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Research article

Organic waste vermicomposting through the addition of rock dust inoculated with domestic sewage wastewater

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A B S T R A C T

The aims of the present study are to assess the organic waste vermicomposting process (cattle manure mixed with tannery sludge) by using inorganic waste (rock dust) inoculated with treated domestic wastewater sewage, as well as the vermicompost application in *Ruellia brittoniana* seedling production. Different proportions of organic and inorganic waste moistened (or not) in wastewater were vermicomposted (by *Eisenia foetida*) for 120 days in the first stage of the experiment. Statistically significant earthworm density increase was observed between the 60th and 90th experimental vermicompositing days in all the assessed groups. There was decreased *E. foetida* population density after 90 days. The K, P, TOC, C/N ratio and Ca, Na and Mg concentrations significantly decreased at the end of the vermicompositing process in comparison to the initial concentrations identified in most treatments. On the other hand, there was pH and N, Fe, Zn and Mn concentration increase in most of the vermicomposts assessed at the end of the experiment. All plants grown in soil containing vermicomposts presented higher Dickson Quality Index (DQI) than the control group, which was cultivated in soil containing commercial topsoil. Plants grown in soil containing 100% cattle manure and tannery sludge, moistened in treated domestic wastewater sewage, showed the highest DQI. Thus, the vermicomposting waste used in the present study, which was inoculated with treated domestic wastewater sewage, is an interesting vermicompost production technology to be used in ornamental plant production.

1. Introduction

The generation of solid waste, such as the organic waste from tannery industries (Nunes et al., 2016), is addressed as one of the biggest challenges faced by industries worldwide (Sharma et al., 2017). This waste remains in the companies' courtyards and has no defined use, the tannery organic waste, in particular, besides demanding proper storage and disposal location, represent risks to the health of humans and to the environment. Therefore, its proper disposal is not enough to solve the waste production issue.

The creation of specific environmental laws and the increasing public awareness about the issue, in the recent decades, have been pressuring companies to turn their production processes into sustainable ones (Varadarajan, 2015; Eggleston and Lima, 2015; Bhinge et al., 2015). However, waste treatment and disposal are just some of the steps to be taken towards developing environmentally sustainable production processes. Accordingly, many studies have assessed the use of wastes for more noble purposes, mainly for their use in agriculture (Malafaia et al., 2016; Silva et al., 2016; Kumar et al., 2016; Carey et al., 2016).

Inorganic wastes have been the target of studies aiming at finding waste application in agriculture (Mendes et al., 2015; Ramos et al., 2017), given the large availability of it. It is estimated that 75% of the total ornamental rock production is lost as rock dust (Campos and Castro, 2007), which is produced throughout all natural stone production stages (extraction, processing and finishing). The most problematic environmental stages

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concern the sawmills and marble shops, because they generate fine or ultrafine material (powder) (Uliana et al., 2015). Buzzi (2008) analyzed sawmill wastes in Espírito Santo State (Brazil) and found that approximately 80% of the fine or ultrafine waste could be classified as non-inert, i.e., are prone to change their characteristics when they are released into the environment. Another particular problem associated with rock dust refers to the possibility of having such wastes causing negative impacts on the health of populations (Dalmora et al., 2016; Vrablik et al., 2017).

Efforts have been done to find applications to the powder from ornamental stone production processes, and some research have shown the feasibility of using fine and ultrafine material in agriculture by incorporating rock powder to the soil (Santos et al., 2015; Paradelo et al., 2016). Soil fertilization by using rock powder can provide a wide range of macronutrients such as nitrogen, phosphorus, potassium, calcium, magnesium and sulfur, as well as of micronutrients such as iron, manganese, copper, zinc and sodium, which are suitable for plant growth (Ramos et al., 2017). However, the availability of nutrients resulting from rock powder depends on the rocks' natural composition, for the production of nutrients is slow and their amount may not be enough for the plant. Anjanadevi et al. (2016) state that nutrients solubilization based on these wastes can be accelerated by mixing them with organic waste in order to stimulate nutrient solubilization through biological pathways.

Thus, studies have been developed to simulate processes or techniques able to optimize inorganic waste solubilization (Sarma et al., 2016; Voisin et al., 2017) and/or to find organic waste applications (Case et al., 2017). Different studies have reported waste vermiprocessing using mushroom (Song et al., 2014) and tomato (Fernández-Gómez et al., 2013) residues, leaf litter (Suthar and Gairola, 2014), sewage (Sahariah et al., 2015), paper (Arumugam et al., 2015), tanning sludge (Malafaia et al., 2015a,b; Nunes et al., 2016), jute mill (Das et al., 2016a), paddy straw (Das et al., 2016b), and food and vegetable processing wastes (Sharma and Garg, 2017). These studies show the likelihood of converting waste of polluting potential, previously discarded into the environment potential, into composts able to be used for more noble purposes.

However, an unexplored research field concerns the use of domestic sewage wastewater to vermicompost co-disposed organic waste by using inorganic waste. One may question if it would be worthy transforming organic or inorganic wastes through vermicomposting processes able to generate high agronomic quality composts. Thus, the aims of the present study were to assess the organic waste vermicomposting process (cattle manure mixed with tannery sludge) by using inorganic waste (rock powder) humidified in treated domestic sewage wastewater, as well as to analyze the applicability of the herein tested vermicompost to produce seedlings of the ornamental species *Ruellia brittoniana*. The study emerged with the hypothesis that it would be possible generating compounds of favorable nutritional characteristics to ornamental plant production by mixing different organic and inorganic wastes (rock powder) humidified in treated domestic sewage wastewater (organic inoculant) substrate through vermicomposting. At this point, it is possible stating that the current study stands out due to its contribution to polluting tannery and marble production waste mitigation since it is the first study to use organic inoculants to vermicompost organic and inorganic substrates.

2. Materials and methods

2.1. Step 1: vermicomposting

Different vermicomposts resulting from organic and inorganic waste mixes at different concentrations were produced in the first stage of the experiment. Three types of waste were used in the vermicomposting process: cattle manure, which was provided by the experimental farm of Goiano Federal Institute (IF Goiano), Urutaí Campus, Urutaí County, GO, Brazil; ornamental rock powder, resulting from the finishing process applied to several ornamental rocks, mainly to granite, slate and marble - provided by a company located in Pires do Rio County, GO, Brazil; and tannery sludge supplied by a tannery industry located in Inhumas County, GO, Brazil. The physicochemical and chemical features of the herein used waste can be seen in Table 1 (see the supplementary material).

The rock powder used in the experiments was composed of samples collected every two weeks over three months. The chemical composition of the marble waste was taken into account, since it changes over time, depending on the rock matrix. The tannery sludge was left to dry before it was mixed to the cattle manure (dry and leathery); thus, the sludge was arranged in approximately 5-cm layers, on plastic sheets - the drying process was natural and lasted 45 days.

The residues were mixed and, subsequently, sieved in 8 mm mesh in order to find uniform particle size and to remove undesirable materials, so that the vermicomposting process could run properly. The organic waste mix comprised 80% cattle manure and 20% liming type tannery sludge, which is an interesting ratio, from a nutritional point of view, as shown by Malafaia et al. (2015a).

The earthworms belonging to species *Eisenia foetida* (red Californian earthworm), family Lumbricidae, were used in the vermicomposting process, since it is widely used in vermicomposting processes involving different waste types (Sharma and Garg, 2017). After the experimental units were defined (Table 2), the vermicomposting process was carried out in plastic containers of volumetric capacity 3 L; 1 kg of substrate (dry) was added to each container, as described by Vig et al. (2011), Malafaia et al. (2015a, 2015b). The temperature during the vermicomposting process was kept between 20 and 25 °C.

The vermicomposting process was conducted in protected environment (in a room at the Goiano IF - Urutaí Campus, GO, Brazil) for 120 days. The window in the vermicomposting room where the worms were stored was covered to prevent light radiation in the environment, in order not to interfere in the earthworms' actions in the substrates.

All the containers were covered with a shading material commercially known as plastic screen Sombrit to avoid leakage and potential worm predation, as well as to allow substrate aeration. The substrate was moistened with drinking water or with treated domestic sewage wastewater to keep the humidity between 30% and 40%, according to Dores-Silva et al. (2011), Malafaia et al. (2015a, 2015b).

The domestic sewage wastewater was used as organic inoculant in the process by assuming that the effluent would provide microorganisms able to help degrading the substrate and that the addition of nutrients enriches the compounds generated at the end of the vermicomposting process.

The drinking water used in the current study was collected in the Goiano Federal Institute water supply system (Goiano IF - Urutaí Campus, GO, Brazil), which is fed by water from the local Water Treatment Plant. The treated domestic sewage wastewater was collected in the wastewater treatment system, which is a stabilization pond located in the institution's surroundings. Three samples were collected throughout the trial period to feature the irrigation water used in the physical, chemical and physicochemical analyses, according to the methodology proposed by APHA et al. (1998). Table 3 (see supplementary material) shows the physicochemical and chemical characteristics of the water used in the experiment.

After the experimental units were set, the mixes were manually