

Development of Tomato on Different Substrates and Irrigation Volumes Undershade House Conditions

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Abstract

The development of tomato saladette was evaluated in different substrates of vermicompost:perlite [VC:P (v:v), with ratios 1:1; 1:2; 1:3 and 1:4] and different volumes of irrigation, under shade net conditions. In substrates three volumes of water were applied: daily watering with 0.50 and 0.75 L and watering every other day with 0.75 L. Seeds were sown 24/02/2013 in polystyrene trays with 200 cavities, padded with Peat moss: seedlings were transplanted 56 days after sowing in 18 L black plastic bags and placed in a line to double array and "tresbolillo" arrangement at 5.3 pots·m⁻². From the interaction among watering volumes and substrates 12 treatments were generated, each with four replicates. The evaluated variables were soluble solids content, polar and equatorial diameters, pulp thickness, number of locules, fruit weight and yield. The experimental design was split-plots in a randomized block design with watering volumes as a large plot and substrates as a small plot. Data were statistically analyzed by ANOVA and means were separated by the LSD_{0.05} test. The outstanding results for polar and equatorial diameters, fruit weight and yield were registered in T7, with 5.56 and 3.81 cm, 44.58 g and 1.703 kg·pot⁻¹, respectively. The VC was able to retain moisture and satisfy the nutrient demand of tomato without applying synthetic fertilizers

Keywords: available moisture; organic manure; *Solanum lycopersicum*; vermicompost; water holding capacity

1. Introduction

In accordance with Fageria *et al.* (2008), in the 21st century, nutrient efficient plants will play a major role in increasing crop yields compared to the 20th century, mainly due to limited land and water resources available for crop production, higher cost of inorganic fertilizer inputs, declining trends in crop yields globally, and increasing environmental concerns. Additionally, growth, development, quality and production of the crops of economic importance depends, among other factors, of the adequate supply of essential nutrients to meet their physiological needs (Ferreira *et al.*, 2003), and of water availability, given its importance for the processes of dissolution and transport of nutrients (Muñoz-Arboleda, 2009).

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On the other hand, under protected conditions, one of the main factor that determine the success of crops are the substrates, since they are the means in which the roots are developed, and these have great influence on their growth and development (Ortega-Martínez *et al.*, 2010). Regarding the growth substrates, Kroeff-Schmitz *et al.* (2002), have pointed out that worldwide there are a lot industries and processes that generate wastes which can contaminate the environment, but on the other hand, these wastes have the potential to be recycled. The recycling of this waste through composting or vermicomposting is a viable alternative for agriculture (Alidadi *et al.*, 2007; Aalok *et al.*, 2008), since with these processes, in addition to generating horticultural substrates broadly available and inexpensive, it is feasible minimize contamination current due to the accumulation of waste in the environment (Kroeff-Schmitz *et al.*, 2002). In this sense, the substrates most commonly used for tomato development and that have shown adequate results for their growth, development and production are: peat, rockwool and coco peat; however, the purchase of these is costly, so it is necessary to find materials that, without impacting performance and quality of the crops, might be less expensive for producers (Ortega-Martínez *et al.*, 2010).

In the organic farming context, different authors, among which highlights Ramesh *et al.* (2005), Aalok *et al.* (2008) and Manivannan *et al.* (2009), have established that the vermicompost (VC), in addition to being materials finely divided such as the peat moss, contains: a) most nutrients in plant available form such as nitrates, phosphates and exchangeable calcium and soluble potassium; b) plant growth regulators and other plant growth influencing materials produced by microorganisms including humates; c) a high porosity, aeration, drainage and water-holding capacity; d) increase size, biodiversity and activity of the microbial population in soil; and e) a large surface area, providing strong absorption capability and retention of nutrients, among others characteristics with which it can potentially promote the development of the crops.

With respect to moisture, several authors emphasize that the VC increases retention of this one (Hernández *et al.*, 2008; Manivannan *et al.*, 2009) VC is a finely-divided peat-like materials (Aalok *et al.*, 2008). This becomes important because retaining moisture, in adequate amounts and homogeneously, is the main characteristic that it searches in the substrates, because through water, the roots assimilate essential elements for development of crops. Furthermore, water is required by plants to perform metabolic processes: through these the mineral substances are converted to different organic compounds, and while the holding capacity of water in the substrates is highest, the waterings will be less frequent (Bastida-Tapia, 2001). The foregoing suggests that the production of different crops, traditionally subject to the use of synthetic fertilizers, implemented through nutrient solutions, can be developed with the application of substrates from organic origin, such as the VC, wherewith it searching for replaces the use of the inorganic fertilizers. The objective of study was to evaluate the development of saladette tomato in different vermicompost: perlite substrates and at different volumes of irrigation, under shade net conditions.

2. Materials and Methods

The experiment was carried out at the Universidad Autónoma Agraria Antonio Narro—UL in Torreón, Coahuila, México (101°40' and 104°45' W and 25°05' and 26°54' N) (Schmidt, 1989). According to Aguirre (1981), the climate of this region is dry desert with rainfall in summer and cool winters. The mean rainfall per year is 241.9 mm and the annual average temperature is 21.5 °C, ranging from 33.7 °C maximum and 7.5 °C as minimum. The annual evaporation average is about 2,396 mm. While the relative humidity in this region varies according to season, with 31, 47, 58 and 40 % for spring, summer, fall, and winter, respectively (CNA, 2002). The shade house used consisted of a metallic structure, of 12.60 x 5.40 x 3.0 m, length, width and high, respectively, covered with anti-aphids mesh (16 x 16 threads·cm⁻², Mesh Plas®).

The experiment was conducted in the period spring-summer 2013, using saladette tomato [*Solanum lycopersicum* L. (Peralta *et al.*, 2005)] *cv.* Ramses (Harris Moran®), which were sown on February 24, 2013, in polystyrene trays of 200 cavities, using Peat Moss (Canadian Sphagnum Peat Moss Association®) as substrate, which were previously saturated with water, then filled the tray and deposited two seeds per cavity. The trays were placed inside the greenhouse, covered with black plastic and watered with tap water [pH 7.57, RAS 2.18 and EC 1.05 dS·m⁻¹, classified as C₁S₁, with a low risk of salinization and alkalization (Ayers and Westcot, 1994)] every three days until the time of transplant, which was performed at 56 days after sowing (DAS), when the plant had an approximate height of 20 cm and they had five to six true leaves, placing one seedling per pot.

Black polyethylene 18 L capacity bags, 500 gauge, type nursery were used as pots. At the shade house, the pots were placed in a line to double array and "tresbolillo" arrangement, with a population density of 5.3pots·m⁻².

The materials used for filling the pots were VC and perlite (P)(Nektarios*et al.*, 2011), type B-12 [Multi-perl Hortícola, Perlita de la Laguna, S.A. de C.V. ®] in four volume ratios (VC:P; 1:1, 1:2, 1:3 and 1:4, identified as S1-S4, respectively). The VC (Table 1) was prepared from a mixture of two types of manure (bovine and goatsmanure mixed with alfalfa residues, in 1:1 ratio by volume) digested by *Eisenia fetida* Savigny, for three months (Durán-Umaña and Henríquez-Henríquez, 2007).

Taking into account the water demand and development of tomato, during the period 1 to 28 days after transplant (dat), in substrates S1-S4 three volumes of water were applied: daily watering with 0.50 and 0.75 L (DWV1 y DWV2, respectively), and watering every otherday with 0.75 L (WEODV2). Furthermore, from day 29 after transplant until to conclude the experiment, the irrigation volume was increased in 0.5 L in all substrates. At the end of the experiment, the total volume of water applied to DWV1, DWV2 and WEODV2 were 209.50, 245.0 and 122.25 L·pot⁻¹, respectively.

Table 1: Chemical characteristics of vermicompost used (dry weight) as substrate for development of tomato under net house conditions

Da	CIC	pH	CE	MO	N	Ca	Mg	P	Mn	Cu	Zn
(g·cm ⁻³)	(meq·100 g ⁻¹)		(mS·cm ⁻¹)	(%)		(meq·100 g ⁻¹)		(ppm)			
1.7	33.1	7.9	9.0	13.6	0.9	111.0	55.6	1146.1	0.75	3.3	0.2

Different agronomic practices were carried out during the development of tomato at shade house, the most important of which were: a) formation pruning (removing the side shoots, leaving one main stem per plant), b) removal of basal leaves after making the harvest of the uppermost cluster (in order to promote air circulation, decrease the humidity level, and reduce the disease risk), c) tutoring of plants (coiling the plant around a raffia fastened to the gavel and the upper structure of the greenhouse, to avoid contact of the plant with ground), and d) pollination (carried out daily between 10:00 and 13:00 h, at early flowering of the crop by hand, using an electric toothbrush for placing on the stalk of the inflorescence for 3 s). The scissors used for pruning were disinfected with sodium hypochlorite solution 5 % (Cloralex, AIEn®) among sessions.

The control of pests and diseases was carried out as follows: yellow traps with Biotac® were placed at strategic points inside the shade house, additionally visual checks of plants were carried out daily. The pest encountered, 69 dat, was red spider mite (*Tetranychus urticae* C. L. Koch), which was controlled with Phytoneem®, applied at doses of 0.25 mL·20 L⁻¹ water.

Fruit quality was determined in four plants per treatment, and 20 fruits per plant. Harvest, including up to the eighth cluster, was performed manually when the fruits reached a pink color. The treatment effects on tomato were evaluated considering number of locules (NL), equatorial and polar diameters (ED and PD), pulp thickness (PT), using a vernier (TRUPER®), soluble solids content (SSC), with a manual refractometer: Master-T, ATAGO®, fruit weight (FW) and fruit yield (Y), with a digital scale: Cubis, Sartorius®.

From the interaction between watering volumes and substrates assessed, 12 treatments (T1-T12), each with four replicates, were integrated. A split plot randomized complete block experimental design was used. The big plot corresponded to the watering frequencies and subplots to the substrates. Data were statistically analyzed by ANOVA and means were separated by the LSD_{0.05} test. Statistical significance was obtained at 95% confidence level ($\alpha = 0.05$). Analyses were performed using the statistical software of Olivares-Sáenz (1993).

3. Results and Discussion

For the variables evaluated in this experiment, except for NL, the ANOVAs showed significance ($P \leq 0.05$) for the interactions watering volumes x substrates (Table 2). Respect to FW 7 of the 12 interactions that were evaluated, corresponding to treatments T4, T5, T6, T7, T8, T10 and T11 (DWV1xS4, DWV2xS1, DWV2xS2, DWV2xS3, DWV2xS4, WEODV2xS3 and WEODV2xS2, respectively) were statistically equal, with values ranged from 39.20 to 44.58 g (Table 2), these values outperformed the other treatments in at least 0.36% of FW.

Of these seven treatments highlighted T10 and T11, as the application of watering every other day, combined with VC, whose content ranged from 33 to 25 % [ratios 1:2 and 1:3 (VC:P)], did not affect the FW, therefore it can be assumed that, under the conditions of this experiment, saving water is feasible, the foregoing agrees with results reported by different authors, which have established that the application of VC, besides increasing the organic matter content of substrates, improves their physical characteristics and quantity of hidroestables aggregates, the bulk density and porosity, favoring the flow of air and water, and the root development of plants (Aguilar-Benitez *et al.*, 2012).

However, the average FW recorded in tomato fruits, 39.3 g, under conditions of shade house, it was far outweighed by the FW average determined by Márquez-Quiroz *et al.*, (2014) whose values ranged from 81.76 to 88.52 g, for the genotypes "Cauhtémoc" and "El Cid", respectively, these tomatoes were developed with organic fertilization under greenhouse conditions. This difference in large part occurs because, in greenhouse conditions the yield of tomato exceeds greatly, the yields of open field systems and protected with shade net (Cih-Dzul *et al.*, 2011).

The larger values for PD and ED were recorded in treatment T7, with 5.6 and 3.8 cm, respectively (Table 2), these values correspond to fruits of small size for tomato type saladette or "Roma" (SAGARPA, 2005a). The PD registered in the fruits of treatment T7 was similar to average reported by Preciado-Range *et al.* (2011) for tomato saladette, *cv.*, "El Cid" whose applied different organic nutrient solutions under greenhouse conditions. Also resulted slightly below of average of 5.9 cm, reported by de-la-Cruz-Lázaro *et al.* (2009) for the fruits of tomato saladette, hybrid SUN-7705, when the plants were developed in mixtures of compost and vermicompost with sand at different levels. Meanwhile, the ED registered was exceeded in 19 and 31 % by the average values reported by de-la-Cruz-Lázaro *et al.* (2009) and Preciado-Range *et al.* (2011), respectively, under conditions handling already described and meanwhile, the ED registered was exceeded in 19 and 31% for the average values respectively, on driving conditions already described.

Table 2: Mean values and statistical significance of variables assessed on tomato saladette developed on different substrates and irrigation volumes under net house conditions.

T	RxS γ	PF (g)	PD (cm)	ED	EP	SSC (°Brix)	NL	R (kg·planta ⁻¹)
T1	DWV1xS1	36.14 ab	4.99 bc	3.32 bc	0.4 b	5.69 ab	3 a	1.394 bcd
T2	DWV1xS2	37.28 ab	4.92 bc	3.37 bc	0.5 ab	5.60 ab	3 a	1.312 cd
T3	DWV1xS3	38.84 ab	5.25 ab	3.50 abc	0.5 ab	5.25 bc	3 a	1.469 abcd
T4	DWV1xS4	43.19 a	5.04 abc	3.33 bc	0.7 a	5.03 c	3 a	1.516 abc
T5	DWV2xS1	39.20 a	4.92 bc	3.57 abc	0.5 ab	5.34 abc	3a	1.582 ab
T6	DWV2xS2	40.82 a	4.96 bc	3.63 ab	0.5 ab	5.42 abc	3 a	1.544 abc
T7	DWV2xS3	44.58 a	5.56 a	3.81 a	0.6 ab	5.26 bc	3 a	1.703 a
T8	DWV2xS4	42.71 a	5.16 ab	3.55 abc	0.5 ab	5.07 c	3 a	1.692 a
T9	WEOD V2xS1	30.16 b	4.55 c	3.23 c	0.5 ab	5.74 a	3 a	1.233 d
T10	WEOD V2xS2	39.68 a	5.18 ab	3.43 abc	0.5 ab	5.60 ab	3 a	1.536 abc
T11	WEOD V2xS3	43.54 a	5.37 ab	3.57 abc	0.5 ab	5.26 bc	3 a	1.576 abc
T12	WEOD V2xS4	39.06 ab	5.12 ab	3.44 abc	0.5 ab	5.07 c	3 a	1.233 bcd
Media general		39.60	5.1	3.5	0.5	5.4	3	1.5
CV (%)		15.87	7.58	7.94	22.77	6.09	6.58	12.38

T = Treatment (T1 – T12); VxS = Interaction watering volumes x substrate; γ = For each cause of variation, means followed by the same letters in the column do not differ (LSD test, $p \leq 0.05$); PD = Polar diameter; ED = Equatorial diameter; EP = pericarp thickness; SSC = soluble solid content; NL = Number of locules; R = Yield; DW = daily watering; WEOD = watering every other day; V = Volume (V1 = 0.5 L·pot⁻¹; V2 = 0.75 L·pot⁻¹); S = Substrates (S1 – S4) CV = coefficient of variation; ns = not significant; * = significant; ** = highly significant.

For the PT, the value of 0.7 cm registered in the fruits of treatment T4 (DWV1xS4) was exceeded, in at least 14.28 %, by the values of PT determined in the rest of the treatments (Table 2). This value was similar to the average values of 0.7 and 0.8 cm for PT reported by Rodríguez-Dimaset *al.* (2008) for *cv.*, "Big Beef" and "Miramar" respectively, as a result of the application of VC as a substrate and was also similar to the average values of PT, 0.73 and 0.75 cm, reported by Márquez-Quirozet *al.* (2014) for "Cuauhtemoc" and "El Cid" cultivars, to evaluate the effect of organic fertilization on yield and nutritional content of tomato saladette in greenhouse.

Regarding the SSC, the tomato fruits of treatment T9 (WEODV2xS1) recorded the highest value, 5.7 °Brix (Table 2). This value was lower, in 1.0 °Brix, at the average value of tomato fruits developed in substrates with different volumes of coconut fiber and different frequencies of drip irrigation (de-Matos-Pires *et al.*, 2011). On the other hand, the value 5.7 °Brix, it exceeded in 28 and 19.12 % at the SSC determined, in the first case, by Preciado-Rangelet *al.* (2011) in saladette tomato fruits, *cv.*, "El Cid" whose plants were fertilized with Steiner solution, and in the second case, by Márquez-Hernández *et al.* (2013) in tomato fruits, *cv.*, "Bosky" and "Big Beef" to evaluate the effect of compost on yield and quality of tomato ball type, both under greenhouse conditions. With the latter it is confirmed established by Pathma and Sakhivel (2012), of what, vermicomposting is the best alternative to conventional composting and differs from it in several ways. Vermicomposting hastens the decomposition process by 2–5 times, thereby quickens the conversion of wastes into valuable biofertilizer and produces much more homogenous materials compared to thermophilic composting.

In the same Table 2, it can be observed that the SSC of the tomato fruits developed in the treatments T1 - T12, fertilized with VC, it was superior in at least 29 % of SSC, regarding the optimal value of 4 °Brix, established by Diez (2001) for tomatoes, whether for industrial processing or for fresh consumption, therefore, it strengthens the hypothesis that this fertilizer promotes the development of tomato fruit with higher SSC, this is consistent with the established by Dorais *et al.* (2001) who have determined that, with increasing salinity in the growth media radical the SSC of the fruits is increased.

The highest yields, which ranged from 1.692 to 1.703 kg·plant⁻¹, were recorded in the treatments T8 (DWV2xS4) and T7 (DWV2xS3) (Table 2). Considering the density, 5.3 plants·m⁻², the yield obtained per superface unit corresponded to 8.968 and 9.023 kg·m⁻², respectively, values slightly higher to 50 % of the yield reported by Cruz-Carrillo *et al.* (2003) for tomato with the same plant density under greenhouse conditions. Additionally, both values were higher in at least 11.2%, the interval registered for tomato yield in the Valley of Culiacan, México, during the autumn-winter crop seasons 2007-2008 and 2008-2009, which ranged from 6.4 to 7.9 kg·m⁻², under conditions of shade house (SAGARPA, 2005b). Furthermore, the values of 8.968 and 9.023 kg·m⁻² corresponded approximately 60% of the average yield reported for the production of tomato under retractable-roof greenhouse conditions in the cycles and region aforementioned (Medina-Medina *et al.*, 2012)

As complement, whether it is considered that the overall average yield recorded was 1.5 kg·plant⁻¹, and since plant density was 5.3 plants·m⁻², by hectare of shade house would be obtained 79.5 t·ha⁻¹, this latter value exceeded significantly to the yield of 10 t·ha⁻¹ reported for organic tomato in field conditions (SAGARPA, 2005b) as described in the two paragraphs above, it helps to highlight the goodness of crop management under shade house conditions.

Finally, for yields 1.692 and 1.703 kg·plant⁻¹ registered in the treatments T8 (DWV2xS4) and T7 (DWV2xS3), which were applied 245.0 L of water·pot⁻¹·cycle⁻¹ (until the eighth cluster) it was determined a productivity of 6.91 and 6.95 kg·m⁻³, under shade house conditions. These values were far outweighed by the productivity of 35 kg·m⁻³, reported by Flores *et al.* (2007) for growing tomato, however in favor of the productivity obtained in this experiment, it emphasizes that this latter value was recorded under greenhouse conditions and as highlighted by Medina-Medina *et al.* (2012), the use of greenhouses with retractable-roof in hot weather, generates higher yields due to higher photosynthetic efficiency, resulting from modifications and adaptations morphological foliars, at the microclimate that is generated in this type of structures.

4. Conclusion

The results obtained suggest that, the VC possesses characteristics that allow it be contemplated as an alternative, both for the process of plant nutrition, as for promote the water holding in substrates, without detriment to the quality and yield of tomato under net house conditions, because nutrient demands of this crop was covered with the VC without applying synthetic fertilizers

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5. References

- Aalok, A., Tripathi, A.K., Soni, P. (2008). Vermicomposting: A Better Option for Organic Solid Waste Management. *J. Hum. Ecol.* 24, 59-64.
- Aguilar-Benítez, G., Peña-Valdivia, C. B., García-Nava, J. R., Ramírez-Vallejo, P., Benedicto-Valdés, S. G., Molina-Galán, J. D. (2012). Rendimiento de frijol (*Phaseolus vulgaris* L.) en relación con la concentración de vermicompost y déficit de humedad en el sustrato. *Agrociencia.* 46, 37-50.
- Alidadi, H., Parvaresh, A. R., Shahmansouri, M. R., Pourmoghadas, H., Najafpoor, A. A. (2007). Combined compost and vermicomposting process in the treatment and bioconversion of sludge. *Pakistan J. Biol. Sci.* 10, 3944-3947.
- Aguirre, L. O. (1981). Guía climática para la Comarca Lagunera CIAN-INIA -SARH. Matamoros Coahuila, México p. 174.
- Ayers, R.S., Westcot, D. W. (1994). Water Quality for Agriculture, FAO Irrigation and Drainage Paper 29 Rev. 1. FAO. Rome p. 174.
- Bastida-Tapia, A. (2001). El medio de cultivo de las plantas. Sustratos para la agricultura moderna. Folleto 1147. Serie de Publicaciones AGRIBOT No. 4. Universidad Autónoma Chapingo, Chapingo, México p. 96.
- Cih-Dzul, I.R., Jaramillo-Villanueva, J. L., Tornero-Campante, M. A., Schwentesius-Rindermann, R. (2011). Caracterización de los sistemas de producción de tomate (*Lycopersicon esculentum* Mill.) en el estado de Jalisco, México. *Trop. Subtrop. Agroecosys.* 14, 501 – 512
- Comisión Nacional del Agua (CNA). 2002. Gerencia regional. Cuencas Centrales del Norte, Subgerencia Regional Técnica y Administrativa del Agua. Torreón, Coahuila.
- Cruz-Carrillo, J., Jiménez, F., Ruiz, J., Díaz, G., Sánchez, P., Perales, C., Arellanes, A. (2003). Evaluación de densidades de siembra en tomate (*Lycopersicon esculentum* Mill) en invernadero. *Rev. Agr. Mesoam.* 14, 85-88.
- de-la-Cruz-Lázaro, E., Estrada-Botello, M. E., Robledo-Torres, V., Osorio-Osorio, R., Márquez-Hernández, C., Sánchez-Hernández, R. (2009). Producción de tomate en invernadero con composta y vermicomposta como sustrato. *Universidad y Ciencia – Tróp. Húm.* 25, 59-67.
- de-Matos-Pires, R.C., Furlani, P. R., Vasconcelos-Ribeiro, R., Bodine-Junior, D., Sakai, E., Lourenção, A. L., Torreneto, A. (2011). Irrigation frequency and substrate volume effects in the growth and yield of tomato plants under greenhouse conditions. *Sci. Agric. (Piracicaba, Braz.)* 68, 400-405.
- Diez, J.M. (2001). Tipos varietales. *In: Nuez, F. (ed.). El cultivo del tomate.* Mundi-Prensa. D.F., p. 796.
- Dorais, M., Papadopoulos, A. P., Gosselin, A. (2001). Influence of electrical conductivity management on greenhouse tomato yield and fruit quality. *Agronomie.* 21, 367-383.
- Durán-Umaña, L., Henríquez-Henríquez, C. (2007). Caracterización química, física y microbiológica de vermicompostes producidos a partir de cinco sustratos orgánicos. *Agron. Costarric.* 31, 41-51.
- Fageria, N. K., Baligar, V. C., Li, Y. C. (2008). The Role of Nutrient Efficient Plants in Improving Crop Yields in the Twenty First Century. *J. Plant Nutr.* 31, 1121–1157
- Ferreira, M.M.M., Ferreira, G. B., Fontes, P. C. R. (2003). Produção do tomateiro em função de doses de nitrogênio e da adubação orgânica em duas épocas de cultivo. *Hort. Bras.* 21, 468-473.
- Flores, J., Ojeda-Bustamante, W., López, I., Rojano, A., Salazar, I. (2007). Requerimientos de riego para tomate de invernadero. *Terra Latinoamericana.* 25, 127-134
- Hernández A., J.A., Guerrero L., F., Mármol C., L. E., Bárcenas B., J. M., Salas, E. (2008). Caracterización física según granulometría de dos vermicompost derivados de estiércol bovino puro y mezclado con residuos de fruto de la palma aceitera. *Interciencia.* 33, 668-671.
- Kroeff-Schmitz, J.A., Dutra de Souza, P. V., Kämpf, A. N. (2002). Physical and chemical properties of substrats with mineral and organic origin for growth of potted plants. *Ciencia Rural, Santa Maria.* 32, 937-944.

- Manivannan, S., Balamurugan, M., Parthasarathi, K., Gunasekaran, G., Ranganathan, L. S. (2009). Effect of vermicompost on soil fertility and crop productivity--beans (*Phaseolus vulgaris*). J. Environ. Biol. 30, 275-281.
- Márquez-Hernández, C., Cano-Ríos, P., Figueroa-Viramontes, U., Avila-Díaz, J. A., Rodríguez-Dimas, N., García-Hernández, J. L. (2013). Yield and quality of tomato with organic sources of fertilization under greenhouse conditions. ΦYTON. 82, 55-61
- Márquez-Quiroz, C., Cano-Ríos, P., Moreno-Reséndez, A., Figueroa-Viramontes, U., Sánchez-Chávez, E., de-la-Cruz-Lázaro, E., Robledo-Torres, V. (2014). Efecto de la fertilización orgánica sobre el rendimiento y contenido nutricional de tomate saladette en invernadero. ITEA. 110, 3 – 17.
- Medina-Medina, J.B., Luna-Ruíz, J. J., Sosa-Ramírez, J., Moreno-Rico, O., Perales-Segovia, C. (2012). Adaptaciones morfológicas foliares en tomate cultivado en bioespacio de techo retráctil con clima cálido. Rev. Mex. C. Agríc. 3, 173 – 186
- Muñoz-Arboleda, F. (2009). Importancia del agua en la nutrición de los cultivos. Carta Trimestral. CENICAÑA. 31, 16 – 18.
- Nektarios, P. A., Kastritsis, S., Ntoulas, N. (2011). Substrate amendment effects on potted plant production and dry weight partition of *Lantana camara*. HortScience. 46, 864–869.
- Olivares-Sáenz, E. (1993). Programa de Diseños Experimentales. V. 2.4. Facultad de Agronomía – UANL. Marín, Nuevo León, México
- Ortega-Martínez, L.D., Sánchez-Olarte, J., Ocampo-Mendoza, J., Sandoval-Castro, E., Salcido-Ramos, B., Manzo-Ramos, F. (2010). Efecto de diferentes sustratos en crecimiento de tomate (*Lycopersicon esculentum* Mill.) bajo condiciones de invernadero. Ra Ximhai. 6, 339-336.
- Pathma, J., Sakthivel, N. (2012). Microbial diversity of vermicompost bacteria that exhibit useful agricultural traits and waste management potential. SpringerPlus 1, 1-19.
- Peralta, I.E., Knapp, S. K., Spooner, D. M. (2005). New species of wild tomatoes (*Solanum* section *Lycopersicon*: Solanaceae) from Northern Peru. Syst. Bot. 30, 424-434.
- Preciado-Rangel, P., Fortis-Hernández, M., García-Hernández, J. L., Rueda-Puente, E., Esparza-Rivera, J. R., Lara-Herrera, A., Segura-Castruita, M. Á., Orozco-Vidal, J. (2011). Evaluación de soluciones nutritivas orgánicas en la producción de tomate en invernadero. Interciencia. 36, 689-693.
- Ramesh, P., Singh, M., Rao, A. S. (2005). Organic farming: Its relevance to the Indian context. Curr. Sci. 88, 561-568.
- Rodríguez-Dimas, N., Cano-Ríos, P., Figueroa-Viramontes, U., Palomo-Gil, A., Favela-Chávez, E., Álvarez-Reyna, V., Márquez-Hernández, C., Moreno-Reséndez, A. (2008). Producción de tomate en invernadero con Humus de Lombriz como sustrato. Rev. Fitotec. Mex. 31, 265-272.
- Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación (SAGARPA) (2005a). PC-020-2005 Pliego de Condiciones para el uso de la Marca Oficial México Calidad Suprema en Tomate p. 22. [Online] Available: http://www.normich.com.mx/archivos/OC/mcs/PLIEGOS%20DE%20CONDICIONES%2012/PC_020_2005_Tomate.pdf. (September 25, 2012).
- Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación (SAGARPA) (2005b). Servicio de Información y Estadística Agroalimentaria y Pesquera (SIAP). Sistema de información agropecuaria de consulta (SIACON). Versión 1.1. México, D. F.
- Schmidt, R.H., Jr. (1989). The arid zones of Mexico: climatic extremes and conceptualization of the Sonoran Desert. J. Arid Environ. 16, 241-256.