Chemical and seasonal controls on the dynamics of dissolved organic matter in a coniferous old-growth stand in the Pacific Northwest, USA

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Abstract. Soil organic matter (SOM) is the largest terrestrial C pool, and retention and release of dissolved organic matter (DOM) cause formation and loss of SOM. However, we lack information on how different sources of DOM affect its chemical composition, and how DOM chemical composition affects retention. We studied seasonal controls on DOM production and chemical controls on retention in soils of a temperate coniferous forest. The O horizon was not usually the dominant source for dissolved organic C (DOC) or N (DON) as has been reported for other sites. Rather, net production of both DOC and DON was often greater in the shallow mineral soil (0–10 cm) than in the O horizon. DOM production in the shallow mineral soil may be from root exudation as well as turnover of fine roots and microflora in the rhizosphere. In the field, the two acid fractions (hydrophobic and hydrophilic acids) dominated the soil solution at all depths. A major portion of net production and removal of total DOC within the soil column was explained by increases and decreases in these fractions, although a shift in chemical composition of DOM between the O and mineral soil horizons suggested different origins of DOM in these layers. A larger loss of the free amino fraction to deep soil water at this study site than at other sites suggested lower retention of labile DON. Field DOM removal measurements suggest that field-measured parameters may provide a good estimate for total DOM retained in mineral soil.

Key words: Dissolved organic carbon, Dissolved organic nitrogen, Lysimeter, Soil solution chemistry, Sorption

Introduction

Soil organic matter (SOM) is the largest terrestrial carbon (C) pool, thus understanding processes that form or degrade SOM is critical for understanding the global C cycle. The dynamics of dissolved organic matter (DOM) controls inputs and outputs of C as well as nutrients to the mineral soil in
forested ecosystems. Both dissolved organic C (DOC) and nitrogen (DON) concentrations generally peak at the bottom of the O horizon, then decrease with increasing soil depth, indicating that the O horizon is a major DOM source while the mineral soil is a sink (Qualls et al. 2000; Michalzik et al. 2001). Processes that control DOM production and retention in soils are only partially understood. Recent studies suggest that DOM is produced by decomposition of both new and old OM and by leakage of metabolites from plant and microbial cells (Christ & David 1996; Kalbitz et al. 2000; Qualls 2000). However, we lack understanding of seasonal and source effects on DOM chemical composition, the control of DOM composition on retention, and the control of retention on DOM composition in soils.

Microbial uptake and abiotic sorption to soil minerals are two major processes by which DOM is removed from soil water and incorporated into SOM. McDowell and Likens (1988) reported that the labile C fraction of soil solution (assumed to be mainly carbohydrates) is very small (approximately 3–6% of total DOC), suggesting that abiotic sorption is responsible for most DOM removal from soil solution. In laboratory incubations of soil solution, Qualls and Haines (1992a) found that the labile (rapidly degradable) fraction of DOC in Oa horizon solution was too small (6–19%) to explain the observed 100-fold reduction in DOC between the O and B horizons. Similarly, in a field study, Yano et al. (in press) found nearly complete removal of DOC and DON within the mineral soil in a temperate coniferous forest even though the labile DOC fraction was <2% of total DOC in O-horizon leachate. These studies suggest the importance of abiotic sorption in SOM formation and a substantial effect of DOM chemical properties on such sorption.

A number of studies have proposed various chemical and physical mechanisms that would cause DOM sorption, such as hydrophobic interactions (e.g. Jardine et al. 1989), ligand exchange (e.g. Greenland 1971; Parfitt et al. 1977; Kaiser & Zech 1997), cation bridging, hydrogen bonding, and Van der Waals forces (Qualls 2000). Therefore, differences in DOM composition should affect the degree of sorption and, consequently, SOM formation. Due to the complex nature of both the sorbate and the sorbent in the natural environment, sorption studies have mostly been limited to laboratory incubation of known DOM compounds and simple minerals (i.e. synthesized clays). Sorption between natural DOM and mineral soils is less frequently studied. More field-relevant studies are needed to understand DOM dynamics in the field.

DOM can be separated by chemical properties based on differences in affinity to various resins (Leenheer 1981; Qualls & Haines 1991). The hydrophilic neutral fraction is rich in polysaccharides (Guggenberger et al. 1994; Dai et al. 1996) and is highly labile, as opposed to the hydrophobic acid (anionic) fraction (Qualls & Haines 1992a; Jandl & Sollins 1997), which is