ELSEVIER

Soil Biology & Biochemistry 37 (2005) 1427–1435

Soil Biology & Biochemistry

www.elsevier.com/locate/soilbio

Microbial community composition on native and drastically disturbed serpentine soils

Shira H. DeGrood*, Victor P. Claassen, Kate M. Scow

Land, Air, and Water Resources Department, Plant and Environmental Sciences, University of California, Building, 1 Shields Avenue, Davis, CA 95616, USA

Received 8 July 2004; received in revised form 9 December 2004; accepted 20 December 2004

Abstract

During construction of roads, entire hillsides can be cut away, dramatically disturbing the ecosystem. Microbial communities play important, but poorly understood roles in revegetating roadcuts because of the many functions they perform in nutrient cycling, plant symbioses, decomposition, and other ecosystem processes. Our objective was to determine relationships among microbial community composition, soil chemistry, and disturbance on a serpentine soil disturbed by a roadcut and then partially revegetated. We hypothesized that the adjacent undisturbed serpentine soil would have a different microbial community composition from barren and revegetated sections of the roadcut and that undisturbed soils would have the greatest microbial biomass and diversity. We measured phospholipid fatty acids (PLFA) and soil nutrient concentrations on barren and revegetated sections of the roadcut and on adjacent undisturbed serpentine and nonserpentine soils. Most roadcut samples had soil chemistry similar to the serpentine reference soil. The microbial biomass and diversity of barren sites was lower than that of revegetated or the serpentine reference site. The nonserpentine reference site had significantly ($P \leq 0.05$) greater microbial biomass than serpentine or disturbed sites but significantly lower relative proportions of actinomycetes, and slow growth biomarkers. The Barren site had the lowest microbial biomass and a significantly ($P \leq 0.05$) greater proportion of that biomass was fungi. Barren, revegetated, and serpentine sites all had dissimilar microbial community composition. The composition of the revegetated communities, however, was intermediate between the serpentine reference and barren soils, suggesting that community composition of revegetated soils is approaching that of an undisturbed site with similar soil chemistry.

Keywords: Phospholipid fatty acid analysis; Disturbance; Serpentine; Revegetation; Microbial community composition; Soil characteristics; Heavy metals; Restoration; Biomarkers

1. Introduction

Drastic disturbance is defined as removal of all the topsoil and biological materials on a site (Box, 1978), as occurs with deep excavation, landslide or mining activity. Disturbance of the soil or substrate causes dramatic changes in the taxonomic and functional diversity of soil microbial communities (Buckley and Schmidt, 2001; Chow et al., 2003; Laiho et al., 2003; Ponder and Tadros, 2002) and the effects of disturbance can be long lasting (Mummey et al., 2002b). Degraded sites may be restored to the original level of biotic integrity or rehabilitated to a modified sustainable ecosystem. In either case, many essential functions for a sustainable community are mediated by soil microorganisms (SER, 2002), including nutrient cycling (Ponder and Tadros, 2002), soil structure (Axelrood et al., 2002; Mummey et al., 2002a), and biological interactions (vanBruggen and Termorshuizen, 2003; Weller, 2002). Therefore, successful revegetation projects depend heavily on regeneration of microbial diversity. Bradshaw (1984a,b) summarized a conceptual model of ecosystem development in which the goal of restoration is to shift a skeletal or disturbed soil material from a state of low biomass and diversity to greater biomass and diversity. Under this model, restoration of original microbial diversity, biomass, and, more accurately, complete microbial community composition, should facilitate sustainable restoration on disturbed sites.

* Corresponding author. Tel.: +1 530 752 0416; fax: +1 530 752 1552.
E-mail address: shbell@ucdavis.edu (S.H. DeGrood).

0038-0717/$ - see front matter
doi:10.1016/j.soilbio.2004.12.013

Microbial populations, however, have received less study on restoration or rehabilitation projects than aboveground communities, despite the essential functions they provide.

In areas, where soil conditions are marginal, the functions of soil microbes are critical for supporting plant growth and revegetation success. Ecosystem recovery on serpentine derived soils, for instance, is may be retarded by harsh edaphic conditions, including high concentrations of heavy metals such as chromium, nickel, cobalt, and manganese; a low calcium:magnesium ratio (Ca:Mg); and deficiencies in nitrogen, phosphorus, and potassium (Prasad and De Oliveira Freitas, 1999; Proctor, 1999; Robinson et al., 1997; Turitzen, 1982). The geological parent material, including the ultramafic mineral serpentinite, generates the low Ca:Mg and high heavy metal content (Proctor, 1999). The unique properties of serpentine soils are reported to reduce plant productivity and to support unique plant communities (Baker et al., 1991; Brooks, 1987; Harrison, 1999; Roberts and Proctor, 1992). The limited available data suggest that microbial and fungal biomass and community structure also differs between serpentinite derived soils and adjacent nonserpentine soils (Amir and Pineau, 1998a,b; Lipman, 1926; Maas and Stuntz, 1969).

Our study site is located on serpentine substrates in central California. After several landslide events closed the highway, a 49,000 m^2 roadcut was constructed in 1992 and seeded with native and exotic erosion control plant species. However, these revegetation attempts have only been successful on sections of the roadcut, where the original topsoil was respread. The rest of the slope remains almost completely barren over a decade later. Lack of plant establishment may be due to physical disturbance of the soil (Hart et al., 1999), disruption of the soil microbial community structure (Klironomos, 2002), and/or shifts in chemical and physical properties of the soil (Chiarucci et al., 1998).

The objective of this study was to investigate changes in microbial communities, soil chemistry, and revegetation of a roadcut site on serpentine substrates. We hypothesized that the microbial community of an undisturbed reference serpentine soil would have greater microbial biomass, diversity, and different community composition than barren or revegetated substrates on the roadcut. We also hypothesized that the community composition of the reference site would be more similar to the revegetated sites than to the barren site.

We used phospholipid fatty acid (PLFA) analysis to measure microbial community composition (Baath et al., 1998; Bossio et al., 1998; Song et al., 1999; Zelles, 1999), both to generate a fingerprint of dominant members of the microbial community and to estimate microbial biomass. The total number of PLFAs in a sample was used as a proxy indicator of microbial diversity to test Bradshaw's conceptual model of ecosystem development (Bradshaw, 1984a,b), which investigates the relationship between total microbial biomass and microbial diversity.

2. Methods

2.1. Study site

The study site is located in the Coast Range of central California, 55 km due north of San Francisco (Colusa County State Route 20mile 1.5). This steep (30°), west-facing roadcut is about 91 m tall, 213 m wide, and extends back from the highway about 228 m, for a total area of about 49,000 m^2. After slope stabilization in 1992, the California Department of Transportation emplaced five horizontal cement interceptor trenches to prevent water runoff across the slope. The surface was seeded with native and erosion-control grasses and shrubs. Plant biomass was reduced to zero within 4 years except on two areas, where topsoil from the site was reapplied. The roadcut substrates had serpentine mineralogy as indicated by the detection of the mineral groups serpentine and chlorite in the clay fraction of the site soils and substrates by X-ray diffraction (D.G. McGahan, personal communication). Serpentinization, or hydrothermal alteration of ultramafic parent materials, is often an incomplete process, resulting in a wide variety of 'serpentinitized' soils and substrates in the field (Burt et al., 2001). For simplicity, however, the substrates and soils in this study are referred to simply as 'serpentine', despite the heterogeneous nature of this mineralogical group.

Two revegetated areas were sampled. The first (Reveg1) received a thin (2–3 cm) topsoil overlay and had moderate revegetation (20% plant cover). The second (Reveg2) received a 1.5 m deep backfill of serpentine topsoil and had dense vegetation (80% plant cover). Samples were collected from under groundcover, which consisted mainly of *Vulpia microstachys* and *Bromus madritensis*, and were near shrub species, including *Arctostaphylos viscida* and *Ceanothus jepsonii* (R. E. O'Dell, personal communication). Shrubs were less than 0.5 m tall. Samples were also collected from an adjacent non-vegetated area (Barren), where no revegetation treatment had been applied (0% plant cover). Four replicate samples were taken at random from each reference site. Each sample was collected to a depth of 10 cm by a trowel, which was rinsed with water after each sampling.

Reference samples were taken from native serpentine and nonserpentine soils to represent undisturbed soil conditions. The serpentine reference site was on the opposite side of the hill from the roadcut, about 30 m away from the top of the roadcut. The nonserpentine reference site was on the slope facing the roadcut, about 200 m away. Both reference sites had similar percent slope as the roadcut. The serpentine reference site was mapped as a Henneke sandy loam (Clayey-skeletal, magnesic, thermic Lithic Argixeroll) (N.R.C.S., 2001). Samples were taken from under herbaceous cover, which included *Lomatium marginatum* and *Agoseris*