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Green Manure And Sewage Sludge Used To Recover The Fertility Of A Degraded Oxisol

Carolina dos Santos Batista Bonini[2]✎, Luis Gustavo Akihiro Sanches Suzuki[1], Marlene Cristina Alves[2], Luis Eduardo Akiyoshi Sanches Suzuki[3]

[1] Monsanto of Brasil Ltda, Rod. MG 188, km 158,5, Distrito Industrial - 38600-000 - Paracatu, MG - Brazil
[2] UNESP – São Paulo State University - Department of Soil, Plant and Agricultural Engineering.C.P. 31, Av. Brasil, 56 - 15385-000 - Ilha Solteira, SP - Brazil
[3] UFPel - Faculty of Agronomy Eliseu Maciel – Department of Soil, C.P. 354, Campus Universitário, s/n - 96010-900 – Capão do Leão, RS - Brazil

Abstract: For soil remediation is necessary an adequate management that provides the maintenance and enrichment of the soil organic matter, for that, one alternative is the use of green and organic manure combined with correct fertilization. The objective of this research was to evaluate the effect of green manure and sewage sludge in the recovery of the chemical attributes of an Oxisol. The research was installed in an Oxisol in which was taken out a layer of soil of 8.60 meters. The treatments were: area without management and with the soil exposure; area with natural vegetation of "Savannah"; only native tree *Astronium fraxinifolium* Schott; *A. fraxinifolium+Canavalia ensiformis*; *A. fraxinifolium+Raphanus sativus*; *A. fraxinifolium+Brachiaria decumbens*+60 t ha^{-1} of sewage sludge based on dry mass. Were evaluated the soil chemical characteristics to the layers 0.00–0.05; 0.05–0.10; 0.10–0.20 and 0.20–0.40 m. The soil presents high degree of chemical degradation but the sludge improve some chemical characteristics of the degraded soil, being possible reduce or, in some cases, exclude the use the mineral fertilizer. It is recommended the application of lime in the sludge to correct its pH, being possible use it without acidify the soil. The lime is significant to improve the soil chemical characteristics, while in the first year the green manure do not influence these

Key words: organic matter, environmental, soil chemistry, organic fertilizer, mineral fertilizer

Introduction

Data from the National Research of Sanitation 2000 (IBGE, 2002) showed that among the basic sanitation services offered in Brazil, is the sewage that has less presence in Brazilian municipalities. The sewage sludge is produced during the process of water treatment and one of the problems encountered is its final control, and its use in agricultural areas is a good option in terms of agronomic, economic and environmental, since it may be used as a source of organic matter and nutrients to plants.
Studies evaluating the effects of application of sewage sludge in the soil are still incipient, specially long-term studies evaluating human and the environment impacts. Bezerra et al. (2006) used sewage sludge and obtained satisfactory results in the reclamation of degraded areas. The natural regeneration is slow; the addition of organic matter is able to accelerate this process. For the specific case of this study, the degraded areas in question are related to "areas of loan", that are places where the soil is removed to form the body of the dam.
Rodrigues et al. (2007) reported the direct relation of organic matter on the cation exchange capacity of soil, researching the regeneration capacity of a basement in an area of loan, this area which was removed almost 10 m in some places, for the Hydroelectric construction.
The green manure promotes benefits on the chemical, physical and biological properties of soil (Delarmelinda et al., 2010). The effects promoted by green manure on soil chemical attributes are variables, depending on the species used, the management of biomass, the time of planting and cutting of green manure,

✎ **Carolina dos Santos Batista Bonini (Correspondence)**
✉ carolsbatistabonini@hotmail.com.br

the residence time of wastes in the soil, the local conditions and the interaction between these factors (Alcântara et al., 2000). Considering the importance of recovery of degraded areas, the production of sewage sludge in treatment stations and its proper agronomic and environmentally destination, the objective of this study was to evaluate the effect of green manure and sewage sludge in the recovery of the chemical properties of a degraded Oxisol.

Material and Methods

The experiment was conducted in February 2004, at the Teaching and Research Farm, belonging to the College of Engineering, Campus of Ilha Solteira of the "Universidade Estadual Paulista" (UNESP), municipality of Selvíria, Mato Grosso do Sul State, Brazil. With the geographical coordinates of 51°22' west longitude of Greenwich and 20°22' south latitude, with an altitude of 327 meters. It presents average annual precipitation, temperature and humidity of air respectively of 1,370 mm, 23.5°C and 70-80%. The native vegetation of the area in study is Savannah.

The relief is plan and almost plan, and the original soil is a Ferralsol (Fao, 1990). The experiment was conducted in an "area of loan", where was removed a layer of soil with an average thickness of 8.60 meters for use in the build of the Hydroelectric Power Plant of Ilha Solteira, São Paulo State, Brazil. Its building began in the 60s decade and the area which the soil was removed is exposed since 1969. After removal of the soil layer, still remained a B horizon, where the experiment was installed. The Table 1 shows the texture of the soil in study.

Table 1 - Particle size distribution of the experimental area. Average of four replications

Layer, m	Sand	Silt	Clay
		g kg^{-1}	
0.00 – 0.05	665	79	256
0.05 – 0.10	666	88	246
0.10 – 0.20	657	78	265
0.20 – 0.40	663	70	267
	Standard deviation		
0.00 – 0.05	1.708	1.258	2.708
0.05 – 0.10	3.202	3.873	3.096
0.10 – 0.20	2.500	1.258	2.646
0.20 – 0.40	4.349	1.633	3.304

The experimental design was a randomized block with six treatments and five replications, totaling 30 plots. Each plot occupied an area of 96 m^2 (12 m × 8 m), with a total of 480 m^2 per treatment. For the treatment with native vegetation (Savannah) were used 5 points distributed randomly in the forest.

The treatments were constituted of: no management in the area and the soil exposed (control plot); area with native vegetation of Savannah; only native tree species of *Astronium fraxinifolium* (Schott); *A. fraxinifolium*+*Canavalia ensiformis*; *A. fraxinifolium*+ *Raphanus sativus*; *A. fraxinifolium*+*Brachiaria decumbens*+sewage sludge.

The preparation of the area was carried out with a subsoiling, followed by a leveling disk harrow. Liming was performed at 2 t ha^{-1} and then one disk for incorporation, but in the control plot and in the area with native vegetation of Savannah, they did not undergo any type of management.

A native tree species was implanted in February 2004 with a spacing of 3 m × 2 m, therefore, 25 plants per plot. This is a native tree species of Savannah and of easy production of seedlings in nurseries.

The spacing and density of seeds used for green manure and pasture were as follows:

Raphanus sativus: sowing broadcast, using 20 kg ha^{-1}. After its distribution was made a harrowing superficially to increase the contact between the seed and soil. Sowing was made on February 20, 2004 and February 18, 2005.

Canavalia ensiformis: spacing of 0.50 m between rows with a density of 10 seeds m^{-1}. It re-sowing was required after 55 days , due to the attack of ants, in the year 2004. Sowing was made on February 20, 2004, with re-sowing on April 15, 2004 and February 18, 2005.

Braquiaria decumbens: sowing to haul, using 20 kg ha^{-1}. After its distribution, was made a harrowing superficially to increase the contact between the seed and soil. Sowing was realized on April 20, 2005.

The sewage sludge used was obtained from the Sewage Treatment Station of Araçatuba city - SANEAR, São Paulo State, Brazil. This treatment station is operating since 2000, being treated in the station 70% of the sewage of the city and the other 30% of sewage is treated in stabilization ponds. The treatment process used in the station is biological through the activated sludge system.

Based on some works, Abreu Junior et al. (2005) stated that levels of heavy metals and pathogens remain within acceptable limits when the agronomic use of sewage sludge is derived from biological treatment of wastewater, predominating domestic sewage. In the presence of metals and pathogens, the sludge will be restricted for agricultural purposes, which is not the case of sludge used in this study (Tables 2 and 3).

A standard dose of 60 t ha^{-1} on dry sludge basis was applied, with 85.42% humidity. The dose of sludge applied was defined by considering researchs with recovery of degraded areas (Pagliai et al., 1981, Jorge et al., 1991, Melo et al., 1994, Vaz and Gonçalves, 2002). The sludge was distributed by hand and incorporated with harrow.

Table 2 - Chemical characterization of sewage sludge used. Values of one sample.

*OM	N	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Zn
g dm^{-3}	g kg^{-1}						mg kg^{-1}				
200	71.26	18.79	15.14	11.06	3.44	7.78	16.37	160.04	960.6	115.74	583.48

*O.M. = Organic matter; N= nitrogen; P resin= phosphorus; K= potassium; Ca= calcium; Mg= magnesium; S: sulfur; B: boron; Cu: copper; Fe: iron; Mn: manganese; Zn: zinc. Fonte: Alves et al. (2007).

Chemical analysis of soil was performed before implantation of the experiment and after 361 days. According to the methodology described by Raij and Quaggio (1983) were evaluated the levels of phosphorus (P), potassium (K+), magnesium (Mg^{2+}) and calcium (Ca^{2+}) by the extraction method with ion exchange resin. The content of organic matter (OM) was determined by colorimetric method and pH in calcium chloride, and the potential acidity (hydrogen and aluminum) (H+Al) at pH 7.0. Were calculated the amounts of bases (SB = Ca^{2+} + Mg^{2+} + K^{+}), cation exchange capacity at pH 7.0 (CEC = SB + (H + Al)) and base saturation $\left(V\% = \frac{100 \times SB}{CEC} \right)$.

Table 3 - Chemical characterization for toxicity of sewage sludge used. Values of one sample.

Parameter	Results	Maximum limit
	mg kg^{-1}	
Aluminium	0.100	0.200
Arsernic	nd	0.050
Barium	0.400	1,000
Cadmium	0.004	0.005
Lead	0.003	0.050
Cyanide	nd	0.1000
Clorides	39,000	250,000
Copper	0.040	1,000
Total Chromium	nd	0.050
Hardness	120,000	500,000
Phenol	nd	0.001
Total Iron	2,860	0.300
Fluorides	0.640	1,500
Manganese	0.300	0.100
Mercury	nd	0.001
Nitrate	4,700	10,000
Silver	0.020	0.050
Selenium	nd	0.010
Sulfate	27,900	400,000
Sodium	48,400	200,000
Surfactants	nd	0.200
Zinc	3,640	5,000

nd: not detected. Analysis method based on the 20th edition of "Standard Methods for the Examination of Water and Wastewater." Analyses performed according to NBR 10004 - Solid Waste.

The soil samples were collected before and 361 days after implantation of treatments, with a hand auger at depths from 0.00-0.05, 0.05-0.10, 0.10-0.20 and 0.20-0.40 m. Each replicate of soil sample for plot was composite of five sub-samples (single samples).

The data were analyzed by analysis of variance and Tukey test to compare the means at 5% of significance, using the Sanest computer program (Zonta and Machado, 1991).

Results and Discussion

There was difference between treatments and period of study (before and 361 days after installed the treatments) for soil chemical properties, except for organic matter and potassium. It is noteworthy that, in general, before the beginning of the study, the chemical properties did not differ significantly between treatments, considering, therefore, as homogeneous plots (Tables 4, 5, 6 and 7).

Before install the treatments the levels of organic matter, phosphorus, potassium, calcium, magnesium, and base saturation were considered very low to low, pH levels indicating high acidity and medium to high levels of cation exchange capacity (CEC), according to limits set by Raij et al. (1996). After deployment, there was an increase in pH, improving the acidity at medium to low levels. The CEC now has average values, as well as potassium in treatment with sewage sludge.

The phosphorus content remained almost constant during the study, for all treatments, except for treatment with sewage sludge that reach extremely high value of 167.6 mg dm^{-3} after 361 days of deployment. According to Brady (1989) the organic matter after be mineralized is a major source of phosphorus, which may indicate that the sludge has a rapid mineralization and high levels of phosphorus.

Table 4 - Mean values of phosphorus (P), organic matter (OM), hydrogen potential (pH), potential acidity (H + Al) and cation exchange capacity (CEC) of soil at different layers (0.00 to 0.05 and 0.05 - 0.10 m) and treatments before and 361 days after implantation of treatments, in Selvíria / MS, in the year 2005.

Treatment [1]	P mg dm^{-3}		O.M. g dm^{-3}		pH $CaCl_2$		H + Al mmol$_c$ dm^{-3}		CEC mmol$_c$ dm^{-3}	
	before	361 days	before	361 days	before	361 days	before	361 days	before	361 days
					0,00 – 0,05 m					
Control plot	1.6Aa	1.6Ab	6.8Aa	5.8Aa	4.48Aa	4.86Ab	16.4Ab	14.2Bc	23.1Ab	22.5Ae
Savannah	4.0Aa	4.8Ab	28.2Aa	29.8Aa	4.24Aa	4.48Ab	31.0Ba	34.6Aa	36.9Ba	49.9Aa
AA	1.0Aa	1.4Ab	4.2Aa	4.2Aa	4.38Ba	6.00Aa	15.8Ab	10.4Bd	20.9Bb	28.6Ade
AA+CE	2.6Aa	1.6Ab	5.0Aa	4.4Aa	4.44Ba	6.22Aa	16.6Ab	10.0Bd	23.3Bb	37.5Abc
AA+RS	1.0Aa	1.0Ab	3.8Aa	2.6Aa	4.36Ba	6.20Aa	15.6Ab	10.0Bd	21.3Bb	31.8Acd
AA+BD+SS	0.8Ba	167.6Aa	4.0Aa	10.2Aa	3.52Bb	5.16Ab	13.2Bb	18.6Ab	18.5Bb	43.8Aab
					0.05 – 0.10 m					
Control plot	1.0Aa	1.0Ab	3.4Aa	3.0Aa	4.44Aa	4.66Ab	16.4Ab	14.4Bc	21.3Ab	20.8Ac
Savannah	4.0Aa	2.8Ab	13.8Aa	14.8Aa	4.12Aa	4.22Ab	31.0Aa	30.4Aa	41.7Aa	36.6Ba
AA	1.0Aa	1.0Ab	2.4Aa	3.6Aa	4.42Ba	6.06Aa	15.4Ab	10.4Bd	19.8Bb	29.2Ab
AA+CE	1.0Aa	1.0Ab	2.4Aa	3.2Aa	4.24Ba	6.38Aa	16.8Ab	10.0Bd	20.7Bb	39.4Aa
AA+RS	1.0Aa	1.0Ab	2.0Aa	3.0Aa	4.34Ba	6.24Aa	15.6Ab	10.4Bd	19.8Bb	32.3Aab
AA+BD+SS	1.0Ba	153.2Aa	2.6Aa	7.2Aa	4.44Aa	4.72Ab	15.4Bb	21.8Ab	19.8Bb	39.2Aa

Mean values followed by the same letter, capital letter in the line and lowercase letter in the column, do not differ statistically at the 5% level according to the Tukey test. [1]Control plot: area without management and with the soil exposure; Savannah: area with natural vegetation of “Savannah”; AA: only native tree *Astronium fraxinifolium* Schott; *AA+CE: A. fraxinifolium+ Canavalia ensiformis*; AA+RS: *A. fraxinifolium+Raphanus sativus*; AA+BD+SS: *A. fraxinifolium+Brachiaria decumbens*+60 t ha^{-1} of sewage sludge based on dry mass.

Table 5 - Mean values of phosphorus (P), organic matter (OM), hydrogen potential (pH), potential acidity (H + Al) and cation exchange capacity (CEC) of soil at different layers (0.10-0.20 and 0.20-0.40 m) and treatments before and 361 days after implantation of treatments, in Selvíria / MS, in the year 2005.

Treament [1]	P mg dm^{-3}		O.M. g dm^{-3}		pH $CaCl_2$		H + Al mmol$_c$ dm^{-3}		CEC mmol$_c$ dm^{-3}	
	before	361 days	before	361 days	before	361 days	before	361 days	before	361 days
0.10 – 0.20 m										
Control plot	1.0Aa	1.0Ab	2.0Aa	1.6Aa	4.32Aa	4.46Abc	15.6Ab	14.8Ab	19.4Ab	18.0Ac
Savannah	2.0Aa	1.6Ab	9.4Aa	9.6Aa	4.04Aa	4.08Ac	26.0Aa	26.8Aa	29.0Aa	30.2Aa
AA	1.0Aa	1.0Ab	1.4Aa	2.0Aa	4.40Ba	5.46Aa	15.8Ab	11.8Bb	19.2Ab	22.6Abc
AA+CE	1.0Aa	1.0Ab	2.0Aa	2.0Aa	4.20Ba	5.42Aa	17.2Ab	11.8Bb	19.7Ab	23.8Aabc
AA+RS	1.0Aa	1.0Ab	1.2Aa	1.0Aa	4.24Ba	5.12Aab	15.2Ab	12.2Bb	18.0Ab	19.4Abc
AA+BD+SS	1.0Ba	38.0Aa	2.2Aa	2.8Aa	4.22Ba	4.84Aab	16.6Ab	15.0Ab	19.6Bb	26.0Aab
0.20 – 0.40 m										
Control plot	1.0Aa	1.0Aa	1.2Aa	1.0Aa	4.26Aa	4.30Ba	16.0Ab	14.6Ab	18.4Aab	15.8Ab
Savannah	1.0Aa	1.0Aa	6.8Aa	7.8Aa	3.96Aa	4.06Aa	24.0Aa	24.2Aa	25.6Aa	26.0Aa
AA	1.0Aa	1.0Aa	1.2Aa	1.2Aa	4.28Aa	4.60Aa	15.8Ab	13.0Bb	18.5Aab	16.1Ab
AA+CE	1.0Aa	1.0Aa	1.0Aa	1.0Aa	4.18Aa	4.34Aa	16.4Ab	14.6Ab	18.5Aab	16.7Ab
AA+RS	1.0Aa	1.0Aa	1.2Aa	1.0Aa	4.12Aa	4.34Aa	16.0Ab	13.8Bb	17.8Ab	15.9Ab
AA+BD+SS	1.0Aa	1.0Aa	1.4Aa	1.2Aa	4.20Aa	4.38Aa	16.2Ab	14.0Bb	18.0Ab	17.9Ab

Mean values followed by the same letter, capital letter in the line and lowercase letter in the column, do not differ statistically at the 5% level according to the Tukey test. [1]Control plot: area without management and with the soil exposure; Savannah: area with natural vegetation of "Savannah"; AA: only native tree *Astronium fraxinifolium* Schott; *AA+CE: A. fraxinifolium+ Canavalia ensiformis*; AA+RS: *A. fraxinifolium+Raphanus sativus*; AA+BD+SS: *A. fraxinifolium+Brachiaria decumbens*+60 t ha^{-1} of sewage sludge based on dry mass.

Table 6 - Mean values of potassium (K), calcium (Ca), magnesium (Mg), sum of bases (BS) and saturation (V) of the soil at different layers (0.00 to 0.05 and 0.05 - 0.10 m) and treatments before and 361 days after implantation of treatments, in Selvíria / MS, in the year 2005.

Treament[1]	K mmolc dm^{-3}		Ca mmolc dm^{-3}		Mg mmolc dm^{-3}		BS mmolc dm^{-3}		V %	
	before	361 days	before	361 days	before	361 days	before	361 days	before	361 days
0.00 – 0.05 m										
Control plot	0.84Aa	1.52Aa	3.8Aa	4.0Ac	2.2Aa	3.0Ad	6.7Aa	8.3Ac	29.0Aa	36.6Ac
Savannah	1.20Aa	1.00Aa	2.0Ba	7.2Ac	3.0Ba	7.0Abc	6.1Ba	15.2Ab	16.0Ba	29.6Ac
AA	0.62Aa	0.44Aa	2.6Ba	12.8Ab	1.8Ba	5.2Acd	5.1Ba	18.2Ab	24.0Ba	62.2Aab
AA+CE	1.22Aa	0.58Aa	3.6Ba	17.4Aa	2.0Ba	9.6Aab	6.7Ba	27.5Aa	28.8Ba	72.4Aa
AA+RS	0.88Aa	0.62Aa	3.0Ba	14.0Aab	2.0Ba	6.8Ac	5.7Ba	21.8Aab	26.6Ba	67.8Aab
AA+BD+SS	0.90Aa	1.64Aa	2.6Ba	13.2Aab	1.8Ba	10.2Aa	5.3Ba	25.2Aa	22.6Ba	57.8Ab
0.05 – 0.10 m										
Control plot	0.44Aa	0.80Aa	2.8Aa	3.0Ac	1.8Aab	2.6Ad	4.9Aab	6.4Ac	23.2Ba	32.6Ab
Savannah	1.20Aa	0.64Aa	5.0Aa	2.0Bc	4.0Aa	3.6Acd	11.1Aa	6.2Bc	21.0Aa	16.4Ac
AA	0.40Aa	0.30Aa	2.4Ba	12.8Aa	1.4Bab	5.6Abc	4.4Bb	18,8Ab	22,0Ba	64,4Aa
AA+CE	0.66Aa	0.36Aa	2.2Ba	19.4Aa	1.0Bb	9.6Aa	3.9Bb	29.4Aa	19.0Ba	73.0Aa
AA+RS	0.68Aa	0.44Aa	2.2Ba	14.4Ab	1.2Bb	7.0Aab	4.2Bb	21.9Ab	21.6Ba	64.4Aa
AA+BD+SS	0.58Aa	0.64Aa	2.4Ba	10.4Ab	1.4Bab	6.4Ab	4.4Bab	17.4Ab	22.0Ba	44.8Ab

Mean values followed by the same letter, capital letter in the line and lowercase letter in the column, do not differ statistically at the 5% level according to the Tukey test. [1]Control plot: area without management and with the soil exposure; Savannah: area with natural vegetation of "Savannah"; AA: only native tree *Astronium fraxinifolium* Schott; *AA+CE: A. fraxinifolium+ Canavalia ensiformis*; AA+RS: *A. fraxinifolium+Raphanus sativus*; AA+BD+SS: *A. fraxinifolium+Brachiaria decumbens*+60 t ha^{-1} of sewage sludge based on dry mass.

Table 7 - Mean values of potassium (K), calcium (Ca), magnesium (Mg), total bases (SB) and bases saturation (V) of the soil at different layers (0.10-0.20 and of 0.20-0.40 m) and treatments before and 361 days after implantation of treatments, in Selvíria / MS, in the year 2005.

Treament[1]	K		Ca		Mg		BS		V	
	mmolc dm^{-3}								%	
	Before	361 days	Before	361 days	Before	361 days	Before	361 days	Before	361 days
					0.10 – 0.20 m					
Control plot	0.30Aa	0.36Aa	2.0Aa	2.0Ab	1.6Aa	1.2Aa	3.8Aa	3.2Ab	19.2Aa	17.8Ab
Savannah	0.80Aa	0.36Aa	0.0Aa	1.8Ab	2.0Aa	1.2Aa	2.8Aa	3.4Ab	10.0Aa	11.2Ab
AA	0.22Aa	0.28Aa	1.8Ba	7.4Aa	1.2Aa	3.0Aa	3.4Ba	10.8Aa	17.4Ba	46.6Aa
AA+CE	0.58Aa	0.22Aa	1.6Ba	8.0Aa	0.8Ba	3.2Aa	2.5Ba	12.0Aa	12.6Ba	46.8Aa
AA+RS	0.26Aa	0.26Aa	1.8Ba	4.8Aab	0.6Aa	2.0Aa	2.8Aa	7.2Aab	15.6Ba	36.0Aa
AA+BD+SS	0.40Aa	0.26Aa	1.8Ba	7.2Aa	1.0Ba	3.6Aa	3.0Ba	11.0Aa	15.6Ba	40.6Aa
					0.20 – 0.40 m					
Control plot	0.20Aa	0.12Aa	1.6Aa	1.2Aa	0.4Aa	1.0Aa	2.4Aa	1.8Aa	12.8Aa	10.6Aab
Savannah	0.30Aa	0.28Aa	0.0Aa	0.8Aa	1.0Aa	0.8Aa	1.6Aa	1.8Aa	6.0Aa	6.6Ab
AA	0.14Aa	0.40Aa	1.6Aa	1.8Aa	0.8Aa	1.2Aa	2.7Aa	3.1Aa	14.0Aa	19.6Aab
AA+CE	0.18Aa	0.18Aa	1.6Aa	1.4Aa	0.4Aa	1.0Aa	2.1Aa	2.1Aa	11.2Aa	12.4Aab
AA+RS	0.16Aa	0.16Aa	1.2Aa	1.6Aa	0.2Aa	1.0Aa	1.8Aa	2.1Aa	10.0Aa	13.2Aab
AA+BD+SS	0.22Aa	0.18Aa	1.2Aa	2.6Aa	0.2Aa	1.0Aa	1.8Aa	3.9Aa	10.2Ba	21.4Aa

Mean values followed by the same letter, capital letter in the line and lowercase letter in the column, do not differ statistically at the 5% level according to the Tukey test. [1]Control plot: area without management and with the soil exposure; Savannah: area with natural vegetation of "Savannah"; AA: only native tree *Astronium fraxinifolium* Schott; *AA+CE: A. fraxinifolium+ Canavalia ensiformis*; AA+RS: *A. fraxinifolium+Raphanus sativus*; AA+BD+SS: *A. fraxinifolium+Brachiaria decumbens*+60 t ha^{-1} of sewage sludge based on dry mass.

The residues of urban sewage have great contribution of nitrogen and phosphorus present in the feces and urine, the remains of food, in detergents and other products of human activities. The excessive level of nutrients in the mass of water, especially nitrogen and phosphorus, is the main factor in stimulating the eutrophication of water (Von Sperling, 1996). The use of sewage sludge may reduce significantly the sludge disposal cost component of sewage treatment as well as provide a large part of the nitrogen and phosphorus requirements of many crops (Tamrabet et al., 2009; Ahmed et al., 2010).

In general, most tropical soils under natural conditions have lower levels of organic matter, as a result of high temperatures and high precipitation that accelerate the decomposition. However, the organic matter content may be increased with proper management and incorporation of organic waste. The organic matter levels found are considered low (Tables 4 and 5). But, the values were substantially increased at the end of experiment in *A. fraxinifolium+Brachiaria decumbens*+60 t ha^{-1} of sewage sludge treatment. In this treatment the organic matter increased 155 and 138%, respectively for the layers 0-0.05 and 0.05-0.10 m. Similar results were reported by Kitamura et al. (2008).

The sludge incorporation or its maintenance on soil surface, and its constitution, may influence its degradation, with consequent effects on soil fertility. Andrade et al. (2005) for example, applied the alkaline sludge on the surface of an Oxisol with eucalyptus, and did not incorporate the residue. Five years after its application the authors observed the sludge particles detached from the soil, assuming that most of the interaction between sludge and soil microbiota occurred at the interface between sludge-soil. There was no adverse effect on the main biological parameters of soil and was improved traits related to soil fertility due to the high content of organic matter and nutrients and low heavy metal content of waste from industrial production of fibers and PET resins (Trannin et al., 2007).

The pH was similar in all treatments with lime, except for dealing with sewage sludge, which also received lime, but it had a low pH and the potential acidity (H+Al) increased due to application of sewage sludge, which was also observed by Trannin et al. (2005) and Bezerra et al. (2006). The authors attributed this behavior to the fact that the sewage sludge was produced without the addition of lime, thus presenting low corrective efficiency, and mineralization of organic nitrogen and subsequent nitrification, which may have contributed to the soil acidification. The biodegradation of organic matter may also contribute to soil acidification by production of organic compounds (Camargo et al., 1999), since the application of lime reduced the potential acidity in the other treatments.

The CEC in the sludge treatment was similar to the area of Savannah, showing the benefit of organic fertilizer. Furthermore, the increase of CEC with the application of sludge was more pronounced compared to other treatments that received only the liming. This behavior was also observed by Melo et al. (1994) and Bezerra et al. (2006) testing increasing doses of sewage sludge.

The potassium, calcium and magnesium content increased in the soil, probably due the content in the sludge and to application of lime whit magnesium getting the calcium to high values and magnesium medium to high values (Raij et al., 1996). Therefore, the sum of bases and base saturation increased in these treatments. Trannin et al. (2005) also found that the increase in the sum of bases and base saturation was more involved in the application of lime with magnesium than the biosolids of the industry of fiber and PET resins. Similar results were detected per Trannin et al. (2008).

The application of sewage sludge provides an increment of all chemical variables when compared the initial soil chemical conditions and 361 days after the treatments effects. Sewage sludge application in the soil and mineralization afterwards increase concentrations of various nutrients in the soils, particularly N (OM), P and Ca. Excess of P delivered to soils is an inherent consequence of sewage sludge (Tables 4 and 5), a fact that is not observed for the other nutrients in short-term trials (Barbarick and Ippolito, 2000). Sewage sludge have similar N and P concentrations but plants need from 7 to 15 times less P than N, which leads to a surplus of P stocked in the soils (Barbarick and Ippolito, 2000). Wei and Liu (2005) verified increase of Cu and Zn in the soil layer of 0.00-0.20 m, and little effect in the deeper soil (> 0.20 m), with consequent accumulation of Cu and Zn in the barley grains and cabbage leaves, in a filed study conducted during three years testing rates of sewage sludge (0 to 400 t ha^{-1}).

This increase in the nutrients was also observed in others works (Da Ros et al., 1993; Silva et al., 1998; Simonete et al., 2003; Trannin et al., 2005). The another treatments with liming had similar behavior among themselves, indicating that only the realization of liming was enough to improve chemical conditions of soil, and the green manure has not brought greater benefits to the soil, a fact that might be observed at long term.

Bezerra et al. (2006) verified improvement of the chemical characteristics of soil treated with sewage but no effect of sludge on two tree species used for the recovery of a degraded area by mining the topsoil. On the other hand, Khan et al. (2007) verified a gradual increase in the wheat grain and total dry matter yield with the increase rate of sewage sludge (0 to 80 t ha^{-1}), associated to the supply of more nutrients to plant, although they recommended the rate of 40 t ha^{-1} to avoid the possible risk of metals uptake and accumulation in the soil. Bozkurt and Yarilgaç (2003) also pointed out the possibility of the Zn and other metals reach dangerous level for public health with application of high amounts of sewage sludge in the soil over long periods.

Among the green manure, the *C. ensiformis* stood out compared to wild radish, with higher levels of calcium, magnesium, sum of bases, base saturation and CEC, however, lower potassium content, probably due to extraction by the crop. According to Testa et al. (1992), the use of legumes may be able to produce high amounts of waste to allow, the long-term, reduction in leaching of cations and increase in CEC, which is accompanied by proportional increases in calcium, magnesium and potassium, and consequently in sum of base of the soil.

For the layers study, in general, the differences between treatments were more pronounced to a depth of 0.20 m, perhaps associated with the effect of the incorporation of lime and performance of green manures in the surface layers of soil.

Considering the characteristics of sewage sludge used, there would be no environmental problems with its implementation. Togay et al. (2008) recommended the rate of 60 t ha^{-1} of sewage sludge to increase bean yield and absence of pollution or toxic levels of heavy metals, while Mohammad and Athamneh (2004) suggested addition of 40 t ha^{-1} to calcareous soil to achieve acceptable level of lettuce growth with minimal adverse effect on plant and soil qualities. The characterization of the quality of sludge for agricultural use and environmental friendly is essential, however, is not enough, because it is also necessary to assess the suitability of the soil and topography, water resources and environmental regulations. Streck et al. (2008) point out some characteristics of soil and land for waste disposal. Whereas some soil characteristics such as depth, texture, mineralogy, rocks rockiness, groundwater and soil erodibility, and factors such as slope, soil study would be able to dispose of waste.

Conclusions

The improvement of soil chemical properties by green manure is not effective in the first year of study.

Sewage sludge improves some chemical characteristics of degraded soil, and may reduce or even exclude the use of mineral fertilizer.

It is recommended the application of lime in the sewage sludge to correct its pH, thus the sludge may be used without acidify the soil.

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