Research Note

CHEMICAL AND PHYSICAL PROPERTIES OF TWO HIGHLY WEATHERED SOILS MIXED WITH COMPOST[1]

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Soils are being degraded around the world as a consequence of climate change, intensive cropping, and inappropriate management practices (O'Neal et al., 2005) that enhance soil erosion and topsoil depletion. Eroded and bare soil is exposed to environmental pressures that can increase its organic matter loss via CO_2 release (Fullen, 1991; Fullen and Brandsma, 1995). Compost provides organic matter that can associate with clays, improving soil aggregation and chemical and physical properties of soils.

Soil quality is reduced as its organic carbon content decreases leading to decreasing crop yields (Carpenter et al., 2001; Lugo-López et al., 1981a). Such decrease impairs physical, chemical and biological properties of soils. Organic matter has a buffering capacity; pH in acid soils tends to increase, whereas in alkaline soils it tends to decrease. Soil exposure to environmental pressures can result in nutrient-deprived soils. When soils undergo weathering processes, hydrogen ions replace exchangeable cations, such as Ca^{2+}, Mg^{2+}, K^+, and Na^+ and soil pH decreases. As the soil becomes more acid, its capacity to fix P into unavailable form increases. Another consequence is an increase in exchangeable Al^{3+}, which may reach toxic levels to crops. A 2% SOC has been suggested as the minimum level for good quality soils (Nandwa, 2001). At 0- to 30-cm depth, some Puerto Rican soils have less than 7.2 kg C/m^2 (Vázquez, 1997), equivalent to 2% SOC when soil bulk density is 1.2 Mg/ha. Several studies have also shown that compost improves soil aggregation, bulk density and water holding capacity (Six et al., 2004).

The objective of this study was to evaluate physical and chemical properties of two highly weathered soils amended with coffee pulp compost. The organic carbon content of the coffee pulp compost was 34.4% and the C:N ratio was 9:1. The low C:N ratio and high humic substances/total organic carbon ratio (approximately 22% w/w) indicated that this compost was a good source of stable organic matter. Total nutrient content of the compost was: N, 3.6%; P, 0.5%; K, 3.1%; Ca, 2.6%; Mg, 0.2%; and Na, 0.15%. The electrical conductivity was 3.6 mS/cm (Table 1).

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TABLE 1.—*Chemical and physical properties of coffee pulp compost.*

	EC[1]	OC[2]	N_T[3]	P_T[3]	P_a[4]	C:N	HS/OC	N-NO_3^-	K^+	Ca^{2+}	Mg^{2+}	Na^+
pH	mS/cm	%	%	%	%		%	%	%	%	%	%
6.82	3.59	34.4	3.64	0.46	0.29	8.62	21.8	0.33	3.11	2.59	0.24	0.15

[1]Measured in a 1:1 suspension
[2]OC-loss in ignition method
[3]N_T, P_T = total nitrogen and phosphorus
[4]P_a = available P

Soil samples were collected from cultivated areas at Adjuntas and Corozal Agricultural Experiment Substations of the University of Puerto Rico, Mayagüez Campus. The soils selected for the study were: Adjuntas (very-fine, kaolinitic, isohyperthermic Inceptic Hapludox) and Corozal series (very-fine, parasesquic, isohyperthermic Typic Hapludults) (Beinroth et al., 2003). Both soils are formed in clayey residuum from weathered volcanic rock (Beinroth et al., 2003). The SOC pools at 0- to 30-cm depth for Adjuntas and Corozal series were 0.38 and 0.76% (1.37 and 2.74 kg C/m^2), respectively, both below the precaution threshold value of 2%.

The soils were air dried, ground, passed through 1-cm sieves, and mixed with one-year-old coffee pulp compost at the following ratios: 0, 5, 10, 15 and 20% compost (w/w). One week after the compost addition, the soils were transported to the laboratory and stored at 4° C until analysis. The pH was measured in water and 1N KCl, using a 1:1 soil mixture: water ratio. Electrical conductivity was also measured at 1:1 soil mixture: water ratio. Total Kjeldahl Nitrogen (TKN) was analyzed using an Autoanalyzer Technicon II (Bremner and Mulvaney, 1982)[6]. Total phosphorus was extracted using AOAC method 957.02, and was measured in an Autoanalyzer Technicon II. Inorganic N was extracted with 2 M KCl. The supernatant was filtered through a 0.45-µm Whatman Nylon syringe filter and analyzed for ammonia-N and nitrate-N by using USEPA Methods 350.1 and 353.2, respectively. Exchangeable Ca^{2+}, Mg^{2+}, K^+ and Na^+ were extracted with 1 M ammonium acetate at pH 7, and exchangeable Al^{3+} with 1M KCl. The above-mentioned exchangeable cations were measured by Atomic Absorption Spectrometry (AAS). Available P was determined by the Bray I method. Soil water content at field capacity was measured by the gravimetric 1/3 bar method. Bulk density, total porosity, and air-drained space were determined by using a NCSU Porometer™ (Raleigh, NC). These analyses were performed on a 347.5-cm^3 sample in a 7.6-cm tall aluminum cylinder. Total porosity was measured by measuring the water space occupied in saturated samples. Drained air space was measured after a two hour draining period. Analysis of variance and least significant difference (LSD) tests at $p \leq 0.05$ were performed on chemical and physical soil data.

Tables 2 and 3 show the effect of compost on soil pH, EC, NO_3^-, NH_4^+, available P, exchangeable K^+, Ca^{2+}, Mg^{2+}, Na^+ and Al^{3+} of soil: compost mixture. Total porosity, air space, bulk density and field capacity are shown in Table 4. The pH of Adjuntas soil was 4.92 in water and 3.74 in KCl, and for Corozal soil it was 4.75 in water and 3.90 in KCl.

[6]Company or trade names in this publication are used only to provide specific information and does not constitute an endorsement by the Agricultural Experiment Station of the University of Puerto Rico.

TABLE 2.—*Chemical and physical properties of soils amended with coffee pulp compost.*

Identification	pH_W	pH_{KCl}	EC[1] mS/cm	NO_3^- mg/kg	NH_4^+ mg/kg	Bray I-P mg/kg
Adjuntas: Compost						
0%	4.92 b[2]	3.74 e	0.07 e	9 e	39 a	7 d
5%	4.75 c	3.97 d	0.56 d	161 d	52 a	22 c
10%	4.81 cb	4.12 c	1.04 c	276 c	60 a	35 b
15%	5.07 a	4.37 b	1.53 b	394 b	54 a	50 a
20%	5.16 a	4.75 a	1.94 a	512 a	47 a	52 a
Corozal: Compost						
0%	4.75 e	3.90 e	0.38 e	32 e	7 d	56 c
5%	4.94 d	4.23 d	0.88 d	174 d	7 d	79 b
10%	5.41 c	4.55 c	1.36 c	318 c	12 c	94 a
15%	5.18 b	4.68 b	1.89 b	473 b	17 b	93 a
20%	5.56 a	4.87 a	2.39 a	569 a	21 a	100 a

[1]EC= electrical conductivity
[2]Means in the same column followed with same letter do not differ at $p < 0.05$.

Compost additions to the soils increased pH, electrical conductivity (EC), available NO_3^-, available P, and exchangeable K^+ (Table 2). The increase in nutrient content by addition of compost provides for a decrease in the application of inorganic fertilizers for optimum production.

Adjuntas and Corozal soils showed pH_{KCl} values of 3.7 and 3.9, respectively. Exchangeable Al^{3+} for Adjuntas soil was 5.92 cmol/kg and for Corozal soil 2.11 cmol/kg. Adding compost to the Adjuntas soil gradually decreased exchangeable Al^{3+} down to non-

TABLE 3.—*Exchangeable cations of soil-compost treatments.*

Identification	K^+	Ca^{2+}	Mg^{2+}	Na^+	Al^{3+}
			cmol/kg		
Adjuntas: Compost					
0%	0.46 e[1]	2.37 d	1.22 d	0.30 e	5.92 a
5%	3.69 d	3.12 c	2.03 c	0.33 d	2.48 b
10%	6.70 c	3.04 c	1.99 c	0.38 c	1.03 c
15%	9.26 b	3.72 b	2.21 b	0.42 b	0.33 d
20%	11.32 a	4.26 a	2.59 a	0.47 a	ND[2]
Corozal: Compost					
0%	1.06 e	5.36 a	1.09 d	0.40 c	2.11 a
5%	4.41 d	5.56 a	2.07 c	0.48 b	ND
10%	7.30 c	5.44 a	2.47 b	0.50 ab	ND
15%	9.65 b	5.81 a	2.80 ab	0.52 ab	ND
20%	12.30 a	5.47 a	2.82 a	0.54 a	ND

[1]Means in the same column followed with same letter do not differ at $p < 0.05$.
[2]Non-detectable ND

TABLE 4.—*Physical properties of soil-compost treatments.*

Identification	Total Porosity % Vol	Air Space % Vol	Bulk Density g/mL	Available Water Field Capacity[1] g/g
Adjuntas: Compost				
0%	0.66 c[2]	0.15 bc	0.81 a	0.25 d
5%	0.70 ab	0.20 a	0.74 b	0.26 c
10%	0.71 a	0.20 a	0.70 c	0.27 b
15%	0.69 ab	0.18 ab	0.67 d	0.28 b
20%	0.68 bc	0.14 c	0.67 d	0.29 a
Corozal: Compost				
0%	0.71 b	0.31 a	0.73 a	0.27 c
5%	0.72 ab	0.28 ab	0.70 b	0.28 c
10%	0.73 a	0.28 ab	0.65 c	0.30 b
15%	0.72 ab	0.24 bc	0.63 cd	0.31 a
20%	0.73 a	0.22 c	0.62 d	0.30 b

[1]1/3 bar method.
[2]Means in the same column followed with same letter do not differ at $p < 0.05$.

detectable levels at 20%. Adding 5% compost to Corozal soil resulted in non-detectable levels of exchangeable Al^{3+}, whereas for Adjuntas soil the same application neutralized 3.44 cmol/kg of Al^{3+}. Thus, the 5% compost addition was more than enough to neutralize all exchangeable Al^{3+} present in Corozal soil. The humic substances have two main mechanisms to interact with exchangeable Al^{3+}: through the buffering capacity of humic substances that increase the soil pH, which in turn causes a decrease in the solubility of Al^{3+}; and through the formation of insoluble complexes between humic substances functional groups and Al^{3+}. A decrease in exchangeable Al^{3+} can increase available phosphorus, since less Al^{3+} is available to form $AlPO_4$. The soils amended with compost showed an increase in soil organic matter and in available P (Table 3). Aluminum is a main factor limiting agricultural production in highly weathered acid soils. This study shows that compost additions can decrease exchangeable Al^{3+}, and increase available P and organic matter, three important benefits that improve soil quality.

As compost increased, exchangeable Mg^{2+} and Na^{+} increased in both soils (Table 3). However, the effect of compost on exchangeable Ca^{2+} depended on the soil series. In the Adjuntas series, significant increases in exchangeable Ca^{2+} were measured among treatments. In the Corozal series there were no significant differences in exchangeable Ca^{2+} after compost treatments, probably because of its already higher Ca concentrations.

Table 4 shows no major trends for total porosity or air space in either soil. However, bulk density decreased as compost increased in both soils. The field capacity increased as compost amendment increased. The data is in accordance with the findings of Lugo-López et al. (1981b) who reported that when soil organic matter increased from 1 to 2% there was an increase in the amount of water retained at field capacity.

Coffee pulp compost is an excellent source of both mature organic matter and nutrients. The compost also decreased exchangeable Al^{3+} in the soils. Additional benefits to soil quality may result from the increase in water holding capacity and the decrease in bulk density.

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