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Corn production in soil containing *in natura* tannery sludge and irrigated with domestic wastewater

Guilherme Malafaia[a,*], Fernando Godinho de Araúj[a], Dieferson da Costa Estrela[a], Abraão Tiago Batista Guimarães[a], Wilson Mozena Leandro[b], Aline Sueli de Lima Rodrigues[a]

[a] Goiano Federal Institute—Campus Urutaí, Urutaí, Goiás, Brazil
[b] Department of Agronomy—Federal University of Goiás, Goiânia, Goiás, Brazil

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ABSTRACT

This research was developed with the objective of assessing chemical alterations in soil and corn (*Zea mays* L.) yield (plot area BG 7049H), using Haplic Plinthosol treated with tannery sludge and irrigated with domestic wastewater. Dried and sieved *in natura* tannery sludge was added to the soil in concentrations of 9 Mg ha^{-1} and 18 Mg ha^{-1}. Pots kept in a protected environment during 150 days were used in the experiment. The treatment arrangement consisted of a 2 × 6 factorial—two irrigation types and six fertilization treatments in completely randomized design (CRD), with 5 repetitions. By the end of the experiment, the total ear weight, 100-grain weight and productivity, were assessed. Additionally, soil samples of each experimental unit were collected for determination of pH and K, Ca, Mg and Cu concentrations. The results showed that the 9 and 18 Mg ha^{-1} doses, plus irrigation with domestic wastewater, caused an increase in pH and P, K, Mg and Ca concentrations, which attested increased soil fertility. On the other hand, the application of such doses, even if together with irrigation with wastewater, did not promote a yield of the corn culture equivalent to that obtained with mineral fertilizers. New studies using tannery sludge together with wastewater or other organic substrates are recommended, in order to offer to rural producers the opportunity to use relatively small doses of tannery sludge, so that the reuse of such residues become viable from the economical, agricultural and environmental points of view.

1. Introduction

An increase in residue production from various sources has been recently identified, and it is mostly due to population growth and global consumption patterns (Roth and Garcias, 2008). The industrial sector dedicated to bovine leather processing, represented by the tannery industries, is characterized as a major producer of solid residues that result from industrial bovine hide and skin tanning processes. The use of leather is traditional in Brazil, especially in Northeastern Brazil and in the Rio Grande do Sul State, where cities have grown surrounding dried beef and tannery industries.

In Brazil, processing of one ton of marinated skin results in 200–250 kg of finished leather, approximately generating 600 kg of solid residues. According to Zupancic and Jemec (2010), processing of bovine hide and skin in the European Union, for example, generates *ca.* 400 to 900 thousand tons of tannery sludge (by wet weight) and 170 thousand tons of leather residues per year.

Part of these residues is disposed in sanitary landfills, "*lixões*", or in industrial landfills, which results in high risk of environment contamination and damage to humans, once these residues contain high concentrations of organic matter and several toxic chemical products (Godecke et al., 2012). Therefore, the disposal of these residues represents high maintenance costs for these industries, mainly because it requires large areas and toxic materials are concentrated in the soil. Besides, these residues represent loss of raw materials and energy, demanding significant investments in treatments to control pollution (Pelizer et al., 2007).

In this sense, several studies have been carried out aiming at contributing to the definition of alternatives, not only for the treatment of these residues, in order to minimize possible impacts to the environment (Aber et al., 2010; Kiliç et al., 2011; Religa et al., 2011), but also for the use of these residues in certain activities. One of the alternatives for the destination of tannery sludge is its

* Corresponding author at: Rodovia Geraldo Silva Nascimento, Km 2,5—Zona Rural, Urutaí, GO, Brazil. Fax: +55 6434651900.
E-mail addresses: guilhermeifgoiano@gmail.com, guilherme@nupeb.ufop.br (G. Malafaia).

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use as fertilizer in agriculture (Teixeira et al., 2011). Considering the increase in cost of agricultural inputs, this would be an attractive alternative in soil fertilization, promoting higher crop productivity.

Different studies have shown the advantages of the use of *in natura* tannery sludge in silviculture, such as paricá (*Shizolobium amazonicum*; Tavares et al., 2013), *Leucaena* (Araújo et al., 2006), and angico (*Anadenthera*; Silva and Araújo, 2011). Examples in agriculture are: sugarcane ratoon (Batista and Alovisi, 2010), *conilon* coffee (Berilli et al., 2014), bean (Prado and Cunha, 2011), lettuce (Bastos et al., 2011), soya (Costa et al., 2001), wheat, lettuce and radish (Castilhos et al., 2002), and corn (Konrad and Castilhos, 2002; Ferreira et al., 2003; Souza et al., 2005; Borges et al., 2007; Araújo, 2011).

When it comes to corn culture, several studies have shown that the use of *in natura* tannery sludge added to soil cultivated with maize plants is viable, the sludge being a good nutrient source for the development of the plant and yield. However, better results have been achieved when high doses of tannery sludge are applied together with mineral fertilizers. Borges et al. (2007) point out that the higher production of grains and green phytomass are observed when 144 Mg ha^{-1} of tannery sludge are applied together with NPK (400 kg ha^{-1}). In turn, Konrad and Castilhos (2002) and Ferreira et al. (2003) show that higher corn grain yields are obtained with 20.5 Mg ha^{-1} and 21.3 Mg ha^{-1} of tannery sludge applied with phosphorous and potassium fertilizers, respectively.

If on one hand these concentrations are interesting under the agronomic point of view, on the other hand, a certain difficulty is imposed to rural producers when it comes to transportation of large amount of tannery sludge and the costs of such transportation. Besides, the necessity of additional chemical fertilization increases production costs.

Therefore, more studies are necessary in order to contribute with alternatives that conciliate relatively lower tannery sludge doses and additional chemical fertilization, so that the use of these residues becomes attractive not only from the environmental but also from the economic point of view. In this sense, the objective of the present study is the assessment of the use of *in natura* tannery sludge in corn (*Zea mays* L.) culture, in conjunction with domestic wastewater irrigation, considering that this type of water can supply a continuous input of nutrients and water for the culture, promoting decrease in production costs, increase in culture yield and improvement of the quality of the soil.

Table 1
The main initial characteristics of the soil (Haplic Plinthosol) samples and tannery sludge used in the composition of the substrate for the corn (*Zea mays* L.) culture, treated with tannery sludge and irrigated with domestic wastewater. Urutaí, Goiás, Brazil, 2013.

Attributes	Results	
	Soil	Tannery sludge
pH (H_2O)	6.28	–
N (g dm^{-3})	–	7.47
P (mg dm^{-3})	9.55	7.90
K (mg dm^{-3})	10.10	139.10
Ca (cmolc dm^{-3})	1.09	196.42
Mg (cmolc dm^{-3})	0.55	9.67
Na (g dm^{-3})	–	12.50
Cu (mg dm^{-3})	4.90	1.50
Fe (mg dm^{-3})	337.30	5.251.21
Mn (mg dm^{-3})	128.10	12.05
Zn (mg dm^{-3})	8.70	89.50
Organic matter (%)	0.20	44.36
Clay (%)	20.00	–
Silt (%)	40.60	–
Sand (%)	39.40	–
Cr (mg dm^{-3})	0.00	0.00
CEC (cmolc dm^{-3})	2.57	–

Legend: (–)—parameter not assessed. Total macro- and micronutrient concentrations were assessed, without discriminating changeable and/or available fractions. CEC—Cation exchange capacity.

Table 2
Experimental units set for corn (*Zea mays* L.) culture treated with tannery sludge and irrigated with domestic wastewater. Urutaí, Goiás, Brazil, 2013.

Treatments	Types of irrigation water	
	Supply water	Waste water
Control (soil only)	x	
Soil + NPK	x	
Soil + *in natura* sludge (dose A)	x	
Soil + *in natura* sludge (dose A) + PK	x	
Soil + *in natura* sludge (dose B)	x	
Soil + *in natura* sludge (dose B) + PK	x	
Control (soil only)		x
Soil + NPK		x
Soil + *in natura* sludge (dose A)		x
Soil + *in natura* sludge (dose A) + PK		x
Soil + *in natura* sludge (dose B)		x
Soil + *in natura* sludge (dose B) + PK		x

Legend: dose A—9 Mg ha^{-1}; dose B—18 Mg ha^{-1}; urea concentration—130 kg ha^{-1}; superphosphate concentration$_5$—100 kg ha^{-1}; potassium chloride concentration—50 kg ha^{-1}.

2. Material and methods

The present study was carried out in a protected environment located in the experimental area of the Unidade Educacional de Produção (UEP) de Olericultura of the Instituto Federal Goiano (IF Goiano)—Urutaí Campus (Goiás, Brazil), during February and June 2013. The protected environment was a simple arc with east-west direction. A metallic structure of 30 m in length, 7 m in width, 3.0 m in height, and 1.2 m in arc height was built and covered with a 0.15 mm-thick low-density polyethylene film. The sides were made of 2.0 × 2.0 mm Clarity screen. Corn was planted in samples of a superficial layer of Haplic Plinthosol, collected in an area close to the protected environment. The physical and chemical characterization of the soil samples (Table 1) was made following the method described in Empresa (1997).

The tannery sludge used in our study was supplied by Indústria Curtume Sulino S.A., located in Pires do Rio (Goiás, Brazil). It consisted of a mixture of residues produced during skin hair removal and residues from the tannery industry primary treatment station. It is worth mentioning that Indústria Curtume Sulino treats the effluents generated during the bovine hide and skin tanning stage separately from other residues and effluents. Therefore, no Cr concentrations were detected in the tannery sludge used in this study. Table 1 presents the characterization of the tannery sludge used, according to Tedesco et al. (1995).

Before the installation of the experimental units, both soil and tannery sludge were dried and sieved (2-mm mesh). The treatment arrangement consisted of a 2 × 6 factorial (2 irrigation types and 6 fertilization treatments), in completely randomized design (CRD), with 5 repetitions, totalizing sixty experimental units, as shown in Table 2.

The dose of NPK used in treatments labeled "soil + NPK" (Table 2) was calculated on the basis of the culture nutritional necessities, nutrient concentrations present in the soil, and in the crop yield expectation, according to Sousa and Lobato (2004), resulting in 10 Mg ha^{-1}. NPK sources were urea, simple superphosphate and potassium chloride, respectively. Tannery sludge doses added to the soil were calculated according to the N concentration present in the residue. Nitrogen is a highly demanded element in corn culture, resulting in a sole 130 kg ha^{-1} dose. Thus, the following tannery sludge doses were established: 9 Mg ha^{-1} (dose A) and 18 Mg ha^{-1} (dose B, a double dose A). There was no cover fertilization in this