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Yield and nutrition of tomato using different nutrient sources

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ABSTRACT

The effect of alternative sources of nutrients was evaluated on yield, nutrition and fruit quality of tomato cv Santa Clara in an agro ecological system, under natural conditions in Montes Claros, Minas Gerais State, Brazil. The experimental design was of completely randomized blocks with seven treatments and four replications, using eight plants per experimental plot. The treatments comprised of 1) conventional fertilization with NPK; 2) organic compost + natural phosphate + rock dust, applied separately; 3) organic compost produced from the addition of natural phosphate and rock dust + green manure; 4) organic compost produced from the addition of rock dust + natural phosphate + green manure; 5) organic compost produced from the addition of natural phosphate and rock dust + green manure; 6) natural phosphate + rock dust; and 7) organic compost + natural phosphate + rock dust + green manure. The highest production was obtained using chemical fertilizers. There was no difference among the treatments regarding the content of foliar nutrients and fruit diameter, pH and total soluble solids. The use of mineral and organic fertilizers significantly reduced the incidence of soft rot and pests in comparison to the use of chemical fertilizers.

Keywords: *Lycopersicon esculentum*, organic fertilization, mineral nutrition.

RESUMO

Produção e nutrição do tomateiro com diferentes fontes de nutrientes

Com o objetivo de analisar fontes alternativas de nutrientes na produtividade, nutrição e qualidade dos frutos do tomateiro (*Lycopersicon esculentum*) cv Santa Clara, em sistema agroecológico, no período chuvoso, de setembro a janeiro, conduziu-se um experimento, em condições de campo, no município de Montes Claros-MG. O delineamento experimental foi de blocos ao acaso, com sete tratamentos e quatro repetições. Os tratamentos foram 1) adubação convencional, com NPK; 2) composto orgânico + fosfato natural + pó-de-rocha, aplicados separadamente; 3) composto orgânico, produzido com a adição de fosfato natural e pó-de-rocha + adubação verde; 4) composto orgânico, produzido com pó-de-rocha + fosfato natural + adubação verde; 5) composto orgânico, produzido com fosfato natural e com pó-de-rocha + adubação verde; 6) fosfato natural + pó-de-rocha e; 7) composto orgânico + fosfato natural + pó de rocha + adubação verde. A maior produção foi obtida com o uso de adubos químicos e não houve diferença entre os tratamentos quanto aos teores foliares de nutrientes e diametro, pH e sólidos solúveis totais dos frutos. O emprego de adubos orgânicos e minerais reduziu significativamente a incidência de podridão bacteriana e o ataque de pragas no tomateiro em relação aos adubos químicos.

Palavras-chave: *Lycopersicon esculentum*, adubação orgânica, nutrição mineral.

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Tomato (*Lycopersicon esculentum*) is a crop with high nutritional requirements and its production is influenced by the availability of nutrients (Ferreira *et al.*, 2003), among other factors. These nutritional requirements are met through the use of nutrient sources which vary depending on the cultural practices adopted by the farmer. The use of conventional or organic sources of nutrients influence in different ways in the farm and, in a prominent way, in the yield and composition of fruits, in the nutrient dynamics and in the soil physical attributes (Toor *et al*, 2006; Montemurro, 2009).

In this way, Toor *et al*. (2006) observed the influence of nutrient sources in the chemical composition and flavor of tomato fruits. The same authors have reported greater uptake of macronutrients (N, P and K) in organically fertilized plants in comparison to plants grown with mineral solution. Moreover, Solaiman & Rabanni (2006) demonstrated agronomical and economic advantages of using organic fertilizers on the tomato crop.

Environmental impacts from the indiscriminate use of fertilizers and pesticides in agriculture, as manifested in cases of poisoning, contamination of waterways and air, and the successive increases in the prices of this inputs have been indicating to researchers, farmers and consumers the necessity of a more sustainable agriculture, which is expected to produce healthier food (Araujo *et al.*, 2001; Tamiso, 2005; Wang, 2006).

Besides the benefits of the reutilization of nutrients and nutritional balance, the use of organic sources of nutrients has contributed to the improvement of soil physical, chemical and biological attributes (Rosen & Allan, 2007).

The objective of this research was to study the feasibility of using organic and mineral sources as an alternative to conventional chemical fertilizers used for nutrition and production of tomato in the rainy season in the region of Montes Claros, Minas Gerais State, Brazil.

MATERIAL AND METHODS

This research was carried out in a Red-Yellow Inceptisoil in an experimental field at the Pradinho Community (area with 154 km^2, 16º 50'S and 43º 51'W, 16º 53'S and 43º 52'W, 16º 53'S and 43º 52'W and 16º 53'S and 43º 52'W), between December 2006 and April 2007 in the county of Montes Claros, Minas Gerais State, Brazil. The main climate, according to the Köppen classification, is Aw - tropical of savannah with dry winter and humid summer. The native vegetation was the Brazilian savannah (also known as Cerrado), whose chemical analyses, determined according to Embrapa (1997), in the 0-20 cm layer were: pH= 6.0; organic matter= 47.9 g dm^{-3}; H^+ + Al^{+3}= 32.4 $mmol_c$ dm^{-3}; Al= 0 $mmol_c$ dm^{-3}; K^+= 0.56 $mmol_c$ dm^{-3}; P residual= 37.5 mg L^{-1}; P mehlich= 14.9 mg dm^{-3}; Ca= 68.0 $mmol_c$ dm^{-3}; Mg= 22.0 $mmol_c$ dm^{-3}; Clay= 300 g dm^{-3}; Silt= 340 g dm^{-3}; Fine sand= 330 g dm^{-3}, Coarse sand= 30 g dm^{-3}.

The experimental design was randomized blocks with seven treatments and four replications. Each plot consisted of 16 plants spaced 1.0 x 0.5 m, and the useful plot consisted of the four central plants. The treatments consisted of the following fertilizations 1) 30 g of 4-14-8 and four top-dressings applied each fifteen days 30 days after transplanting with 20 g of 20-05-20 per hole [this treatment corresponded to the conventional fertilization used by the growers of the Community of Pradinho (control treatment)]; 2) two liters of simple organic compost + 120 g of rock phosphate and 200 g of rock dust, applied separately in each hole; 3) green manure, two liters of organic compost + 25 g Gafsa phosphate + 200 g of rock-dust, applied separately in each hole; 4) green manure, two liters of organic compost + 10.26 g of rock-dust + 120 g of rock phosphate applied separately in each hole; 5) green manure and two liters of organic compost + 25 g of Gafsa phosphate + 10.26 g of rock-dust applied in each hole; 6) 120 g of phosphate + 200 g of rock-dust, applied separately in each hole; 7) green manure, two liters of simple organic compost + 120 g of Gafsa phosphate + 200g of rock-dust, applied separately in each planting hole.

The simple organic compost consisted of cotton bolls and cattle manure in a 2:1 ratio, respectively. The composition of each material used in the production of the organic composts is presented in Table 1.

The soil tillage consisted of a plowing and a disking operation and the planting holes were prepared manually. The adopted irrigation system was the furrow irrigation, with an irrigation shift of two days.

In plots where green manure was applied, pigeon pea (*Cajanus cajan* (L.) Mill) was sown laterally to the planting rows of tomato, spaced 0.5 m between rows and with a density of 20 seeds per meter, 60 days before application of other treatments and transplanting of tomato seedlings. The plants of pigeon pea were cut 150 days after its planting (flowering stage) and incorporated into the soil. The tomato fruits were harvested 120 days after their transplant.

The tomato plantlets, cv.Santa Clara, were produced in greenhouses, using trays containing commercial substrate (Plantmax®), and transplanted to the experimental area 27 days after sowing. One single stem of one plant per hole was tutored and periodically disprouted. The ends of the plants were removed when they reached 1.80 m height.

Spraying with extracts of neem (*Azadirachta indica*) and the release of *Trichogramma* sp. for controlling tomato pests were carried out. Biofertilizers and the Bordeaux mixture were used for disease prevention and for providing nutrients to plants, according to the methodology proposed by Fernandes *et al.* (2005).

The biofertilizer was prepared 30 days before the start of the experiment in the following composition: 430 g of boric acid, 570 g of wood ash, 850 g of calcium chloride, 43 g of ferrous sulphate, 60 g of bone meal, 60 g of meat meal, 143 g of silicon-magnesium thermo-phosphate, 4.5 kg of molasses, 30 g of sodium molybdate, 30 g of cobalt sulphate, 43 g of copper sulphate, 86 g of manganese sulphate, 143 g of magnesium sulphate, 57 g of zinc sulphate, 67.5 g of castor bean meal, 30 drops of iodine solution 1%, 500 mL of cow urine, 20 L of cow milk, 100 L of manure, completing the volume to 200 L with water.

At the flowering stage, tomato leaf samples were collected and the amounts of nutrients in plant tissues were determined according to the methodologies proposed by Martinez *et al.*, (1999) and Malavolta *et al.*, (1997), respectively. Analyses of organic fertilizers were carried out according to Kiehl (1985).

The harvest began 134 days after transplanting. The fruits were harvested weekly and evaluated for marketable yield, fruit weight, number of fruits per plant, transversal diameter of the fruit, pH, total soluble solids (^{0}Brix), class of size and type depending on the number of defects.

The pH was determined in the pure undiluted extract, with a potentiometer and the soluble solids content was determined through a manual refractometer, with results expressed in degrees brix. The diameter and the measures for the classification of fruits according to the size classes were obtained through a digital caliper.

The size classification of oblong fruits was held following the standards of the Brazilian Ministry of Agriculture, Livestock and Supply, into large (transversal diameter greater than 60 mm), medium (transversal diameter between 50 and 60 mm) and small (transversal diameter between 40 and 50 mm).

Towards the defects, the fruits were classified according to type and number of defects, according to the standards of the Ministry of Agriculture, Livestock and Supply, into severe (rot, over-ripened and apical rot) and light (spotted, hollow, warped and immature). The evaluation of the defects caused by the action of insects was done according to the methodology proposed by Ferreira *et al.*, 2004.

All data were subjected to analysis of variance and means were compared by the Scott-Knott test at 5% of probability.

RESULTS AND DISCUSSION

There was no statistically significant difference for weight per fruit, fruit

Table 1. Characteristics of the organic composts used in the experiment * determined from the mass dried at 65ºC (características dos compostos orgânicos utilizados no experimento * determinados com base na massa seca a 65ºC). Montes Claros, UFMG, 2007.

Attributes	Compost type			
	Simple	Enriched with rock-dust	Enriched with natural phospate	Complete
pH in water	6.60	7.10	6.30	6.50
pH in $CaCl_2$	6.20	6.70	6.10	6.40
Humidity at 65ºC (%)	4.80	3.20	3.70	3.70
Humidity at 105ºC (%)	10.30	6.70	7.60	7.60
Organic carbon (%)*	49.20	31.80	38.90	39.00
Total mineral residue (%)*	42.70	62.50	54.90	54.90
Soluble mineral residue (%)*	13.20	17.90	17.80	24.40
Insoluble mineral residue (%)*	29.60	44.60	37.10	30.50
Nitrogen (%)*	1.80	1.30	1.40	1.40
C/N ratio (%)*	15.90	14.20	16.10	16.10
P_2O_5 (%)*	0.53	0.40	1.19	3.00
K_2O (%)*	1.00	2.81	0.88	1.17
CaO (%)*	2.05	2.22	2.81	7.88
MgO (%) *	0.77	0.56	0.64	0.73
S (%) *	0.20	0.10	1.60	2.40
B (mg/kg) *	85.00	128.00	109.00	96.00
Zn (mg/kg) *	81.00	64.00	75.00	80.00
Fe (%) *	2.11	3.96	3.18	2.46
Mn (mg/kg)*	211.00	333.00	282.00	220.00
Cu (mg/kg) *	30.00	40.00	28.00	34.00

diameter, pH and brix, whereas for yield and number of fruits per plant, treatments differed ($p<0.05$). The greatest values of fruit yield and number of fruits per plant were obtained in the control treatment, which received conventional fertilization with chemical fertilizers, whereas the others did not differ statistically (Table 3).

The yield of treatments with alternative sources of nutrients varied from 28 to 55% of that obtained in the control treatment (Table 3). The highest yield obtained in the treatment with conventional fertilization in comparison to the others and the absence of differences among the treatments with organic and mineral fertilizers can be explained by the high nutritional requirement of the tomato crop in a short period of time. Probably, in the most demanding stage of the tomato crop, organic and mineral sources of "low solubility" used in the "treatments with alternative fertilization" did not provide the nutrients, especially N, P and K in the same amounts of the "chemical fertilizers" used in the treatment with conventional fertilization.

Nitrogen is the nutrient most required by plants, and to achieve high rates of growth, yield and fruit quality of tomato under field conditions, the amount to be applied must be equal to the plant demand (Ferreira *et al.*, 2006). According to these authors, this increased demand occurs during the stages of fruit growth, since the accumulation of soluble solids occurs during this period.

According to Huett & Dettmann (1991), nitrogen promotes physical and physiological changes in the plant and this nutrient is related to photosynthesis, root development and activity, nutrient uptake, cell growth and differentiation. Besides being, according to the authors, one of the nutrients absorbed in greater quantity, nitrogen also influences processes involving growth and development, influencing directly on source-sink relations by altering the distribution of assimilates between the vegetative and the reproductive part.

The transformation of organic nitrogen in ammonia and nitrate, which are forms absorbed by plants is slow and can not meet the needs of the plants during the greater nutritional requirement stage (Kiehl, 1993), explaining, perhaps, the lower yield of the treatments which did not received mineral nitrogen. In this sense, the absence of significant differences among these treatments can also be explained.

Although the green manure of faba bean did not meet the tomato demand for nitrogen it may have favored populations of phosphate-solubilizing fungi and bacteria, which play a key role in supplying phosphorus to plants (Silva Filho & Vidor, 2001). This ability of microorganisms to solubilize phosphates is related to their ability to produce organic acids and extracellular polysaccharides (Kim *et al.*, 1997). Souche *et al.* (2007) found that microorganisms isolated from the rhizosphere of pigeonpea are effective to solubilize phosphorus from a phosphate rock.

Another factor that may have contributed to the lower yield of tomato plants in treatments with alternative sources of fertilizers was the low dissolution of potassium from the rock-dust. In the case of low-solubility sources, the availability of nutrients can be enhanced by adding these sources in the composting process of organic waste. According to Rodrigues & Sumioka (2003), Alcantara *et al.* (2000) and Araújo & Almeida (1993), the composting process increases the available forms of nutrients to plants. However, in this study, no difference was found among the treatments in which rock-dust and phosphate were applied alone or together with organic wastes for composting (Table 3).

Besides the availability of nutrients, the incidence of pests and diseases might have affected productivity, mainly because the crop was carried out during

Table 2. Chemical composition of the inputs used in the experiment; *Analytical determinations carried out from dry matter at 65ºC; nd= not determined. **Figures provided by the respective manufacturers (composição química dos insumos utilizados no experimento; *determinações analíticas realizadas na matéria seca a 65oC; nd= não determinado; **valores fornecidos pelos respectivos fabricantes). Montes Claros, UFMG, 2007.

Components	Cotton boll*	Cattle manure*	Granite rock-dust	Gafsa natural phosphate	4-14-8 Fertilizer**	20-5-20 Fertilizer**
C/N ratio	22.50	14.30	nd	nd	nd	nd
Total N (%)	2.10	2.50	nd	nd	4.00	20.00
P_2O_5 (%)	0.28	1.05	nd	28.90	14.00	5.00
K_2O (%)	2.03	1.33	1.32	0.14	8.00	20.00
CaO (%)	1.49	1.41	35.06	60.00	nd	nd
MgO (%)	0.58	0.89	2.62	2.00	nd	nd
SiO_2 (%)	nd	nd	22.70	nd	nd	nd
AlO_3 (%)	nd	nd	7.01	nd	nd	nd
Fe_2O_3 (%)	nd	nd	2.51	nd	nd	nd
Na_2O (%)	nd	nd	1.64	nd	nd	nd
S (g kg^{-1})	0.10	0.10	nd	32.00	nd	nd
B (mg kg^{-1})	35.00	53.00	nd	nd	nd	nd
Zn (mg kg^{-1})	19.00	96.00	nd	370.00	nd	nd
Fe (%)	0.33	1.29	nd	0.42	nd	nd
Mn (mg kg^{-1})	57.00	243.00	nd	27.00	nd	nd
Cu (mg kg^{-1})	10.00	40.00	nd	19.00	nd	nd

the rainy season. Loss *et al.* (2004), also working with the cultivar Santa Clara, tutoring one stem per plant, in conventional production system during the rainy season, obtained an average yield of 39.34 t/ha, and attributed this low productivity to losses caused by pests and diseases. In this work, even in the treatments with conventional fertilization, the spraying of pesticides used in conventional crops was not carried out.

A high infestation of whitefly (*Bemisia argentifolii*) was observed in plants of pigeon pea, whereas an insignificant attack of this insect was found in tomato plants. Picanço *et al.* (2004), studying the financial impacts of the integrated pest management in tomato, found that the surrounding tracks, such as of pigeon pea in combination with other practices of integrated pest management, reduced the number of insecticide applications. According to the authors, the surrounding tracks act like sources of attraction and habitation for insects including natural enemies of insect pests of the crop.

The diseases that attacked the crop were septoria (*Septoria lycopersici*), hollow stalk (*Erwinia carotovora*) and bacterial wilt (*Ralstonia solanacearum*). Among the pests, we observed a higher incidence of corn earworm (*Helicoverpa zea*), which caused major damage in the early harvests. However, the damage caused by this insect decreased over the crops, probably because of the release of *Trichogramma* sp in the area of cultivation. Moreover, application of bio-fertilizers may also have provided some control of this insect and other pests. Nunes & Leal (2001) found positive results in controlling the tomato worm using biofertilizers.

The average weight per fruit of tomato was not affected by treatments, and the average was 105.6 g (Table 3). This value is similar to that obtained by Peixoto (1999), which was 121.5 g.

Regarding the number of fruits per plant, the treatment with conventional fertilization presented the greatest number, whereas the treatments which received alternative fertilization did not differ statistically. In the treatments with conventional fertilization, 20 fruits per plant were obtained, a number very close to that obtained by Peixoto *et al.* (1999), which was 22.6. In the treatments with alternative fertilization, on average, 9.5 fruits per plant were obtained, which is 52.5% less than the treatments with conventional fertilization. The lowest number of fruits per plant in the treatments with alternative sources can be attributed to flower abortion, due to the possible plant nutritional deficiency.

The characteristics of fruit quality were defined according to the parameters established for conventional tomatoes, since there are no parameters for the marketing of organic tomato.

According to Ferreira *et al.* (2004) and Filgueira (2000), the tomato cultivar Santa Clara, for the market, must present a diameter greater than 52 mm. In this study, all treatments presented average values ranging from 53 to 55 mm, given the market demand for this parameter.

For the pH of the fruit, no pattern was found in comparison to the fresh tomato. In this study, we found that the pH did not differ among treatments, with values ranging from 4.5 to 4.7 (Table 3). According to Ferreira *et al.* (2005), the pH of tomato fruits is not changed by the use of organic fertilizer or not.

The flavor of the tomato fruit can be

Table 3. Total weight of fruit, fruit weight per plant, number of fruits per plant, diameter of fruit, brix and pH of the extract of tomato fruits produced under different fertilization; means followed by the same letter in column do not differ (Scott-Knott, 5%); *C= organic compound, F= Gafsa phosphate, P= rock-dust, V= green manure, CF= organic compost prepared with Gafsa phosphate, CP= organic compost prepared with rock-dust and CFP= organic compost prepared with Gafsa phosphate and rock-dust. **Numbers in brackets represent the percentage of yield of each treatment in relation to the treatment with conventional fertilization (peso total de frutos, peso de frutos por planta, número de frutos por planta, diâmetro do fruto, pH do extrato e brix de frutos de tomate produzidos sob diferentes adubações; médias seguidas da mesma letra na coluna não diferem entre si (Scott-Knott, 5%); *C= composto orgânico, F= fosfato de Gafsa, P= pó-de-rocha, V= adubação verde, CF= composto orgânico preparado com fosfato de Gafsa, CP= composto orgânico preparado com pó-de-rocha e CFP= composto orgânico preparado com fosfato de Gafsa e pó-de-rocha; **números entre parênteses representam a percentagem da produtividade de cada tratamento em relação ao tratamento com adubação convencional). Montes Claros, UFMG, 2007.

Treatments*	Marketable yield (t ha^{-1})	Weight/fruit (g)	Fruits/plant	Diameter (mm)	pH	Brix
Control	44 (100%)** a	110 a	20 a	55 a	4.5 a	3.5 a
C+F+P	24 (55%) b	101 a	12 b	54 a	4.6 a	3.5 a
CF+P+V	22 (50%) b	110 a	10 b	55 a	4.6 a	3.4 a
CP+F+V	22 (50%) b	99 a	11 b	54 a	4.7 a	3.2 a
CFP+V	13 (28%) b	91 a	7 b	53 a	4.6 a	3.5 a
F+P	20 (45%) b	112 a	9 b	53 a	4.6 a	3.1 a
C+F+P+V	15 (34%) b	95 a	8 b	55 a	4.7 a	3.4 a
CV(%)	33.7	13.1	28.3	4.9	2.2	10.8

Table 4. Classification of tomato fruits according to the size class; averages followed by the same letter in column do not differ (Scott-Knott, 5%); *C= organic compost, F= Gafsa phosphate, P= rock-dust, V= green manure, CF= organic compost prepared with Gafsa phosphate, CP= organic compost prepared with rock-dust and CFP= organic compost prepared with Gafsa phosphate and rock-dust (classificação dos frutos de tomate de acordo com a classe de tamanho; médias seguidas da mesma letra na coluna não diferem entre si (Scott-Knott, 5%); *C= composto orgânico, F= fosfato de Gafsa, P= pó-de-rocha, V= adubação verde, CF= composto orgânico preparado com fosfato de Gafsa, CP= composto orgânico preparado com pó-de-rocha e CFP= composto orgânico preparado com fosfato de Gafsa e pó-de-rocha). Montes Claros, UFMG, 2007.

Treatment*	Classification (% of fruits)			Defects (% of fruits)	
	Small	Medium	Large	Bacterial rot	Insect attack
Control	5 a	57 a	38 a	23 a	24 a
C+F+P	18 b	62 a	20 b	10 b	10 b
CF+P+V	20 b	66 a	14 b	14 b	8 b
CP+F+V	16 b	64 a	20 b	11 b	9 b
CFP+V	20 b	64 a	16 b	12 b	8 b
F+P	18 b	66 a	16 b	11 b	9 b
C+F+P+V	18 b	62 a	20 b	12 b	7 b
CV (%)	17,4	7,0	13,1	23,7	21,81

measured by the soluble solids content, expressed by the degree brix. Most tomato cultivars produce fruit with brix ranging from 5.0 to 7.0 (Ferreira *et al*. 2005). The values obtained in this study ranged from 3.1 to 3.5. These results are in agreement with Ferreira *et al*. (2006), who found average values of 3.7 and 3.5, with and without organic manure, respectively. According to these authors, the environmental and cultural conditions given to the tomato plants do not interfere with the content of soluble solids.

Regarding to the group, fruits were classified as oblong, since they presented longitudinal diameter greater than the transversal (Brasil, 2002). Regarding to the class, there was a predominance of medium size, of 57% for the treatment with conventional fertilizer and 64% on average for the other treatments with alternative fertilization (Table 4).

Ferreira *et al*. (2005) also found a higher percentage of small fruits in organic fertilization in comparison to the conventional fertilization.

For the number of defects, according to Brasil (2002), only a serious defect was found, which was associated to the bacterial rot and no light defect was found. The treatment with conventional fertilization showed a higher percentage of fruits with symptoms of bacterial wilt, 23% in average, compared to other treatments, which did not differ among themselves and had an average of 12% of fruits with rot symptoms (Table 4).

Fruits produced in the treatment with conventional fertilization presented a higher percentage of fruits with defects associated to entomological attacks (24% on average), whereas the other treatments did not differ and showed an average of 8.5% of fruits with symptoms (Table 4). According to Leite *et al*. (2003), the higher availability of nitrogen in the soil promotes a greater amount of amino acids in plant vessels, resulting in a higher attack of insects. Probably, in the treatment with conventional fertilization, the increased availability of nitrogen in soil, as confirmed by its higher content in the leaves, explains the higher incidence of pest attack in this treatment in comparison to the others.

This classification undervaluates commercial organic tomato and does not fit the standard of quality of organic tomato (Ferreira *et al*., 2005). According to Luz *et al*. (2007), consumers of organic tomatoes accept fruit shapes and colors not accepted in the conventional market and are willing to pay more for them. In this study, fruits with rot symptoms (bacterial wilt) and with defects were discarded from the yield evaluation.

For the foliar nutrients at the flowering stage, there was no statistically significant difference among treatments and the mean values were 50 g kg^{-1} N, 4.4 g kg^{-1} P, 39 g kg^{-1} K, 26 g kg^{-1} Ca, 2.3 g kg^{-1} Mg, 6.5 g kg^{-1} S, 38 mg kg^{-1} B, 29 mg kg^{-1} Zn, 173 mg kg^{-1} Fe, 45 mg kg^{-1} Mn and 42 mg kg^{-1} Cu.

In the treatments with conventional fertilization, in which soluble sources of N, P and K were applied to the soil, the contents of these nutrients in leaves were similar to other treatments, possibly due to the application of low doses of nutrients.

In general, except for nitrogen, foliar nutrient levels were lower than the reference values for the tomato crop, which are, according to Martinez *et al*. (1999) of: 45.9 g kg^{-1} N, 5.6 g kg^{-1} P, 57.2 g kg^{-1} K, 44.0 g kg^{-1} Ca, 5.0 g kg^{-1} Mg, 37 mg kg^{-1} Zn, 268 mg kg^{-1} Fe, 290 mg kg^{-1} Mn and 40 mg kg^{-1} Cu. For phosphorus, the species, cultivar, age of the plant tissue, the nutrient form and the soil attributes affect the levels of nutrients in plant tissues (Muniz *et al*., 1985). These factors may also influence the leaf levels of other nutrients.

Regarding the visual symptoms of nutritional deficiency, there was a small number of fruits with cracks at the base, probably due to boron deficiency and symptoms of apical rot, probably due to calcium deficiency (Filgueira, 2000). Also conditions of soil moisture and temperature can induce the development of nutritional deficiencies.

Despite the reduced yield provided by the alternative fertilization treatments and the diseases problems, which were aggravated by the rainy season in association to the susceptibility of the cultivar 'Santa Clara' to diseases, we obtained considerable yield in comparison to the national average yield and quality for marketing.

According to Santos & Noronha (2001), in the studied crop seasons, despite the application of high quantities of pesticides, yield was reduced on 30 and 14% by fungal diseases and pest attacks, respectively. Only the average cost of pesticides accounted for 28% of the production. Moreover, these authors inferred that the tomato producers do not care about their health and, also, the lack of technical assistance and the absence of preventive control with crop residues induce an increase in pests and diseases and, consequently, in the indiscriminated use of pesticides.

Since tomato is a crop of high economic risk, product quality and the target market are decisive to the price. Especial products such as organic tomatoes achieve better prices. Furthermore, Mitchell *et al*. (2007) found that organic tomatoes presents higher levels of flavonoids than the conventional tomatoes. These substances with antioxidant properties help to protect against cardiovascular diseases and some cancers.

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