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Tannery sludge compost amendment rates on soil microbial biomass of two different soils

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ABSTRACT

Composting is recognized as one of the most cost-effective and environmentally sound alternatives for organic waste recycling. Long-composted wastes have the potential to substitute for inorganic fertilizers. We investigated the effect of tannery sludge compost (TSC) amendment rates on microbial biomass and activity in Brazilian soils. The soils (sandy and clayey soils) were amended with TSC at rates of 0 (control), 7.5, 15, 30 and 60 Mg ha^{-1} (equivalent to 0, 0.3, 0.6, 1.2 and 2.4 g per 100 g of soil, respectively), incubated at 28 °C for 60 days. Soil Microbial biomass, soil respiration and enzyme activities were evaluated at 15, 30 and 60 days after incubation. The application of 7.5 Mg ha^{-1} TSC significantly increased the microbial biomass and activity. There were no negative or positive effects by the application of 7.5 Mg ha^{-1} on soil enzymes. The results of this study suggest that TSC increased soil microbial biomass and activity when it was amended at a low rate. On the other hand, the amendment with the TSC, in all rates, did not negatively affect the soil microorganisms and their activities.

1. Introduction

Tannery industries occupy an important place in the Brazilian economy, with assets of about 21 billion U.S. dollars and an annual release of more than 1 million tons of tannery sludge [36], 3% of which is solids [34]. In Brazil, there is no set method for tannery sludge disposal, and the common disposal method is landfilling. The high annual production of tannery sludge has created a series of economical, social and environmental problems.

The tannery sludge is usually high in organic matter, chemical nutrients and heavy metals, mainly chromium (Cr^{3+}) [13]. The occurrence of metals (especially Cr, Fe, Mn, Zn, Cu, Pb, Ni and Cd) in complex forms in tannery sludge is a serious concern due to the likelihood of food chain contamination and risk to human health [19]. Tannery sludges, which are classified as hazardous, are frequently deposited above ground, representing a serious risk for soil, vegetation and groundwater. The safe disposal of sludge is one of the major environmental concerns worldwide.

Landfilling and land application of the sludge are suggested as the most commonly recommended disposal techniques [35,37]. However, landfilling is not a suitable method because a large volume of soil is required to cover the waste to prevent the leaching of potentially toxic compounds [16]. Additionally, landfilling is also becoming more expensive due to limited land mass, so industries must look for cheaper ways to dispose of their wastes. Therefore, it is necessary to find new methods for recycling and recovering organic waste as an alternative to landfilling [1].

Composting has long been recognized as one of the most cost-effective and environmentally sounds alternatives for organic waste recycling [7,8,18]. During composting, organic matter decomposes to produce carbon dioxide, water vapor, inorganic nutrients and stable organic material containing humic-like substances [30, 33]. Additionally, composting can be applied to reduce pathogens [20] and toxic organic compounds [6]. This method has been used to process sludge of different origins, such as sewage sludge and textile sludge [7,8,10].

However, knowledge of the short-term effects of these wastes on soil microbial processes is important to maintain soil environmental quality. Microbial processes are important for soil fertility and plant growth. Microorganisms mineralize, oxidize, reduce and immobilize mineral as well as organic materials in soil [15]. Any compound that alters the number or the activity of soil microorganisms can affect soil biochemical processes and ultimately influence soil fertility and plant growth [22].

Soil microbial biomass and activity are early and sensitive indicators of soil stress caused by wastes [7]. Microbial biomass is

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the living component of soil organic matter (SOM) [22]. It has been suggested that microbial biomass could be a sensitive indicator of changes in soil processes [15]. Soil respiration is one of the most valuable parameters for quantifying microbial activities in soil [4].

Moreover, enzyme activities can provide an indication of quantitative changes in SOM. Dehydrogenase (DHA) and fluorescein diacetate hydrolysis (FDA) activity typically occur in all intact, viable microbial cells. As these enzymes are usually related to the presence of viable microorganisms and their oxidative capability [39] as well as soil microbial activity [5], they are important to show the effect of tannery sludge compost on soil microbial activity.

The hypothesis of this study is that changes in soil microbial biomass and activity should be expected when an industrial waste is applied in different rates. Previous studies had been shown changes in soil microbial biomass and activity after application of sewage sludge [10,17,31] and textile sludge [7,8]. However, there are few studies about tannery sludge compost on these soil microbial properties. Therefore, the aim of this research was to evaluate the effect of tannery sludge compost (TSC) amendment rates on microbial biomass and activity in Brazilian soils in two contrasting soils.

2. Material and methods

2.1. Tannery sludge composting

Tannery sludge was collected from the wastewater treatment plant of a tannery located at Teresina city, Piauí state, Brazil. The compost was produced with tannery sludge a structuring material (sugarcane straw and cattle manure) mixed in the ratio 1:1:3 (sludge: sugarcane: cattle manure). The composting processes were carried out in our research facility using the Beltsville aerated-pile method [40] for 85 days. The size of pile was 2 m long by 1 m wide by 1.5 m high. The pile was turned twice during the first and second week and once a week during the rest of the bio-oxidative phase. The bio-oxidative phase of composting was considered finished when the temperature of the pile was stable and near that of the surrounding atmosphere (30 °C). This stage was reached after 55 days of composting, and then the turnings were stopped to allow the compost to mature over a period of 30 days. The temperature increased quickly at the beginning of the process to high thermophilic values (70 °C), which contribute to the hygiene of the end product due to pathogen, weed and seed reduction.

On day 85, 20 subsamples were randomly collected from compost to produce a composite sample. The chemical characteristics of TSC were determined by the EPA 3051 method [41] and are shown in Table 1. Bio-available heavy metals content were determined by EPA method 3050B [41].

2.2. Soil characteristics

Two different soil types were collected, from fields with sandy and clay soils. The sandy soil was collected from the experimental station of Federal University of Piauí and classified as Oxisol soil. The clay soil was collected from the experimental station of Embrapa Mid-North, Piauí, Brazil, and classified as a typical Acrisol soil. Soil samples were collected from the surface layer of the soil up to a depth of 10 cm. The soil sample was passed through a 2-mm sieve to remove large residue fragments. The principal characteristics of the soils are shown in Table 2.

The soils were amended with TSC at rates of 0 (control), 7.5, 15, 30 and 60 Mg ha^{-1} (equivalent to 0, 0.3, 0.6, 1.2 and 2.4 g per 100 g of soil, respectively). The bio-available heavy metals content in each treatment were determined by the EPA 3050B method [41].

Table 1
Chemical properties of tannery sludge compost (TSC).

Properties	TSC	Limits of heavy metal permitted[a]
pH	7.8	–
Moisture content a 65 °C (%)	42.7	–
C_{org} (g kg^{-1})	187.58	–
Total N (g kg^{-1})	1.28	–
Total P (g kg^{-1})	4.02	–
Exchangeable K (g kg^{-1})	3.25	–
Ex. Ca (g kg^{-1})	95.33	–
Ex. Mg (g kg^{-1})	6.80	–
Total S (g kg^{-1})	9.39	–
Cu (mg kg^{-1})	17.83	4300
Fe (mg kg^{-1})	5171.67	–
Mn (mg kg^{-1})	1848.73	–
Zn (mg kg^{-1})	141.67	7500
Mo (mg kg^{-1})	9.28	–
Ni (mg kg^{-1})	21.92	420
Cd (mg kg^{-1})	2.87	85
Cr (mg kg^{-1})	2255.0	3000
Pb (mg kg^{-1})	42.67	75

[a] CETESB [14].

2.3. Microbial parameters

The soil respiration was monitored in an aerobic incubation procedure over 60 days by measuring CO_2 evolved [3] and soil CO_2 was daily measured. Soil microbial biomass C (MBC) was determined according to Vance et al. [42] with extraction of organic carbon (C) from fumigated and unfumigated soils by 1 M K_2SO_4. Organic C was measured using dichromate digestion, and an extraction efficiency coefficient of 0.38 was used to convert the difference in soluble C between the fumigated and the unfumigated soil in microbial C. FDA hydrolysis was measured according to the method of Schnurer and Rosswall [38]. Dehydrogenase activity was determined using the method described by Casida et al. [12] and based on the spectrophotometric determination of triphenyl tetrazolium formazan released by 5 g of soil during 24 h at 35 °C. The data were collected at 15, 30 and 60 days.

The results are the means of determinations made of four replicates. Data were compared through analysis of variance (ANOVA). The means were compared by using least significant difference values calculated at the 5% level.

3. Results

The TSC was found to be rich in all the heavy metals studied, including Ni, Cd, Cu, Cr and Pb. Changes in soil characteristics of both the sandy and clayey soils after TSC application are shown in Table 3. The application of TSC increased the heavy metals content considerably compared to unamended soils. These increases were

Table 2
Physical and chemical properties of soils.

Properties	Sandy soil	Clay soil
Sand (%)	61.3	18.4
Silt (%)	28.5	31.2
Clay (%)	10.2	50.4
pH	5.9	6.1
P (g kg^{-1})	2.02	3.23
K (g kg^{-1})	40.2	29.6
Ca (cmolc kg^{-1})	1.61	1.89
Mg (cmolc kg^{-1})	0.47	0.71
Al (cmolc kg^{-1})	0.01	0.05
CEC (cmolc kg^{-1})	3.52	4.85

CEC – Cation Exchange Capacity.