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REGULAR ARTICLE

Development of "Serrano" pepper in vermicompost: perlite substrates under shade net conditions

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ABSTRACT

The growth of "Serrano" pepper (*Capsicum annuum* L.) under shade net conditions was evaluated, using different mixtures of vermicompost:perlite (VC:P, by volume), at the Comarca Lagunera in northern México. During 2012 spring-summer season, "Camino Real" cultivar was evaluated in five mixtures of VC:P, with ratios 0:1, 1:1, 1:2, 1:3 and 1:4. Nutrient solution was applied only in the first mixture (control) while VC was used as organic nutrient all other mixtures. Fruit length, pulp thickness, number of locules, equatorial diameter, fruit weight, number of fruits and yield were the variables evaluated. The five mixtures, with six replications, were distributed according to a completely randomized design. Data were statistically analyzed by analysis of variance and means were separated by the $LSD_{0.05}$ test. The maximum yield, 37.13 t•ha^{-1}, with any synthetic fertilizers, was obtained in the mixture VC:P with ratio 1:1, therefore is possible to conclude that the VC was capable to meet the nutrient demand of Serrano pepper.

Keywords: *Capsicum annuum*; Food production; Organic amendment; Protected agriculture; Vegetable growth

INTRODUCTION

The agricultural activities and worldwide food production are in a period of change. In the more economically developed countries, agriculture has been intensified and specialized through time and food security is no longer concern. Nowadays, there is a wide-ranging censure of this structural and technological development and humankind makes ever-increasing demands for a reduction in the use of traditional farming inputs for example synthetic fertilisers, pesticides, and prophylactic medicines (Fjelsted-Alrøe and Steen-Kristensen, 2004; Turhan et al., 2008; Morgera et al., 2012). On the other hand, in the developing countries, food security is often a problem of great relevance and some in favor of industrial inputs as the solution to insufficient and inadequate food production (Fjelsted-Alrøe and Steen-Kristensen, 2004; Turhan et al., 2008).

In traditional agriculture, heavy doses of synthetic fertilizers and pesticides are often applied to soils to enhance the yield of different crops, this production model puts pressure on agroecosystems which leads to decreased soil fertility (Turk and Fallah, 2014). Additionally, these agrochemicals cause health problems among consumers (Aktar et al., 2009) due to their adverse effects, thus there is interest in the adoption of organic fertilizers (Márquez-Quiroz et al., 2014). In fact, Trewavas (2004) highlights that, a common demand is that conventional agriculture seeks to dominate nature whereas organic agriculture works with nature. In this context, there is an increasing interest in organic farming. Organic farming represents an alternative and more holistic view of agriculture and food production, which directly addresses the problems faced in conventional agriculture (Fjelsted-Alrøe and Steen-Kristensen, 2004; Turhan et al., 2008). Additionally, the organic agriculture is often seen by the public as producing agrochemicals free food and being more environmental friendly (Trewavas, 2004).

Earthworm farming - vermiculture or vermicomposting - is a bio-technique for converting the solid organic waste into

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vermicompost (VC) (Francis et al., 2003; Alidadi et al., 2007; Aalok et al., 2008). The earthworms during their feedings fragment the organic waste, enhance microbial activity and accelerate rates of decomposition, leading to a humification effect through which the unstable organic wastes are oxidized and stabilized, as in composting but by a non-thermophilic process (Atiyeh et al., 2001). Furthermore, this proccess accelerate the decomposition by 2–5 times, thereby quickens the conversion of wastes into valuable biofertilizer and produces much more homogenous materials compared to thermophilic composting (Pathma and Sakthivel, 2012). In vermicomposting, the breeding and proliferation of earthworms and the use of its castings has become an important tool of waste recycling over the world. Essentially, vermiculture takes advantage of earthworms as natural bioreactors for cost-effective and environmentally sound waste management (Sharma et al., 2005; Alidadi et al., 2007; Pathma and Sakthivel, 2012).

Vermicomposting is a process for stabilization of organic waste with the participation of earthworms and microorganisms (Aira et al., 2007; Huang et al., 2013). Microorganisms are responsible for biochemical degradation of the waste materials; while earthworms play their roles as mechanical blenders and drivers of the process through modifying the biological, physical and chemical status, gradually reducing the C/N ratio of wastes, increasing the surface area attachable by microorganisms, and converting the waste materials into ones more favourable for microbial activity and further decomposition. During this process, the important plant nutrients such as N, K, P and Ca present in waste materials are converted into more available forms for plant growth (Atiyeh et al., 2001; Huang et al., 2013). The increase availability of these elements mostly occurs because, vermicomposting accelerates the rate of mineralization, in which the chemical compounds of the organic matter decompose or oxidize into forms that could be easily assimilated by the plants (Pathma and Sakthivel, 2012). For these reasons, vermicomposting has been considered as an environmental friendly and cost effective technology for the treatment and recycling of different organic waste materials, particularly for non developed countries (Huang et al., 2013).

Nowadays numerous studies have demonstrated the potential of different VC, not only as a substitute for peat as a growth substrate or when used as soil amendments, but also to stimulate plant growth and suppress soil-borne diseases (Atiyeh et al., 2000a). Different greenhouse and field studies have evaluated the effects of a variety of VCs on a wide range of crops *e.g. Lactuca sativa*, L. and *Solanum lycopersicum*, L. (Atiyeh et al., 2000b, 2000c, 2001; Márquez-Quiroz et al., 2014), *Phaseolus vulgaris* L. (Manivannan et al., 2009; Aguilar-Benítez et al., 2012), *Cucumis melo* L. (Moreno-Reséndez et al., 2010); *Solanum tuberosum* L. (Romero-Lima, 2000); *Zea mays* L. (Verdugo, 2013); *Fragaria × ananasa* Duch. (Romero-Romano et al., 2012); *Petunia hybrida* Juss. (Chamani et al., 2008); *Capsicum annuum* var. Annuum (Fortis-Hernández et al., 2008); *Saccharum officinarum* L. (da Silva et al., 2002); *Tamarindus indica* L. (Oliva et al., 2008); *Cucumis sativus* L. (Díaz-Méndez et al., 2014); among others. Most of these researches have confirmed that VCs have significant beneficial effects on plant growth when used as soil amendments or as components of plant growth substrates, that improved seed germination, enhanced seedling growth and development and increased overall plant productivity. The greatest plant growth responses and largest yields have usually occurred when VCs constituted only a relatively small proportion (20-40 %) of the total volume of a plants growth media, with greater proportions of VCs substituted into the plant growth medium not always improving plant growth further (Atiyeh et al., 2000a, 2001). In this context, Romero-Lima et al. (2000) suggest that the use of organic fertilizers, to meet crops demands, is an alternative, that can be used to reduce the use of agrochemicals, including synthetic fertilizers, and to increase the yield and quality of agricultural products.

The described in the above paragraphs suggest that growth of different crops in greenhouses, traditionally subject to use of nutrient solutions might be satisfied with the use of organic substrate such as VC, thus reducing employment of synthetic fertilizers.The objective of study was to evaluate Serrano pepper development in substrates of vermicompost: perlite under shade net conditions.

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). The climate of this region is dry desert with rainfall in summer and cool winters (Aguirre, 1981). The precipitation is 241.9 mm and annual mean temperature is 21.5 °C, ranging from 33.7 °C maximum and 7.5 °C minimum. The annual evaporation average is about 2,396 mm, while the relative humidity varies according to season, with 31, 47, 58 and 40 % in spring, summer, fall, and winter, respectively (CNA, 2002). The shade house used consisted of a metallic structure, 12.60 m length, 5.40 m width, and 3.0 m high, covered with anti-aphids mesh (16 x 16 threads•cm^{-2}, Mesh Plas®).

The experiment was conducted in the period spring-summer 2012, using "Serrano" pepper (*Capsicum annuum* L.) *cv*. Camino Real (Harris Moran®), which were sown on

April 10, 2012, 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, SAR 2.18 and EC 1.05 dS•m^{-1}, classified as C_1S_1) every three days until the time of transplant, which was performed at 47 days after sowing (DAS), when the plant had an approximate height of 15 cm and they had five to six true leaves, placing one seedling per pot. Black polyethylene 20 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 12.5 pots•m^{-2}.

The materials used for filling the pots were VC and perlite (P), type B-12 (Multiperl Hortícola, Perlita de la Laguna, S.A. de C.V. ®) (Baixauli-Soria and Aguilar-Olivert, 2002) in five volume ratios (VC:P; 0:1, 1:1, 1:2, 1:3 and 1:4, treatments T0 – T4), in T0, sand with nutrient solution (Table 1) was used as a control. The VC (Table 2) was prepared from a mixture of three types of manure (goats, horses, rabbits, 1:1:1 ratio by volume) digested by *Eisenia fetida* Savingy, for three months (Bansal and Kapoor, 2000).

Tap water was used in treatments T0 – T4, applying 1.0 L•pot^{-1}•day^{-1}; additionally, in T0, 0.3 L•pot^{-1}•day^{-1} of nutrient solution was applied, this quantity derived from preliminary experiences at local level and taking into account four stages of crop development. This solution was prepared with highly soluble substances of technical grade, available in the regional market and diluted in water. Quantities of these products for preparing nutritive solution are shown in Table 1.

Table 1: Fertilizers used in nutrient solution according to growth stage of the Serrano pepper crop, developed under shade net conditions

Fertilizer	Plant phenological stage	
	Transplant to start of 2nd picking (g)	2nd – 7th picking
Calcium nitrate [$Ca(NO_3)_2$; 15.5-0-0 19]	6.6	6.6
Potassium nitrate [KNO_3; 13-0-46]	4.24	8.28
Magnesium sulfate [$MgSO_4$; 0-0-0-0-9.1]	3.49	5.41
Monoammonium phosphate (MAP) [$NH_4H_2PO_4$; 12-61-0]	2.96	2.96
Phosphoric acid [H_3PO_4; 85%; (mL)]	1.5	1.5

Fertilizers were diluted into 20 L of water

The control method for 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 each week. The pests found were *Bemisia argentifolli* (Bellows and Perring) *Dactylopius coccus* (Costa) and *Thrips tabaci* (Linderman), regarding to disease, 50 days after sow, shoots of mildew (*Leveillula taurica* Lev. Arnaud) appeared, which were controlled with organic insecticides and fungicides, respectively (Table 3).

The variables measured, considering three fruits•pot^{-1}•cut^{-1}, were: fruit length (FL), equatorial diameter (ED), number of locules (NL) and pulp thickness (PT), considering the fleshy part of the pericarp, whereas the total of fruits harvested was contemplated to obtain the number of fruits (NF), fruit weight (FW) and total yield (TY) variables. The experimental design, used to evaluate the effect of treatments with six replicates each, was completely randomized. Data were analyzed statistically by analysis of variance and means were separated by the $LSD_{0.05}$ test with the experimental design program version 2.4 of Olivares-Sáenz (1993).

RESULTS AND DISCUSSION

The data assessed corresponding to those values registered until the 10th cut-off, performed 164 days after transplanting (DAT). The ANOVAs showed highly significant differences ($P \leq 0.01$) among treatments for the variables FL, ED and PT, significant differences ($P \leq 0.05$) among treatments for NF and FW, and in turn NL and TY were statistically equals (Table 4).

Overall, in Table 4 it can be appreciated that with treatment T4, five of the seven variables showed the highest values. Other general trend is that as the content of VC was reduced, the evaluated variables increased their values, except for variables NF and TY. Increases that were recorded in the variables, to less concentration of VC in treatments T4, coincided with the findings reported by Atiyeh et al. (2000c), who concluded that applying small amounts of pig manure VC generated a significant increase in total seedling biomass of tomato crop. Additionally, these authors determined that the decreased growth in plants that had VC levels greater than 60 % was due to a high concentration of soluble salts, poor aeration, heavy metal toxicity and plant phytotoxicity. A similar behavior to that recorded for Serrano pepper crop in this experiment,

Table 2: Chemical analysis of the material used during the growth of Serrano pepper under shade net conditions

Material	(mg•kg^{-1})									pH	EC (dS•cm^{-1})
	N	P	K	Ca	Mg	Na	Fe	Zn	Mn		
VC	48.8	38.7	361.8	258.0	25.5	194.8	3.9	1.45	3.71	8.2	2.4

Table 3: Pests, diseases, products and doses applied to control during development from Serrano pepper under shade net conditions

Pest/disease	Products	Doses (mL•L^{-1} of H_2O)
Bemisia argentifolli	BIOLYD	8•8
Dactylopius coccus	FHYTO-NEEM	7•7
Thrips tabaci	FHYTO-FOAM	7•7
	BIODIE * E	6•8
Leveillula taurica	MILDOUT	4•6

Table 4: Average values, variation coeficient, statistical significance and LSD test (5%) of the variables evaluated in *Capsicum annuum* cv. Camino real crop, development in substrates of vermicompost: Perlite under shade net conditions

T	Composition¶		(cm)			NL^{ns}	NF*	FW*	TY^{ns}
	VC	P	FL**	ED**	PT**			(g)	(t•ha^{-1})
T0	0	1	5.7b	1.4b	**0.24a**	**3a**	86b	5.8ab	19.90a
T1	1	1	5.6b	1.5b	0.14b	**3a**	**180a**	5.2b	**37.13a**
T2	1	2	**7.7a**	**1.8a**	**0.22a**	2.6a	101ab	5.2ab	20.50a
T3	1	3	**7.0a**	**1.7a**	**0.21a**	**3a**	120ab	5.3b	28.91a
T4	1	4	**7.9a**	**1.7a**	**0.25a**	**3a**	80b	**7.1a**	25.38a
Media			6.8	1.6	0.21	2.9	113	5.7	26.36
CV (%)			11.6	11.7	16.12	10.15	62.90	24.06	60.82

¶=Ratio v: v; FL=Fruit length; ED=Equatorial diameter; PT=Pulp thickness; NL=Number of locules; NF=Number of fruits; FW=Fruit weight; TY=Total yield. ns, * and **=Not significant, significant ($P \leq 0.05$) and highly significant ($P \leq 0.01$), respectively. The same letters in columns correspond to non-significant differences at LSD ($P \leq 0.05$)

with lower concentrations of VC, was reported by Atiyeh et al. (2002) on the growth and productivity of French marigold plants (*Tagetes patula* L.).

Treatments T2, T3 and T4, which included VC, outperformed the control treatment (perlite and nutrient solution), concurring with the results reported by Rodríguez-Ortiz et al. (2010), who concluded that VC fertilization during transplanting of green onions (*Allium cepa* L.) favored a higher growth of this species when compared with plants receiving synthetic fertilization. In the same sense, according to the specifications of the official mark "*México Calidad Selecta*" for Serrano pepper (SAGARPA-ACERCA-BANCOMEXT-SE, 2004), the fruits of the treatments T2, T3 and T4 correspond to large fruit size. Likewise, based on the Mexican Norm, NMX-FF-025-SCFI-2007, the values registered for FL and ED in the fruits of the treatments T2, T3 y T4 were classified as great size, while that the WF registered in all treatments corresponded to fruits of small size (Table 4). In a particular way, the FL and ED registered in the fruits of the treatments T2, T3 and T4, and whose values ranged from 7.0 to 7.9 and from 1.7 to 1.8 cm, respectively, were slightly lower, to the highest values of 8.7 and 1.9 cm, reported by Vázquez-García et al. (2010) for these variables in 19 varieties of Serrano pepper. Additionally, the WF determined in the fruits of treatment T4 (7.1 g) were the highest value obtained in this experiment, 41.80 % lighter than highest values of WF (12.2 g) reported by the same authors.

Values of PT registered in the fruits of treatments T0 - T4, were outweighed by data reported by Vázquez-García et al. (2010) that, in 19 varieties of Serrano pepper, reported values between 2.5 and 3.9 cm for this variable. The PT of fruits acquires importance because the weigth of the fruits increases with the thickness as well as the transportation resistance and the shelf life of fruits, without diminishing their quality (Córdova, 2003). According to Vázquez-García et al. (2010) in México Serrano pepper is mostly used for consumption as fresh fruit, thus life of anaquel for their fruits represents an important factor for its marketing.

Although the total yield in the treatments evaluated in this experiment was statistically equal, the treatments (T1 – T4) that were fertilized with VC surpassed, in at least, 3 % the yield of the control (T0). The production potential of 37.13 t•ha^{-1} reached under shade net conditions in the treatment T1, and equally yields obtained in treatments T2, T3 and T4 (20.50, 28.91 and 25.38 t•ha^{-1}), were quite satisfactory because they overcome the national Mexico average yield of 17.26 t•ha^{-1} for pepper crop under field conditions (SIAP, 2013). Therefore, it may be assume that these four treatments favored the development of the Serrano pepper.

CONCLUSIONS

The results showed that the mixtures of vermicompost with perlite, without applying synthetic fertilizers, had favorable impact on growth of Serrano pepper. The production of Serrano pepper under shade net conditions with organic fertilizers resulted in a satisfactory yield. The use of VCs can be considered as an alternative fertilization method for organic production in these conditions, since they contain soluble nutrients that can meet the nutritional requirements of this crop.

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Author contributions

A.M.R.: Designed and performed research, wrote and revised the manuscript. R.H.G.: contributed to the development of experimental part. N.R.D.: performed chemical analyzes and reviewed the manuscript. J.L.R.C.: Analyzed the data and reviewed the manuscript. C.M.Q. and P.P.R.: revised the manuscript. All authors read and approved the final manuscript.

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