APPLIED SOIL ECOLOGY 36 (2007) 1–9

available at www.sciencedirect.com

journal homepage: www.elsevier.com/locate/apsoil

Changes in N cycling and microbial N with elevated N in exotic annual grasslands of southern California

Abby G. Sirulnik [a,*], *Edith B. Allen* [a], *Thomas Meixner* [b], *Mark E. Fenn* [c], *Michael F. Allen* [d]

[a] *Department of Botany and Plant Sciences, University of California, Riverside, CA 92521, USA*
[b] *Department of Hydrology and Water Resources, University of Arizona, Tucson, AZ 85721, USA*
[c] *USDA Forest Service, Pacific Southwest Research Station, Forest Fire Laboratory, 4955 Canyon Crest Drive, Riverside, CA 92507, USA*
[d] *Department of Plant Pathology and Center for Conservation Biology, University of California, Riverside, CA 92521, USA*

ARTICLE INFO

Article history:
Received 28 July 2005
Accepted 22 November 2006

Keywords:
Nitrogen
Mineralization
Mediterranean
Grassland
Microbial

ABSTRACT

The impacts of nitrogen (N) fertilization and N deposition on N mineralization and microbial biomass were studied in exotic annual grasslands in southern California. The goal of the study was to understand how N deposition impacts N availability to the grasslands by studying mineralization in plots in an urban area that has received chronic N deposition for 50 years compared with N fertilized and control plots in a rural area. Fertilized plots had higher net and gross rates of N cycling than did soils from the control. The effect of soil mineral N concentrations on microbial N varied between and within growing seasons. Lower microbial N corresponded to more net N release and higher microbial N corresponded to less net N release. Urban soils often had higher NO_3^- concentrations than did soils from the rural site but there was no difference in NH_4^+ concentrations. Urban soils also had lower mineral N concentrations than the fertilized soils and mineralization patterns in the high N deposition soils did not resemble those in the fertilized soils, indicating that the levels of N deposition at this site were well below the experimental fertilization rate. The levels of soil mineral N in the rural site were considerably higher than from other studies in the same plots in recent years. This corresponds with rapidly increasing suburbanization of the rural site and increasing N deposition, as suggested from a recent air pollution model. Although the urban and rural soils were not as different in mineral N concentrations as expected, soils in exotic grasslands near urban areas across the region can have mineral N concentrations as high as the fertilized soils, indicating that increased N cycling and altered microbial N may occur under N deposition.

1. Introduction

In heavily polluted regions of southern California, summer dry nitrogen (N) deposition contributes up to 35–45 kg N ha^{-1} $year^{-1}$ to lower elevations dominated by shrubs and exotic grasses (Bytnerowicz et al., 1987; Bytnerowicz and Fenn, 1996). In high N deposition areas, drought deciduous and semi-deciduous perennial shrub and annual forb species of the native coastal sage scrub (CSS) vegetation, though still present, are greatly reduced in abundance and have been replaced by exotic annual grasslands (Mooney, 1988; Minnich and Dezzani, 1998). Because N deposition is a significant source of exogenous N to the expanding exotic annual grasses (Allen et al., 1998; Padgett et al., 1999), it is important to understand how N deposition affects ecosystem function in the grasslands.

* *Corresponding author at*: 119 South Highland Avenue, 2E, Ossining, NY 10652, USA. Tel.: +1 914 762 3713; fax: +1 914 762 3713.
E-mail address: abbysirulnik@verizon.net (A.G. Sirulnik).
0929-1393/$ – see front matter
doi:10.1016/j.apsoil.2006.11.004

In the Mediterranean-type climate, plants become active in the late autumn or early winter when annual rains follow a long summer drought. Plant biomass accumulation occurs between the onset of the rainy season and depletion of soil water in the late spring. In the absence of N deposition, inorganic soil N accumulates on the soil surface via litter and fine root mineralization throughout the summer drought period (Jackson et al., 1988). Mineral N is rapidly immobilized by microorganisms when the first winter rains fall (Jones and Woodmansee, 1979; Kieft et al., 1987; Schimel et al., 1989) and is available for plant uptake after N is mineralized from the microbial pool. N deposition may increase the rate at which N is mineralized from the microbial pool (Fisk and Schmidt, 1996; Kiefer and Fenn, 1997; Falkengren-Grerup et al., 1998; Chen et al., 2002) and thus becomes available to plants (Olff et al., 1994). In southern California, N deposition can result in surface soil mineral N levels as high as 85 $\mu g\,N\,g^{-1}$ (Padgett et al., 1999). N is mineralized at a faster rate from grass litter enriched in N as a result of N deposition (Sirulnik et al., 2007) and if high concentrations of soil N also result in increased soil N mineralization, it could mean even faster rates of N availability when the rainy season begins.

In this study, we investigated whether N additions to exotic annual grasslands of southern California result in faster soil N cycling by measuring soil N mineralization in artificially fertilized and control plots. To corroborate whether altered N mineralization was related to altered net N retention by microbial organisms, changes in microbial N were compared with changes in net N mineralization rates. Additionally, to test if fertilization is a suitable experimental surrogate for N deposition, we compared N cycling and microbial N in soils that have been artificially fertilized with those that have received chronic N deposition.

To determine if soil N mineralization is affected by added mineral N and if an added N effect on mineralization can be explained by changes in microbial N, we measured (1) net N mineralization, (2) microbial N, and (3) gross N mineralization.

2. Materials and methods

2.1. Experimental sites

The study was conducted at two sites along an N deposition gradient on the Perris Plain of southern California: an undeveloped region of the University of California, Riverside campus (33.97°N, 117.32°W) and Lake Skinner in the Western Riverside County Multi-Species Reserve near Temecula, CA (33.60°N, 117.02°W). Lake Skinner is protected habitat that has historically received relatively low levels of urban pollution (Padgett et al., 1999). The University of California, Riverside, is an urban area that has received chronic elevated levels of N deposition from the Los Angeles Basin for over 50 years. Summer atmospheric N (NO_3^- and NH_4^+) concentrations in 1994 were approximately 40 $\mu g\,N\,m^{-3}$ in Riverside and 18 $\mu g\,N\,m^{-3}$ at Lake Skinner (Padgett et al., 1999). In September of 1994, at the end of the summer N deposition season, surface soil mineral N was 40 and 8 $\mu g\,N\,g^{-1}$ soil in Riverside and Lake Skinner, respectively (Padgett et al., 1999). Climate, soil, and historical vegetation are similar between the two sites (Table 1). The climate is Mediterranean-type with 90% of plant growth occurring from November to April. Total annual (September–August) precipitation in the years during which the study was conducted was 8.3, 28.3 and 17.3 cm, respectively, in Riverside and 7.5, 31.9 and 14.1 cm, respectively, at Lake Skinner (Temecula) (CIMIS) for years 2001–2002, 2002–2003, and 2003–2004, respectively. The rainy season of 2001–2002 was a record drought year. Historic native vegetation was CSS at both sites. In Riverside, most native CSS has been replaced with exotic annual grasses. At

Table 1 – Soil and site information for urban (Riverside) and rural (Temecula) fertilized and control plots

	Urban	Rural fertilized	Rural control
Soil characteristics			
N (%)[a]	0.11	0.15	0.12
C (%)[a]	0.77	1.48	1.22
OM (%)[b]	1.25	2.16	1.97
pH[c]	6.45	6.45	6.45
Soil order	Entisol	Entisol	Entisol
Texture[d]	Sandy loam	Sandy loam	Sandy loam
Parent material[d]	Colluvium, granite	Colluvium, granite, with additions of gabbro	Colluvium, granite, with additions of gabbro
Site characteristics			
Elevation (approx.)	450–600	450–600	450–600
Slope (approx.)	10°	10°	10°
Aspect	Northwest	Northwest	Northwest
Precipitation[e] (cm) (30 years average)	36	29	29

[a] Analyzed by Carlo Erba combustion gas analyzer (Method 972.43 in Official Methods of Analysis of AOAC International, 1997) on 10 cm × 3 cm diameter cores collected in November 2002, sieved through a 2-mm sieve, and composited into three samples of three subsamples.
[b] Analyzed by modified Walkley–Black method (Nelson and Sommers, 1996) at the Division of Agriculture and Natural Resources (DANR) Analytical Lab. Davis, California.
[c] Analyzed by glass electrode in a 1:2 soil to water solution.
[d] Wood et al. 2006.
[e] California Irrigation Management Information System.