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Managing the value of composts as organic amendments and fertilizers in sandy soils

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ABSTRACT

Nutrient rich composts are employed at low rates to minimize risks of N and P losses; this limits their value as soil improvers through C addition and the build up of soil organic matter. Blending with nutrient-poor composts such as those from the organic fraction of municipal solid waste could reduce the risks of nutrient losses while maintaining the positive effects on soil organic matter. We conducted a 2-yr experiment with composts of diverse origin: organic fraction of municipal solid waste (MC), cattle feedlot manure (FC), poultry litter (PC) and biosolids (BC), alone or blended (FC-MC, PC-MC) in a sandy soil under the humid warm climatic conditions of NE Argentina. We studied the effects of a single application (40 Mg ha^{-1}) on the surface soil (0–10 cm) properties of a permanent subtropical pasture through annual chemical and biological analyses. On five dates, available N and P were also determined at 0–10 cm and 55–65 cm. Soil total C and N increased over time while potential N mineralization and CO_2 emission decreased. All amendments resulted in similar increments of soil C and N despite marked differences in quantity and quality of organic matter inputs. Because MC had substantial amounts of Ca carbonates, it contributed to a reduction of available P from manure composts through dilution and precipitation. The release of available P from biosolids composts (where P is bound to Fe and Al) was lower than from manure composts (where P is bound by Ca phosphates). The highest environmental risk from compost application would likely be the leaching of soluble N produced during the composting process and released immediately after field application. Blending with N-poor MC would contribute to nitrate dilution.

1. Introduction

Disposal of manure and biosolids is cause for increasing concern in many countries due to the constantly growing demand for meat products and the increased construction of wastewater treatment plants. Due to their low C/N ratio and high available-P content, manures and biosolids can lead to nitrate leaching into groundwater and P runoff into surface waters, making land application a major nonpoint source of water pollution (Pierzynski, 1994; Moore et al., 1995; Siddique and Robinson, 2003; Sims and Sharpley, 2005). Low application rates are therefore needed to minimize environmental problems, and this limits the value of manure and biosolids as organic amendments, i.e., as soil improvers through carbon addition and the build up of soil organic matter (SOM).

Composting nutrient-rich wastes with carbon-rich materials stabilizes organic matter, resulting in products of low N mineralization rates. This improves the amendment value of organic wastes with respect to N pollution (Chang and Janzen, 1996; Escudero et al., 2012), but has little or no effect on P availability (Sharpley and Moyer, 2000; Dao et al., 2001). Several treatments have been proposed to reduce easily available P of raw and composted organic wastes, including P precipitation as Fe and Al salts or P adsorption on amorphous Fe and Al oxides and biochar (Moore et al., 1995; Callahan et al., 2002; Bock et al., 2015). In fact, available P in biosolids is often reduced by coagulation-sedimentation during sewage treatment through addition of Fe and Al salts (McCoy et al., 1986; Wen et al., 1997; EPA, 2004). An alternative involves blending and co-utilization of different wastes to minimize negative environmental impacts and to take advantage of synergistic effects in soil (Cooperband, 2000). For example, N and P-rich

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composts from animal manures or biosolids could be blended with nutrient-poor sources, such as composts from the organic fraction of municipal solid waste, which have low N- and P contents but are often reported as rich in Ca carbonates (Beck-Friis et al., 2003; Kowaljow and Mazzarino, 2007). This could dilute the high N and P contents, and decrease P availability through the formation of Ca-P precipitates.

Risks of nutrient losses vary with soil type and climate. Higher losses are expected in sandy soils due to low nutrient retention and lack of SOM protection (Weber et al., 2007; Guo and Li, 2012), and in humid and warm climates where microbial activity and decomposition are enhanced (Mtambanengwe and Mapfumo, 2006; Tu et al., 2006). In northeastern Argentina, sandy soils are developed from alluvial deposits of two large rivers (Paraná and Uruguay) under a subtropical humid climate. Their texture makes them prone to losing nutrients and organic matter and poses a serious threat to water quality when used for agriculture; therefore, management practices are needed that increase the build-up of SOM and reduce the loss of nutrients.

The objectives of this work were to determine the extent to which composts of diverse origin: organic fraction of municipal solid waste (MC), cattle feedlot manure (FC), poultry litter (PC) and biosolids (BC), alone or blended (FC-MC, PC-MC), differed in their effects on the properties of a sandy soil in subtropical NE Argentina. The study addressed two broad aspects related to the patterns of compost effects on soil: (a) the amendment value, in terms of increase and persistence of SOM, and (b) the fertilizer value, in terms of the supply of available nutrients, and the associated risks of losses. We hypothesized that (a) even under the extreme conditions of coarse-textured soils and humid warm climates, the application of stabilized organic matter would increase SOM due to limited microbial activity, and (b) mixtures of nutrient-rich manure composts with nutrient-poor MC would reduce the risks of nutrient losses while maintaining positive effects on SOM.

2. Materials and methods

2.1. Study site

The study was conducted near Santa Ana (province of Corrientes) in northeastern Argentina (27° 27′ 25.70″ S and 58° 40′ 26.76″ W, 65 m a.s.l.). The climate is subtropical, with a mean annual temperature of 21–22° C and a mean annual precipitation of 1100–1200 mm. Soils are classified as argic Udipsamments (Arenosols according to ISSS-ISRIC-FAO, 1998), have a sandy (0–40 cm) to sandy loam texture (40–100 cm), with a buried argillic horizon below 130 cm (Escobar et al., 1996). They are characterized by very low fertility at the surface (0–10 cm): 2.2 g kg^{-1} of organic C, 0.2 g kg^{-1} of total N, pH of 6.3, 0.02 dS m^{-1} electrical conductivity, 0.9 mg kg^{-1} Olsen-P and 0.03 kg kg^{-1} water content at 0.01 MPa. Soil textural composition at 0–10 cm is 91.0% fine sand (0.05–0.5 mm), 2.2% coarse sand (0.5–2.0 mm), 4.2% silt and 2.6% clay. The vegetation is a permanent grassland dominated by *Andropogon lateralis* and a mixture of the grasses *Sporobolus indicus* and *Paspalum notatum*, plus the forbs *Desmodium incanum*, *Bidens pilosa* and *Richardia* sp. During the study period (October 2011-December 2013), mean monthly temperatures varied from 13.6° C to 28.5° C, and monthly precipitation from 13 mm to 266 mm, June and July being the coldest and driest months (Fig. 1).

2.2. Compost characteristics

2.2.1. General characteristics

Biosolids compost (BC) and municipal compost (MC) were produced in NW Patagonia, in the cities of Bariloche (biosolids composting plant) and Villa La Angostura (municipal treatment plant), respectively. For the production of BC, biosolids were co-composted with wood shavings and yard trimmings, while MC was obtained from the organic fraction of municipal solid waste. The manure composts (FC and PC) were experimentally produced at the Universidad National de Córdoba (in central Argentina) and at the Universidad Nacional del Nordeste (in NE Argentina), respectively. FC was produced from beef cattle feedlot manure and sawdust, and PC from poultry manure, sawdust and rice hulls. Organic C, N and P were lower in MC than in BC, FC and PC; conversely, MC had the highest values of pH, total Ca and Ca carbonate (Table 1). Extractable P as percentage of total P was higher in manure composts (PC and FC), but the highest values of total P and N corresponded to PC and BC. All composts were stable and mature according to the following threshold values (Gómez-Brandón et al., 2008; Leconte et al., 2009): water soluble carbon (WSC) < 10 g kg^{-1}, WSC/total N < 0.7, NH_4-N/NO_3-N < 0.3, NH_4-N < 400 mg kg^{-1}, germination index (GI) > 60% (Table 1). Trace elements (Table S1) were below limits set in some European countries for composts (Houot et al., 2005; BOE, 2013). Differences

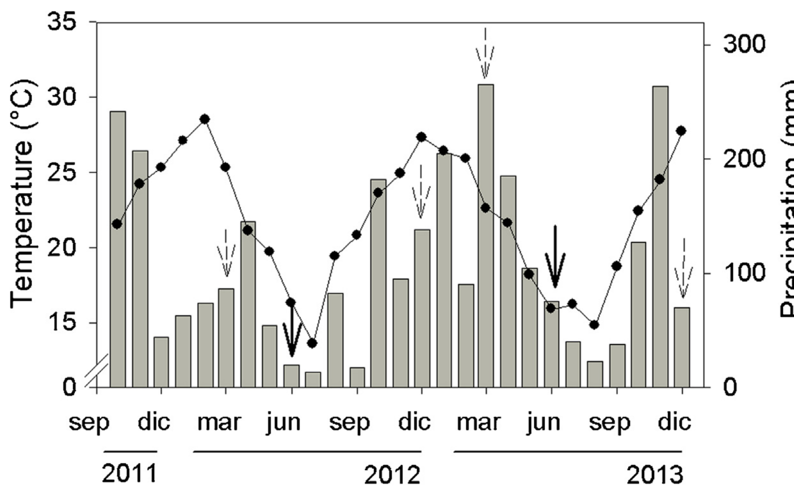

Fig. 1. Mean monthly temperatures (lines) and monthly precipitation (bars) during the study period. Arrows indicate soil sampling dates (full arrows for chemical and biological characterization at 0–10 cm; full- and dashed arrows for inorganic N and P analyses at 0–10 and 55–65 cm).