Ecological nutrient solutions on yield and quality of melon fruits
Soluciones nutritivas ecológicas en la producción y calidad de melón

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SUMMARY

Due to health benefits, organic food products have increased their demand in recent years. The objective was evaluating the effects of three ecological nutrient solutions, (Tea of compost, vermicompost, and leachate of vermicompost), on yield and quality of melon plants. As a control, an inorganic nutrient solution was used. Our results showed that compost tea promoted fruit yield equivalent to the inorganic nutrient solution. Plants fertilized with compost tea yielded fruits with the highest value of soluble solids content (9.98 ºBrix). Regarding antioxidant capacity, fruits fed with compost tea and vermicompost leachate obtained higher values than fruits fed with nutrient solution, fruits fed with vermicompost leachate obtained statistically higher values than fruits fed with chemical nutrient solution. Concerning to total phenolic content plants fed with vermicompost leachate obtained the highest value statistically similar to control plants fed with the Steiner nutrient solution.

Index words: Cucumis melo, *compost tea, nutraceutical quality, vermicompost tea.*

RESUMEN

Debido a los beneficios para la salud, los productos alimenticios orgánicos han aumentado su demanda en los últimos años. El objetivo fue evaluar los efectos de tres soluciones nutritivas ecológicas (té de composta, vermicomposta y lixiviado de vermicomposta) sobre el rendimiento y la calidad de las plantas de melón. Como control, se utilizó una solución nutritiva inorgánica. Nuestros resultados mostraron que el té de composta promovió el rendimiento de fruta equivalente a la solución de nutrientes inorgánicos. Las plantas fertilizadas con té de composta produjeron frutos con el mayor valor de contenido de solidos solubles (9.98 °Brix). En cuanto a la capacidad antioxidante, las frutas con té de composta y lixiviado de vermicomposta obtuvieron valores más altos que las frutas con solución nutritiva, las frutas con lixiviado de vermicomposta obtuvieron valores estadísticamente más altos que las frutas con solución química nutritiva. Con respecto al contenido total de fenoles, las plantas con lixiviado de vermicomposta obtuvieron el valor más alto estadísticamente similar a las plantas control con solución nutritiva Steiner.

Palabras clave: Cucumis melo, *te de composta, calidad nutraceutica, te de vermicomposta.*

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INTRODUCTION

The application of nutrient solutions, both chemical and organic, have been used to increase yield and manipulate the nutritive content of fruits and vegetables (Preciado *et al*., 2011). In recent years, customers have been increasingly demanding for fresh and safe products (Yiridoe *et al*., 2005). Ecological growing plants are widely recognized as the safest option (Willer and Kilcher, 2011). The consumer of environmentally friendly food production is referred to as an "ecological consumer" (Fraj and Martinez, 2006). These customers are eager to pay more than usual for vegetables certified as natural products, because they believe that such products contain higher values in phyto nutrients and antioxidant capacity (Thilmany *et al.*, 2007). In some studies, organic vegetables have shown better nutritional quality conditions. This could be owing to a higher content of phytochemicals compounds (Hallmann and Rembiałkowska, 2012). One of the agricultural practices that has been widely accepted is the application of solid and liquid organic materials, principally, compost and vermicompost leachates (Jarecki *et al.*, 2005), and compost and vermicompost teas (Preciado *et al.*, 2011). Some studies, however, suggest that yield obtained using organic production is usually lower compared to conventional system (Hallmann and Rembiałkowska, 2012). In this respect, De Ponti *et al.* (2012) mentions that after reviewing 362 papers comparing organic against conventional production, the average yields are indeed lower, but by only 20%, while the profitability of environmentally friendly products is actually, on average, 30% *superior* than produce from traditional systems. The better quality of naturally produced vegetables has been reported several times (Vrček *et al.*, 2014). As an example, Preciado *et al.* (2011) informed a lower yield in tomato fruits fertilized with organic nutritive solutions, but such fruits had higher soluble solids content than tomato fertilized with chemical solutions. The aim of this research was to evaluate yield, and nutraceutical quality of melon fruits with different ecological nutrient solutions.

MATERIALS AND METHODS

Cultivation Management

An automatic plastic tunnel-type greenhouse, was used to carry out this experiment. This facility is located in Instituto Tecnológico de Torreón. Melon seedling (Cruisier hybrid) of 30 days old were transplanted into twenty L black polyurethane bags (a single seedling was transplanted per bag), containing 80% river sand and 20% perlite as growing medium. Each bag had six holes underneath to allow drainage. Before use, river sand was sanitized using tap water with a concentration of 2700 mg L^{-1} of sodium hypochlorite. Plants were then placed in greenhouse with a density of four plants for square meter. An automatic drip irrigation system watered plants three times a day, adding a volume enough to drain 30%. Throughout the growing cycle, the drainage was kept between 20 to 30%. In the Beginning at flowering stage, and until fruit development, polinization was performed mechanically by hand from noon to 14:00h. Plants were kept at only one stem per plant and were attached by plastic string to the greenhouse frame. All fruits were hanging from the greenhouse structure using plastic mesh pockets.

Experimental Design and Treatments

In a completely randomized design, three ecological nutrient solutions and a control were evaluated:1) compost tea; 2) vermicompost tea; 3) vermicompost leachate (collected from vermicompost obtention); and 4) Steiner universal solution (Steiner, 1984), with ten replicates per treatment. Bovine manure was the source for the compost and vermicompost teas used, and were prepared according to the method proposed by Ingham (2005). The ecological solutions pH was adjusted using citric acid (Capulín *et al.*, 2007) and maintained at a range from 5.5 to 5.8. The electrical conductivity (EC) was kept at 2 dS m^{-1} by diluting the ecological solutions with tap water to evade phytotoxicity (Oliva *et al.*, 2010) (Table 1).

Table 1. Chemical composition of nutrient solutions applied to soilless melon plants, grown under greenhouse conditions. Concentrations indicated in milliequivalent per liter (me L^{-1}).

	Steiner Solution	Compost tea	Vermicompost tea	Vermicompost leachate
	- - - - - - - - - - - - me L^{-1} - - - - - - - - - - - -			
N	12	1.5	1.71	1.35
P	1	0.41	0.48	0.35
K	7	6.52	8.95	6.26
Ca	9	0.75	0.85	0.95
Mg	4	1.39	1.56	0.90
Na	1.56	17.7	10.50	6.7
S	7	37.32	51.77	27.22
Cl	5.6†	20.08	16.59	17.85

† Contained in water used for preparing the Steiner nutrient solution.

Analytical Tests

The commercial quality of the fruit (fresh fruit weight, equatorial and polar diameter, peel and pulp width, and soluble solids content), and the nutritive quality (antioxidant capacity by the $ABTS^+$ and $DPPH^+$ methods and phenolic content) were evaluated.

Extract's Preparation for Phenolic Content and Antioxidant Capacity

One-gram sample (lyophilized pulp) was mixed in 10 mL methanol in plastic tubes with a twist cap, that were kept for 6 h at 20 rpm and 5 °C in a shaker (ATR Inc., USA). Then, Tubes were set in the centrifuge for 10 min at 3000 rpm, and the supernatant was removed for posterior analytical tests.

Total Phenolic Content

Total phenolic content was obtained by a modified method of Folin-Ciocalteau (Esparza *et al*., 2006). Results were reported in % of gallic acid per dry weigh in grams (% AG/g DW).

Antioxidant Capacity in Trolox Equivalent ($ABTS^+$ method)

The antioxidant capacity was determined using method described in Esparza *et al*. (2006). The results were informed in mg g^{-1} equivalent Trolox of dry weight.

Antioxidant Capacity in Trolox Equivalent ($DPPH^+$ method)

The antioxidant capacity also was determined by a modified $DPPH^+$ method devised by Brand-Williams *et al.* (1995), to report the results in mg g^{-1} equivalent Trolox of dry weight.

Statistical Analysis

All variables described above were evaluated by one-way ANOVA by the GLM method of SAS statistical package version 9.1 (SAS Institute, 2009). Tukey simultaneous test was used for comparing statistical means, at ($P \leq 0.05$).

RESULTS AND DISCUSSION

Yield and Fruit Marketable Quality

Weight and fruit size are important because it affects yield and influences the final selection of product by the consumers (Montaño-Mata and Méndez, 2009). Our results show that treatment with compost tea affected yield and fruit quality, being statistically similar to the Steiner solution which showed the highest yield value. The treatments with vermicompost tea and leachate were statistically lower (Table 2). These results agreed with Budiastuti *et al.* (2012) who reported that fruits obtained under organic or natural fertilization generally have smaller size and lower weight and yield than those produced using conventional chemical fertilization. This, due to a lower nutrient concentration in organic solutions (Preciado *et al*., 2011). According with Tapia *et al*. (2010) it should be noted that the fruit weight of melons produced in our study was within marketing acceptable values. Except for vermicompost-tea treatment which showed the lowest yield and weight value. The highest yield values were obtained with the fertilization treatments using the more nitrogen-rich Steiner solution, since this macro nutrient is directly involved in yield and final fruit weight in vegetables (Sainju *et al.*, 2003; Rodríguez *et al.*, 2005). Hence, the slightly lower yields are understandable, considering that the organic nutrient solutions had to be diluted to avoid salt phyto-toxicity in plants (Oliva *et al*., 2010) (Table 1). Hereafter, the suggestion is that the lower fruit size and weight in melon grown under the natural nutrient solutions treatments was caused by nitrogen deficit. Rembiałkowska (2007) states that high yield in conventional crops are often associated to a high nitrogen availability. Hence, some alternatives that can be used to increase nitrogen and other nutrients content in natural solutions include the mixture of organic nutrient sources (Ingham, 2005), in addition to using less diluted fertilizer solutions (González Solano *et al.*, 2013). Nevertheless, those natural solutions must be assessed to meet the specific crop mineral requirements (Alam and Chong, 2010). In contrast fruits from high yielding plants are usually characterized by their low biochemical content (Hallmann and Rembiałkowska, 2012).

Compost-tea treatments, were superior with respect to very important quality criteria, such as soluble solids content (Budiastuti *et al*., 2012). Montaño-Mata and Mendez (2009) explain that consumers prefer melon fruits with a soluble solids content ranging 8-10 °Brix. In our study plants fertilized with compost-tea showed the highest soluble solids content (9.98; Table 2). These outcomes are similar to those published by Preciado *et al*. (2011), who informed a higher soluble solid content in tomato organically fed compared to conventional chemical fertilized fruits rich in nitrogen. A negative correlation occurs between nitrogen supply by chemical fertilizer application and production of soluble solid content (Parisi *et al.*, 2004). Soluble solids content in fruits may increase due to a low level of water absorption, hence, fruits store solutes as simple sugars, such as glucose, fructose and sucrose (Goykovic and Saavedra, 2007). Another cause of soluble solids accumulation in fruits is salt buildup in the nutrient solution, particularly an increase of sodium and chloride content (Wu and Kubota, 2008). These findings suggest that the application of ecological solutions, particularly compost-tea, should be considered as a feasible fertilizer alternative that may replace traditional chemical fertilization; since the decrease in yield can be remedied by obtaining premium quality and higher price as organic product (De la Cruz-Lázaro *et al.*, 2010).

Fruit Nutraceutical Quality

The quantity and type of antioxidants contained in fruits and vegetables are affected by agricultural practices and post-harvest produce handling (Schreiner and Huyskens, 2006; Huyskens *et al.*, 2006). The results found from this study suggest that the treatments applied affected nutraceutical quality of melon fruits.

In our study (Table 3) fruits with the treatment with compost tea and vermicompost leachate reached statistically higher values by the $DPPH^{+}$ method, than fruits fed with chemical nutrient solution. Fruits with the treatment of vermicompost leachate reached statistically higher values by the $ABTS^{+}$ method, than fruits fed with chemical nutrient solution. In regards to total phenolic content plants fed with vermicompost leachate got the highest value statistically similar to control plants fed with the chemical Steiner nutrient solution (Table 3). Differences among treatments concerning antioxidant capacity and phenolic content could be associated with the low concentration of nitrogen in the ecological solutions applied (Table 1). When plants are subjected to nitrogen deficiency create higher quantities of sugars and secondary metabolites such as organic acids, vitamins, pigments, phenolic compounds and terpenoids (Herms and Mattson, 1992). The antioxidant capacity of melon produced in the current experiment is even higher than those values found by Salandanan *et al.* (2009), who reported as well a higher content of phenolics and antioxidant

Table 2. Commercial quality parameters of soilless melon fruits grown using different nutrient solutions under greenhouse conditions.

Treatment	Weight	Yield	Diameter		Soluble solids
			Polar	Equatorial	
	kg fruit^{-1}	g m^{-2}	°Brix	cm	
Steiner solution	0.99 a†	8.102 a	10.87 a	9.77 a	8.63 b
Compost tea	0.80 b	6.909 a	8.53 bc	8.85 b	9.98 a
Vermicompost tea	0.62 c	4.215 b	7.73 c	8.13 c	8.75 b
Vermicompost leachate	0.75 b	5.208 b	8.90 b	8.53 bc	8.50 b

† Values followed by different letter in columns are significantly different (Tukey $P < 0.05$).

Table 3. Antioxidant capacity and total phenolic content of soilless Cantaloupe melon fruits grown using different nutrient solutions under greenhouse conditions.

Treatments	Total phenolic content	Antioxidant capacity ABTS + method	Antioxidant capacity DPPH + method
	% GA[†]/g DW[‡]	mg/g ET[§] DW	mg/g ET DW
Steiner solution	0.503 ab[¶]	1.70 b	3.23 c
Compost tea	0.433 b	1.43 b	8.12 a
Vermicompost tea	0.466 b	2.10 ab	6.36 b
Vermicompost leachate	0.650 a	2.49 a	8.53 a

[†] Gallic acid. [‡] DW dry weight. [§] ET equivTrolox. [¶] Values followed by different letter in columns are significantly different (Tukey $P < 0.05$).

capacity in organic fruits than in chemically fed fruits. Hence, the higher antioxidant capacity of organic melons could be attributed to the increase in phenolic compounds production due to the nitrogen deficit in the ecological solutions applied. Hence, we endorse the use of natural nutrient solutions, as the ones studied in this experiment, as fertilizer substitutes for production of soilless melon fruits with enhanced quality.

CONCLUSIONS

Fertilization treatments using Steiner solution and compost tea caused the highest yield values, however melon plants fertilized with compost tea had the highest concentration of total soluble solids (9.98 ºBrix). Regarding nutraceutical quality of fruit, fertilized with ecological solutions particularly with compost tea and vermicompost leachate were higher than chemically fertilized melons, being a viable alternative as ecological nutrient sources for soilless production of melon fruits with improved quality.

REFERENCES

Alam, M. Z. and C. Chong. 2010. Recycled liquid Cattle manure as a sole fertilizer source for growing container nursery stock in a closed system. HortScience 45: 157-160. doi: 10.21273/HORTSCI.45.1.157.

Brand-Williams, W., M. E. Cuvelier, and C. Berset. 1995. Use of a free radical method to evaluate antioxidant activity. LWT-Food Sci. Technol. 28: 25-30. doi: https://doi.org/10.1016/S0023-6438(95)80008-5.

Budiastuti, S., D. Purnomo, T. D. Sulistyo, S. P. Rahardjo, L. Darsono, and Y. V. Pardjo. 2012. The enhancement of melon fruit quality by application of the fertilizer and gibberellin. J. Agric. Sci. Technol. B 2: 455-460.

Capulín-Grande, J., R. Núñez-Escobar, J. L. Aguilar-Acuña, M. Estrada-Botello, P. Sánchez-García y J. J. Mateo-Sánchez. 2007. Uso de estiércol líquido de bovino acidulado en la producción de pimiento morrón. Rev. Chapingo Serie Hortic. 13: 5-11.

De la Cruz-Lázaro, E., R. Osorio-Osorio, E. Martínez-Moreno, A. Lozano-del Río, A. Gómez-Vázquez y R. Sánchez-Hernández. 2010. Uso de compostas y vermicompostas para la producción de tomate orgánico en invernadero. Interciencia 35: 363-368.

De Ponti, T., B. Rijk, and M. K. van Ittersum. 2012. The crop yield gap between organic and conventional agriculture. Agric. Syst. 108: 1-9. doi: https://doi.org/10.1016/j.agsy.2011.12.004.

Esparza-Rivera, J. R., M. B. Stone, C. Stushnoff, E. Pilon-Smits, and P. A. Kendall. 2006. Effects of ascorbic acid applied by two hydrocooling methods on physical and chemical properties of green leaf lettuce stored at 5 °C. J. Food Sci. 71: 270-276. doi: 10.1111/j.1365-2621.2006.tb15653.x.

Fraj, E. and E. Martinez. 2006. Environmental values and lifestyles as determining factors of ecological consumer behaviour: An empirical analysis. J. Consumer Market. 23: 133-144. doi: 0.1108/07363760610663295.

González Solano, K. D., M. N. Rodríguez Mendoza, L. I. Trejo Téllez, J. Sánchez Escudero y J. L. García Cué. 2013. Propiedades químicas de tés de vermicompost. Rev. Mex. Cienc. Agríc. 5: 901-911. doi: 10.29312/remexca.v0i5.1297.

Goykovic Cortés, V. y G. Saavedra del Real. 2007. Algunos efectos de la salinidad en el cultivo del tomate y prácticas agronómicas de su manejo. Idesia (Chile) 25: 47-58. doi: http://dx.doi.org/10.4067/S0718-34292007000300006.

Hallmann, E. and E Rembiałkowska. 2012. Characterisation of antioxidant compounds in sweet bell pepper (*Capsicum annuum* L.) under organic and conventional growing systems. J. Sci. Food Agric. 92: 2409-2415. doi: 10.1002/jsfa.5624.

Herms, D. A. and W. J. Mattson. 1992. The dilemma of plants: To grow or defend. Quart. Rev. Biol. 67: 283-335.

Huyskens-Keil, S., H. Prono-Widayat, P. Lüdders, and M. Schreiner. 2006. Postharvest quality of pepino (*Solanum muricatum* Ait.) fruit in controlled atmosphere storage. J. Food Engin. 77: 628-634. doi: https://doi.org/10.1016/j.jfoodeng.2005.07.028.

Ingham, E. R. 2005. The compost tea brewing manual. Soil Foodweb Incorporated. Unisun Communications. Corvallis, OR, USA.

Jarecki, M. K., C. Chong, and R. P. Voroney. 2005. Evaluation of compost leachates for plant growth in hydroponic culture. J. Plant Nutr. 28: 651-667. doi: https://doi.org/10.1081/PLN-200052639.

Montaño Mata, N. J. y J. R. Méndez-Natera. 2009. Efecto de reguladores de crecimiento sobre el epicarpo, mesocarpo y sólidos solubles totales del fruto de melón (*Cucumis melo* L.) cv. Edisto 47. Rev. Cient. UDO Agríc. 9: 295-303.

Oliva-Llaven, M. Á., L. Rodríguez-Hernández, P. Mendoza-Nazar, B. Ruiz-Sesma, J. D. Álvarez-Solís, L. Dendooven, and F. A. Gutiérrez-Miceli. 2010. Optimization of worm-bed leachate for culturing of tomato (L*ycopersicon esculentum* Mill) inoculated with Glomus fasciculatum and Pseudomonas fluorescens. Electron. J. Biotechnol.13: 4-5. doi: http://dx.doi.org/10.4067/S0717-34582010000200004.

Parisi, M., L. Giordano, A. Pentangelo, B. D'Onofrio, and G. Villari. 2004. Effects of different levels of nitrogen fertilization on yield and fruit quality in processing tomato. Acta Hortic. 700: 129-132. doi: https://doi.org/10.17660/ActaHortic.2006.700.19.

Preciado-Rangel, P., M. Hernández-Fortis, J. L. García-Hernández, E. Puente-Rueda, J. R. Esparza-Rivera, A. Herrera-Lara, M. A. Castruita-Segura y J. A. Orozco-Vidal. 2011. Evaluación de soluciones nutritivas orgánicas en la producción de tomate en invernadero. Interciencia 36: 689-693.

Rembiałkowska, E. 2007. Quality of plant products from organic agriculture. J. Sci. Food Agric. 87: 2757-2762. doi: 10.1002/jsfa.3000.

Rodríguez, J. C., N. L. Shaw, D. J. Cantliffe, and Z. Karchi. 2005. Nitrogen fertilization scheduling of hydroponically grown 'Galia' muskmelon. Proc. Fla. State Hort. Soc. 118: 106-112.

Sainju, U. M., R. Dris, and B. Singh. 2003. Mineral nutrition of tomato. Food, Agric. Environ. 1: 176-183.

SAS Institute. 2009. SAS/SAT user´s guide. Version 9.2. SAS Institute. Cary, NC, USA.

Salandanan, K., M. Bunning, F. Stonaker, O. Külen, P. Kendall, and C. Stushnoff. 2009. Comparative analysis of antioxidant properties and fruit quality attributes of organically and conventionally grown melons (*Cucumis melo* L.). HortScience 44: 1825-1832. doi: https://doi.org/10.21273/HORTSCI.44.7.1825.

Schreiner, M. and S. Huyskens-Keil. 2006. Phytochemicals in fruit and vegetables: Health promotion and postharvest elicitors. Crit. Rev. Plant Sci. 25: 267-278. doi: https://doi.org/10.1080/07352680600671661.

Steiner, A. A. 1984. The universal nutrient solution. pp. 633-649. *In:* Proceedings 6th International Congress on Soilless Culture. ISOSC. Lunteren, Wageningen.

Tapia-Vargas, L. M., H. R. Rico-Ponce, A. Larios-Guzmán, I. Vidales-Fernández, and M. E. Pedraza-Santos. 2010. Nutritional management based on nutrient status, fruit quality, and yield relationships in cantaloupe. Rev. Chapingo Serie Hortic. 16: 49-56. doi: 10.5154/r.rchsh.2010.16.006.

Thilmany, D., C. Bond, J. Keeling-Bond, C. Stushnoff, F. Stonaker, M. Bunning, and P. Kendall. 2007. Eat your fruits and veggies: Exploring fresh-produce market choices. J. Food Distrib. Res. 38: 154-160. doi: 10.22004/ag.econ.162279.

Vrček, I. V., D. V. Čepo, D. Rašić, M. Peraica, I. Žuntar, M. Bojić, G. Mendaš, and M. Medić-Šarić. 2014. A comparison of the nutritional value and food safety of organically and conventionally produced wheat flours. Food Chem. 143: 522-529. doi: 10.1016/j.foodchem.2013.08.022.

Willer, H. and L. Kilcher. 2011. The World of Organic Agriculture: Statistics and Emerging Trends 2011. IFOAM, Bonn, & FiBL. Frick Switzerland. ISBN PDF version 978-3-940946-84-3 (IFOAM) and 978-3-03736-194-8 (FiBL).

Wu, M. and C. Kubota. 2008. Effects of high electrical conductivity of nutrient solution and its application timing on lycopene, chlorophyll and sugar concentrations of hydroponic tomatoes during ripening. Sci. Hortic. 116: 122-129. doi: https://doi.org/10.1016/j.scienta.2007.11.014.

Yiridoe, E. K., S. Bonti-Ankomah, and R. C. Martin. 2005. Comparison of consumer perceptions and preference toward organic versus conventionally produced foods: A review and update of the literature. Renew. Agric. Food Syst. 20: 193-205. doi: 10.1079/RAF2005113.