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Department of Horticultural Science
University of Minnesota, St.Paul, MN

Rehabilitation of Alpine Disturbances: Beartooth Plateau, Montana

Farida Yusuf

The impacts of mineral development and of recreational uses are increasing on alpine ecosystems in the western United States. Such activities threaten to disrupt these fragile ecosystems and are already causing serious deterioration of aesthetic, watershed and wildlife habitat value in some areas. This paper discusses some of the results of interventions for rehabilitation purposes, which were carried out on the McLaren Mine, located on the Beartooth Plateau, near Cooke City, Montana. The McLaren Mine is an example of a site severely disturbed due to mining. Thus, it was found to be a suitable demonstration site for reclamation studies.

The geology of the Beartooth Plateau is characterized by an uplift Pre-Cambrian granitic mass from which extensive sedimentary materials have been eroded (Beven 1923, Loverling 1929). Most of the highly mineralized zones lie on the flanks of the main Beartooth uplift, as is exemplified by the Stillwater complex on the north and the Cooke City Mining District on the southwest. McLaren Mine is located about 8km (5 miles) north of Cooke City, Montana, at the elevation of about 3000m in a subalpine-alpine transition zone. This shallow open-pit mine was operated for the extraction of copper, silver and gold, on a site that now occupies a disturbed area of about 13.5 ha. It has essentially been abandoned since the early 1950's except for sporadic exploration. In addition to adverse visual impacts, soil erosion and sedimentation are occurring as a result of the near total lack of a vegetation cover. The oxidation of heavy concentrations of pyritic materials is causing severe off-site water quality problems. Acid drainage is killing the native vegetation adjacent to the mine and has already resulted in the complete destruction of the aquatic ecosystem in the upper Stillwater River.

A series of studies were initiated on the McLaren Mine by Ray W. Brown and Robert S. Johnston, plant physiologist and research hydrologist respectively, who were attached to the Forest Science Laboratory, Logan, Utah. The studies have since been incorporated into the SEAM (Surface Environment and Mining) Program of the USDA Forest Service. The intended goal of the projects was to find out what kinds of interventions could help return a disturbed alpine site to a self-sustaining system with natural successional processes as soon as possible. This included providing protection and surface stability to the disturbances, as well as providing aesthetic appeal and site productivity. Techniques such as shaping and contouring the site, fertilizing, mulching, seeding and planting were used in the hope of accomplishing this objective. These techniques of amending the site can alter the extreme conditions of the disturbed land so the edaphic and microclimate factors are commensurate with the physiological tolerance limits of plants adaptable to the region. The primary hydrologic objective was to reduce runoff and erosion while providing for the movement of water. Establishing protective plant cover was adopted as the principal means of achieving this hydrologic objective. This paper will discuss three out of the many experiments carried out on the McLaren Mine. Two of the studies were carried out in the field. The other one was carried out in a greenhouse.

FIELD EXPERIMENTS

A revegetation study was initiated on the McLaren mine in 1974. The study was conducted using 72 sub-plots (each 2m square), which were established on rough-graded mine spoils 30m square. Topsoil, consisting of the upper 60cm of material from relatively undisturbed remnant of native soil within the mine disturbance, was spread over half of the study site to a depth of 20cm. Thus, two main sub-plots were established, each was 15 by 30m in size and consisted of 36 sub-plots.

Seed of the native species (e.g *Deschampsia caespitosa* and *Carex paysonis*) was collected from areas immediately adjacent to the McLaren mine, then cleaned and prepared. Seed of introduced species (e.g *Alopecurus pratensis* and *Festuca arundinacea*) was purchased from commercial outlets and only strains that originated in the Rocky Mountain States were used.

The revegetation treatments applied to each main plot included 9 replications each of 4 randomly located treatments:

- mixture of seeded native species with fertilizer
- mixture of seeded native species without fertilizer
- mixture of seeded introduced species with fertilizer
- mixture of seeded introduced species without fertilizer

The fertilizer used was a 16-16-16 granular mixture applied at an equivalent rate of 100 lb N per acre. Plots were broadcast seeded in the fall and fertilizer was applied. Plots were then thoroughly raked and packed.

At the same time that the plots were seeded, 76 transplants of native species collected from road cuts near the mine were also established. Whole, dormant plants were transplanted in rows between the subplots. Among the species that were transplanted were *Deschampsia caespitosa* and *Carex paysonis*.

In 1976, another experiment was conducted on a site of about 1.0 ha (2.4 acres) in an area with a west aspect and a 15% slope, on the north edge of the mine. The rehabilitation plan for this study area included shaping and contouring the spoil and revegetation (seeding, transplanting and associated treatments). The spoil materials and topography of the site were characteristic of the entire disturbed site, and was selected so as not to interfere with future mineral exploration or other rehabilitation activities.

Before the experiment was carried out, the entire 1.0 ha of the site was shaped and contoured with a crawler-mounted D9 dozer as site preparation. The spoil materials with the lowest pH and the highest concentrations of toxic substances were used to fill depressions, and were covered with the best growing medium available on site. The entire area was rough-graded and contoured to conform to the natural topography of the area using only the materials available on the site.

After site preparation, experiments which included soil amendments, seeding, planting and mulching were carried out. Amendments were applied to ameliorate the limiting edaphic factors where feasible. Lime was applied at the rate of 2200 kg per ha to increase the spoil pH from about 3.0 to 5.0, and provide increased nutrient availability to plants in the acid soils. A granular fertilizer with an N-P-K ratio of 18-46-5 with 0.8% zinc was applied at the rate of 672 kg per ha. Dried steer manure was then applied to the surface at the rate of 2200 kg per ha. These three amendments were incorporated into 15cm of the soil surface.

Two revegetation studies were carried out on the prepared and amended site. One study focused on seeding whereas the other study focused on transplanting. The revegatation plot studies (Brown and Johnston 1976) which were carried out in 1974 showed that most commercially available introduced species were not suitable for seeding in the McLaren Mine. Therefore, only a mixture of native species was used for seeding. The seed was applied uniformly over the surface with a seeder-packer pulled by a dozer at a bulk rate of 83 kg per ha. The seeder-packer ensured intimate contact between the seed and soil particles and firmed the seedbed. About 0.7 ha of the study area was seeded.

The study on transplanting was carried out on the remaining 0.3 ha of the study site. Grass transplant plugs which were grown from seed collected the previous year were planted in this area. Both native and introduced species were used in this experiment (the adaptability of introduced species used as transplants had not been tested previously on this site). These plants were grown from seed in plant tubes by the U.S Forest Service, Coeur d'Alene Nursery, in northern Idaho. The plants were allowed to harden-off on the site for about three weeks prior to planting. Among the native plants used were *Deschampsia caespitosa* and *Poa alpina*. *Alopecurus pratensis* and *Festuca arundinacea* were among the introduced species that were used.

A surface mulch consisting of 2500 kg per ha of straw, tacked down with water soluble asphalt emulsion, was blown onto the site with a power mulcher. The entire seeded area was covered with the mulch. An effort was made to avoid thick accumulations of straw on the site that might act as an excessive heat trap and barrier to seedling emergence.

GREENHOUSE EXPERIMENT

Revegetation research in the alpine zone stressed the essential role of fertilization as an amendment (Brown and Johnston 1976). Virtually no documentation was available of the role played by other common amendments such as lime and organic matter. In order to extend the rather limited scope of small plot studies that have been done in the past to large scale revegetation, quantitative evaluations of such amendments were needed. This was particularly important since so little was known about the growth and development responses of native species to revegetation methods.

A study was carried out on the effects of various soil amendments on plant growth and development. Representative spoil material was collected and sieved to separate out the large rocks. The sieved material was then separated into 7 equal fractions to which various amendments were incorporated. A total of 7 treatments, each replicated 4 times, were prepared. These included:

1. Control: no amendments added to the spoil material
2. Fertilizer: a granular 18-24-6 N-P-K ratio fertilizer was incorporated into the spoil at the equivalent rate to provide 0.005% N (100lb) per acre.
3. Fertilizer-Lime: fertilizer was added as in 2 above, plus hydrated lime was incorporated at an equivalent rate of 2000 lb per acre, to raise soil pH.
4. Fertilizer -Lime-Straw: fertilizer and lime amendments were added as described above. Straw was added at an equivalent rate of 5% by volume.
5. Fertilizer-Straw: fertilizer and straw were added as described above.
6. Fertilizer-Lime-Manure: fertilizer and lime amendments were added as described above. Manure was added at an equivalent rate of 5% by volume.
7. Fertilizer-Lime-Manure: fertilizer and steer manure were added as described above.

Seeds of two species that seem to have broad adaptability for revegetation of high elevation disturbances; a native tufted hairgrass (*Deschampsia caespitosa L.*) and an introduced species, Garrison meadow foxtail (*Alopecurus pratensis L.*), were planted in equally spaced rows in different containers that contained the different soil amendments. These containers were placed in a greenhouse, with the environmental conditions controlled.

ASSESSMENT

Assessment of success for all the studies was mostly based on the results and
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observations made during the study period. The results of the first study in the field (carried out in 1974), studying native species versus introduced species showed that native species were apparently better adapted for revegetation compared to introduced species. The density of native species was significantly higher than introduced species under all treatments. Plant densities were generally higher on fertilized plots under all treatments, illustrating the importance of fertilizer application. However, introduced species on the topsoil plot showed no appreciable differences between the effects of

treatments with or without fertilizer. Native species were more responsive to fertilizer than were introduced species on both soils. The native plants were at least climatically adapted and were more capable of surviving periods of environmental stress. Fertilizer was found to improve plant growth and survival of first-year seedlings. However, the degree of plant development after one growing season was minimal due to the severe nature of climate and soil environments.

Transplants of native species appear to offer a successful alternative to seeding. The mature plants selected for transplanting were capable of tolerating greater micro-environmental stress than were seedlings. Thus, the use of transplants may ensure rapid plant establishment and development on alpine disturbances. If native species are to be used extensively, however, there is a need to develop nurseries for the large-scale production of plants and seeds.

The results of the second field experiment (carried out in 1976) suggested several conclusions. Shaping and contouring appeared to be a vital step in the program. The shaping and contouring eliminated wind-swept ridges that tend to scour during the winter and become parched barrens during the summer. It also removed depressions and other irregularities that might become pockets of deep snow accumulation and ponds of acid water that frequently wash out and spill onto the natural plant communities downslope. Snow distribution on the study site was very homogenous early in the spring, which appeared to promote uniform infiltration of snow-melt water, a more regulated rate of runoff and evenly distributed plant emergence and development.

This study showed that for the native species used, certain treatments were essential to alter conditions of the spoils sufficiently to support plant growth and development. These treatments included lime, organic matter, fertilizer and a surface mulch. The assessment was done by comparisons of these results with results of previous revegetation plots. Previous revegetation plots essentially used the same species but treatments that did not include lime, organic matter or a surface mulch. Average plant cover for the plots with additional treatments were ten times greater than the plots without those treatments.

As for the transplants, the average survival of all species was 65%, but there was a substantial difference between native and introduced species. The natives had an average of 75%, whereas the introduced species had only 39%. Therefore, transplants of native species had a higher average of survival compared to transplants of introduced species. The data also showed that on the average, the native species had a higher production per plant than did the introduced species. However, two out of the six introduced transplants showed encouraging results. These two species were *Alopecurus pratensis* and *Poa compressa*. Further studies need to be carried out on the potential of these two species for revegetation purposes.

The results of the study of effects of various soil amendments on plant growth and development (Greenhouse study) showed that the greatest levels of plant growth and development were achieved under the highest levels of soil fertility. Generally, amendments including both fertilizer and manure resulted in the greatest average number of culms and leaves, leaf area, average plant height and shoot and root production for both the species studied. The use of lime as an amendment resulted in some unexpected effect. Normally, spoil material from the McLaren Mine is quite acid, with a pH range of 2.0-4.5. However, the spoil material collected for this study had a pH of 6.1. Lime seemed to depress the growth and development of both species. For example, the fertilizer-manure amendment resulted in larger, more developed plants than the fertilizer-lime-manure amendment. Similar responses were noted with the fertilizer-lime-straw and fertilizer-lime treatments. The addition of lime may be detrimental when the pH is already relatively high. The addition of straw resulted in relatively greater levels of growth and development than the control or fertilizer treatments. However, straw was not as effective as manure, presumably because of its low nutrient value and its tendency to reduce the available nitrogen in the soil by increasing the carbon-nitrogen ratio. The role of straw in revegetation is probably more important as a surface mulch to retard evaporation and to reduce the incidence of frost action in the soil.

CRITIQUE

The rehabilitation research program at the McLaren Mine, Beartooth Plateau, has come up with some very good studies and methods on how to reclaim and enhance revegetation on this highly disturbed site. However, there are some methods that need to be improved and further studied.

Shaping and contouring the site by burying the toxic materials and covering it with topsoil is a good move in providing appropriate growing medium on a site which once had toxic material on the surface. However, no mention was made on how the toxic material was prevented from moving upwards or downwards in the soil. If no toxic containment was installed, toxic material may eventually seep into the soil and cause toxicity to once again be a problem. There was also no mention on what kind of topsoil was used to cover the toxic materials. However, the fact that only the materials available on site were used to cover the depressions, and not "alien" soil from other areas, was a positive step in ensuring that the site would be reclaimed to as close as it could possibly get to how it was prior to disturbance.

The study on effects of various soil amendments on plant growth was carried out rather well, but could still be improved. The inclusion of a control is useful as a comparison between treated and untreated soils in the sense that we can measure the extent of the effectiveness of the amendments. Having replicates of each amendment helps reduce the variations in the results by taking the average results of each amendment and making conclusions based on this average.

The study also, however, showed unexpected results with regards as to why it was found that liming showed detrimental effects on plant growth and development. A conclusion was made that the addition of lime may be detrimental when the pH of soil is already high (in this study, the pH of the soil used was 6.1). However, although liming generally helps plant development in soils that have low pH, no test was conducted on the soils that were highly acid in the McLaren Mine. The soil sample in this study was of a much higher pH (6.1), and the conclusion of lime being a retardant on soils of high pH was made without any comparison to effects of liming on soils of low pH.

The study on effects of various soil amendments on plants was conducted in a greenhouse. Although the results of experiments carried out in field studies are generally similar to results carried out in a greenhouse, this is not necessarily always true. In a greenhouse, the environmental conditions are controlled at an optimum level to favor and enhance plant growth and development. In the field, environmental conditions are not always consistent or predictable, and amendments to the soil on the field may not show the same effects on plant growth as in the greenhouse. For example, if the site was exposed to a extremely long and hot summer, the high increase in the rate of evaporation from the topsoil could increase the pH significantly enough to influence the effect of liming on plant growth. Bioassay studies are only capable of evaluating plant responses to edaphic factors, but they are not designed to evaluate interactions with other limiting factors such as climate variables. Environmental conditions in the field are infinitely more complex than those reproduced in this greenhouse study. Consequently, comparison between these data and actual field trials may be somewhat different.

The study on revegetation was carried out rather well. The results of the study gave clear indications on which kinds of plants were best suited for revegetation purposes. The success and failure of these plants to survive and develop were well documented and reported. Comparison of plant growth and development between the seeding and transplanting methods, and between native and introduced species, is useful in selecting revegetation species. A commendable step in the collection of seeds that was carried out is that all the native species seeds were collected from surrounding undisturbed sites and all the introduced species seeds that were purchased were strains that originated in the Rocky Mountain States. This method of obtaining seeds was to ensure that only species that were indigenous to the area were used. Since the rehabilitation program is still in the research phase, definite conclusions that could hinder or prevent further studies to be carried out on other species should be avoided. For example, since there are some transplants of introduced species (*Alopecurus pratensis* and *Poa compressa*) that show encouraging results on plant development, further research should be carried out on these species to test their potential as revegetation species. This could help reduce total dependence on native species, and these species could function as a back-up for revegetation efforts.

The suggestion of having nurseries for large-scale production of plants and seeds is highly recommended to ensure the supply of readily available seeds and plants for a revegetation project. Many alpine species can be successfully grown and encouraged to produce abundant viable seed crops in nurseries.

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