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Compost supplementation with nutrients and microorganisms in composting process

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ABSTRACT

The composting is an aerobic, microorganism-mediated, solid-state fermentation process by which different organic materials are transformed into more stable compounds. The product obtained is the compost, which contributes to the improvement of physical, chemical and microbiological properties of the soil. However, the compost usage in agriculture is constrained because of its long-time action and reduced supply of nutrients to the crops. To enhance the content of nutrients assimilable by the plants in the compost, its supplementation with nutrients and inoculation with microorganisms have been proposed. The objective of this work was to review the state of the art on compost supplementation with nutrients and the role played by the microorganisms involved (or added) in their transformation during the composting process. The phases of composting are briefly compiled and different strategies for supplementation are analyzed. The utilization of nitrogenous materials and addition of microorganisms fixing nitrogen from the atmosphere or oxidizing ammonia into more assimilable for plants nitrogenous forms are analyzed. Several strategies for nitrogen conservation during composting are presented as well. The supplementation with phosphorus and utilization of microorganisms solubilizing phosphorus and potassium are also discussed. Main groups of microorganisms relevant during the composting process are described as well as most important strategies to identify them. In general, the development of this type of nutrient-enriched bio-inputs requires research and development not only in the supplementation of compost itself, but also in the isolation and identification of microorganisms and genes allowing the degradation and conversion of nitrogenous substances and materials containing potassium and phosphorus present in the feedstocks undergoing the composting process. In this sense, most important research trends and strategies to increase nutrient content in the compost are provided in this work.

Contents

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1. Introduction

The fast increase of world population and the economic activities derived have generated serious environmental issues like pollution of soil, air and water (Shilev et al., 2007). This population growth has led to an increase in the use of chemical fertilizers in order to multiply the agricultural production causing soil erosion and loss of its physicochemical and microbiological equilibria (Altomare and Tringovska, 2011; White and Brown, 2010). In a similar way, the utilization of chemical fertilizers has significantly increased to reach more productive harvests from worn soils provoking negative environmental impacts (White and Brown, 2010). In particular, the excess fertilizers applied causes water contamination by runoff and percolation. Thereby, the agrochemicals are carried to natural water streams leading to their eutrophication (White and Brown, 2010). For these reasons, the need to produce alternative environmentally friendly agricultural supplies that contribute to improve the physical, chemical, and microbiological features of the soil, and that contain, in turn, nutrients for the plants has arisen. In this sense, compost-type biofertilizers have the potential to meet these requirements.

The composting is considered to be an aerobic, thermophilic, microorganism-mediated, solid-state fermentation process through which different organic materials are transformed into more stable compounds that are precursors of humic substances (Füleky and Benedek, 2010; Sharma et al., 1997; Zapata, 2009). Main feedstocks used for composting are agricultural and agro-industrial wastes as well as putrescible organic residues (Füleky and Benedek, 2010; Jaramillo and Zapata, 2008). Most beneficial effects of compost application are shown in Table 1. The main effect of the compost is not to immediately enrich the soil with essential elements for the growth and development of plants like nitrogen, phosphorus, and potassium, but to contribute to the improvement of the soil structure and to allow the nutrient mobilization to the plants, which leads to a more suitable soil equilibrium (De Bertoldi et al., 1983). Although the bio-inputs obtained by composting are very useful for the plants, they have the apparent drawback of not supplying the appropriate macronutrient concentrations required for the plant nutrition compared to chemical fertilizers. In a generic way, these requirements are estimated as follows: 1.5% nitrogen, 0.2% phosphorus, and 1.0% potassium (Castro and Gómez, 2010). This causes a competitive disadvantage that diminishes the compost demand. For this reason, it is necessary to carry out comprehensive research aimed at improving the nutritional aspects of the compost regarding the macronutrient content. By enhancing the compost nutritional features, an agricultural bio-input that supplies not only nutrients to the soil, but also improves its physicochemical and microbiological properties could be obtained. It is worth to highlight that the action of the compost on the soil is different to that one of the chemical fertilizers. Therefore, it is not possible to directly compare the compost and the synthetic fertilizers since the action of the former occurs slowly to reach a long-time equilibrium in the soil.

The beneficial effects of compost are mostly long-term as evident from Table 1. When compost is supplemented with nutrients or inoculated with nutrient-transforming microorganisms, the upgraded bio-input obtained offers additional long-term benefits at the time of its application to the soil. Thus, the soil amended with compost supplemented with nitrogenous compounds has a slow rate of nitrogen mineralization due to its immobilization. Immobilization of nitrogen occurs when the accessible mineralized nitrogen species (NH_4^+, NO_3^-) are taken up by microorganisms preventing them from being accessible by plants or when nitrogen is linked to the soil organic matter. The immobilized nitrogen will be available to plants after the microorganisms die and the nitrogen is released (Al-Bataina et al., 2016). In this way, composted organic materials release nitrogen at rates considered to be slow (1–3% of total N/year), and the leaching process can extend for many years as long as the composted organic materials are decomposing. In contrast, the nitrogen release rates from chemical fertilizers are

Table 1
Compost benefits in the soil.

Aspect	Benefit	References
Physic	The particle size in the compost contributes to generate spaces that facilitate water retention and air exchange	De Bertoldi et al. (1983); Shilev et al. (2007)
	Improvement of the soil structure helping to preserve the physicochemical and microbiological balance in the soil	De Bertoldi et al. (1983); Mora (2006); Shilev et al. (2007)
	Increase of the A horizon (fertile soil layer)	Marosz (2012); Mora (2006)
	Enhancement of the movement of nutrients in the soil	Shilev et al. (2007)
Chemical	Input of organic matter to the soil to improve its fertility	Mora (2006)
	Stabilization and mineralization of organic matter	Füleky and Benedek (2010); Sharma et al. (1997)
	Generation of precursors of humic substances	De Bertoldi et al. (1983); Füleky and Benedek (2010); Zapata (2009)
	Reduction of the concentration of pesticides in soil by forming bonds with organic molecules of the compost	Mora (2006)
Microbiological	Supply of microorganisms that contribute to soil formation and movement of nutrients	De Bertoldi et al. (1983); Osorio (2009); Sarker et al. (2012); Xie et al. (2014)
	Increased growth of roots and microorganisms in the rhizosphere	Donn et al. (2014); Labidi et al. (2007); Marosz (2012); Wickramatilake et al. (2011); Zayed and Abdel-Motaal (2005); Zhang et al. (2014)
	Bioremediation by microorganisms contributing to the degradation of toxic agents	Shilev et al. (2007)
	Recovery and prevention of the soils desertification	Cellier et al. (2012)
	Supply of beneficial microorganisms controlling plant pathogens	Kinkel et al. (2012); Shen et al. (2013); Shilev et al. (2007); Suárez-Estrella et al. (2013)

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