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Changes in soil properties and in the growth of *Lolium multiflorum* in an acid soil amended with a solid waste from wineries

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Abstract

The agronomic utility of a solid waste, waste perlite (WP), from wine companies was assessed. In this sense, the natural characteristics of the waste were measured, followed by the monitoring of its effects on the chemical properties of acid soils and the growth of *Lolium multiflorum*. Taking into account that heavy metals associated to the waste (such as Cu, Zn and Mn) could cause problems when used as amendment, the changes in their total levels and in their soil fractionation were also studied, together with their total contents in *L. multiflorum*. The high content in C (214 g kg^{-1}), N (25 g kg^{-1}), P (534 mg kg^{-1}) and K (106 g kg^{-1}) of WP turned it into an appropriate amendment to increase soil fertility, solving at the same time its disposal. WP contributed to increase soil pH (in 2 pH units) and cation exchange capacity (CEC increased in 3 $cmol_c$ kg^{-1} units), but reduced the potential Cu phytotoxicity due to a change in Cu distribution towards less soluble fractions. The growth of *L. multiflorum* adequately responds to the treatment with WP at addition rates below 2.5 g kg^{-1}, whereas the imbalance between nutrients can justify the reduction in biomass production at higher WP addition rates. The levels of heavy metals analyzed in *L. multiflorum* biomass (8–85 g kg^{-1}) do not seem to cause undesirable effects on its growth.

Keywords: Winery organic wastes; Perlite; Must filtration; Soil amendment; Fertilizer

1. Introduction

Industrial transformation of agricultural products is an important source of co-products and wastes that should be adequately treated to avoid detrimental effects in the surrounding environment (Saviozzi et al., 1994). Spain is the European country with larger surface devoted to vineyards and the third in wine production (FAOSTAT, 2006), and together with France and Italy accounts for the 50% of wine production in the world. These figures, indicative of the economic relevance in Spain of wineries, are also a symptom of the high quantities of co-products and wastes generated, which were approaching 1.5 million Ton in 2005 (FAOSTAT, 2006). European legislation establish that part of the wineries wastes be devoted to alcohol distillation (Council Regulation EC 1493/1999), but anyway many of the small wine merchants do not fulfil with the normative and do dispose the wastes in the environment. Moreover, the management of all these different materials is not easy; there are solid materials such as grape stalks, grape marcs and wine lees, but also liquids like vinasses.

There are many alternatives for reusing these waste materials (Arvanitoyannis et al., 2006). Their direct application to soil is one of the most efficient for disposal or increasing in value (Madejón et al., 2001; Díaz et al., 2002), above all considering their contribution in organic

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matter and other nutritive elements to the soil-plant system (Bustamante et al., 2007a). Saviozzi et al. (1994) have demonstrated that the incorporation of winery wastes to soils can increase the levels in available N, K, P and S. Similar results were found by Arias-Estévez et al. (2007), who have also found an increase in soil CEC and a change in Cu distribution towards less soluble fractions. Their contribution in organic matter, the gradual release of N and the high levels of K are the advantages that Bertran et al. (2004) have obtained with the application of composted winery wastes to soil, while Ferrer et al. (2001) consider that a neutral pH and their contribution in P are the most relevant benefits of the agronomic reutilization of a solid waste from wineries. Anyway, other studies have demonstrated non-desirable effects such as the lowering of micronutrients and the increase in polyphenols (Bustamante et al., 2007b), or the accumulation of heavy metals associated to the wastes (Karaca, 2004). Together with the potential use of these wastes for amending soils, they can also be used in the immobilization of heavy metals (Li et al., 2004; Villaescusa et al., 2004; Martínez et al., 2006) and pesticides (Andrades et al., 2004; Fernández et al., 2005; Romero et al., 2006). In these cases, their high sorption capacity due to their high organic matter contents can be joined to their low economic and environmental costs as regards to active carbon and peat.

In this paper, we assess the agronomic utility of a waste from wine companies. In this sense, the natural characteristics of the waste were measured, followed by the monitoring of its effects on the chemical properties of acid soils and the growth of *Lolium multiflorum*. The main novelty is the use of waste perlite under direct application to an acid sandy soil to improve both its properties and the growth yield of *L. multiflorum*. Taking into account that heavy metals associated to the waste (such as Cu, Zn and Mn) could cause problems when used as amendment, the changes in their total levels and in their soil fractionation were also studied, together with their total contents in *L. multiflorum*.

2. Methods

2.1. Expanded perlite (EP) and waste perlite (WP)

Expanded perlite (EP) is the commercial name of an aluminium-silicate of volcanic origin used in grape must filtration before the start of fermentation. Due to its high sorption capacity, EP is able to remove non-desirable components in wine such as rests of grape stalks and marcs and also part of the microbe biomass. As a result of this process a waste perlite (WP) is obtained. Usually, EP is used at a rate of 200–250 g hL^{-1} (Ribéreau-Gayon et al., 1977) and, taking into consideration that wine production in Spain can reach 4 GL (FAOSTAT, 2006), the quantity of WP by year in Spain can be close to 9000 Ton, to what is necessary to add the contribution to weight of sorbed vegetal material and other impurities. This figure gives an idea of the paramount environmental importance of the removal of this waste without any control. EP (Celatom perlite, from AGROVIN) was used without any prior treatment to fine a wine in a local winery of the quality wine produced in a specified region known as Ribeiro (Galicia, NW Spain). The resulting sludge (waste perlite, WP) was dried in air and passed through a 1 mm mesh sieve. Expanded and waste perlite properties were determined following the procedures described below for soil samples. Protein was determined as per Lowry et al. (1951) following extraction for 24 h with 0.5 M NaOH at 30 °C.

2.2. Greenhouse pot experiment and crop growth

A greenhouse experiment with *L. multiflorum* was performed in pots by adding different amounts of WP per kg of soil. The soil selected was from a C horizon layer of Arenic Regosol developed from two-mica granites. PVC pots 12 cm high and 13 cm in diameter were filled to a depth of 2 cm with 0.5–1.0 cm gravel and then made up to about three-fourths of their volume with control soil or a soil-and-waste mixture (1 kg). Soil was mixed with WP in proportions of 0.5, 1, 2.5, 5, 10 and 15 g of waste perlite per kg of soil. Control soil contained no waste perlite. Four pots were used per treatment, making 28 in all.

The following methodology was based on the procedures standardized by the International Seed Testing Association (ISTA, 2007). Seedlings of the fast-growing species *L. multiflorum* (150) were sown in each pot with day and night temperatures of 25 ± 3 °C and 15 ± 3 °C, respectively. In order to maintain soil moisture content at 15%, water soil loss was compensated for by two daily additions of distilled water. Thirty-five days after planting, plants were removed from the pots and the aerial part was separated from the root, and each part was washed successively with distilled water and 0.001 M HCl before being placed for 3 min in an ultrasound bath (Selecta Ultrasons-H) to remove any remaining substrate. Afterwards, plant material was then washed again with distilled water, dried to constant weight in an oven at 65 °C, and weighed. To asses the success of seed germination in pot experiment after residue additions, it was counted the number of seeds germinated at days 3 and 10 after sown and the results were expressed as percentage. As comparison, a laboratory germination test was run as follows. A 1:10 (w/v) suspension of perlite waste in distilled water was shaken for 1 h and filtered. The bottom of each of six Petri dishes was lined with filter paper, and the paper was wetted with the perlite filtrate in three and with distilled water in the other three. Fifty *L. multiflorum* seeds were placed in each dish, and the percentage that had germinated was recorded on days 3, 7 and 10.

2.3. Soil analyses

Once the plants had been removed, a soil sample was taken of each pot and treatment for general soil characterization and selective extractions of Cu, Zn and Mn.