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Evaluation of compost from seaweed and fish waste as a fertilizer for horticultural use

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ABSTRACT

Composting may be an effective process for treating fish waste and drift seaweed to recover organic matter and nutrient resources and to produce fertilizers for organic agriculture. The aim of this study was to evaluate the use of this type of compost as a fertilizer in a horticultural crop rotation. A greenhouse trial was carried out to test the effects of the compost on a tomato crop and its residual effects on the succeeding lettuce crop. Different compost rates (C1, C2 and C3: 40 t ha^{-1}, 50 t ha^{-1} and 66 t ha^{-1}) were compared to single rates of a mineral fertilizer (M) and of a certified organic fertilizer made from dehydrated broiler litter (BL) as well as to the control treatment, which lacked fertilization (C). Tomato yield increased significantly (5.56 kg $plant^{-1}$) with the highest rate of compost compared to the mineral and control treatments (4.54 and 4.58 kg $plant^{-1}$, respectively). This increased yield was associated with an increase in the diameter and weight of the fruits. Moreover, the lettuce yield improved with compost rates C2 (395 g $lettuce^{-1}$) and C3 (367 g $lettuce^{-1}$), showing a strong residual effect of the compost. This compost is suitable as organic soil fertilizer and may be recommended for improving horticultural crop yields.

1. Introduction

The organic matter (OM) content of soil is one of the main indicators of its quality and agronomic productivity, and the influence of OM on the physical, chemical and biological qualities of soil has been widely reported (Reeves, 1997). Organic matter accumulates in soil when carbon (C) inputs exceed C outputs, and in agricultural systems, losses of OM due to mineralization generally exceed gains because of the large amounts of OM removed during crop harvesting. The practice of harvesting most biomass of crops along with other factors, such as intensive soil tilling, accelerates the loss of C from the soil (Weil and Magdoff, 2004). Organic materials have been used for centuries to counteract these losses of soil OM and to supply variable amounts of nutrients to the soil.

Suitable materials for composting are found abundantly in coastal areas. One such material is fish waste, which is yielded as a by-product of fish markets and fish processing industries. Depending on the type of transformation, the waste may represent between 30 and 45% of the initial weight of the product. The most common destination for these by-products is fishmeal production, in a management system that yields economic benefits for the businesses involved. Fish waste is suitable for agricultural use because it contains large amounts of nutrients, such as N, P and Ca (Illera et al., 2010). Several fertilizers made from fishmeal are now commercially available and some are authorized for use in organic agriculture (EC Regulation 2092/91, 1991). Even fish effluent can be used to irrigate cherry tomato plants (Castro et al., 2006).

Another resource available in coastal areas is beached seaweed that is deposited on beaches in large amounts as a result of tidal or wind action. Drift seaweed is a natural resource in coastal habitats and has been used sustainably in agriculture for several centuries (Zemke-White and Ohno, 1999; McHugh, 2003) due to its value as a fertilizer. Seaweed is particularly rich in potassium (K) and micronutrients as well as growth activators such as auxins, cytokines and alginates, which improve the soil structure (Blunden, 1991; Verkleij, 1992; López-Mosquera and Pazos, 1997; Stirk et al., 2004; Papenfus et al., 2013). In addition, seaweed is a resource with many applications in human life, such as human food, animal feed or in the industry due its high polysaccharide content. Nevertheless, algae sometimes represents a waste, causing eutrophication and generating the so-called green tides (Morand and Briand, 1996) that cause serious environmental problems in different parts of the

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world. These green tides affect coastal activities such as the recreational use of beaches (Rosenberg, 1985; Piriou and Menesguen, 1992; Eyras et al., 1998), aquaculture and shellfish harvesting (Niell et al., 1996). When this occurs, the algae are usually removed and dumped, leading to the loss of a potentially valuable resource.

Both of the above-mentioned materials are of great potential use in agriculture. However, the stabilization of these types of materials is recommended prior to their use to prevent problems associated with the appearance of phytotoxic substances (Michalak and Chojnacka, 2013) and to diminish their water contents and transportation costs. Composting is one of the least expensive methods of stabilizing waste materials. Several studies have evaluated the fertilizer effects of composts and have suggested composting as one of the most appropriate techniques for producing organic fertilizers (Han et al., 2014; Potoky et al., 1988; Piriz et al., 2003). Composting fish waste has also been suggested as a valid method of transforming this waste into useful soil amendments for agricultural purposes (Frederick et al., 1989).

The application of high quality organic amendments to agricultural land has the benefit of being environmentally sustainable and compatible with organic production systems. Organic agriculture is undergoing constant growth worldwide, and at present 1.8 million farmers in 162 countries apply organic agricultural techniques to more than 37 million hectares of land (Willer and Kilcher, 2013). These farms cover the demands of a large market of consumers who are willing to pay relatively high prices for organic products (Govindasamy et al., 1998), reaching a value of 59.100 million US dollars in 2010 (MAGRAMA, 2011).

Tomato is one of the most important crops in Europe, with a production of approximately 16 million tonnes in 2012 of which one third were grown in Spain (EUROSTAT, 2013). However, the effect of organic fertilizers on tomato production is not entirely clear. Some authors have reported higher yields with organic fertilizers compared to mineral fertilizers (Moral et al., 1996; Eyras et al., 1998), whereas other authors either suggested the opposite (Heeb et al., 2005a; Heeb et al., 2005b, 2006) or did not find any significant differences in the tomato yields produced by these two types of fertilizers (Kong et al., 2005). The discrepancy in the findings may be due to the heterogeneity of the physical and chemical characteristics of the different organic fertilizers, which may give rise to different yields even under the same crop conditions. This was shown by comparison of eight types of organic fertilizers (Kanal and Kuldkepp, 1993), which included cattle dung with and without litter, pig slurry, peat compost formed from hen and pig slurry, sawdust-duck manure, non-composted peat and straw litter with pig slurry applied to potato and cereal crops. The findings of that study indicate that the results obtained with different types of organic fertilizers are not readily comparable, and thus a specific agronomic evaluation is required for each type of organic fertilizer, crop and type of management.

The objectives of this research study were as follows: (i) to evaluate fish waste and seaweed compost as a fertilizer for greenhouse-grown tomato; and (ii) to evaluate the residual fertilizing effect of the compost on a lettuce crop grown immediately after harvesting the tomato without any further addition of fertilizer.

2. Materials and methods

2.1. Materials

The trial was carried out in a greenhouse with acidic soil (pH 4.2) developed from quartz schist. The soil had a low effective cation exchange capacity (CECe) (8.2 cmol (+) kg^{-1}), high electrical conductivity (5.6 dS m^{-1}) and an appropriate OM content of 3.1%. In spite of the low initial pH value, it was not amended because the Al saturation in CECe (which is the main limiting factor in acidic soils) was low enough (4.7%) to allow for the proper production of the tested crops.

The compost derived from seaweed and fish waste was produced using the Windrow method with the following feedstock materials: (1) drift seaweed (mainly comprising *Laminaria* spp. and *Cystoseira* spp.) collected on the northern coast of Galicia (NW Spain), (2) mackerel (*Trachurus trachurus* L.) waste from a fish filleting plant, and (3) pine bark (10–15 mm), which was included as a structural material and as a source of carbon. The final ratio of these materials was 1:1:3 (v/v). The thermophilic stage lasted for approximately 45 days, and after the maximum temperature was reached, the pile cooled slowly until it was close to ambient temperature. Water was not added throughout the process. After 10 weeks, the maturity of the compost was established by measuring parameters such as the degree of stability and performing the Dewar flask test and phytotoxicity test. The finished compost had an OM content of 82%, indicating that this compost may be suitable as an organic soil amendment. The compost contained essential nutrients, with an N–P–K ratio of 2–0.6–0.7 (% dry weight). Most of the N (89%) was in organic forms. The neutral pH (6.8) ensured a good availability of the nutrients for the plants and for biological activity. The C/N ratio was approximately 22 and the heavy metal content was low. The only limiting feature was the high salinity (2.5 dS m^{-1} 1:5). A detailed description of the composting process and its characterization can be seen in Illera-Vives et al. (2013).

The dehydrated broiler litter, was produced with fresh chicken manure passed through a drying tunnel at 250 °C before being triturated with a hammer mill, homogenized, and finally pelleted in a granulator press to 5-mm diameter pellets with a length of 12–14 mm. A detailed description of this process and its characterization can be seen in Lopez-Mosquera et al. (2008). The commercial fertilizer had an N–P–K ratio of 3:1.3:2.5 (% dry weight), with 80% of the N in organic forms and a neutral pH (7.1). Its low C/N ratio (11.5) ensured easily mineralization (approximately 60% for the first crop). The chicken manure contained very low amounts of heavy metals.

2.2. Experimental design

The experiment was conducted using a completely randomized design of six treatments and three repetitions. In April 2011, 18 plots of 1.5 m^2 were established in a single-layer polythene greenhouse (300 m^2) with automatic ventilation in Lugo (Galicia, NW Spain; 42°59′N 7°32′W). The treatments included three compost rates (40, 50 and 66 t ha^{-1} (fresh weight), designated C1, C2 and C3, respectively); one slow-release NPK (20–2.2–8.3) treatment of mineral fertilizer (M) applied at a rate of 1.15 t ha^{-1}; and one commercial organic fertilizer based on dried broiler litter (BL) certified for organic agriculture (15 t ha^{-1} fresh weight). A control treatment (C), without fertilizers, was also included. The above-mentioned treatments were applied by superficial ploughing (10 cm).

Treatment compost rates were calculated based on the demand of 230 kg ha^{-1} N for approximately 110 t ha^{-1} tomato yield (Rodriguez del Rincón, 1982) and considering an annual rate of mineralization of 60% for BL (Evers, 1998), and lower rates for the compost were used (50% for C1, 40% for C2, and 30% for C3) due to the higher C/N ratio of the compost. A summary of all of the treatments can be seen in Table 1.

2.3. Tomato–lettuce rotation

Six greenhouse-reared tomato seedlings (*Solanum Lycopersicum* var. Valentim (Seragrap)) were planted in each plot (108 plants in total), with a between-plant spacing of 0.50 m. The plants were trained on vertical poles and the apical buds were removed after