

# Effects of Biological Soil Crusts on Seedling Growth and Mineral Content of Four Semiarid Herbaceous Plant Species

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**Abstract:** A growing body of evidence indicates that biological soil crusts of arid and semiarid lands contribute significantly to ecosystem stability by means of soil stabilization, nitrogen fixation, and improved growth and establishment of vascular plant species. In this study, we examined growth and mineral content of *Bromus tectorum*, *Elymus elymoides*, *Gaillardia pulchella*, and *Sphaeralcea munroana* grown in soil amended with one of three levels of biological soil crust material: (1) a low-fertility sand collected near Moab, UT, (2) sand amended with a 1-cm top layer of excised soil crust, and (3) crushed-crust material. Plants were harvested after 10 weeks growth, dried, weighed, and leaves were ground for nutrient analysis. Root architecture was also quantified. Soil crust additions significantly affected nearly all variables examined. Both aboveground and belowground biomass were significantly increased in the presence of crust material. The effect of soil crust additions is likely due to the increased nitrogen content of the crusts. Nitrogen tissue content of all four species was greatly enhanced in crusted soils. All species showed a decline in root/shoot ratios with crust additions, indicating a shift in plant allocation patterns in response to improved soil fertility. The proportion of fine feeder roots, as measured by specific root length, also declined with the addition of soil crust material. These data support other studies suggesting that soil crusts have a positive effect on establishment of associated vascular plant species.

## Introduction

Biological soil crusts are a common surface feature of arid and semiarid lands throughout the world (West 1990). While

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the ecological role of these crusts varies according to their composition (Belnap and others 2001; Evans and Johansen 1999), available information indicates that biological crusts contribute to a variety of ecological functions, including soil stabilization, nitrogen (N) fixation, nutrient availability, and vascular plant establishment. We examined the effects of biological crust additions on the growth, N content, and root architecture of four plant species: *Elymus elymoides*, *Gaillardia pulchella*, *Sphaeralcea munroana*, and *Bromus tectorum*. Complete results of the study are available in Pendleton and others (2003).

## Methods

We transplanted 2-week-old seedlings into 6-inch pots containing one of three soil treatments: (1) a steam-sterilized low-fertility sand collected near Moab, UT, (2) crushed soil crust material, and (3) 6-inch circles of intact soil crust placed over the low-fertility sand. We also inoculated plants with spores of the arbuscular mycorrhizal fungus *Glomus intraradices* obtained from Brokrow Nursery in Saticoy, CA, at the time of transplanting. Plants were grown in a greenhouse and bottom watered as needed using a capillary mat system.

Seedlings were harvested after 10 weeks growth in the treatment media. Shoots and roots were separated, dried, and weighed. Ground leaf and stem tissue was analyzed for N content at the Soil-Plant Analysis Laboratory, Brigham Young University, Provo, UT, using a micro-Kjeldahl procedure. Dried root tissue was rehydrated and fixed in 70 percent ethanol. Total root length was calculated using a modified line intersect method (Tennant 1975), and specific root length was calculated as meters root length per gram dry root weight. We also confirmed colonization of all plants by mycorrhizal fungi (Koske and Gemma 1989).

Statistical analyses were performed using SAS version 8.1 for personal computers (SAS Institute 1999–2000). Variables were analyzed separately by species, first using a MANOVA procedure to determine the significance of treatment effect, followed by univariate analyses using a one-way ANOVA or GLM procedure.

## Results and Discussion

Soil treatment had a significant effect on growth and N content of all four plant species (table 1). Plants grown in the crushed-crust medium were 6 to 8 times the size of plants growing in sand only. Significant differences also occurred between plants grown in the crust-over-sand and sand treatments. Plants grown in crusted soils were larger and had higher N concentrations in their stem and leaf tissue. Total uptake of N by plant shoots, calculated as biomass  $\times$  concentration, was without exception greatest in the crushed-crust medium, followed by the crust-over-sand treatment. Other studies have reported increased growth and mineral content, especially N, of plants grown in crusted soils as compared to blow sand (Belnap and others 2001).

The relative allocation between root and shoot biomass was also affected by the addition of crust material (table 1). Root/shoot ratios of all species decreased with increasing crust additions, indicating that plants invested proportionately fewer resources in root tissue as nutrient availability increased (Kachi and Rorison 1989). Values for specific root length, which measures the relative proportion of fine feeder roots to larger conducting roots, were also lower in crusted soils, again indicating less biomass investment in fine feeder roots for plants growing in higher nutrient soils.

Biological soil crusts contain a large reservoir of bioessential elements that slowly become available for plant growth. The high concentration of nutrients relative to the underlying soil comes from the active fixation of nitrogen and carbon, as well as the accumulation of small dust particles (Belnap and others 2001; Harper and Pendleton 1993). Crust material

used in this experiment was high in organic matter, N, calcium, and magnesium. Next to water, N is the factor most limiting to plant growth in arid environments (Evans and Belnap 1999). Mycorrhizal plants in particular may benefit from the fixation of atmospheric N by soil crusts. Considerable evidence indicates that mycorrhizal fungi play an important role in N uptake (Hodge and others 2001).

In the Colorado Plateau region, trampling or other compressional disturbance when crusts are dry and brittle destroys the integrity of the crust, causing a short-lived flush of nutrients similar to that experienced by plants growing in the crushed-crust treatment. A rapid increase in nutrient availability could disrupt community dynamics, resulting in differential establishment and increased reproductive success of exotic annual species such as *Bromus* sp. (McLendon and Redente 1991). Subsequent loss of the crust community through wind and water erosion reduces the number of mycorrhizal propagules and other microorganisms associated with the crust layer (Harper and Pendleton 1993). The resulting reduction in soil fertility and stability of such a degraded ecosystem could have profound and lasting consequences (Evans and Belnap 1999).

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**Table 1**—Growth measures and tissue nitrogen content of plants grown in different soil treatments. Letters following means denote significant treatment differences at  $P < 0.05$  using the Student-Newman-Keuls multiple range test.

	Shoot biomass	Root biomass	Root/shoot ratio	Specific root length	Nitrogen concentration	Total shoot N
	-----g-----			mg	percent	mg
<b><i>Sphaeralcea munroana</i></b>						
Crushed crust	3.91a	0.86a	0.21a	7,848a	2.39a	0.925a
Crust over sand	.51b	.29b	.57b	9,434b	2.49a	.127b
Sand	.30c	.25b	.84c	13,054c	1.99b	.059c
P value	<0.0001	<0.0001	<0.0001	<0.0001	.0254	<0.0001
<b><i>Gaillardia pulchella</i></b>						
Crushed crust	4.66a	1.14a	.26a	9,622a	1.30ab	.566a
Crust over sand	.83b	.36b	.45b	10,927a	1.45a	.122b
Sand	.62c	.31b	.51b	10,846a	1.11b	.067c
P value	<0.0001	<0.0001	<0.0001	.3900	.0433	<0.0001
<b><i>Elymus elymoides</i></b>						
Crushed crust	1.48a	.26a	.18a	9,731a	1.66a	.241a
Crust over sand	.30b	.14a	.44b	16,442b	1.65a	.051b
Sand	.16c	.06a	.46b	20,997b	1.44a	.023c
P value	.0073	.1621	.0051	.0137	.3900	.0101
<b><i>Bromus tectorum</i></b>						
Crushed crust	3.19a	.90a	.26a	14,496a	1.64a	.477a
Crust over sand	.79b	.40b	.54b	24,238b	1.09b	.083b
Sand	.40c	.22c	.58b	24,422b	.96c	.037c
P value	.0004	.0099	<0.0001	.0051	<0.0001	<0.0001

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