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Avaliação da produtividade e qualidade de tomate produzido no solo e em hidroponia na região Noroeste de Portugal

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Resumo

A cultura hidropónica de tomate na região NW de Portugal poderá substituir o sistema de produção convencional no solo, na época de primavera/verão, se o aumento de produtividade e a qualidade dos frutos compensar os custos de produção adicionais. Com este objectivo as cultivares de tomate Durinta (tipo cacho) e Romana (tipo chucha) foram produzidas na Póvoa de Varzim, para comparar culturas convencionais produzidas em solo de textura arenosa, com culturas hidropónicas em substrato de fibra de coco, no interior de estufas sem aquecimento. A plantação e a colheita de tomate hidropónico ocorreram um mês antes da cultura produzida no solo. A produtividade e as características de qualidade dos frutos (calibre, cor, firmeza, pH, sólidos solúveis totais, acidez total e concentração de N, P, K, Ca, Mg e Fe dos frutos) foram avaliadas em três repetições de cada tratamento, com base em quatro plantas por repetição.

A produtividade da cultura hidropónica de tomate da cv. Durinta (16,7 kg m^{-2}) aumentou e a matéria seca (6,3 g 100 g^{-1}) diminuiu comparativamente com a produção convencional no solo (12,7 kg m^{-2} e 6,7 g 100 g^{-1}, respetivamente), enquanto para a cv. Romana a produtividade e teor de matéria seca foram semelhantes em ambos os sistemas de produção (média de 9,7 kg m^{-2} e 7,3 g 100 g^{-1}, respetivamente). As características de qualidade, como o calibre dos frutos, a cor e a firmeza, não foram influenciados pelo sistema de produção e revelaram-se dependentes da cultivar. Os frutos da cv. Durinta produzidos em hidroponia foram menos doces e, para ambas as cultivares, possuíam menor acidez. A concentração dos frutos em N, Mg e Fe foram semelhantes para ambas as cultivares, independentemente do sistema de produção. O teor em P e Ca do tomate hidropónico para ambas as cultivares, bem como o conteúdo de K da cv. Romana, foram superiores aos frutos produzidos no solo. A qualidade dos frutos e as diferenças de produtividade entre os dois sistemas de produção podem não ser preponderantes para a tomada de decisão dos produtores, embora a produção hidropónica, considerando os referidos problemas de solo e a melhor gestão das estratégias de marketing, com a antecipação da colheita na estação da primavera/verão e com a possibilidade de produção de tomate na época de outono/inverno, possa ser uma opção rentável.

Palavras-chave: acidez, calibre, coco, firmeza, nutrientes

Yield and quality evaluation of tomatoes produced in soil and hydroponics in the Northwest of Portugal

Abstract

Hydroponic tomato production in NW Portugal will only replace the conventional crop system for the spring/summer season, if increased tomato yield and quality overcome the additional production costs. Two cultivars (truss tomato cv. Durinta and plum shaped tomato cv. Romana) were cultivated in Póvoa de Varzim to compare hydroponically grown tomato using coconut fibre as the growing medium, with tomato grown in a sandy soil, inside unheated span type greenhouses. Planting and harvest of hydroponic tomato occurred one month before soil grown tomato. Tomato quality characteristics (colour at maturity, size and firmness, pH, total soluble solids, entitled total acidity, N, P, K, Ca, Mg and Fe contents) were assessed in three different plots based on four plants per plot.

Hydroponic tomato yield of cv. Durinta (16.7 kg m^{-2}) increased and dry matter (6.3 g 100 g^{-1}) decreased compared to conventional tomato (12.7 kg m^{-2} and 6.7 g 100 g^{-1}, respectively), whereas for cv. Romana yield and dry matter content were similar in both crop systems (9.7 kg m^{-2} and 7.3 g 100 g^{-1}, respectively). Fruit quality characteristics such as size, colour and firmness were not affected by the production system but they were cultivar dependent. Hydroponic tomato acidity decreased compared to conventional tomato for both cultivars and the soluble solids decreased for cv. Durinta. The N, Mg and Fe fruit contents were similar for both cultivars independently of the production system. The P and Ca contents of hydroponic tomato for both cultivars, and K content for cv. Romana, were higher compared to soil production. Fruit

quality and yield differences between the two systems may not be relevant for growers' decision to switch to the hydroponic system; however, it may be a profitable option to control soilborne pests and diseases and to improve marketing strategies, with crop anticipation in the spring season and the additional tomato production in autumn/winter season..

Keywords: acidity, coconut, firmness, grade, nutrients

Introduction

Hydroponic production systems are capital-intensive but there is a renewed interest on these, particularly in regions where there is concern about controlling ground water pollution caused by nutrient surplus or soil pesticides. This is the case for the NW Portuguese protected area of the free aquifer between Esposende and Vila do Conde (Nitrate Vulnerable Zone no. 1) where a specific Local Action Plan was established limiting the amounts of N application. In addition, the intensive conventional horticultural production in this region is being affected by increasing soilborn pests and diseases and hydroponic production was introduced recently, mainly for the production of two tomato crops per year with coconut fibre substrate in unheated greenhouses. For the early spring/summer season, farmers are concerned about the advantages in yield and fruit quality, between hydroponics and conventional soil tomato production, which has lower production costs.

Tomatoes described as full flavoured by the breeder are characterized by having higher contents of sugar, soluble solids and aromatic volatile compounds, and lower contents of organic acids than those considered to be less flavoured (Tando et al., 2003). Many consumers believe that greenhouse vegetables grown in soil are superior in sensory quality and in vitamins and mineral contents compared to those grown in other growing media (Johansson et al., 1999) and for this reason it is important to investigate the effect of substrates growing systems. A couple of studies have shown that there are no major differences between the physicochemical and sensory quality of conventional tomatoes grown in soil or in rock-wool slabs, although the electrical conductivity (EC) in the growth media and the physiological state of the tomato fruit at harvest affected tomato quality (Gundersen et al., 2001; Thybo et al, 2006). Tomato yield and fruit quality were assessed in NW Portugal to compare conventional soil production with increasing soil born problems but lower costs, with a hydroponic system, that requires increased skills to manage than conventional soil-based systems, to investigate if advantages in yield and fruit quality advices hydroponic tomato as an alternative to conventional soil production for the early spring/summer season.

Materials and Methods

Two cultivars (truss tomato cv. Durinta and plum shaped tomato cv. Romana) were cultivated in Póvoa de Varzim, NW Portugal (41º 22' N, 8º 45' W and 37 m high), to compare hydroponically grown tomato using coconut fibre as the growing medium, with tomato grown in a sandy soil, in rows covered with black polythene film. Both production systems were conducted inside unheated span type greenhouses, covered with polythene film. The two tomato cultivars grown in soil were established inside the same greenhouse (60.0 x 16.0 x 2.5 m^3), while the hydroponic crops were grown in two different greenhouses of the same producer (cv. Durinta: 40.0 x 8.0 x 2.5 m^3 and cv. Romana: 40.0 x 10.0 x 1.8 m^3). The coconut fibre polythene bags (1.0 x 0.18 x 0.16 m^3; Fico Vegetable Bags, Ispemar) were used in the previous two years, to produce two tomato crops each year: January-July and August-December. The nutrient solution was kept at pH 6.0-6.5 and the EC was 1.8 dS m^{-1} in the first 3 weeks and 2.0-2.2 dS m^{-1} thereafter.

The tomato crops were performed according to the local procedure. The hydroponic crops were planted at 20 January and tomato yield was evaluated throughout 18 harvests, starting 111 and 115 days after planting, respectively for cv. Romana and cv. Durinta, from May to July. The harvesting period was 58 days for cv. Romana and 54 days for cv. Durinta. During this season the outside mean, maximum and minimum air temperatures were 13.6ºC, 18.1ºC and 9.1ºC, respectively. For the greenhouse soil system, crops were planted at 20 February and yield was evaluated throughout 16 harvests, starting 112 days after planting for both cultivars, from June to August. The harvesting

period was 54 days for cv. Romana and 40 days for cv. Durinta, Here, the outside mean, maximum and minimum air temperatures during the season were 15.5ºC, 20.1ºC and 10.8ºC, respectively. The outside relative humidity was approximately 82% for both crop seasons.

In both crop systems planting was carried out in double lines. The hydroponic crops consisted of 3 plant pairs per bag with 2 m between bags (2.7 plants m^{-2}) and the soil grown crops were planted at 0.40 m between plants, with 0.40 m between lines of each double line and 1.5 m between double lines (2.6 plants m^{-2}). Integrated crop protection was performed and crops were drip irrigated with drips introduced in the hydroponic culture bags and under the black polythene film row cover in the conventional production. Fertigation in both crop systems were performed with the same fertilizers (potassium nitrate - 13.5:0:46; calcium nitrate - 15.5:0:0+19 Ca; magnesium sulphate - 10 kg Mg/100 kg; phosphoric acid - 75 kg H_3PO_4/100 kg and nitric acid - 12 kg N/100 kg). Fertilization rates were decreased for soil grown crops compared to hydroponic crops (Table 1).

Table 1. Mineral nutrients applied to tomato crops grown in the soil and hydroponically.

Production system	N	P	K	Ca	Mg
			kg ha^{-1}		
Soil	293.5	160.0	460.0	95.0	50.0
Hydroponic	558.7	202.2	1104.0	162.1	133.3
			(%)		
Soil/Hydroponic	52.5	79.1	41.7	58.6	37.5

At the commercial harvest, 4 plants of each replicate treatment were used to quantify the number and grade of fruits (transversal diameter), fresh and dry weights, fruit colour and firmness. Fruit firmness was measured by a fruit pressure tester (TR Snc) and expressed as the average of the maximum force (kg) needed to penetrate each fruit with an 8 mm cylindrical probe at a crosshead speed of 50 mm min^{-1}. Tomato pH, total soluble solids, titratable acidity and N, P, K, Ca, Mg and Fe contents, were assessed at five harvests throughout the harvest period, in both production systems. The soluble solid content was determined using an ABBE Refractometer (Vitrilab), the pH was performed with a potentiometer and titratable acidity was determined by titration to pH 8.1 with a 0.1N NaOH solution in the presence of phenolphthalein and expressed as percentage of citric acid. Tomato dry matter (DM) content was determined after drying in a ventilated oven at 70ºC to constant weight and the dried material was used for the analysis of major and trace elements. Total N and P in the plant material were measured by molecular spectroscopy after digestion with sulphuric acid; K was measured by flame photometry, and Ca, Mg and Fe by atomic spectroscopy, after nitric-perchloric acid digestion. Comparisons between means of crop treatments were performed by the least significant difference (LSD) test. All statistical calculations were performed using SPSS 15.0 for Windows (SPSS Inc.) and statistical significance was indicated at a probability level of P=0.05.

Results and Discussion

The accumulated fruit dry weight throughout the season was higher for cv. Durinta compared to cv. Romana in both production systems. The total fruit dry weight of cv. Durinta in the hydroponic crop system was increased compared to bare soil, whereas for cv. Roman total fruit dry weight was identical in both production systems. Similarly, hydroponic cv. Durinta achieved a higher yield (16.7 kg m^{-2}) than the soil grown crop (12.7 kg m^{-2}) while for cv. Romana, yields (9.7 kg m^{-2}) were identical in both production systems (Figure 1). The total number of fruits m^{-2} for both cultivars were similar between production systems; cv. Durinta had 124 and 114 fruits m^{-2} respectively for hydroponic and soil grown crops, whereas for cv. Romana there were 117 and 113 fruits m^{-2} respectively. The lower yield of cv. Romana in the hydroponic system compared to cv. Durinta probably resulted from lower fruit grades, as 20% of the total number of fruits were <35 mm and this fruit grade was negligible in all the other crops (Figure 2).

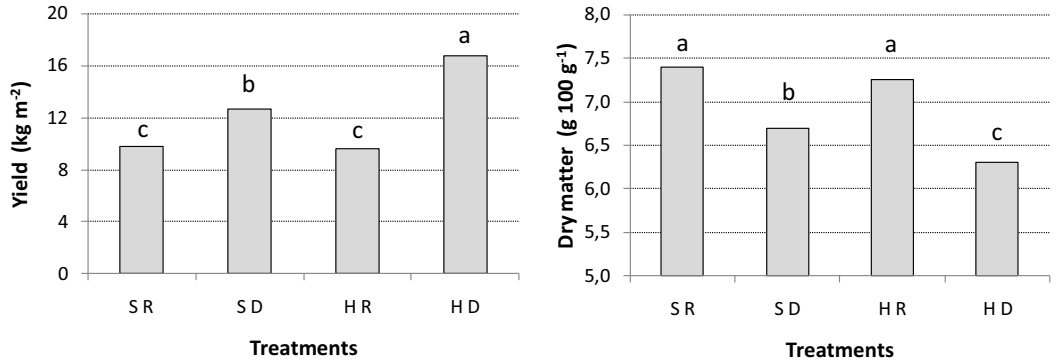

Figure 1. Tomato yield (kg m^{-2}) and dry matter content (g 100 g fw^{-1}), for crops grown on soil (S) and hydroponically (H) and for both cultivars, Romana (R) and Durinta (D). Different letters above bars means significant differences between crop treatments.

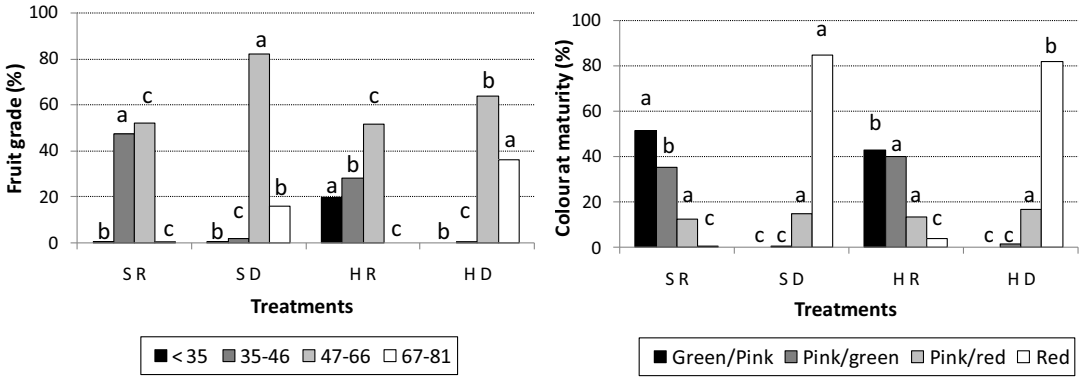

Figure 2. Fruit grade and colour at maturity (% of total number of fruits), for crops grown on soil (S) and hydroponically (H) and for both cultivars Romana (R) and Durinta (D). Different letters above bars means significant differences between crop treatments.

The lower fruit grade of cv. Romana compared to cv. Durinta in the hydroponic system might be a consequence of induced pollination deficiencies, caused by the higher humidity conditions during flowering inside the greenhouse, which had a lower height (1.8 m) and volume (720 m^3) than the greenhouse of cv. Durinta (2.5 m height, 800 m^3). However, fruit grade was also a characteristic of the cultivar. For both production systems, the cv. Durinta produced about 99% of fruits with a diameter between 47 and 81 mm, while cv. Roman had only 52% of fruits with this diameter (Figure 2). The colour at maturity also was a cultivar dependent characteristic. The cv. Romana had 84.8% of fruit green/pink and pink/green, while cv. Durinta had 99.0% of the fruits pink/red and red (Figure 2). Firmness was increased for plum shaped tomato cv. Roman (mean of 4.3 kg) compared to truss tomato cv. Durinta (mean of 2.7 kg). In spite of Singh et al. (2003) suggestion that plant nutrition and soil water availability may affect fruit firmness here, fruit firmness was different between cultivars but not between crop systems, suggesting that firmness is mainly a genetic trait dependent on the degree of maturation. The average fruit DM content of cv. Romana (7.3 g 100 g^{-1}) was significantly increased compared to cv. Durinta (6.5 g 100 g^{-1}) (Figure 1). Similarly, the total soluble solids content of fruits varied with the cultivars, being higher in cv. Romana (5.2 g 100 g^{-1}) compared to cv. Durinta (4.8 g 100 g^{-1}). While for the cv. Romana no significant differences were found in DM and °Brix between crop systems, for cv. Durinta these characteristics showed increased values in the soil system. This suggests that fruit soluble solids content is a genetic trait of the cultivar but is also influenced by the fertilization and irrigation practices and by temperature, as previously reported by Silva et al. (2003). Hydroponic tomatoes in coconut fibre also showed increased mean moisture content than soil grown tomatoes in a study reported by Hernández Suárez et al. (2008). The values of pH, DM content,

soluble solids and titratable acidity of tomatoes grown in both systems were within the levels reported for tomatoes grown in soil and on rock-wool slab (Tando et al., 2003). The titratable acidity, expressed as g of citric acid per 100 g of sample, measures the amount of organic acids and indicates the astringency of the fruit. Together with the pH influences the flavour. The average pH of fruits for both cultivars was similar (approximately 4.4) but fruits of the cv. Romana had a higher titratable acidity (0.65 g 100 g^{-1}), compared to the fruits of cv. Durinta (0.52 g 100 g^{-1}). The pH was higher and total acidity was lower for hydroponic crops of cv. Romana compared to soil grown tomato and a similar trend was found for cv. Durinta. In this study, the results suggests that hydroponic system compared to soil system production may affect fruit soluble solids, pH and total acidity, since hydroponic fruits showed lower soluble solids and were less acidic. Similar results were found by Hernández Suárez et al. (2008) comparing hydroponic tomatoes in coconut fibre with intensive soil grown crops.

The content of the major and trace elements in tomato fruits (Table 2) were found to be within the normal range for tomatoes grown in soil and hydroponically (Guil-Guerrero and Rebolloso-Fuentes, 2009; Gundersen et al., 2001). The N, Mg and Fe fruit contents were similar for both cultivars and were independent of the production system. However, in comparison with soil production system, the P and Ca content of hydroponic tomato for both cultivars, as well as K content of cv. Romana, was higher (Table 2). However, Gundersen et al. (2001) who compared the major and trace element concentrations in Danish greenhouse tomatoes cultivated in soil and in rockwool slab, reported that Ca, Ni, Sr, and Zn had higher concentration and Mn, Mo, and Na had lower concentration in soil-grown tomato fruits compared to hydroponic tomato, while the other elements were not significantly different. Thybo et al. (2006) in a study to evaluate the physical, chemical and sensorial properties of organic tomatoes grown in compost beds and in soil reported that these growing systems had small effect on the chemical composition and sensory quality of tomatoes harvested at comparable maturity.

Table 2. Tomato nutrient content (g/100g dry matter) and nutrient accumulation (kg ha^{-1}) by the fruits of soil grown and of hydroponic crops, for both cultivars. In each column different letters means significant differences between crop treatments ($p<0.05$).

Production system	Cultivar	N	K	P	Ca	Mg	Fe
		g/100g DM			mg/100g DM		
Soil	Romana	1.71 ns	3.47 b	360.0 d	199.7 c	155.6 ns	32.3 ns
	Durinta	1.66	3.80 b	378.8 c	207.6 bc	143.7	30.5
Hydroponic	Romana	1.75	4.86 a	442.4 b	223.5 b	146.3	42.9
	Durinta	1.82	4.14 b	478.5 a	263.2 a	159.3	39.8

Production system	Cultivar	N	K	P	Ca	Mg	Fe
		kg ha^{-1}					
Soil	Romana	124.2 c	251.2 c	26.1 c	14.5 c	11.3 b	2.3 b
	Durinta	140.9 b	323.1 bc	32.2 b	17.6 b	12.1 b	2.6 b
Hydroponic	Romana	122.4 c	340.9 b	31.0 b	15.7 bc	10.3 b	3.0 b
	Durinta	191.6 a	440.5 a	50.4 a	27.8 a	16.9 a	4.2 a

The nutrient accumulation by fruits of cv. Durinta was generally higher compared to cv. Romana, which is in agreement with the higher yield achieved by the former cultivar. The same was true for the hydroponic tomatoes of cv. Durinta that accumulated more nutrients than fruits produced in soil. For cv. Romana the hydroponic system also provided a greater accumulation of K and P, but similar amounts of N, Ca, Mg and Fe, compared to soil grown tomatoes (Table 2). The nutrient recovery rate by the fruits, which measures the rate of the nutrients taken up by the fruits from the applied mineral fertilizers, was lower for the hydroponic crops (mean of 21.4 kg 100 kg^{-1}) compared to soil grown crops (mean of 33.2 kg 100 kg^{-1}). This could be explained by higher nutrient demand by the roots and foliage of the hydroponic plants compared to the soil grown crops, but also may indicate that the hydroponic crop management, namely the nutrient solution content, must be better adjusted to crop

growth and development. The lower nutrient recovery rate can be an environmental problem if the nutrient solution is not recycled or disposed properly.

Conclusions

Hydroponic tomato yield of cv. Durinta increased and dry matter content decreased compared to conventional soil grown tomato, whereas for cv. Romana yield and dry matter content were similar for both crop systems. Growing system had only a minor effect on the chemical composition and sensory quality of tomatoes harvested at comparable maturity. Quality characteristics such as fruit size, colour and firmness were not affected by the production system but they were cultivar dependent. Hydroponic system appeared to produce tomatoes with slightly lower sweetness, lower intensity in sourness and higher content in P, Ca and K compared to soil grown tomatoes. Although differences were found in these quality parameters, generally the differences were small, or not statistically significant, indicating that tomato quality is rather robust across growing systems when harvested at comparable maturity. This study shows that, for the truss tomato cv. Durinta, increased yield combined with harvest anticipation may compensate increased production costs of the hydroponic system, but this was not clear for plum shaped tomato cv. Romana. Furthermore, hydroponics may be one solution to the salinity and soilborne pests and diseases problems already found in the region, which could endanger tomato yields. Hydroponics system also requires less use of manpower and tillage, which contribute to recover the higher investment required for this crop system, including the fertilizers costs. Fruit quality and yield differences between the two production systems may not be relevant for growers' decision, but to switch to the hydroponic system in order to control soilborne problems and to improve crop management and marketing strategies, with the crop anticipation in the spring season and the additional tomato production in autumn/winter season, may be a profitable option.

Bibliography

Guil-Guerrero, J.L. and Rebolloso-Fuentes, M.M. (2009). Nutrient composition and antioxidant activity of eight tomato (Lycopersicon esculentum) varieties. *Journal of Food Composition and Analysis* **22**, 123-129.

Gundersen, V., McCall, D. and Bechmann, I.E. (2001). Comparison of major and trace element concentrations in Danish greenhouse tomatoes (*Lycopersicon esculentum* cv Aromata F1) cultivated in different substrates. *Journal of Agriculture and Food Chemistry* **49**, 3808-3815.

Hernández Suárez, M., Rodríguez Rodríguez, E. and Díaz Romero, C. (2008). Chemical composition of tomato (Lycopersicon esculentum) from Tenerife, the Canary Islands. *Food Chemistry* **106**, 1046-1056.

Johansson, L., Haglund, A., Berglund, L., Lea, P. and Risvik, E. (1999). Preference for tomatoes, affected by sensory attributes and information about growth conditions. *Food Quality and Preference* **10**, 289-298.

Silva, J.B.C.S., Giordano, L.B., Furumoto, O., Boiteux, L.S., França, F.H., Villas Bôas, G.L., Branco, M.C., Medeiros, M.A., Marouelli, W., Silva, W.L.C., Lopes, C.A., Ávila, A.C., Nascimento, W.M. and Pereirai, W. (2003). Cultivo do tomate para industrialização. *Embrapa Hortaliças, Sist. de Produção*, 1.

Singh, Z., Kennison, K. and Agrez, V. (2003). Regulation of fruit firmness, maturity and quality of late maturing cultivars of peach with preharvest application of ReTainTM. *Acta Horticulturae* **628**, 277-283.

Tando, K.S., Baldwin, E.A., Scott, J.W. and Shewfelt, R.L. (2003). Linking sensory descriptors to volatile and non-volatile components of fresh tomato flavour. *Journal of Food Science* **68**, 2366-2371.

Thybo, A.K., Edelenbos, M., Christensen, L.P., Sørensen, J.N. and Thorup-Kristensen, K. (2006). Effect of organic growing systems on sensory quality and chemical composition of tomatoes. *LWT Food Science and Technology* **39**, 835-843.