Emir. J. Food Agric. 2013. 25 (9): 666-672
doi: 10.9755/ejfa.v25i9.15979
http://www.ejfa.info/

PLANT SCIENCE

Organic fertilization: An alternative to produce jalapeño pepper under greenhouse conditions

S. T. López-Espinosa[1], A. Moreno-Reséndez[2*], P. Cano-Ríos[2], N. Rodríguez-Dimas[2], V. Robledo-Torres[2] and C. Márquez-Quiroz[2]

[1]*Graduate Program in Science in Agricultural Production (Programa de Posgrado en Ciencias en Producción Agropecuaria), Universidad Autónoma Agraria Antonio Narro, Unidad Laguna, Periférico Raúl López Sánchez km 1.5 y, Carretera a Santa Fe s/n., C.P. 27059, Torreón, Coahuila, México*
[2]*Universidad Autónoma Agraria Antonio Narro, Unidad Laguna, Periférico Raúl López Sánchez km 1.5 y Carretera a Santa Fe s/n., C.P. 27059, Torreón, Coahuila, México*

Abstract

The experiment was conducted during fall-winter seasons of years 2011-2012 to determine the effects of vermicompost tea (VCT) on growth and productivity of “Hechicero” jalapeño pepper plants grown under organic and synthetic fertilization in greenhouse. Five different fertilization forms were applied to plants [F1 = sand + inorganic nutrient solution (control group); F2 = sand + VCT on concentration of 10%; F3 = mixture of sand + compost (ratio 1:1; v:v) + VCT on concentration of 2.5%; F4 = mixture of sand + vermicompost (ratio 1:1; v:v) + VCT on concentration of 2.5% y F5 = mixture of sand + compost + vermicompost (ratio 2:1:1; v:v:v) + VCT on concentration of 2.5%]. Treatments F4 and F5 showed an increased yield of 70 and 45% with regard to the yield obtained with F1; the F1 and F2 yields were not statistically different at the 0.05 significance level. The fruit length and the pericarp thickness were increased until 7.55 and 7.01% in F5, respectively. These results suggest that, since there were differences in yield when using the organic and inorganic nutrient source, VCT combined with mixtures of sand + compost + vermicompost may be considered a successful alternative fertilizer for organic jalapeño pepper production in greenhouse.

Key words: *Capsicum annuum*, Glasshouse, Vermicompost, Organic farming

Introduction

Manure, crop residues, green manures, dairy industry sludge, herbal pharmaceutical industry waste, biosolids of agribusiness and food processing waste, once they are properly treated through the process of composting and/or vermicomposting are some of the potential sources of nutrients in organic production systems (Ramesh et al., 2005; Alidadi et al., 2007). According to Ramesh et al. (2005), organic production is an alternative for consumers who prefer food free of pesticides and synthetic fertilizers-risk-free, with high nutritional value. Additionally, organic materials are the safer sources of plant nutrient without any detrimental effect to crops and soil (Hasanuzzaman et al., 2010).

Nowadays, it is widely recognized that de compost (C) and vermicompost (VC) are sources of slow-release nutrients, available for plants (Atiyeh et al., 2001; Chaoui et al.,2003; Cruz-Rodrigues et al., 2003; Raviv, 2005) and prevents nutrient losses into the environment (Giuffré et al., 2011). There is evidence that the addition of C and VC to soils and growing media promotes the development and productivity of different horticultural crops such as tomato (*Solanum lycopersicon* L.) (Gutiérrez-Miceli et al., 2007; Moreno-Reséndez et al., 2013), lettuce (*Lactuca sativa* L.) (Steffen et al., 2010), pepper (*Capsicum annuum* L.) (Arancon et al., 2004a), garlic (*Allium sativum* L.) (Argüello et al., 2006), strawberry (*Fragaria vesca* L.) (Arancon et al., 2004b), wetland rice (*Oryza sativa* L.) (Hasanuzzaman et al., 2010), and other species of commercial interest.

On the other hand, when mixing C or VC with inert growth media, such as sand, the physical and chemical characteristics of the latter show an important improvement, and the vegetable

Received 28 January 2013; Revised 19 March 2013; Accepted 02 April 2013; Published Online 02 June 2013

*Corresponding Author

A. Moreno-Reséndez
Universidad Autónoma Agraria Antonio Narro, Unidad Laguna. Periférico Raúl López Sánchez km 1.5 y Carretera a Santa Fe s/n., C.P. 27059, Torreón, Coahuila, México

Email: alejamorsa@yahoo.com.mx

specimens that grow in it can avoid hypoxia. Also, it has been established that both C and VC can satisfy the nutrient demand of several crops, developed in greenhouse conditions, during the first two months post-transplantation (Márquez-Hernández et al., 2006). However, after this time the crops expressed nutrient deficiencies, especially of N (Rodríguez-Dimas et al., 2007); this may be due to the low rate of N mineralization of both C and VC. Thus, it has been suggested that in production systems under protected conditions, nutritional stress of the culture can be avoided by adding other sources of nutrition, including the vermicompost tea (VCT).

The VCT, a water-based VC extract containing high levels of beneficial microbes and soluble nutrients (Edwards et al., 2010), has attracted the attention of growers and researchers in recent years. The most important reason to apply VCT is to supply microbial biomass, fine particulate organic matter, and soluble chemical components of VC to plant surfaces and soils in a way not possible or achievable with solid VC. However, relatively little work has been done to investigate the effect of VCT on growth and yield of vegetable crops.

We hypothesized that VCT as a fertilizer would positively affect plant growth and productivity of jalapeño pepper. Therefore, the specific objective of this study was to investigate the effects of VCT on growth and productivity of jalapeño pepper in different media under organic and synthetic fertilization.

Materials and Methods

The experiment was conducted during fall-winter seasons of years 2011-2012, in the Comarca Lagunera region (101° 40' and 104° 45' W and 25º 05' and 26º 54' N), in a greenhouse at Universidad Autónoma Agraria Antonio Narro – Unidad Laguna (UAAAN-UL). The greenhouse is semicircular, with acrylic cover and protected reinforced mesh shade during the warmer seasons, gravel floor and automatic cooling system through wet wall and two extractors. It has side windows of 1.20 m high, covered and protected with acrylic roller anti-aphids mesh (Mesh Plas®).

Treatments were distributed according to a completely randomized design; yield of jalapeño (*Capsicum annuum* L.) *cv.* Hechicero (Harris Moran®) with five forms of fertilization was assessed.

The evaluated fertilization forms were: F1 = sand + inorganic nutrient solution (control group); F2 = sand + VCT at 10% of concentration; F3 = mixture of sand + C (ratio 1:1; v:v) + VCT at 2.5% of concentration; F4 = mixture of sand + VC (1:1; v:v) + VCT at 2.5% of concentration, and F5 = mixture of sand + C + VC (ratio 2:1:1; v:v:v) + VCT at 2.5% of concentration.

Seeds were planted on October 1, 2011, in germinating trays of 200 cavities filled with Peat Moss (Premier®). The transplant took place on November 7, 2011, placing one plant per container. These containers consisted of black polythene bags with a capacity of 18 L, filled with volume basis. The population density was 4 pots•m^{-2}. The sand used in the substrates was previously disinfected with a solution of 5% NaOCl.

The manure-based vermicompost was provided by the vermicompost module of UAAAN-UL, and consisted of separated horse and goat solids (mixed in a 1:1 ratio by volume) with alfalfa (*Medicago sativa* L.), processed by earthworms (*Eisenia* spp.) in indoor beds (Atiyeh et al., 2000a) for a period of 90 days (Bansal and Kapoor, 2000). The compost was provided by Max Compost®. The basic chemical properties of the substrates are summarized in Table 1. The nutrient solution used in F1 treatment (Table 2) was recommended by Castellanos-Ramos and Ojodeaagua-Arredondo (2009).

Table 1. Chemical analysis of the materials used during the development of jalapeño pepper under greenhouse conditions (n = 1).

	N	P	K	Ca	Mg	Na	Fe	Zn	Mn	pH	EC
	(%)						(mg•kg^{-1})				(dS•m^{-1})
C	2.41	1.19	3.355	8.76	0.942	0.567	5920	260	160	8.5	6.7
VC	1.27	0.15	0.882	6.92	0.596	0.101	7090	330	210	7.9	2.4
S	0.011	0.0005	0.01	0.004	0.0016	0.007	ND	1.2	2.4	7.5	0.65
VCT	0.83	0.49	0.71	3.23	0.75	0.2	6.4	2.7	4.9	8	2.0

C = compost; VC = vermicompost; S = sand; VCT = vermicompost tea; ND = not detected; EC = electrical conductivity.

Table 2. Concentration of the nutrient solution used to develop greenhouse jalapeño pepper.

Stage/Ion	NO_3^-	NH_4^+	$H_2PO_4^-$	K^+	Ca^{2+}	Mg^{2+}	SO_4^{2-}	HCO_3^-	Na^-	Cl^-	EC
	($mmol•L^{-1}$)										($dS•m^{-1}$)
Planting and establishment	6.0	0.5	1.5	4.0	4.0	1.0	1.5	1.0	<5.0	3.0	1.4
Flowering and fruitsetting	8.0	0.5	1.5	6.0	4.0	1.5	3.0	1.0	<5.0	3.0	1.8
Onset of ripening and harvest	10.0	0.05	1.5	7.0	4.0	2.0	3.0	1.0	<5.0	5.0	2.2

EC = electrical conductivity.

The VCT at 10% of concentration was prepared using the method recommended by Edwards et al. (2010), with a variation that consisted in introduce the bag with VC in a container with 20 L of water for 5 min to wash excess salts, before being subjected to oxygenation. Whereas in a container of 60 L of capacity, 45 L of water were oxygenated with an air pump (Biopro: BP9891. Tiray® Technology Co Ltd) for 2 h before inserting the bag with 4.5 kg of VC; oxygenation was performed continuously until completion of the process (24 h). In addition, we added 40 g of piloncillo or panela, a product similar to molasses, made from unrefined sugarcane (*Saccharum officinarum* L.) juice (Solis-Pacheco et al., 2006), as an energy source to promote the growth and development of microorganisms.

The VCT was constantly applied throughout the whole cycle, and to preserve its quality it remained aerated 24 $h•day^{-1}$. For treatment F2, 0.5 L of VCT at 10% of concentration was poured in each pot; for treatments F3, F4 and F5, the VCT was diluted to a 1:3 ratio using 1 L of VCT per 3 L of water to give a concentration of 2.5%, and each pot received 1 L. The pH of VCT was adjusted to a value of 5.5 with food grade citric acid ($C_6H_8O_7*H_2O$), applied on a concentration of 5 mM (1.2 $g•L^{-1}$) (Capulín-Grande et al., 2007).

To satisfy the water demand of the crop, a drip irrigation system was used in all treatments, and the amount of water applied, according to the phenological stage of the crop, ranged from 0.35 to 1.9 $L•plant^{-1}•day^{-1}$. It was classified as low-salinity and low sodium water (C_1S_1, with a sodium absorption ratio of 2.18) (Ayers and Westcot, 1994), it presented an EC of 1.05 $dS•m^{-1}$, pH 7.8; the cation concentrations were Ca^{2+} = 3.51, Mg^{2+} = 0.48, K^+ = 0.22, Na^+ = 2.71 $mmol•L^{-1}$, and the anion values were HCO_3^- = 3.12, Cl^- = 2.3, SO_4^{2-} = 2.62 $mmol•L^{-1}$. During the growing period, which lasted 134 days after transplanting (dat), the temperature in the greenhouse ranged from 17.4 to 36.9°C, while the relative humidity ranged between 20 and 79%.

Plant height and total yield was recorded in each experimental unit. Fruit quality was determined in four plants of each treatment, 15 fruits per plant, considering the following variables: individual weight, pericarp thickness, number of locules in the fruit, fruit length and equatorial diameter.

To analyze the behavior of the plant height over time, we used linear regression analysis, while for yield and fruit quality an analysis of variance was performed among treatments; means were separated using Fisher´s least significant difference (LSD) test in SAS statistical software (SAS, 1999). Statistical significance was obtained at 95% confidence level ($\alpha = 0.05$).

Results and Discussion

The growth dynamics of jalapeño plants, *cv.* Hechicero, are presented in Table 3, the regression line fits the data well. In our experiment, the tallest plants at the end of the crop cycle (134 dat) were in the treatment F5, with a value (1.55 m) that was statistically different from the other plants recorded in the remaining treatments (Table 3); these results suggest that VCT consistently enhanced plant growth, which agrees with the findings of previous studies (Sanwal et al., 2006; Hargreaves et al., 2008; Hargreaves et al., 2009). Also noteworthy is the fact that treatment F4 [mixture of sand + VC (ratio 1:1; v: v) + VCT at concentration of 2.5%] recorded the second highest plant (1.16 m).

Pant et al. (2009) found that the use of VCT had a greater effect on plant height under VC fertilization, and had much smaller effect on plant height under Osmocote fertilization. Additionally, Keeling et al. (2003) and Siddiqui et al. (2008) observed that application of VCT and compost tea on oilseed rape plant and okra plants, increased root development, plant growth and tap root length, respectively; although we did not measure root growth and nutrient uptake, plants grown in F4 and F5 showed better plant height and nutrient uptake compared to control plants, suggesting that these two variables might be part of the mechanisms involved in plant growth stimulation. Our results might be due to the presence of the VC and the VCT, materials that provide higher quality than manure generated by traditional methods of composting (Santamaría-Romero et al., 2001; Panikkar et al., 2004; Lopes-Pereira et al., 2005).

Table 3. Regression equations for fertilization sources regarding plant height in jalapeño pepper under greenhouse conditions.

Treatment	Regression equation*	R^2	Final height (m)
F1	y = 0.7142x – 2.5217	0.95	0.93 c
F2	y = 0.4937x – 4.2867	0.94	0.62 e
F3	y = 0.5757x – 4.5035	0.92	0.73 d
F4	y = 0.8486x + 2.2051	0.91	1.16 b
F5	y = 1.2648x – 14.797	0.97	1.55 a

*y= height; x = das. Values with the same letter in last column are statistically equal, LSD test $P \leq 0.05$.

Treatments F4 and F5 (which included VC and VCT) outperformed the control treatment (sand and nutrient solution), concurring with the results reported by Rodriguez-Ortiz et al. (2010), who concluded that VC fertilization at 1.5 to 3.0 t•ha^{-1} during transplanting of green onions (*Allium cepa* L.) favored a greater height of this species when compared with plants receiving synthetic fertilization. Arancon et al. (2007) reported that humic, fulvic and other organics acids extracted or produced by microorganisms in VCT could induce plant growth. Garcia-Martinez et al. (2002) showed that water extract of compost contained a compound with molecular structure and biological activity analogous to auxins. Leachate from well decomposed compost contains cytokinin-like substance, derived from hydrolysis of cyanogenic glucosides by the enzyme β-glucosidase produced by microbes (Arthur et al., 2001). Although phytohormones or growth regulators in VCT were not measured in the present study, they may play an important role in plant responses.

The F1 and F5 yield, fruit length, pericarp thickness and number of fruits were statistically different at the 0.05 significance level (Table 4). The heaviest fruits were obtained with treatments F1 and F5, in that order, while the lowest weight was recorded in treatment F2. On the other hand, according to the specifications of the official mark "México Calidad Suprema" for chili (SAGARPA-ASERCA, 2011), F4 and F5 treatments correspond to large fruit size.

The difference in yield obtained in the F1 and F5 treatments was due to the number of fruits per plant, not to the weight of fruits. The overall average yield obtained in our experiment was 208.74% higher than the average yield (14.76 Mg•ha^{-1}) obtained by Mexican producers under irrigation and rainfed conditions (SIAP, 2011). The F4 and F5 treatments increased the yield until 70.7 and 45.42% respectively, in relation to the average obtained for the control group F1. While the F5 treatment increased the yield until 17.42% compared with the F4 treatment yield. The F2 and F3 treatments were not statistically different to the control group F1 (Table 4). The results contrast with those reported by Subler et al. (1998), who stated that the best crop development occurs when applying between 10 and 20% VC, although, Atiyeh et al. (2000a, 2000b) indicated that using more than 20% of VC in the growth substrate decreases the yield of the plant. In our experiment, the jalapeño plants in T3, T4 and T5 treatments consumed 92.73, 165.65 and 194.52 kg of N to obtain the respectively yield (Inzunza-Ibarra et al., 2010).

Table 4. Mean values and statistical difference of the variables evaluated in jalapeño pepper grown with organic and synthetic fertilizer under greenhouse conditions.

Treatment	WF (g)	FL (cm)	ED	PT	NF	NL	Yield (Mg•ha^{-1})
F1	38.4 a*	8.21 b	3.18 a	0.57 bc	31 bc	2 b	40.68 b
F2	29.9 b	8.09 b	3.22 a	0.57 bc	30 c	2 b	35.44 b
F3	35.9 a	8.26 b	3.16 a	0.56 c	28 c	3 a	33.12 b
F4	36.3 a	8.41 b	3.36 a	0.59 b	41 ab	3 a	59.16 a
F5	39.4 a	8.83 a	3.34 a	0.61 a	48 a	2 b	69.47 a
mean	36.01	8.36	3.25	0.58	36	2.4	45.57
CV (%)	11	4	7	4	30	9	31

*Values with the same letter within each column are statistically equal, LSD test $P \leq 0.05$. WF = weight of fruit; FL = fruit length; ED = equatorial diameter; PT = pericarp thickness; NF = number of fruits; NL = number of locules; CV = coefficient of variation.

Furthermore, when making the extrapolation of percentage to kilograms of N per hectare for each one of sources of organic fertilizers (Table 1), considering a mineralization of 11% (Eghball, 2000; Adegbidi y Briggs, 2003), the N available needed in the treatments F3, F4 and F5, was 607.3, 320.0 and 463.6 kg•ha^{-1}, respectively. Therefore, we may assume that these three treatments showed adequate levels of N that favored the development of the jalapeño pepper. However, factors as leaching, a lower rate of mineralization, the volatilization and the adsorption process (Sikora and Szmidt, 2001), solely allowed reaching the yields already indicated. Regardless, it is important to note that the obtained yields reflects the high amounts of nutrients contained in C, VC and VCT, as mentioned by Edwards et al. (2010).

Conclusions

The results obtained showed that VCT, prepared from the VC (made with horse and goat manure with alfalfa straw, mixed in a 1:1 ratio by volume), caused positive effects on development indicators of jalapeño pepper. During this study, the organic production of jalapeño pepper under protected conditions and using organic fertilizers resulted in a high yield. The use of VCT, C and VC can be considered as an alternative fertilization method for organic production in greenhouses, since they contain soluble nutrients that can satisfy the nutrient demand of this plant.

Acknowledgements

The present experiment was funded by the project "Development of vegetal species in greenhouse using VC, with efficiency in water consumption" (Desarrollo de especies vegetales en invernadero con VC eficientando el consumo de agua), awarded by the Sub-department of Higher Education (Subsecretaría de Educación Superior) of the Mexican Department of Public Education (Secretaría de Educación Pública) through the Program for Faculty Enhancement [Programa de Mejoramiento del Profesorado (PROMEP)], earned by the Sustainable Systems for Agricultural Production Academic Corps [Cuerpo Académico de Sistemas Sustentables para la Producción Agropecuaria (CASISUPA)] with key: UAAAN-CA-14.

References

Adegbidi, H. G. and R. D. Griggs. 2003. Nitrogen mineralization of sewage sludge and composted poultry manure applied to willow in a greenhouse experiment. Biomass Bioenerg. 25:665-673.

Alidadi, H., A. R. Parvaresh, M. R. Shahmansouri, H. Pourmoghadas and A. A. Najafpoor. 2007. Combined compost and vermicomposting process in the treatment and bioconversion of sludge. Pak. J. Biol. Sci. 10(21):3944-3947.

Arancon, N. Q., C. E. Edwards, R. M. Atiyeh and J. D. Metzger. 2004a. Effects of vermicompost produced from food waste on the growth and yields of greenhouse peppers. Bioresour. Technol. 93:139-144.

Arancon, N. Q., C. A. Edwards, P. Bierman, C. Welch and J. D. Metzger. 2004b. Influences of vermicomposts on field strawberries: 1. Effects on growth and yields. Bioresour. Technol. 93:145-153.

Arancon, N. Q., C. A. Edwards, R. Dick and L. Dick. 2007. Vermicompost tea production and plant growth impacts. BioCycle 48:51-52.

Argüello, J. A., A. Ledesma, S. B. Núñez, C. H. Rodríguez and M. D. D. Goldfarb. 2006. Vermicompost effects on bulbing dynamics, nonstructural carbohydrate content, yield, and quality of 'Rosado paraguayo' garlic bulbs. Hortsci. 41:589-592.

Arthur, G. D., A. K. Jäger and J. Van Staden. 2001. The release of cytokinin-like compounds from Gingko biloba leaf material during composting. Env. Exp. Bot. 45:55-61.

Atiyeh, R. M., N. Q. Arancon, C. A. Edwards and J. D. Metzger. 2000a. Influence of earthworm-processed pig manure on the growth and yield of greenhouse tomatoes. Biores. Technol. 75(3):175-180.

Atiyeh, R. M., S. Subler, C. A. Edwards, G. Bachman and J. D. Metzger. 2000b. Effects of vermicomposts and composts on plant growth in horticultural container media and soil. Pedobiol. 44(6):579-590.

Atiyeh, R. M., C.A. Edwards, S. Subler and J. D. Metzger. 2001. Pig manure vermicompost as a component of a horticultural bedding plant medium: effects on physicochemical properties and plant growth. Biores. Technol. 78:11-20.

Ayers, R. S. and D. W. Westcot. 1994. Water Quality for Agriculture. FAO Irrigation and Drainage Paper 29 Rev. 1. FAO. Rome. p.174.

Bansal, S. and K. K. Kapoor. 2000. Vermicomposting of crop residues and cattle dung with *Eisenia foetida*. Biores. Technol. 73:95-98.

Capulín-Grande, J., R. Nuñez-Escobar, J. L. Aguilar-Acuña, M. Estrada-Botello, P. Sánchez-García and J. J. Mateo-Sánchez. 2007. Use of bovine liquid acidulated manure for production of sweet pepper. Rev. Chapingo Serie Hort. 13(1):5-11.

Castellanos-Ramos, J. Z. and J. L. Ojodeagua-Arredondo. 2009. Formulación de la solución nutritive, In: J. Z. Castellanos (Ed.). pp. 131-156. Manual de producción de tomate en invernadero. Intagri. México.

Chaoui, H. I., L. M. Zibilske and T. Ohno. 2003. Effects of earthworm casts and compost on soil microbial activity and plant nutrient availability. Soil Biol. Biochem. 35:295-302.

Cruz-Rodrigues, V., V. C. de Almeida-Theodoro, I. F. de Andrade, A. I. Neto, V. do Nascimento-Rodrigues e F. Villa-Alves. 2003. Produção de minhocas e composição mineral do vermicomposto e das fezes procedentes de bubalinos e bovinos. Ciênc. Agrotec. Lavras. 27(6):1409-1418.

Edwards, C. A., A. Askar, M. Vasko-Bennet and N. Q. Arancon. 2010. The use and effects of aqueous extracts from vermicompost or teas on plant growth and yields, In: C. A. Edwards, N. Arancon and R. Sherman (Eds.). pp. 235–248. Vermiculture Technology, CRC Press, Boca Raton, FL.

Eghball, B. 2000. Nitrogen mineralization from field-applied beef cattle feedlot manure or compost. Soil Sci. Soc. Am. J. 64(6):2024-2030.

García-Martínez, I., F. Cruz-Sosa, A. Larqué-Saavedra and M. Hernández-Soto. 2002. Extraction of auxin-like substances from compost. Crop Res. 24(2):323-327.

Giuffré, L., R. Romaniuk, R. P. Ríos and M. M. Zubillaga. 2011. Sustainable management in pecan cultivation in Argentina. Emir. J. Food Agric. 23(3):243-248.

Gutiérrez-Miceli, F. A., J. Santiago-Borraz, J. A. Montes-Molina, C. C. Nafate, M. Abud-Archila, M. A. Oliva-Llaven, R. Rincón-Rosales and L. Dendooven. 2007. Vermicompost as a soil supplement to improve growth, yield and fruit quality of tomato (*Lycopersicum esculentum*). Biores. Technol. 98(15):2781-2786.

Hargreaves, J. C., M. S. Adl, P. R. Warman and H. P. V. Rupasinghe. 2008. The effects of organic amendments on mineral element uptake and fruit quality of raspberries. Plant Soil. 308:213-226.

Hargreaves, J. C., M. S. Adla and P. R. Warman. 2009. Are compost teas an effective nutrient amendment in the cultivation of strawberries? Soil and plant tissue effects. J. Sci. Food Agric. 89:390-397.

Hasanuzzaman, M., K. U. Ahamed, N. M. Rahmatullah, N. Akhter, K. Nahar and M. L. Rahman. 2010. Plant growth characters and productivity of wetland rice (*Oryza sativa* L.) as affected by application of different manures. Emir. J. Food Agric. 22(1):46-58.

Inzunza-Ibarra, M. A., M. Villa-Castorena, E. A. Catalán-Valencia and A. Román-López. 2010. Nutrient extraction and yield of jalapeño pepper under mulch plastic and irrigation levels. Terra Latinoamericana 28(3):211-218.

Keeling, A. A., K. R. McCallum and C. P. Beckwith. 2003. Mature green waste compost enhances growth and nitrogen uptake in wheat (*Triticum aestivum* L.) and oilseed rape (*Brassica napus* L.) through the action of water-extractable factors. Biores. Technol. 90:127-132.

Lopes-Pereira, E. W., C. M. S. Borges-Azevedo, J. Liberalino-Filho, G. H. de Sousa-Nunes, J. Erivan-Torquato and B. R. Simôes. 2005. Produção de vermicomposto em diferentes proporções de esterco bovino e palha de carnaúba. CAATINGA 18(2):112-116.

Márquez-Hernández, C., P. Cano-Rios, I. Chew-Madinaveitia, A. Moreno-Reséndez and N. Rodríguez-Dimas. 2006. Substrates in the organic production of greenhouse cherry tomato. Rev. Chapingo Serie Hort. 12(2):183-189.

Moreno-Reséndez, A., E. Carreón-Saldivar, N. Rodríguez-Dimas, J. L. Reyes-Carrillo, P. Cano-Ríos, J. Vásquez-Arroyo and U. Figueroa-Viramontes. 2013. Vermicompost management: An alternative to meet the water and nutritive demands of tomato under greenhouse conditions. Emir. J. Food Agric. 25(5):385-393.

National Organic Standards Board (NOSB). 2004. Compost Tea Task Force Report. 21 p. Available in: <http://www.ams.usda.gov/AMSv1.0/getfile?dDocName=STELPRDC5058470>. Assesed on: August 8, 2012.

Panikkar, A. K., S. J. Riley and S. P. Shrestha. 2004. Risk Management in vermicomposting of domestic organic waste. Env. Health 4(2):11-19.

Pant, A., T. J. K. Radovich, N. V. Hue, S. T. Talcott and K. A. Krenek. 2009. Vermicompost extracts influence growth, mineral nutrients, phytonutrients and anti-oxidant activity in pakchoi (*Brassica rapa* cv. Bonsai, chinensis group) grown under vermicompost and chemical fertilizer. J. Sci. Food Agric. 89:2389-2392.

Ramesh, P., M. Singh and A. S. Rao. 2005. Organic farming: Its relevance to the Indian context. Curr. Sci. 88(4):561-568.

Raviv, M. 2005. Production of high-quality composts for horticultural purposes: A mini-review. Hort. Tech. 15(1):52-57.

Rodríguez-Dimas, N., P. Cano-Rios, E. Favela-Chávez, U. Figueroa-Viramontes, V. de Paul-Álvarez., A. Palomo-Gil, C. Márquez-Hernández and A. Moreno-Reséndez. 2007. Vermicompost as organic alternative in tomato greenhouse production. Rev. Chapingo Serie Hort. 13(2):185-192.

Rodríguez-Ortiz, J. C., C. Loredo-Osti, J. A. Alcalá-Jáuregui, L. Beltrán-Sánchez, J. J. Tapia-Goné, C. Villar-Morales and J. L. García-Hernández. 2010. Effect of doses and application moment of vermicompost in the production of onion (*Allium cepa*) type cambray. AGROFAZ 10(2):99-106.

Santamaría-Romero, S., R. Ferrera-Cerrato, J. J. Almaraz-Suárez, A. Galvis-Spinola and I. Barois-Boullard. 2001. Dinámica y relaciones de microorganismos, C-orgánico y N-total durante el composteo y vermicomposteo. Agrociencia 35(4):377-384.

Sanwal, S. K., K. Laxminarayana, D. S. Yadav, N. Rai and R. K. Yadav. 2006. Growth, yield, and dietary antioxidants of broccoli as affected by fertilizer type. J. Veg. Sci. 12:13-26.

SAGARPA-ACERCA. 2011. Pliego de condiciones para el uso de la marca oficial México Calidad Suprema en chile. Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación - Apoyos y Servicios a la Comercialización Agropecuaria. BANCOMEXT. ASERCA. PC-011-2004. 16 p. Available in: <http://www.normich.com.mx/archivos/OC/mcs/PLIEGOS%20DE%20CONDICIONES%2012/PC_011_2004_Chile_vsj.pdf>. Assesed on: August 8, 2011.

SIAP. 2011. Anuario Estadístico de la Producción Agrícola: chile verde. Modalidad: riego y temporal. Servicio de Información Agroalimentaria y Pesquera. Available in: <http://www.siap.gob.mx/aagricola_siap/icultivo/index.jsp> Consulted: August 8, 2011.

Siddiqui, Y., S. Meon, R. Ismail, M. Rahmani and A. Ali. 2008. Bio-efficiency of compost extracts on the wet rot incidence, morphological and physiological growth of okra (*Abelmoschus esculentus* [(L.) Moench]). Sci. Hort. 117:9-14.

Sikora, L. J. and R. A. K. Szmidt. 2001. Nitrogen source mineralization rates, and nitrogen nutrition benefits to plants from compost. In: P. J. Stoffela and B. A. Kahn (Eds.). pp. 287-305. Compost utilization in horticultural cropping system. CRC Press LLC.

Statistical Analysis System (SAS). 1999. SAS/STAT User´s Guide. Version 8.0 SAS Institute Inc. Cary N. C. USA.

Steffen, G. P. K., Z. I. Antoniolli, R. B. Steffen and R. G. Machado. 2010. Cáscara de arroz y estiércol bovino como sustrato para la multiplicación de lombrices de tierra y la producción de plántulas de tomate y lechuga. Acta Zool. Mexicana (n.s). Número Especial. 2:333:343.

Solís-Pacheco, J. R., F. Pérez-Martínez, I. Orozco-Ávila, J. L. Flores-Montaño, E. Ramírez-Romo, A. Hernández-Rosales and B. Aguilar-Uscanga. 2006. Description of a technical a process to make unrefined Brown sugar (“Piloncillo”) from sugarcane. e-Gnosis. 4(1):1-8.

Subler, S., C. A. Edwards and J. Metzger. 1998. Comparing vermicompost and composts. Biocycle 39:63-66.