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Carbon and nitrogen limitations of soil microbial biomass in desert ecosystems

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Abstract. Microbial biomass nitrogen was measured in unamended (dry) and wetted soils in ten shrubland and grassland communities of the Chihuahuan desert, southern New Mexico, by the fumigation-extraction method. Microbial biomass-N in dry soils was undetectable. Average microbial biomass-N in wetted soils among all plant communities was 15.3 $\mu g\ g^{-1}$ soil. Highest values were found in the communities with the lowest topographic positions, and the minimum values were detected in the spaces between shrubs. Microbial biomass was positively and significantly correlated to soil organic carbon and extractable nitrogen ($NH_4^+ + NO_3^-$). In a stepwise multiple regression, organic carbon and extractable nitrogen accounted for 40.9 and 5.6%, respectively, of the variance in microbial biomass-N among all the samples. Among communities, the soil microbial biomass was affected by the ratio of carbon to extractable nitrogen. Our results suggest a succession in the control of microbial biomass from nitrogen to carbon when the ratio of carbon to nitrogen decreases during desertification.

Introduction

The microbial community plays an essential role in the transformation and cycling of organic matter and plant nutrients in the soil. Because nitrogen (N) is usually the nutrient in greatest demand by plants, estimates of the amount of N in microbial biomass have received considerable attention. This pool, by forming part of the potentially mineralizable soil N, acts as both a sink and a source of labile nutrients, capable of supplying a significant proportion of the N used by plants (Jenkinson & Ladd 1981; Marumoto et al. 1982; Bonde et al. 1988). Vitousek & Matson (1984) concluded that microbial biomass, if conserved during forest management, retains N in harvested loblolly pine plantations. Competition between microbial biomass and plants for N is an important factor in controlling both the amount and form of N in the soil (Jackson et al. 1989). In arid and semiarid ecosystems, nitrogen is an important factor limiting the productivity of perennial vegetation, since nitrogen amendments produce significant growth responses during the wet season (Fisher et al. 1987; Sharifi et al. 1988).

Discontinuous and stochastic rainfall is the dominant variable controlling plant growth in arid ecosystems. Many soil microorganisms are intolerant of low soil moisture, and changes in soil moisture status can result in rapid changes in the magnitude of microbial biomass (Harris 1981; Bottner 1985; Schnurer et al. 1986). In some cases, turnover of the microbial biomass is enhanced by soil drying-rewetting cycles (Ross 1987; Wardle & Parkinson 1990). In other cases, rewetting of dry soil may kill soil microbes through osmotic stress (Kieft et al. 1987).

Some authors suggest that the activity of soil microbes is less sensitive to soil water potential than is water uptake by plants and that a substantial amount of water is present at high tension during the dry season that is unavailable to plants but extractable by microbes (Calder 1957; Singh et al. 1989). In dry tropical ecosystems, Singh et al. (1989) found that microbial biomass accumulated and conserved nutrients in a biologically active form during the dry period and released them rapidly at the beginning of the wet season. Their findings suggest that in other ecosystems with frequent cycles of drying-rewetting, such as desert ecosystems, microbial biomass could play a similar role.

During the last 100 years, large areas of semiarid grasslands in the southwestern United States have been replaced by communities dominated by arid shrublands, especially creosotebush (*Larrea tridentata*) and mesquite (*Prosopis glandulosa*). This process has meant a shift from homogeneous to heterogeneous soil resource distribution (Schlesinger et al. 1990). Soil fertility in the new shrubland communities is relatively high at the base of shrubs, where soil is protected from erosion by wind and water. These changes affect abundance and distribution of N in desert soils, which determines plant productivity during the wet season (Fisher et al. 1988; Sharifi et al. 1988; Breman & de Witt 1983). The distribution of microbial biomass is also heterogeneous in desert shrublands, and its size and activity may affect the N availability in arid and semiarid ecosystems (Burke et al. 1989).

The objective of this study was to document the size and distribution of soil microbial biomass in different plant communities of the Chihuahuan desert, the factors that affect its abundance, and the changes in microbial biomass that occur during desertification.