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INFLUENCE OF MUNICIPAL SOLID WASTE COMPOST ON SOIL PROPERTIES AND PLANT REESTABLISHMENT IN PERI-URBAN ENVIRONMENTS

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ABSTRACT

Soils in urban areas often present characteristics that might submit these environments to erosion processes. Applying municipal solid wastes (MSW) composts to soils have been suggested as a means to improve physical and chemical properties. A field experiment with a completely randomized design was conducted in a Typic Argiudoll from a degraded area in Buenos Aires City. The objective was to evaluate the effect of MSW compost application on soil properties, residue decomposition and Poa (*Poa pratensis* L.) reestablishment. At the beginning of the trial, compost was prepared and applied in a bare soil on 0.25 m^2 square plots afterwards litterbags were incorporated and Poa was sown. Compost amounts were: 0 (control); 2 (low); 4 (medium) and 7 kg m^{-2} (high) on fresh matter basis. During the trial residue decomposition and aerial dry matter (DM: g $treatment^{-1}$) were evaluated, at the end soil physical and chemical parameters were measured. Medium and high compost rates increased organic C, total N and extractable P. Addition of 2 kg m^{-2} affected soil organic C as well, but in a minor fee. Soil physical properties were improved after MSW compost addition. In medium and high doses, augmentations in organic matter reduced bulk densities and enhanced water infiltration. Aerial DM was significantly affected by treatments ($p < 0.05$). Medium dose improved soil properties and plant DM in the same amount as the highest rate. MSW compost application in urban soils is a viable alternative, since allows the full restoration of an area with serious environmental problems.

Key words: soil restoration, municipal solid waste compost, soil properties.

INTRODUCTION

Soils intensively affected by human activities might present special features such as mixed horizons, foreign materials and thin topsoil (Short *et al.,* 1986; Civeira and Lavado, 2008). Normally, these soils are poor in organic matter (OM) (e.g., < 1%) and fertility with reductions in their most important physical properties, such as structural stability and water retention. Eventually, these characteristics might have a detrimental effect on plant growth and submit this particular environment to erosion processes (Vetterlein and Hüttl, 1999; Scharenbroch *et al.*, 2005). Consequently, deteriorated soils in populate cities do not tolerate agricultural or recreational uses and turned these environments into places with low probability of community progress.

Due to urban soils present different characteristics compared to agricultural ones, their intrinsic properties and rehabilitation techniques have not yet been sufficiently relieved (Larson and Pierce, 1991; Scharenbroch *et al.,* 2005). In recent decades, the application of organic wastes from different origins (manure, sewage sludge and municipal organic wastes) to degraded soils is a practice globally accepted to recover, replenish and preserve OM, fertility and vegetation (Vetterlein and Hüttl, 1999; Civeira and Lavado, 2008). Before application to soils, organic wastes should been stabilized using composting techniques. The use of composted organic wastes produces changes in soil physical, chemical and biological properties and can enhance plant growth after its application. However, the influence of C rich materials, like municipal organic wastes compost, on soil physical, chemical and biological properties depends upon several factors: amount and components of added organic materials, soil type and weather conditions (Unsal and Ok, 2001; Drozd, 2003). As pointed out by Giusquiani *et al*. (1995) and Drozd (2003) the use of composts from municipal solid wastes (MSW) improves the restoration of degraded soils and allows an appropriate final disposition

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of such materials, solving a major environmental and economical problem generated in the cities.

Considering that soil recovery in urban environments depends upon several factors, such as those mentioned above, the objective of this study was to study the response of an urban degraded soil to different MSW compost application rates, as an alternative to MSW disposal and soil recovery. As indicators of soil response physical (bulk density, soil moisture, and water infiltration) and chemical (pH, electrical conductivity, organic C, total N, and extractable P) parameters were evaluated. Plant re-establishment (total DM) and residue decomposition rates were also measured in a field experiment in Buenos Aires city.

MATERIALS AND METHODS

Compost preparation

The MSW used in this study were obtained from local homeowners and a supermarket. These sources presented mixed organic domestic wastes (fruits and vegetables), including gardens and grass trimmings. The inorganic fraction was manually separated from the organic fraction. The MSW organic fraction were shredded and placed in a pile. The pile was thoroughly mixed every 2 d, to ensure that all MSW were exposed to high temperatures. The pile was also watered every 4 d in order to maintain the aerobic and composting process in optimum conditions. Compost temperature was monitored every 10 d approximately with a mercury in-glass soil thermometer. Compost characterization is presented in Table 1.

Site description and experimental design

The field trial was laid out between January 2006 and June 2007 in Buenos Aires city (34º35' S, 58º26' W). The climate is temperate with annual precipitation average varying between 900 and 1600 mm and annual mean temperature of 18 ºC. The experimental units were 0.25 m^2 rectangle shape and established in a 3 m^2 square. The soil was a Typic Argiudoll that presented no surface horizon and many foreign materials such as wood, glass and bricks, which were removed before the establishment of the experiment. Soil characteristics are presented in Table 2.

The MSW compost was used for a one-time application on the 0.25 m^2 plots at the beginning of the trial, in the following doses: 0 (control); 2 (low); 4 (medium) and 7 kg m^{-2} (high) on a fresh matter basis. Compost was surface-applied with rakes to bare soil and seeds of Poa were subsequently sown. The treatments were assigned in a completely randomized design to each experimental unit and were carried out in three replicates (12 experimental plots). Soil physical and chemical properties were measured twice, at the beginning and at the end of the experiment. Three composite soil samples were taken from each plot at depths of 0 to 20 cm with a 5 cm diameter bucket auger in January 2006 (before treatment), and then again in June 2007. The following soil analyses were carried out in soil samples: Organic C content, by ashing; total Kjeldahl N (total N) by the Kjeldahl method (Bremner, 1960); available P by the Bray and Kurtz method (Bray and Kurtz, 1945) (extractable P); electrical conductivity (EC) in soil extracts and pH in water (1:2.5). Bulk density (BD) was measured by the core method; water infiltration (INF) by a variation of the USDA-NRCS method (1999) and soil moisture by the gravimetrically method. MSW compost was analyzed by the same methods as for the soil samples for organic C, total N, available P, EC and pH. Poa aerial DM for each treatment was measured in order to compare MSW compost effects on planted vegetation during the experiment. Plant cuttings were performed 14 times to a residual height of 5 mm for all treatments. Plant samples were collected, dried at 70 ºC for 48 h and weighed to obtain total aerial DM data for each treatment.

Table 1. Characteristics of municipal solid wastes compost. (Dry basis).

pH	6.82
Electrical conductivity, dS m^{-1}	1.98
Organic C, g kg^{-1}	23.5
Total N, g kg^{-1}	0.15
C:N ratio	156.6
Extractable P, mg kg^{-1}	175.2

Table 2. Soil characteristics in the urban site.

pH	6.56
Electrical conductivity, dS m^{-1}	2.15
Organic C, g kg^{-1}	16.18
Total N, g kg^{-1}	0.95
Extractable P, mg kg^{-1}	12.38
Bulk density, g cm^{-3}	1.52
Infiltration, cm h^{-1}	75
Moisture, %	8

Plant residue decomposition sampling and analysis

In order to evaluate plant residue decomposition in the soil, litterbags, 20 x 20 cm, were constructed of transparent nylon containers with a 2 mm^2 mesh size, following the method used by Lachnicht *et al.* (2004). Twenty-five grams of Poa shoots were placed into each litter bag and then incorporated on the upper soil layer (10 cm) of each experimental unit and its replications before sowing. During the trial each litterbag was unburied and weighed on seven different dates 0, 30, 60, 90, 120, 150 and 180 d. Decomposition rates were calculated dividing litterbags weight in each sampling date (g) and days the litterbag remained in the soil between each sampling date (30 d).

Statistical analysis

The experimental data from each treatment were subjected to ANOVA and means were compared by tests of least significant differences (LSD), at the confidence level of $p < 0.05$. The statistical software used was INFOSTAT (2002).

RESULTS AND DISCUSSION

Compost process and general characteristics

The compost pile reached the thermophile (> 45 ºC) phase rapidly 10 d after its establishment (Figure 1). Elevated temperatures lasted approximately 20 d and descended to lower values (< 30 ºC) in the subsequent weeks, showing a typical biodegradation curve. These temperatures corresponded to optimum biological activity (around 40 ºC). Once the pile achieved the thermophile phase pathogens inside the residues were considered eliminated as discerned in the literature (Tognetti *et al*., 2007; Weber *et al*., 2007). Values of the C/N ratio indicated an advanced maturity stage, as a result a stabilized and quality compost was obtained (Hassen *et al*., 2001, Eggen and Vethe, 2001). Least duration of thermophilic phase (close 4 wk) indicates a normally extended decomposition and a rapid transition to the stabilization stage (Zucconi and De Bertoldi, 1987). After 3-mo stabilization phase was over and compost was ready for soil application.

Compost organic C content (Table 2) was elevated and similar to values (20 and 55%) cited by other authors (Grigatti *et al*., 2004; Weber *et al*., 2007). Based on literature data, total N content (Table 2) was low for

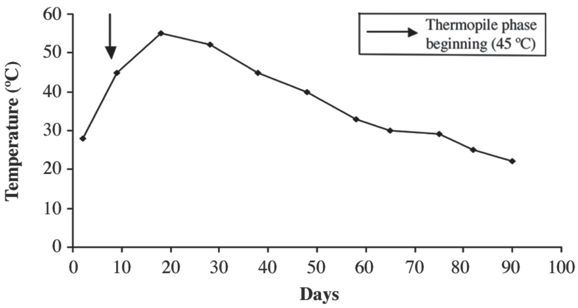


Figure 1. Temperature during municipal solid wastes composting.

this type of compost (Tognetti *et al.,* 2007). Zucconi and De Bertoldi (1987) observed low total N contents in composts due to ammonia volatilization and related them with elevated temperatures during composting process. In our case, ambient temperatures were superior to 35 °C during composting period (data not shown) so N volatilization could have taken place. The final C/N ratio (Table 2) was elevated, probably due to N loss by ammonia volatilization favored with high temperatures. In addition, wastes included in the compost were fruits, vegetables and grass clippings normally with high C/N ratio, which also favoured microbial N immobilization. These particular characteristics could have raised final C/N ratio more than expected values. If compared with other composts, which usually contain less than 10 mg kg^{-1} of extractable P, this compost should be classified as relatively high in available P. The obtained MSW compost was no saline and neutral, values of pH and EC achieved at 90 d were within the range acceptable for plant growth recommended by Rynk (1992; 2003), and similar to other reported for MSW composts (Cooperband and Middleton, 1996).

Soil chemical and physical properties

Chemical properties (Table 3) showed a high response after the MSW compost addition to soil. Compost application positively affected total N content in soils. The LSD test revealed a significant difference ($p < 0.05$) for doses of 2 kg m^{-2} upwards. Organic C was also affected by MSW compost addition: Higher values of organic C were observed in low, medium and higher doses of compost, the highest levels were observed for 4 and 7 kg m^{-2}. Nevertheless, the soil organic C was not explained by the quantity of compost applied. Extractable P was also increased in soils with significant differences between control and the other treatments: medium and high doses presented the greatest increase in extractable P in soils (Table 3). Some authors observed that MSW compost effectively supply P to soil with P concentration increasing with increasing application rates (Iglesias-Jiménez and Álvarez, 1993). They also reported that MSW composts provided equivalent amounts of P to soil as mineral fertilizers.

The C/N ratio showed a difference due to MSW compost application. The LSD procedure revealed a significant increase with higher doses of MSW compost ($p < 0.05$). The highest levels were observed for 4 and 7 kg m^{-2}. As expected, MSW compost application consistently increased soil OM and soil C/N ratio to levels greater than not amended ones (Crecchio *et al.,* 2004; Walter *et al*., 2006).

Compost additions affected soil pH; medium and high doses raised pH from 6.5 to 6.9. Tognetti *et al*. (2007)

Table 3. Changes in soil chemical and physical properties after compost application.

	Treatments			
	0	2	4	7
	kg compost m^{-2}			
pH	6.51a	6.62a	6.90b	6.95b
Electrical conductivity, dS m^{-1}	2.15a	2.21a	2.22a	2.22a
Organic C, g kg^{-1}	16.12a	18.52b	21.35c	22.23c
Total N, g kg^{-1}	0.95a	0.98a	1.05b	1.12b
Extractable P, mg kg^{-1}	12.32a	13.50a	17.95b	18.52b
C:N ratio	16.94a	17.5a	20.93b	21.04b
Bulk density, g cm^{-3}	1.52a	1.45b	1.32c	1.31c
Infiltration, cm h^{-1}	78a	84b	90c	92c
Moisture, %	41a	58b	71c	77c

Means followed by the same letter in the same row do not differ ($p < 0.05$).

informed soil pH increases when mature composts were applied. However, changes in pH, like in this case, were not always proportional to doses.

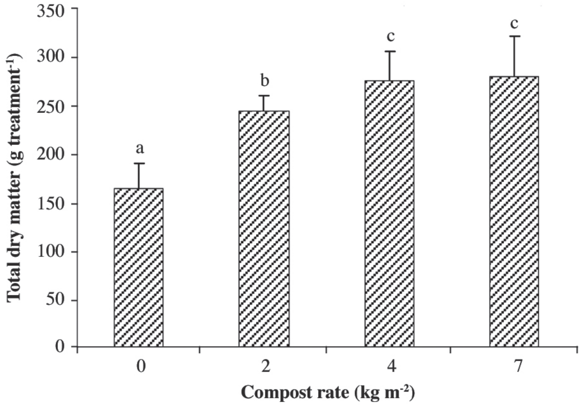
In the present study, organic C, total N and extractable P increased with MSW compost application, significant increases were observed for 4 and 7 kg m^{-2} doses. Application of 2 kg compost m^{-2} affected soil organic C as well, but in a minor extent. In addition, a significant positive correlation was identified between organic C and soil N and P content for medium and higher compost doses ($R^2 = 0.91$; $p < 0.05$ and $R^2 = 0.89$; $p < 0.05$, respectively). It should be considered that a lower application rate could be affecting nutrient availability, plant development and soil restoration. There was no significant difference between applying medium or high compost dose (Table 3). As pointed out by other authors, increasing compost application rates not always augmented organic C and nutrients contents (like total N and extractable P) in soils (among others, Giusquiani *et al.*, 1995; Barzegar *et al.*, 2002). Limited organic C and nutrients after addition of much higher rates of composted MSW have been attributed to rapid mineralization of labile organic matter (Flavel and Murphy, 2006).

Soil physical properties, in a similar way to chemicals, were also improved after MSW compost addition. MSW compost application tended to reduce BD at the end of the experiment (Table 3). By the final sampling date treatments with medium dose and high dose (4 and 7 kg m^{-2}, respectively) had significantly lower ($p < 0.05$) bulk densities than the control and the low dose treatment as well The decrease in BD appears to have been due to dilution of the denser mineral fraction by the less dense MSW compost doses. These results are in line with Haynes and Naidu (1998) and Civeira and Lavado (2006) who reported that lighter compost particles might penetrate the soil matrix and eventually decrease bulk densities.

Soil moisture and water infiltration were significantly affected by MSW compost additions at the end of the experiment ($p < 0.05$) (Table 3). Medium and high compost doses (4 and 7 kg m^{-2}, respectively) showed the maximum soil moisture and water infiltration rates compared to control and 2 kg m^{-2}. An increase of water infiltration and moisture should be considered a consequence of total porosity augmentation in soils after MSW composts application (Weber *et al.*, 2007). Although, it is commonly mentioned that compost improve physical conditions particularly water holding capacity studies on soil moisture change are scarce. In some cases, compost and other organic wastes did not increase soil moisture. This result was probably due to augmentations in plant cover and water utilization in compost-amended soils (Giusquiani *et al.*, 1995; Cooperband, 2000; Meyer *et al.*, 2001). Despite of that, in the present study the MSW compost penetrated the soil surface and improved measured physical properties: BD, moisture retention and water infiltration (Table 3) (Risse and Faucette, 2001).

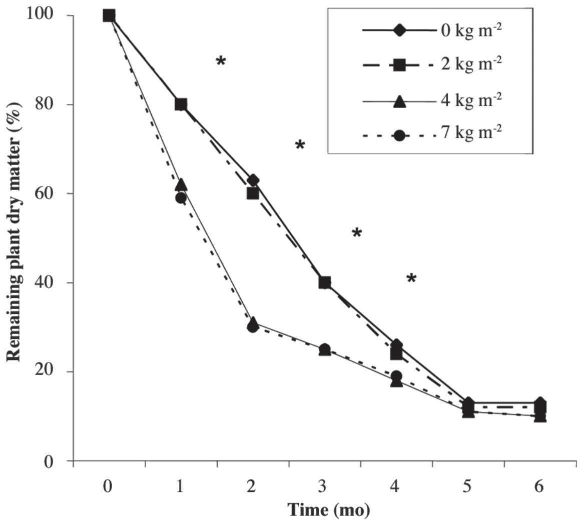
Plant aerial dry matter

Poa pratensis sp. total aerial DM (g DM $treatment^{-1}$) was significantly affected by treatments ($p < 0.05$) (Figure 2). Medium and high doses (4 and 7 kg m^{-2}) accumulated about two times more aerial biomass than control treatment. No significant differences were observed between 4 and 7 kg m^{-2} doses ($p > 0.05$). Improvements in plant biomass have been reported elsewhere (Zhang *et al.*, 2000; Garcia-Gomez *et al.*, 2002), mainly due to compost effects on nutrients availability in soils. In the present study, despite the low total N content in MSW compost, medium and high doses provided adequate N for plant growth and



Different letters indicate differences among estimated treatment means at the 0.05 probability level.
Values are means with standard error as error bars.

Figure 2. ***Poa pratensis*** **sp. total dry matter (g treatment^{-1}) as affected by compost doses.**



An asterisk indicates differences among treatments for the same time ($p < 0.05$).

Figure 3. Plant residue decomposition as remaining plant dry matter in bags. Results are means of three replicates.

support. Therefore, some studies (Iglesias-Jiménez and Alvarez, 1993; Mylavarapu and Zinati, 2009) suggested that elevated doses of MSW compost increase inorganic N forms and also provide a consistent nutrient supply during the initial growing season and could meet subsequent plant demand. At the end of the experiment, higher and medium MSW compost doses exhibited higher organic C, nutrients contents and superior physical properties in the topsoil. As expected, these better soil conditions in the plots where MSW compost were applied resulted in higher shoot growth.

Residue decomposition

Plant residue decomposition from the 1st month until the 4th month showed significant differences among treatments ($p < 0.05$) (Figure 3). The addition of 4 and 7 kg compost m^{-2} increased two times residue decomposition compared to control and 2 kg m^{-2} dose. After 4-mo residue decomposition showed similar trends and presented no significant differences between treatments ($p < 0.05$). The size of the pores of the litterbags (2 mm) limited accessibility of the residues to larger invertebrates so the observed breakdown of the residues could primarily be attributed to microorganisms and smaller invertebrates Treatments with MSW compost addition raised plant residue decomposition more than control treatment in the first months. This was probably, because of augmentations in soil microbial biomass activity and C mineralization during this initial stage (Giusquiani *et al.*, 1995; Bhattacharyya *et al.*, 2003; Crecchio *et al.*, 2004).

Plant decomposition rates were significantly different between treatments ($p < 0.05$) in the first three sampling dates (Table 4). Increasing compost application to soils, augmented decomposition: medium and high doses (4 and 7 kg compost m^{-2}) presented maximum decomposition rates compared with control and 2 kg compost m^{-2}. All treatments showed the highest values at the beginning, and the lowest ones, at the end of the assay. Subsequently the initially superior decomposition rates, a moderate decrease in all treatments was observed previously

Table 4. Mean decomposition rates of plant residue as affected by compost application rates at different sampling times.

	Decomposition rates					
Treatments	30 d	60 d	90 d	120 d	150 d	180 d
kg m^{-2}	g d^{-1}					
0	0.17a	0.14a	0.18a	0.11a	0.11a	0.00a
2	0.17a	0.16a	0.17a	0.12a	0.10a	0.00a
4	0.32b	0.25b	0.05b	0.06b	0.06b	0.01a
7	0.34b	0.24b	0.04b	0.05b	0.05b	0.01a

Means followed by the same letter in the same column do not differ ($p < 0.05$).

becoming constant. Plant decomposition rates became constant earlier in 4 and 7 kg m^{-2} doses than in control and 2 kg m^{-2} (Table 4). Microbial population of this soil, as well as its residue decomposition, depends mainly on the amount and type of compost applied (Bhattacharvya *et al*., 2003; Crecchio *et al*., 2004).

CONCLUSIONS

MSW compost addition on this degraded soil recovered plant growth, raised residue decomposition, and improved physical and chemical properties. As expected, organic matter increased after MSW compost application. Superficial (0-20 cm) organic C augmentation enhanced properties and played a fundamental role in the recovery of the topsoil, allowing the improvement of the surrounding environment. There were no significant differences between applying medium dose and high dose to soil. Possibly, an optimum application threshold was reached; beyond that, higher levels of compost doses would not considerably increase soil restoration. However, application rates should be appropriately adjusted in order to minimize detrimental effects and environmental problems. The results of this study showed that the use of MSW compost in this type of soils is an accurate alternative, since provides a nearby available source of nutrients and allows the full recovery of a severe damaged ecosystem with critical environmental problems.

RESUMEN

Efecto de la aplicación de compost de residuos sólidos municipales sobre las propiedades de los suelos y el establecimiento de plantas en ambientes peri-urbanos. Los suelos de las áreas urbanas presentan características que pueden someter estos ambientes a procesos erosivos. La aplicación de composts de residuos sólidos urbanos (MSW) a los suelos es una práctica que mejora sus propiedades. El objetivo del trabajo fue evaluar el efecto del compost de MSW sobre las propiedades, la descomposición de residuos y el restablecimiento de la especie Poa (*Poa pratensis* L.) en estos suelos. En un Argiudol típico degradado de la ciudad de Buenos Aires se realizó un ensayo con diseño completamente aleatorizado. Se preparó e incorporó compost en parcelas de 0,25 m^2 en las siguientes cantidades: 0 (testigo); 2 (baja); 4 (media) y 7 kg m^{-2} (alta), se enterraron bolsas de descomposición y posteriormente se sembró Poa. Periódicamente se evaluaron la tasa de descomposición de residuos y la materia seca (MS) aérea y al finalizar las propiedades físicas, y químicas. Las dosis media y alta de compost aumentaron el C orgánico, N total y P extractable. La adición de 2 kg m^{-2} afectó el C orgánico en menor medida. Las propiedades físicas mejoraron con la adición del compost, el aumento de la materia orgánica redujo la densidad aparente y mejoró la infiltración en las dosis media y alta. La MS fue afectada por los tratamientos. La dosis media mejoró las propiedades de los suelos y los niveles de MS en el mismo nivel que la dosis alta. La aplicación de compost de MSW en suelos urbanos es una alternativa para recuperar áreas con problemas ambientales.

Palabras clave: Restauración suelos, compost, residuos sólidos urbanos, propiedades físicas y químicas.

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