



# Microbial Enzymatic Activity in Degraded Arid Soils: Implications for Plant Community Restoration

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## ABSTRACT

Soil health evaluation is a critical component of plant community remediation efforts. Arid lands, with minimal carbon and water contents, low nutritional status and restricted, seasonal activity pose specific challenges to restoration of both soil and vascular plant communities. Cryptobiotic soil crusts contribute to ecosystem stability through increased water infiltration, soil aggregate stabilization, and nutrient cycling. It is hypothesized that microbial metabolic profiles in arid soils and soil crusts are sensitive to relatively minor compaction and fracturing disturbances such as livestock grazing, off-road vehicle use, trampling by humans, and drilling and mining activities. Post-disturbance recovery rates for soil bacterial and fungal populations are understudied.

Total soil enzymatic activity of rhizosphere and non-rhizosphere soils was assessed across sites in New Mexico with varied disturbance regimes (undisturbed, shrub encroachment, actively grazed, surface-mined remediated, gas-drilled remediated). Sites encompassed two ecoregions (northern Chihuahuan desert, Arizona/New Mexico Plateau). Microbial activity was measured using the MicroResp™ system, which quantifies the CO<sub>2</sub> emitted through respiration by microbes within whole soil samples supplemented with various carbon sources (simple and polymeric sugars, amino acids, carboxylic acids, fatty acids). Preliminary comparison of rhizosphere and non-rhizosphere soils indicates that the divergence in enzymatic activity profiles was more obvious for the undisturbed areas than for the remediated areas, and that activity was not substantially different between types of disturbance regime. Gradients in enzymatic activity profiles from rhizosphere to non-rhizosphere soils may prove to be a useful tool in assessing the rate and status of remediation of arid lands including: 1) the significance of local climatic, edaphic, and management conditions on the soil microbial metabolic activity range; and 2) the general health status of degraded or remediated arid region soils.

## SIGNIFICANCE

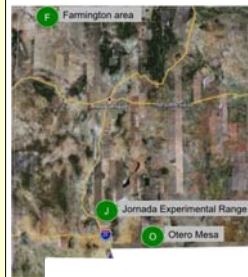
Evaluation of soil microbial activity is an important tool in gauging soil health prior to plant restoration efforts. Functional diversity of the soil microbial community is commonly used in this assessment of soil health as it relates to the activity of soil microflora involved in carbon cycling. Functional diversity can be assessed through SIR (substrate induced respiration) utilizing certain carbon sources. Soil microbes in different microenvironments will have varying responses to different substrates, thus catabolic fingerprint information of each location specific community can be obtained. The impact on soil microbiology of differing approaches to plant reestablishment efforts can then be evaluated through the catabolic fingerprint of the soil community to illustrate the relationship between soil microbial diversity and plant restoration success.

## OBJECTIVES

The purpose of this study was to evaluate total-soil enzymatic activity profiles across three locations in two distinct arid zones: the Northern Chihuahuan desert (Jornada Experimental Range and Otero Mesa) and the tablelands in the Arizona/New Mexico Plateau (Farmington area). Total soil enzymatic activity of samples was compared:

- 1) between rhizosphere and non-rhizosphere; and
- 2) among varied disturbance regimes.

### Key to sites and disturbance regimes:



Disturbance	Location
Undisturbed	Arizona/Colorado Plateau
Surface-mined, remediated	Arizona/Colorado Plateau
Shrub encroachment	Northern Chihuahuan Desert
Active grazing	Northern Chihuahuan Desert
Gas-drilled, remediated	Northern Chihuahuan Desert

## METHODS

Soil cores were taken from each site and separated into rhizosphere- and non-rhizosphere samples. Rhizosphere soil was considered the soil that stuck to roots after gently shaking them. Samples were kept in sterile bags in cold storage until they could be analyzed in the laboratory. At sampling, the soil water content of all samples was less than 3%.

Microbial activity of each sample was measured using the MicroResp™ system (Figure 1), which quantifies the CO<sub>2</sub> respired by microbes within whole soil samples supplemented with various carbon sources (list of substrates below). Respired CO<sub>2</sub> is quantified by measuring the changes in color of an indicator dye (cresol red) with the change in pH when CO<sub>2</sub> reacts with the bicarbonate present in the indicator gel. Respiration assays were carried out after the soil water content was corrected to the calculated equivalent of the soil's field water potential.



Figure 1. MicroResp™ assembly showing deep well plate on the bottom which contains whole soil samples supplemented with various carbon sources. A detection plate (made with agar, sodium bicarbonate, potassium chloride, and cresol red) is placed on top, with a porous rubber seal sandwiched between the two plates. Typical reactions are left to incubate for 6h after which the detection plate is read in a spectrophotometer.

Simple Sugars	Amino Acids	Carboxylic Acids
arabinose	alanine	α -ketoglutaric acid
glucose	arginine	ascorbic acid
mannose	cysteine	fumaric acid
	glycine	malic acid
	histidine	protocatechuic acid
	phenylalanine	uric acid

## RESULTS

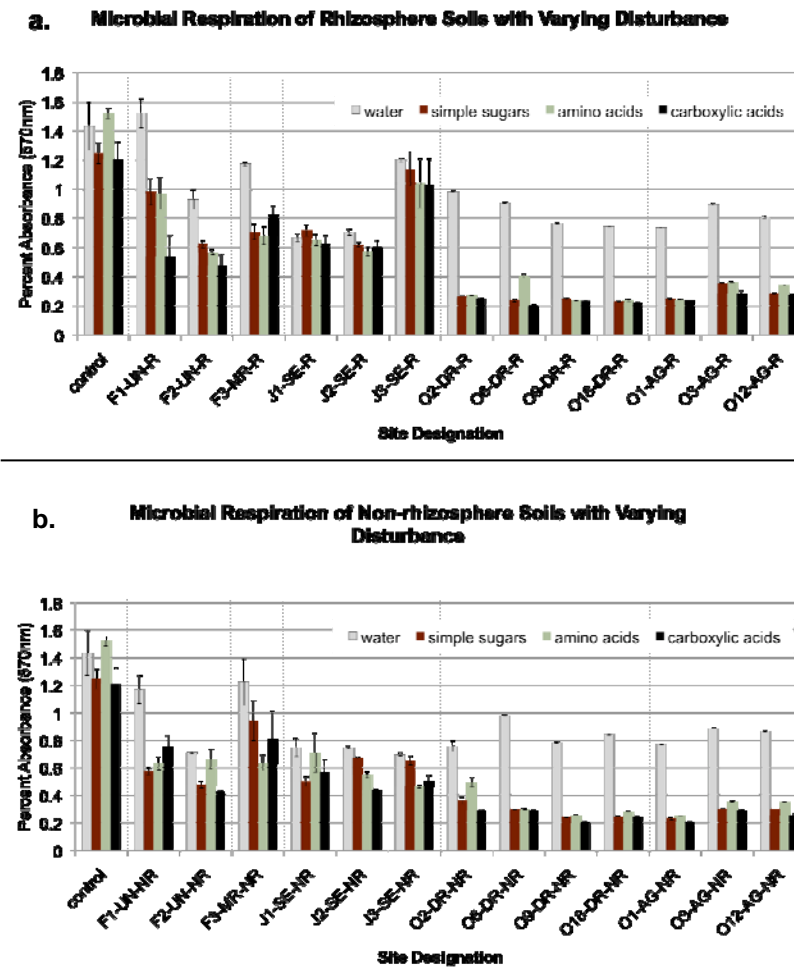


Figure 2. Microbial respiration rates in response to water (control), simple sugars, amino acids, and carboxylic acids, compared between rhizosphere (a) and non-rhizosphere (b) soils. Site designation labels include three parts separated by hyphens such that the label reads Location-Disturbance regime-Rhizosphere/Non-rhizosphere. Location abbreviations are: Farmington (F); Jornada Experimental Range (J); or Otero Mesa (O); and numbers indicate sample number. Disturbance regimes are abbreviated: undisturbed (UN); shrub encroachment (SE); natural gas drilled remediated (DR); and actively grazed (AG). Rhizosphere and non-rhizosphere samples are identified as R and NR, respectively. Respiration rate is inversely proportional to percent absorbance at 570 nm.

### Similarity Analysis of Chihuahuan Desert Grassland Amino Acid and Carboxylic Acid Activity Profiles: Dendrogram with Average Linkage & Euclidean Distance

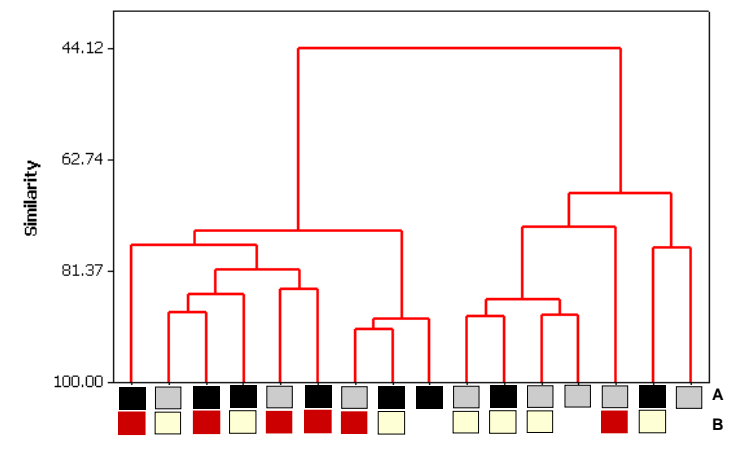


Figure 3. Dendrogram showing grouping of rhizosphere soils (■) and non-rhizosphere soils (□) in row A, and grouping of disturbance regimes in row B, in this case gas drilling remediated (DR, ■) and actively grazed (AG, □). Disturbance regimes that do not have a colored block in row B are representative samples that are neither DR or AG.

## CONCLUSIONS

Simple sugars and carboxylic acids as carbon sources induced the greatest response in microbial activity regardless of rhizosphere status of the soil (Figure 2). In general the Northern Chihuahuan desert samples ("J" and "O") exhibited more complex enzymatic activity profiles than the undisturbed Arizona/New Mexico Plateau ("F") samples. This was particularly the case with Otero Mesa, a relatively intact grassland.

Comparison of rhizosphere and non-rhizosphere soils indicates that the divergence in enzymatic activity is greater for the native undisturbed areas than for the remediated areas (Figure 2). A possible explanation for this could be the mixing of rhizosphere and non-rhizosphere soils during disturbance and subsequent restoration activities; sites with the greatest amount of disturbance and remediation efforts had the least separation in microbial activity between rhizosphere and non-rhizosphere samples.

The virtually identical results in the rhizosphere and non-rhizosphere soils on Otero Mesa ("O" samples) may be a result of the shallow soils above the petrocalcic horizon. However, when comparing only Otero Mesa soils supplemented with amino acids and carboxylic acids, samples clustered based on disturbance regime (drilling-remediated, and active grazing; Figure 3). This clustering indicates that there are different but subtle impacts of different types of disturbance on soil microbial activity.

The gradients in enzymatic activity profiles from rhizosphere to non-rhizosphere samples may be useful in assessing the rate and status of remediation of such lands. Thus, for arid lands, the enzymatic activity profiling may be used to evaluate: 1) the significance of local climatic and edaphic conditions on the metabolic range of soil microbial activity; and 2) the health status of degraded or remediated arid region soils.

## ACKNOWLEDGEMENTS

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