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[ILUSTRACIÓN OMITIR]

RESUMEN

Dos residuos orgánicos (compost de lodo de depuradora y un residuo sólido urbano) fueron aplicados al suelo para mejorar el arraigo de diferentes especies: coscoja (Quercus coccifera L.), pino piñonero (Pinus pinea L.), pino carrasco (Pinus halepensis Miller), almez (Celtis australis L.) y enebro (Juniperus communis L.). Este estudio fue realizado durante tres años (1998, 1999 y 2000) en una finca situada en la provincia de Toledo, España. Los experimentos que se llevaron a cabo fueron: (a) variación en el perfil del suelo (0-15 y 15-30 cm.) de los parámetros químicos: pH, CE, N, P, K, carbono oxidable, Ca y metales pesados (Zn, Cu, Pb, Cr, Ni y Cd) y (b) el efecto tóxico de algunos metales pesados. Los principales resultados fueron para la profundidad 0-15 cm, encontrándose diferencias significativas para el nitrógeno, el fósforo, el potasio y el carbono oxidable. Sin embargo, la conductividad eléctrica y el calcio no están afectados por los tratamientos. Para la profundidad de 15-30 cm existen diferencias significativas para el pH, el nitrógeno, el fósforo, el potasio, el carbono oxidable y el calcio.

La aplicación de estos residuos provocó un incremento en la concentración de metales pesados en el suelo y en las hojas de las especies estudiadas, el cual que no superó en ningún momento los valores límites establecidos por las normativas europea y española.

PALABRAS CLAVE

Reforestación, metales pesados, parámetros agronómicos

ABSTRACT

Two organic residues (sewage sludge compost and municipal solid waste) were applied to the soil in order to improve the rooting of different vegetable species: kermes oak (Quercus coccifera L.), stone pine (Pinus pinea L.), aleppo pine (Pinus halepensis Miller), european nettle tree (Celtis australis L.) and juniper (Juniperus communis L.). This study was conducted during three years (1998, 1999 and 2000) at a plot located in the province of Toledo, Spain. The experiments were carried out in order to study: (i) the variation through the soil profile (0-15 and 15-30 cm) of different chemical parameters and elements such as: pH, EC, N, P, K, oxidisable carbon, Ca and heavy metals (Zn, Cu, Pb, Cr, Ni and Cd), and (ii) the toxic effect of those heavy metals in the plant. The main results were in the 0-15 cm depth with a significant increment ($p < 0.05$) for nitrogen, phosphorus, potassium, pH, and oxidable carbon. Moreover, the electrical conductivity and calcium were not affected by the treatments. There is a statically significant difference for pH, nitrogen, phosphorus, potassium, oxidable carbon and calcium parameters in soil samples from the 15-30 cm depth. The differences, in the N and P of the soil were higher in those soils treated with waste. An increment of heavy metals was found in the soil and in the leaves of all species. However, heavy metal concentrations in the treated soils were below Spanish and European legal limits and no toxic effects were observed in the plants.

KEYWORDS

Reforestation, heavy metals, agronomic parameters

1. INTRODUCTION

One of the most serious problems of the agricultural soils is the decrease of organic matter, mainly in arid and semiarid regions. Soil is a non-renewable natural resource, on a human time-scale (Albadalejo and Díaz, 1990). The United Nations Environmental Program (UNEP 1992) has established that 23% of the European soils are chemically, physically or biologically degraded by a large content of heavy metals, chemical fertilizers or pesticides, by compacting and erosion or by loss of organic matter and biodiversity that may significantly change crop development. Improving its quality and productive capacity, preventing erosion, improving root development and expansion and replacing the nutrients removed by crops and fauna alive is a society responsibility (García et al., 2000).

Plants have a range of potential cellular mechanisms that may be involved in the detoxification of heavy metal and thus tolerance to metal stress (Hernández et al., 1991). These include roles for the following: for mycorrhiza and for binding to cell wall and extra cellular exudates; for reduced uptake or efflux pumping of metal at the plasma membrane; for chelation of metals in the cytosol by peptides such as phytochelatins; repair of stress-damaged proteins; and for the compartmentation of metal in the vacuole by tonoplast-located transporters (Hall, 2002).

Alternative compounds to the traditional manures commonly used to replace removed nutrients and improve some soil physical properties are sewage sludge compost and municipal solid wastes since not adverse effects have been shown (Beltrán et al., 2000, Delgado et al., 2002). It has been very well documented that sewage sludge application to the soils (Querejeta et al., 1998, Martínez et al., 1999), substantially increases nutrient content and crop growth (Smith, 1996) as well as soil physical properties soils (Constantini et al., 1995, .Peñuelas 1996, Querejeta et al., 2000). Sewage sludge compost contains most nutrients for plants growth, particularly N and P, in addition this use of sewage sludge compost avoids the accumulation of sewage sludge in the environment (García et al., 1991). The aim of this work was to study the effect of the addition of sewage sludge compost and municipal solid waste on the chemical properties of forest soils and the con centration of the heavy metals in the plants.

Materials and methods

This study was conducted during 3 years (1998, 1999 and 2000) at a plot located in the province of Toledo, Spain with a soil Inceptisol and where local climate is mesomediterranean (Rivas, 1987).

Three different treatments to the soil surface were applied: (1) control, without fertilization, (2) municipal solid waste, 8000 kg [ha.sup.-1] and (3) sewage sludge compost, 8000 kg [ha.sup.-1] application. The treatments were applied on top of the soil and were not ploughed down.

The experiment was conducted following a random block; each treatment was replicate three times. Experimental plots were planted with 250 nursery plants, 3.5 m between the lines and 2.0 m between plants (5 lines of 100 m long each with 50 plants per line). The seedlings (2 years old) were grown in a nursery-pot of 250 [cm.sup.3] and were planted in January 1998 after the amendments were applied.

A clay loam soil with low organic matter content was selected for this study. Soil characteristics determined were: pH (1:2.5 in water) 8.35, electric conductivity (1: 5, 25[degrees] C) 0.16 d[Sm.sup.-1], oxidisable organic carbon 0.54%, Kjeldahl nitrogen 0.009%, available phosphorus by Olsen method 16.7 mg [kg.sup.-1] and available potassium by ammonium acetate 280 mg [kg.sup.-1] (MAPA, 1994).

Sewage sludge compost and municipal solid waste were applied over the soil in October 1997, and it was tilled before transplanting the seedlings in January 1998.

The municipal solid waste from Valdemingómez Recycling Plant (Madrid), had before composting. 44% organic matter, 10% plastics, 4% metals, 21% paper, 7% glass and 1% wool. They were treated with a composting process and refining treatment to obtain the organic material for agricultural use (García et al., 1998).

The sewage sludge compost applied in this study was obtained mixing sewage sludge from the six wastewater treatment plant in Madrid. This mixture was under bioxidation process before using it (Beltrán et al., 1999). Twelve representative samples of both wastes were taken from the top and inside the pile and stored at 4[degrees] C while they were waiting to be analysed. rials (dry weight).

The analysis reported in this table were as follow: pH by a potenciometric method in a soil water suspension of 1:2.5 ([wv.sup.-1]); electric conductivity was determined with a conductivitymeter (soil/water ratio, 1:5, 25[degrees] C); oxidisable carbon by Walkely Black method (APHA, AWWA, WPCF, 1992); nitrogen by Kjeldahl method (Hesse, 1971) and P, K, Ca and heavy metals Cu, Pb Cr, Zn, Ni and Cd concentrations were determined by atomic absorption spectroscopy (AAS), previous acid digestion (180[degrees]C) with HN[O.sub.3]/HCl[O.sub.4] (1:3) (APHA, AWWA, WPCF 1992).

Three soil samples (at the beginning, at the middle and at the end of the line) were collected in field at the depths of 0-15 cm for each species and each treatment and other three samples were collected at 15-30 cm. at the same time. After that, the samples of soil were air-dried, passed through a 2 mm sieve and stored for analysis.

Kjeldahl nitrogen, pH, EC, oxidisable carbon and heavy metals were measured as described for the wastes. available phosphorus and available potassium were determined by MAPA method (MAPA 1994) and mineral nitrogen (N[H.sub.4.sup.+] - N + N[O.sub.3.sup.-] - N) was measured by the procedure by Brenmer (1965).

Leaves from young tree were harvested (at the same of three samples of soil, for each species and each treatment) and oven dried at 65[degrees] C, grounded and stored for analysis, and the heavy metals were measured by atomic absorption spectroscopy (AAS), previous acid digestion (180[degrees]C) with HN[O.sub.3]/HCl[O.sub.4] (1:3) (APHA, AWWA, WPCF, 1992).

Statistics analysis of variance (ANOVA) was carried out by SAS/SAT version 6.12 (SAS/SAT, 1999), and multiple range test used conducted.

2. RESULTS AND DISCUSSION

The response variables were those related to the heavy metals concentration in seedlings as well as to the properties of soil. Special importance was attached to the possible contamination with heavy metals (factor which limits the use of these materials).

Heavy metals in the leaves

Table 1. Chemical analysis of sewage sludge compost (SSC) and municipal solid waste (MSW) used in the These values always were below Spanish and European legal limits for sewage sludge application.

	Moisture Content (%)	O.M. (%)	O.C. (%)	Kjeldahl Nitrogen (%)	P (%)	K (%)	Ca (%)	pH (1:2.5)	E.C. dSm^{-1} (1:5.0)
SSC	29.00	42.10	17.8	2.30	0.97	0.21	2.62	7.00	11.83
MSW	19.60	56.20	18.0	1.80	0.19	0.03	2.00	7.60	12.55

	Pb (mg/kg)	Cd (mg/kg)	Ni (mg/kg)	Cr (mg/kg)	Cu (mg/kg)	Zn (mg/kg)
SSC	<10	<3	52.8	570	290	2273
MSW	<10	<3	23.0	30	138	478
E.U. Limit pH>7*	1200	40	400	1500	1750	4000

Heavy metals (mg/kg) in waste. Directive 86/278/CEE*

Table 2 shows heavy metals in Quercus coccifera, Pinus pinea, Pinus halepensis, Celtis australis and Juniperus communis. under three different treatments applied to the soil plowed under: control, municipal solid waste and sewage sludge compost. It can be observed that there is an increment of heavy metals in the leaves for all the species when organic residues were applied.

The difference was higher for chromium in Quercus coccifera and Juniperus communis for nickel in Pinus pinea and Celtis australis and finally for zinc in Pinus pinea. However no visual toxic effects due to the heavy metals in the plants were observed.

The strategy adopted by plants generally aim, to avoid the build-up of excess metal levels in the cytosol, preventing in that way the onset of toxicity symptoms (Wagner et al., 1993; Smith and Kline, 1996). The plants achieved this by various mechanisms but likely to be employed in general metal homeostasis.

Agronomic parameters in soil profile

Table 3 shows the parameters analysed in the 0-15 cm depth soil profile increment a statistically significant difference ($p < 0.05$) for nitrogen, phosphorus, potassium, pH, oxidable carbon. Moreover, the electrical conductivity and calcium were not affected by the treatments. There is a statically significant difference for pH, nitrogen, phosphorus, potassium, oxidable carbon and calcium parameters were determined in soil samples from the 15-30 cm depth.

The contributions of organic mater to fertility are well known and within the water soluble fraction it is of special importance (Pagliai et al., 1981; Arduini et al., 1998) so the important role of organic matter in degraded soils should not be forgotten (Reddy and Overcash, 1981).

Soil degradation is synonymous of loss of quality and fertility and there is a close relationship between soil fertility and the organic matter content (Parr et al. 1989, Saur 1994). Furthermore, the soils of Spain are susceptible to physical degradation basically due to water erosion.

Soil organic matter content is involved in these processes since runoff will affect the uppermost layer of soil, which is where much of the organic matter accumulates (Williams and Goh, 1982; Kuiters and Mulder, 1993).

Heavy metals in soil profile

Table 4 shows the summary of heavy metals found in the soil profile corresponding to the different treatments. Lead and zinc concentration (0-15 cm) were found to be significant difference ($p<0.05$), however nickel and copper were not affected by treatments. At 15-30 cm depth nickel, copper, chromium and lead differed significantly among treatments, however no effect was observed in cadmium concentrations.

Chromium showed particularly higher values at the 0-15 cm depth. Direct toxicity for the trees and also direct and indirect toxicity for the other biotic components of the forest soil produced by heavy metals are exposure-dependent (Berry, 1987). Exposure is a function of two factors, deposition from the atmosphere and chemical availability (Sims and Kline, 1991).

Heavy metals may be adsorbed or chelated by organic matter (humic, fulvic acids), clay, and/or hydrous oxides of aluminium, iron and/or manganese (Arduini et al., 1996). Adsorbed heavy metals remain in equilibrium with chelated and free metals. Heavy metals may also be precipitate by inorganic compounds of low solubility such as oxides, phosphates or sulphates. Miller and McFee (1983) for instance, have suggested that lead may be present in the soil profile in the following forms: bound to organic matter 43%; bound to ferro-manganese The Directive 86/278/EEC specified rules for the sampling and analysis of sludge and soils. It set out the requirements for keeping the detailed records of quantities of sludge produced, the quantities used in agriculture, the composition and properties of the sludge, the type of treatment and the sites where the sludge is used (Marmo 1999).

Limit values for heavy metal concentrations in sewage sludge indented for agricultural use and in sludge-treated soils are in Annexes 1 A, 2 B and 3 C of the Directive. However, some of the provisions of the Directive could be improved in order to take into account the new scientific evidence and technological progress with the view of ensuring the long-term protection of the soil of the Community. It is what the Commission is about to do with the current work on the revision of Directive 86/278/ EEC.

Nitrogen (N[H.sub.4.sup.+] - N + N[O.sub.3.sup.-] - N) on soil profile hydrous oxides 39% as insoluble precipitates 10%; and biologically available (exchangeable) 8%. Moreover heavy metals concentrations in soils were below the Spanish and European legal limits (Guidi et al. 1990). Coherently The evolution of nitrogen (N[H.sub.4.sup.+] - N + N[O.sub.3.sup.-] - N) in soil profile 0-15 and 15-30 cm) in spring and in autumn 1998, 1999 and 2000 for control, sewage sludge and municipal solid waste treatments is represented in figure 1 and 2, respectively. In spring 1998, mineral nitrogen was highly influenced by the riches treatments (Figure 1), but there were few differences between control and municipal solid waste treatments. The mineral nitrogen in plot fertilised with sewage sludge compost was approximately ten times higher than in the control, at both depths (0-15 cm and 15-30 cm).

In autumn of the same year, the mineral nitrogen in the 15-30 cm depth soil sample was lower in municipal solid waste treatment than in the control. The higher C/N ratio in municipal solid waste caused a lower mineralization of nitrogen in the soil (Chae and Tabutabai, 1986; Delgado et al., 1999).

During the spring of 1999, the content of mineral nitrogen was higher in plot fertilised with sewage sludge compost in both depths) than in control and municipal solid waste treatments, however in autumn of the same year, the nitrogen in soil was similar in the three treatments. This can be due to the rainfall those days before helped the nitrogen to leach, as nitrate, towards deeper profiles of the samples (Berger and Glatzel, 2001).

Last year (2000) of the study the increment of mineral nitrogen for both, the sewage sludge compost and the municipal solid waste treated soils, may have been due to the organic matter mineralization, transferring nitrogen to the soil, in the same way for both treatments tested (Oreke, 1985).

DATA ANALYSIS

A statistic analysis of variance (ANOVA) was carried out for a multiple range test for agronomic factors and heavy metals in the soil profile for year 2000 (Tables 3 and 4). The conclusions were:

--I0-15 cm depth n this depth of the soil profile a statistically significant difference ($p<0.05$) for nitrogen, phosphorus, pH, oxidisable carbon and heavy metals means (lead and zinc) was found.

--In this same depth of soil profile there was not found a statistically significant difference ($p>0.05$) for electrical conductivity, calcium, potassium. and heavy metals (nickel and copper).

15-30 cm depth

--In this depth of the soil profile a statistically significant difference: pH, nitrogen, phosphorus, potassium, oxidable carbon, calcium and heavy metals (nickel, copper, chromium. and lead).

--In this same depth of the soil profile there was not found statistically significant difference for electric conductivity and the heavy metal (cadmium).

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Table 3. Agronomic parameters in soil profile (0-15 and 15-30 cm), for the three different treatments applied

	Depth (cm)	Control	Sewage Sludge	Municipal Solid Waste
pH 1:2.5 H_2O	0-15	8.30 ^{b} (0.19)	8.20 ^{a} (0.17)	8.26 ^{b} (0.17)
	15-30	8.50 ^{c} (0.19)	8.40 ^{b} (0.19)	8.30 ^{a} (0.18)
E.C. dS/m 1:5.0 H_2O	0-15	0.19 ^{a} (0.11)	0.22 ^{a} (0.11)	0.21 ^{a} (0.10)
	15-30	0.23 ^{a} (0.12)	0.24 ^{a} (0.14)	0.22 ^{a} (0.11)
Kjeldahl Nitrogen	0-15	0.009 ^{a} (0.011)	0.028 ^{c} (0.011)	0.023 ^{b} (0.011)
(%)	15-30	0.005 ^{a} (0.010)	0.009 ^{b} (0.010)	0.008 ^{b} (0.010)
Available Phosphorus	0-15	18.20 ^{a} (8.10)	26.30 ^{b} (10.20)	17.80 ^{a} (8.10)
($mgkg^{-1}$)	15-30	13.60 ^{a} (5.30)	20.60 ^{b} (8.30)	11.70 ^{a} (5.20)
Available Potassium	0-15	290 ^{a} (60)	301 ^{a} (60)	320 ^{a} (80)
($mgkg^{-1}$)	15-30	240 ^{b} (50)	220 ^{a} (50)	210 ^{a} (50)
Oxidisable carbon	0-15	0.57 ^{a} (0.15)	0.68 ^{b} (0.18)	0.69 ^{b} (0.18)
(%)	15-30	0.54 ^{a} (0.15)	0.59 ^{b} (0.15)	0.59 ^{b} (0.15)

Note: Each value is the mean of 15 samples. Within each agronomic parameter, means followed by the same letter are not significantly different ($p>0.05$), based on the analysis of variance (ANOVA) multiple range tests. In parenthesis, standard deviation for each measure

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Table 1. Chemical analysis of sewage sludge compost (SSC) and municipal solid waste (MSW) used in the These values always were below Spanish and European legal limits for sewage sludge application.

	Moisture Content	O.M. (%)	0.C. (%)	Kjeldahl Nitrogen

	(%)			(%)
SSC	29.00	42.10	17.8	2.30
MSW	19.60	56.20	1.80	1.80

	P (%)	K (%)	Ca (%)
SSC	0.97	0.21	2.62
MSW	0.19	0.03	2.00

	pH (1:2.5)	E.C. dS[m.sup.-1] (1:5.0)
SSC	7.00	11.83
MSW	7.60	12.55

	Pb (mg/kg)	Cd (mg/kg)	Ni (mg/kg)
SSC	<10	<3	52.8
MSW	<10	<3	23.0
E.U. Limit pH>7 *	1200	40	400

	Cr (mg/kg)	Cu (mg/kg)	Zn (mg/kg)
SSC	570	290	227.3
MSW	30	138	478
E.U. Limit pH>7 *	1500	1750	4000

Heavy metals (mg/kg) in waste. * Directive 86/278/CEE

Table 2. Heavy metals (mg/kg) in leaves seedlings with different treatments: control, sewage sludge and municipal solid waste

	Control	Sewage Sludge
	Cr	
Quercuscoccifera	0.43 [+ or -] 0.03	5.89 [+ or -] 3.53
Pinus pines	0.67 [+ or -] 0.13	2.12 [+ or -] 0.68
Pinushalepensis	0.05 [+ or -] 0.02	1.20 [+ or -] 0.32
Celtis australis	1.21 [+ or -] 0.74	1.42 [+ or -] 0.68
Juniperuscommunis	1.47 [+ or -] 0.68	4.03 [+ or -] 2.84
	Zn	
Quercuscoccifera	19.00 [+ or -] 0.23	21.00 [+ or -] 0.51
Pinus pines	30.00 [+ or -] 12.2	51.00 [+ or -] 14.5
Pinushalepensis	13.00 [+ or -] 1.66	27.00 [+ or -] 2.28
Celtis australis	13.00 [+ or -] 1.66	19.00 [+ or -] 0.23

Juniperus communis	8.00 [+ or -] 0.17	12.00 [+ or -] 0.21
	Pb	
Quercuscoccifera	0.00 [+ or -] 0.00	0.20 [+ or -] 0.05
Pinus pines.	0.00 [+ or -] 0.00	0.20 [+ or -] 0.05
Pinushalepensis	0.20 [+ or -] 0.05	0.30 [+ or -] 0.03
Celtis australis	0.04 [+ or -] 0.02	2.30 [+ or -] 0.77
Juniperuscommunis	0.00 [+ or -] 0.00	0.20 [+ or -] 0.05

	Municipal Solid Waste	Control
	Cr	Ni
Quercuscoccifera	3.95 [+ or -] 2.84	0.80 [+ or -] 0.15
Pinus pines	0.95 [+ or -] 0.14	0.00 [+ or -] 0.00
Pinushalepensis	0.27 [+ or -] 0.05	0.20 [+ or -] 0.74
Celtis australis	1.25 [+ or -] 0.72	1.70 [+ or -] 0.70
Juniperuscommunis	4.63 [+ or -] 0.84	1.30 [+ or -] 0.36
	Zn	Cu
Quercuscoccifera	20.00 [+ or -] 0.50	1.50 [+ or -] 0.80
Pinus pines	41.00 [+ or -] 2.27	1.00 [+ or -] 0.50
Pinushalepensis	17.00 [+ or -] 0.23	0.10 [+ or -] 0.03
Celtis australis	14.00 [+ or -] 0.23	3.70 [+ or -] 0.78
Juniperus communis	8.00 [+ or -] 1.13	3.20 [+ or -] 1.12
	Pb	Cd
Quercuscoccifera	0.10 [+ or -] 0.05	0.00 [+ or -] 0.00
Pinus pines.	0.10 [+ or -] 0.05	0.20 [+ or -] 0.05
Pinushalepensis	0.30 [+ or -] 0.03	0.00 [+ or -] 0.00
Celtis australis	2.30 [+ or -] 0.77	0.40 [+ or -] 0.02
Juniperuscommunis	0.00 [+ or -] 0.00	0.00 [+ or -] 0.00

	Sewage Sludge	Municipal Solid Waste
	Ni	Ni
Quercuscoccifera	1.30 [+ or -] 0.32	1.30 [+ or -] 0.32
Pinus pines	1.10 [+ or -] 0.12	0.00 [+ or -] 0.00
Pinushalepensis	5.10 [+ or -] 3.30	2.30 [+ or -] 1.85
Celtis australis	4.30 [+ or -] 2.85	1.75 [+ or -] 0.70
Juniperuscommunis	1.60 [+ or -] 0.38	1.60 [+ or -] 0.70
	Cu	Cu
Quercuscoccifera	2.70 [+ or -] 0.70	2.20 [+ or -] 0.68
Pinus pines	1.50 [+ or -] 0.64	1.10 [+ or -] 0.32
Pinushalepensis	1.10 0.74	0.60 [+ or -] 0.13
Celtis australis	5.30 3.53	4.60 [+ or -] 3.51
Juniperus communis	4.00 [+ or -] 1.75	3.60 [+ or -] 2.53
	Cd	Cd
Quercuscoccifera	0.74 [+ or -] 0.056	0.00 [+ or -] 0.00
Pinus pines.	1.00 [+ or -] 0.74	0.60 [+ or -] 0.60
Pinushalepensis	1.60 [+ or -] 0.056	1.10 [+ or -] 0.74
Celtis australis	1.10 [+ or -] 0.32	1.00 [+ or -] 0.21
Juniperuscommunis	0.20 [+ or -] 0.05	0.10 [+ or -] 0.05

Note: Mean [+ or -] Standard deviation of three replicates.

Table 3. Agronomic parameters in soil profile (0-15 and 15-30 cm), for the three different treatments applied

	Depth (cm)	Control	Sewage Sludge
pH 1:2.5 [H.sub.2]0	0-15	8.30 (b) (0.19)	8.20 (a) (0.17)
	15-30	8.50 (c) (0.19)	8.40 (b) 0.19
E.C. dS/m 1:5.0 [H.sub.2]0	0-15	0.19 (a) (0.11)	0.22 (a) (0.11)
	15-30	0.23 (a) 0.12	0.24 (a) 0.14
Kjeldahl Nitrogen	0-15	0.009 (a) (0.011)	0.028 (c) (0.011)
(%)	15-30	0.005 (a) (0.010)	0.009 (b) (0.010)
Available Phosphorus	0-15	18.20 (a) (8.10)	26.30 (b) (10.20)
(mg[kg.sup.-1])	15-30	13.60 (a) (5.30)	20.60 (b) (8.30)
Available Potassium	0-15	290 (a) (60)	301 (a) (60)
(mg[kg.sup.-1])	15-30	240 (b) (50)	220 (a) (50)
0xidisable carbon	0-15	0.57 (a) (0.15)	0.68 (b) (0.18)
(%)	15-30	0.54 (a) (0.15)	0.59 (b) (0.15)

	Depth (cm)	Municipal Solid Waste
pH 1:2.5 [H.sub.2]0	0-15	8.26 (b) (0.17)
	15-30	8.30 (a) (0.18)

E.C. dS/m 1:5.0 [H.sub.2]0	0-15	0.21 (a) (0.10)
	15-30	0.22 (a) 0.11
Kjeldahl Nitrogen	0-15	0.023 (b) (0.011)
(%)	15-30	0.008 (b) (0.010)
Available Phosphorus	0-15	17.80 (a) (0.10)
(mg[kg.sup.-1])	15-30	11.70 (a) (5.20)
Available Potassium	0-15	320 (a) (80)
(mg[kg.sup.-1])	15-30	210 (a) (50)
0xidisable carbon	0-15	0.69 (b) (0.18)
(%)	15-30	0.59 (b) (0.15)

Note: Each value is the mean of 15 samples. Within each agronomic parameter, means followed by the same letter are not significantly different (p>0.05), based on the analysis of variance (ANOVA) multiple range tests. In parenthesis, standard deviation for each measure

Table 4. Heavy metals (mg/kg) in soil profile (0-15 and 15-30 cm) for the three different treatments applied (2000 year)

Amended	Control	Sewage Sludge	Municipal Solid Waste
		Cr	
0-15 cm	33.17 (a) (11.20)	52.41 (c) (15.20)	38.67 (b) (10.30)
15-30 cm	24.17 (a) (9.11)	27.70 (b) (9.10)	25.19 (a) (9.10)
		Zn	
0-15 cm	53.60 (a) (15.30)	65.32 (c) (18.10)	61.05 (b) (18.10)

15-30 cm	53.16 (b) (15.30)	62.20 (c) (10.10)	50.32 (a) (15.32)
		Pb	
0-15 cm	43.43 (a) (11.20)	40.43 (b) (11.80)	43.14 (a) (11.20)
15-30 cm	40.04 (a) (11.22)	45.07 (b) (11.80)	41.15 (b) (11.20)
Amended	Control	Sewage Sludge	Municipal Solid Waste
		Ni	
0-15 cm	16.57 (a) (8.10)	17.57 (a) (8.10)	17.07 (a) (8.10)
15-30 cm	12.93 (a) (6.10)	15.93 (b) (8.20)	13.28 (a) (7.11)
		Cu	
0-15 cm	16.57 (a) (8.32)	17.57 (a) (8.30)	17.07 (a) (8.20)
15-30 cm	11.50 (a) (7.50)	15.57 (b) (0.30)	11.63 (a) (6.02)
		Cd	
0-15 cm	0.23 (a) (0.12)	0.27 (b) (0.12)	0.25 (a) (0.12)
15-30 cm	0.22 (a) (0.12)	0.26 (a) (0.12)	0.25 (a) (0.12)

Note: Each value is the mean of 15 samples. Within each heavy metals, means followed by the same letter are not significantly different (p>0.05), based on the analysis of variance (ANOVA) multiple range tests. In parenthesis, standard deviation for each measure

Table 4. Heavy metals (mg/kg) in soil profile (0-15 and 15-30 cm) for the three different treatments applied (2000 year)

Amended	Control	Sewage Sludge	Municipal Solid Waste	Control	Sewage Sludge	Municipal Solid Waste
		Cr			Ni	
0-15 cm	33.17^{a} (11.20)	52.41^{c} (15.20)	38.67^{b} (10.30)	16.57^{a} (8.10)	17.57^{a} (8.10)	17.07^{a} (8.10)
15-30 cm	24.17^{a} (9.11)	27.70^{b} (9.10)	25.19^{a} (9.10)	12.93^{a} (6.10)	15.93^{b} (8.20)	13.28^{a} (7.11)
		Zn			Cu	
0-15 cm	53.60^{a} (15.30)	65.32^{c} (18.10)	61.05^{b} (18.10)	16.57^{a} (8.32)	17.57^{a} (8.30)	17.07^{a} (8.20)
15-30 cm	53.16^{b} (15.30)	62.20^{c} (18.10)	50.32^{a} (15.32)	11.50^{a} (7.50)	15.57^{b} (8.30)	11.63^{a} (6.02)
		Pb			Cd	
0-15 cm	43.43^{a} (11.20)	48.43^{b} (11.80)	43.14^{a} (11,20)	0.23^{a} (0.12)	0.27^{b} (0.12)	0.25^{a} (0.12)
15-30 cm	40.04^{a} (11.22)	45.07^{b} (11.80)	41.15^{b} (11.20)	0.22^{a} (0.12)	0.26^{a} (0.12)	0.25^{a} (0.12)

Note: Each value is the mean of 15 samples. Within each heavy metals, means followed by the same letter are not significantly different (p>0.05), based on the analysis of variance (ANOVA) multiple range tests. In parenthesis, standard deviation for each measure

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