Original Article

TOMATO YIELD AND QUALITY UNDER VARIOUS COMBINATIONS OF ORGANIC COMPOST

PRODUÇÃO E QUALIDADE DE TOMATE CULTIVADO SOB OITO TIPOS DE COMPOSTO ORGÂNICO

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ABSTRACT: The number of growers and planted area dedicated to organic farming have increased considerably. Consequently, demand has increased for alternative organic composts in terms of quantity and new options for direct use with crops. Making use of local industrial byproducts is also important throughout Brazil and the rest of the world. Therefore, it was evaluated the effect of eight types of organic composts, produced with different percentages of poultry litter and crushed sugarcane on tomato yield and quality. The experiment was carried out during the 2013 growing season at the experimental farm of the Agricultural Research Company of Minas Gerais state (*Empresa de Pesquisa Agropecuária do Estado de Minas Gerais*) located in Prudente de Morais, MG, Brazil. It was evaluated different formulations of poultry litter and crushed sugarcane (0, 10, 20, 30, 40, 50, 50, 60 and 70%) yielding eight types of alternative Bokashi used as organic compost in the production of two tomato cultivars (Santa Clara and the Verano hybrid). It was found that the various formulations of alternative Bokashi, except the alternative Bokashi B1, strengthened components of tomato yield and quality. We found that composts of poultry litter and crushed sugarcane increase tomato yield and quality and can be and excellent alternative, especially for organic farmers.

KEYWORDS*: Solanum lycopersicum. S*ustainability. Poultry litter. Bokashi.

INTRODUCTION

Brazilians and others around the world are opting for organic products. Currently, more than 750,000 hectares of farmland in Brazil are managed organically. From 2014 to 2015 the number of organic farmers in Brazil increased by 51.7% with the greatest concentration (333,000 hectares) in the southeast of the country (MAPA, 2015). Increases in the area of cultivated land have led to greater demand for organic fertilizers. Moreover, higher prices for inorganic fertilizer have sparked interest in alternative fertilizers and especially in locally available organic fertilizers.

Organic fertilizers are highly beneficial for plants, especially when applied months before planting (FILGUEIRA, 2008; SEDIYAMA, et al., 2014). Tomatoes require relatively high fertilizer applications to maximize productivity. Most soils in the Brazilian state of Minas Gerais require 1,200 kg ha^{-1} of P_2O_5 to produce 100 tons of tomatoes per hectare in conventional cultivation (FILGUEIRA et al, 1999). Conversely, reducing applications of P_2O_5 by up to 100 kg ha^{-1} on tomato crops can save BR R$200.00 per hectare or approximately BR R$ 11 million nationwide (SILVA; MALUF, 2012).

Bokashi organic compost supplies organic plant nutrients and results from composting with anaerobic bacteria (EM-Effective Microorganisms), yeasts and lactic acid specific to organic compost (SOUZA; RESENDE,2003).

Growers have also used poultry litter as an organic compost. Poultry litter includes all the material used as floor covering in poultry production facilities and is contaminated with bird droppings, leftover feed and feathers (MENEZES et al., 2004).Composting this residue for use as a solid organic fertilizer minimizes environmental damage that might have otherwise resulted from the accumulation of this material (ÁVILA et al., 2007).Using poultry litter in agriculture improves the yield and quality of various species (BOATENG et al., 2006; ADELI et al., 2007; SILVA et al., 2011; VIEIRA et al., 2015) such as tomatoes (MUELLER et al., 2013) and improves attributes of the soil (VALADÃO et al., 2011).

Received: 01/02/16
Accepted: 06/06/16

Crushed sugarcane has characteristics that are beneficial to agriculture. Several studies have confirmed the benefits of this byproduct of sugar and alcohol production (CALGARO, et al., 2008; SEDIYAMA et al., 2011; SEDIYAMA et al., 2014).

Although results are promising, information is scarce on the influence of new Bokashi formulations that combine poultry litter and crushed sugarcane, on tomato quality and yield. Therefore, we studied the effect of eight organic composts with different percentages of poultry litter and crushed sugarcane on tomato quality and yield.

MATERIAL AND METHODS

The experiment was carried out at the Santa Rita experimental farm of the Agricultural Research Company of Minas Gerais state (*Empresa de Pesquisa Agropecuária do Estado de Minas Gerais - EPAMIG/URECO – Fazenda Experimental Santa Rita*) located in Prudente de Morais, MG, Brazil (19º27'29,99"S, 44º08'58,13" and at an altitude of 709 m). The soil, Dystrophic Red Latosol clay texture (Embrapa, 1999) conventional cultivation, presented soil with the following characteristics: pH H_2O =6.7; H+Al = 2.69 ($cmol_c\ cm^{-1}$); P Mehlich = 58.679(mg/dm^3); Organic matter (Carbon %) = 5.01; Al = 0.006 ($cmolcdm^{-3}$); Ca = 8.51 ($cmolcdm^{-3}$); Mg = 1.24 ($cmolcdm^{-3}$); K = 317.51 ($mgdm^{-3}$); SB = 10.562 ($cmolcdm^{-3}$); CEC = 13.252 ($cmolcdm^{-3}$). According to Köppen, the climate of the region was classified as Cwa (mesothermal climate with hot and rainy summer), annual average temperature of 22.1 ° C with a minimum of 10.7 ° C, taking place in July and maximum of 29, 3 ° C in February. The average annual rainfall is 1,340 mm, 1,155 mm from November to April and 185 mm from May to October. Two tomato cultivars were used: cv. Santa Clara and Verano.

Seeds were sown on March 4, 2013 in 128 cell polystyrene trays that had been filled with earthworm humus (34.6 cm3 per cell). Seeds were placed two per cell with later thinning leaving one seedling per cell. There was no need supplemental fertilization of seedlings. The seedlings were grown in a greenhouse.

Eight types of organic composts called "Alternative Bokashi" (AB) were prepared, wetted and inoculated with effective microorganisms (EM-4) and curdled milk (Table 1).

Table 1. Composition of the eight Alternative Bokashi formulations used in tomato production (SeteLagoas, UFSJ, 2013).

Ingredients(Kg)	ALTERNATIVEBOKASHITYPES							
	AB1	AB2	AB3	AB4	AB5	AB6	AB7	AB8
*PoultryLitter	0	10	20	30	40	50	60	70
**Crushed Sugarcane	70	60	50	40	30	20	10	0
MagnesiumThermophosphate	20	20	20	20	20	20	20	20
Charcoal (fine powder)	10	10	10	10	10	10	10	10
Total (kg)	100	100	100	100	100	100	100	100

* mixture of corn cobs and corn crop residues **mature sugarcane

Each formulation received the same application of 20 kg of magnesium thermophosphate and 10 kg of charcoal (fine powder) regardless of the proportions of poultry litter and crushed sugarcane.

In order to assess the different combinations of organic composts and possible interactions "cultivars x Bokashi type," we conducted a field experiment consisting of randomized blocks in a 2 x 8 factorial arrangement [two tomato cultivars (Santa Clara and Hybrid F1 Verano) and eight combinations of organic compounds called Alternative Bokashi (AB)], with three replicates for a total of 16 treatments.

It was used as control an original formulation of organic compound developed by EMATER-MG Sete Lagoas and called for technicians and producers as "Alternative Bokashi" composing the AB4 treatment. The plots consisted of eight plants (spaced 1m x 0.5m) in a total area of 4 m^2 (2m x 2m). Four plants were evaluated from the central 2 m^2 (2m x 1m) of each plot.

The eight types of AB were ready twenty-eight days after forming the organic composts. The composts were odorless and darkly colored at the time of application.

The seedlings were transplanted into the field thirty-five days after sowing. In planting was applied 1 kg of each type of AB per plant and then, were held six fertilization in coverage with the first cover, performed at 10 days after transplanting. The other covers, a total of five covers, were spaced 15 days from the first coverage. In the first three covers was used 100 grams of each type of AB per plant and the remaining three covers was used 200 grams of AB per plant a total fertilization (planting and coverage) 1900 g per plant.

The crops were managed organically (SOUZA; RESENDE, 2003).

The following yield characteristics were evaluated: Total Yield, Commercial Yield, Non-Commercial Yield, Total Yield per Plant, Commercial Fruit Yield per Plant, Total Number of Fruits per Plant, Number of Commercial Fruits per Pl Number of Fruits per Bunch, Number of Commercially-viable Fruits per Bunch, Number of Non-commercial Fruits per Bunch, Total Fruit Mass and Commercially-viable Fruit Mass.

The following physicochemical characteristics of the fruit were also measured: dry matter, °Brix, pH and titratable acidity.

Total soluble solids were measured using a digital refractometer (R2mini) and expressed as °Brix. Dry matter content was calculated as the difference between the initial and final weight of a sample dried in a vacuum oven at 70 ° C (AOAC, 2002). pH was determined using a potentiometer and titratable acidity with 0.01 N NaOH solution and phenolphthalein as an indicator (AOAC, 2002).

Data were submitted to analysis of variance where the sum of mean squares was compared by an F test (α=0.05). Means were compared by the Tukey test (α=0.05).Data were evaluated using SISVAR (FERREIRA, 2008) statistics software.

RESULTS AND DISCUSSION

For none of the characteristics that make up the components of the production was no significant interaction between factors (cultivars and types of Bokashi). It was observed significant differences for all traits, both level of cultivars as well as level of Bokashi. However, for Bokashi the difference occurred only AB1 (Table 2).

Table 2. Total Yield (TY) Commercial Yield (CY), Non-Commercial Yield (NCY), Total Yield per Plant (TYP), Commercial Fruit Yield per Plant (CFYP), Total Number of Fruits per Plant (TNFP), Number of Commercial Fruits per Plant (NCFP) as a function of different Bokashi types (Sete Lagoas, UFSJ, 2013).

BokashiType	Yield Components -YC(t ha^{-1})					YC –Unit	
	TY	CY	NCY	TYP	CFYP	TNFP	NFCP
B1	34.28b	18.29b	16.00b	1.71b	0.91b	17.33b	7.79b
B2	84.50a	53.48a	36.21a	4.22a	2.67a	33.08a	16.43a
B3	82.29a	49.23a	33.05a	4.11a	2.46a	34.25a	18.62a
B4	84.26a	44.09a	40.16a	4.21a	2.20a	34.87a	16.37a
B5	91.36a	46.61a	44.74a	4.56a	2.33a	37.70a	17.37a
B6	91.06a	48.76a	42.22a	4.55a	2.43a	36.95a	18.20a
B7	83.37a	44.49a	38.39a	4.14a	2.22a	34.75a	15.70a
B8	95.56a	50.26a	45.29a	4.77a	2.51a	40.70a	20.20a
Cultivars							
Santa Clara	81.27a	38.84b	41.54a	4.01a	1.94b	30.86b	13.31b
Verano	80.38a	49.97a	32.48b	4.05a	2.49a	36.55a	19.36a
CVs (%)	16.07	18.67	22.97	16.13	18.67	13.02	22.11

Means followed by the same letter within a column do not differ by the Tukey test at 5%.

Total yield losses varied from 40.16 to 48.97% regarding the various types of Bokashi. These losses consisted of fruits that were deemed non-commercial. A portion of these losses was due to an intense attack by tomato moths (*Tuta absoluta*) and large tomato borers (*Helicoverpa zea*) which were controlled by biological measures (the *Trichogramma* egg parasitoid).

In terms of commercial production (Table 2) the means achieved were below Brazilian averages (58.55 t ha^{-1}) from the five producing regions (AGRIANUAL, 2008). However, total yield values (80.38 – 95.56 t ha^{-1}) with Alternative- Bokashi formulations (except B1) were higher than national averages (AGRIANUAL, 2008). The ratios of poultry litter to crushed sugarcane in treatments B2 through B8 did not influence any of the characteristics evaluated.

Averages for total fruit yield per plant and commercial yield per plant did not differ among treatments except for treatment B1 where the values of both of these components were lower (Table2). Values for the Santa Cruz tomato group were higher than those found by Higuti et al. (2010) who worked with different groups of tomatoes using conventional production practices and found means of 2.36 kg plant^{-1} (total yield) and 1.76 kg plant^{-1} (commercial yield) for the Deborah hybrid in the

Santa Cruz group. Regardless of total yield, the percentage of rejected fruit was high (> 50%). This result affected all yield components including the number of commercially viable fruits per plant.

No significant differences were found among treatments (except for treatment B1) regarding Number of Fruits per Bunch, Number of Commercially-viable Fruits per Bunch, Number of Non-commercial Fruits per Bunch, Total Fruit Mass and Commercially-viable Fruit Mass (Table 3). It was also not observed the interaction between the factors (tomato cultivars and types of bokachi) Conversely, the Number of Fruits per Bunch and Number of Commercially-viable Fruits per Bunch were significantly higher for the hybrid cultivar Verano than for the Santa Clara cultivar (Table 3). However, these differences may be attributed to plant genotype as a function of the different organic composts. Therefore, future studies should evaluate more genotypes.

Table 3. Number of Fruits per Bunch (NFB), Number of Commercially-viable Fruits per Bunch (NFCB), Number of Non-commercial Fruits per Bunch (NFNCB), Total Fruit Mass (TFM), Commercially-viable Fruit Mass (CFM) as a function of different types of Bokashi (Sete Lagoas, UFSJ, 2013).

BokashiType	YieldComponents –YC (Unit)			YC (g)	
	NFB	NFCB	NFNCB	TFM	CFM
B1	2.89b	1.30b	1.46b	99.61b	116.05b
B2	6.16a	2.66a	2.92a	117.06a	147.67a
B3	5.70a	3.10a	2.60a	119.95a	133.26a
B4	5.81a	2.72a	3.08a	121.77a	137.22a
B5	6.28a	3.06a	3.37a	121.32a	137.38a
B6	6.16a	3.03a	3.12a	123.78a	134.76a
B7	5.77a	2.61a	3.15a	120.50a	144.66a
B8	6.78a	3.36a	3.41a	117.06a	125.29a
Cultivars					
Santa Clara	5.26b	2.20b	2.95a	125.64a	138.82a
Verano	6.02a	3.27a	2.83a	109.74b	130.25a
CVs (%)	11.50	22.78	18.85	9.27	14.49

Means followed by the same letter within a column do not differ by the Tukey test at 5%.

Tomato yield can be significantly affected by the number of plants per unit area, the number of fruits per plant and the average fruit weight (SILVA et al.1997). In general, the total number of fruits per bunch, which is directly reflected in the number of fruits per plant, naturally adjusts to six fruits per bunch or raceme. This held true in the current experiment in all treatments except B1. The ideal number of tomatoes per bunch is six (SHIRAHIGE et al. 2010) regarding the yield and quality of Santa Cruz and Italiano Tomatoes as a function of fruit thinning. Nevertheless, the potential number of tomato fruit per bunch is much greater than six. This suggests that the lower number of fruits per bunch in the present study may be related to some nutritional deficiency in the types of compost used.

Boron is an essential mineral for tomato plants and is absorbed through the roots as boric acid H_3BO_3 and borate (B[OH]4-). Boron assists in the formation of the cell wall and stable complexes of the plasma membrane, and stimulates pollen germination and pollen tube elongation (LÄUCHLI, 2002). Thus, pollen germination and pollen tube growth is directly associated with the essential nutrients boron and calcium (MARSCHNER, 1995). Since these nutrients are immobile in the plant and transported mainly by the xylem (FERNANDES, 2006; MALAVOLTA, 2006), inadequate supply can lead to lower yield due to reduced pollination (LAVIOLA; SANTOS- DIAS, 2008).

Furthermore, flower abortion in tomato plants can increase due to pests, diseases, and, most significantly, because of water stress, nitrogen excess or deficiency (FILGUEIRA, 2008) and nutritional imbalance. In addition to reducing the total number of fruits per bunch in the current study, these factors also reduced the number of commercially viable fruit per bunch (Table 3). This reduction and a reduction in total fruit yield were principally due to an intense attack by tomato moths (*Tuta absoluta*) and further aggravated by potentially inadequate Ca and B, as previously mentioned.

The average mass of all fruit and commercially viable fruit was well below the standard for Santa Clara (200 g fruit^{-1}). It was expected that pruning above the sixth floral branch (leaving only six bunches) and the significant loss of fruit from these branches would naturally increase the weight of the remaining commercially viable fruit. Silva et al. (1997) produced Santa Clara tomatoes with a mean mass of 208.63 g by pruning above the fourth flowering branch and applying 600 kg $ha^{-1}$of P_2O_5 (triple superphosphate), 100, 200, 400 and 800 kg ha^{-1}ofN (nitrocalcium) and 200, 400, 800 and 1200 kg $ha^{-1}$of K_2O (KCl). Lower fruit growth in the present study was probably due to some disruption in nutrient assimilation, which may or may not be associated with the types of organic compounds used.

According to Minani and Haag (1979), normal tomato plant development may be understood as the interaction of diverse external factors such as temperature, light, photoperiod, water, soil (nutrients) and climate that interact with internal factors such as genetic makeup, phytohormone levels and nutrient levels. In terms of nutrients, the B1 treatment (0% poultry litter and 79% crushed sugarcane) produced the worst performance in all yield components. Conversely, the treatments from B2 (60% crushed sugarcane and 10% poultry) to B8 (0% crushed sugarcane and 70% poultry litter) significantly increased yield components relative to B1.

pH had no significant impact on the Bokashi treatments and was the only factor that did not affect fruit quality. The Santa Clara cultivar had higher pH levels than the Verano cultivar (4.21 and 4.13, respectively). Some reports show that most of the factors affecting the quality of vegetable products are controlled genetically. Thus fruit quality differs between tomato cultivars (SINGH et al., 2000; RAVINDER-SINGH et al., 2001; WARNER et al., 2004) and is also influenced by other factors such as soil fertility and climatic conditions.

The principle characteristics that should be used to determine tomato quality are: pH, concentration of soluble solids, total acidity, vitamin C content, nitrate content, color and fresh weight (ANAÇ et al. 1994). However, these characteristics can be influenced by nitrogen fertilization (ARMENTA - BOJORQUEZ et al., 2001; OBERLY et al., 2002; FLORES et al., 2003; VALENCIA et al., 2003; WARNER et al., 2004) that might have been in excess or lacking in the organic fertilizer used in the present study. Ferreira et al (2006) studied tomato quality in relation to nitrogen and organic fertilizer application rates in two seasons and found that tomato fruit pH was not changed by higher N rates, reaching average pH of 4.58 and 4.61 with and without adding organic matter to the soil, respectively. These values are similar to those found in the present study (4.11 to 4.26).

According to Ferreira et al (2006), the percentage of total soluble solids is reflected in fruit flavor and expressed as total soluble solids (TSS). Most tomato growers produce fruit with TSS values that range from 5.0 to 7.0. However, in the present study, TSS varied from 3.03 to 3.90 and titratable acid varied from 0.17 to 0.35g of citric acid per 100 g of fruit. Silva et al (2013), worked with the Santa Clara cultivar and found mean TSS of approximately 4.1 and titratable acidity of 0.36 of citric acid 100 $g^{-1}$of fruit, which they considered to be within normal ranges for tomatoes. Genúncio et al. (2006), studied hydroponically grown tomato cultivars (UC-82, T-93 and Saladinha) using different concentrations of a nutrient solution and found values for total solids (2.5 to 3.9) that were well below those found in the current study. Therefore, it appears that the alternative Bokashi applications we used did not negatively affect fruit quality. Interactions between factors were also observed regarding fruit dry matter. Nevertheless, variations in dry matter levels were normal and were in line with averages for fruit mass (8.75% to 16.43 % - Santa Clara and 10.57% to 14.90% - Verano).

CONCLUSIONS

The different formulations of Alternative Bokashi, except B1, strengthened components of tomato yield and quality.

The mixture of crushed sugarcane with poultry litter is a viable alternative for the production of Alternative Bokashi for use in organic tomato production.

RESUMO: O cenário atual da agricultura orgânica demonstra aumento considerável do número de produtores e área plantada. Consequentemente, há maior demanda por novas alternativas de compostos orgânicos, não só em volume, mas também disponibilizar novas opções para uso direto no sistema de cultivo. A busca pelo aproveitamento de subprodutos gerados pelas indústrias locais é pauta no Brasil e no mundo. O objetivo do trabalho foi avaliar o efeito de oito tipos de compostos orgânicos produzidos com diferentes porcentagens de cama de frango e cana de açúcar triturada na produção e qualidade do tomate.O experimento foi instalado na fazenda experimental da Empresa de Pesquisa Agropecuária do Estado de Minas Gerais localizada no município de Prudente de Morais, MG no ano agrícola de 2013. Foram avaliadas diferentes formulações entre cama de frango e cana de açúcar triturada(0, 10, 20, 30, 40, 50, 50, 60 e 70%) resultando em oito tipos de *Bokashi* alternativo utilizado como composto orgânico na produção de duas cultivares de tomate (Santa Clara e Híbrido Verano). Pode-se verificar que as diferentes formulações de Bokashi Alternativo, com exceção da B1, potencializaram os componentes de produção e qualidade do tomate. O uso de cama de frango associado com cana de açúcar triturada promove incrementos na produção e qualidade de tomate demonstrando ser uma excelente alternativa, especialmente para produtores orgânicos.

PALAVRAS-CHAVE: *Solanum lycopersicum.* Sustentabilidade. Cama de frango. Bokashi.

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