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Tomato fertigation with dairy cattle wastewater

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ABSTRACT

The use of wastewater in the fertigation of agricultural crops increases productivity and product quality, and contributes to reduce environmental pollution. In this work, the objective was to evaluate how the use of dairy cattle wastewater (DCWW) in the fertigation of tomatoes affected production and productivity, as well as foliar nutritional contents, in an organic farming system. Treatments consisted of six nitrogen doses (0, 50, 100, 200, 300 and 400%), having N recommendation for tomato (100 kg/ha) as reference, applied using DCWW via fertigation. DCWW is made up of washing water, urine, feces and milk. Stem diameter, branch length, weekly fruit yield per plant and aggregate productivity were evaluated. N, P, K, Ca, Mg, S, Cu, Mn, Fe, Zn and B foliar contents were quantified. Data were submitted to analysis of variance ($p \leq 0.05$) and, where significant, polynomial regression models were applied. Treatment means were compared by the Tukey test ($p \leq 0.05$). The highest production, productivity and nutrient foliar accumulation were observed when 400% of the N dose recommended for tomato was used. There was an increasing linear effect on weekly and aggregate yield and also on nutrient accumulation in leaves as function of the applied N dose. N fertilization in tomato organic production can be carried out using DCWW via fertigation, but with a complementary mineral fertilization to supply plants with adequate amounts of phosphorus and potassium.

Keywords: *Solanum lycopersicum*, foliar analysis, nitrogen fertilization, final disposal.

RESUMO

Fertirrigação do tomateiro com água residuária de bovinocultura de leite

O aproveitamento de águas residuárias na fertirrigação de culturas agrícolas promove aumento da produtividade e qualidade dos produtos, contribuindo para a redução da poluição ambiental. O objetivo deste trabalho foi avaliar os efeitos da fertirrigação com água residuária da bovinocultura de leite (ARB) sobre os teores nutricionais em folhas do tomateiro, a produção e produtividade desta cultura em sistema orgânico de produção. Os tratamentos consistiram de seis doses de nitrogênio (0, 50, 100, 200, 300 e 400%) com base na recomendação para o tomateiro (100 kg/ha), por meio da fertirrigação orgânica com água residuária de bovinocultura de leite (ARB) composta pela água de lavagem, urinas, fezes e leite. Foram avaliados: o diâmetro do caule, comprimento dos ramos; a produção semanal de frutos por planta e a produtividade acumulada ao longo do ciclo da cultura. Na análise de concentração de nutrientes presentes na folha foram quantificados os teores de N, P, K, Ca, Mg, S, Cu, Mn, Fe, Zn e B. Os resultados foram submetidos à análise de variância ($p \leq 0,05$) e quando significativos, estes foram analisados por modelos de regressão polinomial e as médias comparadas pelo teste de Tukey ($p \leq 0,05$). Observaram-se valores máximos de produção, produtividade e acúmulo dos nutrientes nas folhas do tomateiro no tratamento com 400% da dose de nitrogênio recomendada para a cultura. Houve efeito linear crescente na produção, na produtividade acumulada e no acúmulo dos nutrientes nas folhas em função da dose de ARB aplicada. A adubação nitrogenada no cultivo orgânico do tomateiro pode ser realizada por meio da fertirrigação com a ARB e deve ser complementada na forma mineral, visando fornecer a quantidade adequada de fósforo e potássio para as plantas.

Palavras-chave: *Solanum lycopersicum*, análise foliar, adubação nitrogenada, disposição final.

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Although organic farming systems handle waste in an integrated manner, effluent destination still challenges farmers and, moreover, specialists and regulatory agencies. Although farmers are responsible for adequate effluent treatment and disposal, the high investment costs required to treat dairy cattle wastewater (DCWW), due to the large volumes used to wash feces, urine and milk, often makes the process unviable for many of them. Eliminating wastewater in the soil-plant system without agronomic and environmental criteria is not an alternative, since it can cause soil and surface and groundwater contamination, as well as toxicity to plants. However, if well planned, the operation can bring benefits, such as supplying nutrients and water to plants and reducing the need for fertilizers and, consequently, fertilizer pollution pressure (Erthal *et al*., 2010a).

When handled with technical criteria, disposing DCWW in the soil is an economically viable way of incorporating nutrients and an ecologically correct method to recycle the residues generated in the production sector. In addition, the planned use of wastewater reduces pressure over primary water resources, thus becoming an effective strategy to preserve water, both in quality and quantity (Medeiros *et al*., 2007).

Fertigation is an option to apply DCWW to crops. This practice has been growing mainly because it generates savings in fertilizers per production unit, reduces labor and improves uniformity of nutrient distribution, among other advantages (Eloi e*t al*., 2007). However, crops to be fertigated with wastewater must also have certain adequate characteristics, such as quick growth, large root mass and high capacity to absorb nutrients (Matos *et al*., 2008). The reference for defining the wastewater application rate depends on the soil-plant capacity to absorb residues without affecting soil, plant and groundwater quality (Erthal *et al*., 2010b). In general, N contents have been used as one of the references to establish fertigation depths.

Tomatoes, one of the most popular vegetables in Brazil, are, at one time, among the most N demanding crops and the most sensitive to climatic variations (Zotarelli *et al*., 2009). As tomatoes have high production costs due to great fertilizer and agrochemical demands (Agrianual, 2009), DCWW use may turn out to be an important economic alternative.

In view of the above mentioned, in this work we aimed to evaluate the impact of fertigation with wastewater from dairy cattle on leaf nutritional content, production and yield of tomatoes grown in organic farming.

MATERIAL AND METHODS

The work was carried out at the State Center for Research in Organic Farming (CEPAO/PESAGRO-Rio), in greenhouse, located in the city of Seropédica, Rio de Janeiro State (22°48'00"S, 43°41'00"W, altitude 33 m), from May to September, 2012.

The cherry tomato cultivar Perinha Água Branca, cultivated in an organic farming system, was used. Seedlings were transplanted 15 days after germination into 12 L pots, with 70x60 cm spacing between pots, one plant per pot. Substrate consisted of a homogeneous mixture of three parts of clay and two parts of sand, one part of the commercial substrate Top Garden, type base soil, used as soil conditioner, and 2% of organic compost from vermicompost. Planting fertilization consisted of dolomitic lime 95% relative power of total neutralization, thermophosphate (16.5% P_2O_5) and potassium sulfate (50% K_2O), aiming at correcting acidity and raising phosphorus and potassium initial contents, respectively (Pereira & Ferreira, 2010).

Substrate chemical analysis was carried out in the Soil Laboratory of the Federal University of Viçosa, with the following results: pH = 5.1; total nitrogen = 0.8 g/kg; phosphorus = 19 mg/dm^3; potassium = 106 mg/dm^3; calcium = 3 cmolc/dm^3; magnesium = 0.92 cmolc/dm^3; copper = 0.63 mg/dm^3; manganese = 18.2 mg/dm^3; iron = 54.1 mg/dm^3 and zinc = 3.1%.

Drip irrigation with NETAFIM® drippers was used, 2.4 L/h flow rate, 10 mca service pressure, 92.5% application uniformity coefficient, and half-day fixed irrigation shifts. Irrigation was managed to keep substrate moisture near field capacity, between -220 and -180 kPa (Guimarães & Fontes, 2003). The wastewater from dairy cattle (DCWW) used here was prepared to present characteristics similar to those described in literature (Erthal *et al*., 2010a): 70% of volume corresponded to clean well water, with no chemical treatment, and 30% to fresh bovine manure collected from the farmyard of the Integrated Agroecological Production System (SIPA) of Embrapa Agrobiology, city of Seropédica. Wastewater analysis was carried out in the Environmental Monitoring Laboratory I - Waters and Effluents, of the Department of Engineering of the Rural Federal University of the state of Rio de Janeiro. Wastewater presented the following characteristics: pH= 7.4; electrical conductivity = 2.55 dS/m; total solids = 22,100 mg/L; chemical oxygen demand = 20,080 mg/L; biochemical oxygen demand = 4,712 mg/L; total nitrogen = 486.5 mg/L; $N\text{-}NH_4^+$ = 117.5 mg/L; total phosphorous = 75 mg/L. DCWW analyzes were performed according to recommended methods (APHA, 1995) and prepared always at least 48 hours before use.

The nitrogen dose of 100 kg/ha, recommended in literature for tomatoes, for a 180-day cycle (Pereira & Ferreira, 2010), was the reference used to determine the DCWW depth in each treatment. Treatments were: 0 (T1, control), 50 (T2), 100 (T3), 200 (T4), 300 (T5) and 400% (T6) of the reference N dose, to be provided to plants by means of fertigation using DCWW. Treatments were split in 52 applications, twice a week, during the whole growing period, starting with 30-day old plants. Other nutrients were supplied through complementary organic fertilization with Agrobio®, 25 L distributed with a back sprayer (Deleito *et al*., 2005). The experiment was carried out in a completely randomized design, eight replications, and four plant (two stems) plots, 32 plants per treatment in total.

Stem diameter (SD), branch average length (BL), weekly fruit production per plant, total fruit yield at the end of the cycle and foliar nutrient contents (N, P, K, Ca, Mg, S, Cu, Mn, Fe, Zn and B) were evaluated. BL was assessed using a measuring tape and, SD, using a digital caliper, both 06, 26, 48, 76 and 93 days after DCWW application. Aggregate fruit yield was estimated in t/ha.

Fruits were harvested only at physiological maturity stage, that is, when turning from reddish to red. Plants were harvested individually and fruits were weighed in scale with 0.1 g accuracy. Harvests were carried out 72, 93 and 107 days after planting, starting on August 9, 2012. Aggregate yield estimate was based on the accumulated production of each experimental plot along the harvests.

Leaf sampling to analyze nutrient content was performed on July 05, 2012, following the methodology proposed by Malavolta (1992). Samples were formed using the fourth leaf from the apical end of all plants of each plot, collected at flowering. Analyzes of nutrient concentration in leaves were performed at the Foliar Analysis Laboratory of the Department of Soils of the Federal University of Viçosa, state of Minas Gerais, to quantify N, P, K, Ca, Mg, S, Cu, Mn, Fe, Zn and B, according to methodology proposed by the Brazilian Agricultural Research Corporation (Embrapa, 1999). Data were submitted to analysis of variance ($p \leq 0.05$) and, when significant, adjusted to polynomial regression models. Treatment means were compared by Tukey test ($p \leq 0.05$).

RESULTS AND DISCUSSION

Dairy cattle wastewater (DCWW) had no significant effects over tomato stem diameter (SD) or branch length (BL), assessed 06, 26, 48, 76 and 93 days after DCWW application. SD and BL averages considering all treatments were 7.9 mm and 99.1 cm, respectively. In general, N increases plant vigor. N has a fundamental role in plant metabolism, since it participates directly in protein and chlorophyll biosynthesis (Porto *et al*., 2014), which are associated with branch length and stem diameter (Navarrete *et al*., 1997). However, none of the DCWW depths applied here significantly affected tomato SD or BL, possibly due to the higher nitrogen uptake by fruits, as shown in traits related to fruit production. Souza *et al*. (2010) observed similar results using swine wastewater. The complementary organic fertilization used in all treatments is likely to have contributed to this result too, since the supply of other nutrients via foliar fertilization may have been sufficient for the adequate development of tomato stems and branches.

Fruit weekly production per plant as a function of DCWW depths fit into a linear model. Therefore, maximum yield was reached at 400% of the recommended N for tomato (Figure 1). Increases in production in relation to the control dose (0% N) were 12 and 47%, respectively, for 100 and 400% of the recommended N, applied via DCWW, 107 days after planting (DAP). Fayad *et al*. (2002), studying nutrient uptake by tomatoes grown in the field and in protected cultivation, observed the highest N uptake occurred 120 DAP. This may explain why weekly fruit production observed 107 DAP was significantly higher than 72 and 93 DAP. Increases in N, P and K due to DCWW application probably contributed to increase production, since nutrient availability is known to affect tomato yield and quality (Kolota & Osinska, 2000). N and K are the two nutrients with the largest uptake and, in addition, the uptake of one increases the demand for the other (Cantarella, 2007).

Aggregated fruit yield along the cycle also fit into a linear regression model (Figure 2). Doses 50, 100, 200, 300 and 400% of the recommended N yielded 3, 7, 15, 22 and 30% more, respectively, than 0% N, demonstrating DCWW improves tomato productivity, with clear advantages to farmers. Hence, DCWW applied via fertigation was effective in complementing tomato fertilization. Increases observed here in tomato yield due to growing nitrogen doses applied via fertigation with DCWW are related to the nutrients present in wastewater (Souza *et al*., 2010), which improve soil fertility and provide plants with the necessary conditions to yield more.

N, P and K leaf contents also fit into linear equations (Figure 3) and were significantly altered by N doses supplied via fertigation with DCWW, with increases in nutrient accumulation in the plant aerial part. From dose 100% of the recommended N onwards, 4, 11 and 13% increments in N, P and K contents, respectively, in relation to the control were observed. The highest increases in nutrient contents, namely 17, 44 and 53% in N, P and K, respectively, took place with 400% of the recommended N. Studies on nutrient uptake dynamics by tomato showed K uptake was larger than N between 48 and 72 days after transplanting (Fayad *et al*., 2002), in agreement with the larger increase in K contents observed here, once analysis was carried out in leaves collected within the mentioned period. Although K uptake percentage was higher than N, N average content in tomato leaf samples was higher than K in all treatments. Increase in N and K contents had already been observed in leaves of cherry tomato fertigated with different doses of nutrient solution containing macro and micronutrients (Soares *et al*., 2005).

N, P and K levels were significantly altered by the different N doses supplied

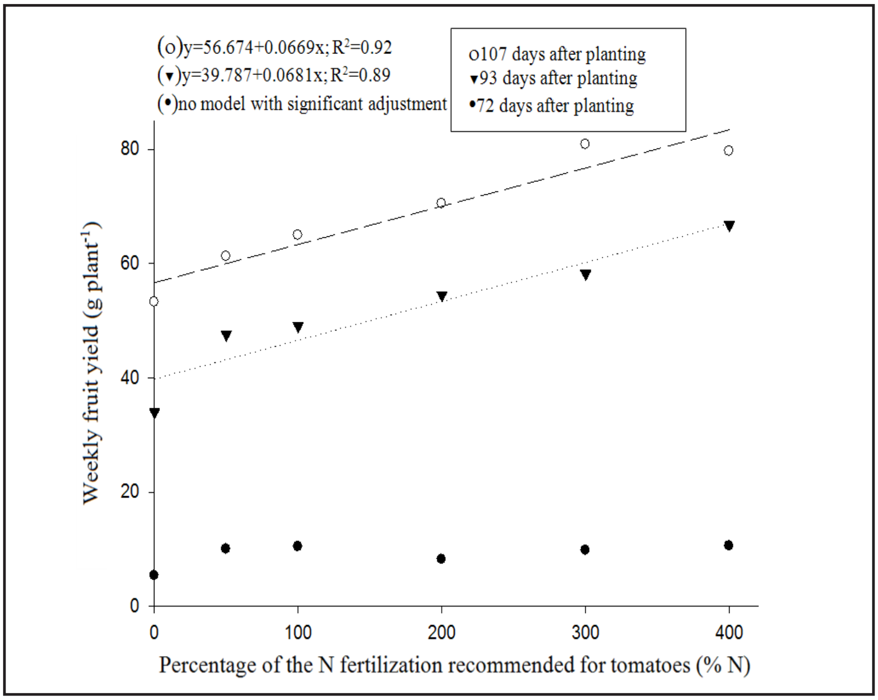

Figure 1. Weekly fruit yield of tomato grown under fertigation with different doses of dairy cattle wastewater. Seropédica, UFRRJ, 2012.

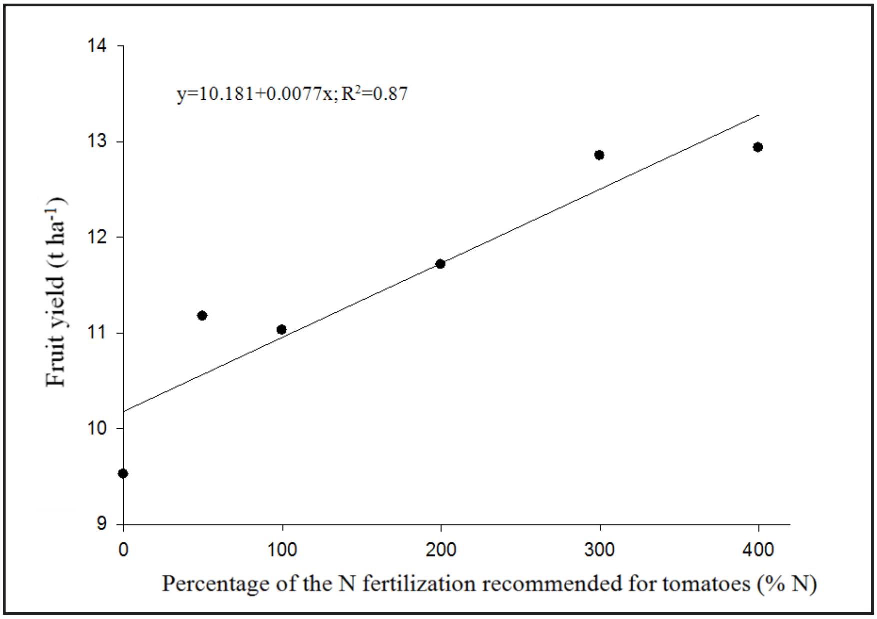

Figure 2. Fruit yield in tomato grown under fertigation with different doses of dairy farming wastewater. Seropédica, UFRRJ, 2012.

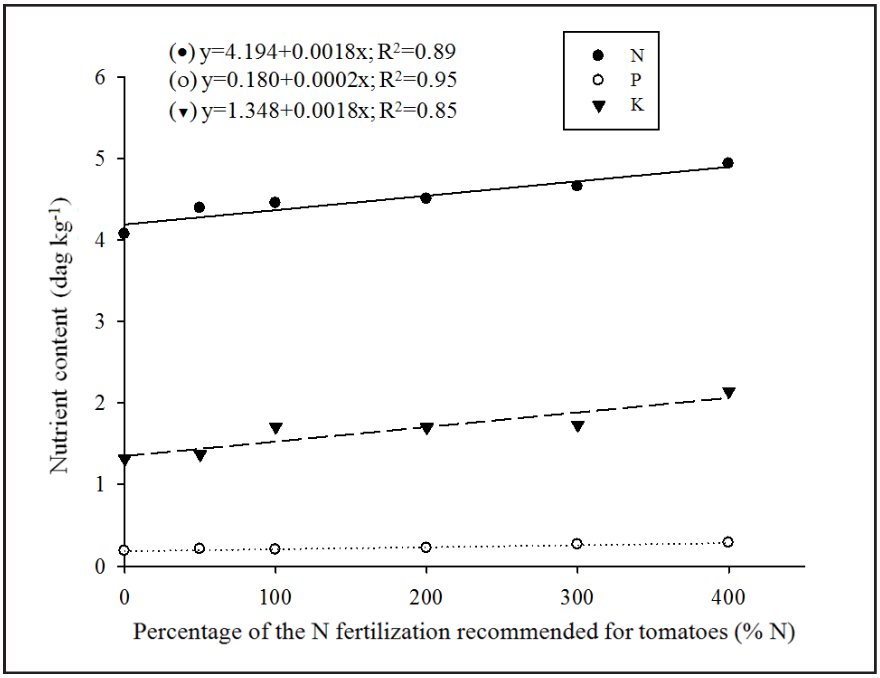

Figure 3. Average N, P and K leaf contents of tomato grown under fertigation with different doses of dairy farming wastewater. Seropédica, UFRRJ, 2012.

via DCWW (Table 1). There were significant differences in N foliar level among doses corresponding to 50, 200, 300 and 400% of the N recommended for tomato in relation to 0%. The only exception was dose 100% of the recommended N, which did not differ from any of the other treatments. Considering P, foliar accumulation was significantly higher at doses 300 and 400% compared to doses 0 and 100% of the N recommended for tomato, whereas dose 200% did not differ from other treatments and dose 50% differed only from dose 400%. In relation to K, the only significant difference occurred between doses 50 and 400% of the recommended N, with a significant increase in K foliar content at dose 400% in relation to dose 50% of the N recommended for tomato. Average P and K foliar contents were 46% and 40%, respectively, of the minimum adequate content for tomato development (Alvarenga, 2004). However, no deficiency symptoms were visually observed, and fruit yield and quality were high in the experiment. Wastewater is rich in macro and micronutrients. However, part of these nutrients is available only after organic material is mineralized. It would not be unlikely that mineralization have not had enough time to occur, leading to the low P content observed in the leaf analysis. Furthermore, in the present case, P levels in DCWW were already low, which may also have contributed to the results. For K, probably its availability in DCWW and soil fell shorter than tomato needs. Thus, to meet tomato P and K demands (Alvarenga, 2004), it would have been necessary to complement P and K in mineral form.

Calcium contents were within the recommended range for tomato at all DCWW doses (Table 1). Ca low variation allows concluding its origin is most likely linked to the limestone used as base fertilization. Calcium is a very important cell wall component in fruit formation. On the other hand, magnesium deficiency was identified (Table 1), although no visual symptoms were observed and plants on the experiment had good productivity. Nevertheless, it would be wise to consider supplementing Mg when growing tomatoes using fertigation with DCWW. Mg deficiency results in chlorosis (Daflon *et al.*, 2014) and, consequently, reduction on photosynthetic efficiency, negatively impacting yield. Sulfur contents were on average 26% above the recommended maximum value (Table 1). However, no plants showed visual toxicity symptoms.

Regarding micronutrients, contents in tomato leaves did not vary significantly as function of treatments. Cu, Mn, Fe, Zn and B contents, as average of all treatments, were 958.7; 240.5; 141.7; 28.3 and 55.5 mg/kg, respectively. Cu foliar contents are above the adequate for tomato development, but no toxicity symptoms were observed. Cu contents may have been influenced by sprayings with the Bordeaux mixture three days before leaf sampling. The Bordeaux

Table 1. Average N, P, K, Ca, Mg, and S contents in leaf samples, as dry weight, of tomato grown under fertigation with different doses of dairy farming wastewater. Seropédica, UFRRJ, 2012.

Dairy farming wastewater level (%)[1]	N* (g/kg)	P* (g/kg)	K* (g/kg)	Ca (g/kg)	Mg (g/kg)	S (g/kg)
0%	36.8b	1.8c	16.6ab	25.2^{ns}	8.6^{ns}	12.4^{ns}
50%	44.4a	2.0bc	15.0b	26.4^{ns}	8.2^{ns}	13.4^{ns}
100%	42.7ab	1.9c	18.7ab	25.3^{ns}	7.9^{ns}	11.9^{ns}
200%	44.9a	2.2abc	17.9ab	25.2^{ns}	7.7^{ns}	11.7^{ns}
300%	46.9a	2.5ab	16.8ab	24.9^{ns}	7.4^{ns}	12.9^{ns}
400%	46.7a	2.6a	22.5a	24.7^{ns}	7.6^{ns}	13.1^{ns}
Adequate contente (g/kg)**	40-60	4-8	30-50	14-40	40-80	3-10

^{ns}= Non-significant, Tukey test, p>0.05; Means followed by same letters in the column do not differ from each other, Tukey test, p>0.05; **As recommended by Alvarenga, (2004); [1]Amount of N deployed by fertigation using dairy farming wastewater, as percentage of the N fertilization recommended for tomatoes, i.e., 100 kg N/ha.

mixture contains Cu and is used to control diseases caused by fungi. High Cu concentration in plants can be extremely toxic, causing symptoms such as chlorosis, necrosis, leaf discoloration and inhibition of root growth (Yruela, 2005). Nevertheless, none of these symptoms were observed visually. Contents of the other micronutrients were within the range considered suitable for tomato (Alvarenga, 2004).

In conclusion, tomato nitrogen fertilization in organic farming systems can be successfully carried out by means of fertigation with dairy cattle wastewater. However, phosphorus and potassium must be supplemented using mineral sources. The highest weekly and aggregated tomato yield, as well as the highest nutrient foliar contents, were observed when 400% of the nitrogen dose recommended for tomato was used.

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