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Compost effect on bacterial and fungal colonization of kermes oak leaf litter in a terrestrial Mediterranean ecosystem

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Abstract

Mediterranean soils are generally low in organic matter and have a low water holding capacity. Moreover, recurrent fires are common in Mediterranean regions and increase the deterioration of these soils. Soil properties and ecosystem resilience after fire could be improved by amendment with compost, which is a source of organic matter and nutrients. A way to determine ecosystem integrity is to study leaf litter breakdown, which is a vital process in the functioning of terrestrial ecosystems and involves fungi and bacteria.

In this study, we determined fungal and bacterial biomass associated with decomposing oak leaves (*Quercus coccifera* L.) in a burnt shrub amended ecosystem during 1.5 years. Three treatments were studied: control, 50 t ha^{-1} and 100 t ha^{-1} of co-composted sewage sludge and green wastes. Bacterial biomass was not affected, although moisture, N and P concentrations in litter were increased by the amendment. However, fungal biomass was depressed on plots amended with 100 t ha^{-1}, and negatively correlated to exchangeable P. For all treatments, both types of microorganisms followed marked seasonal dynamics, with peaks of biomass during the wet periods of the year.

Keywords: Mediterranean ecosystem; Sewage sludge compost; Leaf litter; Ergosterol; Bacterial numbers; Microbial biomass; *Quercus coccifera* L.

1. Introduction

Soils under Mediterranean climate are undergoing degradation due to water erosion and recurrent fires, which affect their fertility (De Luis et al., 2001). Nitrogen, which is often a limiting plant nutrient in soil, is easily lost by volatilisation during wildfires.

Guerrero et al. (2001) pointed out that organic matter addition is a suitable technique for accelerating the natural recovery process of burned soils. The spreading of biosolids, defined as the nutrient rich product of wastewater treatment, can improve the low fertility of soils and constitutes an alternative to landfill disposal. Biosolids are a source of organic matter and plant nutrients (Brockway, 1983; Martinez

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et al., 2003) and can improve soil physical, chemical and biological properties (McKay and Moffat, 2001; Caravaca et al., 2002). But biosolids present potential environmental risks. Their use can induce heavy metal and organic contaminants accumulation in soils (Brockway, 1983), as well as the discharge of nutrients, especially N and P, to surface and ground waters (Martinez et al., 2003). To decrease risks of heavy metal and salt leaching, the organic matter of biosolids can be stabilized by composting (Garcia et al., 1990; Planquart et al., 1999). In addition, mixing biosolids and other organic wastes with large C/N ratios (such as green wastes) can reduce the rate of nitrogen leaching (McKay and Moffat, 2001). Therefore, compost presents better agronomic potential than biosolids.

Compost amendment has been frequently shown to increase soil fertility (Caravaca et al., 2002; Martinez et al., 2003), plant biomass (Guerrero et al., 2001) and nutrition (Moreno et al., 1996). As a consequence, it could lead to a high nutrient content litter and enhance litter breakdown. Litter breakdown is the principal pathway of nutrients' return to soil in a form available to plants (Kavvadias et al., 2001). This aspect is especially important on Mediterranean nutrient-poor soils where plant communities rely, to a great extent, on the recycling of litter nutrients (Cañellas and San Miguel, 1998). Factors contributing to the litter breakdown are: soil fertility, litter quality and supply and climatic conditions (Kavvadias et al., 2001.

The litter breakdown process involves three types of organisms: invertebrates, fungi and bacteria. The crucial role of microorganisms is clearly established, and consecutive changes in fungal and bacterial biomass dynamics are a useful way to investigate the impact of factors controlling leaf breakdown (Gessner and Chauvet, 1994; Isidorov and Jdanova, 2002). Moreover, the soil microbial biomass is often regarded as an early indicator of changes which may occur in the long term with regard to soil fertility. Likewise, Wardle et al. (1999) showed that microbial biomass responds to addition of fertilizers and of organic residues.

Most studies deal with total microbial biomass (fumigation-incubation, fumigation-extraction, substrate induced respiration and ATP methods; Martens, 1995), i.e. bulked fungi and bacteria (Borken et al., 2002; Khan and Scullion, 2002; Kunito et al., 2001). However, the respective roles of bacteria and fungi in the litter breakdown process are different. Fungi are able to decompose and assimilate as refractory compounds as lignin or tanins (Criquet, 1999), although bacteria are not thought to assume notable importance before the leaf material has been partially broken down and decomposed by fungi (Jensen, 1974). Thus, it is of great interest to study separately their reactions to compost amendment.

In this study, bacterial and fungal biomass were determined on kermes oak (*Quercus coccifera* L.) leaf litter on a Mediterranean burnt area amended with sewage sludge and greenwaste compost. Kermes oak is one of the most important shrub species in the Mediterranean basin, where it covers more than 2 Mha and accounts generally for 60–70% of the total litter (Cañellas and San Miguel, 1998).

Our objectives were to (i) determine the effects of compost amendment on kermes oak leaf litter colonization by bacteria and fungi, (ii) offset the drastic Mediterranean climatic conditions (e.g. drought) against the potential improvement of soil fertility by compost, (iii) provide comprehensive data on leaf litter breakdown in terrestrial Mediterranean ecosystems by separately quantifying fungal and bacterial biomass.

2. Material and methods

2.1. Study site and experimental design

The experiment was carried over 6000 m^2 on the plateau of Arbois (Southern Provence, France; 5°18′6″E–43°29′10″N in WSG-84 Geodetic system) at 240 m above sea level and under Mediterranean climatic conditions (Fig. 1). The soil was a silty-clayey chalky rendzina, with a high percentage of stones (77%) and a low average depth (24 cm). The last fire occurred in June 1995 and the site was colonised by typical Mediterranean sclerophyllous vegetation, with 70% total cover; *Q. coccifera* L. and *Brachypodium retusum* Pers. being the two dominant species. This natural vegetation belongs to the holm oak (*Quercus ilex* L.) succession series.

Compost was surface applied in January 2002. The experimental design was a complete randomised block of twelve plots of 500 m^2. Four plots did not receive any compost (D0 = control), four received 50 t ha^{-1}