Article

Solarized bovine manure in tomato production under shade mesh conditions

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Abstract

In organic agriculture, the resources available in the region are used sustainably in order to reduce production costs, especially those related to fertilization. The use of organic fertilizers is an alternative for achieving this purpose. The objective of the present work was to evaluate the effect of solarized bovine manure on the production and quality of tomato fruits. A randomized block design with six repetitions was used; the treatments were four doses of solarized manure (0, 40, 80, 120 t ha^{-1}). There was no significant difference for the variables plant height, number of fruits and yield between the different doses of manure, however, with the application of 120 ton ha^{-1} the content of β-carotene and anthocyanins was increased by 60.14 and 64.17%, compared to the witness, respectively. Significant differences in soil pH and EC were recorded at the end of the crop cycle. The use of solarized manure is a sustainable option for the production of tomato in shade mesh, since similar results were obtained without the application of inorganic fertilization.

Keywords: carotenoids, organic fertilizers, yield.

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Introduction

Tomato (*Solanum lycopersicum*) is one of the most consumed products both fresh and processed worldwide (Zecchin and Mógor, 2017). Mexico is the tenth producing country with 3.3 million tons, with yields of 35.9 t ha^{-1} in the open field, 120.3 t ha^{-1} in shade mesh and 175.1 t ha^{-1} in greenhouse conditions (SAGARPA, 2016). Tomato fruit has high contents of bioactive compounds such as folate, ascorbate, polyphenols, carotenoids, vitamins and other essential nutrients, due to this, they are extremely valuable for human health (Ahmed *et al*., 2017).

Excessive amounts of fertilizers and agrochemicals are used in tomato production, which in addition to cost implications, generate risks to human health and the environment (Valenciano and Uribe, 2015). In this context, a sustainable alternative to: i) mitigate the negative environmental effects of fertilizers; ii) reduce the pollution rates of solid organic waste generated in cattle production systems; and iii) improve the organoleptic and nutraceutical quality of the fruits, is the use of organic fertilizers such as vermicompost, compost and solarized bovine manure (Salas-Pérez *et al.*, 2017; Fortis-Hernández *et al.*, 2018).

In addition to the above, the benefits of the use of organic fertilizers are diverse, since in addition to providing organic matter and nutrients, they improve the physical-chemical characteristics (e.g. structure, moisture retention and fertility) of the soil, increase the microbial population present in the soil and has been shown to reduce some diseases induced by soil phytopathogenic fungi (Vázquez *et al.*, 2011; López *et al.*, 2014; Valadez *et al.*, 2). The nitrogen provided by organic fertilizers is organic, which gradually becomes mineralized for the absorption of plants (Ramos and Terry, 2014).

Solarized manure is obtained from the process called solarization, which consists of making mounds of one meter high of manure, moistening up to 25% and covering with plastic without albedo, thus increasing the temperature >60 °C in variable time according to weather conditions and the season of the year of the place (López *et al*., 2014). On the other hand, with the use of solarized manure, production costs are reduced as it is cheaper than fertilizers, being a viable alternative for crop production. In this sense, the objective of the present work was to evaluate four different doses of solarized bovine manure on the production and quality of tomato fruits in shade mesh conditions.

Materials and methods

Study site

The experiment was carried out in a shadow mesh of the company Ganadera-VIGO SA de CV, located at km 21 of the Torreón-San Pedro, Coahuila highway in the parallel 25° 43’ 05’’ north latitude and in the meridian 103° 19’ 19’’ west longitude and at a height of 1 110 masl.

Treatments

The treatments evaluated were four doses of solarized manure (0, 40, 80, 120 t ha^{-1}) in an experimental design of randomized blocks with six repetitions, each experimental unit consisted of sowing beds of 2 m long (1 m between beds), with a distance of 15 cm between floors. The manure used was solarized making a mound of 1 m high and 2 m wide by 3 long, then running water was applied until it reached a moisture content of 55% in order to have a better temperature distribution, followed by covered with a polyethylene plastic without albedo, applying soil around the edges of the plastic.

The nitrogen content of the solarized manure was analyzed using the Kjeldahl method. The amount of nitrogen in the treatments was based on the analysis of the solarized manure, considering that 30% of the N in the manure would mineralize in the first year (Eghball, 2000).

Sampling of the experimental area

Before the establishment of the crop, 10 random soil samples were taken throughout the experimental area. The initial physicochemical characteristics of the soil of the experimental site are presented in Table 1. The pH and electrical conductivity were determined in saturation extract, the texture by the Bouyucos method. The amount of organic matter was estimated with the Walkley-Black method, in addition the bulk density was determined by the paraffin method, according to NOM-021-SEMARNAT-AS-02 (NOM-021-RECNAT, 2001). It should be noted that the pH, electrical conductivity and organic matter content were determined in each experimental unit again at the end of the crop cycle.

Table 1. Physical-chemical parameters of the soil at the beginning of the crop cycle.

Depth	pH	EC (dS m^{-1})	PSI (%)	OM (%)	P (ppm)	Texture	Apparent density (g cm^{-3})
0-30	8.05	2.65	9	1.15	13.5	Loam	1.2

EC= electric conductivity; PSI= exchangeable sodium percentage; OM= organic material; P= available phosphorus.

Crop management

The plant material used was tomato cv. Sahel, which was planted in 200-cavity polystyrene trays (one seed per cavity), which contained Peat Moss (Premier Promix P6X, Quebec, Canada) as a substrate. The trays were covered with a black plastic bag, and it was irrigated daily with a manual atomizer (Truper®, Mexico) until the seeds germinated. The transplant was performed in planting beds when the seedlings had an average between 10 and 15 cm in height and 3 to 5 true leaves, at a distance of 15 cm between plants, with a density of 6.6 plants m^{-2}.

The irrigation of the plants was carried out with a belt twice a day. The pollination was carried out by means of bumblebees (*Bombus*) placing a honeycomb every 30 m^2. The plants were pruned and guided to a single stem and tutored with raffia.

Variables evaluated in plant

Plant height was measured with a flexometer (Truper®, Mexico) from the base of the stem to the apex of growth, the stem diameter was determined at 1 cm from the base of the stem with a digital vernier (Truper®, Mexico), these variables were evaluated at the end of the crop cycle. The number of fruits and yield (t ha^{-1}) was obtained considering the commercial size fruits from the first to the tenth cluster per plant. The average fruit weight was obtained using an analytical scale with a resolution of 0.1 mg Shimadzu® brand.

Carotenoids

Lycopene and β-carotene

The concentration of lycopene and β-carotene was determined by spectrophotometry according to Fish *et al*. (2002), with modifications. For this, 1 g of ground tomato was taken which was mixed with 20 mL of acetone: ethanol: hexane (1:1:2, v/v). The obtained mixture was subjected to an ultrasonic bath (Branson, model 3510, China) for 15 min at 30 °C at a frequency of 40 kHz. To the above mixture was added 5 mL of distilled water which was vigorously stirred for 2 min in a vortex, then the sample was centrifuged at 10 000×g for 10 min (Thermo Scientific, model ST 16R, Germany).

In spectrophotometer (Jenway, Techne Inc., model 6715 UV/Vis, USA) the absorbance to the supernatants at 503 and 478 nm was recorded for lycopene and β-carotene, respectively. The carotenoid concentration was determined using standard curves and expressing the results in mg of lycopene and β-carotene per 100 g of fresh weight (PF).

Anthocyanins

Anthocyanins were determined according to the technique described by Lee *et al*. (2005), by difference in pH and were expressed as equivalent mg of cyanidine 3-glycoside per 100 g of dry sample.

Statistical analysis

The results obtained were analyzed by means of an analysis of variance and where significant differences were detected, the separation of means was performed using the Tukey test ($p\leq 0.05$), using SAS 9.3 program (SAS, 2016).

Results and discussion

Plant height

Plant height was not affected by the doses of solarized manure used (Table 2). A greater height increases the number of leaves and greater area to perform photosynthesis and consequently the yield (Rodríguez *et al*., 1998). Plant height was similar to that reported by Márquez *et al*. (2006); Márquez-Hernández *et al*. (2013), the highest plant height was recorded in the treatment with 120 t ha^{-1}, probably due to the presence of natural hormones such as biostimulators and growth regulators and humic acids, generated by microorganisms capable of producing auxins, cytokinins and gibberellins (Azarmi *et al.*, 2008; Mahmoud *et al.*, 2009).

Number of fruits

The supply of solarized manure did not affect the number of fruits per plant (Table 2), with the use of any dose of manure the greatest amount of fruits per plant is obtained, these results could be related to the effect of the set of phytohormones promoters present in the applied organic fertilizers (Ramos and Terry, 2014) and humic substances of low molar mass to which properties similar to these phytohormones are attributed (Murillo *et al*., 2016), which could favor the production of flowers and fruit curds of greater weight.

Yield

No significant difference was detected for the yield variable due to the application of different doses of solarized manure. However, the dose of 120 t ha^{-1} exceeded 6% of the control treatment (Table 2). The previous results could be attributed to the improvement of the physicochemical and microbiological properties of the soil due to the use of manure (Hernández-Rodríguez *et al*., 2010). The poor response in the yield of manure treatments is probably due to the fact that microorganisms require nitrogen for their metabolism and thus be able to initiate manure transformations, whereby nitrogen undergoes immobilization; which could explain the non-response in yield the first year of its application (Salazar-Sosa *et al*., 2004).

Table 2. Average values of plant height, number of fruits, tomato yield, by effect of four doses of solarized manure.

Manure (t ha^{-1})	Height (cm)	Number of fruits	Yield (t ha^{-1})
0	191	28	127
40	191	30	132
80	191	30	132
120	195	30	135
Significance	ns	ns	ns

Means values of treatments with different letters in a column are statistically different according to the Tukey test ($p \leq 0.05$). ns= not significant.

The results obtained in this work are consistent with the provisions of Tüzel *et al*. (2004) who mention that organic fertilizers are an alternative to replace inorganic fertilization; in addition to the price of the product being organic, it increases from 20 to 40% with respect to the value obtained in the traditional system (Sloan, 2002; Hernández-Rodríguez *et al*., 2010), the commercial value of such production would be greater than a conventional production.

Carotenoids

Regular consumption of tomatoes has been correlated with the reduction in the risk of suffering a variety of pathologies such as cancer and cardiovascular diseases (Borguini and Ferraz, 2009). This positive effect is attributed to antioxidants, in particular, carotenoids (lycopene and β-carotene), which have the ability to neutralize reactive oxygen species and prevent oxidative changes in the human body (Gutiérrez-Tlahque *et al*., 2018; López-Palestina *et al*., 2018). These results indicate a higher content of carotenoids (β-carotenes and lycopene), as the dose of manure is increased (Table 3).

Table 3. Average values of β-carotene, lycopene and anthocyanins in tomato fruits, by effect of four doses of solarized manure.

Manure (t ha^{-1})	β-carotene (mg 100^{-1} PF)	Lycopene (mg 100^{-1} PF)	Anthocyanins (mg cyanidine-3- glycoside 100 g^{-1} PS)
0	1.38 c	4.75	0.067 b
40	2.15 ab	4.8	0.10 a
80	1.49 bc	5.23	0.75 ab
120	2.21 a	5.29	0.11 a
Significance	*	ns	*

Means values of treatments with different letters in a column are statistically different according to the Tukey test ($p \leq 0.05$). *= significant $p < 0.05$; ns= not significant.

It is known that lycopene content varies with the dose and type of fertilization, harvest time, variety and environmental conditions (Waliszewski and Blasco, 2010), in this regard Illera-Vives *et al*. (2012), indicates that the increase in carotenoids is associated with an increase in salinity of the radical environment, therefore, manure by having an excess of soluble salts, can cause stress that increases the production of these carotenoids. Borghesi *et al*. (2011), reported that saline stress increases in the tomato fruit the concentration of carotenoids and anthocyanins, the above represents an option with exploitation potential to obtain fruits of tomatoes with higher nutraceutical quality.

Soil parameters at the end of the crop cycle

Hydrogen potential

The application of solarized manure modified the soil pH (Table 4). Any dose of manure increased soil pH relative to the control, similar results have been reported by Fortis-Hernández *et al*. (2009) and Trejo-Escareño *et al*. (2013), who indicate increases in pH with increases in the amount of manure applied to the soil; these pH increases are due to the fact that the ammonification acts as a large proton sink, thus favoring the increase in pH.

Electric conductivity

The electrical conductivity was affected by the different doses of manure used, obtaining the highest electrical conductivity, with the highest doses of manure (Table 4). Eghball (2000) indicates that in farms where manure and residual compost were applied, the electrical conductivity is increased by the effect of the decomposition of the residual OM, which increases the concentration of Ca, Mg and K in the soil.

In this same sense Trejo-Escareño *et al*. (2013), indicate that high doses of manure significantly increase the electrical conductivity in the soil because the mineralization of manure releases high amounts of anions and cations, which leads to increased soil salinity; due to the above, the doses of applied manure should be taken care of since its use without some control method such as soil analysis can cause salinity problems, causing loss of soil structure or inhibition of plant growth (Smith *et al*., 2001), especially in soils with continuous application of manure.

Organic material

The analysis of variance for the content of the organic matter in the soil, did not detect significant differences between the doses of manure and the control; however, as the dose of manure increased, the organic matter increased slightly (Table 4), the above, evidences the favorable effects of the use of manure, especially high doses, this fertilizer being an option to recover the organic matter in degraded soils (Ochoa *et al*., 2009). Organic matter is fundamental in the search for sustainability in agriculture (Johnston *et al*., 2009) and its adequate presence in the soil improves the buffer capacity, enriches the cation exchange capacity, improves the soil structure avoiding erosion and it allows the development of the micro and macro beneficial fauna of the soil (Aslantas *et al*., 2007).

Table 4. Average values of pH, EC and OM in soil at the end of the crop at a depth of 0-30 cm, due to the effect of four doses of solarized manure.

Manure (t ha^{-1})	pH	EC (dS m^{-1})	OM (%)
0	7.7 b	3.1 b	1.3
40	8.4 ab	3.1 b	1.4
80	8.1 a	3.6 ab	1.5
120	7.9 ab	4.3 a	1.6
Significance	*	*	ns

Means values of treatments with different letters in a column are statistically different according to the Tukey test ($p\leq 0.05$). EC= electrical conductivity; OM= organic matter; *= significant $p< 0.05$; ns= not significant.

Conclusions

The use of solarized manure promoted greater yield and nutraceutical quality in tomato fruits, under the conditions of the present experiment. The treatment with 40 t ha^{-1} of solarized manure improved significantly the nutraceutical quality parameters in tomato fruits. The use of manure affected the soil properties, by increasing the electrical conductivity and modifying the pH, manure doses should be taken care of since this when applied in high quantities can cause salinity problems. Therefore, the use of solarized manure is a sustainable option for the production of tomato in shade mesh.

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