Composting process management and compost benefits for soil fertility and plants

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Abstract

Composts are recycled fertilizers with potential. They can influence the soil quality at different levels: supply of nutrients, enhancement of humus content in soil, improvement of soil structure and water hold capacity, reduction of erosion, and stimulation of biological activity. Compost can also suppress plant diseases. However, an optimal management of the composting process, from the choice of the raw materials used up to the storage of the final products is necessary to obtain such positive results. Different factors play a role in the compost production, and consequently the characteristics of the produced composts are considerably diverse. It is also important to choose the compost that is adapted to the target application. To consider here are factors such as climatic conditions, culture, soil type and season of application. With an adapted practice strategy, composts become helpful products for the plant growers, especially in organic production systems.

Keywords: compost quality, composting process management, compost use, soil fertility, disease suppression

INTRODUCTION

Composting of organic waste is a concept well established over the world. The interest for compost is motivated by different reasons. The first one is certainly a meaningful closing of nutrients' cycles. Another important reason is the supply of organic matter to the soil, which has a positive effect on the soil structure, its water retention capacity, air balance and resistance to erosion. Moreover, compost influences soil pH and microbiological activity.

However, the characteristics of composts produced can vary greatly. This variation is due to the input materials, the composting techniques and the management of the composting process. Consequently, the effects of the different composts on environment, soil fertility and plant growth and health can considerably differ. These effects can be positive or negative (Noble, 2011). Therefore, the management of compost quality and the selection of the adapted product for the specific utilization are the basic conditions for a successful use of composts.

COMPOSTING PROCESS MANAGEMENT AND COMPOST QUALITY

Compost is the result of the aerobic decomposition of organic residues. Numerous microorganisms are involved in this process (Ryckeboer et al., 2003). One of the important roles of the composting process management is to create the conditions that are favourable for the inactivation of the harmful microorganisms and that promote the development of the beneficial ones (Fuchs, 2010). Another important role of the composting process management is to avoid the losses of fertilizer (nitrogen) on one hand and the emission of gases damaging the environment (such as greenhouse gases) on the other. An appropriate composting process management is therefore the condition to obtain high quality compost (Boulter et al., 2000).

Importance of the raw materials

The raw materials used as inputs for the compost production influence the

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communities of microorganisms present in the organic residues during the composting process (Klammer et al., 2008; Neher et al., 2013), but also affect the characteristics of the composts produced (Cáceres et al., 2015; Raviv, 2005). Also, the capacity of a compost to suppress plant diseases can be influenced by the raw materials used (Vestberg et al., 2011).

An important aspect of the composting process is the ratio of organic carbon to total nitrogen (C/N) in the starting mixture (Diaz and Savage, 2007). An optimal C/N ratio of the raw mixture resides between 25 and 30. If the ratio is too high, the microorganisms will not have enough nitrogen to grow and be active. If it is too low, nitrogen will be lost through ammonia volatilization. The initial C/N ratio can also influence the characteristic of the compost produced (Nada, 2015).

The physical characteristics of the initial mixture have also a great influence on the composting process (Druilhe et al., 2013). Ideally, its structure should have enough free air space to allow sufficient air permeability in the whole material. The higher the compost pile, the coarser the mixture should be prepared. If the pile is too large to enable an adequate aeration, the compost quality will be reduced (Michel, 1999).

Temperature

Composting is an exothermic process. The energy that is not used by the microorganisms is lost in the form of heat in the mass (Diaz and Savage, 2007). Hence, the temperature of a compost pile can increase up to 90°C. Such high temperature is not desirable. This is because numerous beneficial microorganisms cannot survive it and also because the rate of degradation of organic substrates decreases when temperature rises up to 70°C (Vinneras et al., 2010). Moreover, ammonia emissions are much more important when temperature in the compost pile is very high (Eklind et al., 2007). The optimal temperature for the degradation of organic substrates lies around 55°C (Eklind et al., 2007). However, high temperature is important for the elimination of weeds and pathogens. Therefore, as a compromise, a temperature between 60 and 70°C in the compost pile during the thermophilic phase is optimal (Vinneras et al., 2010).

Management of moisture and optimal aeration

The two most important parameters to manage the composting process are moisture and aeration.

Microorganisms need water to be active. The optimal moisture content of the input material lies between 50 and 60% (Agnew and Leonard, 2003; Diaz and Savage, 2007). The microbial activity is reduced if the moisture content is below 45% (Boulter et al., 2000). However, an elevation of the moisture content up to 75% has no significant effect on the compost quality if the aeration of the material is secured (Guo et al., 2012). In some case, a high moisture content can lead to an early cooling of the compost pile and thus to a decrease of the microbial activity. Nevertheless, the optimal moisture content depends on the material treated (Richard et al., 2002). Especially the maximum permissible moisture content depends on the structural strength of the mixture (Diaz and Savage, 2007).

Composting is an aerobic process, thus sufficient oxygen has to be present in the rotting material. The O_2 consumption rate is generally high during the thermophilic stage of the process and decreases during the curing period. Passive or active aeration of the compost pile has to guaranty sufficient oxygen in the pile (Michel, 1999; Poulsen, 2011). The aeration rate will also influence the process and the quality of the compost produced (Nada, 2015). In order to have an optimal repartition of the air in all the material, the mixture should have an adequate structure; which means that the structure should allow the air circulation in all parts of the material. If the oxygen level is too low in the pile, a negative shift in the population of microorganisms can be observed (Enticknap et al., 2006; Watanabe et al., 2008). The activities of the aerobic microorganisms are inhibited and anaerobic processes start. This has a consequence on the compost quality. The pH of the material will decrease following the formation of organic acids, which can be phytotoxic and produces odour emissions (Michel, 1999). Nitrification (transformation from ammonium to nitrate) can be inhibited due to oxygen starvation. Low aeration also restricts the decomposition of toxic compounds in the compost, which can therefore make it phytotoxic (Guo et al., 2012; Hanajima et al., 2007). In addition, volatile organic acid production, which are responsible for odour emission, decrease significantly when sufficient oxygen is available in the pile (Michel and Reddy, 1998). Also the emission of climatic gases like methane can be observed during the thermophilic conditions of the process when the oxygen content in the pile is equal or less than 2.5% (Beck-Friis et al., 2003; Shen et al., 2011). On the other hand, a very intensive aeration will reduce moisture content and increase nitrogen losses in the form of ammonia emissions and production of N_2O (Bueno et al., 2008; de Guardia et al., 2008; Jiang et al., 2015). As the oxygen demand depends on the mixture of materials as well as on their decomposition stage, aeration should be adapted. Last but not least, a proper storage of the output products is important to maintain the quality and benefits of the compost (Boulter-Bitzer et al., 2006).

Control of the compost quality

Depending on the raw materials used and the process management, the quality of the compost produced can vary considerably. Therefore, it is necessary to control its quality so that the most appropriate compost for the specific use can be produced (Fuchs et al., 2014a; Raviv, 2005).

To insure that it was high enough for the duration required to eliminate weeds and pathogens, the evolution of the temperature has to be recorded periodically, daily or one to three times per week depending on the duration of the process.

Secondly, nutrient content has to be analysed so that a fertilization balance can be performed; depending of the nutrients present in the compost added to the soil, the grower can then complete the fertilization of the culture with other fertilizers in order to cover the demand of the plants.

Finally, measurement of the mineralized form of nitrogen, pH and salt content have to be performed to check whether this input product is the one mostly adapted for the desired application (Fuchs et al., 2014a). Especially the NO_3-N/N_{min}-ratio is a good indicator of the effective maturity of the compost, and gives important information about the possible application target of the compost. This ratio is an important value to predict whether the compost will provide nitrogen to the plant or on the contrary, immobilize the nitrogen present in the soil. If this ratio is below 0.2, there is an important risk of nitrogen immobilization in the field in the case of lignin-rich compost.

COMPOSTING BENEFITS FOR SOIL FERTILITY

Compost influences the chemical, physical and biological soil parameters. Some effects of compost are observable after a short time, others only later on. The effects can also vary with the different types and qualities of the compost used and the type of soil and/or climatic conditions. Therefore, it is important to analyze the specific situation in order to predict the evolution of soil fertility in relation to the compost used.

Influences on chemical characteristics of soil

Compost contains all the different nutrients that the plant needs including the trace elements (Sager, 2007). However, the quantity of the different chemical elements can considerably vary depending on the starting mixture and the process management (Fuchs et al., 2008). Therefore, it is not possible to plan the fertilization effect of a compost using mean values out the literature, but specific analyses have to be performed for each compost.

An important aspect of compost is its nitrogen content. The nitrogen in composts is mainly present as organic nitrogen, which is mostly not available to plants. Depending on its content of mineralized nitrogen as well as on its maturity stage, compost can immobilize nitrogen in the field or deliver available nitrogen to the plant (Fuchs et al., 2008; Gale et al., 2006; Gutser et al., 2005). The prediction of the effect of compost on the available nitrogen in the soil can be done by analyzing the relation between NH_4-N and NO_3-N it contains (Fuchs et al., 2008) or the labile component of C and N (Beraud et al., 2005).

Composts can also influence the pH of soils. The liming effect of compost can be notable, mostly because the quantity of calcium is important in composts. Therefore, the pH of acid soils can be improved using compost (Eldridge et al., 2014; Fuchs et al., 2014b; Vo and Wang, 2015). However, the pH of a soil will not be enhanced if its value is already high. In some cases, a very high pH value in the soil can even be reduced by the use of compost (Avnimelech et al., 1994; Stamatiadis et al., 1999). This effect is probably due to the soil humic acids contained in composts (García-Gil et al., 2004). García-Gil et al. (2004) describe that compost has a very good buffer capacity effect in the soil, increasing its pH when its value is below 7, and decreasing it when it is above 7.

Influences on humus content and physical characteristic of soils

The content of organic matter of a soil is an important factor for its fertility. Compost brings an important quantity of – depending on its maturity stage – more or less stabilized organic matter (Fuchs et al., 2008). Compost amendments improve the quantity of organic matter in soil (Kätterer et al., 2014; Yu et al., 2012; Diacono and Montemurro, 2010; Zhang et al., 2014). However, this improvement depends on the maturity of the compost, where a more stable product will have a higher efficiency at building up humus in arable land (Molina-Herrera and Romanya, 2015). The effect of compost on soil organic matter affects positively various physical soil properties. The soil structural stability is increased (Tejada et al., 2009), soil macroporosity and water content at saturation are increased with a corresponding decrease in bulk density (Arthur et al., 2011; D'Hose et al., 2012).

Influences on soil biology

Composts influence also the soil biology. After their use, the microbial biomass is increased (Fliessbach et al., 2005; Chu et al., 2007; Tabuchi et al., 2008). The composition of the microbial communities is also influenced by compost use and its diversity enhanced (Fliessbach et al., 2005; Dambreville et al., 2006; Tabuchi et al., 2008; Zaccardelli et al., 2013). Moreover, the enzymatic activities in soil are improved by compost addition (Chu et al., 2007; Nayak et al., 2007). These effects are not only due to the compost microorganisms, but also to indigenous microorganisms of the soil that are promoted by the addition of compost (Chu et al., 2007). The effect of compost on soil microbial activity can disappear after some months, when the organic matter is stabilized (Darby et al., 2006).

COMPOSTING BENEFITS FOR PLANT GROWTH AND HEALTH

The influence of compost on soil characteristics will of course affect plant growth. Mainly, compost makes a variety of nutrients available to the plant, especially nitrogen. However, not only the nutrients are relevant to plant growth. With the improvement of soil structure, water holding capacity and porosity, the compost creates better conditions for the plant development, which is then less stressed and can therefore better grow. As a result, compost influences positively the yield of the cultures, especially in organic agriculture; however, compared with mineral fertilization, no relevant positive differences in yields are observed (Martinez-Blanco et al., 2013).

Influence on plant health

A good compost comes with the guarantee of absence of pathogens and weeds (see above). In addition, compost can protect plants from diseases, which is an important property that differentiates compost from mineral fertilizers. This capacity of compost to suppress plant diseases has been already described a long time ago (Hoitink et Fahy, 1986; Noble and Coventry, 2005; St.Martin and Brathwaite, 2012). The mechanisms of disease suppression are mostly based on the microbiological activity of the compost (Chen and Nelson, 2008; Zaccardelli et al., 2013). The disease suppressivity of compost is not always the same, and different composts can protect plants against different diseases (Termorshuizen et al., 2006). However, other mechanisms, such as competition for carbon can also play an important role in this protection, and in some case, also heat-treated composts can protect plants against diseases (Serra-Wittling et al., 1996).

Not all composts have the capacity to protect plants against diseases (Fuchs, 2002;

Termorshuizen et al., 2006). Apart from the raw material used (Raviv, 2005), compost management (Boulter et al., 2000; Fuchs et al., 2008; Vestberg et al., 2011) and also compost maturity (Zmora-Nahum et al., 2008) can play a role on the suppression capacity of a compost. Next to the production processes, storage of compost will also affect the activity of a compost (van Rijn et al., 2007).

In some case, the suppression potential of composts can be enhanced by adding antagonistic microorganisms (Postma et al., 2003; Pugliese et al., 2011).

IMPORTANCE OF COMPOST CHOICE IN RELATION TO ITS UTILIZATION

As described above, composts can have different characteristics and properties. In addition, different target applications have different needs. In order to obtain the best results when using compost, it is important to choose a product adapted to the end use and the expected goal. Different factors such as the climatic situation, the soil type, the culture or the season of application will also play important roles.

CONCLUSIONS

Composts are organic fertilizers or amendments with a great potential to improve or secure the fertility and to allow a better plant growth. Quality compost can also be considered as a potential plant protection agent. However, the efficacy of a compost depends upon its quality. Compost processes have to be strictly controlled and well managed. The most important points in this process are the raw mixture used and the management of moisture content and aeration. Because of the different characteristics and properties that quality composts can have, it is important to choose a compost considering how and where it will be applied and the goal of its application. It is also advised to keep in mind the effect of external factors on its performance.

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