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Phosphorous extractability and ryegrass availability from bio-waste composts in a calcareous soil



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HIGHLIGHTS

- Four stable composts were selected on the basis of the water soluble P (H₂O-P).
- Sequential extraction showed composts had also different labile P (H₂O + NaHCO₃).
- Pot test on ryegrass showed different P apparent recovery (ARF) for each compost.
- Ryegrass ARF fitted to H₂O-P and NaHCO₃-P in the short and in the middle term.

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ABSTRACT

In this work four stable bio-waste composts (C1, C2, C3, C4) were selected on the basis of their increasing water soluble P (H₂O-P). The P speciation was assessed via sequential chemical extraction (SCE) on the same products. Moreover, the plant-available P was assessed via apparent recovery fraction approach (ARF) in a pot test on ryegrass over 21 weeks at 15 mg P kg⁻¹ of soil. An inorganic P source (P-chem) was added as a reference at the same P rate in addition to a non-fertilized control (Control). SCE showed that the sparingly soluble P (HCl-P) was the most important fraction in all composts: C1 (HCl 65% > NaHCO₃ 17% = NaOH 17% > H₂O 1%); C2: (HCl 51% > NaOH 23% > NaHCO₃ 18% > H₂O 7%); C3: (HCl 58% > NaOH 21% > NaHCO₃ 12% > H₂O 9%); C4: (HCl 39% > NaOH 23% > NaHCO₃ 22% > H₂O 16%). The plant test showed that the different treatments had a different ARF (%) at the first harvest: P-chem (14.7) > C4 (14.4) > C3 (14.1) > C2 (3.4) > C1 (3.1), compared to the cumulated ARF (%) of the six harvests: C4 (50.1) > C3 (35.0) > C1 (21.1) > C2 (18.3) > P-chem (17.4). Data showed a good correlation of H₂O-P vs. plant ARF at the first harvest and a good correlation of labile P (H₂O-P + NaHCO₃-P) vs. total plant ARF over 21 weeks. The free and labile P forms from SCE can be a valuable tool in the assessment of fast and middle term plant-available P form stable bio-waste composts in calcareous soils.

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* Corresponding author. E-mail address: marco.grigatti@gmail.com (M. Grigatti). high level of crop production, most (about 80%) of the P derived from rock phosphate is utilized for these aims (Cordell et al., 2009). For resource conservation, it is important that recycling of nutrientrich organic waste (mainly nitrogen and phosphorus) can represent an important pathway to return P to the soil-system as an alternative to phosphate rock extraction (Van Vuuren et al., 2010). It is widely recognized that returning recycled organic matter (OM) to the soils can be a winning strategy to preserve their organic carbon content; to maximize the beneficial effects from this practice, the best option is to return well stabilized OM to the soils. The use of stabilized OM such as compost can strongly reduce the risks derived from the use of fresh materials in soils, like GHG emissions, in addition to the potential phytotoxicity and possible immobilization of nitrogen (N). Many investigations have dealt with this topic, and N availability from compost has been widely investigated after OM addition to agricultural soils (Bachmann et al., 2011; Barbanti et al., 2011; Grigatti et al., 2014), while much less information is available on the use of P by plants from this kind of products (Brod et al., 2015a,b; Grigatti et al., 2015). In this framework the main problem regarding the rational utilization of compost as a valuable source of P is the amount and the timepattern of the element's release which can restrict P plant accessibility, or oppositely can lead to environmental problems by possible leaching (Preusch et al., 2002; Löbermann et al., 2007; Garcia-Albacete et al., 2012). In composts, P may be present in many different forms such as free, labile, or bounded, it being inorganic or organic (Sharpley and Moyer, 2000; Takahashi, 2013; Nanzer et al., 2014), thus reflecting the different forms of potentially available P for plants (Garcia-Albacete et al., 2012; Vandecasteele et al., 2014; Grigatti et al., 2015). To study these aspects sequential chemical extraction (SCE) was successfully applied to composts of many different types, aiming to determine the pattern of P solubility (Dou et al., 2000; Takahashi, 2013; Grigatti et al., 2015), while X-ray diffraction was used to assess the presence of crystalline compounds in similar products (Komiyama et al., 2013; Hashimoto et al., 2014; Grigatti et al., 2015). SCE procedures with increasing strength extractants (i.e. H₂O; NaHCO₃ pH 8.5, 0.1 N NaOH, 1 N HCl) can well describe the different P fractions indicated as: free-P, labile-P, metal bounded-P, and sparingly soluble-P (Hedley et al., 1982; Dou et al., 2000). In this framework, the free-P forms are recognized to be readily available to plants, but on the other hand these are the first to be possibly leached once added to soil. In this light a better knowledge of the free-P forms in composts besides the labile-P ones can be important for their rational utilization for plant nutrition and also for environmental issues. Both increases and decreases of free P forms (H₂O-P) have been reported during the composting of different types of waste (Wei et al., 2015), showing that different raw materials and process conditions affected this feature. It is also reported that mineralization of the organic P fractions (often bound to metals) can occur during composting, with a shift towards the NaHCO3 extractable inorganic P (considered to be easily accessible for plants immediately after H₂O-P), and towards the sparingly soluble fraction (extractable in HCl), not available for plants (Traoré et al., 1999; Eneji et al., 2003). The metal-bound fraction extractable in alkali is claimed to become available to plants in the long term (Hedley et al., 1982). As previously said, several studies focused on the assessment of P extractability from different kinds of organic waste, mainly relating this issue to their chemical characteristics (Garcia-Albacete et al., 2012; Vandecasteele et al., 2014), while there are fewer studies that also involve biological tests with plants (Brod et al., 2015a,b; Grigatti et al., 2015). The laboratory assessment of

Phosphorous (P) is a key element for plant growth. To sustain a

P solubility from composts provides a good insight into its potential availability to plants. In this framework, in addition to SCE, plant tests may be usefully adopted to investigate these aspects (Khan and Joergersen, 2012), providing more complete insight into the amount of actual plant-available P and also into its pattern of release over time. To study this aspect, Italian ryegrass (*Lolium multiflorum*) is often utilized in phosphorus recovery studies (Khan and Joergersen, 2012; Grigatti et al., 2015); due to the fast growth of this plant it can be utilized in a multiple-cuts arrangement in a short time (about 4–6 months), providing the opportunity to also describe the element's uptake kinetics. A better understanding of potential P availability and plant P uptake from composts can help their rational use, also reducing the utilization of rock phosphate for a more sustainable agriculture.

In this light we selected four stable bio-waste composts on the basis of increasing water soluble P from a collection of composts of different origin and stabilization level (oxygen uptake rate, OUR). On these four composts we investigated the relationships between chemically extractable P determined via sequential extraction and plant P recovery in a calcareous soil. The aims of this work were (i): to assess the phosphorus fractionation via SCE; (ii) to assess the relationships between the extractable P forms following SCE and plant P uptake. To do this the selected bio-waste composts were utilized as fertilizer in a pot test, and the P uptake was determined over 21 weeks on ryegrass via apparent recovery fraction assessment in comparison with chemical P source [Ca(H₂PO₄)₂•H₂O].

2. Materials and methods

2.1. Organic products

Four composts were collected by C.I.C. (Consorzio Italiano Compostatori), from different composting plants in Italy in 2013 (Table 1). These were produced from separately collected bio-waste (BW) and green waste (GW) from gardens and parks. More specifically, compost C1 was obtained after 60 days of composting of the residues of the anaerobic digestion of BW mixed with GW (20 + 80% V/V). Composts C2 and C3 consisted of BW and GW (20 + 80% V/V) and composted for 90 days. Last, C4 consisted of BW and GW (10 + 90%), composted for 90 days. All fresh products were analyzed for pH, electric conductivity (EC) in H₂O (1:10), total solids (TS), and volatile solids (VS) content. The OUR was determined on fresh products according to Grigatti et al. (2007), in three replicates. The organic products were then air dried, ball milled and analyzed for the main physical-chemical parameters. On the air dried-ball milled products, the total carbon (TC) and total nitrogen (TN) were determined by using an elemental analyzer (Thermo Fisher Scientific). Total nutrients and trace elements content was determined by ICP (Inductively Coupled Plasma-OES, Spectro Arcos, Ametek) on ≈ 250 mg of samples after microwave assisted digestion with 65% HNO3 + 37% HCl, all the analyses were done in two replicates. The main physico-chemical characteristics of the organic products are reported in Table 1.

2.2. Sequentially extractable phosphorus

The phosphorous fractionation was done according to Dou et al. (2000). The inorganic P (Pi) was colorimetrically determined on the extracts (Watanabe and Olsen, 1965). Total P in the extracts (Picp) was determined by ICP-OES. Organic P (Po) was calculated as the difference between Picp and Pi in the first four fractions.

2.3. X-ray diffraction

The X-ray powder diffraction (XRD) patterns of compost

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