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Vermicompost management: An alternative to meet the water and nutritive demands of tomato under greenhouse conditions

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Abstract

Different studies have suggested that the use of vermicompost as part of the plant growth media can provide nutrients and retain moisture while promoting the development of crops. To corroborate this assumption we tested the effects of vermicompost supplementation to tomato (saladette type) under greenhouse conditions. The evaluated treatments included four mixtures (T1, T2, T3, and T4) of vermicompost and river sand, with volume ratios 0:1, 1:1, 1:2 and 1:3, respectively. Physical and chemical tests were performed in each mixture to determine nutritional elements (N, P, K, Ca, Mg, Na, Fe, Cu, Zn, Mn, organic matter, pH, texture, cation-exchange capacity, electric conductivity, and apparent density) and water holding capacity. Treatment with 0:1 volume ratio (T1) was used as control, and it was fertilized with a nutrient solution [KNO_3, $Ca(NO_3)_2$, $Mg(NO_3)_2$, phosphoric acid concentrate, and multi Maxiquel (Bioagro ®)]. Seeds were sown in polystyrene trays with 200 cavities, padded with peat moss; seedlings were transplanted 37 days after sowing in 20 L black plastic bags. Harvest, including up to the fifth cluster, was performed manually, when the fruits reached a pink color. The treatment effects on tomato were evaluated considering the number of fruits, number of locules, equatorial and polar diameters, pulp thickness, soluble solids, fruit weight and fruit yield. The four treatments were repeated eight times in a completely randomized design. Data were statistically analyzed by analysis of variance and means were separated by the $LSD_{0.05}$ test. Five of the variables studied - number of fruits, number of locules, soluble solids, pulp thickness, and yield- showed highly significant difference ($P \leq 0.01$) among treatments; the polar diameter showed significant differences ($P \leq 0.05$), and both equatorial diameter and weight of fruit were not significantly different among the substrates tested. The maximum yield (50.29 $t \bullet ha^{-1}$) was obtained in treatment T2 with a water volume of 40 L•pot-1, followed by T1 (49.93 $t \bullet ha^{-1}$), applying a water volume of 95.72 $L \bullet pot^{-1}$. Derived from the results of the best treatment (T2), and under conditions described, the productivity was estimated in 30.66 $kg \bullet m^{-3}$. Since no synthetic fertilizers were used during the crop production, the results indicate that the vermicompost was able to satisfy the nutrient demand of tomato plants and reduces the volume of water required by this crop.

Key words: Earthworm, Humus, Organic manure, *Solanum lycopersicum*, Water holding capacity

Introduction

Today, one of the most viable alternatives to solve the problem of solid waste disposal is the process of composting (Valadares-Veras and Povinelli, 2004). The composting process is a suitable treatment used to produce a stable product, rich in humic-like substances that are environmentally safe and practicable at acceptable operational costs (Salas and Ramírez, 2001; Amir et al., 2003; Valadares-Veras and Povinelli, 2004), from a diverse range of organic waste to generate high-quality fertilizer for crops (Santamaría-Romero et al., 2001, Sharma et al., 2005). From time immemorial, humans -and mainly the farmers- have used the wastes generated by anthropogenic activities, such as organic amendments, to improve the physical, chemical and biological properties of soil (Leal and Madrid-de-Cañizalez, 1998; Romero-Lima et al., 2000).

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The use of these products is based on the fact that the presence of organic matter in the soils promotes, among other things: a) the conservation of moisture, b) increased permeability, c) the slow release and solubilization of nutrients for plants, d) improvement of soil structure, e) the soil buffering capacity, f) soil biological activity, and g) the natural control of pests and plant diseases (Cruz-Rodrigues et al., 2003). In addition, the incorporation of biodegradable materials to the soils promotes the synthesis of organic compounds that bind particles into aggregates, the increase of pore space, greater and more rapid infiltration, and water storage (Leal and Madrid de Cañizalez, 1998; Acevedo-Sandoval et al., 2001). Organic compounds are also reservoirs of macro and microelements, essential for plant development (Leal and Madrid de Cañizalez, 1998). In fact, the application of amendments to the soils, such as manure from different animals and sewage sludge is a very environmentally attractive practice, since it also provides a useful destination for these wastes (Dick et al., 2002).

In recent decades, the use of organic fertilizers has become increasingly important for several reasons, among which: a) from the ecological point of view, there is an increased concern for promoting ecofriendly agricultural practices (the use of organic fertilizers improves soil conditions that have been damaged by excessive use of agrochemicals and their over-exploitation), and b) from the economics point of view, the use of fertilizers and organic products has been promoted by organic agriculture, which represents an added value to the obtained products (their prices are higher than those of conventional agriculture products, so this practice becomes more attractive to the farmers) (Nieto-Garibay et al., 2002).

This suggests that the use of vermicompost (VC), as part of the growth media, allows meeting the nutrient demand, as well as retaining and meeting the water needs of crops developed under greenhouse conditions. Therefore, we evaluated the effect of different mixtures of VC with river sand on the availability of nutrients and moisture during the growth of tomato (*Solanum lycopersicum* L.) under protected conditions (greenhouse).

Materials and Methods

The study was carried out in a greenhouse of the Horticulture Department at the Universidad Autonoma Agraria Antonio Narro, Unidad Laguna (UAAAN-UL), in Torreon, Coahuila, México (101°40’ and 104°45’ W long and 25°05’ and 26°54’ N lat) (Schmidt, 1989). According to Aguirre (1981), the climate of this region is dry desert with rainfall in summer and cool winters. The annual precipitation is 241.9 mm and the average temperature is 21.5°C, ranging from 33.7°C maximum and 7.5°C minimum. The average annual evaporation is approximately 2,396 mm. The relative humidity in this region varies according to season, with 31, 47, 58 and 40% in spring, summer, fall, and winter, respectively (CNA, 2002).

The greenhouse used in this study is semicircular, has reinforced acrylic coating, damp wall, extractors, gravel floor, and measures 8 x 23 m, width and length, respectively. It has side windows of 1.20 m high, also covered with reinforced acrylic, which can be rolled up and are protected with anti-aphids mesh. The acrylic cover is protected with shade mesh during the warmer seasons.

The experiment was conducted in the period summer-fall-winter 2008, using the tomato variety Sun-7705 (Nunhems USA, Inc. ®) saladette type of indeterminate cycle, which were sown on 8 July 2008 in polystyrene trays of 200 cavities, using Peat moss (Canadian Sphagnum Peat Moss Association ®) (Atiyeh et al., 2000) as substrate, which were previously saturated with water, then filled the tray and deposited one seed per cavity. The trays were placed inside the greenhouse, covered with black plastic and watered with tap water (pH 7.57 and classified as C1S1) every three days until the time of transplant, which was performed at 44 days after sowing (DAS), when the plant had an approximate height of 15 cm, placing one seedling per pot. Black polyethylene 20 L capacity bags, 500 gauge, type nursery and 20 L of capacity were used as gavels. At the greenhouse, the gavels were placed in a line to double array and “*tresbolillo*” arrangement, and a distance of 30 cm between plants, with a population density of 4.1 gavels•m^{-2}.

The materials used for filling the pots were VC and river sand (RS) in four volume ratios VC:RS, 0:1, 1:1. 1:2 and 1:3, v:v, each of which corresponds to T1, T2, T3 and T4, respectively. The mixtures used in each treatment (T1 – T4) were analyzed physically and chemically (Table 1). The RS was previously washed with tap water and sun-dried for 48 h, while the VC was prepared from a mixture of three types of manure (goats, horses, rabbits, 1:1:1 ratio by volume) digested by *Eisenia fetida* Saving., for three months (Atiyeh et al., 2000; Bansal and Kapoor, 2000; Ndegwa et al., 2000).

In the control treatment T1 (VC:RS, 0:1, v:v) nutrient solution was applied on the basis recommended by Zaidan and Avidan (1997) matched for the synthetic products applied. This solution was prepared with highly soluble substances of technical grade, available in the regional market [KNO_3, $Ca(NO_3)_2$, $Mg(NO_3)_2$, phosphoric acid concentrate and multi Maxiquel (Bioagro ®)], and diluted in water. The concentrations of the macroelements of this solution, applied according to phenological stage of crop, are presented in Table 2.

Considering the objective of evaluating the effect of different mixtures VC:RS on the availability of nutrients and moisture during the development of tomato, the gavels with mixtures that included VC (T2 – T4) were watered with tap water without the application of the nutrient solution, seeking to meet the metabolic needs only with VC, which contains an increasing availability of nutrients (Mangrich et al., 2000; Atiyeh et al., 2001; Gunadi et al., 2002; Valadares-Veras and Povinelli, 2004).

The water volume and frequency of irrigation applied (Table 3) in treatments T2 - T4 was determined according to: a) the content of VC in each gavel, since the use of VC as growth media promotes moisture retention (Atiyeh et al., 2000, 2001 and 2002, Cruz-Rodrigues et al., 2003); b) curves of soil moisture retention of each treatment (Figure 1); and c) considering four critical stages during the physiological development of tomato [1st stage = transplant to flowering (12 days on average), 2nd stage = flowering to fruit set (10 days on average), 3rd stage = Fruit set at the beginning of ripening (14 days on average) 4th stage = Harvest (30 days on average until the fifth cluster)]. One more physiological stage was added to the stages suggested by González-Meza and Hernández-Leos (2000) [1st stage = transplant to onset of fruit formation, 2nd stage = training fruit first cut, and 3rd stage = period harvest, which demand the greatest amount of irrigation] in response to climatic conditions and past experience in the management of this crop under greenhouse conditions in the Comarca Lagunera.

Table 1. Physical and chemical characteristics of VC and mixtures (VC, RS) used as substrates for the development of tomato.

Components (concentration)§	VC	RS (T1)	T2	T3	T4
N (%)	1.55	0.008	0.17	0.18	0.09
P (ppm)	879.12	4.49	244.75	234.15	145.85
K (meq•100 g^{-1})	14.70	0.11	2.46	1.84	0.84
Ca (meq•L^{-1})	10.67	0.05	5.28	2.14	26.70
Mg (meq•L^{-1})	12.35	0.08	1.56	1.06	0.90
Na (meq•L^{-1})	4.30	3.04	3.00	1.65	40.54
Fe (ppm)	13.08	12.72	12.96	11.91	12.06
Cu (ppm)	8.64	5.31	5.19	5.37	5.31
Zn (ppm)	8.04	2.10	4.35	3.30	2.94
Mn (ppm)	10.86	3.90	6.72	6.21	5.82
EC (mS•cm^{-1})	31.90	0.55	2.42	1.89	1.44
OM (%)	24.65	0.20	2.80	1.77	1.32
CEC (meq•100 g^{-1})	20.00	4.50	4.00	8.00	6.00
pH	8.52	7.48	8.00	7.97	7.94
BD (g•cm^{-3})	0.69	1.47	1.32	1.39	1.45
Texture	SCL	SL	SL	SL	SL

VC = Vermicompost; RS = River Sand; SCL = Sandy clay loam; SL = Sandy loam; §OM = organic matter (Walkley Black); Nt = total nitrogen Kjeldahl; P (modified Olsen); Cu, Fe, Zn and Mn (extracted by DTPA and determination by atomic absorption, Perkin – Elmer 2380); Ca, Mg y Na (soil saturation extract and determination by atomic absorption, Perkin – Elmer 2380); CEC = Cation-exchange capacity, with ammonium acetate as saturated solution; pH and EC = Electric conductivity, saturation extract and determined with Orion model 162; Texture = Bouyoucos method; BD = Bulk Density

Table 2. Concentration of macro elements in the nutrient solution.

Plant phenological stage	N	P	K
	(mg•L^{-1})		
Transplanting to flowering (1st stage)	100 – 120	40 – 50	150 – 160
Flowering to fruit set (2nd stage)	150 – 180	40 – 50	200 – 220
Fruit set at the beginning of ripening (3rd Stage)	80 – 200	40 – 50	230 – 250
Harvest (4th stage)	80 – 200	40 – 50	230 – 250

Table 3. Irrigation frequency and amount of water applied during the stages of physiological development of tomato.

Treatments	Irrigation (h)	1st stage	2nd stage	3rd stage	4th stage	TVWAPGT (L)
		Water volume applied per pot (L¶)				
AR (T1)	24	0.560	0.80	1.5	2.0	95.72
T2	72	1.0	2.0	2.0	2.0	40
T3	48	1.0	1.0	2.0	2.0	55
T4	24	1.0	1.0	1.0	2.0	96

1st stage = transplant to flowering (12 days on average), 2nd stage = flowering to fruit set (10 days on average), 3rd stage = Fruit set at the beginning of ripening (14 days on average) 4th stage = Harvest (30 days on average until the fifth cluster); h = period of time in hours between watering, ¶In each treatment, the volume of water for irrigation was performed in two applications: half in the morning (between 9:00 and 10:00 h) and half in the afternoon (between 16:00 and 17:00 h); TVWAPGT = Total volume of water applied per gavel for tomato phenological cycle.

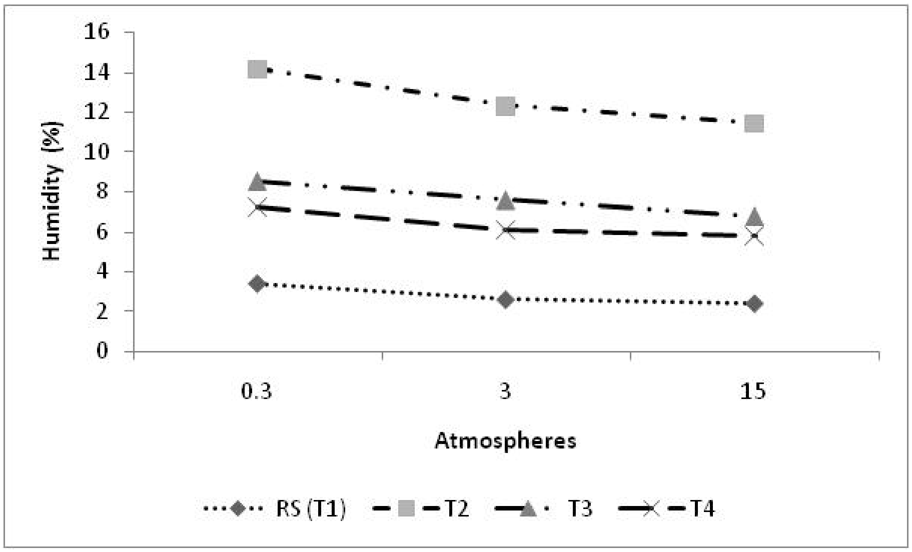

Figure 1. Water retention curves of the mixtures VC:RS used as substrates in the treatments evaluated.

Different agronomic practices were carried out during the development of the tomato crop inside the greenhouse, 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 (this promotes air circulation, decreases the humidity level, and reduces the risk of disease), 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), d) pollination (carried out daily between 11:00 and 14:00 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, AlEn ®) between sessions.

The control of pests and diseases was carried out as follows: for silver leaf whitefly (*Bemisia argentifolii*, Bellows and Perring), the use of FLY-NOT (Agrorgánicos Nacionales, SA de CV ®) (20 mL•8 L^{-1} water) and Vel Rosita detergent (Colgate-Palmolive Company ®) (1 mL•1 L^{-1} water) was implemented on a weekly basis and in periods of peak daily presence; for thrips (*Frankliniella occidentalis*), the use FLY-NOT in the same previous dose, and KALIL 95 (Sociedad de Producción Rural, Ganadera, Agrícola y Forestal, MAPIMI R.I.®) (50 mL•10 L^{-1} of water) mixed with 5 mL of oil to achieve adhesion of the product to the leaves; powdery mildew (*Leveillula taurica*), which appeared prior to the conclution of the harvest, was controlled with weekly application of Fungibac plus (Bilper Group ®) (15 mL•20 L^{-1} of water).

The fruit harvest was done weekly by hand, once they reached a pink color and until the genotype reached the fifth cluster. The treatments' effects on tomato were evaluated considering the number of fruits per plant (NFPP), number of locules (NL), equatorial diameter (ED), polar diameter (PD), pulp thickness (PT), soluble solids (SS), fruit weight (FW), and yield (R). The four treatments were repeated eight times in a completely randomized design. Data were statistically analyzed by analysis of variance and means were separated by the $LSD_{0.05}$ test (Olivares-Sáenz, 1993).

Results and Discussion

Quality variables

Five of the quality variables evaluated in the fruit -NFPP, NL, SS, PT, and R- showed highly significant difference ($P \leq 0.01$) among treatments; PD showed significant difference ($P \leq 0.05$), and both ED and FW were not significantly different among the substrates tested. Comparison of treatment means with the $LSD_{0.05}$ test showed that treatment T2 exceeded or was statistically similar to the control treatment for the variables PD, NFPP, NL, PT and R, but not for SS, where T1 was higher. Both treatments T1 and T2 surpassed the treatments T3 and T4 (Table 4). The amount of VC used in treatment T2 produced a similar effect on the results of Atiyeh et al. (2001), who reported that the growth of tomato seedlings was greater when the VC from pig manure replaced the commercial growth media Metro-Mix 360 with amounts ranging between 25 and 50% by volume.

Polar diameter

In the case of the polar diameter, the highest value was registered in treatment T2 (5.31 cm) (Table 4). Therefore, according to the standard NMX -FF-031-1997-SCFI, these tomatoes were considered medium-sized. This value was slightly lower than the range of PD (5.7 to 6.1 cm) reported by de la Cruz-Lazaro et al. (2009) during the development of hybrid-7705 Sun using compost and VC as substrates in different proportions. In the same way, the recorded diameter of 5.3 cm was also similar to those reported by Rodriguez-Dimas et al. (2008), who determined values of 6.1 and 5.4 cm in PD for Big Beef and Miramar genotypes, respectively, on treatment with the mixture VC:RS (which also exceeded the control treatment with sand and nutrient solution) highlighting that genotypes used by Rodriguez Dimas correspond to globe type tomatoes.

Equatorial diameter

In a similar behavior as the observed in a study by de la Cruz Lazaro et al. (2009), the ED of the Sun-7705 hybrid used in the present study showed no statistical differences for the evaluated sources of variation. The highest average value for ED was recorded in treatment T1 with 4.47 cm and the lowest averages corresponded to the treatments that included VC in different proportions. However, it is important to notice that in all treatments, the ED ranged between 4.03 and 4.47 cm, which is slightly below the range for this type of tomato, as reported by the same authors, whose values ranged between 4.24 and 5.10 cm when developed on growth media with different proportions of compost and VC.

The average ED of fruits grown with treatments that included VC was 4.14 cm, therefore these fruits can be classified as medium-sized. This results can be of great importance due to the desirable effect that could be achieved on fruit size of hybrid globe type tomatoes, with the use of VC in the production system; as noted by Ucan-Chan et al. (2005), the international market -specially USA- and selected national markets of Mexico prefer and pay more for fruits with ED larger than 6 cm.

Table 4. Mean values of quality variables assessed during the development of the tomato crop in mixtures of river sand and VC under greenhouse conditions.

Treatments	PD (cm)	ED cm)	NFPP	NL	SS (ºBrix)	PT (mm)	FW (g)	R ($t \cdot ha^{-1}$)
T1	5.11 ab	4.47 ns	19.87 a	2.41 ab	5.36 a	5.33 ab	57.61 ns	49.93 a
T2	5.31 a	4.28 ns	20.75 a	2.57 a	4.92 b	5.76 a	60.23 ns	50.29 a
T3	4.87 b	4.11 ns	16.37 b	2.51 a	4.37 c	4.86 b	54.89 ns	39.81 b
T4	4.88 b	4.03 ns	17.00 b	2.39 b	4.27 c	4.90 b	57.03 ns	41.04 b
Mean	5.04	4.22	18.50	2.47	4.73	5.21	57.44	45.27
SD	0.21	0.20	2.14	0.08	0.51	0.42	2.20	5.62
SEM	0.11	0.10	1.07	0.06	0.25	0.21	1.10	2.81
CV (%)	6.1	8.9	14.5	5.01	6.07	9.1	14.9	14.8

RS = River sand; PD = polar diameter; ED = equatorial diameter; NFPP = number of fruits per plant; NL = Number of locules; SS = soluble solids; PT = pulp thickness; FW= fruit weight; R = yield; SD = Standard Deviation; SEM = Standard Error of the Mean. The same letters by column correspond to non-significant differences at LSD ($P \leq 0.05$).

Number of fruits per plant

The analysis of variance of this variable, closely related to yield, showed a highly significant difference ($P \leq 0.01$) among treatments. The highest average value was obtained with treatment T2 (20.75 fruits•plant^{-1}), as shown in table 4. Considering whole digits, the descending order of treatment results for this variable was T2>T1>T4>T3, with values of 20, 19, 17 and 16 fruit•plant^{-1}, respectively.

The number of fruits per plant obtained in treatment T2 (VC without application of synthetic fertilizers) was lower only by two fruits, compared to 22.4 fruit•plant^{-1} reported by Ucan-Chan et al. (2005), who fertilized tomato crops with a nutrient solution (N 250, P 60, K 300, Ca 300, S 200, Mg 75, Fe 3, Mn 0.5, B 0.5, Cu 0.1 and Zn 0.1 mg•L^{-1}).

The range of NFPP obtained in this experiment (16 to 20 fruits•plant$^{-1)}$ was comparable to the range reported by Ramírez et al. (2005) in two experimental saladette tomato hybrids with determinate and indeterminate growth habit (18 to 25, and 16 to 23 fruits•plant^{-1}, respectively) after application of prohexadione-Ca, a growth retardant whose toxic effect on humans has not yet been fully clarified.

Number of locules

The analysis of variance showed highly significant difference ($P \leq 0.01$) for this variable among treatments with an average of 2.4 locules and a CV of 5.1%. The treatment T2 recorded the highest number of locules with 2.57, and the treatment showed the lowest number with 2.39 locules (Table 4).

Treatments T2 and T3, which included the largest concentrations of VC, statistically outperformed the control treatment T1 (artificially fertilized). As a result of application of VC to globe tomato, Moreno-Resendez et al. (2008) reported a similar behavior (5 and 4.9 locules on André and Adela genotypes, respectively) with the mixture VC:Sand; in this study, the treatment (12.5:87.5;%:% based on weight) also had a greater NL than the control group (100% sand with application of nutrient solution).

Soluble Solids

The analysis of variance for soluble solids demonstrated highly significant differences ($P \leq 0.01$) between treatments with an average of 4.73 °Brix and a CV of 6.07%. Comparison of means showed that control treatment (T1) recorded the highest value (5.36 ºBrix), followed by treatment T2 (4.92 °Brix), as shown in Table 4. Treatments T4 and T3 were statistically equal, and recorded the lowest values of SS.

Soluble solids concentration recorded in the present work, which ranged from 4.27 to 5.36 °Brix, was slightly higher than the range of 4.1 and 5.0 °Brix reported by de la Cruz Lazaro et al. (2009) when they evaluated tomato production using the hybrid SUN-7705, under greenhouse conditions by applying compost and VC mixed with sand, as growth media. Two tomato hybrids, Big Beef and Miramar, were studied by Rodríguez Dimas et al. (2008), and some results showed that in earthworm humus growth media, the concentration of SS ranged between 4.8 to 5.3 and 4.9 to 5.3 °Brix, respectively. The range of SS determined in this experiment greatly exceeded the 4.04 °Brix reported by Márquez-Hernández et al. (2008) when they used organic substrates during the production of tomato, with genotype Bosky, under greenhouse conditions.

Although the SS produced by treatments T2, T3, and T4 (which included the VC) were inferior to those of the control treatment (T1), their range of results (4.27 - 4.92 °Brix) can be fairly compared to the range that Diez (1995) established as optimal levels for tomato (4.4 to 5.5 °Brix). Therefore, it can be argued that VC application has a positive effect of on SS content.

It is possible to assume that the conductivity recorded in the VC (31.90 mS•cm^{-1}, Table 1), favored the SS content, which is consistent with the assumption reported by Goykovic-Cortez and Saavedra del Real (2007), that salinity on tomato plants causes positive effects because the fruit not only has higher acidity and carotenoid pigments, but also increases the SS contents. This benefit is of great importance, although the latter authors also have noted that the salts have adverse effects on germination and in different organs of tomato plants.

Pulp thickness

The treatments showed highly significant difference ($P \leq 0.01$) among each other when PT variable was tested. The highest value, 5.76 mm, was reached by treatment T2, followed by treatment T1, while treatments T3 and T4 showed decreasing values as VC content in the growth media was reduced (Table 4).

The results obtained in this experiment were surpassed by the values reported for globe tomatoes, genotypes Miramar and Big Beef, raised with earthworm humus by Rodríguez Dimas et al. (2008), who determined pericarp thickness of 8.4

and 7.0 mm, respectively; Márquez-Hernández et al. (2008) with genotype Bosky, using organic substrates as growth media, showed values between 7.0 and 8.9 mm. These differences are probably due to the type of tomato saladette evaluated in this experiment. However, the present study reveals that VC promotes the development of the outer covering of tomato, which could probably lead to a longer shelf life of the fruit, since the strength of the pericarp also increases fruit firmness (Mena-Violante et al., 2009).

Fruit weight

The fruit weight had no statistical difference among the different treatments evaluated. However, in Table 4 it can be seen that in treatment T2, the fruit weight was heavier than fruits from treatments T1, T3 and T4, with at least 2.6 g more of weight•fruit^{-1}. Even though there is no statistical difference, it can be noticed that as the amount of VC in the evaluated mixtures decreases, FW becomes lighter. This situation is complementary to the results reported by Atiyeh et al. (2000), who concluded that the application of small amounts of VC which were mixed with standard and high quality growth media, significantly enhanced the development of tomato plants.

The weight reported for fruits of saladette tomato from 54.89 to 60.23 g in this experiment was very similar to the ranges of 42.5 to 62.5 g and 61.3 to 63.4 g reported by Ramírez et al. (2005) for the same type, with indeterminate and determinate growth, respectively, after applying prohexadione-Ca, in order to slow plant growth, stimulate the formation of flowers and thereby increase the number of fruits. However, although in the case of this product is not clarified its mechanism of action, from the standpoint of endogenous hormone, there is evidence that other growth retardants, such as daminozide and chlormequat, have the disadvantage of a long period of persistence in plant tissue and toxicological effects to humans, which would restrict its application in organic farming systems.

Tomato yield

The analysis of variance for this variable, of great importance in the selection of an appropriate treatment to increase tomato production, recorded highly significant difference ($P \leq 0.01$) among treatments. As shown in Table 4, the maximum yield was obtained in treatment T2 (50.29 t•ha^{-1}), followed by control treatment T1 (49.93 t•ha^{-1}). Additionally, when comparing the best treatment (T2), treatmentsT3 and T4 were overpassed by 10.48 and 9.25 t•ha^{-1}, respectively.

The yields obtained in this study exceeded those reported by de la Cruz Lázaro et al. (2009), who assessed the same hybrid SUN-7705 with a mixture of vermicompost and sand 50%, and obtained 39.81 t•ha^{-1}; the difference in yield could be due to raw material and the time of preparation of VC used in each experimental work. As described above, the VC, whose chemical characteristics are presented in Table 1 (all the determinations were carried out in triplicate) used in this study was obtained after passing a mixture of three types of manure (goats, horses, rabbits, 1:1:1 ratio by volume), by a process of decomposition of 90 days, moisture was maintained to about 60–70% of water-holding capacity, watered with potable water (Mangrich et al., 2000; Ndegwa et al., 2000), while that de la Cruz Lazaro et al. (2009) used for the preparation of VC waste of cattle manure, Bahia grass (*Paspalum notatum* Flügge), and black soil (1:1:1, by volume) over a period of 60 days. Both procedures employed earthworms of the species *Eisenia fetida*.

It is necessary to comment that the maximum yield recorded in this experiment was obtained by harvesting only to the fifth cluster and was far below the 200 t•ha^{-1} reported by Flores et al. (2007), who used type saladette tomato, variety Tequila, with synthetic fertilizers, and harvested up to the eighth cluster. When averaged, the harvest per cluster obtained by Flores et al. (2007), can be estimated at 25 t•ha^{-1}, so that the yield on the fifth cluster would be 125 t•ha^{-1}; with this extrapolation, this value exceeds by 60% the maximum yield (50.29 t•ha^{-1}) obtained by treatment T2.

When talking about irrigation requirements, the above comparison becomes relevant when the productivity data of Flores et al. (2007) is extrapolated to obtain the number of kilograms of fruit per cubic meter of water used to the fifth cluster; the estimated productivity of these authors was 20.32 kg•m^{-3} (143 L•plant^{-1}), while the same variable found in the present study reached 30.66 kg•m^{-3}(40 L•plant^{-1}), as seen in Table 4. This situation corroborates that VC, as stated by Atiyeh et al. (2001) and Sharma et al. (2005), is a finely divided peat-like material with high porosity, aeration, drainage, water-holding capacity, and high microbial activity.

Conclusions

Since no synthetic fertilizers were used during the crop production, the results obtained in the present study suggest that VC, due to its physical, chemical, and biological characteristics, is able to satisfy the nutrient demand and to reduce the volume of water required by saladette type tomato, variety Sun-7705. Therefore, VC has potential to support the growth of the vegetable species when they are used as part of the potting media.

Also, from the results obtained it is possible to assume that VC, besides it provides essential elements in adequate quantities to meet crop nutrient demand, and due to its ability to promote moisture retention, could significantly reduce water consumption during the crop cycle without adverse consequences for productivity, which is of vital importance to the economy of farmers and the development of agriculture in semi-desert and desert regions of countries like México.

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