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Characteristic of an Oxisol post-cultivation of the corn using tannery sludge vermicompost and irrigation with domestic wastewater

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The use of organic solid waste/effluent has currently been increasingly enhanced. A waste and effluent currently produced on a large scale that have potential for use in agriculture refers to sludge tannery and wastewater, respectively. However, in Brazil these residues are still little used and there is great reluctance to use them in general agriculture. Thus, this study aimed to evaluate the characteristics of an Oxisol after maize cultivation (*Zea mays* L.) using tannery sludge vermicompost and irrigation with wastewater. After 120 days of cultivation, soil samples were collected for analysis of the: pH, electrical conductivity (EC), total organic carbon (TOC), base saturation (BS), organic matter (OM), N, P, K, Ca, Mg, Cu, Fe, Mn, and Zn. The values for these parameters were compared between the various treatments, as well as the values observed in the soil prior to cultivation. It was observed that the tannery sludge vermicompost and irrigation with wastewater, provided little increase in pH, EC, TOC, base saturation, OM, N, P, K, Cu and Fe compared to their concentrations originally identified in the soil. Moreover, tannery sludge vermicomposts and wastewater constitute good sources of Ca, P, Mg, Mn and Zn, being able to increase the content of these elements in the soil.

Key words: Agro-industrial waste, tannery, *Zea mays* L., Oxisol.

INTRODUCTION

Industrial processes and human activities, in general, have the effect of generation of specific waste, among which we mention those produced by industrial activities, such as bovine skin processing. While this activity generates significant profits, it present problems when is found that the waste and effluent produced by many tannery industries are disposed incorrectly, representing risks to health and to the environment as highlighted by Batista and Alovisi (2010), the sludge tannery, even after receiving treatment in a sewage treatment plant it

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contains significant organic and inorganic fillers such as acids, phenols, sulfates, sulfides, and especially toxic elements such as chromium, which is used during the tanning process.

Tanning is the chemical process that converts animal hides and skin into leather and related products. More than one hundred different chemicals nearly (3,50,000 tonnes/year of inorganic and heavy metal salts, soaps, oils, waxes, solvents, dyes, etc.) used in tanning processes are found in process wastes and wastewaters (Godecke et al., 2012). The major components of the sludge include sulfide, chromium, volatile organic compounds, large quantities of solid waste, suspended solids like animal hair and trimmings. For every kilogram of hides processed, 30 L of effluent is generated and the total quantity of effluent discharged by Indian industries is approximately 45000 to 50,000 m^3/day. Tannery industry plays an important role with respect to environmental pollution due to disposal of large volume of solutions of tanning baths. The discharge of chromium rich tannery sludge is a serious threat for environment with high concentrations of organic and inorganic component that they create risk to human health and environmental aspects (Cetin et al., 2013). Tannery industry is one of the important industries in India (Kushwaha and Upadhyay, 2015) and in many regions of Brazil (Godecke et al., 2012; Meunier and Ferreira, 2015), for example, which earns large foreign exchange through the leather export.

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) pointed 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 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.

Thus, the development of studies that contribute with forms to treat or reuse such materials has been stimulated. An interesting option is the use of substrates from vermicomposting (a process that not only is a form of tanning sludge treatment (Carlesso et al., 2011)), but is also a biotechnology able to transform these residues in noble composts, feasible to be used in other sectors, such as agriculture (Suthar, 2010). As discussed by Varma et al. (20115), during vermicomposting, different important nutrients that are present in the residues are converted, by means of the joint action of earthworms and their intestinal microbiota, in many soluble and available forms to plants than the forms presented *in natura* residues.

Another interesting option is the wastewater reuse in agriculture. There are great demands for the use of wastewater, coming from domestic sewage, especially in water scarcity scenario, we live in today. Different studies have pointed to the potential use of this water in agriculture, due to the fact these has nutrients that are beneficial to the development of plants (Fonseca et al., 2005a, b; Fonseca et al., 2007; Leal et al., 2011; Andrade-Filho et al., 2013; Bonini et al., 2014; Silva et al. 2014). To Hespanhol (2003), the wastewater arising from domestic sewage, contain nutrients whose content meet, if not all, at least most of the nutritional needs of plants in general.

Despite the obvious benefits of using vermicompost and wastewater in agriculture, it is important to assess the impact of these uses on the soil. The study of the characteristics of the soil post-cultivation of the corn using tannery sludge vermicompost and irrigation with domestic wastewater is as important as the impact of waste on crop productivity. Thus, this study aimed to evaluate the characteristics of a Oxisol after corn crop, using the vermicomposting from tannery sludge in association with irrigation of domestic wastewater, considering the lack of studies involving this issue, as well as the need to combine agronomic interest to the environmental.

MATERIALS 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). 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 (0 to 20 cm) of an Oxisol, collected in an area close to the protected environment. The physical-chemical and chemical characterization of the soil samples (Table 1) was made following the method described in Embrapa (1997). The vermicompost used in this study were those produced from vermicomposting substrates made up of 20% of liming and primary tannery sludge types and 80% of cattle manure (Malafaia et al., 2015) (Table 1).

Before the installation of the experimental units, both soil and vermicomposts were dried and sieved (2-mm mesh). The treatment arrangement consisted of a 2×6 factorial (two irrigation types and six fertilization treatments), in completely randomized design, with five repetitions, totalizing sixty experimental units, are 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

Table 1. Main characteristics of the initial soil and tannery sludge vermicompost used in this study.

Variable	Results		
	Soil	Vermicompost (Lc20)*	Vermicompost (Lp20)*
pH ($CaCl_2$)	5.30	8.8	8.8
N (%)	0.11	1.5	1.2
P (Melich – $mg.dm^{-3}$)	5.00	700.0	400.0
K ($mg.dm^{-3}$)	240.00	18,000.0	20,000.0
Ca ($cmolc.dm^{-3}$)	2.60	14.0	14.0
Mg ($cmolc.dm^{-3}$)	0.80	18.0	15.0
CTC ($cmolc.dm^{-3}$)	6.20	82.4	85.4
Na ($mg.dm^{-3}$)	8.00	1,000.0	1,200.0
Cu ($mg.dm^{-3}$)	2.50	5.0	2.9
Fe ($mg.dm^{-3}$)	63.00	244.0	122.0
Mn ($mg.dm^{-3}$)	47.00	68.0	55.0
Zn ($mg.dm^{-3}$)	4.40	36.0	39.0
Organic matter (%)	2.30	29.9	24.2
Sat Al (%)	0.00	0.0	0.0
Base Sat (%)	65.00	100.0	100.0
Total Organic Carbon (%)	1.30	17.3	14.0
Cr ($mg.dm^{-3}$)	<5.00	<5.0	<5.0

*Vermicompost (LC20): tannery sludge vermicompost made up of 20% sludge tannery liming type and 80% of cattle manure. Vermicompost (LP20): tannery sludge vermicompost made up of 20% tannery sludge from the primary type and 80% of cattle manure. Soil analysis were performed according to Embrapa (1997) and vermicompost, according to Tedesco et al. (1995).

Table 2. Experimental units set for corn (*Zea mays* L.) culture treated with tannery sludge vermicompost and irrigated with domestic wastewater.

Treatment	Types of irrigation water	
	Supply water (A)	Wastewater (R)
Soil - control, without chemical fertilizer and without vermicompost (T1)	x	
Soil + NPK (T2)	x	
Soil + 20% of primary tannery sludge vermicompost (VLp20) (T3)	x	
Soil + 20% of primary tannery sludge vermicompost (VLp20) + P (T4)	x	
Soil + 20% of liming tannery sludge vermicompost (VLc20) (T5)	x	
Soil + 20% of liming tannery sludge vermicompost (VLc20) + P (T6)	x	
Soil - control, without chemical fertilizer and without vermicompost (T1)		x
Soil + NPK (T2)		x
Soil + 20% of primary tannery sludge vermicompost (VLp20) (T3)		x
Soil + 20% of primary tannery sludge vermicompost (VLp20) + P (T4)		x
Soil + 20% of liming tannery sludge vermicompost (VLc20) (T5)		x
Soil + 20% of liming tannery sludge vermicompost (VLc20) + P (T6)		X

Mg ha^{-1}. NPK sources were urea, simple superphosphate and potassium chloride, respectively. The doses of tannery sludge vermicompost to be added to the soil were calculated based on the concentration of K, high concentration element in vermicomposts used (Table 1) and K_2O basal dose of 50 kg ha^{-1}. The amount of 60 kg ha^{-1} simple superphosphate was provided via topdressing in two plots of 30 kg ha^{-1}, at 40 and 60 days after sowing. Furthermore, the amount of 130 kg ha^{-1+} urea (nitrogen source) was provided via topdressing in two plots of 65 kg ha^{-1}, at 40 and 60 days after sowing. The dose of liming sludge vermicompost (VLc20) added to the soil corresponded to 6.1 Mg ha^{-1} and the dose of primary sludge vermicompost (VLp20) was 5.5 Mg ha^{-1}. It was not necessary to perform the soil pH correction.

Soil samples to which tannery sludge vermicompost and fertilizers were previously incorporated were placed in 15-L polyethylene pots (volumetric capacity of 12.5 kg). Soon after the installation of the experimental units, the pots were sown with three maize (*Zea mays* L.) seeds (commercial variety LG 6036) (LG Semente®). After 15 days, thinning took place, remaining one plant in each pot. Whenever necessary, phytosanitary treatments were

Table 3. Physical-, chemical- and physico-chemistry-characterization of irrigation water used in the present study.

Attributes	Water supply*	Wastewater*
pH at 25°C	7.38	7.73
Fe dissolved (mg.L^{-1})	0.31	1.26
N total (mg.L^{-1})	2.43	54.57
N organic	ND	4.90
N ammoniacal (mg.L^{-1})	0.07	43.67
Nitrate (mg.L^{-1})	0.33	6.00
Electric conductivity at 25º C (µs.cm^{-1})	67.20	746.33
P total (mg.L^{-1})	0.14	9.10
Orthophosphate (mg.L^{-1})	0.33	20.86
BOD (mg.L^{-1})	0.67	572.11
Total Solids (mg.L^{-1})	73.33	1,290.00
Cu dissolved (mg.L^{-1})	0.35	0.44
Zn (mg.L^{-1})	0.37	0.26
Na (mg.L^{-1})	25.59	56.63
Mn dissolved (mg.L^{-1})	0.57	1.80
Mg dissolved (mg.L^{-1})	1.78	12.16
Ca (mg.L^{-1})	6.28	37.41
K (mg.L^{-1})	7.45	19.16
TOC (mg.L^{-1})	14.95	43.47

ND: Parameter not measured. *The values refers to the average of four samples collected throughout the experimental period. For the characterization of irrigation water monthly samples were collected throughout the experimental period (n = 4) for evaluation of physical-chemical- and physico-chemical parameters, according to the methodology proposed by APHA (1997).

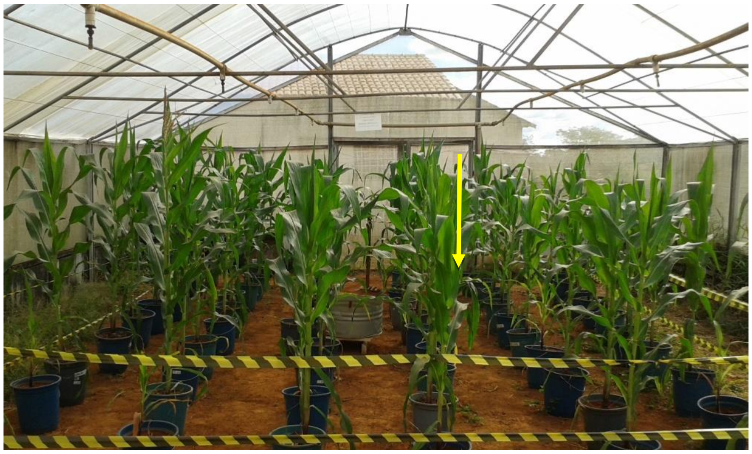

Figure 1. General view experiment and location of the evaporimeter tank used in the study. The yellow arrow indicates the evaporimeter tank

performed.

Irrigation waters came from the water supply system of the Instituto Federal Goiano (IF Goiano) – Urutaí Campus, treated at the Water Treatment Station (ETA) of the campus itself, and from the domestic sewage treatment system (composed of a stabilization pond), also located in IF Goiano. To characterize the irrigation waters, four samples were collected during the experimental period for the determination of physical, chemical and physico-chemical parameters, according to the method proposed by Apha (1997).

The analyses of irrigation waters (supply and wastewater) were carried out by HIDROSERV – Serviços em Recursos Hídricos e Saneamento Ltda. (Goiânia, GO, Brazil). Table 3 presents the characteristics of the irrigation waters used in the present study.

Irrigation was carried out by means an evaporimeter tank developed by Salomão (2012), circular in shape, with internal diameter of 52 cm and (internal) height of 24 cm, mounted under a 15 cm-high wooden pallet and installed inside the protected environment, between the experimental units (Figure 1).

Table 4. Summary of F test of variance analysis for pH, electrical conductivity (EC), total organic carbon (TOC), based saturation (BS), organic matter (OM), N, P, K, Ca, Mg, Cu, Fe, Mn and Zn variables from the studied soil, depending on the type of irrigation water and fertilizer treatments.

Factors	pH ($CaCl_2$)	EC ($\mu S.cm^{-1}$)	TOC (%)	BS (V%)	OM (%)
Factor 1 (irrigation types)	106.66**	26,338.23**	268.52**	172.53**	3.75^{ns*}
Factor 2 (treatments)	16.66**	825.35**	292.91**	65.07**	93.75**
Interaction (factor 1 × factor 2)	7.66**	132.60**	300.26**	39.28**	93.75**
CV (%)	1.93**	1.51**	2.03**	2.66**	6.35**

Factors	N (%)	P ($mg.dm^{-3}$)	K ($mg.dm^{-3}$)	Ca ($cmolc.dm^{-3}$)	Mg ($cmolc.dm^{-3}$)
Factor 1 (irrigation types)	179.79**	4,317.90**	2,083.38**	2.36^{ns}*	60.00**
Factor 2 (treatments)	2.12^{ns}	181.11**	198.53**	63.42**	11.40**
Interaction (factor 1 × factor 2)	1.63^{ns}	123.25**	149.85**	56.68**	10.22**
CV (%)	$008,55^{ns}$	0.007,17**	0.002,71**	04,18**	16,36**

Factors	Cu ($mg.dm^{-3}$)	Fe ($mg.dm^{-3}$)	Mn ($mg.dm^{-3}$)	Zn ($mg.dm^{-3}$)
Factor 1 (irrigation types)	$1,11^{ns}$	1,222.82**	2,139.24**	127.55**
Factor 2 (treatments)	3.77**	170.92**	227.37**	649.18**
Interaction (factor 1 × factor 2)	1.11^{ns}	216.84**	241.93**	317.10**
CV (%)	8.65**	1.94**	2.59**	2.14**

*Significant at 5% probability; **Significant at 1% probability; ns: not significant; CV: variation coefficient in %. Irrigation types: supply water and domestic wastewater.

The calculation of the water volume to be irrigated daily, in order to keep the water retention capacity of the soil in 70% (243.1 ml kg^{-1}) during the experiment, took into account the pot area to be irrigated (0.06 m^2) and evapotranspiration (ETc). The water volume to be restored was measured with a graduated cylinder. To determine ETc, the following equation was used:

$$ETc = kc\ (LT \cdot Kt_c) \qquad (1)$$

where *ETc* = crop evapotranspiration; *kc* = crop coefficient, specific to the phonological cycle phase;
LT = evaporated water layer observed in the evaporimeter tank; Kt_c = corrected tank coefficient (0.94), specific for the evaporimeter tank used in our study.

The water retention capacity of the soil ($C_{100\%}$=347.4 ml kg^{-1}) was determined by means of the soil soaking power, according to Embrapa (1997).

At the end of the experiment (120 days), soil samples from each treatment (five samples of each experimental unit (which corresponds to the five replicates), totaling 60 soil samples (Table 1)) were collected and were analyzed the pH, electrical conductivity (EC), total organic carbon (TOC), based saturation (BS), organic matter (OM), N, P, K, Ca, Mg, Cu, Fe, Mn and Zn, according to the method proposed by Embrapa (1997). Soil analyses were carried out in the Laboratório Terra (Goiânia, GO, Brazil).

The resulting data were treated by means of the analysis of variance, following the factorial model (two-way ANOVA), the factors being "treatment" (six levels) and "irrigation" (two levels), with five repetitions. In the cases of significant F, Tukey test was applied at 5% probability. The residual normality was checked by means of the Shapiro-Wilk test and the Bartlett test was used to check residual homoscedasticity, by means of the software R version 3.0.3 (R Core Team, 2014). Analysis of variance was performed using the software ASSISTAT, version 7.7 beta (free copy).

RESULTS AND DISCUSSION

In this study, it was observed that there was interaction between the sources of variation "irrigation" and "treatments" for the concentration of all parameters in the samples, except for the N and Cu contents (Table 4).

Regarding the soil pH, it was observed that all treatments irrigated with wastewater, with the exception of T2R treatment (which received chemical fertilizer) had a significant increase for this parameter compared to treatments irrigated with water supply (Table 5). It was also observed that the treatments irrigated with water supply (T3A the T6A) which had soil added with tannery sludge vermicomposts also showed an increase in pH, compared to the control treatment (T1A) and gave values of pH similar or superior to treatment T2A (which received chemical fertilizer) (Table 5). These results validated different works developed in different agricultural systems with diverse cultures, which found an increase in soil pH by irrigation with domestic sewage (Andrade-Filho et al., 2013; Oliveira et al., 2014). It is believed that in the present study, the increase of soil pH value can be attributed, among other factors. The addition of exchangeable cations and anions by the effluent, and the addition of organic residues to the soil originated from vermicompost, followed by decarboxylation and deamination, proton consuming processes.

Regarding the base saturation (SB) parameter, the observed values does not follow a defined pattern (that is, associated with a treatment in particular), observed

Table 5. Mean values of the interaction between type of irrigation water x fertilization treatments for pH, electrical conductivity (EC), total organic carbon (TOC), base saturation (BS), organic matter (OM), P, K, Ca and Mg from studied soil.

Types of irrigation	**Trataments**					
	T1	**T2**	**T3**	**T4**	**T5**	**T6**
pH ($CaCl_2$)						
A	4.80bC[2]	5.00aB	5.20bA	5.10bAB	5.00bB	5.2bA
R	5.30aA	5.00aB	5.40aA	5.40aA	5.40aA	5.4aA
BS (V%)						
A	50.00bD	57.00bC	65.00aB	69.00aA	59.00bC	60.00bC
R	69.00aAB	62.00aC	67.00aB	71.00aA	62.00aC	63.00aC
EC (μS.cm^{-1})						
A	68.00bB	47.80bE	54.00bD	73.00bA	59.00bC	49.00bE
R	126.00aB	105.00aD	120.00aC	131.00aA	98.00aE	97.00aE
OM (%)						
A	1.00bD	1.20bC	1.45bB	2.70aA	1.60aB	1.60aB
R	1.60aA	1.60aA	1.60aA	1.60bA	1.60aA	1.60aA
TOC (%)						
A	0.57bD	0.66bC	0.92aB	1.10aA	0.93aB	0.93aB
R	0.93aA	0.93aA	0.93aA	0.93aA	0.93aA	0.93aA
P (mg.dm^{-3})						
A[1]	1.00bB[2]	1.00bB	2.00bA	2.00bA	2.00bA	2.00bA
R	5.00aD	6.00aC	8.10aB	11.00aA	5.00aD	6.00aC
K (mg.dm^{-3})						
A	92.00bA	72.00bD	48.00bE	84.00bB	76.00bCD	80.00bBC
R	100.00aB	120.00aA	92.00aC	88.00aC	104.00aB	120.00aA
Ca (cmolc.dm^{-3})						
A	2.20bD	2.60aC	3.30aA	3.50aA	3.30aA	3.00aB
R	3.40aA	2.70aCD	3.10bB	3.50aA	2.90bBC	2.60bD
Mg (cmolc.dm^{-3})						
A	0.60bA	0.60bB	0.60bB	1.20aA	0.60bB	1.00aA
R	1.30aA	1.00aBC	1.10aABC	1.20aAB	0.90aC	0.90aC
Fe (mg.dm^{-3})						
A[1]	43.00Bd[2]	62.00bA	48.00bC	54.00bB	56.00aB	50.00bC
R	58.00aD	64.00aB	75.00aA	61.00aC	54.00bE	61.00aC
Mn (mg.dm^{-3})						
A	32.00bD	46.00bC	32.00bD	60.00bA	62.00aA	52.00bB
R	62.00aC	69.00aA	66.00aB	71.00aA	58.00bD	62.00aC
Zn (mg.dm^{-3})						
A	6.10aC	8.20bA	6.10bC	5.20bD	8.40aA	7.40aB
R	5.90bC	9.30aA	7.10aB	5.50aD	5.50bD	5.60bD

[1] A: Supply water; R: wastewater; T1: Soil (control); T2: Soil + NPK; T3: Soil + VLp20; T4: Soil + VLp20 + P; T5: Soil + VLc20; T6: Soil + VLc20 + P.

[2] Means followed by the same lowercase letter in the column and uppercase in line do not differ by Tukey test at 5% probability.

than higher values in T1R, T2R, T5R and T6R irrigated with wastewater treatments (Table 5). Analyzing only the treatments irrigated with the water supply, it was observed that the highest values for SB were found in T3A and T4A treatments. Among the treatments irrigated with wastewater, the highest values were identified in T1R, T3R and T4R treatments (Table 5). It is noteworthy that all the results for SB were considered average (51 to 70%), with the exception of T4R treatment, as well as to the vast majority of pH values (5.1 to 5.5).

With regard, EC parameter observed increase in their values in irrigation with wastewater treatments (Table 5), as evidenced by Nichele (2009), in which the corn was conducted in soil irrigated with domestic wastewater. Analyzing separately, irrigation with wastewater and supply treatments, no pattern set for this parameter was observed. It is believed that the observed EC increase in irrigation with wastewater treatments which can be attributed to the addition of salts present in the effluent.

About the OM, an increase was found only in treatments irrigated with wastewater, T1R, T2R, and T3R (Table 5). Among the treatments irrigated with wastewater, there was no significant difference for this parameter. In this case, it is likely that there has been fast mineralization of OM, in all experimental treatments, caused by the high temperatures associated with constant moisture, the result of continuous irrigation experiment with domestic wastewater. Beyond the high percentage of OM observed in T3A, T4A, T5A, and T6A treatments irrigated with the water supply, compared to other treatments, is possibly associated with high organic content present in the vermicompost used, and the high values of OM present in them (Table 1). TOC increase was observed only in T1R and T2R treatments, depending on the application of wastewater (Table 5). These results differ from previous studies that showed increase according to the TOC addition of domestic sewage in the soil (Friedel et al., 2000; Suárez-Abelenda et al., 2013). However, T3A, T4A, T5A, and T6A treatments, irrigated with the water supply, stand out which showed statistically higher TOC values than those found in the T1A and T2A treatments' soils (Table 5). In this case, it is believed that the addition of tannery sludge vermicomposts has directly influenced the level of this parameter in the soil, as both types of vermicomposts used had a high concentration of TOC (Table 1). Moreover, it can be assumed that irrigation with wastewater in soil plus vermicompost treatments (T3R to T6R) did not cause an increase of TOC, due to the fact that the amount of C consumed by microorganisms has been reset by C-effluent or microorganisms have a preference for using the OM of the effluent or vermicomposting as an energy source.

The variation factor "irrigation" with N concentration in soil was the only observed effect (Table 4). The treatments irrigated with wastewater were those that had higher N-total concentrations in soil (Table 4), a result that may be directly related to the high concentration of N-total present in this type of water (Table 3). The N contained in the wastewater used in the present study is 91.02% in its mineral form ($N\text{-}NH_4^+$ + $N\text{-}NO_3^-$), predominantly as $N\text{-}NH_4^+$ (Table 3), form that has commonly been identified in domestic effluents (Fonseca et al., 2005a; Andrade-Filho et al., 2013). Silva (2009), studying the effects of irrigation of corn with treated effluent, also noted a significant increase in N-ammoniacal and nitrate content in the soil after the experiment.

It was observed that irrigation with wastewater provided increment in P-element in the soil (Table 5) when compared with soils irrigated with the water supply, although this increase was very small in relation to the initial content of P in the soil profile (5 mg dm^{-3}) (Table 1). As shown in different studies that evidence the addition of domestic waste to soil, significantly increases the P-content in its surface layer (Costa et al. 2012, Bame et al. 2014), although there are studies that do not show changes in P-concentrations in soils irrigated with wastewater (Fonseca et al., 2005a; Silva, 2009; Nichele, 2009). Analyzing separately the treatments irrigated with the water supply, can show that T3A, T4A, T5A, and T6A treatments showed higher P-concentrations in relation to T1A (control) and T2A (which received chemical fertilizer) treatments. Such results can possibly be explained by the large amount of P present in the used tannery sludge vermicompost (Table 1), which possibly had been made available to the soil, besides the addition of P in T4 and T6 treatments.

Regarding K, although there was sharp decrease of the element relative to its initial concentration in the soil (Table 1), this was a significant increase of the element in soil irrigated with wastewater treatments (Table 5) compared to soils irrigated with the water supply. This data can be directly related to the high concentration of this element in the wastewater used (Table 3). At the end of the experiment, no set pattern was observed in analyzing separately the treatments irrigated with wastewater or not. In the treatments irrigated with the water supply, there is T1A treatment (control), with the highest K-concentration (Table 5), a result that can be explained by the low consumption of the element by the plant, since, crop did not have a good development in this experimental unit. Analyzing only the treatments irrigated with wastewater, T6R treatment (soil + VLc20 + P) was the one with the highest concentration of the element (Table 5).

Regarding Ca and Mg macronutrients, no well-defined standards were identified specifically in relation to any treatment, about their concentrations identified in the soil after cultivation of maize (Table 5). However, there was an increase of elements in the soil after the experiment when their concentrations were compared to the initial concentration observed in the cultivation of the soil profile (Table 1). Among the treatments irrigated with the water supply, it was observed that the T3A, T4A, T5A and T6A treatments (which had soil increased with tannery sludge vermicompost) showed higher Ca-concentrations in relation to T1A treatment (control) and T2A (which received chemical fertilizer). These results are possibly to the element increase provided by the tannery sludge vermicompost used, since such compounds show concentrations, nearly 5.5 times greater than the initial Ca-concentration observed in the soil used to cultivate (Table 1).

At the end of the experiment, it was observed that in soil irrigated with wastewater, the micronutrient Cu did show higher values compared to soils irrigated with water supply (Table 4). In addition, it is emphasized that there were no element additions to the soil in the treatments, when analyzing the initial concentration of the element in soil profile (Table 1). As for Fe, Mn and Zn elements, it was found at the end of the experiment. The soil of most treatments irrigated with wastewater has the highest values of the elements when compared with soils irrigated with water supply (Table 5).

For the Mn element, there was an increase in the soil compared to its initial concentration present in soil used to cultivate. While initially there was a concentration of 47 mg dm^{-3} (Table 1) at the end of the experiment, the average element-concentration in soil irrigated with wastewater treatments was 64.66 mg dm^{-3}, increase which corresponds to almost 1.5 times. Furthermore, increase of Mn was observed, when compared with its initial concentration (Table 1) in all treatments with addition of tannery sludge vermicompost, which is probably due to the contribution provided by compounds used.

On the other hand, relative to their initial concentration in the soil, the soil of all treatments had the Zn-concentration increased (Tables 1 and 5). In this case, it is believed that the component of the contribution provided by the irrigation water supply or wastewater, has been responsible for this increase. From Table 3, it is possible to note that both types of water, especially the water supply, showed Zn values greater than the upper limit permitted by Brazilian law (Brazil, 2005). Moreover, the Zn concentration in the tannery sludge vermicompost used is at least eight times higher than the concentration in soil initially verified (Table 1). The increase of this element in the soil plus vermicompost may also be related to the high concentration of Zn present in coprolites of earthworms. Increases in Zn-levels in coprolites have been observed in previous studies (Cheng and Wong, 2002; Bartz et al., 2010) for various species of worms.

Conclusion

It is concluded that the tannery sludge vermicompost, added to soil and irrigated with wastewater from households, provided little increase in pH, EC, COT, BS, MO, N, P, K Cu and Fe concentrations compared to their initially identified concentrations in soil and does not provide, therefore, changes in the soil for these parameters. On the other hand, tannery sludge vermin-compost and domestic wastewater constitute good sources of Ca, P, Mg, Mn and Zn, being able to increase the content of these elements in the soil. It was suggested that further research be conducted to assess the impact of treatment on aspects of crop production.

Conflict of interests

The authors have not declared any conflict of interests.

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