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Yield and nutrition of sunflower fertilized with sewage sludge stabilized by different processes

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ABSTRACT

The different methods of sewage sludge stabilization modify their physical chemical and biological properties, altering its efficiency when applied in agriculture. The objective of this study was to evaluate the nutrient levels in soil and the yield of sunflower fertilized with sewage sludge stabilized by different processes. The experiment was conducted in Cambisol, with the treatments: control (without fertilization), fertilization with sewage sludge solarized, composted, vermicomposted, limed and chemical fertilizer recommended for sunflower crop. The experimental design a randomized block with four replications. The different methods of sewage sludge treatment did not affect the yield; however, the application of sewage sludge, regardless the stabilization process adopted, was more effective than chemical fertilizer and the control treatment. Overall, fertilization with limed sewage sludge provided higher soil nutrients concentrations, while treatments with composted and vermicomposted sewage sludge showed higher levels of nutrients in the plant.

Key words: *Helianthus annuus,* biossolids, composting, vermicomposting, limed sludge.

RESUMO

Produtividade e nutrição de girassol adubado com lodo de esgoto estabilizado por diferentes processos

Os diferentes métodos de estabilização de lodo de esgoto modificam suas propriedades químicas, físicas e biológicas, podendo alterar sua eficiência para aplicação na agricultura. Objetivou-se, com este trabalho, avaliar a produtividade e os teores de nutrientes, no solo e na planta de girassol, adubada com lodo de esgoto submetido a diferentes processos de estabilização. O experimento foi desenvolvido em cambissolo háplico, com os tratamentos: testemunha (sem adubação), adubação com lodo de esgoto solarizado, adubação com lodo de esgoto compostado, adubação com lodo de esgoto vermicompostado, adubação com lodo de esgoto caleado e adubação química recomendada para a cultura. Utilizou-se o delineamento experimental em blocos casualizados, com quatro repetições. As diferentes formas de tratamento do lodo de esgoto não influenciaram a produtividade; entretanto, a aplicação desse resíduo, independentemente do método de estabilização empregado, mostrou-se mais eficiente que a adubação química e que o tratamento testemunha. A adubação com lodo de esgoto caleado proporcionou maiores teores de nutrientes no solo, enquanto os tratamentos com lodo de esgoto compostado e vermicompostado apresentaram maiores teores de macronutrientes na folha e no pecíolo, exceto no caso do nitrogênio, cujo teor foi maior com a aplicação de lodo de esgoto caleado.

Palavras-chave: *Helianthus annuus*, biossólido, compostagem, vermicompostagem, lodo caleado.

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INTRODUCTION

The sunflower (*Helianthus annuus*) is a plant native from the southwestern United States and northern Canada that belongs to the Asteraceae botanical family. Besides its use as animal feed, the sunflower is constituted of 48-52% of an excellent quality oil for human consumption, and it is also important in canning and paint industries (Rossi, 1998). Recently, in an attempt to reduce dependence on fossil fuels and control emissions of greenhouse gases, sunflower became part in the energy matrix in biofuel production (Silva & Freitas, 2008). Therefore, sunflower cultivation has been expanding in many countries.

Crop production can cause a reduction of organic matter levels and chemical soil depletion, if the replacement does not compensate the nutrient loss by uptake. Considering the high content of organic matter, as well as the expensive availability of nutrients in sewage sludge, its final disposal in cultivated areas has been reported as an alternative to alleviate the problems arising from agricultural production and to the recovery of degraded areas (Guedes *et al.*, 2006; Caldeira Júnior *et al.*, 2009). In addition to the economic benefit in the physical and chemical recovery of soil, the agricultural use of sewage sludge is interesting for an ecological viewpoint, since it eliminates the negative effects of other alternatives for final disposal of waste, and also helps to preserve the world's reserves of nutrients (Aggelides & Londra, 2000; Düring & Gäth, 2002).

Despite several benefits, the use of sewage sludge in agriculture is worrisome because it may contain heavy metals, persistent organics and pathogenic organisms, which, in addition to contaminate the soil and damage the crop development, they can be absorbed by plants and incorporated to the food chain (Düring & Gäth, 2002). Therefore, it is necessary to stabilize the sewage sludge prior to land application, and the most commonly used methods are solarization, composting, vermicomposting and chemical treatment with lime.

The different forms of sewage sludge stabilization promote changes in the physical characteristics of the material and in the bioavailability of nutrients, which may change the results obtained with the agricultural use of the residue. Costa *et al.* (2009) found that the composting process promotes increases in the nutrients of the substrate by reduction of organic carbon for microbial respiration. Garg *et al.* (2006) and Gupta & Garg (2008) evaluating the physical and chemical changes in residues subjected to vermicomposting process, observed increases in the levels of N, P, K and in the electric conductivity of the substrate, and reduction of pH, total organic carbon and of the C:N ratio.

The treatment with lime eliminates pathogens in sewage sludge by raising the pH and temperature of the waste, and promotes insolubility of metals. However, the addition of lime to the sludge may cause phosphorus precipitation of and nitrogen loss by ammonia volatilization (Carneiro *et al.*, 2005; Fia *et al.*, 2005). Chueri *et al.* (2007) observed that raising the soil pH above neutral, due to the application of limed sludge, affected the morphological parameters and the dry matter of wheat plants, and reduced the manganese availability to plants.

Given the above, the present study aimed to evaluate the nutrient content, in soil and in the plant, and the sunflower yield in response to fertilization with sewage sludge stabilized by different processes.

MATERIAL AND METHODS

The experiment was carried out from July to November 2010, at the Institute of Agricultural Sciences, Universidade Federal de Minas Gerais, in Montes Claros, Minas Gerais State, Brazil, lat 16°51'38 "S and long 44°55'00" W in Cambisol. The soil chemical and physical characteristics were assessed according to the methodologies recommended by Embrapa (1997), at 0-20 cm: pH in water = 5,8; P-Mehlich-1 = 3,5 mg dm^{-3}; P-remaining = 16,7 mg L^{-1}; K = 229 mg dm^{-3}; Ca = 3,60 $cmol_c$ dm^{-3}; Mg = 1,50 $cmol_c$ dm^{-3}; Al = 0,20 $cmol_c$ dm^{-3}; H + Al = 3,62 $cmol_c$ dm^{-3}; sum of bases = 5,69 $cmol_c$ dm^{-3}; CEC effective = 5,89 $cmol_c$ dm^{-3}; m = 3%; CEC total = 9,31 $cmol_c$ dm^{-3}; V = 61%; organic matter = 3,39 dag kg^{-1}; grit = 5,60 dag kg^{-1}; fine sand = 14,40 dag kg^{-1}; silt = 38 dag kg^{-1} and clay = 42 dag kg^{-1}; and at 20-40 cm depth: pH in water = 5,5; P-Mehlich 1 = 1,9 mg dm^{-3}; P-remaining = 14,4 mg L^{-1}; K = 117 mg dm^{-3}; Ca = 2,8 $cmol_c$ dm^{-3}; Mg = 0,80 $cmol_c$ dm^{-3}; Al = 0,76 $cmol_c$ dm^{-3}; H + Al = 3,62 $cmol_c$ dm^{-3}; sum of bases = 3,90 $cmol_c$ dm^{-3}; CEC effective = 4,66 $cmol_c$ dm^{-3}; m = 16%; CEC total = 7,52 $cmol_c$ dm^{-3}; V = 52%; organic matter = 2,50 dag kg^{-1}; grit = 4,30 dag kg^{-1}; fine sand = 21,70 dag kg^{-1}; silt = 36 dag kg^{-1} and clay = 38 dag kg^{-1}.

The experimental design was a randomized block with six treatments and four replications, and one chemical treatment (20 kg ha^{-1} N, 70 kg ha^{-1} P_2O_5 and 30 kg ha^{-1} K_2O, at sowing and 40 kg ha^{-1} N 45 days after emergence), according to the recommendations for the use of lime and fertilizers in Minas Gerais State (Comissão de Fertilidade do Solo do Estado de Minas Gerais - CFSEMG, 1999). Urea, superphosphate and potassium chloride were used as sources of N, P and K, respectively. The four treatments with sewage sludge, stabilized by different methods, were applied according to the nitrogen availability. The equations and methodologies described by the Resolution CONAMA 375, from August, 2006, were adopted in the calculations (Brasil, 2006), such as follows: solarizated

(6,12 t ha^{-1}), composted (37,27 t ha^{-1}), vermicomposted (19,17 t ha^{-1}), limed (50,42 t ha^{-1}), and one treatment without fertilization. The cultivated species was the sunflower simple hybrid Helio 863.

The solarized sewage sludge was collected from the wastewater treatment station (WWTS) of the municipality of Juramento, Minas Gerais State. The WWTS has a treatment line comprising the preliminary treatment and anaerobic UASB reactor, connected in series with a post-treatment pond, optional type, and treatment of sewage sludge by the solarization process for drying bed. For composting, the solarizated sewage sludge was mixed to grass resulted from trimming, which the predominat species was *Paspalum notatum*, to obtain a C:N ratio of 30:1. The temperature and moisture were constantly monitored, and in order to control these variables, the compost piles were systematically revolved. To obtain the vermicompost, a pre-composed sewage sludge was prepared mixing a mass of grass resulted from trimming, used one month after the start of the decomposition process, as the substrate for vermicomposting with California red worms (*Eisenia foetida*). The limed sewage sludge was obtained by adding lime in the amount of 50% of the dry sewage sludge. After mixing, the moisture increased to 70%. The chemical characteristics of materials containing sewage sludge are shown in Table 1.

The fertilizations with sewage sludge were performed only once, at planting. The plots consisted of four rows 3.60 m long, spaced at 0.80 m, and the useful area consisted of the two central lines, ignoring 0.4 m from each end. The seeding was performed in grooves with three seeds per hole at a distance of 0.20 m between plants. Thinning was done 15 days after emergence, leaving only one plant per hole. The weeds were controlled by hand-weeding, and the water was supplied through sprinkler irrigation.

At the beginning of flowering, samples were collected from leaves and petioles of the upper third of ten plants randomly selected in the useful area for chemical analysis of the contents of N, P, K, Ca, Mg and S (Tedesco *et al.*, 1995; Malavolta *et al.*, 1997).

The sunflower crop was harvested when the plants reached the stage R9, which the chapters were facing down. For the calculation of productivity, the grain moisture was corrected to 13%. After harvest, eight subsamples per plot of soil were collected between plants in a row at depths of 0-20 and 20-40 cm, to form composite samples for P, K, Ca, Mg and S analysis (Embrapa, 1997).

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

RESULTS AND DISCUSSION

The different sewage sludge methods of treatments did not affect sunflower yield. However, the use of sludge, regardless of the stabilization technology employed, was more efficient than chemical fertilization and the control treatment (Table 2). Considering the P and K levels available in sewage sludge (Table 1), and the doses of the residue added into the soil by sewage sludge treated by different methods: solarized, composted, vermicomposted and limed, were respectively, 45; 239; 132 and 335 kg ha^{-1} of P_2O_5 and 21; 126; 92 and 267 kg ha^{-1} of K_2O. The content of N available was higher in the solarized treatment; therefore, lower doses were necessary to achieve the total N required by the crop. The other treatments exceeded the recommended application of these elements in the culture in the soil conditions during the experiment (70 kg ha^{-1} P_2O_5 and 30 kg ha^{-1} K_2O), even considering the organic P mineralization rate of 60%, as cited by the Commission of Soil Fertility of Minas Gerais State (CFSEMG, 1999). The largest amounts of P, K, Ca, Mg, S applied using sewage sludge (Table 1), in addition to the improvement of soil conditions resulting from the organic matter in the residue (Trannin *et al*., 2008) may explain the higher productivity compared to that obtained by chemical fertilizer.

The yield obtained by the control treatment (1.37 t ha^{-1}) was higher than the national average yield in 2010 (Instituto Brasileiro de Geografia e Estatística - IBGE, 2011), which was 1.14 t ha^{-1}. Treatments with chemical fertilizers, solarized sludge, composted sludge, vermicomposted and limed sludge had yields superiors in 194, 309, 252, 233 and 268% of national average yield, respectively, attesting the potential for agricultural use of sewage sludge in sunflower crop.

Table 1. Chemical characteristics[1] of the sewage sludge solarized, composted, vermicomposted and limed, used in the experiment

Stabilization method	N	P_2O_5	K_2O	Ca	Mg	S
	dag kg^{-1}					
Solarization	2.71 (60)	0.73 (45)	0.34 (21)	0.65 (40)	0.20 (12)	1.61 (99)
Composting	1.45 (60)	0.64 (239)	0.34 (126)	0.71 (265)	0.15 (56)	1.28 (477)
Vermicomposting	1.39 (60)	0.68 (132)	0.48 (92)	0.49 (94)	0.15 (29)	0.92 (176)
Limed	0.83 (60)	0.66 (335)	0.53 (267)	10.93 (5511)	0.23 (116)	1.24 (625)

[1] Methodologies advocated by Tedesco *et al.* (1995).Values in parentheses correspond to the amounts of nutrients applied in kg ha^{-1}. For N, the quantities applied were based on N content available.

Nonetheless, unlike the results observed during this study, Lobo & Grassi Filho (2007) found that, although sewage sludge increases sunflower yield, when applied in higher doses, in a sufficient amount to supply the N required, the yield is not higher than the obtained by chemical fertilizers and by the treatment without fertilizer. Furthermore, Nogueira *et al.* (2006), working in a similar soil condition, found no yield increases in maize and bean fertilized with sewage sludge stabilized by different methods, in relation to the yield obtained with chemical fertilization. However, one should consider that these authors worked with a consortium (maize and beans), and the amount of sludge applied was calculated based only on the requirement of maize.

The stabilization methods hardly changed the P concentration in the sewage sludge (Table 1). However, as a result of the sharp variation of the concentration of nitrogen, the sludge doses changed considerably among treatments, which resulted in a higher amount of P in soil treated with limed sludge and, consequently, higher concentrations of this nutrient in this treatment at 0-40 cm depth (Table 2). For the other treatments, although the levels of P applied in the soil were different, there were no statistical differences, which can be attributed to higher productivity in plots that received fertilization with sewage sludge. Unlike found in this experiment, Nogueira *et al.* (2006) cultivating maize and bean inter cropping, observed higher P content in treatments with chemical fertilizer, compared to the treatments fertilized with stabilized sewage sludge. However, the differences in results between these experiments may be related to the amount of P applied in the soil, which varied mainly due to the need for P of the respective crops.

Based on the K content in the materials, the treatments control, solarized, composted, vermicomposted, limed and chemical fertilization supplied the respective amounts of 0, 21, 126, 92, 267 and 30 kg ha^{-1} K_2O. Despite the differences in the amounts applied, the K content in the soil after the sunflower cultivation, were similar (Table 2). Besides the greatest nutrient export in the treatments with sewage sludge, due to the highest yield, the high concentrations of cations provided by these treatments may have promoted the leaching of nutrients by the displacement of the element in soil colloidal micelle. Moreover, the highest potassium availability increases the nutrient leaching rate, especially considering the constant water supply (Werle *et al*., 2008).

Several authors consider the sludge residue as low-K, as it is found predominantly in the ionic form, which tends to remain in solution during the process of wastewater treatment, and chemical complementation with this element is constantly recommended (Bueno *et al.*, 2011; Guedes *et al.*, 2006; Simonete *et al.*, 2003). However, in the present study, K could not be considered a limiting element of productivity, because the quantities added into the soil by the treatments solarized, composted, vermicomposted and limed were, respectively: 0.7, 4.2, 3, 1 and 8.9 times the recommended. Although the amount of K applied was lower than recommended in the solarized sewage sludge treatment, no deficiency symptom was detected, but it is worth mentioning the high initial levels of K in the soil, ranging 229-117 mg dm^{-3} in the depth of 0-40 cm.

Calcium was the nutrient that has the greatest variation in its levels due to the different processes of stabilization. Its concentration in limed sewage sludge was at least 15 times higher than that observed in other stabilization methods (Table 1). Thus, the application of limed sewage sludge provided higher Ca to the soil at a depth of 0-40 cm. Among other treatments, there were no statistical differences (Table 2). The high Ca content in limed sludge,

Table 2. Productivity and nutrient content in soil in response to the application of mineral fertilizer and sewage sludge

Variables	Depth (cm)	TREATMENTS						CV (%)
		TE	LS	LCO	LV	LCA	AQ	
Yield (t ha^{-1})	-	1.37 b	3.52 a	2.87 a	2.66 a	3.05 a	2.21 b	27.06
P	0-20	1.65 b	2.3 b	5.5 b	4.92 b	11.78 a	3.2 b	45.10
(mg dm^{-3})	20-40	0.90 b	1.15 b	1.63 b	1.65 b	2.63 a	1.47 b	38.82
K	0-20	162.50 a	145.00 a	148.75 a	152.50 a	148.00 a	135.75 a	22.39
(mg dm^{-3})	20-40	82.50 a	72.75 a	60.75 a	79.00 a	83.75 a	70.00 a	29.78
Ca	0-20	3.82 b	4.53 b	4.42 b	4.30 b	10.25 a	3.45 b	17.33
($cmol_c$ dm^{-3})	20-40	2.00 b	3.40 b	2.00 b	2.30 b	5.90 a	1.90 b	47.42
Mg	0-20	0.70 a	0.70 a	0.73 a	0.65 a	0.45 b	0.68 a	17.39
($cmol_c$ dm^{-3})	20-40	0.33 a	0.38 a	0.28 a	0.28 a	0.38 a	0.33 a	27.90
S	0-20	16.85 b	30.08 b	34.88 b	25.85 b	66.10 a	40.28 b	51.55
(mg dm^{-3})	20-40	8.48 b	28.65 b	21.73 b	5.43 b	65.33 a	12.58 b	57.51

TE – Control; LS – solarized sewage sludge; LCO – composted; LV –vermicomposted; LCA – limed; AQ – chemical fertilized.For each variable, means followed by the same letter in the line do not differ statistically at 5% probability by the Scott-Knott test.

thus, its increase in soil due to the application of the residue, results from the addition of large amounts of CaO in lime application process, a fact also observed by Chueri *et al*. (2007) and Guedes *et al*. (2006). The results corroborate with those of Nogueira *et al.* (2006), which evaluated the Ca in soils treated with sewage sludge stabilized by different methods and found the same effect using limed sewage sludge.

For all forms of sewage sludge applied, Mg was the macronutrient with the lowest concentration. Thus, as for the other nutrients evaluated, the treatment with limed sewage sludge supplied the higher doses of this element. However, lower levels of the nutrient at 0-20 cm were observed in this fertilization treatment. Furthermore, there were no statistical differences on this variable among the treatments in a 20-40 cm depth (Table 2). Similarly, Chueri *et al.* (2007), applying doses of sewage sludge up to 10 t ha^{-1}, found no effect on Mg levels in soil.

The concentrations of S varied considerably in sewage sludge, due to the stabilization methods. The S levels observed in sewage sludge composted, vermicomposted and limed are, respectively, 79, 57 and 77% of the S content in sewage sludge solarized (Table 1). Although several studies reported nutrients increases in vermicomposted sludge in relation to the initial content, mainly due to the concentration of nutrients, due to the loss of organic carbon for microbial respiration (Dores-Silva *et al*., 2011; Garg *et al*., 2006; Gupta & Garg, 2008). These facts suggest that, with the advancement of the process of decomposition, the S may have been reduced by bacteria, with consequent loss of the element to the atmosphere, which is found in flooded soils or anaerobic sites of well-drained soil (Alvarez *et al.*, 2007).

The soil input of S in the treatments solarized, composted, vermicomposted and limed, were, respectively, 99, 477, 176 and 625 kg ha^{-1}. Even though the content of S was not greater in the limed sludge, because of the doses applied with this stabilization process, greater amounts of S were added into the soil, resulting in higher concentrations of the element in the soil, for the other treatments, at 0-40 cm depth (Table 2). Considering that the residue was incorporated into the seed furrows (10 cm deep), the influence of the limed sewage sludge treatment on S concentrations at 20-40 cm depth, may have been favored by the presence of large amounts of Ca, which connects with S, resulting on neutral ion pairs with high mobility in soil (Alvarez *et al.*, 1999a).

The N leaf concentration in sunflower plants fertilized with limed sewage sludge was higher than the other treatments (Table 3), reaching values above those considered appropriate according to Malavolta *et al.* (1997). The same behavior was observed in the sunflower petiole, even though the same amount of N available was applied in all treatments. Considering the power of soil liming of the limed sewage sludge, a plausible hypothesis to explain the results is the acceleration of N nitrification rate, by raising the soil pH in this treatment (Silva *et al.* 1994). There were no statistical differences in foliar N among the treatments. However, in the solarized sewage sludge treatment, the N content in the leaf reached appropriate levels, while in the control, chemical, composted and vermicomposted treatments, N contents in leaf were below the optimal (Malavolta *et al*., 1997). Lavado (2006) found no difference in N concentration in shoots of sunflower fertilized with sewage sludge at doses up to 14 t ha^{-1}, compared to the treatment without fertilization.

Fertilization with composted sewage sludge, limed or vermicomposted, presented the phosphorus content in sunflower leaf statistically higher than the levels observed in the other treatments. However, in none of the treatments, the P concentration in leaf reached adequate levels (Malavolta *et al*., 1997). Considering the good P availability in the soil, in the treatment with limed sewage sludge, the P content observed in the leaf was below than the potentially possible, since the proper nutritional level was not reached. Probably, the high calcium content in the soil in this treatment promoted the precipitation of P, and its determination, using the Mehlich-1, may have overestimated the available concentration of this element, because of the possibility of its precipitation with Ca (Fia *et al.*, 2005; Novais *et al.*, 2007). Regarding the P concentrations in the petiole, sunflower plants fertilized with sewage sludge composted and vermicomposted showed higher values than the other treatments.

The K concentration in sunflower leaf did not vary with the treatments and, except for the treatment with limed sewage sludge, whose K content was higher than the considered ideal. All treatments showed K concentration in leaf in appropriate levels. Moreover, there was no difference in the levels of K in the sunflower petiole. These results can be attributed to the high concentration of K in the soil, considering that even in the control treatment, the levels of potassium were rated as very good, according to Alvarez *et al.* (1999b).

Although the content of Ca in the soil in the treatment with limed sewage sludge has been far superior than the others, this treatment, as well as treatment with solarized sewage sludge and the control, showed foliar Ca lower than those of chemical treatment, composted and vermicomposted sewage sludge (Table 3), which reinforces the hypothesis of the precipitation of Ca-P in the treatment with limed sewage sludge, as previously mentioned. In spite of the fact that the composted sewage sludge is the treatment that showed statistically higher levels of Ca in the leaf, only in the chemical and the vermicomposted treatments, the levels of Ca in the leaf

Table 3. Nutrient content in leaf and petiole of sunflower in response to the application of mineral fertilizer and sewage sludge treated in different ways

Nutrient	TREATMENTS						CV	Appropriate level[1]
	TE	LS	LCO	LV	LCA	AQ		
	dag kg^{-1}						%	dag kg^{-1}
				Leaf				
N	3.06 b	3.38 b	3.25 b	3.10 b	4.07 a	3.10 b	8.13	3.3 – 3.5
P	0.18 b	0.19 b	0.23 a	0.23 a	0.26 a	0.21 b	10.27	0.4 – 0.7
K	2.27 a	2.15 a	2.32 a	2.36 a	2.49 a	2.32 a	14.56	2.0 – 2.4
Ca	1.37 b	1.48 b	1.65 a	1.78 a	1.40 b	1.79 a	12.53	1.7 – 2.2
Mg	0.24 b	0.26 b	0.28 a	0.28 a	0.25 b	0.28 a	7.47	0.9 – 1.1
S	0.23 a	0.24 a	0.20 a	0.22 a	0.25 a	0.22 a	21.66	0.5 – 0.7
				Petiole				
N	0.71 b	0.73 b	0.65 b	0.64 b	1.12 a	0.66 b	10.43	-
P	0.11 b	0.11 b	0.17 a	0.18 a	0.14 b	0.12 b	17.52	-
K	3.44 a	3.23 a	2.93 a	2.95 a	3.30 a	3.32 a	11.26	-
Ca	1.18 a	1.06 a	1.23 a	1.31 a	1.19 a	1.17 a	9.91	-
Mg	0.24 a	0.24 a	0.24 a	0.25 a	0.24 a	0.23 a	9.83	-
S	0.14 a	0.14 a	0.15 a	0.15 a	0.16 a	0.14 a	6.87	-

TE – Control; LS – solarized sewage sludge; LCO – composted; LV –vermicomposted; LCA – limed; AQ – chemical fertilized.
[1]Malavolta *et al* (1997).
For each variable, means followed by the same letter in the line do not differ statistically at 5% probability by the Scott-Knott test.

were considered nutritionally adequate, in accordance with Malavolta *et al.* (1997). In chemical treatment, Ca was not added into the soil; however, the level of this element in the soil, even after cultivation was considered good, which may have contributed to this result. Regarding the Ca levels in the petiole, it was observed that this organ was not sensitive to variation in levels of this element in the soil, since there was no difference for that variable between treatments.

The treatments influenced the leaf levels of Mg, and higher levels were observed in the treatments with sewage sludge composted, vermicomposted and chemical fertilization. The same behavior was not observed for the petiole, in which, regardless of the treatment, Mg levels were equal. Even with differences between the treatments, foliar Mg levels were below the nutritionally adequate (Malavolta *et al.*, 1997). Considering the amount of Mg applied into the soil in each treatment, these results can be attributed to the greater availability of this element for plants, except for the treatment with limed sewage sludge, where foliar Mg was not consistent with the amounts applied into the soil. However, according to Vitti *et al.* (2006), the imbalance between Ca and Mg in the soil and high K levels may exacerbate Mg deficiency, furthermore, in this treatment, the proportion of Mg in CEC (< 6%) is considered low.

The highest levels of sulfur in the soil in the limed sewage sludge treatment, did not result in increases in S concentration in sunflower leaf (Table 3), probably because of the high levels of sulfur in the soil, which availability was classified as very good (Alvarez *et al.* 1999b), even in the control treatment. Nevertheless, foliar S were below the considered nutritionally adequate to the culture (Malavolta *et al.*, 1997). As observed on the leaf, the amount of S in the petiole of sunflower was not affected by the treatments.

Considering that the productivity did not vary due to the sewage sludge stabilization methods, the use of solarized sewage sludge is recommended for being the stabilization process that demands less time and labor.

CONCLUSIONS

Sunflower yield is higher with the application of sewage sludge than with chemical fertilizer, regardless the sludge stabilization process.

Fertilization with limed sewage sludge provides the highest levels of nutrients in the soil.

Fertilization with composted and vermicomposted sewage sludge provide the highest levels of macronutrients in leaf and petiole, except for nitrogen, which is greater in the fertilization with limed sewage sludge.

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