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Chemical attributes of a savannah Typic Hapludox soil under management systems

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ABSTRACT. This study was conducted at the Experimental Station belonging to UNESP Engineering University, Ilha Solteira Campus, based in Selvíria, Mato Grosso do Sul State, Brazil, with the aim of evaluating chemical alterations in an Oxisol after being managed for two years with organic and/or chemical fertilization and different tillage systems during the agricultural years of 2004/2005 and 2005/2006. The treatments were: conventional-tillage; chisel tillage and no-tillage; the fertilization treatments were: control (no fertilization); chemical fertilization (300 kg ha^{-1} from the 20-00-20); organic fertilization (cattle manure - 20 Mg ha^{-1}); organic + ½ the recommended chemical fertilization for the used crop; 20 and 30 Mg ha^{-1} of sewage sludge. Soybean was used in the first year and sorghum in the next year, evaluating the soil chemical attributes in four layers. The soil chemical attributes were changed in the first year; the organic fertilization, sewage sludge and organic+chemical fertilization were efficient to change the chemical attributes; the sewage sludge was more efficient in soil P recuperation and, the no-tillage system contributed to soil K increase.

Keywords: cattle manure, sewage sludge, soil management, no-tillage.

RESUMO. Propriedades químicas do latossolo distroférrico típico do cerrado sob sistemas de manejo. O trabalho teve por objetivo estudar as modificações de atributos químicos de um Latossolo Vermelho após dois anos de manejo com adubação orgânica e/ou mineral com diferentes sistemas de cultivo. O experimento foi realizado na área experimental da Universidade Estadual Paulista – UNESP, localizada no município de Selvíria, Estado do Mato Grosso do Sul, no ano agrícola 2004/2005 e 2005/2006. Os tratamentos foram: cultivo convencional; cultivo mínimo e semeadura direta. As adubações foram: testemunha (sem adubação); adubação mineral (300 kg ha^{-1} da fórmula 20-00-20); adubação orgânica (esterco bovino - 20 Mg ha^{-1}); adubação orgânica (esterco bovino) + ½ adubação mineral recomendada para a cultura utilizada; 20 e 30 Mg ha^{-1} de lodo de esgoto. Em um ano foi utilizada a soja como cultura e no seguinte o sorgo. Avaliaram-se os atributos químicos do solo em quatro camadas. Os atributos químicos do Latossolo Vermelho foram modificados no primeiro ano após as adubações; a adubação com esterco, lodo de esgoto e a combinação do esterco+adubação mineral foram eficazes em modificar os atributos químicos do solo estudado; o lodo de esgoto foi mais eficaz na recuperação do P do solo e, a semeadura direta contribuiu para o aumento de K no solo.

Palavras-chave: esterco bovino, lodo de esgoto, manejo do solo, semeadura direta.

Introduction

Savannah soils usually provide low yields due to the high Al saturation, low contents of most of the mineral nutrients that are essential to the plants development, low organic matter content, leading to low CEC and high phosphorus fixation (FAQUIN et al., 2000). The savannah is equivalent to a quarter of the national territory. It is estimated that most of this area can be used for agricultural purposes. One of the challenges of establishing crops in savannah areas is the fertilization management of the economically important cultures under the no-tillage system, especially when it comes to nitrogen, which is largely required by these crops.

The agricultural machinery which is available to prepare the soil leads to alterations in the soil chemical, physical and biological attributes. Each machine prepares the soil in a different way and alters these attributes differently as a consequence (VÁZQUEZ et al., 2006; TORMENA et al., 2008). The intensity in which the soil is revolved and the crops residues are incorporated causes changes in the organic matter content, in the cation exchange capacity, in the pH, in the ion dynamic and in the soil aggregation (TRANNIN et al., 2008).

The no-tillage system is based on crop rotation and is characterized by growing in a soil which is both unprepared and covered by straw for unlimited time. This system usually demands the use of no-tillage seeders to cut the straw, open a small furrow to place the fertilizer and the seeds, not to mention all the conservationist procedures which allow good quality straw to be kept in a proper amount in order to improve the sustainability of the whole ecosystem.

In order to minimize the river pollution, the domestic and industrial wastes have been treated and the outcome is caked sewage sludge. The handling and the final disposal of the sewage sludge are the process most important phases. The agricultural use of sewage sludge as nutrients and organic matter sources is an alternative method for the final disposal of this waste from which some benefits can be gained (ALVES et al., 2006).

The agricultural use of sewage sludge has become a sensible and promising way of disposing it once it is a good nutrient source, especially regarding phosphorus and nitrogen (BINDER et al., 2002). Phosphorus is considered one of the hindering factors to agricultural yields, due to the adsorption and/or fixation processes in soil colloids (CORRÊA et al., 2005). Sewage sludge usually contains low potassium content due to the obtaining process, the opposite of what happens to phosphorus, which is present in a high content and, most importantly, approximately 80% of it is available in the first application year (SIMONETE et al., 2003). Another important factor is the sewage sludge decomposition in the soil which allows a better uptake of the nutrients by the plants as they are slowly released via the organic matter mineralization process (DEBOSZ et al., 2002).

According to Borges and Coutinho (2004), after the sewage sludge application, there was an increase in the organic matter content and in the pH of the soil without correctives. Nascimento et al. (2004), evaluating the chemical changes in a soil under corn and beans crops where sewage sludge was used, observed an increase in the organic matter, total nitrogen, phosphorus, sodium, calcium and magnesium contents though potassium and sodium contents were not altered.

The manure incorporation in the agricultural soils has been done since the beginning of the agriculture. Until half of the 19th century, when the advance of the fertilizer industry took place, the use of manure was the main nutrient source for the plants. Galvão et al. (2008) mentioned that the manure composition varies and is influenced by many factors, such as animal species, breed, age, feed and the way the raw material (manure) is treated, and that cattle manure has 57.1% OM, 1.67% N, 0.86% P_2O_5, 1.37% K_2O and C/N ratio of 32/1.

For Sharpley et al. (2004) and Souto et al. (2005), the benefits of using manure can be ranked as follows: improvement of the soil physical attributes and of the nutrient supply; increase in the organic matter content, leading to better water infiltration as well as an increase in the cation exchange capacity.

Silva et al. (2004), when studying the manure use for corn crops observed that the pH, the exchangeable calcium and magnesium contents and the organic matter content were higher for depths of 0.00-0.20 m than for depths of 0.20-0.40 m. There was an increase in the phosphorus content and there was no difference in the potassium content. Silva et al. (2007), quoted by the same author, also observed linear increases in the potassium and phosphorus contents, with an increase of the manure dose, but he also observed increased pH and Mg and organic matter contents.

Manure was widely used in the past; however, with the development of the chemical fertilizers, the interest in the organic ones decreased. Currently, due to the environmental concern, the interest in the use of manure, that is, sustainable agriculture has increased. Its chemical function is shown by its ability of interacting with metals, oxides and metal hydroxides and of forming organic-metallic compounds acting as N, P and S stock. In acidic soils under savannah, the organic matter effect on the availability of the applied phosphorus has a residual characteristic (MOREIRA et al., 2001; ANDRADE et al., 2002).

Based on what was mentioned, this research work had the objective of studying the changes in the chemical attributes of a Typic Hapludox in a savannah in Mato Grosso do Sul State, after two years under different tillage systems and managements with organic and/or chemical fertilization.

Material and methods

The experiment was conducted at the Experimental Station belonging to UNESP Engineering University, Ilha Solteira Campus, based in Selvíria, Mato Grosso do Sul State, Brazil. The experimental area has 51°22'W and 20°22'S as geographic coordinates and 335 m altitude. The climate is Aw, defined as humid tropical with rains in the summer and drought in the winter, temperature of 24.5°C, precipitation of 1,232 mm and average relative moisture of 64.8%. The studied area soil was classified as Latossolo Vermelho distrófico, according to Brazilian Soil Classification System (DEMATTÊ, 1980; EMBRAPA, 2006), loam texture, moderately plain to slightly ondulated landscape, corresponding to Typic Hapludox (SOIL SURVEY STAFF, 1975).

The area had been under pasture with *Brachiaria decumbens* and intensive grazing for twenty years. During this period, the soil was not corrected or fertilized. No renewal, recovering or maintenance treatment was previously performed in the studied pasture. In November 2001, cotton and corn were grown under no-tillage and conventional tillage systems (harrow and leveling bars). The soil correction was done in order to increase the percent base saturation up to 70%. The chemical fertilization was performed according to the results from the soil chemical analysis and 300 kg ha^{-1} of the 20-0-20 formula was used for both crops (cotton and corn). From April 2002 to October 2003 the area remained fallow, which made the *Brachiaria* grow back again spontaneously.

In October 2003, a soil sampling was performed in order to have another chemical characterization of the experimental area. Composed samples from 20 simple samples were collected from three different soil layers: 0.00-0.05; 0.05-0.10 and 0.10-0.20 m. The analysis results can be observed in Table 1 and were used to determine the P and K amounts to be used for sowing soy according to Mascarenhas and Tanara's recommendations (1996).

The used experimental design was the randomized blocks, in a (3 x 6) factorial design, with 3 tillage systems (conventional – harrow and leveling bars; chisel tillage – subsoil plow and light harrow and, no-tillage) and 6 fertilization treatments (control – not fertilized; chemical fertilization – 300 kg ha^{-1} of the 20-0-20 formula; organic fertilization – cattle manure 20 Mg ha^{-1}; organic fertilization – cattle 20 Mg ha^{-1} + ½ the recommended chemical fertilization; 20 Mg ha^{-1} of sewage sludge and, 30 Mg ha^{-1} of sewage sludge), with 4 blocks. The treatments were applied in 2003 and there were no other applications in the following years.

A hoe was used to establish the organic treatments in order to spread the material on the soil surface; after that, the disc harrow was used. This operation was necessary since the sewage sludge must be incorporated to the soil for sanitary reasons.

On December 27, 2003, IAC 19 soy was sowed with a 0.45-m distance between lines and 20 seeds per meter. In the 2004/2005 yield, foraging sorghum (hybrid BR 700) was sowed with 0.45-m between lines on December 20, using 8.0 kg ha^{-1}. Sorghum was chosen due to its resistance to the drought.

The sewage sludge, predominantly from domestic waste with 85.42% moisture, was obtained from SANEAR, in Araçatuba, Sao Paulo State. The heavy metals content is low and for some elements it is none. The used cattle manure came from the cattle confinement area on a farm belonging to Damha Animal Nutrition Group. Table 2 presents the chemical attributes of the used sewage sludge and cattle manure, according to the proposed by Sarruge and Haag (1974).

The soil samplings were performed after the soy and sorghum harvest. A composed sample from each plot was collected from 5 simple samples from the layers 0.00-0.05, 0.05-0.10 and 0.10-0.20 m. The soil chemical analyses were performed for P, O.M., pH, K, Ca, Mg, H+Al, Al; SB, CEC, and %BS were calculated according to Raij and Quaggio's (1983) methodology.

A variance analysis and the means were compared using Tukey test at 5% probability.

Table 1. Soil chemical characterization of the experimental area before the experiment establishment in October 2003.

Layer (m)	Resin P (mg dm^{-3})	O.M. (g dm^{-3})	pH ($CaCl_2$)	K	Ca	Mg	H+Al	Al	SB	CEC	BS
			(mmol$_c$ dm^{-3})								%
0.00-0.05	10	18	5.6	0.8	20	7	15	0	27.6	42.6	65
0.05-0.10	13	17	5.3	0.2	15	6	16	0	21.0	37.0	57
0.10-0.20	5	15	5.0	0.2	10	5	18	1	16.0	34.0	47

O.M.= organic matter; SB= bases sum; CEC= exchange cation ; BS= bases saturation.

Table 2. Chemical attributes of sewage sludge and cattle manure.

O.M.	N	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Zn	Moisture
(g dm^{-3})	g kg^{-1}						(mg kg^{-1})					kg kg^{-1}
Sewage sludge												
200	71	19	15	11	3	8	16.4	160.1	960.6	115.7	583.5	0.85
Cattle manure												
252	10	5	15	15	3	2	1.0	12.0	7217.0	99.0	51.0	0.33

Results and discussion

According to Table 3, it was observed significance for P only in the depth of 0.05-0.10 m, where the treatments with sewage sludge provided better results; the same was observed by Galdos et al. (2004) in the first years of their experiment. The sewage sludge application works as a correcting fertilization, increasing the initial low contents to very high ones. However, its application in order to increase soil P up to very high contents must be carefully performed in areas where there is surface drainage, as it could lead to the contamination of water courses (TRANNIN et al., 2005). According to Silva et al. (2007) and Sharpley et al. (2004), continuous applications of organic compounds to the soil can probably cause an accumulation of nutrients and their vertical migration as a consequence.

As for the pH, it was observed that the sewage sludge treatments provided the lowest numbers not differing from the chemical and organic fertilization treatments (Table 3). According to Andrade et al. (2002), the organic matter biodegradation can also cause transient acidification in the soil, due to the production of organic acids. According to Oliveira et al. (2002), pH alterations in the soil, caused by the sewage sludge incorporation, are directly related to the type of treatment given to the waste; therefore, only alkaline sewage sludge tends to elevate soil pH, regardless of the nature and organic changes of these materials. Galvão et al. (2008), when studying the nutrient accumulation in sandy soils fertilized with cattle manure, found contrary results, that is, the organic fertilization provided a pH increase.

Differences among the treatments concerning the organic matter were not observed in the studied depths (Table 3). This is due to the waste degradation rate in the soil which, according to Melo et al. (2004)

The time of degradation of organic matter from sewage sludge is very short compared to other organic materials. The results weren´t the same as observed by De Maria et al. (2007), that is, for the authors there was increase in the organic-C content even when applying high doses of the waste.

In all the studied layers, we observed that the use of sewage sludge led to lower K contents when compared to the chemical fertilization, due to the plants absorption and leaching (Table 3). Similar results were observed by Rocha et al. (2004) when studying eucalyptus; K contents decreased 36 months after the application. Trannin et al. (2005), evaluating the use of an industrial biosolid for corn crops, observed low K contents, which can be justified by the Na increase in the soil and plant, considering that this element has antagonistic effect on K due to the competition among these ions for the absorption sites.

As for the potential acidity, it was observed that the sewage sludge use increased it (Table 3) in all soil layers, which can be due to higher organic matter mineralization (COLODRO; ESPINDOLA, 2006). Similar results were observed by Galdos et al. (2004) as the experiments with corn on a soil treated with sewage sludge for two years showed an acidifying effect of the waste, decreasing pH in the 0.00-0.05 m layer from 5.8 to 5.0 and increasing the potential acidity; there were no changes for pH or potential acidity in other depths.

Table 3. Soil chemical attributes regarding treatments and the studied soil layers. Selvíria, Mato Grosso do Sul State, 2004/2005 and 2005/2006 seasons.

Treatments	Resin P ($mg\ dm^{-3}$)	O.M. ($g\ dm^{-3}$)	pH ($CaCl_2$)	K	Ca	Mg	H+Al	Al	SB	CEC	BS %
				------ ($mmol_c\ dm^{-3}$) ------							
Layer 0.00-0.05 m											
Control	7.9 c	19.40	5.3 ab	1.1 c	20.1	8.3	16.9 ab	0.8	29.5	40.4	63
Chemical F.	12.0 c	19.80	5.4 ab	1.3 abc	21.7	7.7	16.5 ab	0.6	41.3	47.5	62
Organic F.	9.7 c	18.70	5.3 ab	1.4 ab	18.5	8.2	16.4 ab	0.6	36.8	44.7	59
Org. + chem.	14.8 bc	18.50	5.5 a	1.5 a	22.5	7.1	15.4 b	0.5	41.8	46.7	64
20 $Mg\ ha^{-1}$*	21.2 ab	18.80	5.1 b	1.1 bc	19.1	7.8	17.9 a	0.7	36.1	46.1	59
30 $Mg\ ha^{-1}$*	23.0 a	19.40	5.1 b	1.3 abc	21.1	8.6	18.1 a	0.8	42.0	48.4	59
Layer 0.05-0.10 m											
Control	11.9 b	17.40	5.1 b	0.7 cd	18.9	7.0	17.5 ab	0.9	26.7	44.0	59
Chemical F.	11.0 b	17.10	5.3 ab	0.9 abc	22.1	7.3	16.8 ab	0.8	30.3	47.2	60
Organic F.	12.4 b	16.80	5.3 ab	1.0 ab	18.6	7.5	17.0 ab	0.9	27.1	45.2	58
Org. + chem.	12.8 b	17.20	5.6 a	1.1 a	23.9	6.8	15.0 b	0.8	31.8	46.9	64
20 $Mg\ ha^{-1}$	22.7 a	16.10	5.1 b	0.6 d	19.6	6.4	18.3 a	0.7	26.9	45.0	57
30 $Mg\ ha^{-1}$	23.7 a	17.20	5.0 b	0.8 bcd	19.1	6.8	18.8 a	1.1	26.8	45.6	54
Layer 0.10-0.20 m											
Control	8.2	13.50	5.1	0.5 c	16.5	6.3	16.8	0.8	23.2	40.6	55
Chemical F.	8.2	14.20	5.3	0.8 abc	17.1	6.5	17.7	0.7	24.4	41.0	57
Organic F.	8.8	12.90	5.2	0.9 ab	15.8	6.5	16.5	0.7	23.3	39.8	56
Org. + chem.	8.9	13.40	5.4	1.1 a	18.3	6.9	16.0	0.8	26.4	42.3	60
20 $Mg\ ha^{-1}$	11.4	14.20	5.1	0.6 bc	15.2	5.7	17.9	0.9	21.6	39.4	53
30 $Mg\ ha^{-1}$	11.7	12.90	5.2	0.7 bc	17.7	5.9	16.8	0.8	22.8	39.6	54

Means followed by the same letter in the column do not statistically differ from each other according to Tukey test at 5% probability. *Sewage sludge.

In Table 4, it is possible to observe that for the nutrients which showed significance, the highest results were obtained in the year of 2004. As for the effect of the interaction sampling year x fertilization (Table 5), significance was only observed for the 0.00-0.05 m layer when the years were compared for the treatments with sewage sludge and, in 2005, the results were higher, which was similar to the observed by Galdos et al. (2004) as, according to him, there was an improvement in the chemical quality of the soil caused by the application of sewage sludge only in the second year after using the waste. Concerning the fertilization, significance was only observed in 2005, when the treatments with sewage sludge showed the best results.

For the 0.10-0.20 m layer, the year of 2004 presented the best results and when the fertilizations were compared again, the treatments with sewage sludge showed the best results with highest values for P soil content (Table 4). Similar results were presented by Barbosa et al. (2002), when, after applying sewage sludge for two years in a row, it was observed that the treatments with the waste led to significant improvement of the soil chemical attributes studied. Colodro and Espindola (2006) also observed an increase in the P soil content in an area which had been treated with biosolid for two years. Although the continuous biosolid application increased the total P soil content, approximately 40% of which was part of the organic P being very stable in the soil and available to the plants.

In regard to magnesium, there was a decrease in its content throughout the year (Table 4), which was similar to the observed by Rocha et al. (2004); the authors noticed a decrease in the Mg content after 32 months from the application day due to the low Mg content in sewage sludge. However, Trannin et al. (2008) evaluated the chemical and physical attributes of a soil treated with industrial sewage sludge where corn was being grown and observed a significant increase in the magnesium soil content, due to the waste characteristics.

There was a pH decrease and increases in the potential acidity (H+Al) and in the exchangeable Al and, therefore, an increase in the Al saturation (Table 3) as a consequence of the sewage sludge application. It can be partly explained by the fact that this waste is produced without adding limestone, having therefore low correcting efficiency. The organic N mineralization and consequent nitrification could also have contributed to the soil acidification. Similar results were observed by Galdos et al. (2004), Trannin et al. (2005) and Colodro and Espindola (2006).

For the effect of the interaction sampling year x tillage concerning K contents (Table 6), it was observed that the significance only occurred for the no-tillage system. Being the year of 2005 the period when the best results were observed, the no-tillage system was proved to be the best when compared to the others. Nevertheless, the results were different from the observed by Trannin et al. (2005), who observed a decrease in K contents, due to the application of sewage sludge, as there was an increase in Na contents in the soil and also in the plants. Therefore, this increase could have been provided by the no-tillage system, once it leads to a better nutrient cycling in the soil where straw from the previous crop is preserved.

Table 4. Soil chemical attributes for different soil layers regarding the years. Selvíria, 2004/2005 and 2005/2006 seasons.

Treatments	Resin P ($mg\ dm^{-3}$)	O.M ($g\ dm^{-3}$)	pH ($CaCl_2$)	K	Ca	Mg	H+Al	Al	SB	CEC	BS
				---------- ($mmol_c\ dm^{-3}$) ----------							%
Layer 0.05-0.10 m											
2004	12.2 a	19.0	5.4 a	1.7 a	29.3 a	9.1 a	17.5 a	1.0 a	39.3 a	55.7 a	70.3 a
2005	17.3 b	19.2	5.2 b	0.9 b	11.8 b	6.8 b	16.3 b	0.4 b	20.1 b	38.6 b	52.8 b
Layer 0.05-0.10 m											
2004	17.8 a	18.2 a	5.4 a	0.7 b	28.8 a	8.8 a	16.8	1.1 a	38.4 a	55.1 a	69.2 a
2005	13.7 b	15.7 b	5.1 b	0.9 a	11.9 b	5.2 b	17.6	0.7 b	18.2 b	36.2 b	49.1 b
Layer 0.10-0.20 m											
2004	11.2 a	14.60 a	5.2	0.9 a	22.7 a	8.0 a	17.3	1.0 a	31.6 a	48.9 a	64.6 a
2005	7.9 b	12.40 b	5.1	0.7 b	10.8 b	4.6 b	16.1	0.7 b	15.6 b	32.1 b	47.3 b

Means followed by the same letter in the column do not statistically differ from each other according to Tukey test at 5% probability.

Table 5. Effect of the interaction between sampling year x fertilization for P contents in different soil layers. Selvíria, 2004/2005 and 2005/2006 seasons.

Years	Control	Chemical F.	Org. F.	Org. + Chem.	20 Mg ha^{-1}*	30 Mg ha^{-1}*
Layer 0.00-0.05 m						
2004	6.6	11.3	10.3	16.0	15.0 b	14.0 b
2005	9.1 B	12.6 B	9.0 B	13.7 B	27.0 a A	32.1 a A
Layer 0.10-0.20 m						
2004	11.3 a	9.6	12.6 a	12.0 a	12.2	12.5
2005	5.1 b C	6.6 BC	4.8 b C	5.9 b C	11.3 AB	10.3 A

Means followed by the different letters, capital letters in the line and minuscule letters in the column, differ from each other according to Tukey test at 5% probability. *Sewage sludge.

Table 6. Effect of the interaction between sampling year x tillage for potassium contents in the 0.05-0.10 m layer. Selvíria, 2004/2005 and 2005/2006 seasons.

	Layer 0.05-0.10 m		
Year	Conventional	Chisel Tillage	No-tillage
2004	0.8 a	0.8 a	0.8 b
2005	0.8 aB	0.8 aB	1.2 aA

Means followed by different letters, capital letters in the line and minuscule letters in the column, differ from each other according to Tukey test at 5% probability.

Conclusion

The chemical attributes of Typic Hapludox were modified in the first year after fertilizations. Manuring, sewage sludge fertilization and the combination manure + chemical fertilization were efficient in modifying the chemical attributes of the studied soil. Sewage sludge was the most efficient treatment for soil P content and the no-tillage system contributed for the increase of the soil K content.

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