WASTE ROCK REVEGETATION: EVALUATION OF NUTRIENT AND BIOLOGICAL AMENDMENTS

by

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Abstract. Lack of salvaged topsoil for the reclamation of historical waste rock piles is a common problem in the arid Great Basin region. Utilization of amended waste rock as a growth media could reduce further disturbance resulting from topsoil harvest, minimize hauling costs, and potentially allow for the use of a higher quality material for plant growth. Getchell Gold Corporation initiated a study in 1995 to determine the suitability of waste rock substrates to support plant growth following application of nutrient and biological amendments. Three nutrient amendments and a biological seed treatment were evaluated for use in establishing vegetative cover on three distinct waste rock substrates. Completely randomized blocks were placed on the three substrates. Treatments included organic fertilizers (Biosol and Gro-Power), a mineral fertilizer (16-20-0), and *Azospirillum* bacterial inoculant, plus controls. The seed mix consisted of *Agropyron riparium*, *Agropyron spicatum*, *Elymus cinereus*, *Poa secunda*, and *Sitanion hystrix*. Canopy and ground cover were monitored for three growing seasons. Conclusions from the study are: 1) two of the three substates supported plant growth following amendment with organic fertilizers; 2) organic fertilizers increased cover substantially over the mineral fertilizer; and 3) *Azospirillum* had no effect on canopy cover.

Additional Key Words: revegetation, waste rock, fertilizer, *Azospirillum*.

Introduction[1]

Revegetation of waste rock dumps poses a substantial economic and technical challenge to the mining industry. The factor often limiting revegetation of these sites is a lack of salvaged topsoil and associated nutrient and microbial deficiencies (Bradshaw and Chadwick 1980, Munshower 1994). The source of topsoil when this resource is limited is harvest from native or agricultural areas. This method creates further disturbance and incurs substantial hauling costs. An alternative approach is to modify regraded waste rock with nutrient and biological amendments and utilize native plant species with tolerance to site conditions. Consequently, a "growth media" or "material which is capable of supporting vegetation" could be created from a waste product (Nevada Reclamation Regulations 1991). By successfully using this approach, significant environmental and economic benefits could be provided to the mining industry.

The goal of this study was to evaluate the potential for revegetating historical waste rock piles at Getchell Mine through the use of nutrient and biological amendments. Specific objectives were to: 1) compare the response of vegetation to organic and mineral fertilizer applications; 2) evaluate the response of vegetation to application of *Azospirillum* microbial inoculant; and 3) determine the response of exotics (mainly cheatgrass) to

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different fertilizer treatments.

Methods

Study Site. Getchell Gold Mine is located north of Golconda in Humboldt County, Nevada. Native vegetation is typical of the Great Basin with Big Sagebrush (*Artemisia tridentata v. wyomingensis*) dominating and associated arid land grasses such as basin wildrye (*Elymus cinereus*), Sandberg's bluegrass (*Poa secunda)*), and bluebunch wheatgrass (*Agropyron spicatum*) (Cronquist et al. 1972, Meikle 1997). Cheatgrass (*Bromus tectorum*) is an aggressive invader on both disturbed and undisturbed areas at the site.

Historical mining activities left three distinct types of waste rock on Getchell Mine property. These have been labeled North Pit Brown Waste Rock (WR), Hornsfelsic WR, and Weathered Granite WR (Table 1). North Pit Brown is a fine textured material typically weathered from volcanic rock types. Hornsfelsic is typically weathered from metamorphic rocks and consists of highly drained, black-gray stony material with low organic matter. Weathered granite was formed by the same geologic process which concentrated gold resources and is characterized by a rocky, gravelly loam soil texture.

Table 1. Characteristics of waste rock substrates.

Location	N. Pit Brown	Hornsfelsic	W. Granite
pH	7.2	6.8	7.2
EC (mmhos/cm)	0.33	0.33	1.10
CEC (meq/100g)	50.0	23.2	16.9
Organic Matter (%)	0.5	1.1	0.3
Texture	loam	loam	sandy loam

Means followed by the same letter in each column are not significantly different (p<0.10).

Study Design. Randomized blocks were established on three common forms of waste rock awaiting reclamation at the site: 1) North Pit Brown WR; 2); Hornsfelsic WR and 3) Weathered Granite WR. A native grass species mix containing equal portions by seed number of streambank wheatgrass (*Agropyron riparium*), bluebunch wheatgrass, basin wildrye, Sandberg bluegrass, and bottlebrush squirreltail (*Sitanion hystrix*) was applied to each block at a rate of 14.1 PLS lbs/acre. The three nutrient amendment types utilized were:1)a mineral fertilizer (16-20-0+ micronutrients @187.5 lbs/acre); 2) Biosol (organic: 6-1-3@1500 lbs/acre); and 3) Gro-Power Plus (organic: 5-3-1@1800 lbs/acre). In addition, a N-fixing bacterial seed inoculant (*Azospirillum*) was tested. There were eight treatments on each of the three substrates: 1) Controls; 2) Control + *Azospirillum*; 3) Mineral Fertilizer; 4) Mineral Fertilizer + *Azospirillum*; 5) Biosol; 6) Biosol + *Azospirillum*; 7) Gro-Power Plus; and 8) Gro-Power Plus + *Azospirillum*. Every treatment was replicated four times resulting in a total of 32 5 meter by 5 meter plots per substrate block.

All plots were sampled for percentage cover by species during June of each year (1996-1998). A subset of six randomly located 0.5 meter X 0.5 meter ($0.25m^2$) quadrats were located within each plot and a cover class was assigned to each species utilizing a modified Daubenmire cover scale (Forest Service Handbook 1987). Observational data concerning flowering status and vigor were collected.

Analysis was conducted using Statgraphics Statistical Software (Manuganistics Inc. Rockville, Maryland). For evaluation purposes, species were combined into the following classes: 1) planting mix species; 2) desirable volunteer species (i.e. - oval-leaf buckwheat (*Eriogonum ovalifolium*)) ; and 3) exotic weeds (i.e.- cheatgrass). Within these classes, means and standard deviations were calculated. Data were evaluated for normality and transformed using arcsin*squareroot(coverage) as recommended for coverage data (Underwood 1997). Analysis of Variance (ANOVA) was used to compare the effect of nutrient amendment and *Azospirillum* treatments on cover class means. Treatments were judged as significantly different at the p <0.10 level.

Results

Comparison of Fertilizer Treatments. Fertilizer response of the seeded species varied by substrate (Table 2). Organic fertilizers performed significantly better in the North Pit Brown substrate but no differences occurred in the Hornsfelsic or Weathered Granite substrates. There was a strong trend (p=0.12) in the Hornsfelsic towards higher coverage with organic fertilizers. Weathered granite, however, did not appear to respond to seeding and fertilization. All planted species were present in the plots and were flowering at the time of data collection. In addition, substantial amounts of rubber rabbitbrush *(Chrysothamnus nauseosus)* and big sagebrush were volunteering on plots.

Table 2. Mean cover (%) of seed mix species by substrate and Multiple Range Test results.

Location	North Pit Brown	Hornsfelsic	W. Granite
Control	2.55a	9.80a	0.00a
Mineral Fertilizer	7.06b	7.91a	0.97a
Biosol	14.4c	13.03a	2.56a
Gro-Power	20.8c	14.72a	0.58a

Means followed by the same letter in each column are not significantly different (p<0.10).

The North Pit Brown waste rock appears best suited to revegetation via amendment with fertilizer. In terms of coverage, Gro-Power and Biosol produced 20.8% and 14.4% coverage of seeded species while mineral fertilizer produced less than half the lower amount (7.06%) and the controls a mere 2.5%. When volunteer species were compared, no significant differences occurred between the cover produced by different fertilizer treatments. Volunteers contributed between 12.9% and 18.1% additional cover to the plots. Total desirable coverage (seed mix + volunteers) for Gro-power (38.9%) and Biosol (27.3%) compares favorably with that of reference plots established on native sites (range of cover: 10.9% - 39.6%) (Meikle 1997).

The Hornsfelsic waste rock appears to be suited for revegetation via amendment with fertilizers as well. Coverage varied from 14.7% on the Gro-power plots to 9.8% on the control plots with no significant differences between any treatments. Although organic fertilizers did not produce significantly more cover than controls, there was a trend towards increased cover on plots fertilized with organics versus mineral fertilizer and controls. Similarly, volunteers produced from the seed bank accounted for 9.3%, 5.6%, 6.1%, and 10.3% respectively for controls, mineral fertilizer, Biosol, and Gro-Power. Overall, total desirable coverage varied from 25.0% to 12.7% in fertilized plots which compares favorably to the reference sites.

The Weathered Granite waste rock failed to produce a vegetative cover regardless of fertilizer amendment. Coverages of planted species were 0.0%, 0.9%, 2.5%, and 0.5% for the control, mineral fertilizer, Biosol, and Gro-power respectively. Volunteer coverage was 1.2%, 2.8%, 8.9%, and 7.8% respectively for the control, mineral fertilizer, Biosol, and Gro-power respectively. Total desirable coverage ranged from 11.4% to 3.9% for all treatments which is not comparable to reference sites. An alternative strategy must be found for establishing vegetation on this waste rock type.

<u>Exotic Response to Fertilizer Treatments</u>. Cover of exotic species was compared with fertilizer treatment to determine whether nutrient addition favored establishment of weedy species (Table 3). Exotics consisted primarily of cheatgrass with minor amounts of Russian thistle (*Salsola iberica*). Fertilizer addition to plots increased exotics significantly in only one instance. In the Weathered Granite substrate, significant differences were apparent between Gro-power and the control treatment although the percentage cover contributed by cheatgrass was very small. No trends are apparent in the influence of fertilizer type and the response of exotics.

Table 3. Mean cover (%) of exotics by fertilizer treatment and Multiple Range Test results.

Location	North Pit Brown	Hornsfelsic	W. Granite
Control	0.93a	2.40a	0.12a
Mineral Fertilizer	0.84a	1.39a	0.61ab
Biosol	4.35a	1.96a	1.56ab
Gro-Power	2.83a	3.35a	0.62b

Means followed by the same letter in each column are not significantly different (p<0.10).

Comparison of *Azospirillum* Treatments. *Azospirillum* had no effect on cover in any of the treatments (Table 4). No significant differences were noted when controls were compared with plots receiving application nor were trends observed. Those sites receiving *Azospirillum* developed 9.2%, 7.6%, and 2.5% cover and controls developed 8.9%, 6.7%, and 2.1% cover on North Pit Brown WR, Hornsfelsic WR, and Weathered Granite WR respectively. In addition, no differences were observed in plant vigor between treatments.

Table 4. Mean cover (%) of seed mix species by *Azospirillum* addition.

Location	N. Pit Brown	Hornsfelsic	W. Granite
Control	8.86a	6.70a	2.12a
Azospirillum	9.23a	7.60a	2.53a

Means followed by the same letter in each column are not significantly different ($p<0.10$).

Discussion

Organic fertilizers were expected to outperform mineral fertilizers on the waste rock substrates. In general, mineral fertilizers are highly soluble and will leach from soil profiles unless adequate exchange sites are available to contain the nutrients. In contrast, organic fertilizers have nutrients bound by humus which are released over an extended period of time. This allows for higher rates of nitrogen (N) application without the consequences of exposing plants to excess N levels or leaching. In this study, plants responded positively to organics in the North Pit Brown WR and Hornsfelsic WR. In contrast, plants responded poorly to mineral fertilizer in these two substrates. While Hornsfelsic did not produce as much cover as the North Pit Brown substrate, it should be noted that this substrate is coarse with a large proportion of rock. Thus, the potential for seedling establishment is reduced by the physical character of the substrate. Weathered Granite did not respond to any fertilization treatment. Decomposed granite soils are known to be difficult to revegetate because of low nitrogen content, coarse texture, and low water-holding capacity. (Claassen and Marler 1998).

Although not a treatment, species selection for infertile substrates deserves attention in revegetating substrates of this nature. Species persistence is highly dependent upon adaptation to competitively acquire a limiting nutrient (Chapin et al. 1986). Tilman and Wedin (1991) demonstrated a shift in species composition resulting from the ability of certain species to successfully acquire nitrogen at very low soil N levels while other species failed. It is also suggested that the initial establishment of a perennial adapted to low N use can inhibit the establishment of annual invaders (Claassen and Marler 1998). All of the species utilized within the seed mix were native to Nevada and adapted to a low soil fertility environment. The long-term establishment success of these species is expected to be highly influenced by their low nitrogen requirements and high competitive ability for nitrogen resources.

High soil nutrient levels via nitrogen fertilization may affect plant competition and result in ruderal plant communities as opposed to the desired community (Wedin and Tilman 1993, Claassen and Marler 1998, McLendon and Redente 1992). Claassen and Marler (1998) provide evidence that high levels of plant available N encourages the rapid growth of ruderal species to the exclusion of native perennials which have slower growth rates and lower nutrient requirements. In addition, high N in a shallow soil profile may promote shallow rooting which is more detrimental to perennials than annuals under drought conditions (Claassen and Marler 1998). Thus, annuals avoid drought as propagules while perennials with shallow roots experience mortality under such conditions. With respect to cheatgrass competition, cheatgrass may be better adapted to nitrogen uptake under high fertilization rates and with high solubility fertilizers which would be available during early spring growth. However, this study demonstrated no response of cheatgrass to mineral fertilizer and a minor response to organic fertilizer.

Azospirillum provided no significant increase in canopy cover regardless of substrate or fertilizer treatment. *Azospirillum* is recognized as a N_2 fixing bacteria that stimulates the density and length of root hairs, the rate and appearance of lateral roots and root surface area (Okon, Y. and C.A.Labandera-Gonzalez 1994, Killham, K. 1994). There are several possible explanations for the lack of cover response to *Azospirillum*. Okon and Labandera-Gonzalez reviewed *Azospirillum* inoculation studies from around the world (1994). A majority of these studies were conducted under conditions of moderate fertility with agricultural production as the objective. Potentially, the *Azospirillum* strain utilized was not adapted to the low fertility climate or soil conditions of the Nevada site. In their review, Okon and Labandera-Gonzalez also note that several field application trials failed due to low concentration of bacteria within the inoculum (1994). Thus, the inoculum used within the study may have had a low concentration of *Azospirillum* bacterium. Another possibility is that the growing conditions have been sufficiently good to mask any benefits being provided by the *Azospirillum*. Regardless of the reason, the application of *Azospirillum* has provided no visible benefits.

Conclusions

Organic fertilizer amendments applied to two of three waste rock substrates produced coverage similar to native reference sites. *Azospirillum* application had no effect on canopy cover when compared by soil substrate or fertilizer treatment and may not be adapted to substrate conditions. The physical texture of the waste rock proved to be a limiting factor to revegetation in one instance. These results suggest a strategy that emphasizes the use of native plant species with adaptation to a low nutrient environment and the use of slow release organic fertilizers for reclamation of mined lands. Also, test plots are encouraged as a tool for evaluating waste rock as a growth medium. The use of test plots allows mine managers to determine which substrates have potential for revegetation following amendment and to evaluate seed mixes and soil amendments prior to large-scale application. In conclusion, use of amended waste rock as a growth media may allow for successful and economical reclamation of historic and existing waste rock piles where topsoil is unavailable.

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