Original Article

SEWAGE SLUDGES IN PHYSIC NUT SEEDLINGS MACRONUTRIENT CONTENTS AND CHEMICAL ATTRIBUTES OF SOIL

LODOS DE ESGOTO NOS TEORES DE MACRONUTRIENTES EM MUDAS DE PINHÃO-MANSO E ATRIBUTOS QUÍMICOS DO SOLO

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ABSTRACT: Ever since the government began providing incentives for biofuel production, physic nut has appeared to be a promising plant, due to the high oil content of the seeds. The purpose of this study was to evaluate the nutrition of physic nut seedlings and changes in the chemical attributes of soil, based on the doses of domestic and industrial sewage sludge. Two experiments were conducted in a design with casualized blocks with four replicates using samples of a “Latossolo Amarelo” that received five doses of each sludge, equivalent to 0; 100; 150; 200 and 300 kg N total ha^{-1}. The domestic sewage sludge raised the calcium and magnesium contents in the dry mass of the aerial part and root, and nitrogen and phosphorus in the dry mass of the aerial part of physic nut seedlings, whereas the industrial sludge raised the calcium and nitrogen in the dry mass of the aerial part and root of the physic seedlings, but did not affect the phosphorus, nitrogen, magnesium and potassium contents in the dry mass of the aerial part and root. The domestic sludge did not alter the soil pH but raised the amounts of phosphorus, calcium + magnesium, cation exchange capacity, organic matter and reduced the exchangeable aluminum, while the industrial one raised the pH and the cation exchange capacity of the soil, increased the amounts of phosphorus, calcium + magnesium, and organic matter and reduced the exchangeable aluminum present in the soil. The domestic and industrial sludges may be used to produce physic nut seedlings; however is necessary studies to evaluate the presence of heavy metals or potentially pathogenic microorganisms.

KEYWORDS: *Jatropha curcas* L. Soil characteristics. Plant nutrition. Organic waste.

INTRODUCTION

Waste generation, whether organic or inorganic, has been a constant concern of humankind, mainly due to appropriate final disposal, besides the inherent potential of some of these materials to cause environmental damage. Discarding organic wastes in agricultural areas may result in an increased concentration of pollutants in the soil, and therefore it is clearly desirable (ROIG et al., 2012) to optimize the dose and frequency of applications to avoid an overload of contamination and derived risks to health and the environment (PASSUELLO et al., 2012).

According to Shams Fallah et al. (2013), the combination of recycling, followed by composting, incineration and disposal in a landfill is the best practical scenario for the management of solid wastes, but disposal in sanitary landfills has a very high maintenance cost and incineration is not an economical alternative, since it generates pollutant gas emissions into the atmosphere (SILVA et al., 2001). Studies using treated sewage sludges, tannery sludge, pig manure, poultry bedding, industrial slag, among others in agriculture has been widely disseminated in this country and in various regions of the planet (HILIMIRE et al., 2013; PRATES et al., 2011; SAMPAIO et al., 2012; YAGUE et al., 2012), besides use in industrial processes or for energy recovery (ROVIRA et al., 2011).

Currently, the use of sewage sludge to produce physic nut seedlings has not been much studied. The use of sewage sludge to fertilize the

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physic nut culture is an economical alternative, reducing costs of mineral fertilization. Besides, it may be an alternative source to supply the nutritional requirements of the plant during the initial phase, which extracts large amounts of nutrients from the soil (LAVIOLA; DIAS, 2008) and responds satisfactorily to fertilization, both in qualitative and quantitative terms (PRATES et al., 2011). Therefore, the use of organic wastes to produce physic nut seedlings can be an agronomically feasible practice in economic terms, due to the possible reduction of expenditures on mineral chemical fertilizers, besides improving the quality of the seedlings produced (BOECHAT et al., 2014).

The purpose of this study was to evaluate the macronutrient contents in the dry mass of physic nut and the alterations in the chemical attributes of the soil, based on the growing doses of domestic and industrial sewage sludges.

MATERIAL AND METHODS

The experiments were conducted under greenhouse conditions, at the following geographical coordinates: Latitude 12° 40' 00" S and longitude 39° 06' 23" W at a mean altitude of 220 m. The mean annual temperature is 24.5 °C, with a hot and humid tropical climate, Aw Am according to the Köppen classification and mean precipitation of 1,224 mm year^{-1} (SEI, 2012).

The soil used was classified as "Latossolo Amarelo Coeso" (EMBRAPA, 2013) or Oxisol Ustox (USDA, 2010) with a sandy-loam texture. Soil samples were collected in the 0-20 cm layer and chemically characterized according to the methodology described in Tedesco et al. (1995), presenting pH 5.2; contents of P 0.002 g dm^{-3}; Ca, Mg, K, Al^{+3} and CEC_{total} 0.46; 0.36; 0.04; 0.20 and 2.97 cmol$_c$ dm^{-3}, respectively and total organic carbon (TOC), soil organic matter (SOM) and N 3.53; 6.08 and 1.05 g kg^{-1}, respectively and base saturation 29.63 %.

Two non-composted sewage sludges were used. They were; Industrial sewage sludge (IS) generated by a dairy product industry from milk processing, besides cheese and butter manufacturing. The organic wastes are placed in an aerated lagoon to reduce the organic load and lime (CaO) is applied to eliminate odors, pathogens and promote the stabilization of the organic material. It is then pumped to the settling lagoon, where the solid part is put through a press filter.

This generates the "organic cake" sludge and domestic sewage sludge (DS) resulting from the treatment of domestic sludge using a physical process to remove coarse solids, a biological system for activated sludge to reduce the biochemical oxygen demand (BOD), as well as biodegradation in an anaerobic reactor to reduce the organic load by dehydration of the sewage sludge on a drying bed (BOECHAT et al., 2012).

The sludges were dried in the shade, delumped, digested (acid digestions) and the extracts were analyzed (TEDESCO et al., 1995; NASCIMENTO et al., 2004.). The results of this analysis are shown in Table 1.

Table 1. Chemical characterization of domestic and industrial sewage sludges samples used in experiments.

Treatment	pH	P_2O_5	Ca	Mg	TOC	SOM	N-total	C:N ratio
	H_2O	g dm^{-3}	— cmol$_c$ dm^{-3} —		——— g kg^{-1} ———			
DS	5.7	9.5	12.0	3.3	235.0	405.1	32.63	7.2
IS	6.9	15.0	39.6	1.6	161.6	278.6	19.2	8.4

DS – domestic sewage sludge; IS – industrial sewage sludge; TOC – Total organic carbon; SOM – Soil organic matter; C:N – carbon:nitrogen.

The experiments were installed in a design with casualized block, with four replicates. The soil samples were air dried and put through a 4 mm mesh sieve. In the first experiment the treatments consisted of a soil sample without the incorporation of sewage sludge (dose 0) and the incorporation, to the soil of four doses of domestic sewage sludge (DS) (0.0; 3.1; 4.6; 6.1 and 9.2 Mg ha^{-1}, on a dry base) and in the second experiment, a control and four doses of industrial sewage sludge (IS) were used (0.0; 5.2; 7.8; 10.4 and 15.6 Mg ha^{-1}, on a dry base). The doses of both sludges were equivalent to 0; 100; 150; 200 and 300 kg of total nitrogen ha^{-1}. The samples were transferred to PVC columns, 75 mm in diameter and 20 cm high, and the soil humidity was maintained close to 70% of the field capacity.

The physic nut seeds were soaked in water for 24 hours and immediately after sown at a depth of five centimeters. The seedlings were thinned out after complete emergence, leaving them visually more vigorous per column. Forty-five days after germination (DAG) the seedlings were cut flush with the soil, separating the aerial part and roots. The samples of the aerial part of the seedlings were washed in distilled water and placed in paper bags. The root samples were washing in running water until all of the adhering soil had been removed, and then with distilled water and placed in paper bags.

The plant biomass samples were placed in an oven with forced air circulation at a temperature of 65 ± 3 ^{o}C until they reached constant weight. After drying the plant material was ground in a Willey type mill, and then submitted to nitro-perchloric digestion, and the macronutrient contents were determined according to the methodology described in TEDESCO et al. (1995). After the plants were collected, a soil sample was taken from each column. The samples were air dried, sieved and then chemical analysis was performed for fertility purposes according to Tedesco et al. (1995).

The data were submitted to analysis of variance (ANOVA) by the F-test. When the effect of the sewage sludge doses was significant, regression analysis was used at a 5% level of significance, through statistical program SISVAR (FERREIRA, 2011).

RESULTS AND DISCUSSION

The calcium (Ca), nitrogen (N), phosphorus (P) and magnesium (Mg) contents in the dry mass of the aerial part (DMAP) of physic nut were significantly different because of the domestic sewage sludge doses. However no dose effect was observed for potassium (K) (Table 2).

Table 2. Summary of the analysis of variance for the variables Ca, Mg, N, P, and K content in the aerial part (AP) of physic nut seedlings based on domestic sewage sludge (DS) and industrial sewage sludge (IS) doses.

Sources of variation	DF	Mean square: Ca	Mg	N	P	K
				Domestic sewage sludge		
Dose	4	17.71*	0.18**	698*	1.02*	15.81^{ns}
Block	3	0.59	0.01	38.85	0.16	1.85
Error	12	1.02	0.05	16.71	0.09	5.18
C.V. (%)		14.76	10.31	6.57	13.22	36.61
				Industrial sewage sludge		
Dose	4	6.82*	1.35^{ns}	145.9*	0.18^{ns}	0.86^{ns}
Block	3	0.30	0.06	11.13	0.05	0.60
Error	12	0.22	0.02	11.07	0.07	5.80
C.V. (%)		9.1	6.55	7.13	13.00	32.55

* Significant at 1% by the F test; ** Significant at 5% by the F test; ^{ns} - not significant; C.V. - coefficient of variation.

In the experiment incorporating the domestic sewage sludge doses, the DMAP of the physic nut seedlings generally presented macronutrient contents in the following order: N > Ca > Mg = P > K, at forty-five DAG (Figure 1). These results corroborated those observed by Laviola; Dias (2008) studying the nutrition of adult physic nut plants. The potassium content in the seedlings did not present a significant difference for control, both in DMAP and in DMR (Tables 2 and 3).

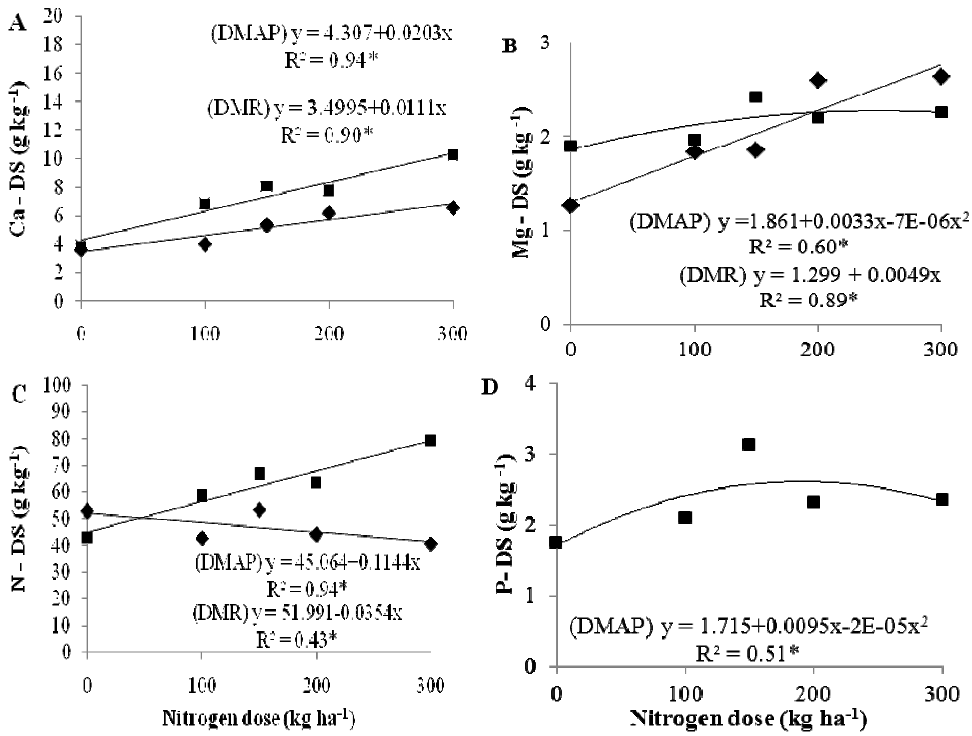

Figure 1. Calcium (A), magnesium (B), nitrogen (C) and phosphorus (D) contents in the dry mass of the aerial part (■ DMAP) and the root (◆ DMR) of physic nut seedlings because of domestic sewage sludge doses based on the total N content; * and ** Significant level of 1 and 5%, respectively.

Table 3. Summary of the analysis of variance for the variables Ca, Mg, N, P, and K content in the roots (R) of physic nut seedlings based on domestic sewage sludge (DS) and industrial sewage sludge (IS) doses.

Sources of variation	DF	Mean square				
		Ca	Mg	N	P	K
				Domestic sewage sludge		
Dose	4	6.82*	1.35*	145.90*	0.18^{ns}	0.85^{ns}
Block	3	0.30	0.06	11.14	0.05	0.59
Error	12	0.22	0.02	11.07	0.07	5.80
C.V. (%)		9.10	6.55	7.13	13.00	32.55
				Industrial sewage sludge		
Dose	4	141.10*	0.12^{ns}	437.12**	0.29**	19.87**
Block	3	4.60	0.08	78.60	0.03	1.74
Error	12	2.80	0.07	71.90	0.05	2.57
C.V. (%)		16.12	14.18	19.62	5.01	23.14

* Significant at 1% by the F test; ** Significant at 5% by the F test; ^{ns} - not significant; C.V. - coefficient of variation.

For the calcium and magnesium contents in the dry mass of the aerial part (DMAP) and of the root (DMR) of the physic nut seedlings, an increment was found with a linear adjustment, and contents were observed in the aerial part between 4.1 and 9.1 g kg^{-1} and in the root between 3.6 and 6.6 g kg^{-1} for calcium at the lowest and highest dose respectively (Figure 1A). The magnesium contents in DMAP varied from 1.9 to 2.4 g kg^{-1} at the doses of 0 and 150 kg ha^{-1} and 1.3 to 2.6 g kg^{-1} at the lowest and highest dose, respectively, with polynomial and linear adjustments of the responses to the doses in the variables evaluated, respectively (Figure 1B). The domestic sewage sludge is a good alternative to increase the availability of calcium and magnesium for the plants due to the contents of these elements (Table 1).

Nitrogen was most necessary element for the physic nut seedlings with contents in DMAP ranging from 43.1 g kg^{-1} at dose 0 and 79.4 g kg^{-1} at dose 300 (Figure 1C). Backes et al. (2009) also found a significant effect in the absorption of N by the castor oil plant (*Ricinus* sp.) because of the increased sludge doses. This response is probably due to the fact that both cultures belong to the family of the Euphorbiaceae (LAVIOLA; DIAS, 2008). According to Silva et al. (2009) the order of macronutrient limitation for physic nut 120 days after the experiment begins is Ca > Mg > K > N > P > S. However, the adjustment of the equation to the N content in the DMR presented a low coefficient of determination, due to variation in the N content as the sewage sludge dose increased. This probably occurred because of the demand for N in the aerial part and a consequent increase in the flux of the element from the roots to the aerial part.

Phosphorus is the third or fourth nutrient most required by physic nut seedling, and is extremely limiting for several cultures, above all in the initial growth phase (LAVIOLA; DIAS, 2008; MAIA et al., 2011). However, for this element a polynomial equation with a low coefficient of determination in DMAP (Figure 1D) was adjusted (Figure 1D) and no dose effect was observed in the contents in DMR (Table 2).

The magnesium, phosphorus and potassium contents in the DMAP and DMR of physic nut fertilized with industrial sewage sludge (IS) doses were not different from the control treatment. However, the calcium and nitrogen contents increased significantly ($p > 0.05$) (Figure 2).

The macronutrient contents in the DMAP of physic nut seedlings fertilized with industrial sewage sludge presented the following order of accumulation: N > Ca > Mg = P > K, at forty-five DAG (Figure 2), corroborating the results observed by Laviola; Dias (2008).

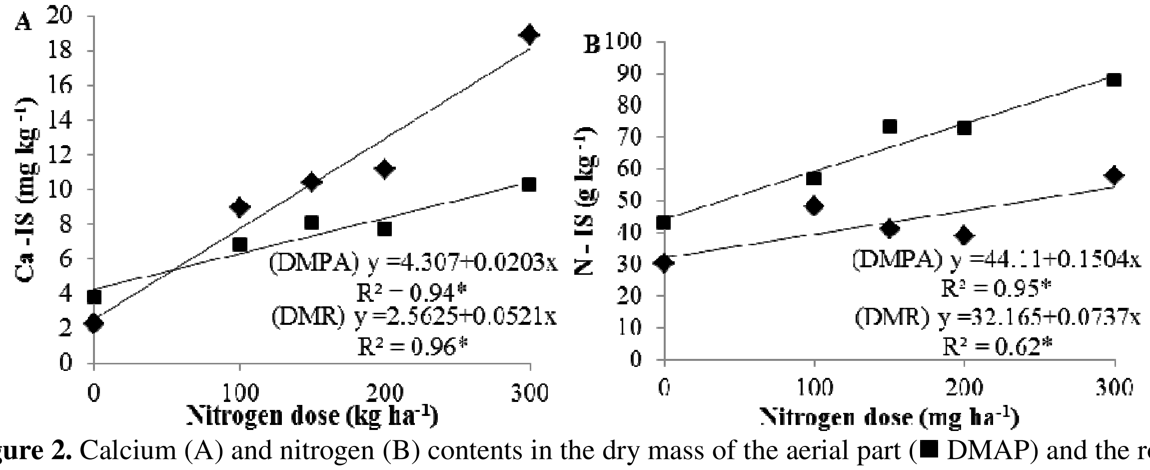

Figure 2. Calcium (A) and nitrogen (B) contents in the dry mass of the aerial part (■ DMAP) and the root (◆ DMR) of physic nut seedlings because of industrial sewage sludge doses based on the total N content; * and ** Significant level of 1 and 5%, respectively.

Once industrial sewage sludge had been incorporated to the soil, an increment of the calcium contents was seen, varying from 3.8 to 10.3 g kg^{-1} in DMAP and between 2.3 and 19.0 g kg^{-1} in DMR at doses 0 and 300 kg N ha^{-1}, respectively (Figure 2A). The N contents observed in DMAP were between 42.9 g kg^{-1} at dose 0 and 87.7 g kg^{-1} at dose 300 kg N ha^{-1} and in DMR between 30.2 and 57.9 g kg^{-1}. Physic nut is a plant that presents a high growth rate, and N is essential to assimilate C and form new organs in the plant.

The Mg, P and K contents in DMAP and DMR were not different from the control treatment using industrial sewage sludge doses (Table 2). Several authors have reported that, despite using increasing doses of sludge, the foliar contents in various cultures did not present significant differences for the control treatment (CAMARGO et al., 2013; PRATES et al., 2011). According to Camargo et al. (2013), although the sewage sludge contributes to the increased contents of this nutrient in the plant, it also promotes increased production of dry matter, provoking a nutrient dilution effect. However, both the increment in the levels of Mg, P and K in DMAP and DMR (Table 2) and the weight of DMAP and DMR in the physic nut seedlings fertilized with DS and IS (BOECHAT et al., 2014) were not significantly different from each other in the experimental condition, and thus there are other factors involved in the plant response.

The reduction of the potassium nutrient with the increment of sewage sludge doses appears to be related to higher losses to leaching, possibly associated with the increased concentration of hydrogen ions in solution, provoking the displacement of these cations from the colloidal complex and their removal from the system (PRATES et al., 2011). This reduction of potassium contents in the aerial part and the root of physic nut, with the increment of sewage sludge doses was also observed by Camargo et al. (2013) and Prates et al. (2011).

The analysis of variance (ANOVA) show that all chemical attributes of the soils evaluated are affected by the incorporation of both sewage sludges at a 1% level of significance, except pH for the domestic sewage sludge (Table 4).

Table 4. Summary of the analysis of variance for values of pH, Ca + Mg, P, exchangeable Al, cation exchange capacity at pH 7.0 (CEC) and soil organic matter (SOM) of the soil after incorporating domestic and industrial sewage sludge doses.

Sources of		Mean square					
variation	DF	pH	Ca+Mg	P	Al	CEC	SOM
				Domestic sewage sludge			
Dose	4	0.16^{ns}	0.36*	220.5*	0.06*	0.59*	2.82*
Block	3	0.04	0.06	11.65	0.005	0.009	0.16
Error	12	0.06	0.01	7.23	0.008	0.03	0.12
C.V. (%)		5.19	10.21	12.96	34.28	6.16	5.04
				Industrial sewage sludge			
Dose	4	4.86*	4.71*	3733.08*	0.008*	1.32*	1.18*
Block	3	0.017	0.036	5.65	0.0	0.04	0.05
Error	12	0.025	0.014	5.11	0.0	0.022	0.19
C.V. (%)		2.36	4.42	4.69	0.0	4.55	6.4

* Significant at 1% by the F test; ** Significant at 5% by the F test; ^{ns} - not significant; C.V. - coefficient of variation.

Soil pH increased when the industrial sewage sludge doses were incorporated, but the domestic sewage sludge did not significantly alter the soil pH (Figure 3A). Backes et al. (2009) evaluating the chemical alterations of soils fertilized with domestic sewage sludge observed linear and significant reductions of the pH as the sludge doses used increased.

Boechat et al. (2013) found that using sewage sludge to correct soil acidity raised the value of pH. Also according to these authors, the initial treatment of this waste basically consists in a biological process, with the addition of limestone or lime ($CaCO_3$ or CaO) to eliminate pathogens and promote the stabilization of the organic waste, so that the carbonate reacts with the hydrogen ions present in the soil solution (liquid phase of the soil) and water and CO_2, molecules are formed, besides the increased concentration of Ca and Mg and available P. However, the soils characteristics should be observed previously, since in alkaline soils this incorporation could be harmful to the plants, because in these soils various micronutrients essential to the plant metabolism become unavailable. The industrial sewage sludge was treated in the plant with limestone, while the domestic sewage sludge did not receive this conditioning in the treatment plant.

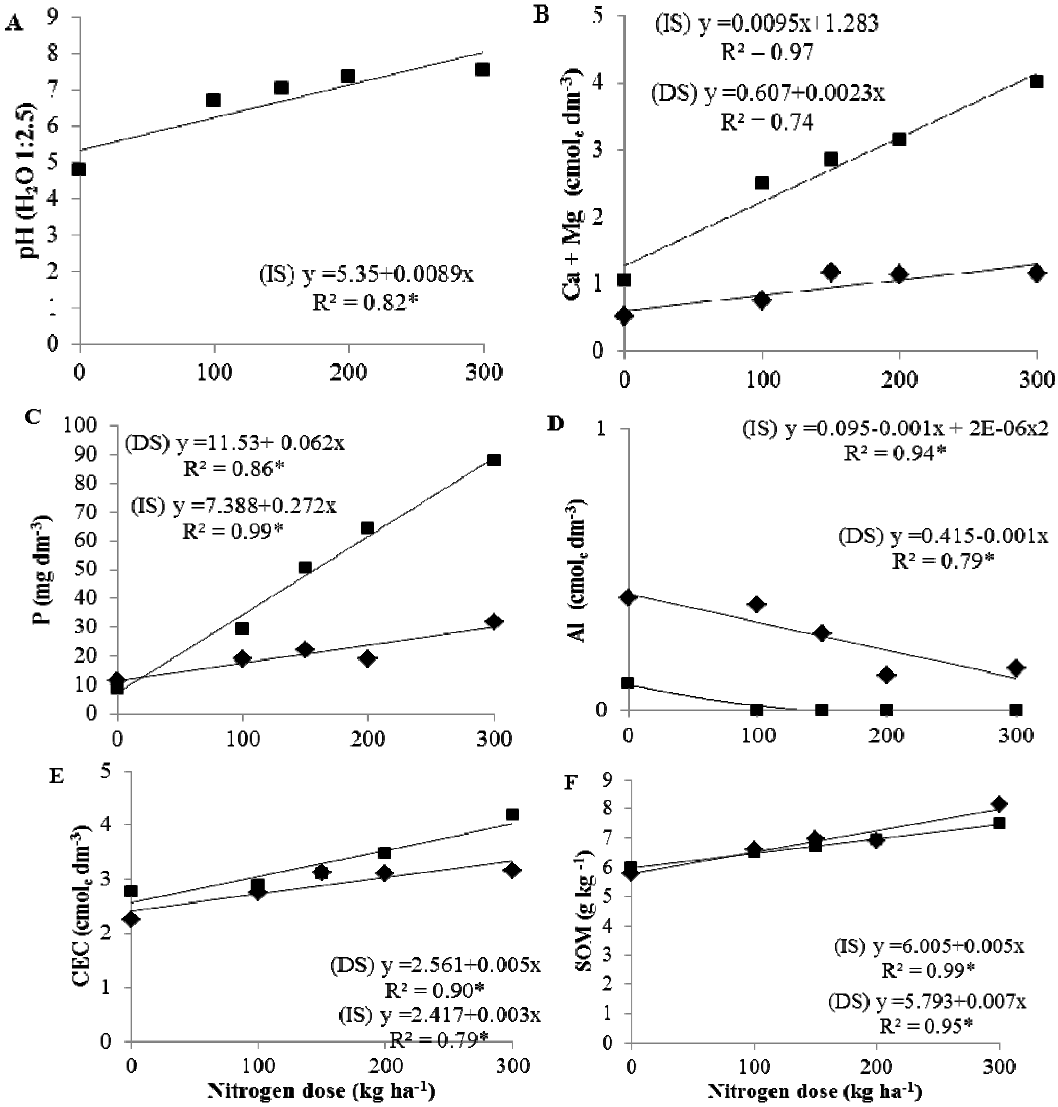

Figure 3. Values of pH (A), calcium + magnesium (B), phosphorus (C), exchangeable aluminum (D), cation exchange capacity at pH 7.0 (E) and soil organic matter (F) of the soil after incorporating domestic (◆DS) and industrial (■ IS) sewage sludge doses.

Another response variable related to the use of limestone in treating sludges is the amount of calcium and magnesium. In Figure 3B it was observed that domestic sewage sludge raised the quantities of these elements in the soil, but there was a much more marked increase using industrial sewage sludge.

Sewage sludges generally have high P contents, which is the main cause of eutrophication of water bodies when they are discharged without control or treatment. The Table 1, shows that the P content in IS is higher than the amount present in DS, and this tendency is also observed in the soil. Both sewage sludges increased the concentration of P in the soil, but the highest elevation occurred in the soil that received increasing doses of IS (Figure 3C).

As the amounts of Ca and Mg in the soil increased, the exchangeable aluminum content of the soil was reduced, with a linear adjustment of the equation to incorporate domestic sewage sludge and polynomial to industrial sewage sludge (Figure 3C). The elevation of the CEC variables and organic matter in the soil was seen after incorporation of both sewage sludges, with linear adjustments of the equations according to the increase in the doses (Figures 3E and F). The increase of CEC in the soil in the treatment with IS is directly related to the increase of contents, especially of Ca and Mg, since CEC was estimated by the sum of bases, as observed by Epstein et al. (1976), however, when DS which presents lower Ca and Mg contents in its composition (Table 1) was incorporated to the soil, an increase of CEC was observed.

CONCLUSIONS

Domestic sewage sludge raises the calcium and magnesium contents in the dry mass of the aerial part and root of physic nut seedlings.

The nitrogen contents in the dry mass of the aerial part and root increase up to the higher dose to both sewage sludges and phosphorus contents in the dry mass of the aerial part increase up to the dose of 150 kg of domestic sewage sludge ha^{-1}.

The potassium contents in the dry mass of the aerial part and root of the physic nut seedlings are not affected by domestic sewage sludge. Industrial sewage sludge raises the calcium and nitrogen contents in the dry mass of the aerial part and root of the physic nut seedlings.

The phosphorus, magnesium and potassium contents in the dry mass of the aerial part and roots of the physic nut seedlings are not affected by the industrial sewage sludge.

The domestic sewage sludge does not alter the soil pH, it raises the amount of phosphorus, calcium + magnesium, cation exchange capacity, organic matter and reduces exchangeable aluminum. Industrial sewage sludge raises the pH and the cation exchange capacity of the soil, it increases the amount of phosphorus, calcium + magnesium and organic matter, and reduces the exchangeable aluminum present in the soil.

The domestic and industrial sewage sludges may be used to produce physic nut seedlings; however is necessary studies to evaluate the presence of heavy metals or potentially pathogenic microorganisms.

RESUMO: Com os incentivos governamentais para produção de biocombustíveis, o pinhão-manso surgiu como uma planta promissora, devido ao alto teor de óleo nas sementes. Objetivou-se, com este estudo, avaliar a nutrição de mudas de pinhão-manso e alterações nos atributos químicos do solo, em função de doses de lodos de esgoto doméstico e industrial. Dois experimentos em um delineamento em blocos casualizados, com quatro repetições, foram conduzidos utilizando amostras de um Latossolo Amarelo que recebeu cinco doses de cada lodo, equivalentes a 0; 100; 150; 200 e 300 kg N total ha^{-1}. O lodo de esgoto doméstico elevou os teores de cálcio e magnésio na massa seca da parte aérea e raiz e de nitrogênio e fósforo na massa seca da parte aérea das mudas de pinhão-manso, enquanto o lodo industrial elevou os teores de cálcio e nitrogênio na massa seca da parte aérea e raiz das mudas de pinhão-manso, porém não afetou os teores de fósforo, nitrogênio, magnésio e potássio na massa seca da parte aérea e raiz. O lodo doméstico não alterou o pH do solo, contudo elevou as quantidades de fósforo, cálcio + magnésio, a capacidade de troca catiônica, a matéria orgânica e reduziu o alumínio trocável, enquanto o industrial elevou o pH e a capacidade de troca catiônica do solo, aumentou as quantidades de fósforo, cálcio + magnésio e matéria orgânica e reduziu o alumínio trocável presentes no solo. Os lodos domésticos e industriais podem ser utilizados na produção de mudas de pinhão-manso, contudo é necessário estudos sobre a presença de metais pesados ou micro-organismos patogênicos .

PALAVRAS-CHAVE: *Jatropha* curcas L.. Características do solo. Nutrição vegetal. Resíduo orgânico.

REFERENCES

BACKES, C.; LIMA, C. P.; FERNANDES, D. M.; GODOY, L. J. D.; KIIHL, T. A. M.; VILLAS BÔAS, R. L. Efeito do lodo de esgoto e nitrogênio na nutrição e desenvolvimento inicial da mamoneira. **Bioscience Journal**, Uberlândia, v. 25, n. 1, p. 90-98, 2009.

BOECHAT, C. L.; SANTOS, J. A. G.; ACCIOLY, A. M. A.; BOMFIM, M. R.; SANTOS, A. C. Industrial and urban organic wastes increase soil microbial activity and biomass. **Revista Brasileira de Ciência do Solo**, Viçosa, v. 36, p. 1629-1636, 2012.

BOECHAT, C. L.; SANTOS, J. A. G.; ACCIOLY, A. M. A. Net mineralization nitrogen and soil chemical changes with application of organic wastes with 'Fermented Bokashi Compost'. **Acta Scientiarum. Agronomy**, Maringá, v. 35, p. 257-264, 2013.

BOECHAT, C. L.; RIBEIRO, M. O.; RIBEIRO, L. O.; SANTOS, J. A. G.; ACCIOLY, A. M. A. Lodos de esgoto doméstico e industrial no crescimento inicial e qualidade de mudas de pinhão-manso. **Bioscience Journal**, v. 30, n. 3, p. 782-791, 2014.

CAMARGO, R.; MALDONADO, A. C. D.; DIAS, P. A. S.; SOUZA, M. F.; FRANÇA, M. S. Diagnose foliar em mudas de pinhão-manso (*Jatropha Curcas* L.) produzidas com biossólido. **Revista Brasileira de Engenharia Agrícola e Ambiental**, Campina Grande, v. 17, n. 3, p. 283–290, 2013. http://dx.doi.org/10.1590/S1415-43662013000300006

EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA - EMBRAPA. Centro Nacional de Pesquisa de Solos. **Sistema brasileiro de classificação de solos**. 3.ed. Rio de Janeiro, 2013. 353p.

EPSTEIN, E.; TAYLOR, J. M.; CHANEY, R. L. Effects of sewage sludge and sludge compost applied to soil on some soil physical and chemical properties. **Journal of Environmental Quality**, Madison, v. 5, p. 422-426, 1976. http://dx.doi.org/10.2134/jeq1976.00472425000500040021x

FERREIRA, D. F. **Sisvar: a computer statistical analysis system**. Ciência e Agrotecnologia, Lavras, v. 35, n. 6, p. 1039-1042, 2011.

HILIMIRE, K.; GLIESSMAN, S. R.; MURAMOTO, J. Soil fertility and crop growth under poultry/crop integration. **Renewable Agriculture and Food Systems**, Cambridge, v. 28, n. 2, p. 173-182, 2013. http://dx.doi.org/10.1017/S174217051200021X

LAVIOLA, B. G.; DIAS, L. A. S. Teor e acúmulo de nutrientes em folhas e frutos de pinhão manso. **Revista Brasileira Ciência do Solo**, Viçosa, v. 32, n. 5, p. 1969-1975, 2008.

MAIA, J. T. L. S.; GUILHERME, D. O.; PAULINO, M. A. O.; SILVEIRA, H. R. O.; FERNANDES, L. A. Efeito da omissão de macro e micronutrientes no crescimento de pinhão-manso. **Revista Caatinga**, Mossoró, v. 24, n. 2, p. 174-179, 2011.

NASCIMENTO, C. W. A.; BARROS, D. A. S.; MELO, E. E. C.; OLIVEIRA A. B. Alterações químicas em solos e crescimento de milho e feijoeiro após aplicação de lodo de esgoto. **Revista Brasileira de Ciência do Solo**, Viçosa, v. 28, p. 385-392, 2004.

PRATES, F. B. S.; SAMPAIO, R. A.; SILVA, W. J.; FERNANDES, L. A.; ZUBA JUNIO, G. R.; SATURNINO, H. M. Crescimento e teores de macronutrientes em pinhão-manso adubado com lodo de esgoto e silicato de cálcio e magnésio. **Revista Caatinga**, Mossoró, v. 24, n. 2, p. 101-112, 2011.

PASSUELLO, A.; CADIACH, O.; PEREZ, Y.; SCHUHMACHER, M. A spatial multicriteria decision making tool to define the best agricultural areas for sewage sludge amendment. **Environment International**, New York, v. 38, p. 1-9, 2012. http://dx.doi.org/10.1016/j.envint.2011.07.013

ROIG, N.; SIERRA, J.; MARTÍ, E.; NADAL, M.; SCHUHMACHER, M.; DOMINGO, J. L. Long-term amendment of Spanish soils with sewage sludge: Effects on soil functioning. **Agriculture, Ecosystems and Environment**, Oxford, v. 158, p. 41-48, 2012. http://dx.doi.org/10.1016/j.agee.2012.05.016

ROVIRA, J.; MARI, M.; NADAL, M.; SCHUHMACHER, M.; DOMINGO, J. L. Use of sewage sludge as secondary fuel in a cement plant: human health risks. **Environment International**, New York, v. 37, p. 105–111, 2011. http://dx.doi.org/10.1016/j.envint.2010.08.004

SAMPAIO, T. F.; GUERRINI, I. A.; BACKES, C.; HELIODORO, J. C. A.; RONCHII, H. S.; TANGANELLI, K. M.; CARVALHO, N. C.; OLIVEIRA, F. C. Lodo de esgoto na recuperação de áreas degradadas: efeito nas características físicas do solo. **Revista Brasileira de Ciência do Solo**, Viçosa, v. 36, p. 1637-1645, 2012.

SEI. Superintendência de Estudos Econômicos e Sociais da Bahia. **Informações geográficas municipais.** Disponível em: <http://www.sei.ba.gov.br/side/frame_tabela.wsp?tmp.volta=sg46&tmp.tabela=t106>. Acesso em: 15 jan. 2012.

SHAMS FALLAH, F.; VAHIDI, H.; PAZOKI, M.; AKHAVAN-LIMUDEHI, F.; ASLEMAND, A. R.; SAMIEE ZAFARGHANDI, R. Investigation of solid waste disposal alternatives in Lavan Island using life cycle assessment approach. **International Journal of Environmental Research**, Tehran, v. 7, n. 1, p. 155-164, 2013.

TEDESCO, M. J.; GIANELLO, C.; BISSANI, C.; BOHNEN, H. & VOLKWEISS, S. J. **Análise de solo, plantas e outros materiais**. 2.ed. Porto Alegre: UFRGS, Departamento de Solos, 1995. 118p. (Boletim Técnico, 5).

SILVA, F. C. da; BOARETTO, A. E.; BERTON, R. S.; ZOTELLI, H. B.; PEXE, C. A.; BERNARDES, E. M. Efeito de lodo de esgoto na fertilidade de um Argissolo Vermelho-Amarelo cultivado com cana-de-açúcar. **Pesquisa Agropecuária Brasileira**, Brasília, v. 36, n. 5, p. 831-840, 2001. http://dx.doi.org/10.1590/S0100-204X2001000500014

SILVA, E. B.; TANURE, L. P. P.; SANTOS, S. R.; RESENDE JÚNIOR, P. S. Sintomas visuais de deficiências nutricionais em pinhão-manso. **Pesquisa Agropecuária Brasileira**, Brasília, v. 44, n. 4, p. 392-397, 2009. http://dx.doi.org/10.1590/S0100-204X2009000400009

USDA - Soil Survey Staff. **Keys to soil taxonomy**. 11.ed. Washington, DC, USDA-Natural Resources Conservation Service, 2010.

YAGUE, M. R.; BOSCH-SERRA, A. D.; ANTUNEZ, M.; BOIXADERA, J. Pig slurry and mineral fertilization strategies' effects on soil quality: Macroaggregate stability and organic matter fractions. **Science of the Total Environment**, Amsterdam, v. 438, p. 218–224, 2012. http://dx.doi.org/10.1016/j.scitotenv.2012.08.063