COMPARISON OF TWO ORGANIC DETERMINATE TOMATO (*Solanum lycopersicon* L) PRODUCTION SYSTEMS IN A CONTROLLED ENVIRONMENT

Fernando de Jesús Carballo-Méndez, Juan Carlos Rodríguez-Ortiz, Jorge Alonso Alcalá-Jáuregui, Humberto Rodríguez-Fuentes, Pablo Preciado-Rangel and José Luis García-Hernández

SUMMARY

In order to compare the organic production of determinate tomato cultivated in soil vs cultivated in substrate in a controlled environment, an assessment was made based on an experimental design of random blocks and three repetitions. The results indicate that both systems perform similarly in terms of yield, fruit quality, plant nutrition and efficiency of nutrients use. The most important variable differentiating the two systems was water use efficiency, in which determinate tomato cultivation in soil proved to be 30% more efficient when compared to cultivation in substrate. In both cases, the fruit obtained was of commercial quality. Total yields reached over a period of four months were 119.28 and 116.73t·ha^{-1} in soil and substrate, respectively.

Introduction

Foodstuffs produced under the model of organic agriculture face a growing demand from consumers at a global level (Sahota, 2016). Possible causes for this trend include the basic principles of care for human health, the environment, and social awareness of the need to improve the livelihoods of families dependent on agricultural activity. The demand for organic products was worth USD 80×10^9 in 2014 (Sahota, 2016), representing a significant opportunity for economic growth and rural development for many countries.

Controlled production systems are another important trend in agriculture, justified by greater control against damage due to weather or disease, and a greater quality of products compared to those grown in an open field (Gamliel and Van Bruggen, 2015). Several studies of tomato production systems have focused on the use of a mixture of inorganic and organic substrates placed in plastic pots, indeterminate varieties, preparations and leachates of organic materials (Preciado *et al.,* 2011; Márquez, *et al.,* 2013; Vázquez *et al.,* 2015).

However, we believe that the organic production of determinate tomato varieties in greenhouse and soil has not been sufficiently investigated. In relation to soil, the International Federation of Organic Agriculture Movements (IFOAM, 2016) states that organic agriculture must be based on living ecological systems - working with them, emulating them and helping to sustain them. Determinate tomato varieties, which are usually planted in an open field and tend to have lower yields than indeterminate varieties, could have relevant advantages justifying their use in organic agriculture, such as low seed price, short stature, reduced labor costs and short cycles. Another advantage is that, due to their short stature, they can be established in simpler protected structures, opening up the possibility of their production in this manner by resource-constrained producers. The objective of this study was to compare two organic tomato production systems: i. in soil *vs* ii. in substrate, in terms of production, fruit quality and nutrition, and water and nutrient use efficiency.

Materials and Methods

The two systems, soil and substrate, were compared in a study conducted in 2013, making use of an experimental design of random blocks and three repetitions. The soil had the following properties: sand 15%, lime 46%, clay 39%, apparent density 1.40g·cm^{-3}, pH 8, electrical conductivity 1.265dS·m^{-1}; N 0.82%, P_2O_5 7.8ppm, K_2O 640ppm, Ca 1628ppm and Fe 0.88ppm. The substrate (mix) was prepared using 6L of river sand, 2.5L perlite (Hortiperl), 2L peat (Lambert), 1L vermiculite (Vermilita) and 0.5L poultry manure (Meyfer), according to OMRI (2013). The characteristics of the resulting mixture were: apparent density 1.34g·cm^3, pH 7.9, electrical conductivity 0.479dS·m^{-1}, N 0.72%, P_2O_5 2.7ppm, K_2O 324ppm, Ca 1140ppm and Fe 0.13ppm. The containers in which the mixture was placed were black 500 caliber pleated polyethylene bags of 15L capacity.

KEY WORDS / Greenhouse / Organic agriculture / Soil / Substrate / Vegetable nutrition /

Received: 04/20/2017. Accepted: 01/16/2018.

Fernando de Jesús Carballo-Méndez. Agronomical Engineer, Universidad Autonoma de Baja California Sur (UABCS), Mexico. M. Sc. student in Agriculture and Livestock Production, Universidad Autónoma de San Luis Potosí (UASLP), Mexico.

Juan Carlos Rodríguez-Ortiz (Corresponding author). Doctor in Agricultural Sciences, Universidad Autónoma de Nuevo León (UANL), Mexico. Professor, UASLP, Mexico. Address: Carretera San Luis Potosí-Matehuala, Km. 14.5 Soledad de Graciano Sánchez 78321, San Luis Potosí. Mexico. e-mail: jcrodort@uaslp.mx

Jorge Alonso Alcalá-Jáuregui. Ph.D. in Natural Resources Managment, Universidad Autónoma de Chihuahua (UACH). Professor, UASLP, Mexico.

Humberto Rodríguez-Fuentes. Doctor in Agricultural Sciences, UANL, Mexico. Professor, UANL, Mexico.

Pablo Preciado-Rangel. Doctor in Agricultural Sciences, Colegio de Postgraduados, Mexico. Professor, Instituto Tecnológico de Torreón (ITT), Mexico.

José Luis García-Hernández. Doctor en Ciencias in the Use, Managment and Preservation of Natural Resources, Centro de Investigaciones Biologicas del Noroeste, Mexico. Professor, Universidad Juárez del Estado de Durango, Mexico.

COMPARACIÓN DE DOS SISTEMAS DE PRODUCCIÓN ORGÁNICA DE TOMATE DETERMINADO (*Solanum lycopersicon* L) EN AMBIENTE PROTEGIDO

Fernando de Jesús Carballo-Méndez, Juan Carlos Rodríguez-Ortiz, Jorge Alonso Alcalá-Jáuregui, Humberto Rodríguez-Fuentes, Pablo Preciado-Rangel y José Luis García-Hernández

RESUMEN

Con el objetivo de comparar la producción orgánica de tomate determinado cultivado en suelo vs cultivado en sustrato en ambiente protegido, se realizó un ensayo con diseño experimental de bloques al azar y tres repeticiones. Los resultados indican que ambos sistemas fueron similares en cuanto a rendimiento, calidad de frutos, nutrición de cultivo y eficiencia en el uso de los nutrientes. La diferencia más importante fue en la variable de eficiencia en el uso del agua, donde el cultivo de tomate determinado en suelo fue más eficiente en un 30% en comparación al cultivo en sustrato. Los frutos obtenidos en ambos sistemas son de calidad comercial. Los rendimientos totales que se alcanzaron en un periodo de cuatro meses fueron de 119,28 y 116,73t·ha^{-1} en suelo y sustrato, respectivamente.

COMPARAÇÃO DE DOIS SISTEMAS DE PRODUÇÃO DE TOMATE ORGÂNICO (*Solanum lycopersicon* L) EM UM AMBIENTE CONTROLADO

Fernando de Jesús Carballo-Méndez, Juan Carlos Rodríguez-Ortiz, Jorge Alonso Alcalá-Jáuregui, Humberto Rodríguez-Fuentes, Pablo Preciado-Rangel e José Luis García-Hernández

RESUMO

Com objetivo de comparar a produção orgânica de tomate determinado cultivado no solo vs cultivado em substrato em ambiente protegido, foi executado um ensaio com desenho experimental de blocos ao acaso e tres repetiçoes. Os resultados indicam que ambos sistemas foram similares em quanto o rendimentoe qualidade de frutos, nutriçao do cultivo e eficiencia em uso de nutrientes. A diferencia más importante foi na variavel de eficiencia em uso de agua, onde o cultivo de tomate determinado em solo foi má eficiente em um 30% em comparaçao o cultivo em substrato. Os frutos obtidos em ambos sistemas sao de qualidade comercial. Os rendimentos totais que se alcansarom em um periodo de quatro meses foram de 119,28 y 116,73t·ha^{-1} em solo e susbtrato, respectivamente.

Thirty day old seedlings of the 'Pony express F1' determinate saladette tomato variety (Harris Moran) were transplanted to both the soil and the substrate growing environment. In the case of soil, 40g of Meyfer® poultry manure was applied to each pot prior to transplanting (equivalent to 1200kg·ha^{-1}). Following transplant, the amount of nutrient supplied was the same for both treatments, as shown in Table I. The poultry compost preparation was made with 0.5kg of poultry manure mixed with 1L of water for 24h. The concentrate obtained had the following composition: 0.24, 0.25, 0.19, 0.07, 0.06% of N, P, K, Ca and Mg, respectively. It also contained 45, 5, 0.01 and 8ppm of Fe, Cu, Mn and Zn, respectively. The concentrate was diluted in irrigation water (electrical conductivity 1.7dS·m^{-1} and pH 7.3) in a 20:1 proportion (water:concentrate), from which an average electrical conductivity of 2.70dS·m^{-1} was obtained. In order to acidify the solution to pH 6.5, 30% acetic acid was used (OMRI, 2013).

The measured variables were: total fruit yield, percentage of fruit classes (small, medium and large), number of fruits per plant, fruit diameter and length, fruit firmness, Brix grade, titratable acidity, SPAD units of leaves (Minolta® Spad 502 chlorophyll meter), sap nitrate content (Cardy-Horiba® C141 ion meter), sap potassium content (Cardy-Horiba® C131 ion meter). Water and nutrient (N, P, K, Fe, Cu, Mn and Zn) efficiencies were estimated using the ratio of application of each input to the final yield of fruits. A variance analysis and comparison of averages was made using the Tukey test (≤0.05) in the Statistical Analysis System 9.0 (SAS, 2002).

Results and Discution

Both determinate tomato production systems, soil and substrate, had similar levels of performance in general, as evidenced by the fact that for the majority of variables evaluated the differences between the two treatments were not statistically significant (Table II).

TABLE I
NUTRITION MANAGEMENT IN SOIL AND SUBSTRATE FOLLOWING TRANSPLANT

Dat	Practice	Frequency
7-140	Application of poultry manure preparation to the irrigation system. Soil was irrigated to the point of 80% available humidity, while the substrate was irrigated three times per day with 20-30% drainage.	Daily
7-140	Application of Agrokelp foliar fertilizer (OMRI). 3L·ha^{-1} dosage. Supply of 6, 0.6, 0.5 and 1.2ppm of Fe, Cu, Mn and Zn, respectively.	Fortnightly
12-70	Application of sodium nitrate fertilizer (OMRI). Dosage of 2kg of N/ha^{1}.	Daily
12-70	Application of potassium sulfate fertilizer (OMRI). Dosage of 2.5kg of N/ha.	Daily

Dat: days after transplant.

TABLE II
RESULTS OF THE COMPARISON BETWEEN TWO SYSTEMS OF ORGANIC PRODUCTION OF TOMATO DETERMINED IN PROTECTED ENVIRONMENT

	Soil	Substrate
Yield		
Total yield (t ha^{-1})	119.28 ±8.22 a	116.73 ±4.87 a
Small fruits (%)	54.99 ±3.91 a	54.87 ±2.47 a
Medium fruits (%)	15.41 ±0.46 b	20.44 ±1.20 a
Large fruits (%)	29.60 ±2.62 a	24.69 ±1.63 a
Number of fruits per plant	56.97 ±3.27 a	56.03 ±2.77 a
Average fruit diameter (mm)	45.67 ±0.37 a	45.86 ±0.15 a
Average fruits length (mm)	59.12 ±0.49 a	59.25 ±0.23 a
Fruit quality		
Firmness small fruits ($kg \cdot cm^{-2}$)	13.58 ±0.55 a	13.20 ±0.39 a
Firmness medium fruits ($kg \cdot cm^{-2}$)	13.57 ±0.50 a	13.90 ±0.53 a
Firmness large fruits ($kg \cdot cm^{-2}$)	13.64 ±0.52 a	14.04 ±0.53 a
Brix fruit grade small fruits	4.38 ±0.12 a	4.85 ±0.07 a
Brix fruit grade medium fruits	4.84 ±0.18 a	5.13 ±0.17 a
Brix fruit grade large fruits	4.91 ±0.09 a	4.83 ±0.11 a
Titratable fruit acidity small fruits (%)	0.86 ±0.01 a	0.82 ±0.07 a
Titratable fruit acidity medium fruits (%)	0.90 ±0.04 a	0.95 ±0.06 a
Titratable fruit acidity large fruits (%)	0.99 ±0.08 a	0.73 ±0.06 b
Plant nutrition		
SPAD units of leaves 20 dat	45 ±0.80 b	54 ±0.93 a
SPAD units of leaves 40 dat	44 ±0.97 b	51.5 ±0.46 a
SPAD units of leaves 80 dat	52 ±0.25 a	52 ±0.31 a
Sap nitrate content 20 dat (ppm)	531 ±36.68 a	533 ±39.6 a
Sap nitrate content 40 dat (ppm)	245 ±19.52 a	220 ±14.07 a
Sap nitrate content 80 dat (ppm)	184 ±10.84 a	150 ±13.27 b
Sap K content 20 dat (ppm)	1274 ±37.50 a	1660 ±102 a
Sap K content 40 dat (ppm)	2736 ±311 a	2153 ±48.55 a
Sap K content 80 dat (ppm)	4773 ±106 a	3757 ±557 a
System efficiency		
Water ($kg \cdot m^{-3}$)	38.34 ±2.64 a	29.42 ±1.24 b
Nitrogen (kg/kg N applied)	562 ±38.79 a	550 ±22.98 a
Phosphorus (kg/kg P applied)	597 ±41.11 a	583 ±24.36 a
Potassium (kg/kg K applied)	501 ±34.55 a	490 ±20.47 a
Iron (kg/g Fe applied)	24.20 ±1.68 a	23.67 ±0.98 a
Copper (kg/g Cu applied)	341 ±23.94 a	333 ±13.92 a
Manganese (kg/g Mn applied)	227.29 ±15.69 a	222.40 ±9.28 a
Zinc (kg/g Zn applied)	145.46 ±10.02 a	142.36 ±5.94 a

Values with equal letters in the two columns are statistically similar (Tukey, 0.05). Dat: days after transplant; ppm: parts per million.

In the case of the yield variables, the only significant difference detected (P≤0.05) was the percentage of medium-sized fruits, in which the soil was 5% superior to the substrate. The total yields achieved over a period of four months in this study of a determinate variety are significant both in soil and in substrate (119.28 and 116.73$t \cdot ha^{-1}$, respectively), in that yields can be obtained twice per year and, being organic, the fruits may be priced up to three times greater than tomatoes produced under conventional systems. The total yields in this study were greater than those reported by Preciado *et al.* (2011), who applied organic fertilizers (preparation of compost, preparation of vermicompost and leachate of vermicompost) to indeterminate tomato production.

In terms of fruit quality, the only statistically-significant difference found (P≤0.05) was in the variable of titratable acidity in large fruits, in which soil-grown fruits were 27% more acid than those of the substrate. The values for the three quality variables are appropriate for commercialization and are similar to those obtained in conventional cultivation systems. In terms of firmness, Castellanos (2008) states that the minimum value required for tomatoes in the maturation stage is 11$kg \cdot cm^{-2}$, and that greater firmness values indicate a more prolonged shelf life, as in the case of this study (>13$kg \cdot cm^{-2}$). In terms of ºBrix, both treatments showed greater values than those reported by Vázquez *et al.* (2015), who obtained values of 4.51 and 4.45º with compost fertilizer or a compost preparation.

In terms of nutritional values, statistically significant differences (P≤0.05) were found in SPAD units at 20 and 40 days after transplant (ddt). At both stages, the substrate-grown plants were superior to those cultivated in soil (17% and 20%, respectively). However, at 80 ddt this situation was reversed and soil-cultivated plants presented significantly greater values. SPAD units are related to the N content of tomato plants (Rodriguez, 1998), which in turn is related to to nitrogen levels in the growth medium that can be attributed to the difference in clay content between in the medium (38.46% soil *vs* 5.17% substrate). Clays have the capacity to retain and release $N\text{-}NH_4$ from the soil interchange complex (Murrel, 2003). For this reason, the dynamics could be that of a high retention of the $N\text{-}NH_4$ that is released at the beginning of cultivation.

Sap nitrate and potassium values, in the three phenological stages, are smaller than the reference values reported for tomatoes by Cadahía (2008) in conventional fertilization systems. This indicates the possibility of raising the dosage of nutrients applied in this study in order to obtain a greater yield.

Finally, of the variables that estimate the efficiency of the systems, the only significant difference (P≤0.05) was found in water use (Table II). Organic tomato cultivation in soil was 30% more efficient than in substrate, owing to a slightly greater yield with less water applied in the soil than in the substrate. This result is especially relevant, taking into consideration that water is the most limiting natural resource for agriculture in Mexico, where 60% of the territory is classified as semi-arid. The greater water use efficiency in soil as compared to substrate has been documented in other studies, and is explained by the high levels of drainage (20 to 30%) allowed in substrate in order to avoid salinity and nutrient imbalance in the solution (Ojodeagua *et al.,* 2008). Sánchez *et al.,* (2014) indicate that short-cycle cultivation of tomatoes can generate water and nutrient savings without reducing average annual production values.

ACKNOWLEDGEMENTS

The research was supported by PROMEP-SEP, Mexico, agreement number PROMEP/103.5/12/2110, UASLP-CA-209.

REFERENCES

Cadahía LC (2008) La savia como índice de fertilización de cultivos hortícolas. In Cadahía LC *La Savia como Índice de Fertilización*. Mundi-Prensa. Madrid, España. pp. 101-149.

Castellanos JZ (2008) *Manual de Producción de Tomate en Invernadero*. Instituto para la Innovación Tecnológica en Agricultura. Guanajuato, Mexico. 212 pp.

Gamliel A, Van Bruggen AHC (2015) Maintaining soil health for crop production in organic greenhouses. *Sci. Hort. 208*: 120-130.

IFOAM (2016) *Principles of Organic Agriculture*. International Federation of Organic Agriculture Movements. www.ifoam.bio/sites/default/files/poa_english_web.pdf

Márquez-Hernández C, Cano-Ríos P, Figueroa-Viramontes U, Avila-Diaz JA, Rodríguez-Dimas M, García-Hernández JL (2013) Yield and quality of tomato with organic sources of fertilization under greenhouse conditions. *Phyton 82*: 55-61.

Murrel TS (2003) Transformaciones de los nutrientes en el suelo. Informaciones Agronómicas Nº 49. INPOFOS. 4 pp.

Ojodeagua AJL, Castellanos RJZ, Muñoz RJJ, Alcántar GG, Tijerina CL, Vargas TP, Enríquez RS (2008) Eficiencia de suelo y tezontle en sistemas de producción de tomate en invernadero. *Fitotec. Mex. 31*: 367-374.

OMRI (2013) *Generic Materials List*. Organic Materials Review Institute. Eugene, OR, EEUU. 102 pp.

Preciado-Rangel P, Fortis HM, García-Hernández JL, Rueda PO, Esparza RJ, Lara HA, Segura CM, Orozco VJ (2011) Evaluación de soluciones nutritivas orgánicas en la producción de tomate en invernadero. *Interciencia 36*: 689-693.

Rodríguez-Mendoza M, Alacántar-González G, Aguilar-Santelises A, Etchevers-Barra J., Santizó-Ricón J (1998) Estimation of nitrogen and chlorophyll status of tomato with a portable chlorophyll meter. *Terra 6*: 135-141.

Sahota A (2016) *The Global Market of Organic Food and Drink*. www.organic-world.net/yearbook/yearbook-2016.html.

Sánchez-Del Castillo FE, Moreno-Pérez J, Pineda-Pineda J, Osuna JM, Rodríguez-Pérez JF, Osuna-Encino F (2014) Hydroponic tomato (*Solanum lycopersicum* L.) production with and without recirculation of nutrient solution. *Agrociencia 48*: 185-197.

SAS (2002) *Statistical Analysis System 9.0*. SAS Institute Inc. Cary, NC, EEUU.

Vázquez PV, López MZG, Cortez MCN, Hernández DG (2015) Efecto de la composta y té de composta en el crecimiento y producción de tomate (*Lycopersicon esculentum* mill.) en invernadero. *Rev. Mex. Agroneg. 19*(36): 1351-1356.