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Use of organic alternatives in the production system of habanero pepper (*Capsicum chinense* Jacq.) under greenhouse conditions

Pedro Vázquez Vázquez* and Merle C. Navarro Cortez

División de Ingenierías en Ciencias Agropecuarias, Universidad Tecnológica de la Costa, Santiago Ixcuintla, Nayarit, México.

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Cultivation of pepper has become the fastest growing practice in recent years, and specifically, habanero pepper which has surpassed its traditional area of cultivation, and has expanded to other areas, conquering the markets of the rest of the country and the world. In the present study, 3 doses of solarized manure (40, 60 and 80 t ha^{-1}) and an absolute control were evaluated for the production of habanero pepper (*Capsicum chinense* Jacq). The results indicated a significant difference between treatments for the plant height at 30 and 90 days after transplantation. However, for the variables: fruit number and fruit weight (kg per experimental unit, kg m^{-2} and kg per plant), the results indicated that there was no significant difference among the treatments evaluated. For the variables: polar diameter of the fruit, a significant difference was observed. However, the treatments did not show a significant effect on the equatorial diameter of the fruit.

Key words: Solarized manure, habanero pepper, organic fertilizers.

INTRODUCTION

Cover cropping in Mexico has been booming in recent days, and by 2010, 12,000 hectares of land for horticultural crops, such as tomato, cucumber, peppers and habanero pepper were quantified, with habanero pepper having greater profitability in the domestic market and in the export market (Macías et al., 2013).

According to Ramírez and Vázquez (2007), peppers have become the fastest growing vegetable in recent years, and the habanero pepper has surpassed its traditional area of cultivation, conquering the markets of the rest of the country and the world, achieving an average yield of 14 t ha^{-1}. Habanero pepper originates from the Amazon basin, but dispersed to Peru, Colombia, Venezuela, Guyana, Suriname, French Guiana and the Caribbean Antilles during the pre-Hispanic period (Salaya, 2010).

In 2004, the production of habanero pepper in the state of Veracruz, as observed by Ruiz (2009) was not greater than 7 t ha^{-1}. Borges et al. (2010), pointed out that for the same year, yields of habanero pepper in the states of

*Corresponding author. E-mail: pvazquez70@hotmail.com Tel: +52 323 23 5 80 00 29. Fax: 52 323 23 5 42 25.

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Table 1. Solarized manure (SM) effect on the mean values of plant height at 30, 60 and 90 DAT (days after transplanting).

Treatments (t SM ha)	Plant height (cm)		
	30 DAT	60 DAT	90 DAT
Absolute control	12.7[b]	33.1[a]	59.9[b]
40	16.3[ab]	46.5[a]	86.2[ab]
60	20.8[a]	57.9[a]	84.7[ab]
80	19.4[ab]	58.6[a]	96.3[a]

Means followed by the same letter in the column do not differ significantly by the Tukey test ($p < 0.05$).

Yucatan, Tabasco, Campeche, Quintana Roo, Veracruz and Chiapas were 5.0, 7.7, 7.1, 10.9, 6.3, 15 and 5.9 t ha^{-1}, respectively, and Macías et al. (2013) reported that in states of Yucatan, Campeche and Quintana Roo, yields were 10 to 40 t ha^{-1} in the open field and 7 to 12 kg m^{-2} under protected agriculture conditions.

Habanero pepper is the main commercial species exploited in the Yucatan Peninsula. This species is of great commercial interest, as a result of the high content of capsaicinoids in the fruit, which can be influenced by the conditions of water stress or nutritional management of the culture (Borges et al., 2010). However, as Sánchez et al. (2010) pointed out, these capsaicinoids are alkaloids that have great importance in human, alimentary and pharmaceutical health, and they are only produced by plants of the genus Capsicum, synthesized in the cells of the surface of the placenta of the mature fruits, and are later deposited in the seeds and walls of the endocarp, as pointed out by González et al. (2006). Pacheco (2005) mentioned that it is used in some drugs for combating gastrointestinal atony and some cases of diarrhea, and this species is used to make capsules that improve blood circulation.

According to Herencia et al. (2011), organic nutrition can improve with practices such as rotating crops with legumes. However, according to Castro et al. (2009), organic fertilizers have high concentrations of macronutrients, and this concentration may vary due to moisture content, so, the analysis of total contents may be a reference for the richness of organic fertilizers. According to Durán and Henríquez (2007), Potassium (K) is an element that is characterized by its low affinity to organic fertilizers; nevertheless, some organic fertilizers contain appreciable amounts of this element.

MATERIALS AND METHODS

The present study was carried out under greenhouse conditions, at the Universidad Tecnológica de la Costa, in the municipality of Santiago Ixcuintla, Nayarit, Mexico. Three doses of solarized manure (40, 60 and 80 t ha^{-1}) and an absolute control were evaluated on the production of habanero pepper (*Capsicum chinense* Jacq). One week prior to transplantation, bovine manure with a moisture content of 56% was incorporated in each of the experimental units (one row of 6 m length or 6 sq m), according to the dose established for the different treatments. It should be noted that the solarized manure was covered with a transparent plastic and kept in a place where it was exposed to the sun most of the day for a period of 6 weeks (May 21, 2014 to July 1, 2014). The transplantation was performed on July 7, 2014, in furrows of 6 m long, 1 m between furrows, and 0.5 m between plants. A randomized block experimental design with three replicates per treatment was used.

The variables that were measured were: plant height (cm) at 30, 60 and 90 days after transplantation, number of fruits and fruit weight (kg) per experimental unit, fruit weight per m^2, fruit weight per plant, polar and equatorial diameter of the fruit. The analysis of variance and the Tukey comparison of means of treatments of the measured variables were performed with the statistical package SAS 9.1.

For nutritional management, foliar sprays of worm humus leachate were weekly applied at a rate of 10 L ha^{-1} from 15 days after transplanting. Also, weekly applications of compound tea mixed with water, at the rate of 1: 1 v/v, directed to the base of the plant in drench. Wormhole leachate solution was prepared by mixing vermicompost and water (1:3 v/v) in a cement stack with a slope of 5%, with an exposure time of 4 weeks; after the time the leachate was ready to be applied.

Compost tea was prepared as follows: a sack filled with 20 kg of compost was placed in a 100-L plastic drum, water was added to make up the total volume of the drum and left to rest for 3 days. Irrigation was done by dripping, using irrigation ribbons with a distance between drippers of 0.15 m. For weed control and moisture conservation, seed beds were quilted with reused newspaper. Pest management was carried out with weekly applications of the biological insecticide made of *Bacillus thuringiensis*, and botanical extracts from garlic, onion and soap.

RESULTS AND DISCUSSION

In Table 1, it is observed that at 30 days after transplantation, there was a significant difference among the evaluated treatments on plant height. The application of 60 t of solarized manure per hectare (60 t SM ha^{-1}) had the highest plant height of 20.8 cm, as compared to the treatments of 80 and 40 t SMha^{-1} and the absolute control, which obtained 19.4, 16.3 and 12.7 cm of plant height, respectively. However, at 60 days after transplantation, the results indicated that for this same variable, there was no significant difference between treatments, but at 90 days, a significant difference was observed between treatments. The treatment of 80 t SM ha^{-1} reached the highest plant height with 96.3 cm, followed by the application of 40 and 60 t SMha^{-1} with 86.2 and 84.7, respectively. The absolute control had the lowest (59.9 cm). The results were higher than those obtained by López et al. (2012), when evaluating the effect of manure, compost, bocashi, vermicompost tea on habanero pepper growth and yield of fresh fruit. In fact, their results indicated that the infusion of manure significantly increased those variables than other evaluated treatments, especially for plant height with 52 cm after 90 days of transplantation, while the lowest height was obtained by the control with a value of 17 cm.

In relation to the variables, fruits numbers and fruit

Table 2. Effect of solarized manure on habanero pepper yield variables, fruit number and weight.

Treatments (t SM ha^{-1})	Fruits numbers	Fruit weight (kg/m^2)	Fruit weight (kg m^{-2})	Fruit weight (kg plant^{-1})
Absolute control	998.7^a	12.3^a	2.05^a	1.03^a
40	771.7^a	9.1^a	1.52^a	0.76^a
60	888.8^a	12.8^a	2.13^a	1.07^a
80	1183.5^a	15.1^a	2.52^a	1.26^a

SM = Solarized manure; means followed by the same letter in the column do not differ significantly by the Tukey test ($p < 0.05$).

Table 3. Solarized manure (SM) effects on polar and equatorial diameter of habanero pepper fruit.

Treatments (t SM ha^{-1})	Polar diameter (cm)	Equatorial diameter (cm)
Absolute control	4.70^{ab}	3.17^a
40	4.37^b	2.90^a
60	4.47^b	3.10^a
80	5.07^a	3.10^a

Means followed by the same letter in the column do not differ significantly by the Tukey test ($p < 0.05$).

weight (kg per experimental unit, kg per square meter and kg per plant) (Table 2) showed that there was no significant difference between the evaluated treatments. These observations may be due to the fact that the availability of nutrients from organic fertilizers is usually low and inconstant as compared to inorganic or mineral fertilizers, since organic requires previous mineralization that can last from weeks to several months, according to Soto (2003). Evanylo et al. (2008), also pointed out that organic fertilizers are considered as soil improvers and that their properties depend on the degree of mineralization of the material used.

However, the results of fruit weight per plant, found in some treatments of the present experiment, such as the applications of 80 and 60 t SM ha^{-1}, which obtained 1.26 and 1.07 kg per plant were higher than those found by López et al. (2012) when evaluating different organic fertilizers on the yield of habanero pepper; the used manure infusion treatment, obtained 949 g per plant. In contrary, the results of the present experiment were lower than those reported by Macías et al. (2013) from a greenhouse study in the states of Yucatan, Campeche and Quintana Roo, where they obtained 7 to 12 kg m^{-2} of fruit**.**

The treatments evaluated had a significant effect on polar diameter of the fruit (Table 3). The applications of 80 t SM ha^{-1} showed the highest diameter of 5.07 cm which was followed by absolute control treatment with a diameter of 4.70 cm, and the applications of 60 and 40 t SM ha^{-1}, with 4.47 and 4.37 cm in diameter, respectively. For the equatorial diameter of the fruit, the results showed that there was no significant difference between the evaluated treatments.

Conclusions

The results of the present study indicate that there was a significant difference between the evaluated treatments, absolute control, 40, 60 and 80 t SM ha^{-1} for plant height at 90 days after transplant, and fruit size (polar diameter). However, there was no significant difference for the yield components: Number and weight of the fruit. This suggests some other evaluations to observe the effect of the solarized manure on later cycles derived from the additive effect in the soil.

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