Applications of Composted Tannery Sludge on Soil Effects on Soil pH, Electric Conductivity and Soil Organic Matter Content

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ABSTRACT

Experiments were carried out under field conditions to evaluate the effects of composted tannery sludge (CTS) on soil pH, electric conductivity (EC) and soil organic matter (SOM) content after three years of application. The treatments consisted of five rates: 0 (control), 2.5, 5.0, 10.0 and 20.0 t ha^{-1}. In each year, soil samples were collected 60 day after CTS application. After three years, The CTS increased about 5, 46 and 69% the soil pH, EC and SOM content as compared with the control. Each soil parameter showed linear increases with CTS application. Consecutive applications of crescent rates of CTS promote linear increases in soil pH, electric conductivity and organic matter content.

Keywords: Composting, Industrial wastes, Salinity soil, Brazil

1. INTRODUCTION

Brazil is one of the biggest leather producers in the world with processing 45 million units per year. In addition, tannery industry in Brazil exports about 28 million units of leather with asserts of 21 billion dollars per year (Santos et al., 2011). Annually, tannery industries generate high volumes of solid wastes, commonly known as tannery sludge (TS), which presents high amounts of organic and inorganic elements (Santos et al., 2011). Therefore, the agricultural use of TS is one alternative for TS recycling (Silva et al., 2010), once that it may promote plant growth supported by its nutrients supply, and increase soil pH with consequent reduction in exchangeable aluminum availability (Canellas et al., 2011).

Moreover, TS organic matter may improve soil physical and biological properties. Adversely, this sludge contains high sodium, hydroxides and carbonates (Selbach et al., 1991) which causing soil alkalinity and salinity in long-term (Ferreira et al., 2003; Teixeira et al., 2006).

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Although TS improve soil properties, in the last years the composting has been suggested as a suitable method for TS treatment before application on soil (Silva et al., 2010; Santos et al., 2011). This biological process improve TS properties improving its quality for soil use.

The agricultural use of composted tannery sludge (CTS) for agricultural purposes implicates in the knowledge of its characteristics, mainly alkalinity, salinity and organic matter content, after composting, and the effects of these characteristics on soil properties, mainly after successive applications. Several studies have already been conducted using tannery sludge aiming to verify the effect of the applications on soil pH, EC and organic matter content in tropical soils (Ferreira et al., 2003; Teixeira et al., 2006), but, there are not studies about the effect of composted tannery sludge on soil pH, EC and OM mainly after consecutives application in soil.

The objective of this work was to evaluate the effect of CTS, after three years of consecutive applications on soil pH, electric conductivity and soil organic matter content.

2. MATERIAL AND METHODS

The experiment was carried out under field conditions at the “Long-Term Experimental Field” from Agricultural Science Center, Teresina, Piauí state (05 º 05 ' S; 42 º 48 ' W, 75 m). The regional climate is dry tropical (Köppen), and it is characterized by two distinct seasons: rainy summer and dry winter, with annual average temperatures of 30 °C and rainfall of 1.200 mm. The rainy season extends from January to April when 90% of total annual rainfall occurs. The soil is classified as Typic Quartzipsamment (Haplic Arenosol, FAO classification) (clay, 10%; silt, 28%; sand, 62% at a depth 0 - 0.20 m). The soil chemical properties (0-2.0 m depth), before the experiment, are shown in Table 1.

Table 1. Soil chemical properties before the installation of experiment.

Chemical properties										
EC	pH	OM	P	K	Ca	Mg	Cr	Cd	Ni	Pb
mSm^{-1}	(H_2O)	($g\ kg^{-1}$)	($mg\ dm^{-3}$)		($cmol_c dm^{-3}$)		--------($mg\ kg^{-1}$)--------			
0.18	6.6	7.88	2.97	46.8	1.19	0.36	2.69	0.07	0.42	2.

EC – Electric conductivity; OM – Organic matter

The experiments were conducted in 2009, 2010 and 2011 with five treatments: 0 (without CTS application), 2.5, 5.0, 10 and 20.0 t ha^{-1} of CTS (dry basis). The experiment was arranged in a completely randomized design with four replications. The plots were marked out (20 m^2 each and 12 m^2 of useful area for soil and plant sampling) including rows spaced 1.0 m apart.

Tannery sludge was collected from the wastewater treatment plant of a tannery located at Teresina, Piauí state, Brazil. The compost was produced with tannery sludge, sugarcane straw and cattle manure in the ratio 1:1:3 for 85-day composting. The size of pile was 2 m long by 1 m wide and 1.5 m high. The pile was turned twice during the first and second weeks and once a week during the rest of period. At the end of the composting 20 subsamples were randomly collected from the pile to produce a composite sample of the compost. The chemical characteristics of composted tannery sludge (CTS) were determined by the EPA 3051 method (USEPA, 1986) and are shown in Table 2. Bio-available heavy metals content were determined by EPA method 3050B (USEPA, 1986).

In each year, CTS was applied ten days before cowpea (*Vigna unguiculata*) sowing. It was spread on the soil surface with incorporation into the 0.20 m layer with a harrow. Cowpea was grown at a density of 5 plants m^{-1} (about 62,000 plants ha^{-1}). Soil samples (0-0.2 m depth) were collected 60 days after CTS application using five subsamples per plot. The soil samples were air dried, sieved (2.0 mm) and stored at room temperature before analyses. Soil pH was estimated in water (1:2.5 v:v) and measured by potenciometry. Soil electric conductivity was evaluated in water (1:1, v:v) and measured by condutivimetry. Soil organic matter (SOM) was determined by the Walkey-Black method. The data were submitted to the analysis of variance (ANOVA) and the means were compared by the Student's test (5% level) and regression analyses.

3. RESULTS AND DISCUSSION

The chemical properties of CTS used annually indicate the stability in your composition (Table 2). The C/N ratio of CTS (<25) corresponded to that of a matured compost (type A). The high values of CTS pH and Ca content are related to hydroxides and carbonates used during tanning process (Selbach et al., 1991). The organic matter from animal leather contributes for high organic matter content in the CTS. The CTS showed high Cd, Pb, Cr and Ni content (Table 2) and, except for Cr, these metals content are below the maximum limits established by CONAMA (2003) for compost type A (Table 2).

The concentration of Cr were 3 to 4 times higher than the maximum limits in compost type B (600 mg kg^{-1} soil) (CONAMA, 2003) and from 1.9 to 2.2 higher than the upper limits for Cr by CONAMA (2006) (Table 2). However, as observed in Table 2, soil pH increased above 7.0 as CTS rates increased and, when soil pH is alkaline, heavy metals stay inert in the soil under forms with low mobility (Hayes and Traina, 1998). Specially for Cr, in pH values above 5.0, Cr is in the insoluble form of $Cr(OH)_3$ (Aquino Neto and Camargo, 2000) reducing the toxic potential. In addition, as the CTS pH is alkaline, Cr is found in the trivalent form (Cr^{3+}), which is more stable and has a low solubility and mobility (Alcântara and Camargo, 2001).

Table 2. Chemical properties of composted tannery sludge (CTS).

Properties	CTS			Limits of heavy metals [a]	Maximum Limits of heavy metal permitted in compost base on sludge's [b]
	2009	2010	2011		
pH	7.8	7.2	7.5		-
C (g kg^{-1})	187.5	195.3	201.2		-
N (g kg^{-1})	1.28	1.39	1.51		-
P (g kg^{-1})	4.02	3.83	4.91		-
K (g kg^{-1})	3.25	3.51	2.90		-
Ca (g kg^{-1})	95.33	84.28	121.18		-
Mg (g kg^{-1})	6.80	5.71	7.21		-
S (g kg^{-1})	9.39	8.43	10.20		A - B
Cu (mg kg^{-1})	17.80	19.51	16.38	1500	100 - 1000
Zn (mg kg^{-1})	141.67	128.31	127.81	2800	200 - 2000
Ni (mg kg^{-1})	21.92	28.61	23.26	420	20 - 80
Cd (mg kg^{-1})	2.87	3.93	1.93	39	2 - 8
Cr (mg kg^{-1})	2,255	2,581	1,943	1000	120 - 600
Pb (mg kg^{-1})	42.67	38.54	40.31	300	100 - 300

The use of CTS increased soil pH, EC and SOM content after three years of application (Table 3). Compared with the values from the first year of application, three years later the soil pH increased about 5%, with application of 20 ton ha^{-1} CTS, while the increase in soil EC ranged from 29 to 46%, with application of 2.5 and 10 ton ha^{-1} CTS, respectively.. The highest increase in soil EC was due to the high sodium content found in the CTS that contribute to promote soil salinity. On the other hand, the pH of CTS ranged from 7.2 to 7.8 (Table 1) and it contributed to lower increase in soil pH as compared with soil EC.

For SOM content, comparing the first year of application and three years later, the values increased 39 to 69%, with application of CTS increased of 2.5 to 20 ton ha^{-1} (Table 3). These results can be attributed to the high OM content in this waste which can contributes to improve the soil quality since SOM is recognized as the main soil conditioner and a source of plant nutrients.

During three years of CTS application, the soil pH, EC and SOM content linearly (Figure 1). The soil pH increased 0.95, 1.45 e 1.75 units for CTS application in 2009, 2010 and 2011, respectively, as compared with control. The regression equations for soil pH in 2009, 2010 and 2011 showed constant increases of 0.03, 0.05 and 0.04 units per ton of CTS applied, respectively. It means that CTS presents a strong potential to elevate soil pH which is attributed to the high carbonate content and to the hydroxides content of CTS (Selbach et al., 1991). These values were higher than 0.01 unit per ton and lower than 0.06 unit per ton found by Ferreira et al. (2003) and Martinez (2005), respectively, with tannery sludge. However, the tannery sludge used by these authors presented lower and higher pH values and Ca contents than CTS used in this study.

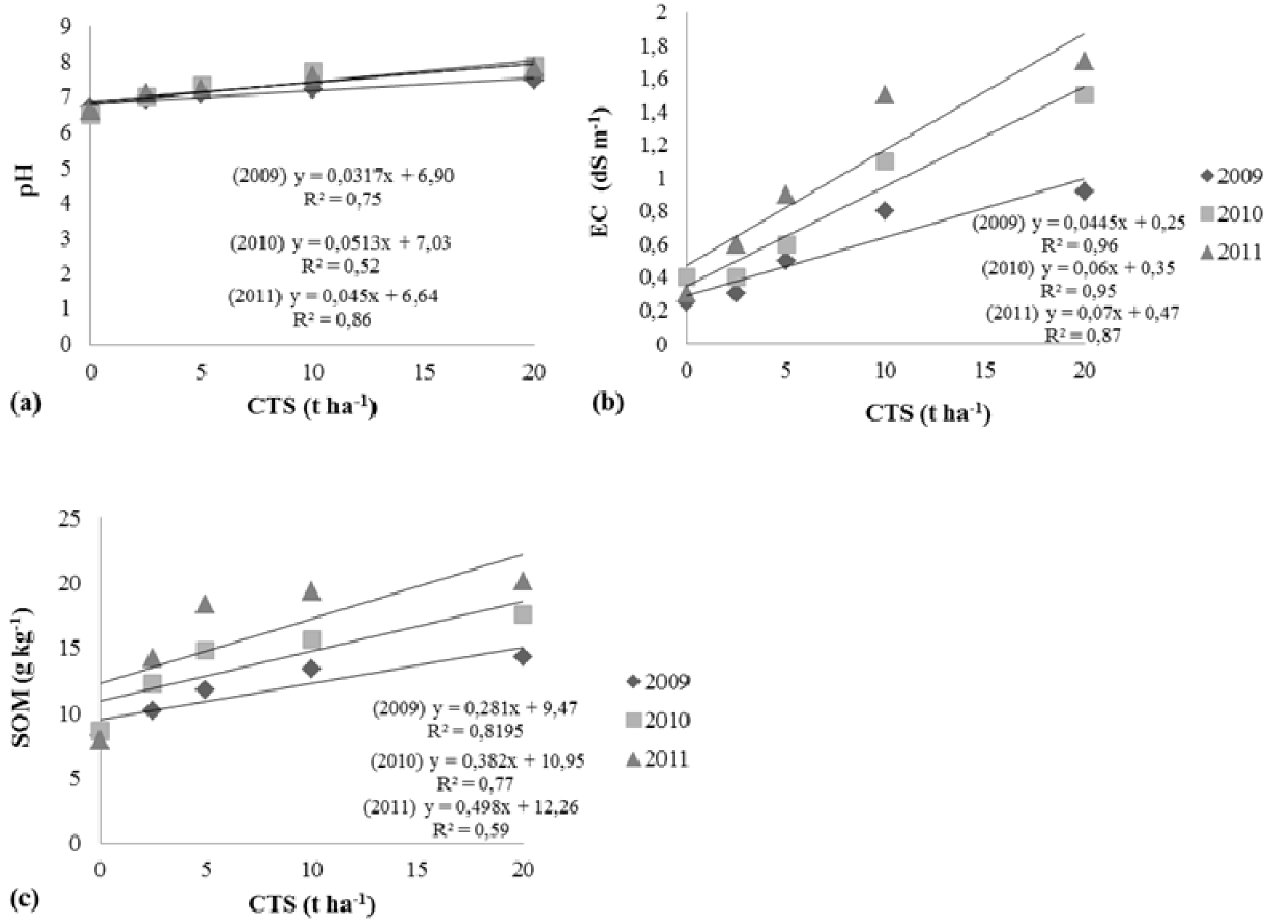

Figure 1. Soil pH (a), electric conductivity (EC) (b) and soil organic matter (SOM) (c) in a Typic Quartzipsamment after three years of CTS application.

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Table 3. Soil pH, eletric conductivity (EC) and organic maater (SOM) at the first and the third year of CTS application.

Rates	CTS application		Diference
	First year	third year	
($t\ ha^{-1}$)	Soil pH		%
0	6.7	6.6	- 1.5
2.5	6.9	7.2	+ 4.3
5	7.1	7.2	+ 1.3
10	7.2	7.5	+ 4.1
20	7.4	7.8	+ 5.4
	EC ($dS\ m^{-1}$)		
0	0.25	0.28	+ 12
2.5	0.31	0.40	+ 29
5	0.44	0.61	+ 38
10	0.80	1.17	+ 46
20	0.92	1.32	+ 43
	SOM ($g\ kg^{-1}$)		
0	8.2	7.8	- 4.0
2.5	10.2	14.2	+ 39
5	11.8	18.4	+ 56
10	13.4	19.3	+ 44
20	14.3	20.1	+ 41

Our results indicated that CTS may be used as soil corrective and it contribute to neutralize Al^{3+} as also reported in others studies (Konrad and Castilhos, 2002; Ferreira et al., 2003; Teixeira et al., 2006). On the other hand, for soil pH above 7.0 may have unbalance in soil chemical properties, mainly decrease micronutrients availability (Novaes et al., 2007).

The soil CE increased 268, 275 and 467% after CTS application in 2009, 2010 and 2011, respectively, as compared with the control. These results indicate that CTS may increase soil salinity after its application in long-term as also reported in others studies (Ferreira et al., 2003; Teixeira et al., 2006). The salinity effect of CTS is due to the presence of salts, such as sodium chloride and others. The regression equations for soil EC with the data obtained in 2009, 2010 and 2011 showed a constant of increases of 0.04, 0.06 and 0.07 $dS\ m^{-1}$ per ton of CTS applied, respectively, and these constants were significantly lower than those found by Martinez (2005), after tannery sludge application in sand soil, that varied between 0.10 and 0.18 $dS\ m^{-1}$ per ton of tannery sludge. However, the tannery sludge used by those author contained about three times more sodium than the CTS used in this study.

The measurements of EC indicate the concentration of soluble salts in soil (Oliveira and Matiazzo, 2002) the values of EC higher than 2.0 $dS\ m^{-1}$ in saturation extract, indicate saline soils. In this case, our results showed that, after three years of CTS application, the values of EC were below this limit. The permanent monitoring of soil EC during soil use of CTS is important to avoid soil salinization.

The results for SOM showed an increase of 74, 102 and 156% after CTS application in the years 2009, 2010 and 2011, respectively, as compared with control. The regression equations for SOM, using the data obtained in those three years, showed a constant of increases of 0.28, 0.38 and 0.49 g kg^{-1} SOM per ton of CTS applied, respectively. These values were higher those found by Mantovani et al. (2005) that were about 0.05 and 0.06 g kg^{-1} SOM per ton of composted urban waste. These results show that CTS, because of its high organic content, presents potential to increase SOM content, improving soil physical, chemical, biochemical and biological properties. In addition, successive applications of CTS would cause increases in SOM as obtained with sewage sludge (Oliveira et al., 2002), fibber and resins sludge (Trannin et al., 2208) and composted urban wastes (Mantovani et al., 2005) and tannery sludge (Santos et al., 2011).

4. REFERENCES

Alcântara, M.A.K., and O. A. Camargo. 2001. Movement of trivalent chromium as influenced by pH, soil horizon and sources of chromium. *Revista Brasileira de Engenharia Agrícola e Ambiental* 5(2):497-501.

Aquino Neto, V., and A. Camargo. 2000. Growth and accumulation of Chromium in lettuce sowed in two oxisols treated with CrCl3 and tannery waste. *Brazilian Journal of Soil Science* 24(2):225-235.

Ferreira, A. S., Camargo, F. A. O., Tedesco, M. J., and C.A. Bissani. 2003. Effects of tannery and coal mining residues on chemical and biological soil properties and on corn soybean yields. *Brazilian Journal of Soil Science* 27(4):755-763.

Hayes, K.F., S. J. Traina. 1998. Metal ion speciation and its significance in ecosystem health. In: *Soil Chemistry and Ecosystems Health*. St. Louis, Proceedings. Madison: SSSA.

Konrad, E. E., and D. D. Castilhos. 2002. Alterações químicas do solo e crescimento do milho decorrentes da adição de lodos de curtume. *Revista Brasileira de Ciência do Solo* 26(3):257-265.

Mantovani, J.R.; Ferreira, M.E.; Cruz, M.C.P.; Barbosa, J.C. 2005. Alterações nos atributos de fertilidade em solo adubado com composto de lixo urbano. *Revista Brasileira de Ciência do Solo* 29(4):817-824.

Oliveira, F.C.; Mattiazzo, M. E. Mattiazzo; Marciano, C. R.; Rossetto, R. 2002. Efeitos de aplicações sucessivas de lodo de esgoto em um latossolo amarelo distrófico cultivado com cana-de-açúcar: carbono orgânico, condutividade elétrica, pH e CTC. *Revista Brasileira de Ciência do Solo* 26(2):505-519.

Santos, J.A.; Nunes, L.A.P.L.; Melo, W.J.; Araújo, A.S.F. 2011. Tannery sludge compost amendment rates on soil microbial biomass in two different soils. *European Journal of Soil Biology* 47(1):146-151.

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F. Araújo, M.D.M. Silva; L.F.C. Leite, F.F. Araújo, N.S. Dias. “Applications of Composted Tannery Sludge on Soil Effects on Soil pH, Electric Conductivity and Soil Organic Matter Content”. EFITA-WCCA-CIGR Conference “Sustainable Agriculture through ICT Innovation”, Turin, Italy, 24-27 June 2013.

Selbach, P.A., M. J. Tedesco, C. Gianello, and L. E. Cavallet. 1991. Descarte e biodegradação de lodos de curtume no solo. *Revista do Couro* 4(1):51-62.

Silva, J. D. C., T. T. B. Leal, A. S. F. Araújo, R. M. Araujo, R. L. F. Gomes, W. J. Melo, and R. P. Singh. 2010. Effect of different tannery sludge compost amendment rates on growth, biomass accumulation and yield responses of Capsicum plants. *Waste Management* 30(4):1976-1980.

Teixeira, K.R.G.; Gonçalves Filho, L.A.R.; Carvalho, E.M.S.; Araújo, A.S.F.; Santos, V.b. 2006. Efeito da adição de lodo de curtume na fertilidade do solo, nodulação e rendimento de matéria seca do caupi. *Ciência & Agrotecnologia* 30(6):1071-1076.

Trannin, I.C.B.; Siqueira, J.O.; Moreira, F.M.S. 2008. Atributos químicos e físicos de um solo tratado com biossólido industrial e cultivado com milho. *Revista Brasileira de Engenharia Agrícola e Ambiental* 12(2):223-230.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY – USEPA. Test method for evaluating solid wastes. Washington, 1986. p.255. (Report Number, SW- 846)

Walkley, A., and I.A. Black. 1934 An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Science* 37(1):29-38.