Influence of sewage sludge application in the recovery of a degraded quartzpisament

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Abstract
Degraded areas are sites that have reduced or lost potential soil capacity, generally caused by unsustainable anthropic exploitation, and therefore the use of organic materials for the recovery of these areas is extremely important. This study aimed to evaluate the efficiency of sewage sludge for the recovery of a quartzpisament which had been degraded by the loss of the superficial layer and high compactation level. The experiment had random block design, 8 treatments and 4 replications. The treatments were: absolute witness (control without sewage sludge and without mineral fertilizer); mineral fertilization, according to calculations for needed doses of N, P and K; supplementation with K; 2.5 Mg/ha of sewage sludge (dry base)+ supplementation with K; 5 Mg/ha of sewage sludge (dry base)+ supplementation with K; 10 Mg/ha of sewage sludge (dry base)+ supplementation; 15 Mg/ha of sewage sludge (dry base)+ supplementation with K; and 20 Mg/ha of sewage sludge (dry base)+ supplementation with K. Sewage sludge was benefical to the recovering soil regarding the significant increase in the main chemical characteristics, phosphorus, organic matter and CTC. The continued application of residue should be used as the recovery measure for the whole degraded area.

Key Words
Sewage sludge; soil fertility; degraded areas.

Introduction
Degraded areas have increased considerably, causing a lot of damage to the environment. They are characterized by the removal of the soil superficial horizon which results in loss of nutrients and organic matter, lack of biological activity and alteration of physical properties, facilitating erosive processes and substrate acidification (Marx *et al.* 1995).

The recovery process of these areas is slow and is related to the soil recovery capacity. Thus, several techniques have been used in order to recover degraded soils and most of them combine mechanical practices that aim to break off compacted layers, with the addition of organic matter (De Maria *et al*. 1999). Sewage sludge has widely been used as a conditioner and fertilizer to recover degraded areas (Brofas *et al.* 2000). Organic matter cycling and decomposition, difficult processes to start in degraded soils, occur quickly with the application of sewage sludge; and depending on the amount of remaining superficial soil, it is possible to significantly recover the soil within 3 to 5 years through an intensive management and use of organic materials that speed up plant growth and the processes of soil formation (Visser 1985).
Considering that degraded areas are areas that have been reduced or lost soil potential capacity, generally caused by unsustainable anthropic exploitation, and that the use of organic materials for the recovery of these areas is extremely important, this study aimed to evaluate the efficiency of sewage sludge from the Sewer Treatment Station of Jundiai, SP, Brazil, for the recovery of a quartzpisament in a degraded area.

Material and methods
This experiment was carried out in the town of Itatinga-SP, Brazil, on one of the farms of Cia. Suzano Bahia Sul de Papel e Celulose, located in the geographical coordinates 23º06’ S latitude 48º36’W longitude and average altitude of 845m**.** The region has annual average rainfall of 1.635 mm, temperature of 19.4°C and relative humidity of 83%. The predominant weather is Cwb according to Köeppen classification.
The original soil is classified as sandy-texture quartzpisament, according to the Brazilian System of Soil Classification (EMBRAPA 2006). Previously, the area had been a lumber deposit, degraded because of the loss of superficial layer and high level of compactation.
Analysis results should that the soil had the following chemical characteristics before the experiment

installation: 4.4 pH ($CaCl_2$); 9 g/dm^3 of organic matter; 4.3 mg/dm^3 of P (resin); 23; 0.4; 4 and 1 mmol$_c$/dm^3 of (H+Al), K^+, Ca^{2+} and Mg^{2+}, respectively; 12.6; 4.6; 27.6; 0.6 and 0.1 mg/dm^3 of B, Cu, Fe, Mn and Zn, respectively, and 18% base saturation.

The experiment was installed in a random block design with 8 treatments and 4 replications, a total of 32 plots of 384 m^2, summing up 1.23 ha. The area of each plot had 49 plants of pioneer, secondary and climax species.

The treatments used in the experiment were: absolute witness, without sewage sludge and without mineral fertilizer; mineral fertilization, according to the needs of N, P and K; supplementation with K; 2.5 Mg/ha of sewage sludge (dry base) + supplementation with K; 5.0 Mg/ha of sewage sludge (dry base) + supplementation with K; 10.0 Mg/ha of sewage sludge (dry base) + supplementation with K; 15.0 Mg/ha of sewage sludge (dry base) + supplementation with K; 20.0 Mg/ha of sewage sludge (dry base) + supplementation with K. The treatment with mineral fertilization was the following one: 260 Kg/ha of the formulate 6-30-10 + 0.3% B at planting; 1.5 Kg/ha zinc sulfate, separately applied according to soil analysis and recommendation Gonçalves *et al*. (1996), was also added. The chemical fertilizers used in the formulate was: ammonium sulfate, simple superphosphate, potassium chloride and boric acid.
The sewage sludge that was used in the experiment came from the sewer treatment station in the city of Jundiai, SP, Brazil, and had the following concentrations: 25; 16.6; 1.9; 12.2; 2.3; 19.2; 440 and 200 g/kg of N, P, K, Ca, Mg, S, O.M. and organic carbon, respectively; 850; 25.950; 584; 573; 0.1; 8.24; 162.7; 37.8 and 164.4 mg/kg of Cu, Fe, Mn, Zn, As, Cd, Cr, Ni and Pb, respectively, 55% of humidity ; 8 C/N ratio; and 5.0 pH.

Liming was done only in the treatments that received chemical fertilization and supplementation with K by applying 1.09 Mg/ha of limestone (PRNT at 91%). The sewage sludge was spread mechanically on the surface and incorporated in the planting line.

The soil samples for analyses were collected at six, and twenty-four months after application, using a Dutch auger in the 0-20 cm layer, then they were air dried, sieved (2mm mesh), homogenized and submitted to chemical analysis. The compound samples were obtained from the mixture of simple samples collected in several points within each experimental plot for soil analysis after sewage sludge application. Soil analysis was done at the Laboratory of Soil Fertility of the School of Agronomical Sciences/UNESP, campus of Botucatu-SP, Brazil. The results were submitted to statistical analysis using software “SISVAR”, version 4.2.

Results and discussion

The results of soil analysis at six months after the sewage sludge application showed increases in the values of pH and calcium and magnesium contents for treatments of mineral fertilization and supplementation with potassium (Table 1). Consequently, an increase in the values of base sum (BS) and V% was verified and that can be explained by the use of limestone in these treatments. Although the treatment with 20 Mg/ha of sewage sludge had not received limestone, it presented a Ca content equivalent to those treatments.

Table 1. Chemical analysis of the soil done six months after sewage sludge application to a degraded area.

Treatments	pH	M.O.	P_{resin}	Ca	Mg	K	SB	CTC	V%
				----------------------mmol$_c$/dm^3----------------					
Witness	4.3 b	13 b	4.7 bc	3 c	0.9 b	0.6	4.7 c	35 c	14 b
Mineral Fertilization	5.0 a	13 b	4.5 c	8 ab	5.8 a	0.6	14.6 a	37 bc	39 a
Supplementation with K	5.0 a	12 b	6.8 bc	9 ab	5.0 a	0.5	14.3 a	35 c	40 a
2.5 Mg/ha SS + K	4.2 b	18 ab	7.0 bc	4 bc	0.6 b	0.5	5.2 c	38 bc	14 b
5 Mg/ha SS + K	4.1 b	18 ab	9.7 bc	3 c	0.5 b	0.6	4.0 c	41 abc	10 b
10 Mg/ha SS + K	4.1 b	18 ab	12.2 abc	5 bc	0.6 b	0.5	5.7 bc	48 abc	12 b
15 Mg/ha SS + K	4.0 b	20 a	14.5 ab	5 bc	0.6 b	0.4	6.4 bc	52 ab	12 b
20 Mg/ha SS + K	4.1 b	20 a	23.5 a	10 a	1.0 b	0.7	11.4 bc	54 a	21 b
CV (%)	4.0	16.6	38.8	34.4	40-7	38.2	29.7	15.2	28.2

Means followed by the same letter in the column do not differ among themselves by Tukey’s Test at 5%.

When compared to treatments with mineral fertilization and supplementation with P, pH decreased, corroborating the data obtained by Simonete *et al*. (2003). The addition of sewage sludge caused the increase in the soil organic matter when compared to the other treatments. The values for the plots that received the

highest dose of sewage sludge were 35% higher than the witness.
The high contents of organic matter in the sewage sludge contributed to the increase of soil CTC, and according to Colodro and Espindola (2006) the CTC increase allows a higher storage of cation elements, making it an important parameter in the evaluation of degraded soil recovery. The impact of soil quality, indicated by CTC, with the addition of sewage sludge, was evident by the addition of 13 (witness) to 54 $mmol_c/dm^3$ for the highest dose of sludge during six months. However, the effect of treatments on the soil base saturation was not verified because the K and Mg contents present in the sludge are low.

A significant increase of P content in the soil was noticed with the use of sludge as 166, 249 and 332 kg/ha of P were added with doses of 10, 15 and 20 Mg/ha, respectively. According to Visser (1985), organic matter cycling and decomposition, difficult processes in degraded soils, occur rapidly with the application of sewage sludge, which can be proved by the obtained data in this experiment because there were significant increases of P and CTC contents in the soil after six months of the residue application in the soil. Melo *et al.* (1994) also observed a very short degradation time of the sewage sludge organic matter, when compared to other organic materials.

At twenty-four months after the sewage sludge application, reduction of the organic matter effects in the soil was verified and the values obtained in the treatments were close to the initial content (9 mg/dm^3). These results influenced directly in the soil CTC that also reduced after 2 years of sewage sludge application.

The treatments that received mineral fertilization and supplementation with K provided the highest pH rates, highest base contents in the soil and, consequently, the highest base saturations, which were expected considering there is a positive correlation of pH in the soil with base saturation.

Sewage sludge continued influencing P contents in the soil and the highest values were verified in the highest applied doses of sludge. However, P contents in this period of time are lower than the ones obtained before the experiment installation, showing that new applications of the residue can be required. According to Visser (1985), it is possible that a significant soil recovery within 3 to 5 years through intensive management and use of organic materials that speed plant growth and the processes of soil formation; however, more frequent applications of organic matter are necessary because in sandy soil, the effects of organic matter had reduced greatly 2 years after application.

Table 1. Chemical analysis of the soil done twenty-four months after sewage sludge application in an degraded area.

Treatments	Twenty-four months after application									
	pH	M.O.	P_{resina}	P_{resina}	Ca	Mg	K	SB	CTC	V%
			$\sqrt{x+0,5}$	Orig.	----------------------$mmol_c/dm^3$----------------					
Witness	4.3 bc	9	1.2	0.5	2 b	0.6 b	0.4 b	3.2 c	30	11 b
Mineral Fertilization	4.6 ab	10	2.1	4.0	4 a	2.7 a	0.5 ab	7.3 a	32	23 a
Supplementation with K	4.8 a	11	1.5	1.5	4 a	1.9 a	0.5 ab	6.0 b	28	22 a
2.5 Mg/ha SS + K	4.3 bc	11	1.5	1.5	2 b	0.8 b	0.6 a	3.5 c	34	11 b
5 Mg/ha SS + K	4.2 c	11	1.5	1.3	2 b	0.6 b	0.5 ab	3.3 c	35	10 b
10 Mg/ha SS + K	4.2 c	10	1.5	1.5	2 b	0.7 b	0.4 b	3.4 c	34	10 b
15 Mg/ha SS + K	4.1 c	13	2.2	4.5	2 b	0.8 b	0.5 ab	3.5 c	36	10 b
20 Mg/ha SS + K	4.2 c	11	1.4	1.0	2 b	0.6 b	0.4 b	3.3 c	35	9 b
CV (%)	3.6	15.2	37.0	117.1	11.4	32.7	15.0	11.3	11.0	14.8

Means followed by the same letter in the column do not differ among themselves by Tukey's Test at 5%.

Conclusions

The sewage sludge provided an increment in soil quality in recovery, with significant increases in the main chemical characteristics phosphorus, organic matter and CTC.
Continued residue application is a recovery produce for the whole degraded area

Bibliography

Brofas G, Michopoulos P, Alifragis D (2000) Sewage sludge as an amendment for calcareous bauxite mine spoils reclamation. *Journal of Environment Quality* **29**, 811-816.

Colodro G; Espíndola CR (2006) Alterações na fertilidade de um latossolo degradado em resposta à aplicação de lodo de esgoto. *Acta Scientiarum* **28**(1) p.15.

De Maria IC, Castro OM, Souza Dias H (1999) Atributos físicos do solo e crescimento radicular de soja em Latossolo Roxo sob diferentes métodos de preparo do solo. *Revista Brasileira de Ciência do solo*, **23**, 703-709.

EMBRAPA (2006) Centro Nacional de Pesquisa de Solos-CNPS. Sistema brasileiro de classificação de solos. Brasília: Embrapa-SPI; Rio de Janeiro: Embrapa-CNPS, pp.306.

Marx DH; Berry CR, Kormanik PP (1993) Application of municipal sewage sludge in forest and degraded land. In 'Agricultural utilization of urban and industrial byproducts: proceedings'. (Eds DL Karlen, RJ Wright, WD Kemper) pp.275-295. (The Soil Science Society of America and The American Society of Agronomy).

Simonete MA, Kiehl JC, Andrade CA, Teixeira CFA (2003) Efeito do lodo de esgoto em um Argissolo e no crescimento e nutrição de milho. Pesquisa Agropecuária Brasileira, v. 38, n.0.

Visser S (1985) Management of microbial process in surface mined land reclamation in western Canada. In 'Soil reclamation processes' (Eds RL TATE III, DA KLEIN) pp.204-241. (New York: Marcell Dekker).