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BELOW-GROUND ECOSYSTEMS PROJECT

constructed and used to simulate rainfall by applying water at a uniform rate (intensity). All runoff and eroded sediment was collected and measured. In addition to infiltration/runoff relationships, this method provides an estimation of the erodibility of the surficial materials by measurements of the quantity of sediment contained in the runoff.

Four different areas were tested at the mine site. Two were unmined areas: one contained soil developed from alluvium, while the second contained sandstone parent material. Two mined areas were also examined: one was an area of "old" minesoil, the other contained regraded and reclaimed "new" minesoil. Before each infiltration test was started, the amount of vegetative cover and the slope characteristics were measured. Soil samples were collected at 7.5-cm increments to a depth of 30 cm for subsequent laboratory analysis, and bulk density was measured at various depths with a neutron probe. Each of the four areas was tested with water application rates of 5 and 10 cm/hr, and at least six individual tests were conducted in each area.

All laboratory analyses required to fully characterize the physical characteristics of the pedologic/geologic materials to a depth of 30 cm were completed during 1980. For each 7.5-cm depth increment, determinations were made for grain-size distribution, average particle density, moisture content before and after testing, and moisture retention characteristics. Organic matter content was also determined for the upper 7.5-cm increment. The quantity of sediment contained in each runoff sample was also measured. All analytical results were compiled, additional parameters were calculated from these basic data, and preliminary data analyses and interpretation were begun. A report describing the results of this study will be prepared in 1981.

2.8 BELOW-GROUND ECOSYSTEMS PROJECT (R. M. Miller, Project Coordinator)

2.8.1 Background

The surface mining of large coal deposits in the western United States will result in the disturbance of extensive tracts of land requiring reclamation. Although the exact criteria defining successful reclamation in the West have yet to be determined, the establishment of vegetation that approximates the pre-mining communities in both composition and productivity is the goal of most reclamation strategies. Furthermore, current regulations require that revegetation be accomplished quickly in comparison to the rate of natural succession. Thus, a better understanding is needed of the ecology, physiology, and edaphic factors in natural and disturbed ecosystems in order to evaluate what constitutes successful reclamation of mined land and to determine what can realistically be expected under the time constraints of Office of Surface Mining regulations.

2.8.2 Approach

Current research in this project is directed at understanding the consequences of different topsoil-handling procedures on reestablishment of below-ground processes ecosystems. Soil physical and chemical characteristics are also being investigated to determine those factors of soil fertility and moisture that may aid or control seedling establishment and vegetation distribution in both disturbed and native soils. Current investigations will also elucidate the role of vesicular-arbuscular mycorrhiza (VAM) in revegetation.

Several investigations are currently under way and address the following questions:

- What is the relationship between colonizing plant species and VAM?
- What are the population dynamics of VAM fungi in disturbed and undisturbed soils?
- What are the soil factors that control VAM and plant community distributions?
- What are the survival dynamics of VAM propagules during topsoil storage?
- What transformations occur in soil during storage that may influence seedling establishment?

2.8.3 Accomplishments

Subproject A: Effects of Stockpiling and Storage on Soils
(R. M. Miller)

During the study on the effects of topsoil storage on vesicular-arbuscular mycorrhiza (see section 2.1.3 in this report), soil samples were also acquired for determination of those soil parameters that may be affected by the stockpiling process. Due to the heterogeneous nature of these storage piles, resulting not only from how they are built but also from the composition of soil and plant materials layered or mixed within, trends are difficult to discern. Correlation coefficients are presented in Table 12 for Jim Bridger stockpiles ranging in age from 0.5 to 6 years.

Many of the changes that take place in stored topsoil are related to the duration of storage. Leaf litter, shrub stems, roots, etc., in the stockpile will be acted upon by the soil microflora; the exact conditions are controlled by the amount of moisture and oxygen present, but the cellulose within the plant material will be broken down, resulting in an increase in water-soluble organic carbon, (Table 13). We believe that this soluble carbon pool is composed of organic acids. The limiting factor for the reaction rate at the Jim Bridger site is moisture, since the anaerobic conditions necessary for organic acid production are present. We are currently investigating acetic acid, butyric acid, and propionic acid levels in stored topsoil. These acids are detrimental to root development and may be the "staling factor" of stored topsoils. Also, since moisture is accumulating due to infiltration of the stockpiles, these acids could be spread throughout the pile from localized pockets of activity.

Table 12 Correlation Coefficients for Soil Parameters, Age, and Moisture Levels[a]

Soil Parameter	Correlation Coefficient Age	In-situ H_2O
Electrical Conductivity	0.44***	0.41***
Water Soluble Carbon	0.58***	0.46**
Organic Carbon	0.37***	0.28**
Total Nitrogen	0.36***	0.31**
Olsen Phosphorus	0.52***	0.09 n.s.
Total Phosphorus	0.31**	0.14 n.s.
Mineral Nitrogen	0.21*	0.02 n.s.
Saturation Percent	0.38***	0.54***
In-situ H_2O	0.42***	--

[a] (n = 96; n.s. = not significant; * = $P < 0.05$; ** = $P < 0.01$; and *** = $P < 0.001$)

Table 13 Some Changes in Organic Carbon during Storage of Soil

	Wakley-Black Organic Carbon (%)	Mineralizable Carbon (µg/g soil; 7 days)	Water Soluble Carbon (µg/g soil)
Atriplex confertifolia community soil	0.81	110	58
Stockpiled topsoil (8 months)	0.67	63	116
Stockpiled topsoil 72 months	0.70	45	169

Many of the factors associated with storage are difficult to quantify. Also, in many cases, the stored soils appear to be more fertile than the undisturbed soils in terms of plant nutrients. The problem, besides the staling factor, is that stockpiling results in a disruption of soil physical characteristics, i.e., loss of soil structure and increased bulk density. In the undisturbed soils, soil aggregates are of major importance to soil stabilization. After storage, a loss of aggregates was evident. Also, increases in electrical conductivity were found with storage and appear to be associated with release of sequestered salts during the breakdown of plant material. The addition of these salts to the soils results in the disperson of clays, causing the soils to seal up. All of these conditions would severely limit seedling establishment on reapplied stored topsoil.

Subproject B: Effects of Topsoil Handling on Soil Microfungi Of the Red Desert (Investigators: R. M. Miller, S. C. Rabatin, and S. Pippen)

In order to better understand the effects of topsoil storage and different topsoil handling techniques on arid soil ecosystems, a synecological study of soil microfungi was undertaken. By means of a soil-dilution plating technique, soil microfungal distributions were determined for three undisturbed plant communities, the reclamation treatment plots, and a five-year-old topsoil stockpile at the Jim Bridger Mine. Table 14 summarizes some of the findings of this investigation. All soil treatments were found to have equal microfungal diversity; this was also true for species richness on a per-sample basis. The total number of microfungal species encountered was found to differ significantly ($P = <0.05$) for the five-year stored topsoil. It appears that this loss of species richness is only temporary since once the soil is reapplied (stored-applied soil), these soils have a richness similar to the other soils evaluated, Table 16. Even though no significant changes in diversity were observed, except for those mentioned above, the disturbed soils, i.e., direct-applied, stored-applied, and five-year stored topsoils, each contain a different soil microfungal community. *Doratomyces stemonites*, *Chrysoporum panorum*, and xerophilic penicillia were found to favor disturbed soils, while *Myrothecium roridum* favored the undisturbed community soils. The predominance of xerophilic penicillia -- mainly *Penicillium cyclopium* series -- in stored and stored-applied topsoils, could be of major consequence, since many studies have associated this group of fungi with storage rot of grains (Pitt, 1979). The increase in the density of xerophilic penicillia during storage and

Table 14 Diversity as Measured by Brillouin's Index and Species Richness (number of taxa) for Soil Microfungi From Stockpiled Topsoil, Reclamation Treatment Plots, and Undisturbed Community Soils[a]

Treatment	Mean No. Taxa/Sample	Total Taxa (550 colonies)	Brillouin's Index
Atriplex confertifolia Community Soil	11.2A	37A	0.7282A
Atriplex gardneri Community Soil	11.1A	38A	0.7726A
Artemisia tridentata Community Soil	13.9A	41A	0.8091A
Direct-Applied Topsoil	12.3A	38A	0.7917A
Stored-Applied Topsoil	13.8A	38A	0.8002A
Stockpiled Topsoil After 5 Years	11.9A	30B	0.7296A

[a] Values followed by same capital letter are not significantly different at $P = 0.05$

the continued high density of these organisms after replacement, along with the associated lack of volunteer native plant establishment on the stored-applied topsoils, suggest an association between this group of fungi and apparent seed loss. Supportive of these findings are the high levels of volunteer native plants established on direct-applied topsoil (Figure 4); these soils also have lower densities of xerophilic penicillia. Studies have been initiated to look at the potential cause/effect of these trends.

Subproject C: Some Effects of Halogeton Litter on Agropyron smithii Seedlings (Investigators: K. L. Fishbeck and R. M. Miller)

Several past studies of disturbed areas in the Great Basin suggest that the annual weedy invader *Halogeton glomeratus* may exclude other plant species and be the dominant plant form for many years after disturbance. One of the ways in which exclusion may occur is through a loss of viability of VAM propagules or the prevention of VAM endophyte infection of roots. Earlier studies in this project indicated that a reduction of VAM infection occurred in *Agropyron* seedlings when halogeton litter was added to the pot. We repeated the experiment and varied the type of litter, dose, application method, and watering regime on *Agropyron smithii* seedlings. After 30 days growth, plants were harvested and measurements were taken for shoot dry weight, root dry weight, leaf height, number of blades, and percent mycorrhizal infection. Leaf and root tissue were analyzed for phosphorus, nitrogen, potassium, copper, and zinc. Soils were analyzed for organic carbon, total nitrogen, total phosphorus, electrical conductivity, and mineral nitrogen.

It appears that the effects of halogeton litter on VAM are dose dependent and that the dose effect is only evident under a frequent watering regime (Table 15). The more moisture, the greater the litter effect. In Table 16, a summary of litter type and dose effects are presented for the 24-hour watering regime. The greatest effect of litter, regardless of type, is on root biomass where, with an increase in litter, a decrease in root biomass occurred. Conversely, shoot biomass results are litter-type dependent with shoot yields in the *Atriplex confertifolia* litter treatment similar to those of the control (no litter). The soil and plant nutritional data are currently being analyzed.

Table 15 Effects of Watering Regimes and Dose Rates of *Halogeton glomeratus* Litter (standing dead) on Mycorrhiza Formation in *Agropyron smithii*[a]

Watering Regime (to 0.3 bar)	Litter Dose (g)		
	0	1.0	3.0
Every Day	69.94 ± 1.73	68.15 ± 2.21	59.58 ± 1.08
Every Other Day	64.00 ± 1.94	62.34 ± 1.75	63.87 ± 1.79

[a] Dose, Dose · water significant at P = <0.05.

Table 16 Litter Effects on *Agropyron smithii* Biomass and Vesicular-Arbuscular Mycorrhizal Infections

Treatment	Litter	Root Biomass	Shoot Biomass	S/R	Total Biomass	Mycorrhiza
		dry wt. (g)			dry wt. (g)	(%)
No Litter	0	0.725 ± 1.340A	0.488 ± 0.029AB	0.748 ± 0.123B	1.213 ± 0.145A	69.9 ± 1.7
Atriplex confertifolia	1	0.559 ± 0.094AB	0.520 ± 0.041A	1.002 ± 0.117B	1.079 ± 0.128AB	69.8 ± 2.4
Atriplex confertifolia	3	0.411 ± 0.022BC	0.513 ± 0.031AB	1.271 ± 0.127B	0.924 ± 0.028BC	67.6 ± 2.0
Agropyron smithii	1	0.448 ± 0.060B	0.455 ± 0.020ABC	1.129 ± 0.228B	0.903 ± 0.066BC	72.3 ± 1.6
Agropyron smithii	3	0.321 ± 0.051BC	0.365 ± 0.038CD	1.257 ± 0.255B	0.686 ± 0.066CD	66.3 ± 2.4
Halogeton glomeratus	1	0.350 ± 0.049BC	0.403 ± 0.057BCD	1.154 ± 0.051B	0.752 ± 0.106CD	68.2 ± 2.2
Halogeton glomeratus	3	0.185 ± 0.046C	0.299 ± 0.024D	2.365 ± 0.835A	0.484 ± 0.068D	59.6 ± 1.1

NOTE: Means in the same column followed by different letters are significantly different ($P = <0.05$); n = 5.

Halogeton litter appears to cause a decrease in infection of Agropyron roots with mycorrhizal fungi. The question that needs to be answered is whether these effects are on the germination of mycorrhizal spores or on the infection process itself.

Subproject D: Soil Parameters and Mycorrhiza Infection Potential
(R. M. Miller and K. A. Albrecht)

The soil factors that appear to be associated with high inoculum potentials are for the most part related to plant-available soil moisture levels, soil-plant moisture availability and soil aeration. Correlation coefficients for mycorrhizal infection potential by treatment versus each of the significant soil parameters are presented in Table 17. For all plots, an osmotic effect was evident; with increasing soil salinity there is a corresponding decrease in infection potential. Soils that have favorable aeration characteristics also have high inoculum potentials. The positive correlations for sand and porosity and the negative association of 0.3-bar moisture level and silt support this contention. In an arid ecosystem, soils that retain moisture also accumulate salts. Thus, soils with good porosity and drainage characteristics have high mycorrhizal inoculum potentials. These soil factors support VAM fungi in which most of the reproductive effort is allocated within the root, essentially giving rise to ecotypes of the Glomus fasiculatus group which produce few spores externally. The production of large numbers of spores would not be advantageous since the soils that could retain the moisture necessary to enable spore germination in arid ecosystems are also soils in which the osmotic conditions would be detrimental to the germination process.

Subproject E: Soil Factors Controlling VAM Spore Distribution
(R. M. Miller, S. C. Rabatin, and A. Westman)

VAM spore numbers in undisturbed soils at the Bridger site have been investigated (Miller, 1980). It was found that Atriplex gardneri community soils contained few, if any, spores, whereas Atriplex confertifolia and Artemisia tridentata community soils contained approximately 16 and 20 spores per 100 g, respectively. The only VAM species encountered were of the Glomus fasiculatus complex. The soils from these undisturbed communities have subsequently been analyzed for more than 30 soil chemical and physical parameters. Table 18 presents those soil factors found to influence spore distribution significantly.

The investigation indicates that soils with good aeration and drainage characteristics favor a higher spore density than those soils with high salt contents, i.e., soils with high electrical conductivity and low pH. These findings are in agreement with the bioassay data, which displayed similar trends.

In order to determine moisture effects on spore production, Agropyron smithii was grown under glasshouse conditions for three years on soil from an Atriplex confertifolia-Artemesia tridentata community at the Bridger site. The watering regime was an every-other day schedule. At the

Table 17 Relationship between Infection Potential and Soil Parameters for Undisturbed and Reclamation Treatment Soils at the Jim Bridger Mine Site[a]

Soil Parameter	Mycorrhizal Infection Potential (Correlation Coefficients)		
	Undisturbed Soil	Reclamation Treatment Soils	Undisturbed Plus Reclamation
Electrical Conductivity	-0.509**	-0.365**	-0.465***
Exchangeable Potassium Percentage	-0.445*	n.s.	-0.387**
Available Phosphorus	n.s.	0.384**	n.s.
Total Phosphorus	n.s.	n.s.	-0.278**
Total Cations	n.s.	-0.522***	-0.314**
Exchangeable Potassium	-0.624***	0.379**	n.s.
Exchangeable Calcium	n.s.	-0.499***	-0.274**
Exchangeable Magnesium	-0.426*	-0.334**	-0.330**
pH (5:1)	n.s.	0.332**	n.s.
Moisture (0.3 bar)	-0.580**	n.d.	n.d.
Porosity	0.543**	n.d.	n.d.
Field Moisture	n.s.	-0.345**	-0.272**
Sand	0.557**	n.s.	n.s.
Silt	-0.465*	n.s.	-0.268**
Clay	n.s.	0.305*	n.s.
Number of Samples	25	60	85

[a](n.s. = not significant; n.d. = not determined; * = P = <0.05; ** = P = <0.01; *** = P = <0.001).

end of the three year period, a seven-fold increase in spore numbers was found over the number of spores extracted from the soil at the time of collection (Table 19). Analysis of variance for square-root transformed counts reveals a highly significant (0.01 < P < 0.001) component of variance due to glasshouse effects. Fungal species differences were also observed; although both soils were dominated by spores representing the <u>Glomus fasciculatus</u> complex, glasshouse soils revealed <u>Glomus mosseae</u> as a small fraction (2.5%) of the total spore number. <u>Glomus mosseae</u> spores have not been observed previously in soils from the Bridger study area. This suggests that water may be the limiting factor responsible for spore density. However, the native soils that support high spore numbers are also the soils which drain readily. Also, considering the infrequent nature of rainfall event at the mine site, conditions necessary to produce high spore densities are rare. Those soils that have high moisture levels also have high salt accumulation, nullifying the moisture effect.

Table 18 Significant Correlation Coefficients for VAM Spores and Soil Parameters for Undisturbed Community Soils[a]

Soil Parameter	Correlation Coefficient
pH	-0.533**
Electrical Conductivity	-0.51**
Cation Exchange Capacity	0.410*
Extractable Phosphorus	0.462*
Organic Carbon	0.436*
Total Nitrogen	0.431*
Soil Moisture (0.3 bar)	-0.467**
Field Moisture	-0.377*
Particle Density	-0.469**
Porosity	0.481**
Sand	0.485**
Clay	-0.497**
Total Cations	-0.453*

[a] n = 27.

Table 19 Variation in the Total Number of Endomycorrhizal Fungus Spores from Undisturbed Jim Bridger Soil and a Comparable Soil[a] Supporting *Agropyron smithii* in a Glasshouse for Three Years

Sample[b]	Bridger Soil	Glasshouse Soil
1	11	233
2	8	302
3	71	248
4	57	123
5	39	528
Mean	37	269
Std. Error	12	67

[a] From an *Atriplex confertifolia*-*Artemisia tridentata* community.

[b] 100 g.

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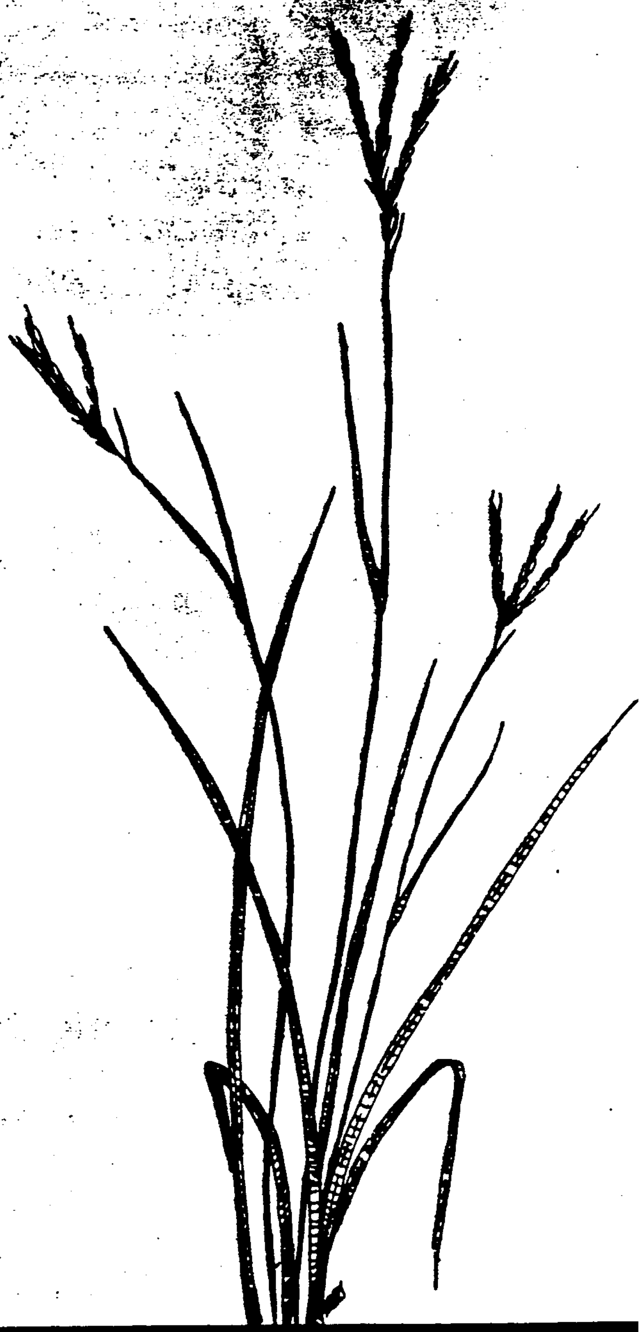

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