

Enzyme Activity in Temperate Desert Soils: Influence of Microsite, Depth, and Grazing

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Abstract: The enzyme status of soil influences mineralization kinetics, and thus, the supply of nutrients to plants. We quantified urease, asparaginase, glutaminase, phosphatase, and arylsulfatase activity in a sagebrush/grass ecosystem northeast of Reno, NV. Enzyme activity was evaluated by depth (0 to 5 cm, 5 to 10 cm, 10 to 20 cm), microsite (sagebrush, crested wheatgrass, cheatgrass, cryptogamic crust in shrub interspace, noncryptogamic crust in shrub interspace), and treatment (grazed and ungrazed). For most enzymes evaluated, there was a significant depth x microsite interaction. In general, enzyme activity declined with depth. Moreover, the noncryptogamic interspace microsite often had the lowest enzyme activity among the other microsites. Depending on soil depth and microsite, the grazing treatment significantly reduced urease, asparaginase, and alkaline phosphatase activity compared to the ungrazed treatment. Enzyme activity is an important soil attribute and may serve as a robust measure of soil health.

Introduction

Soil is a critical component of the Earth's biosphere. From food production, degradation of toxic compounds, and as a medium for the geochemical recycling of many elements, proper management of soil is crucial for the continued prosperity of humans. Yet, given that most soils of the world have only been intensively cultivated and grazed for a relatively short period of time, there are concerns whether our soil resources are sustainable (Hillel 1991). Scientists have recently attempted to quantify soil health or quality as an index of sustainability (Doran and others 1994). One potentially important soil attribute that may be a good proxy for soil health is enzyme activity (Dick 1994; Saviozzi and others 2001) because it is an integration of life processes occurring within the soil. The study was conducted to ascertain how several common soil enzymes vary by soil depth, soil microsite, and grazing in a sagebrush/grass plant community.

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Methods

Field

The study area is in the Bedell Flat area, 30 km north of Reno, NV (119° 50' E 39° 51' N). The slope is less than 4 percent with a northeastern aspect. Elevation is 1,548 m. The soil is mapped as the Bedell series, a coarse-loamy, mixed, mesic, Aridic Argixeroll developed in mixed colluvium dominantly from granite. Present vegetation consists of crested wheatgrass (*Agropyron desertorum* [Fischer] Schultes), cheatgrass (*Bromus tectorum* L.), big sagebrush (*Artemisia tridentata* ssp. *tridentata* Nutt.), needle-and-thread (*Hesperostipa comata* Trin. & Rupr.), Thurber's needlegrass (*Achnatherum thurberianum* [Piper] Barkworth), squirreltail (*Elymus elymoides* [Raf.] Swezey), and green rabbitbrush (*Chrysothamnus viscidiflorus* [Hook.] Nutt.). On July 19, 1995, soil (four replicates) was collected from grazed and ungrazed treatment plots. The plots are on either side of an enclosure constructed in 1958. Three depths were sampled (0 to 5 cm, 5 to 10 cm, and 10 to 20 cm). Microsites sampled on the grazed plot included sagebrush, (ARTR), cheatgrass, (BRTE), and noncryptogamic barren shrub interspaces (INTER). Microsites sampled in the ungrazed plot included crested wheatgrass, (AGDE), cryptogamic crust covered shrub interspaces (CRPTO), cheatgrass (BRTE), and sagebrush (ARTR).

Laboratory

The soils were returned to the laboratory where they were air dried and sieved to remove material greater than 2 mm in size. The soils were then stored in paper bags in the refrigerator prior to the particular enzyme assays. Assays were completed within 2 weeks. Enzyme activity procedures are as outline in Tabatabai (1994). Three enzymes that cleave amine groups (amidohydrolases) were evaluated: asparaginase, urease, and glutaminase. These assays are based on the determination of ammonium released when buffered soil (5 g) is incubated individually with known amounts of the substrates, L-glutamine, L-asparagine, or urea at 37 °C for 2 hours. After incubation, cleaved ammonium is extracted with 2 M KCl containing AgSO₄ to stop enzyme activity. Ammonium present in the original soil and ammonium cleaved due to non-enzymatic processes are subtracted out via running a blank. Ammonium is quantified using a flow injection membrane-diffusion method. Quantification of arylsulfatase, and acid and alkaline phosphatase activity is based on the cleaving of the sulfate or phosphate group attached to *p*-nitrophenyl. One g of THAM-buffered soil is incubated with the appropriate

substrate at 37 °C for 1 hour. The *p*-nitrophenyl remaining is extracted with KCl and quantified colorimetrically.

Statistics

For each individual enzyme, data were analyzed using a fixed effect, two-way analysis of variance with unequal replication for depth and microsite. A separate two-way analysis of variance was performed on depth and treatment for microsites CRPTO/INTER, BRTE, and ARTR. If the analysis showed a significant F-value, mean separation was accomplished using Duncan's new multiple range test. For the prepared graphs, variance of data is shown by standard error about the mean.

Results

There was a significant ($P = 0.05$) depth \times microsite interaction for enzyme activities of urease, asparaginase, arylsulfatase, and glutaminase (fig. 1). Urease and arylsulfatase activities were more variable than asparaginase or glutaminase activity. Moreover, the INTER microsite generally has the lowest enzyme activities among the microsites and the most inconsistent trend in enzyme activities with depth. Urease activity displayed a declining trend with depth for the CRPTO, ARTR, and BRTE microsites, but activity for the INTER site significantly increased with

depth. Asparaginase was the only enzyme whose activity consistently declined with depth. Arylsulfatase activity was inconsistent with depth. The ARTR microsite had the highest enzyme activities, but only statistically higher in the 0- to 5-cm depth increment for urease and asparaginase.

Alkaline phosphatase had significant main effects for depth and microsite (fig. 2). Enzyme activity declined significantly with depth. The CRPTO microsite had the most activity followed by ARTR, AGDE, BRTE, and finally INTER with the least enzyme activity.

Asparaginase and urease activities were influenced by a significant microsite \times treatment interaction (fig. 3). In the 0- to 5-cm depth increment, the grazed plot had significantly less enzyme activities of asparaginase and urease in the INTER microsite compared to the ungrazed CRPTO microsite. In addition, for the BRTE microsite, urease activity was significantly less in 10- to 20-cm depth increments of the grazed plot compared to the corresponding ungrazed plot. Finally, alkaline phosphatase activity was significantly less on the grazed INTER microsite than on the ungrazed CRPTO sites.

Discussion

Plant microsite did significantly affect enzyme bioassays, which has been reported in the literature (Neal 1973; Saviozzi and others 2001). In general, enzyme activity was highest in

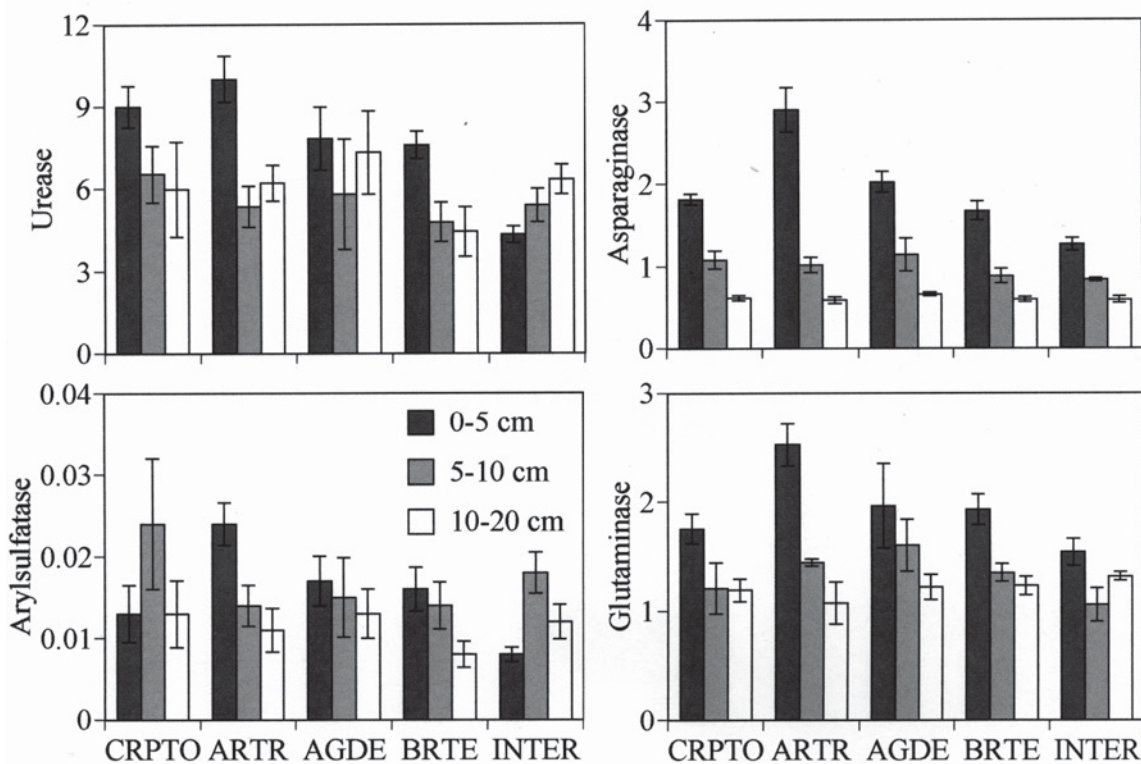


Figure 1—Soil enzyme activities that were influenced by a significant soil depth by microsite interaction. Units are μmol of substrate cleaved $\text{g}^{-1} \text{hr}^{-1}$.

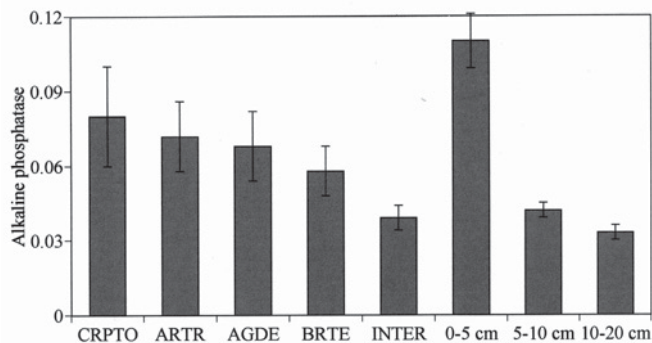


Figure 2—Phosphatase activity main effects of microsite and soil depth. Units are μmol of substrate cleaved $\text{g}^{-1} \text{hr}^{-1}$.

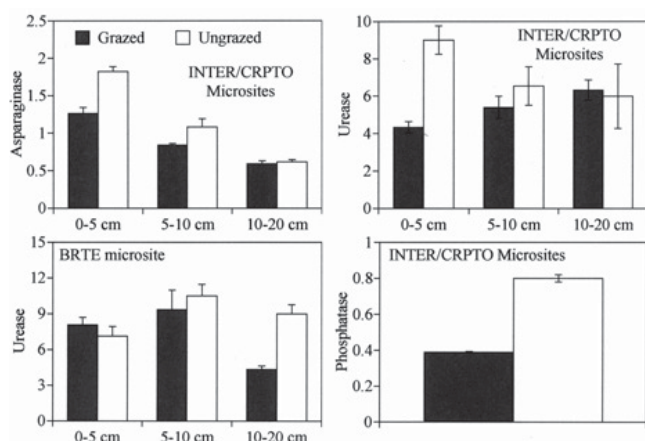


Figure 3—Soil enzyme activities that were influenced by a significant main effect or interaction with treatment. Units are μmol of substrate cleaved $\text{g}^{-1} \text{dry soil hr}^{-1}$.

the surface soil (0 to 5 cm). Burke and others (1989) and Bolton and others (1993), whose experiments were also conducted in a sagebrush ecosystem, found similar results. For the cryptogamic crust and sagebrush interspace sites, however, enzyme activity was least in the 0- to 5-cm depth increment. The lack of higher plant life, which would afford

some moderation of the intense desert sun and engender greater microbial numbers, may explain these findings. Grazing-induced reduction of enzyme activities has been reported in the literature (Holt 1996). Given that enzyme activity of soil is both a microbial (largely) and a plant mediated process (Tate 1995), one would suspect that grazing has reduced those microbes and higher plants that produce urease, asparaginase, and alkaline phosphatase. This conclusion is of course complicated by the fact that, in the shrub interspaces where the grazing effect is most pronounced, the soil lacks well-expressed cryptogamic organisms. The large reduction in urease activity on grazed BRTE microsites is perplexing; however, it seems reasonable to speculate that grazing of cheatgrass may have reduced root elongation into the 10- to 20-cm depth increment. It seems plausible that the grazing reduction of the amidohydrolases urease and asparaginase could potentially reduce N mineralization kinetics (Holt 1997). Likewise grazing-induced reduction of phosphatase could reduce P availability. We are planning future experiments to clarify these unknowns.

References

- Bolton, H., Jr.; Smith, J. L.; Link, S. O. 1993. Soil microbial biomass and activity of a disturbed and undisturbed shrub-steppe ecosystem. *Soil Biology and Biochemistry*. 25: 545-552.
- Burke, I. C. 1989. Control of nitrogen mineralization in a sagebrush steppe landscape. *Ecology*. 70: 1115-1126.
- Dick, R. P. 1994. Soil enzyme activities as indicators of soil quality. In: *Defining soil quality for a sustainable environment*. SSSA Spec. Publ. 35. Madison, WI: Soil Science Society of America: 107-124.
- Doran, J. W.; and others, eds. 1994. *Defining soil quality for a sustainable environment*. SSSA Spec. Publ. 35. Madison, WI: Soil Science Society of America. 244 p.
- Hillel, D. J. 1991. *Out of the Earth, civilization and the life of the soil*. New York: The Free Press. 321 p.
- Holt, J. A. 1997. Grazing pressure and soil carbon, microbial biomass and enzyme activities in semi-arid Northeastern Australia. *Applied Soil Ecology*. 5: 143-149.
- Neal, J. L., Jr. 1973. Influence of selected grasses and forbs on soil phosphatase activity. *Canadian Journal of Soil Science*. 53: 119-121.
- Saviozzi, A.; Levi-Minzi, R.; Cardelli, R.; Riffaldi, R. 2001. A comparison of soil quality in adjacent cultivated, forested, and native grassland soils. *Plant and Soil*. 233: 251-259.
- Tabatabai, M. A. 1994. Soil enzymes. In: *Methods of soil analysis, part 2, microbiological and biochemical properties*. Madison, WI: Soil Science Society of America: 775-833.
- Tate, R. L. 1995. *Soil microbiology*. New York: John Wiley & Sons. 398 p.