Chapter 11

MICROBIAL PROCESSING OF HUMIC SUBSTANCES FROM MEADOW AND FOREST SOILS

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ABSTRACT

Soil organic matter represents the main carbon reservoir of the biosphere. Recent concern for increasing atmospheric CO₂ level and global warming results in growing interest in the sequestration of organic C in soil organic matter. This is true especially for humic substances which represent differently extractable fractions of soil organic matter. Humic acids account for recalcitrant components of humic substances, but even these compounds may become subject to degradation and transformation by soil microorganisms. The contributions of various species of fungi, actinomycetes, and also non-mycelial aerobic or anaerobic bacteria to these processes have been studied mainly under laboratory conditions. The degradation of humic acids can be followed by optical, gravimetric and chemical methods, and also by using microbiological and biochemical procedures. We report on the value of a multi-factorial approach that includes both quantitative and qualitative parameters. This approach is illustrated by analysis of humic acids extracted from two soils under permanent meadow, and from a forest soil. When added as either supplemental source of nutrients or as the sole source of carbon or nitrogen, between 9 % and 63 % of humic acids were microbially utilized and structurally altered. The formation of microbial biomass was enhanced up to

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4-fold in comparison to cultures without humic acids. Humic acids from soils under permanent meadow were more resistant to microbial degradation than those from a forest soil. A complex microbial assemblage from forest soil could mineralize up to 74% of C present in liquid cultures enriched with humic acids. Our studies combine with other experiments in the literature to demonstrate that humic acids play a major role in both the sequestration of soil C, and as substrates for the soil community.

INTRODUCTION

Soils form the largest reservoir of carbon (C) in terrestrial ecosystems; the pool of 1200 to 1500 x 10^9 Mg C is five times the mass of C in vegetation (Batjes, 1996; Breuer, 1999). The pools of C in forests are very dynamic; in New Zealand, about half the annual CO2 emissions from energy and industrial uses are offset by new forests that have been converted from large areas of pasture (Parfit et al. 2003). A small fraction of the total organic matter found in soil comes from recently added plant detritus, but most of the soil organic matter is comprised of highly altered compounds known as humic substances. The bulk humic substances are commonly divided into humic acids (alkali-soluble but acid-insoluble), fulvic acids (soluble in both alkali and acids), and insoluble humins. In total, humic substances usually comprise between 60 to 80 % of the soil organic matter. Their main characteristic is a high molecular weight polymeric structure based mainly on different phenolic precursors originating from lignin degradation and cell pigments released from decaying plant and/or microbial cells (Haider et al., 1975). Humic substances are generally regarded as highly resistant to biological and chemical degradation (Brady and Weil, 2002). Schulten and Schnitzer (1997) presented a complicated structural model of humic substances, which could give a reason for a high degree of their stability. Nevertheless, even relatively stable sinks of matter and energy have finite rates of turnover, depending in part on environmental and biological conditions. For example, evidence and opinions differ regarding the decline in soil organic matter following disturbances such as clearcutting (e.g., Beyer et al., 2001; Johnson and Curtis, 2001; Rusco et al., 2001, Yanai et al., 2003).

In general, C storage in terrestrial ecosystems changes with shifts in the balance between primary production and the decomposing activity of heterotrophic microorganisms (Post et al. 1997). The stability and degradability of humic substances in soils are a fundamental part of understanding the role of soils in the global CO2 budget. In this chapter, we review the state of knowledge on the dynamics of humic substances, and then