca⁺⁺, 0.4 Cl⁻, 11.5 NO₃⁻, 2.2 H₂PO₄⁻, 2.2 SO₄⁻. EC and pH values were 1.8 dS m⁻¹ and 5.5, respectively.
- NS 0,3: 0.3 Na⁺, 0.4 NH₄⁺, 4.0 K⁺, 1.5 Mg⁺⁺, 4.4 Ca⁺⁺, 0.2 Cl⁻, 6.8 NO₃⁻, 0.8 H₂PO₄⁻, 1.8 SO₄⁻. EC and pH values were 1.2 dS m⁻¹ and 5.7, respectively.
- NS 0,6: 0.3 Na⁺, 0.1 NH₄⁺, 8.0 K⁺, 3.0 Mg⁺⁺, 6.0 Ca⁺⁺, 0.3 Cl⁻, 13.5 NO₃⁻, 1.5 H₂PO₄⁻, 1.2 SO₄⁻. EC and pH values were 2 dS m⁻¹ and 5.7, respectively.

During the first month of growth, plants were irrigated with NS 0,3; NS 0,6 was used in the second month; subsequently NS 0,6 and NS 0,3 were used alternately in order to maintain a constant EC of 1.5 dS m⁻¹ until the end of the cycle.

Plants were transplanted on 17 August 2013, trained to a single stem and grown up to the seventh truss at a density of 2.6 plants m⁻². The experiment ended on 17 December 2013. A bumblebee colony was provided to aid pollination.

Consumption, EC and pH of the NS were recorded daily. Ionic composition of the recirculated NS was determined fortnightly, with samples taken after refilling the tanks.

Electrical conductivity, pH and ionic composition of the aqueous extracts (1:1.5 v/v - growth medium:deionized water) from three layers of the substrate (0-5, 5-17 and 17-

21 cm from pot bottom) were determined after harvesting. Each layer was mixed well with water for 20 min and then filtered before measurements.

Electrical conductivity and pH values of all samples were determined by Metrohm 856 Conductivity Module; ionic composition by ion chromatography using Dionex ICS-1500/ICS-1600 RFIC.

The leaf chlorophyll concentration was determined weekly on the fifth true leaf of four plants per plot by using a hand-held SPAD-502 meter device that estimates chlorophyll *in vivo* by transmittance of red (650 nm) and infrared (940 nm) radiation through the leaf, and calculating a relative SPAD meter value that should "correspond to the amount of chlorophyll present in the same leaf" (Minolta, 1989).

Dry above-ground biomass was determined on two plants per plot. Plant organs were separated into fruits, stems, leaves, and roots and dried in a forced-air oven at 80°C for 72 h.

Fruit quality was assessed by measuring the EC, pH, titrable acidity, dissolved solid content and dry residue of blended fruit. To determine titrable acidity and dissolved solid content (°Brix) the 905 Titrand-Metrohm and the Refracto 30 PX-Mettler Toledo were used, respectively. To determine the dry residue, the samples of blended tomato berries were dried on ceramic plates at 65°C for 72 h.

3. Results and Discussion

The daily consumption of NS was highest at mid-cycle (1 L per plant per day) and there were no differences between the two treatments. With the recirculated NS, there were no significant effects of substrate reuse on EC. The average EC value was 1.3 dS m⁻¹ in the first month after transplantation, it then increased to 1.7 dS m⁻¹ in the second month and gradually decreased until the end of the cycle up to a value of 1.5 dS m⁻¹ according to the management and composition of the NS supplied. In aqueous extracts from the three layers sampled at the end of the cycle, the EC of fresh substrate tended to increase from the base (0.7 dS m⁻¹) towards the upper part of the vessel (2.5 dS m⁻¹). In pots with reused substrate, EC values were higher for both the intermediate (2.6) and top (9.6 dS m⁻¹) layer. This confirms that excess salts tend to accumulate upwards due to capillary rise. In aqueous extracts of the three layers, the concentration of all elements increased towards the upper part of the vessel and more intensely in the reused vessels.

The initial average pH value of the recirculated NS was 5.7 and increased up to 6.3 for both treatments during the first 30 days after transplantation (DAT). With reuse in the advanced stage of the cycle (80 DAT), the pH of the recirculated solution decreased (5.7); the pH value was 6.2 for fresh and 5.7 for reused substrate at the end of the cycle. Regarding aqueous extracts, pH values were lower in the upper layer: in pots with fresh substrate pH was 6.9 for the bottom and 5.9 for the top layer; in reused substrate, the average value was 6.5 for the bottom and 6.3 for the top.

For both treatments the initial average SPAD value was 39.1; at 75 DAT for plants cultivated on fresh substrate it was on average 41.7, and 37.9 on reused substrate. At the end of the cycle, SPAD decreased to a value of 32.3 for both.

Reuse of substrate resulted in a slight decrease in production (3.4%): the average marketable yield was 5.4 kg m⁻² on fresh substrate and 5.3 kg m⁻² on reused substrate. The effect of reuse was minimal (3.7%) also on fruit weight with an average of 22.6 g on fresh and 21.7 g on reused substrate noted. With an average value of 106 g/m² plants cultivated on reused coconut fiber showed a negligible increase of stem biomass (0.2%); also fruit biomass suffered a small change from 498 g/m² to 519 g/m² while leaf biomass was reduced by 12.2% with an average value of 266 g/m² and 233 g/m² on fresh and reused substrate, respectively.

Titrate acidity, pH and °Brix decreased linearly with the order of the cluster: pH average value was reduced from 4.17 to 4.10; titrate acidity from 0.61 to 0.51% and °Brix between 5.5 and 4.3. Electrical conductivity and dry residue had a more constant trend ranging between 4.54 - 4.21 dS m⁻¹ and 6.9-6.6%, respectively.

Urrestarazu *et al.* (2008) grew a tomato crop on almond shell residue reused for 530 days (after four crops) in an open, drip irrigated system without significant yield and fruit quality parameter differences compared to the fresh substrate. They did not encounter phytotoxicity problems because the run off from the open system eliminated root exudates and excess residual salts from previous tomato crops as observed in a tomato crop grown on a substrate added with a compost which was very rich in salts (Stipic *et al.*, 2012).

In our work the system was closed with zero run off and for the subirrigation, salts and root exudates of the reused substrate accumulated in upper layers due to capillary rise, but still remained in the system. This spatial distribution and the presence of a suitable microflora allowed a normal yield compared to the fresh substrate despite the intense monoculture after two consecutive crops of tomato with the same cultivar and rootstock in pots containing 10 L of substrate with all previous radical residues.

The experiment is still underway with a tomato crop growing on a coconut fiber substrate reused after four tomato crops to confirm these results and to characterize the microflora.

4. Conclusions

This work has demonstrated that it is possible to carry out a soilless monoculture of tomato with gutter subirrigation, a technique still not widespread for the cultivation of fruit vegetables. Reuse of the coconut fiber did not induce phytotoxicity and there were no significant effects on the quantity and quality of the product obtained. Subirrigation allows all the excess ions to accumulate in the upper part of the substrate; in this way there is no increase of the EC

in the lower part of the vessel where roots are massively present nor is there alteration of the re-circulated nutrient solution composition.

This confirms that, compared with traditional drip irrigation, gutter subirrigation with coconut fiber simplifies management of the re-circulated nutrient solution in soilless closed loop systems of a fast-growing species such as cherry tomatoes. The comparison between fresh and reused substrate showed that it is possible to reuse coconut fiber at least three times, thus reducing costs in terms of production and the environment.

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