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Vermitechnology: Sustainable Practices in Mexico

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ABSTRACT

Earthworms remain valid as an object of study and the information generated is diverse. This review summarizes the overall situation of vermitechnology in Mexico, gathering theories that have been offered and techniques that have been developed for urban waste management, agro-industry, manures, toxicity tests, removal of substances such as peptides and soil remediation, as well as other techniques, that show corrective, preventive or improvement actions with environmental, social and economic involvement, promoting sustainable development.

Keywords: bio-manure, residual management, vermicompost, waste management, worms
Abbreviations: VC, vermicompost

CONTENTS

INTRODUCTION

Modern agriculture has created substantial harmful effects on air, soil, water and biodiversity, making it one of the largest polluting sectors (Bellarby *et al.* 2008). Given the huge ecological footprint of industrial agriculture, environmentalists have advocated better management practices, such as sustainable agriculture that emphasizes on farming practices that protect soil, water and biodiversity. Sustainable farming has come to be viewed as an eco-friendly alternative to modern agriculture (Hiranandani 2010).

The degradation and inadequate administration of soil are threatening the opportunities and flexibility to increase the uses of this resource (Dumanski and Pieri 2000; Tilman and Lehman 2001). Recently, great interest has been shown in the development of novel, eco-friendly processes, based on the use of biological systems, among which earthworm breeding stands out (vermiculture or worm composting). This biological route has proven to be successful in the processing of sewage sludge (Nauhauser *et al*. 1988; Domínguez *et al*. 2000 and Domínguez 2004; in Domínguez and Ed-wards 2004), inactivation of pathogenic organisms in sludge (Teixeira 2007), and a great variety of human, agricultural and livestock residues, which constitute a serious soil pollution problem (Atiyeh *et al*. 2000b). Reusing waste materials and taking advantage of their energy rather than simply disposing of them, have become priorities (Spinosa 2007; Sperling and Andreoli 2007).

Vermicompost (VC) has a great potential in horticulture and agriculture (Edwards *et al.* 2004) for the improvement of soil characteristics (pH, organic matter increase, porosity, and nutrient retention capacity), constituting an alternative due to its physical, chemical, biological (Atiyeh *et al*. 2002), and nutritional characteristics (Orozco *et al.* 1996), as well as characteristics related to the elimination of plagues and diseases. In addition to being a quality organic fertilizer, it allows replacing synthetic fertilizers and has great moisture retention capacity (Atiyeh *et al*. 2000a; Brown *et al*. 2000).

This work basically shows the results and conclusions of research studies conducted in Mexico during the last decade, which have evaluated earthworm performance in the transformation of different types of waste, the potential of VC in the yield of different agroforestry products and as a soil improver, and pathogen inhibition-removal efficiency of earthworms.

VERMICOMPOST: EVALUATION OF AGRICULTURAL AND FOREST RESOURCES

Romero-Lima *et al.* (2000) point out that the application of high doses of VC does not produce good results in potato culture; however, at the recommended dose of fertilizer (165-200-300), a higher N concentration is obtained as well as better biological quality due to increased protein content.

Velasco-Velasco *et al.* (2001) showed that VC alone and inoculated with fungi (*Glomus intraradix*) and bacteria (*Azospirillum brasilense*) in the production of tomatillo has a positive effect on photosynthetic rate, dry matter accumulation, and yield, exceeding the control by 120% in total dry weight and by 26% in yield, with the VC - *G. intraradix* fungus combination.

Reyes *et al.* (2002) tested the application of VC and inoculation with mycorrhizal fungi in the propagation process of avocado in greenhouse. They evaluated the applica-

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Invited Mini-Review

tion of unmixed VC in the growth substrate, which consisted of a mixture of orchard soil + forest soil + vermiculite, and the application of mycorrhizal fungi in plants without transplanting. As a reference, they conducted inoculation with mycorrhizal fungi in transplanted plants. They observed that the application with VC was effective in increasing graft growth, increasing final height from 39.6 to 48.0 cm. Nitrogen fertilization did not exceed the treatment with worm compost. The fungi application was not effective, and transplanting delayed grafting by 50 days.

The serious environmental pollution problems created by slaughterhouse wastes such as blood and rumen contents led Abraham-Gutiérrez *et al.* (2004) to evaluate the potential of such wastes as organic fertilizers. They evaluated the use of blood meal and VC from bovine rumen content in jicama (*Pachyrhizus erosus* L.) cultures. They determined that VC from rumen content did not produce favourable yields in this type of crop, but that it did produce high yields when combined with wood ash and blood meal.

Moreno-Reséndez *et al.* (2005) evaluated the production of tomato (*Lycopersicon esculentum* Mill var. 'Floradade') under greenhouse conditions with VC generated from different manure sources, pointing out that commercial growing media can be replaced by mixes that include different VC concentrations. VC/sand mixtures at ratios of 25:75 and 50:50 (weight %), corresponding to VC prepared with a) horse manure, b) horse manure + goat manure with alfalfa straw (1: 1), c) goat manure with alfalfa straw, and d) goat manure with alfalfa straw + garden waste (mainly grass and leafs) managed to meet the nutritional demand of the tomato crop. The obtained results allow us to consider that nutrient solutions prepared with highly soluble inorganic salts, which are traditionally used in hydroponic production systems, can be replaced by products such as VC, of which content of nutrient elements could meet the needs of plant species (Moreno-Reséndez *et al.* 2005).

Toral *et al.* (2005) evaluated the yield of roselle with the application of different amounts of VC from bovine manure. The best treatment was with 3.5 ton/ha and the second best was 2.0 ton/ha.; both in a single application, 15 days before sowing. They concluded that the incorporation of organic matter through VC humus will promote soil recovery and the conservation of natural resources.

The work of López-Moctezuma *et al.* (2005) shows that soils enriched with coffee-pulp VC (40%) and inoculated with arbuscular mycorrhizal fungi (AMF) or with AMF + *Bacillus pumilus* exhibit technological prospects in papaya (*Carica papaya* L.) propagation.

Valencia-Maldonado *et al.* (2006) characterized three types of substrate (soil from the Ticomán Lagoon as the control, VC from fruit and vegetable residues, and soil from the Ticomán Lagoon + chemical fertilizer), and evaluated adaptation to transplanting, growth, survival, and number of leaves on the Mexican giant hyssop (*Agastache mexicana*) plant in these substrates. The best yield was observed with VC, and its microbiological quality makes it a substrate suitable for use in the cultivation of plants for therapeutic use.

Márquez-Hernández *et al.* (2006) evaluated different mixtures of VC with sand or perlite under greenhouse conditions in the production of cherry tomatoes (*Lycopersicon esculentum* Mill). The four best mixtures were VC: sand (50: 50), and VC with perlite at 25, 37 and 50%, obtaining a better yield (48.507 t/ha^{-1}) than that obtained in the field.

The objective of the work of Valdez-Pérez *et al.* (2006) was to evaluate the source of nitrogen in stabilized biosolids, VC and inorganic fertilizer, in the production of bean plants under greenhouse conditions. The highest concentration of $N\text{-}NO_3$ was observed in the treatment with VC, as was the highest nutrient availability, showing higher plant dry weight and growth velocity (0.54 cm day^{-1}).

Rodríguez-Dimas *et al.* (2007) evaluated the yield and quality of the tomato crop (*Lycopersicon esculentum* Mill.) in the autumn-winter cycle of 2004-2005, in Big Beef and Red Chief genotypes grown under greenhouse conditions. This study showed that treatments with VC and micronutrients, and treatments with VC extract can be suitable for tomato production in greenhouses, combined with organic fertilizers.

The quality of the fruit produced using organic substrates allows reducing and avoiding the transition period that is required for field production. Márquez-Hernández *et al.* (2008) mention that when producing organic tomato in greenhouse, its yield exceeds that of tomato grown in the field by 9.14-fold.

Rodríguez-Dimas *et al.* (2008) evaluated VC + sand at a ratio of 1:1 + chelated micronutrients (S1), VC + sand, without micronutrients (S2), and sand + inorganic nutrient solution (control) (S3), in the production of two tomato hybrids under greenhouse conditions. With S1, they achieved a higher content of soluble solids and pericarp thickness in the fruit than with the other two substrates, concluding that this mixture could be a viable option for producing organic tomato in greenhouse.

Moreno-Reséndez *et al.* (2008) determined the optimum concentration of the VC:sand mixture that meets the nutritional needs of two tomato (*Lycopersicon esculentum* Mill.) genotypes, using as control sand with the Hoagland nutritional solution. The highest yields were observed in the Adela genotypes (17.37) in sand and nutrient solution, and the André genotype (17.05 kg m^{-2}) in a mixture of VC:sand at a ratio of 12.5: 87.5. The largest fruits were obtained with the genotype André in the VC: sand mixtures at 12.5: 87.5 and 50: 50. The researchers suggest that VC has physical and chemical characteristics that allow developing tomato genotypes with characteristics similar to the Hoagland nutritional solution, diluted to 50% of its normal concentration.

Options for the diversification of horticulture in high tropical regions can be found in floriculture. Cruz-Castillo *et al.* (2008) evaluated the effect of different types of worm compost (coffee pulp + bovine manure; coffee pulp + poultry manure + sugar cane bagasse) on growth and post-harvest life of the 'Green Goddess' calla lily. They pointed out that the use of worm compost as substrate significantly increased spathe size (length and width), and scape and spadix length, compared to the treatment with chemical fertilizers and Organozyma®. Likewise, calla lilies produced a greater number of shoots at a higher worm compost concentration.

The production of tomato (*Lycopersicon esculentum* Mill) in greenhouse conditions has also been evaluated by de la Cruz-Lazaro *et al.* (2009), in substrates elaborated with mixtures of compost and VC with sand. The highest average yield (39.811 t ha^{-1}) was obtained with compost generated from the decomposition of bovine manure, corn (*Zea mays* L.) stubble, elephant grass (*Pennisetum purpureum* Schumacher) and black soil (CEMZT) at 75% + sand, and VC from manure, Bahia grass (*Paspalum notatum* Flügge) and black soil (VEPT) at 100 and 50% + sand. This yield was higher than that recorded in organic tomato field production, without affecting fruit quality.

Moreno-Reséndez *et al.* (2010) evaluated the development of muskmelon (*Cucumis melo* L.) using 4 types of VC generated with *Eisenia fetida* from animal manure (horse, goat, rabbit and bovine) mixed with river sand, as a substitution for synthetic fertilizers. They determined that greater VC percentages (independent of manure source) had significant effects on yield, fruit weight, equatorial and polar diameters, pulp thickness, placenta cavity, and days to harvest. They concluded that VC, independent of source, met the nutritional demand of muskmelon, since no synthetic fertilizer was used.

Rodríguez-Canché *et al.* (2010a) evaluated VC produced from residual sludge from septic systems in the production of habanero pepper seedlings, as compared with the commercial substrate peat moss. They discovered that the largest increases in seedling height (9.58, 9.28 and 10.58 cm) were obtained with 100% sewage sludge VC substrates, generated with the different earthworm densities (1.0, 2.0 and 2.5 kg·m^2, respectively) and that the highest values of agriculturally important nutrients were observed in the substrates that contained the highest amounts of VC.

Altamirano and Aparicio-Rentería (2002) evaluated the effect of VC as an alternate substrate, combined with mine soil and forest soil, on the germination and initial growth of *Pinus oaxacana* and *Pinus rudis*. They determined that, mainly, the substrate made up of 30% mine soil, 20% forest soil + 50% VC from coffee produced the best initial growth results for both species. No significant differences were determined in relation to germination between the evaluated treatments.

VERMICOMPOST: SOIL IMPROVER

With the objective of improving soil conditions, Félix-Herrán *et al.* (2010a) compared the quality of mature composts generated from chickpea residues (CH), tomato shoot (T), soybean residues (S), neem tree pruning residues (N), and garden grass pruning residues (G), and mixtures of these materials, VC generated from plant residues and bovine manure, and VC generated from sugarcane bagasse with bovine manure, based on their physical, chemical and organic properties. VC from sugarcane bagasse showed the highest water-holding capacity (98.5 mL H_2O/100 g of compost). They concluded that this compost, as well as composts S, N, G and CHT, could make good plant covers, and that both vermicomposts could be used for nutrient incorporation (nitrogen and phosphorus) instead of being used for activation of soil microflora, due to their low content of humic substances in relation to the others.

Félix-Herrán *et al.* (2010c) determined the respiration rate and microbiological properties (total fungi and bacteria, and chitin-, cellulose- and pectin-degrading microorganisms) of ten mature composts originating from tomato (*Lycopersicum esculentum)*, common bean (*Phaseolus vulgaris*), chickpea (*Cicer arietinum*), neem (*Azadirachta indica*), a mixture of garden grass (*Cynodon dactylon*), neem-chickpea, bean-chickpea and a mixture of all of the above, VC from plant residues (market waste), and VC from sugarcane bagasse (*Saccharum officinarum*). The results indicate that the properties of the different composts vary depending on the organic matter from which they originated, and that the composts show a greater abundance of bacteria than of fungi, and higher growth rates at acid pH than at neutral pH, in addition to their effect as soil microflora activators.

VERMICOMPOSTING: LEACHATE

The water that is used to maintain the moisture levels that are required for earthworms to participate in the organic matter decomposition process generates leachates, which are a product of the washing of compounds and soluble substances. García-Gómez *et al.* (2008) researched the manner in which the dilution of VC leachates combined with different concentrations of NPK triple 17 and polyoxyethylene tridecyl alcohol as dispersant and polyethylene nonylphenol as adherent increases fertilizer intake efficiency, affecting corn plant development. The VC leachate was pathogen-free and resulted in a germination rate of 65%. Leachate diluted to 50% and mixed with 170 g of NPK was best for plant development and germination (65%), whereas the dispersant and adherent did not have significant effects. They concluded that VC leachate can be used as liquid fertilizer in corn crops when mixed with fertilizer, and that in addition to microelements, it contains humic and fulvic acids, which promote growth.

Other studies with VC leachates have been conducted by Moreno-Reséndez *et al.* (2009), who showed that their application complemented conventional fertilization and that it had significant effects on watermelon crop yield.

VERMICULTURE: EARTHWORM GROWTH AND PATHOGEN INHIBITION-REMOVAL

Santamaría-Romero *et al.* (2001) conducted a study to evaluate the quality of and differences between compost and VC, analyzing C-organic and N-total dynamics, and studying their relationship with microorganisms during the production of compost and VC from grass clippings mixed with rabbit manure (3: 1). pH (8.5) and electrical conductivity (8 dS m^{-1}) caused damage to earthworms and microorganisms; the most notorious loss of nitrogen occurred in VC.

Santamaría-Romero and Ferrera-Cerrato (2002) evaluated the population dynamics of the earthworm *Eisenia andrei* in different substrates, and concluded that organic market waste is an excellent nutritional substrate for this type of earthworms, given that an increase of over 1200% was achieved in respect to the inoculated amount (1000 organisms·m^{-2}), in only four months.

Gutiérrez *et al.* (2007) evaluated the population dynamics of the earthworm *Eisenia foetida,* fed with fresh and composted manure from cattle fed on ground stubble and multinutrient blocks, and from sheep fed corn silage and concentrate. The treatments were: T1. Composted bovine manure, T2. Composted sheep manure, T3. Fresh bovine manure, and T4. Fresh sheep manure. The response variables were: temperature, pH, number of cocoons, total biomass, and number of adult and young earthworms. In fresh manure, the earthworms died during the first three days ($P < 0.05$). The composted bovine manure showed the highest number of cocoons (201.75 ± 94.46), as compared with the composted sheep manure, which showed a lower number of cocoons (89.0 ± 11.74); however it did have highest adult earthworm viability (81.75 ± 16.47) as compared with the composted bovine manure (45.25 ± 15.19). They concluded that composted manures are better than fresh manures as far as earthworm population dynamics is concerned.

The dynamics and quantification of groups of bacteria that participate in the biodegradation of tequila agave bagasse have been studied. Rodríguez-Macias *et al*. (2005) showed that, independent of the process (composting and vermicomposting) and treatment that were used, the number of colony-forming units, fungi, and actinomyces decreased significantly with respect to time, obtaining bio-fertilizers that can be used in agriculture.

Contreras-Ramos *et al.* (2005) evaluated the efficiency of *Eisenia fetida* in the reduction of pathogens and toxic organic compounds from textile industry waste, household waste, cow manure and oat straw. The earthworm humus that showed the best stability after two months was obtained with 1,800 g of straw, 800 g of manure and 70% water content. This earthworm humus, which had less than 3 CFU of *Salmonella* spp. and no fecal coliforms, *Shigella* spp. or helminth eggs, showed an 80% germination rate for cress (*Lepidium sativum*).

The presence of *Salmonella* in biosolids and VC applied to the soil compromises the safety of fresh agricultural products and the health of fieldworkers. Espinoza *et al.* (2006) determined the survival rate of *Salmonella typhimurium* in VC and biosolids, simulating the introduction of this bacterium from an external source. They concluded that the biosolid and VC microflora inhibits the survival of *S. typhimurium*, thus reducing the possible risk of contamination of fresh produce and negative effects on the health of farm workers.

Villa-Briones *et al.* (2008) tested the effect of VC and manure for the management of the false root-knot nematode *Nacobbus aberrans* under greenhouse and field conditions. Their incorporation significantly reduced root gall index (27 and 40%, respectively) of tomato (*Lycopersicon esculentum* Mill.), compared with the control, increased root volume (13.1 and 14.7-fold), root dry weight (5.8 and 7-fold) and shoot dry weight (1.6 and 1.9-fold), whereas root necrosis was reduced (28.5 and 25%, respectively). Benefits in the field were generally observed in soil improved with VC.

The microbiological role of VC from sugarcane bagasse and plant residues in the growth inhibition of the fungi *Fusarium oxysporum*, *Rhizoctonia solani* and *Pythium* sp. has been evaluated by Félix-Herrán *et al.* (2010b). Both vermicomposts showed a good inhibition of *F. oxysporum*, whereas a smaller inhibition halo was observed in *Pythium* sp. and none in *R. solani.*

Rodríguez-Canché *et al.* (2010b) evaluated the potential of the earthworm *Eisenia fetida* in the removal of pathogens (fecal coliforms, helminth eggs, and *Salmonella*) from septic sludge. Three densities (1, 2, and 2.5 kg m^{-2}) were evaluated. After 60 days, the earthworms reduced pathogen concentrations to permissible levels, producing class A biosolids according to Official Mexican Standard NOM-004-SEMARNAT-2002 on Environmental Protection.

CONCLUSION

The efficiency of VC has been studied considerably more in agricultural than in forest products, tomato being the favourite resource. Although no reference is made to particular locations in this review, most of the studies have been conducted in the north and center of Mexico, showing that VC, both as a process and as a product, has broad potential in this country.

REFERENCES

Abraham-Gutiérrez JH, Gil-Muñoz A, Sandoval-Castro E, Peña-Olvera BV, Almeida-Acosta FHE (2004) Influencia de la harina de sangre y fertilizantes en características físicas y rendimiento de jícama. *Terra Latinoamericana* **22 (4)**, 475-483

Altamirano QMT, Aparicio-Rentería A (2002) Efecto de la lombricomposta como sustrato alterno en la germinación y crecimiento inicial de *Pinus oaxacana* Mirov. y *Pinus rudis* Endl. *Foresta Veracruzana* **4 (1)**, 35-40

Atiyeh RM, Arancon N, Edwards CA, Metzger JD (2000a) Influence of earthworm-processed pig manure on the growth and yield of greenhouse tomatoes. *Bioresource Technology* **75**, 175-180

Atiyeh RM, Arancon NQ, Edwards CA, Metzger JD (2002) The influence of earthworm–processed pig manure on the growth and productivity of marigolds. *Bioresource Technology* **81**, 103-108

Atiyeh RM, Subler S, Edwards CA, Bachman G, Metzger JD, Shuster W (2000b) Effects of vermicomposts and composts on plant growth in horticultural container media and soil. *Pedobiologia* **44**, 579-590

Bellarby J, Foereid B, Hastings A, Smith P (2008) Cool farming: Climate impacts of agriculture and mitigation potential. *Greenpeace International* Amsterdam, The Netherlands, 37 pp

Brown GG, Barois I, Lavelle P (2000) Regulation of soil organic matter dynamics and microbial activity in the drilosphere and the role of interactions with other edaphic functional domains. *European Journal of Soil Biology* **36**, 177-198

Contreras-Ramos SM, Escamilla-Silva EM, Dendooven L (2005) Vermicomposting of biosolids with cow manure and oat straw. *Biology and Fertility of Soils* **41**, 190-198

Cruz-Castillo JG, Torres-Lima PA, Alfaro-Chilmalhua M, Albores-González ML, Murguía-González J (2008) Lombricompostas y apertura de la espata en poscosecha del alcatraz 'Green Goddess' (*Zantedeschia aethiopica* (L) K. Spreng) en condiciones tropicales. *Revista Chapingo Serie Horticultura* **14 (2)**, 207-212

de la Cruz-Lázaro E, Estrada-Botello MA, 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 Trópico Húmedo* **25 (1)**, 59-67

Domínguez J (2004) State of the art and new perspectives on vermicomposting research. In: Edwards CA (Ed) *Earthworm Ecology* (2nd Edn) CRC Press LLC, pp 401-424

Domínguez J, Edwards CA (2000) Vermicomposting of sewage sludge: effect of bulking materials on the growth and reproduction of the earthworm *Eisenia andrei*. *Pedobiologia* **44**, 24-32

Domínguez J, Edwards CA (2004) Vermicomposting organic wastes: A review. In: Shakir SH, Mikhaïl WZA (Eds) *Soil Zoology for Sustainable Development in the 21st Century*, Cairo, pp 369-396

Dumanski J, Pieri C (2000) Land quality indicators: Research plan. *Agriculture, Ecosystems and Environment* **81**, 93-102

Edwards CA, Domínguez J, Arancon NQ (2004) 18. The influence of vermicompost on plant growth and pest incidence. In: Shakir SH, Mikhaïl WZA (Eds) *Soil Zoology for Sustainable Development in the 21st Century*, Cairo, pp 397-420

Espinoza RE, Castro del CN, Martínez RCI, Soto BJM, Chaidez QC (2006) Inhibición de *Salmonella typhimurium* en biosólidos y vermicomposta por efecto de la microflora. *XV Congreso Nacional de Ingeniería Sanitaria y Ciencias Ambientales* 24 al 26 de mayo del 2006. EXPO Guadalajara

Félix-Herrán JA, Martínez RR, Azpiroz RHS, Serrato FR, Armenta BAD, Rodríguez QG, Apodaca SMA, Osalde PV (2010b) Propiedades microbiológicas de las compostas que inhiben el crecimiento de *Fusarium oxysporum*, *Rhizoctonia solani* y *Pythium* sp. In: Martínez RR, Rodríguez de la OJL, Ramírez VB (Eds) *Biotecnología Aplicada a Recursos Forestales*, Libros Técnicos: Serie Forestal. Universidad Autónoma Indígena de México, Universidad Autónoma de Chapingo, Colegio de Posgaduados-Puebla, pp 261-273

Félix HJA, Martínez RR, Azpiroz RHS, Serrato FR, Armenta BAD, Rodríguez QG, Olalde PV (2010a) Propiedades físico-químicas y orgánicas de compostas maduras producidas a partir de diferente materia orgánica. In: Martínez RR, Azpiroz RHS, Rodríguez de la OJL (Eds) *Biotecnología Aplicada a Recursos Forestales*, Libros Técnicos: Serie Forestal. Universidad Autónoma Indígena de México, Universidad Autónoma de Chapingo, Colegio de Posgaduados-Puebla, pp 275-290

Félix-Herran JA, Serrato-Flores R, Armenta-Bojorquez AD, Rodríguez-Quiroz G, Martínez-Ruiz R, Azpiroz-Rivero HS, Osalde-Portugal V (2010c) Propiedades microbiológias de compostas maduras producidas a partir de diferente materia orgánica. *Ra Ximhai* **6 (1)**, 105-113

García-Gómez RC, Dendooven L, Gutiérrez-Miceli FA (2008) Vermicomposting leachate (worm tea) as liquid fertilizer for maize (*Zea mays* L) forage production. *Asian Journal of Plant Sciences* **7 (4)**, 360-367

Gutiérrez VE, Juárez CA, Mondragón AJ, Rojas SAL (2007) Dinámica poblacional de la lombriz *Eisenia foetida* en estiércol composteado y fresco de bovino y ovino (Dynamics population earthworm *Eisenia foetida* in fresh and composted manure of bovine and ovine). *REDVET. Revista Electrónica de Veterinaria* **VIII (7)**, 1-8

Hiranandani V (2010) Sustainable agriculture in Canada and Cuba: A comparison *Environment, Development and Sustainability* **12**, 763-775

López-Moctezuma H, Ferrera-Cerrato R, Farias-Larios J, Aguilar-Espinosa S, Bello MR, López-Aguirre JG (2005) Micorriza arbuscular, *Bacillus* y sustrato enriquecido con Vermicomposta en el desarrollo de plantas de papayo. *Terra Latinoamericana* **23 (4)**, 523-531

Márquez-Hernández C, Cano R.P, Chew MYI, Moreno RA, Rodríguez DN (2006) Sustratos en la producción orgánica de tomate cherry bajo invernadero. *Revista Chapingo Serie Horticultura* **12**, 183-188

Márquez-Hernández C, Cano RP, Rodríguez DN (2008) Uso de sustratos orgánicos para la producción de tomate en invernadero. *Agricultura Técnica de México* **34**, 69-74

Moreno-Reséndez A, Gómez, FL, Cano RP, Martínez CV, Reyes CJL, Puente MJL, Rodríguez DN (2008) Genotipos de tomate en mezclas de vermicompost: arena en invernadero. *Terra Latinoamericana* **26**, 103-109

Moreno-Reséndez A, García C, Valdez-Rodríguez VM, Madero-Tamargo E, Preciado-Rangel Pablo (2009) Producción de sandía con fertilización sintética y lixiviado de vermicompost. *Memorias de la XXI Semana Internacional de Agronomía* 3-6 November 2009, Gómez Palacio, Durango

Moreno-Reséndez A, Meza-Morales H, Rodríguez-Dimas N, Reyes-Carrillo JL (2010) Development of muskmelon with different mixtures of vermicompost:sand under greenhouse conditions. *Journal of Plant Nutrition* **33**, 1672-1680

Moreno-Reséndez A, Valdés-Perezgasga MT, Zarate-López T (2005) Desarrollo de tomate en sustratos de vermicompost/arena bajo condiciones de invernadero. *Agricultura Técnica Chile* **65 (1)**, 26-34

Nauhauser EF, Loehr RC, Malecki MR (1988) The potential of earthworms for managing sewage sludge. In: Edwards CA, Nauhauser EF (Eds) *Earthworms and Environmental Management*, SPB, The Hague, pp 9-20

Orozco FH, Cegarra J, Trujillo LM, Roig A (1996) Vermicomposting of coffee pulp using the earthworm *Eisenia fetida*: Effects on C and N contents and the availability of nutrient. *Biology and Fertility of Soil* **22**, 162-166

Reyes AJC, Ferrera-Cerrato R, Alarcón A (2002) Aplicación de vermicomposta y hongos micorrízicos en la producción de planta de aguacate en vivero. *Fundación Salvador Sánchez Colin. Memoria 1998-2001.* Centro de Investigaciones Científicas y Tecnológicas del Aguacate en el Estado de México, Coatepec Harinas, México, pp 80-88

Rodríguez-Canché L, Cardoso-Vigueros L, Carvajal-León J, Poot-Dzib S de la C (2010a) Production of habanero pepper seedlings with vermicompost generated from sewage sludge. *Compost Science and Utilization* **18 (1)**, 42-46

Rodríguez-Canché LG, Cardoso-Vigueros L, Maldonado-Montiel T, Martínez-Sanmiguel M (2010b) Pathogen reduction in septic tank sludge through vermicomposting using *Eisenia fetida. Bioresource Technology* **101**, 3548-3553

Rodríguez-Dimas N, Cano-Ríos P, Favela-Chávez E, Figueroa-Viramontes U, Paul-Álvarez V, Palomo-Gil A, Márquez-Hernández C, Moreno-Reséndez A (2007) Vermicomposta como alternativa orgánica en la producción de tomate en invernadero. *Revista Chapingo Serie Horticultura* **13 (2)**, 185-192

Rodríguez-Macias R, Quintero-Lizaola R, Alcántar-González G, Ordaz-Chaparro V, Volke-Haller V (2005) Dinámica y cuantificación de grupos microbianos en compost y vermicompost de bagazo de agave tequilero. *Terra Latinoamericana* **23 (1)**, 97-104

Rodríguez-Dimas N, Cano RP, Figueroa VU, Palomo GA, Favela ChE,

Álvarez RV de P, Márquez HC, Moreno RA (2008) Producción de tomate en invernadero con humus de lombriz como sustrato. *Revista Fitotecnia Mexicana* **31 (3)**, 265-272

Romero-Lima MR, Trinidad-Santos A, García-Espinosa R, Ferrera-Cerrato R (2000) Producción de papa y biomasa microbiana en suelo con abonos orgánicos y minerales. *Agrociencia* **34 (3)**, 261-269

Santamaría-Romero S, Ferrera-Cerrato R (2002) Dinámica poblacional de *Eisenia andrei* (Bouché 1972) en diferentes residuos orgánicos. *Terra Latinoamericana* **20**, 303-310

Santamaría-Romero S, Ferrera-Cerrato R, Almaraz-Suárez JJ, Galvis-Spinola A, Barois-Boullard I (2001) Dinámica y relaciones de microorganismos, c-orgánico y n-total durante el composteo y vermicomposteo. *Agrociencia* **35**, 377-384

Sperling von M, Andreoli CV (2007) Introduction to sludge management. In: Andreoli CV, Sperling von M, Fernandes F (Eds) *Biological Wastewater Treatment Series (Vol 6) Sludge Treatment and Disposal*, IWA Publishing, London, UK, pp 1-3

Spinosa L (2007) Introduction and overview. In: Spinosa L (Ed) *Wastewater Sludge: A Global Overview of the Current Status and Future Prospects*, Water 21 Market Briefing Series, IWA Publishing, London, UK, pp 1-3

Teixeira PM (2007) Pathogen removal from sludge. In: Andreoli CV, Sperling Mv, Fernandes F (Eds) *Biological Wastewater Treatment Series* (Vol 6) *Sludge Treatment and Disposal*, IWA Publishing, London, UK, pp 120-148

Tilman D, Lehman C (2001) Human-caused environmental change: Impacts on plant diversity and evolution. *Proceedings of the National Academy of Sciences USA* **98 (10)**, 5433-5440

Toral FJR, Pérez GA, Carreón AJ, Martínez RJL, Rodríguez RR, Casas SJF (2005) Niveles de fertilización orgánica mediante vermicomposta en el cultivo de la jamaica. *Avances en la Investigación Científica en el CUCBA*. XVI Semana de la Investigación Científica. Centro Universitario de Ciencias Biológicas y Agropecuarias-CUCBA, pp 193-197

Valdez-Pérez MA, Ramos VAC, Franco HMO, Flores CLB, Dendooven L (2006) Biosólidos estabilizados y vermicomposta de biosólidos como fuente de nitrógeno en cultivos de frijol. *Memorias del XV Congreso Nacional de Ingeniería Sanitaria y Ciencias Ambientales,* 24 al 26 de mayo del 2006, EXPO Guadalajara, 6 pp

Valencia-Maldonado P, Sánchez-García ML, Moreno-Rivera ML, García-Velasco G, Franco-Hernández MO (2006) Tratamiento de residuos de frutas y verduras por vermicomposteo. *Memorias del XV Congreso Nacional de Ingeniería Sanitaria y Ciencias Ambientales*, 24 al 26 de mayo del 2006, EXPO Guadalajara, 9 pp

Velasco-Velasco J, Ferrera-Cerrato R, Almaraz-Suárez JJ (2001) Vermicomposta, micorriza arbuscular y *Azospirillum brasilense* en tomate de cáscara. *Terra Latinoamericana* **19 (3)**, 241-248

Villa-Briones A, Zavaleta-Mejía E, Vargas-Hernández M, Gómez-Rodríguez O, Ramírez-Alarcón S (2008) Incorporación de vermicomposta para el manejo de *Nacobbus aberrans* en jitomate (*Lycopersicon esculentum* Mill.) *Revista Chapingo Serie Horticultura* **14 (3)**, 249-255