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Nutrient release from composts into the surrounding soil

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ABSTRACT

Improved understanding of the effect of compost application on soil properties is critical for optimizing the desired effects of compost application. However there are no studies on the effect of composts on soil properties within the first centimetres of the compost layer. In this microcosm study three composts from different feedstocks, namely C1 (from animal manures) and C2 and C3 (from the organic fraction and municipal solid waste) were applied as a layer which was separated from the soil by a mesh. Microcosms without compost served as controls. Microbial and chemical properties of the soil were determined at 0–5 and 5–10 mm distance from the mesh after 30 and 63 days. During the 63 day incubation, the total C, N and P and available N concentrations in the composts decreased whereas the available P concentration increased. The composts induced higher microbial biomass and activity, total organic C and available N and P concentrations up to 10 mm into the surrounding soil with greater effects after 30 than after 63 days. The increase in nutrient concentrations was generally greater in soil adjacent to the two finer-textured composts with the higher nutrient concentration (C1 and C3) than in the coarser-textured compost (C2) which had lower nutrient concentrations, however the differences in nutrient concentrations in the soil were small compared to those among the composts. The 0–5 and 5–10 mm layers did not differ in most of the measured properties except for greater soil respiration and N and P availability in the 0–5 mm layer. It is concluded that composts release nutrients into the surrounding soil over a period of 2 months which increase nutrient availability and microbial activity, with the zone of influence extending at least 10 mm from the compost-soil interface.

1. Introduction

Soil degradation as a result of poor management is a major environmental and agricultural concern and often related to a loss of organic matter and low nutrient availability. To enhance productivity and restore degraded soils, fertiliser application is often necessary. With fertiliser prices increasing, organic amendments such as composts, manures or plant residues as sources of nutrients and organic matter are becoming more attractive (Sanchez-Monedero et al., 2001; Tejada et al., 2009). Compared to residue or manure application, composts contain highly degraded organic material (Mylavarapu and Zinati, 2009; Zameer et al., 2010) and may therefore have longer-lasting effects than the more rapidly decomposing residues and manures. In previous studies of Duong et al. (2012), Kawasaki et al. (2008) and Jedidi et al. (2004), the effect of composts on soil properties is dependent on their nutrient concentration and particle size which in turn are affected by compost feedstocks, composting conditions and duration.

The effect of compost mulches on soil properties is often assessed in the underlying soil without consideration of the distance from the compost layer. It is well-known that the detritusphere (the soil surrounding residues) is a hotspot of microbial activity and nutrient availability (Bastian et al., 2009; Gaillard et al., 2003; Poll et al., 2008, 2010). Lupwayi et al. (2004) and Jedidi et al. (2004) found that TOC, MBC and microbial activity of the 0–5 cm soil layer were significantly higher than in deeper soil layers after organic matter addition. Therefore it is reasonable to assume that the effect of composts on soil properties is also most pronounced in immediate vicinity of composts. This is of practical interest as roots grow towards such hotspots and could therefore take advantage of the nutrients released from the composts. However, there are no studies on chemical and biological properties in the immediate vicinity of composts.

Therefore the aims of this study were to assess (i) nutrient concentration and microbial activity in 0–5 mm and 5–10 mm distances from a layer of compost, (ii) changes in compost properties over time and (iii) how these parameters are influenced by compost properties.

2. Materials and methods

2.1. Experimental design

A sandy clay loam was collected from 0 to 20 cm depth in a natural bushland in Monarto (latitude 35°05′S, longitude 139°06′E and

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elevation 166 m) in the semiarid region of South Australia, on the eastern slopes of the southern Mount Lofty Ranges.

The soil has the following properties: Sand 71.9%; silt 6.4%; clay 21.8%; pH 8.6 (1:5 soil: water); electrical conductivity (EC1:5) 0.07 dS m^{-1}; total organic C 14.4 g kg^{-1}; dissolved organic C (DOC) 1.9 mg kg^{-1}; water-holding capacity (WHC) 0.25 g g^{-1}; total P 137 mg kg^{-1}; resin P 2.8 mg kg^{-1}; total N 1.9 g kg^{-1} and available N 12.6 mg kg^{-1}. The soil was air-dried at room temperature and all visible plant debris were removed manually before sieving to <5 mm. The soil was pre-incubated for 10 days at 75%, previous studies had shown that soil respiration and plant growth were maximal at this water content in soils of similar texture (Mat Hassan et al., 2011; Setia et al., 2011). Three composts were used in this experiment: C1 (from animal manure) and C2 and C3 (from the organic fraction of municipal solid waste).

Two PVC end caps (height 20 mm, diameter 70 mm) were filled with 110 g of pre-incubated soil and adjusted to a bulk density of 1.5 g cm^{-3}. Fine nylon mesh (0.1 mm × 0.8 mm) was cut into circles with a diameter of 85 mm and placed over the soil to cover the open side of each cap. The three composts were placed on the mesh of one of the microcosms corresponding to 27, 23 and 27 g moist composts per microcosm for C1, C2 and C3, respectively. Then the second cap was placed on the compost so that the compost layer was between the two meshes. In the unamended treatment, the soil in the two end caps was separated by the two layers of mesh. The two caps were held together with rubber bands and sealed with tape to prevent composts from falling out. Holes on the closed sides of the PVC caps allowed adding water and ensured aeration. The microcosms were incubated at 25 °C in the dark for 63 days. The moisture content was maintained by weight by adding water every 4 days. The microcosms were destructively harvested after 30 and 63 days. There are four replicates per treatment and sampling time. At each sampling, the two PVC caps were carefully separated from each other and the two layers of mesh with composts in between were removed and collected for determination of compost properties. The soil from the two end caps of each treatment was collected in different distances from the mesh: 0–5 mm and 5–10 mm.

2.2. Analyses

2.2.1. Physicochemical analyses of soils and composts

Soil particle size was determined by the hydrometer method (Ashworth et al., 2001).

Soil and compost pH and EC were measured in a 1:5 soil/water suspension (w/w) after 1 h end-over-end shaking at 25 °C. The EC is a measure of the concentration of soluble salts in a solution and 1 dS m^{-1} of EC is equivalent to 585 mg NaCl L^{-1}. The soil field capacity was measured using a pressure plate connected to a 100-cm water column ($\Psi m = -10$ kPa) (Klute, 1986).

Inorganic N (NH_4^+-N and NO_3^--N) of soil and composts was extracted with 2 M KCl at a 1:10 dry soil:solution ratio with 1 h shaking (Keeney and Nelson, 1982). The supernatant was filtered through a Whatman no. 42 filter paper and stored at 4 °C until analysis. Available N was then measured by the Kjeldahl distillation method as described by Mckenzie and Wallace (1954). Available P was extracted with anion exchange resin membranes following Kouno et al. (1995); P was analysed colorimetrically as described by Murphy and Riley (1962). For total P of soil and compost, 100 mg of air-dried soil or 250 mg of compost was digested by adding 7 mL nitric and perchloric acid mixtures (6:1). Total P was measured using the phosphovanado-molybdate method (Hanson, 1950; Kitson and Mellon, 1944). Total N in soil and compost was determined using the method from Bradstreet (1965).

Total organic C (TOC) of soil and compost was measured using wet digestion with sulphuric acid and an aqueous dichromate mixture and the digests were then back-titrated for the residual potassium dichromate with ferrous sulphate (Walkley and Black, 1934). For dissolved organic C (DOC), 5 g of soil or compost was shaken with 25 mL distilled water (1:5 w/v soil:solution ratio) for 60 min at a speed of 200 rpm. The soil extracts were then centrifuged at 28,200 ×*g* for 10 min; then supernatant vacuum-filtered through a 0.45 μm filter and stored at −20 °C until analysis. The C concentrations in the extracts were measured as described below for MBC.

The method to determine the germination index (GI) was adapted from Zucconi et al. (1981) using *Triticum aestivum* L as test plant (three replicates). Ten grams of moist compost was shaken with 100 mL distilled water for 1 h, centrifuged for 15 min at 10,600 ×*g* and the supernatants were filtered. Ten wheat seeds were placed on filter paper Whatman no. 1 in a Petri dish of 10 cm diameter and 2 mL of the extract was added. Two mL of reverse osmosis (RO) water was used for the control. After 48 h, the root length of each wheat seedling was measured. The germination index is expressed as a percentage based on total length of roots on the compost test plates × 100 and divided by total length of roots on the control plates.

2.2.2. Biomass determination

Microbial biomass C (MBC) was determined at the end of the experiment by fumigation extraction (Vance et al., 1987) as described in Anderson and Ingram (1993) using 5 g of soil. Organic carbon in the extracts was determined after dichromate digestion by titrating with 0.033 M acidified ferrous ammonium sulphate (Anderson and Ingram, 1993). Microbial biomass C was calculated from the difference between chloroform fumigated and non-fumigated samples. No multiplication factor was used because the relationship between actual microbial biomass and that derived by this method in these soils is not known.

2.2.3. Respiration

For respiration, 30 g of moist soil of each layer and microcosm was placed in cores of 3.7 cm in diameter and 5 cm height with a nylon mesh base and adjusted to a bulk density of 1.5 g cm^{-3}. The cores were placed in 1 L glass jars with gas-tight lids equipped with a septum for measurement of respiration over 14 days. Respiration was measured with a Servomex 1450 series food-pack gas analyser every 24 h for the first four days, and every 48 h from day 6 to day 14. For each measurement period, the CO_2 concentration in the headspace was measured immediately after sealing the jars. The closed jars were then incubated for a defined duration and then a second measurement of the CO_2 concentration in the headspace was taken. After the second measurement, the jars were opened to refresh the headspace in the jars using a fan. The CO_2 that evolved from the each sample was calculated as the difference between the initial and final CO_2 concentrations for each measurement period. The infra-red gas analyser was calibrated using known amounts of CO_2 injected into glass jars similar to those used for the samples. Linear regression was used to define the relationship between CO_2 concentration and detector response. This relationship was used to calculate the CO_2 concentration in the jars. The calculated CO_2 concentration was multiplied by the gas volume of the jars to obtain the mL of CO_2–C respired during each measurement period and divided by the soil dry weight.

2.3. Statistical analysis

A complete randomised block design with four replicates was used with 3 (compost) × 2 (sampling time) × 2 (soil layers) factorial design. The data was statistically analysed by three-way analysis of variance (GenStat® for Windows 11.0, VSN Int. Ltd, UK, 2005). If there were no significant differences between the two soil layers, the average of the two layers was calculated and the data re-analysed by two-way analysis of variance. Tukey test and linear regression were used to determine significant differences and correlations of treatments in the measured parameters. Significant differences refer to $P \leq 0.05$.