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Application of a green manure and green manure composted with beet vinasse on soil restoration: Effects on soil properties

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Abstract

Beet vinasse (BV), a green manure constituted by *Trifolium pratense* L. uncomposted (TP) and composted with beet vinasse (at 1:1 rate, (TP + BV)1, and 2:1 rate, (TP + BV)2) at 10 t organic matter ha^{-1} rate were applied during a period of four years for purpose of restoration of a Xelloric Calciorthid located near Seville (Guadalquivir Valley, Andalusia, Spain). The effect on the plant cover, soil physical (structural stability and bulk density), chemical (exchangeable sodium percentage), and biological properties (microbial biomass, soil respiration and enzymatic activities such as dehydrogenase, urease, β-glucosidase, phosphatase and arylsulfatase) were determined. The application of BV had a detrimental impact on soil physical (structural stability decreased 16.5% and bulk density increased 18.7% respect to the control soil), chemical (exchangeable sodium percentage increased 87.3% respect to the control soil), and biological properties (microbial biomass, soil respiration, and dehydrogenase, urease, β-glucosidase, phosphatase and arylsulfatase activities decreased by 53.5%, 24.5%, 27.8%, 15%, 39.7%, 42.7%, and 65.6%, respectively with respect to the control soil), probably because high quantities of monovalent cations (Na principally) were introduced into the soil by the vinasse, thus destabilizing its structure. The application of TP had a positive impact on soil physical (structural stability increased 5.9% and bulk density decreased 6.1% respect to the control soil), and biological properties (microbial biomass, soil respiration, and dehydrogenase, urease, β-glucosidase, phosphatase and arylsulfatase activities increased by 66.3%, 45.6%, 97.7%, 98.9%, 97.7%, 87.2%, and 89.4%, respectively with respect to the control soil). However, when BV was co-composted with a green manure, principally at a 2:1 rate, the resulting compost had a positive effect on soil physical (structural stability increased 10.5% and bulk density decreased 13.5% respect to the control soil), and biological properties (microbial biomass, soil respiration, and dehydrogenase, urease, β-glucosidase, phosphatase and arylsulfatase activities increased by 68.9%, 46.2%, 97.5%, 98.4%, 99.1%, 90.5% and 91.6%, respectively with respect to the control soil). After four years, the percentage of plant cover decreased 64.3% in the BV-amended plots respect to the control soil, whereas increased 82.8%, 81.6% and 81% in the (TP + BV)2, (TP + BV)1 and TP treatments, respectively. While the application of BV deteriorates the soil and therefore does not contribute to its restoration, the application of TP, and BV composted with TP protects the soil and will contribute to its restoration.

Keywords: Soil restoration; Beet vinasse; Green manure; Green manure composted with beet vinasse

1. Introduction

One of the major environmental concerns is soil degradation. Inappropriate technologies have resulted in soil quality deterioration, leading to soil organic matter losses and structure degradation, affecting water, air and nutrients flows, and consequently plant growth (Golchin et al., 1995; Tejada et al., 2006b). For this reason, the application of organic wastes with a high organic matter content, such as fresh and composted urban wastes (Ros et al., 2003), shredded and composted plant materials derived from

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municipal landscape (Walker, 2003), and cotton gin compost and poultry manure (Tejada et al., 2006b) to semiarid soils has become a common environmental practice for soil restoration, maintaining soil organic matter, reclaiming degraded soils, and supplying plant nutrients.

Organic by-products originating from industrial processes represent an important source of nutrients, especially for organic fertilization. In this respect, beet vinasse, a final by-product of the sugar industry, is a product of great interest because of its organic matter content (398 g kg^{-1}), N (32.5 g kg^{-1}) and K (126 g kg^{-1}) concentrations. Sugar beet is processed to produce crystalline sugar, pulp and molasses, the last being fermented to produce alcohol. After removal of the alcohol by distillation the remaining material is known as vinasse. In SW Spain, the annual production of beet vinasse is about 5×10^3 Mg (Madejon et al., 2001).

However, beet vinasse presents a high Na concentration (21 g kg^{-1}). This aspect is the main responsible for the deterioration of soil physical, chemical and biological properties after the addition of beet vinasse to soil under dryland conditions, favouring soil erosion as well as a decrease in soil microbial biomass and in crop productivity (Tejada and Gonzalez, 2005, 2006a). Some authors have suggested that the problems associated with the addition to soil fresh residues (such as beet vinasse) may be overcome by co-composting with solid agricultural wastes (Madejon et al., 2001; Diaz et al., 2002).

The application of green manures to soil is considered a good management practice in any agricultural production system because stimulate soil microbial growth and activity, with subsequent mineralization of plant nutrients (Eriksen, 2005), and therefore increase soil fertility and quality (Doran et al., 1988). Leguminous and non-leguminous plants are used as green manures. Leguminous green manures can fix large quantity of atmospheric N_2 and can provide useful amounts of organic matter on soil. Non-leguminous green manures only can increase the organic matter in soil and do not fix atmospheric N_2. For this reason, beet vinasse may be overcome by co-composting with green manures.

Physical and chemical properties have been used to evaluate the effects of the application of different sources of organic matter on soil during long-term experiments (Tejada and Gonzalez, 2004). However, such properties change very slowly and need many years to provide any significant results. In contrast, microbiological and biochemical properties are very responsive and provide immediate and precise information on small changes occurring in soil (Dick and Tabatabai, 1993). In fact, they may also indicate the soil's potential to sustain microbiological activity (Paul and Clark, 1989).

In view of the above, the objective of this study was to evaluate the effects of using fresh beet vinasse, green manures and beet vinasse composted with green manures as a bulking agent, as soil amendments at different rates on soil restoration, comparing some physical (soil structural stability and soil bulk density), chemical (exchangeable sodium percentage) and biological soil properties (soil respiration, soil microbial biomass and soil enzymatic activities) in a semiarid Mediterranean agro-ecosystem.

2. Methods

2.1. Site and properties of organic wastes

The study was conducted from October 2001 to October 2005 near Seville (Guadalquivir Valley, Andalusia, Spain) on a Xerollic Calciorthid (Soil Survey Staff, 1987) with a 2% slope. The general properties of this soil (0–25 cm) are shown in Table 1. Soil pH was determined in distilled water with a glass electrode (soil:H_2O ratio 1:1). Soil electric conductivity was determined in distilled water with a glass electrode (soil:H_2O ratio 1:5). Soil texture was determined by the Robinson's pipette method (SSEW, 1982) and dominant clay types were determined by X-ray diffraction. Soil Kjeldahl-N was determined by the Kjeldahl method (MAPA, 1986). Total $CaCO_3$ was measured by estimating the quantity of the CO_2 produced by HCl addition to the soil (MAPA, 1986). Soil organic carbon was determined by oxidizing organic matter in soil samples with $K_2Cr_2O_7$ in sulphuric acid (96%) for 30 min, and measuring the concentration of Cr^{3+} formed (Sims and Haby, 1971).

The organic wastes applied were: fresh non-depotassified beet vinasse (BV), a green manure composted and constituted by leguminous plants (*Trifolium pratense*, L.) (TP), and a compost obtained by mixing of TP and BV at a 1:1 rate [(green manure:beet vinasse) (weight:weight)] and 2:1 rate [(green manure:beet vinasse) (weight:weight)].

Plant residues were composted. Prior to composting, the residues were crushed using a shredder (Bione sgon 2.0, Sandri Garden srl). TP residues were composted in trapezoidal piles (2 m high by 2 m width by 3 m bug) and under aerobic conditions. The compost was turned once a week during the first month and every other week thereafter in order to maintain an aerobic environment in the pile. During the thermophilic phase, the piles were watered regularly

Table 1
Initial soil characteristics and standard error in parenthesis (data are the means of four samples)

pH	7.6 (0.14)
Electrical conductivity (dS m^{-1})	0.23 (0.04)
Clay (g kg^{-1})	313 (15)
Silt (g kg^{-1})	259 (22)
Sand (g kg^{-1})	428 (31)
Texture	Clay loam
Dominant clay types	Illite, illite-montmorillonite (interstratified)
$CaCO_3$ (g kg^{-1})	351 (25)
Kjeldahl N (g kg^{-1})	0.9 (0.03)
Total C (g kg^{-1})	6.3 (0.09)
C/N ratio	7 (3)