Catena 77 (2009) 238–247

Contents lists available at ScienceDirect

Catena

journal homepage: www.elsevier.com/locate/catena

Effects of a vermicompost composted with beet vinasse on soil properties, soil losses and soil restoration

M. Tejada [a,*], A.M. García-Martínez [b], J. Parrado [b]

[a] Departamento de Cristalografía, Mineralogía y Química Agrícola, E.U.I.T.A. Universidad de Sevilla, Crta de Utrera km. 1, 41013 Sevilla, Spain
[b] Departamento de Bioquímica, Toxicología y M.L. Facultad de Farmacia. Universidad de Sevilla, C/ Prof. García González 2, 41012 Sevilla, Spain

ARTICLE INFO

Article history:
Received 10 November 2008
Received in revised form 9 January 2009
Accepted 20 January 2009

Keywords:
Soil erosion
Soil restoration
Beet vinasse
Vermicomposts

ABSTRACT

The use of organic rich wastes instead or as a complement of mineral fertilizers is considered a good environmental practice, provided that the organic wastes are not severely polluted (e.g. occurrence of heavy metals, organic pollutants and/or pathogens). However, the effect of a particular organic waste on soil properties, soil loss and soil restoration depends on its chemical composition. In particular, the application of fresh beet vinasse showed a detrimental impact on the soil's physical, chemical and biological properties, increasing soil loss and decreasing plant cover, probably because it contains high quantities of monovalent cations, such as Na^+, which destabilize the soil structure. The main objective of this work was to study the effect of beet vinasse co-composted with a vermicompost (constituted by green forages) at rates of 5 and 10 t kg organic matter ha^{-1}, on physical (structural stability and bulk density), chemical (exchangeable sodium percentage) and biological (soil microbial biomass-C, soil respiration and soil enzymatic activities) properties of soils and, consequently, how its application may contribute to soil loss and soil restoration. The experiment was carried out for three years on a Xerollic Calciorthid located near Seville (Guadalquivir Valley, Andalusia, Spain). The co-composting of beet vinasse and green waste vermicompost had a positive effect on the soil's physical, chemical and biological properties, leading to a decrease in soil loss (31.2% compared with unamended soil) and an increase in plant cover (68.7% compared with unamended soil). These results suggest that the co-composting of beet vinasse with vermicomposts protects the soil and contributes to its restoration, thus representing a good strategy for recovering semiarid areas.

1. Introduction

Organic byproducts with lowest heavy metal contents and free of organic pollutants and/or pathogens resulting from industrial processes represent an alternative to inorganic fertilizers and an important source of nutrients, especially for organic farming. In particular, beet vinasse (BV), a byproduct of the sugar industry, is a product of great potential agricultural interest, because of its organic matter (OM) content, and N and K concentrations (Madejon et al., 2001). Sugar beet is processed to produce crystalline sugar, pulp and molasses, the last being fermented to produce alcohol. After the alcohol removal by distillation, the remaining material is known as vinasse. In SW Spain, the annual production of BV is about 5×10^3 Mg (Madejon et al., 2001).

Despite the high OM and nutrients it contains, BV contains a high Na concentration (21 g kg^{-1}). This sodium is mainly responsible for the deterioration of soil physical, chemical and biological properties after the addition of BV to soil under dryland conditions, favouring soil erosion as well as a decrease in soil microbial biomass and in crop productivity (Tejada et al., 2006a,b, 2007). Also, these authors found that the low heavy metal concentration in BV didn't cause inhibition in the soil biological activity. For this reason, Tejada et al. (2008) suggested co-composting the BV with other organic wastes to dilute the Na concentration. However, this dilution effect will depend on the chemical nature of the organic waste. Tejada et al. (2008) found that the co-composting of BV with green manures was very effective, avoiding a deterioration of the soil properties.

However, traditional methods of composting results in losses of 55% of OM and from 30 to 50% of N (Ketkar, 1993). Vermicomposting, utilizing earthworms, has been recognized as an eco-biotechnological process that transforms complex organic substances into a stabilized humus-like product (Benítez et al., 2000). Earthworms accelerate the mineralization rate and convert the manures into casts with higher nutritional value and degree of humification than traditional method of composting (Albanell et al., 1988). The increased mineralization and conservation of nutrients is due to the activity of earthworms in the decomposition and conservation mechanism (Suthar, 2007). The

* Corresponding author. Tel.: +34 954486468; fax: +34 954486436.
E-mail address: mtmoral@us.es (M. Tejada).

0341-8162/$ – see front matter © 2009 Published by Elsevier B.V.
doi:10.1016/j.catena.2009.01.004

application of vermicompost 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, and therefore produce an increase soil fertility and quality (Arancon et al., 2006; Ferreras et al., 2006). Thus, the co-composting of BV with vermicomposts might be a solution to the above mentioned problems, also in dryland conditions.

Several authors have shown the importance of the soil OM matter content on soil erosion indicating that an increase in soil OM content entails a decrease in soil loss (Barthès et al., 1999; Auerswald et al., 2003; Tejada and González, 2007). The soil OM content is involved in water erosion processes since runoff affects the uppermost layer of soil, in which most of the OM accumulates.

One of methods considered most effective in controlling soil erosion is the restoration of eroded soils. In this respect, the application of organic wastes with a high OM content, such as fresh and composted urban wastes (Ros et al., 2003), sewage sludge (Moreno et al., 1999), shredded and composted plant materials derived from municipal landscaping (Walker, 2003), and cotton gin compost and poultry manure (Tejada et al., 2006b), to semiarid soils has become a common environmental practice for restoring soils.

The objective of this study was to evaluate the effects of beet vinasse composted with a vermicompost as bulking agent on physical, chemical and biological properties of a soil located in a semiarid Mediterranean ecosystem, and their potential in the control of soil erosion as well in its restoration.

2. Material and methods

2.1. Site description and organic wastes features

The study was carried out from October 2003 to October 2006 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.

The climate is semiarid with an average annual precipitation of 400 mm for the three experimental years, concentrated in the spring and autumn months. The mean annual temperature of the three experimental years was 17.3 °C and mean potential evapotranspiration was 700 mm year^{-1}. Thus the long-term water deficit, calculated by the Thorntwaite method, is 436 mm. July and August are the driest months.

The area is a fragile environment strongly marked by erosion. Harsh physical conditions and inadequate soil uses by man have resulted in a dissected landscape where furrows, rills and gullies scour both the hill slopes and the weak deposits which fill the low-lying regions.

Table 1
Initial soil characteristics

pH	7.7 (0.2)
Electrical conductivity (dS m^{-1})	0.22 (0.09)
Clay (g kg^{-1})	319 (15)
Silt (g kg^{-1})	272 (27)
Sand (g kg^{-1})	409 (39)
Texture	Clay loam
Dominant clay types	Illite, illite–montmorillonite (interstratified)
Instability index (log 10.Is)	1.53 (0.06) (slightly stable)
Bulk density (Mg m^{-3})	1.47 (0.04)
Total carbonates (g kg^{-1})	341 (22)
Total N (g kg^{-1})	0.83 (0.04)
Total C (g kg^{-1})	6.4 (0.05)
C/N ratio	7.7 (2.1)
Exchangeable sodium percentage	2.1 (0.1)

Data are the means of four samples. Standard error is reported in parenthesis.

Table 2
Characteristics of green forages before the vermicomposting process

pH (1/10 ratio)	7.5 (0.1)
Organic matter C (g kg^{-1})	529 (24)
Total N (g kg^{-1})	5.4 (0.3)
C/N ratio	77.6 (4.3)
Total P (g kg^{-1})	4.5 (0.4)
Total K (g kg^{-1})	5.6 (0.7)

Data are the means of five samples. Standard error is reported in parenthesis.

The organic wastes applied were a fresh non-depotassified beet vinasse (BV), vermicompost (V), and a compost obtained by the co-composting of the BV and the V (BVV) at a 1:1 rate (weight:weight).

The vermicompost was obtained using green forages (constituted basically by grasses, green vegetable leaves, herbs and plant materials) as substrate. The general properties of the green forages utilized are shown in Table 2. Organic matter was determined by dry combustion (MAPA, 1986). Total C was determined by dichromate oxidation (Yeomans and Bremner, 1988). Total N was determined by the Kjeldahl method (MAPA, 1986). After nitric–perchloric (1:1) acid digestion of both organic wastes, total P was determined by the Willians and Stewart method, described by Guitian and Carballas (1976) and total K by atomic emission spectrometer.

Green forages were vermicomposted on a bed consisting of a wooden frame (Benítez et al., 2002). Each bed was filled with 80 kg of substrate and inoculed with 800 adult epigeic earthworms (*Eisenia fetida*). The worms were introduced in the green waste material after three weeks of the beginning the composting. The moisture level of both organic wastes was maintained at about 65–70% during the vermicomposting period by periodically sprinkling with water. The vermicomposting process lasted 85 days.

The combination of BV and V (BVV) was composted in trapezoidal piles (2 m high × 2 m wide × 3 m long) 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 to maintain the moisture content at around 55%, according to McKinley et al. (1985). The composting process was considered to have concluded after 83 days, when the C/N ratio and the temperature had become constant.

Table 3
Characteristics of organic wastes used

	BV	V	BVV
pH (H_2O)	4.8 (0.1)	7.0 (0.2)	8.4 (0.2)
Density (Mg m^{-3})	1.26 (0.08)		
Organic matter (g kg^{-1})	395 (22)	311 (34)	632 (38)
Humic acid-C (g kg^{-1})	0.67 (0.19)	64.8 (3.1)	64.6 (2.7)
Fulvic acid-C (g kg^{-1})	81.3 (4.8)	22.6 (1.6)	98.7 (5.2)
Total N (g kg^{-1})	33.8 (2.1)	13.5 (1.8)	44.8 (2.3)
C/N ratio	5.8 (1.2)	11.5 (2.4)	7.1 (1.6)
P (g kg^{-1})	0.4 (0.1)	8.1 (1.1)	7.9 (1.6)
Ca (mg kg^{-1})	35 (6)	11.9 (0.8)	30 (2.4)
Mg (mg kg^{-1})	14 (2)	7.2 (0.6)	16.2 (1.1)
Na (g kg^{-1})	20 (3)	0.3 (0.1)	9.6 (1.2)
K (g kg^{-1})	120 (18)	12.6 (1.3)	126 (3.8)
Fe (mg kg^{-1})	221 (13)	198 (24)	242 (20)
Cu (mg kg^{-1})	2.3 (0.4)	1.4 (0.6)	2.5 (0.8)
Mn (mg kg^{-1})	3.1 (0.5)	1.9 (0.8)	3.6 (0.4)
Zn (mg kg^{-1})	11 (0.8)	3.2 (0.9)	12.8 (0.5)
Cd (mg kg^{-1})	<0.1 (<0.01)	<0.1 (<0.01)	<0.1 (<0.01)
Pb (mg kg^{-1})	<0.1 (<0.01)	<0.1 (<0.01)	<0.1 (<0.01)
Ni (mg kg^{-1})	<0.1 (<0.01)	<0.1 (<0.01)	<0.1 (<0.01)
Cr (mg kg^{-1})	<0.01 (<0.001)	<0.01 (<0.001)	<0.01 (<0.001)

Data are the means of five samples. Standard error is reported in parenthesis.