HIGH ALTITUDE REVEGETATION EXPERIMENTS ON THE BEARTOOTH PLATEAU PARK COUNTY, MONTANA AND PARK COUNTY, WYOMING[1]

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Abstract. ERO Resources Corporation (ERO) is conducting revegetation tests on the Beartooth Plateau to assist Federal Highway Administration (FHWA) in identifying techniques that maximize opportunities for successful revegetation along high altitude portions of U.S. Highway 212, the Beartooth Highway. A portion of the Beartooth Highway that travels through alpine and subalpine areas is proposed for reconstruction by FHWA. ERO and FHWA have conducted revegetation experiments since 1999 to identify the most successful revegetation techniques for revegetating alpine areas. This paper presents the findings of the fourth year of annual monitoring of one of the revegetation experiments.

In September 1999, ERO placed revegetation tests plots in an existing gravel borrow area along the Beartooth Highway. The variables tested were soil salvaging, seeding rates, soil amendments, and reapplication of Kiwi Power™ or inorganic fertilizer. Native seed was collected on Beartooth Plateau and used for direct seeding of the revegetation test plots.

Results from this study will assist mining, oil and gas, and utility companies, highway departments, and other land management agencies in revegetating high altitude disturbances to meet requirements of various state, local, and federal permits. The 2003 monitoring indicated that of all the variables tested, topsoil placement appeared to have the most beneficial effect on vegetation cover. Fertilizer reapplication, seeding rate, and organic material application did not have statistically significant effects on vegetation cover.

Additional Key Words: alpine revegetation, native plant restoration, highway revegetation, soil amendments, seeding rates, topsoil.

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Introduction

FHWA, in cooperation with the U. S. Forest Service and National Park Service, is proposing to reconstruct portions of the Beartooth Highway, also known as U.S. 212 (Wyoming FH 4), from KP 39.5 (MP 24.5) to the Montana/Wyoming state line at KP 69.4 (MP 43.1), Park County, Wyoming. About 13 kilometers (8 miles) of this section of road are in subalpine environments. The remaining 17 kilometers (11 miles) are in alpine areas on the Beartooth Plateau. The entire portion to be reconstructed is within the Shoshone National Forest. Road reconstruction would include widening and realigning portions of the roadway.

FHWA was concerned about successfully revegetating disturbed areas at such high altitudes. Revegetation of high altitude disturbances is often a slow process because of a short growing season, low temperatures during the growing season, and plants' exposure to wind, snow, and ice (Barbour and Billings 1988). The growing season ranges from 40 to 90 days, and frost may occur throughout the season (Brown and Chambers 1989). Soils may be rocky and weakly developed. Additionally, many species adapted to alpine environments are not commercially available or do not establish well from seed.

To assist with minimizing project impacts and maximizing revegetation success, FHWA retained ERO to evaluate and identify revegetation techniques most suitable for reclaiming native vegetation in alpine areas. As part of the evaluation, ERO constructed revegetation test plots in an existing gravel borrow area along the Beartooth Highway in Montana in 1999 (Montana Borrow Area). Four variables were tested at the Montana Borrow Area revegetation test plots: topsoil placement, seeding rates, soil amendments, and reapplication of fertilizer and Kiwi Power™. The test plots have been monitored annually since 2000. Annual monitoring provides the basis for conclusions regarding revegetation effectiveness associated with the listed variables.

This paper includes a literature review of past alpine and subalpine revegetation research, which provided a foundation for the revegetation test included in this paper, revegetation test plot design, and results and conclusions of revegetation test plots. It also discusses additional studies that FHWA has conducted on the Beartooth Highway.

Literature Review

Prior to developing the revegetation test plots, a thorough literature review of high altitude revegetation studies was conducted. ERO also consulted with several people knowledgeable in reclamation of sensitive natural areas, including Ray Brown formerly with Rocky Mountain Research Station (RMRS), Dale Wick and Joyce Lapp of Glacier National Park (GNP), Eleanor Williams Clark of Yellowstone National Park (YNP), Mark Majerus of USDA Bridger Plant Materials Center, Steve Parr of USDA Meeker Plant Materials Center, several contractors specializing in reclamation of natural areas, and suppliers of plant materials, seed, soil amendments, and surface mulches. Several variables have been tested in alpine areas, including seed types and sources, soil salvaging, and soil amendments such as fertilizer, organic amendments, and surface mulches. Studies relevant to revegetation along the Beartooth Highway are summarized in the following sections.

Soil Amendments

In a 1989 study, Brown and Chambers (1989) concluded that fertilizer, organic matter, and surface mulching were essential to re-establish alpine vegetation. Other studies have shown that applying fertilizer is very important to establishing alpine vegetation (Brown et al. 1976; Brown and Johnston 1976; Brown and Johnston 1978). Microbial activity is slow at high altitudes because of cool temperatures and a short frost-free season. This lack of microbial activity slows decay of plant material into available nutrients and nutrient cycling. Brown theorized that it may be advantageous to fertilize in a systematic manner over a period of years to generate organic material from colonizer species that will help to build soil for later successional species (Brown et al. 1996; Brown, pers. comm. 1999). However, results from test plots placed on Craig Pass in YNP indicated no increase in vegetation cover with the application of fertilizer (Majerus 1987).

Organic matter such as compost, sewage sludge, and manure incorporated into the soil was shown to greatly enhance vegetation establishment in previous studies on the Beartooth Plateau (Brown et al. 1976). Organic material helps sustain the nitrogen cycle in the soil by providing microbes and nutrients necessary to support a plant community. Eleanor Williams Clark, Chief Landscape Architect of YNP, expressed concern that using compost could introduce seed of undesirable species to a site. Yellowstone also avoids compost, fertilizer, or other organic material because wildlife may be attracted to nutrients in these materials, resulting in wildlife conflicts with vehicles (Clark 2001).

Organic material such as sewage sludge or manure is heavy, bulky, and costly to haul. For some highway projects in Idaho, KiwiPower™ and Fertil-Fibers NutriMulch™ have been successful in revegetating drastically disturbed sites (Arriago 2001). According to the manufacturer, KiwiPower™ is an organic soil treatment that contains organic enzymes, bacterial activators, and biostimulants. Fertil-Fibers NutriMulch™ is an organic fiber bulk with an N-P-K ratio of 6:4:1. It is intended to work as an organic amendment and a fertilizer. KiwiPower™ and Fertil-Fibers NutriMulch™ may be more expensive than ordinary fertilizer, but much cheaper than organic material such as compost, sewage sludge, or manure, because of lower transportation costs.

Soil Salvaging

Soil salvaging has been shown to be advantageous in numerous reclamation settings, especially in alpine areas. Salvaged soil contains organic mater, nutrients, and seed microorganisms and adapted to or generated by the unique combination of parent materials, organisms, topography, and climate of a given site (Williams and Marvel 1990). In alpine areas where topsoil may be thin (2 to 5 cm), collecting the upper portion of subsoil near the soil surface is important because of the plant materials and microbes it contains. Transplanting soil was the most successful revegetation technique in Brown and Johnston's trials on the Beartooth Plateau (1976). In YNP, topsoil salvaging and replacement is considered to be the most important factor in revegetating disturbances (Clark 2001).

Plant Materials

FHWA recognizes the importance native plant species on highway disturbances (Harper-Lore and Wilson 2000). Researchers also have studied the effect of seed source on alpine revegetation. Studies have show that commercially available introduced species are not appropriate for alpine disturbances (Carlson 1986; Brown and Johnston 1978). A limited number of native alpine species also are available (Brown and Amacher 1997). Although commercially available seed may be the same species as one that grows above timberline, it may not be specifically adapted to alpine area (Johnson and VanCleave 1978).

Collecting and growing out seed native to the project area is one method that may be effective for successfully establishing plants, limiting the introduction of weeds to a site, and maintaining the genetic integrity of vegetation in an area. However, collection and growout of native seed requires careful planning, as was noted by Johnson (1981) on the Alaska pipeline project. Also, seed growout may not be successful in producing the desired amount of seed because of unpredictable seed crops, as was the case for the Alaska pipeline project. Native seed production may be unpredictable—some stands may not produce seed in some years, or individuals of a species may be scattered throughout an area, and difficult to collect (Dunne 1997). Proper harvest and storage are essential to the viability of collected seed (Weisner 1997). Constraints on seed production, such as climatic conditions in a particular year, are difficult to predict (Chambers et al. 1994).

In its revegetation projects in YNP and Grand Teton National Park (GTNP), seed was collected on or near project sites to preserve the genetic integrity of seed on the site, and to provide a seed source well adapted to the area (Majerus 1997a, 1997b; Clark 2001). Studies in GTNP comparing the use of native seed collected from a project site versus native seed from commercial sources found that seed collected on-site outperforms commercially available seed (Cotts and Redente 1991, 1995; Guillame et al. 1986). Research also has noted the importance of incorporating species with a number of adaptations and from early and middle seral stages in seed mixes (Brown and Chambers 1989). Ecologists refer to the transition stages that a plant community passes through from the time it is first disturbed to the time it reaches a climax state as seral stages (Burrows 1990). Examples of seral stages include pioneer communities and climax communities, considered the highest sere of a plant community. In between these two extremes, a plant community may be in transitional stages, or seres, for decades to hundreds of years. Often it is not possible to acquire this variety of species from commercial sources, and high seral species may not establish well in recently disturbed areas.

In recent years, reclamation in GNP has successfully used containerized stock grown from seed collected in GNP. Plantings included grass and forb species, and some shrub species (Wick pers. comm. 1999; Lange and Lapp 1997). Plantings grown from seed collected in GNP were used in subalpine environments, but this technique has not been tested in alpine areas of GNP. It is possible that planting alpine species could be more successful than seeding because of low germination and establishment rates from seed, and because many alpine species spread through rhizomes.

Ray Brown, formerly with RMRS, has had very good success planting and transplanting live plant materials at subalpine mine disturbances near Cooke City, Montana (Yousef 2000).

<u>Surface Mulch</u>

Surface mulch such as straw, erosion control fabric, or hydromulch can moderate surface temperatures, limit wind at the soil surface, and may prevent the formation of needle ice on the soil surface (Brown and Chambers 1989; Berg et al. 1986). Some surface mulches may be ineffective in alpine areas because of high winds.

Using erosion control mats or blankets as a surface mulch to moderate environmental conditions at alpine revegetation sites has been shown to be effective (Munshower 1994). Several kinds of erosion control blankets are on the market, some consisting of straw, coconut fiber, a mix of the two, or jute netting for areas of high erosive energy such as streams. Straw mats are the least expensive blankets; however, they readily decompose and do not hold together on steep slopes or in areas subjected to intense erosion. Coconut fiber mats are almost twice as expensive as straw fabric, but have more structural integrity. Coconut mats will hold together on slopes, withstand more erosion than straw fabrics, and breakdown more slowly (Munshower 1994). This type of blanket is thicker and darker than straw, which may inhibit seed germination and emergence. Another type of blanket is constructed from 70% straw and 30% coconut. These intermediate priced blankets are less expensive than coconut fiber blankets, but have some of the structural qualities of coconut fiber mats.

By shading the soil surface, surface mulches moderate soil surface temperatures (Munshower 1994). In alpine areas, however, it is possible that where average soil surface temperatures are already quite low, surface mulches, especially erosion control mats, may limit solar radiation on the soil surface and as may result in lower soil surface temperatures, which could inhibit germination. An alternative to erosion control blankets may be wood chips. YNP has used 70% fir/pine and 30% cedar wood chips successfully for several years (Clark 2001). The combination of cedar and pine or fir is important because cedar whips are more fibrous and form a matrix on the soil surface, while fir and pine wood chips are heavier; this combination helps to hold the mulch in place. Bonded fiber matrix, a new surface mulch similar to hydromulch, also is gaining popularity for use on disturbed sites.

Study Location and Design

Variables included in the Montana Borrow Area revegetation test plots were selected based on previous revegetation research and revegetation projects in alpine and subalpine areas. Research on the Beartooth Plateau indicates that very high seeding rates may be important in establishing alpine vegetation (Brown 1999). In phone conversations, Mr. Brown indicated that a high seeding rate was an important variable to investigate on the Beartooth Plateau (Brown 1999). At high elevations, it is possible that competition between seedlings has less of an impact on whether a seedling persists than the extreme environmental factors present at high elevations. Seeding rates were investigated to determine if very high seeding rates are beneficial. Because quantities of topsoil in portions of the project site may be limited, the revegetation test plots were designed to investigate if topsoil is necessary, and if organic amendments, such as composted organic material and Kiwi Power™ and Fertil Fibers™, could be used to help build soil and start nutrient cycling. Reapplication of fertilizer and Kiwi Power™ also was investigated as a way to start nutrient cycling in soil.

The Montana Borrow Area test plots are located in an abandoned section of a gravel borrow area along the Beartooth Highway in Montana. Most of the abandoned borrow area has been converted to a parking area/trailhead to Line Creek Plateau. Test plots are located on the north side of the parking area.

Combinations of the four variables were tested for a total of eight treatments plus one control treatment (Fig. 1). Each of the eight treatments was replicated four times for a total of 36 test plots. Each plot measures 25 m^2. Control plots (C), on which the lower density seeding rate and fertilizer were applied, also were established. Fertilizer and seed were applied to control plots because it was assumed that during highway construction, disturbed areas would be seeded and fertilized at a minimum. Seed mixes seeded at the Montana Borrow Area test plots are listed in Table 1. In the fall of 2000 and 2001, fertilizer and Kiwi™ products were reapplied to the northern half of the plots on which these products were originally applied. Fertilizer and Kiwi Power™ were applied to the northern half of the plots, for a total of 72 plots, so that replications of the plots with each treatment would remain the same.

The four variables tested on the plots were:

1. Organic amendments plus fertilizer (O) versus surface application of Kiwi Power™ and Fertil-Fibers NutriMulch™ (K)
2. High seeding rate (H) versus very high seeding rate (VH)
3. Topsoil salvaging and replacement (S) versus no topsoil (N)
4. Reapplication of fertilizer or Kiwi Power™ versus no reapplication of fertilizer of Kiwi Power™

Construction of Test Plots

The test plots were placed in September 1999. A complete description of test plot construction is included in an as-built report (ERO 1999). The top 5 cm of soil present at the site were stripped from all 36 revegetation test plots including the four control test plots; the plots were graded as uniformly as possible, given the rocky nature of the soil. About 5 cm of topsoil salvaged from a nearby borrow area was evenly graded on 16 revegetation test plots.

Table 1. Montana Borrow Area seed mixes.

		Lower Density Plots		**Higher Density Plots**	
Scientific Name	**Common Name**	**PLS† (lbs/ac)**	**Seeds/ft^2**	**PLS (lbs/ac)**	**Seeds/ft^2**
Deschampsia caespitosa	Tufted hairgrass	0.88	45	1.75	90
Poa alpina	Alpine bluegrass	1.48	45	2.95	90
Phleum alpinum	Alpine timothy	1.25	25	2.5	50
Festuca ovina	Sheep fescue	1.75	32.5	3.5	65
Trisetum spicatum	Spike trisetum	0.38	12.5	0.75	25
Antennaria lanata	Wooly pussytoes	0.40	45	0.8	90
Artemisia scopulorum	Rocky Mountain sage	1.02	45	2.05	90
Lupinus argentea	Lupine	7.50	4.5	15	9
	Total	14.66	254.5	29.3	509

†PLS = Pure Live Seed

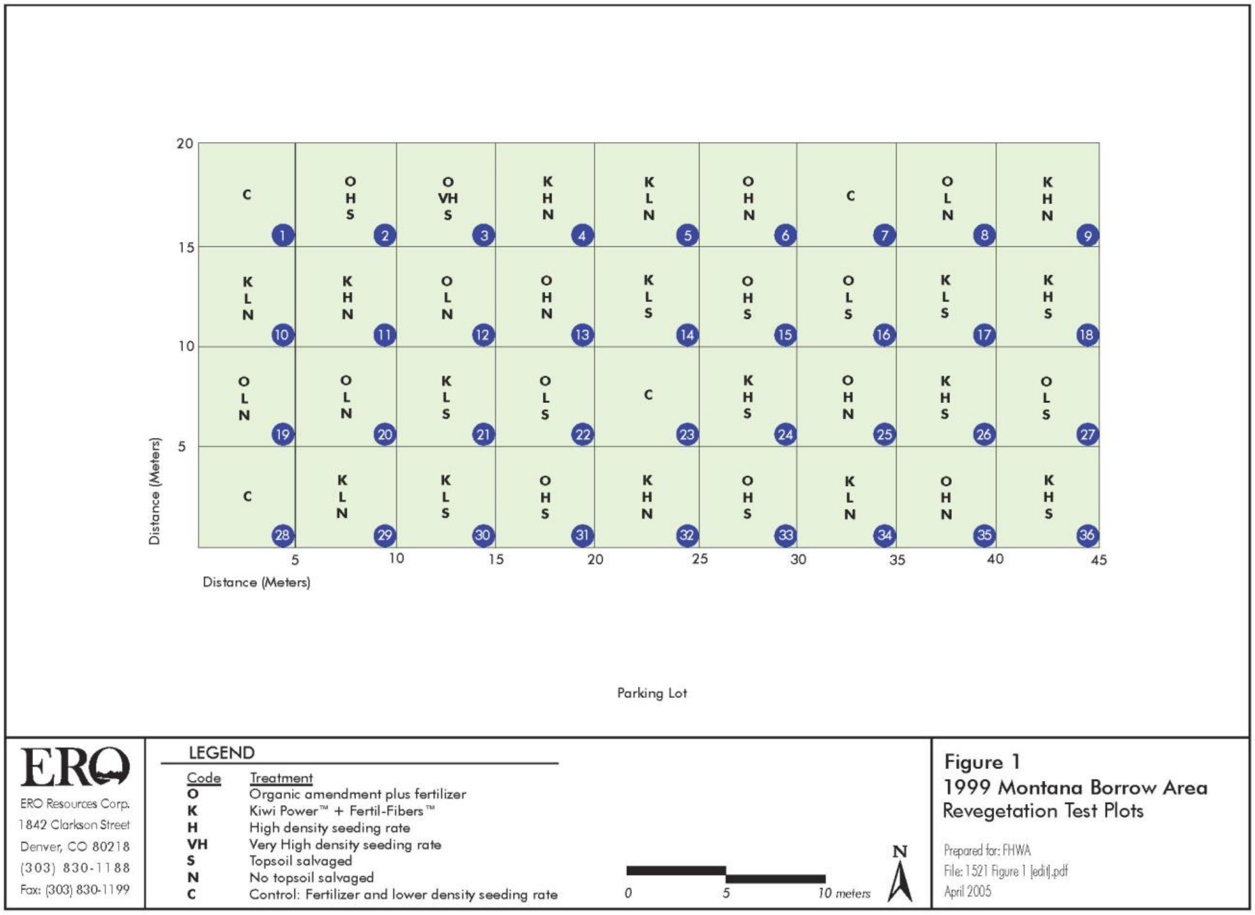

Figure 1. Montana Borrow Area seed mixes

Two organic amendment treatments were applied to the revegetation text plots. In half (16) of the test plots, compost and fertilizer were applied. In the remaining 16 test plots, Kiwi Power™ and Fertil-Fibers NutriMulch™ were applied. Kiwi Power™ was applied in a slurry at a rate of 46.8 l/ha with 7,791 l/ha of water using a backpack sprayer. Fertil-Fibers NutriMulch™ was applied at a rate of 2,250 kg/ha in dry pellet form with a hand-held broadcast seeder.

In the remaining test plots, composted organic material was applied in combination with fertilizer. Composted organic material was applied at a rate of about 18 metric tons/ha of dry weight organic material, which was estimated to provide about 2.5 percent organic matter to the test plot soil based on laboratory test conducted on the composted organic material. AgriBasics™ fertilizer with a ratio of 17:17:17 Nitrogen-Potassium-Phosphorus (N-P-K) was broadcast at a rate of 675 kg/ha over plots that received organic material and also over the control plots. Fertilizer was broadcast with a hand-held broadcast whirly-bird type seeder.

Before seeding, plots were disced to incorporate organic amendments. Plots with no topsoil or organic amendments were also disced to ensure even treatment of all plots. Following discing, plots were broadcast seeded by hand and raked. Erosion control blankets, composed of 70:30 straw: coconut bound with biodegradable mesh were placed on all plots.

Reapplication of Fertilizer and Kiwi™ Products to the Montana Borrow Area Revegetation Test Plots

In September 2000 and 2001, Kiwi Power™ was reapplied to the northern half of the 16 test plots that received Kiwi Power™, and fertilizer (organic amendment plus fertilizer) was reapplied to the northern half of the 16 plots that received fertilizer in the fall of 1999. Fertilizer also was applied to the northern half of the four control plots, which had been treated with fertilizer in 1999. On the northern half of the 16 test plots on which fertilizer was applied in 1999, fertilizer with an N-P-K ratio of 17:17:17 was reapplied at a rate of 672 kg/ha. On the northern half of the 16 test plots treated with Kiwi Power™ in 1999, Kiwi Power™ was reapplied at a rate of 46.8 l/ha with 7,791 l/ha of water. No amendments have been reapplied since 2001.

Monitoring Methods

From September 8 to 11, 2003, ERO visited the revegetation test plots and recorded information on vegetation and soil. Data collected from the Montana Borrow Area test plots were compared using parametric or non-parametric Analysis of Variance (ANOVA), paired T-Tests, and non-parametric Rank Sum Tests. Parametric ANOVAs compare the mean of several samples, and non-parametric (Kruskall-Wallace) ANOVAs compare the median of samples; therefore, results are presented using both means and medians. If ANOVA indicated a significant treatment effect, Tukey's tests or Dunn's pairwise comparisons were conducted to determine which treatment groups had significant differences. All results listed as being statistically significant are significant at a probability of 0.05 or less.

Vegetation Cover

Quantitative monitoring was conducted in all revegetation test plots, and included measurement of vegetation cover, species richness, and soil nutrients and organic matter in five 20cm x 50cm randomly placed quadrats in each test plot. In each quadrat, cover values were recorded for each vegetation species, rock, soil, litter, and erosion control fabric. At the Montana Borrow Area test plots, vegetation cover was sampled in five quadrats in the northern half (fertilizer and Kiwi Power™ reapplied), and five quadrats in the southern half of each test plot (fertilizer and Kiwi Power™ not reapplied) so that the northern halves of the plots, on which fertilizer and Kiwi Power™ were reapplied, could be compared to the southern halves of the plots, on which fertilizer and Kiwi Power™ were not reapplied.

Total vegetation cover data for each treatment were statistically analyzed. Total vegetation cover data also were grouped and compared according to organic amendment treatment, soil treatment, seeding treatment and fertilizer reapplication, slope and aspect treatment, where applicable. For example, at the Montana Borrow Area, all test plots treated with organic matter were grouped together (16 plots, 80 quadrats) and tested against those treated with Kiwi™ products (16 plots, 80 quadrats) and against the control plots (4 plots, 20 quadrats).

Vegetation cover was analyzed using ANOVA on the southern half of each plot (fertilizer and Kiwi Power™ not reapplied). In addition, all plots on which fertilizer and Kiwi Power™ were reapplied were grouped and compared with all plots on which fertilizer and Kiwi Power™ were not reapplied.

Species Richness

Species richness, or the number of different plant species present, was recorded in each plot, and species richness of all treatments was compared. During monitoring, biologists documented all species present on each revegetation test plot regardless if the species fell within a 20cm x 50cm quadrat.

Soil Nutrients

One soil sample was collected from each test plot. A soil sample was taken from the top 15 cm on each test plot and analyzed by Colorado Analytical Laboratories. Each soil sample was analyzed for pH, electrical conductivity, organic matter, nitrate-nitrogen, phosphorous, potassium, zinc, iron, molybdenum, and copper; texture and lime (carbonates) were estimated. Soil parameters examined in this report—organic matter, nitrogen, phosphorus, and potassium—were statistically analyzed; the results are discussed in this report. Soil sample results were grouped according to treatment and analyzed statistically. Soil samples were taken from the northern and southern halves of each plot. In one set of statistical tests, results from the northern and southern halves of the plots were compared. Where data from the northern and southern halves of the plots are not compared, only data from the southern portion of the plots are presented.

Results and Discussion

All results listed as being statistically significant are significant at a probability of 0.05 or less. For clarity, the following abbreviations are used in discussing the results:

O Organic matter

K Kiwi™ products

H High seeding rate

VH Very high seeding rate

S Salvaged topsoil

N No topsoil

C Control

R Fertilizer or Kiwi Power™ reapplied

For example, "OHS" means a plot was treated with organic material, high seeding rate, and topsoil. Abbreviations followed by "-R" (e.g., OHS-R) mean that data is from the northern half of the plot where fertilizer or Kiwi Power™ was reapplied.

Vegetation Cover Analysis

The highest cover was recorded on plots treated with OVHS-R, OVHS, OHS, KVHS, and OHS-R. The lowest cover was recorded on plots treated with C-R, OHN-R, KHN, and KHN-R (Table 2). An ANOVA conducted on all treatments (reapplied and non-reapplied) revealed significant differences between OVHS-R v. KHN, KVHN, and OHN, and between C-R and OVHS, OHS, KVHS, and OVHN.

Table 2. Montana Borrow Area vegetation cover analysis: all treatments, fertilizer/Kiwi Power™ reapplied, and fertilizer/Kiwi Power™ not reapplied.

Treatment (Mean % Vegetation Cover)	**C (52.45%)**	**KHS (57.30%)**	**KVHS (59.15%)**	**KHN (48.70%)**	**KVHN (49.50%)**	**OHS (60.10%)**	**OVHS (61.60%)**	**OHN (50.40%)**	**OVHN (58.55%)**
C-R (43.95%)			Y			Y	Y		Y
KHS-R (53.15%)									
KVHS-R (54.10%)									
KHN-R (49.10%)									
KVHN-R (49.45%)									
OHS-R (59.15%)									
OVHS-R (64.85%)				Y	Y			Y	
OHN-R (48.40%)									
OVHN-R (52.30%)									

R= fertilizer and Kiwi Power™ reapplied. Y = significant difference (P=0.05)

On vegetation cover on the southern half of the plots where fertilizer and Kiwi Power™ were not reapplied, ANOVA showed significant differences among treatments. Treatments with the highest mean percent cover were OVHS (61.60%), OHS (60.10%), KVHS (59.15%), and OVHN (58.55%). Treatments with the lowest median cover were KHN (48.70%), KVHN (49.50%), OHN (50.40%), and C (52.45%). Differences between OVHS v. KHN and KVHN were statistically significant.

Three of the four plots with the highest vegetation percent cover were treated with topsoil, while the four plots with the lowest cover were not treated with topsoil. From this data, it is apparent that topsoil may have a beneficial effect on vegetation cover.

Soil Treatments. When vegetation cover was grouped according to soil treatment on the portion of plots on which fertilizer and Kiwi Power™ were not reapplied, plots treated with topsoil had significantly higher median cover than plots not treated with topsoil (Table 3). Plots treated with topsoil also had significantly higher mean cover than control plots. There was no significant difference between plots not treated with topsoil and control plots.

Table 3. Montana Borrow Area, vegetation cover analysis: grouped by soil treatments, fertilizer/Kiwi Power™ not reapplied.

Treatment (Mean % Vegetation Cover)	**C**	**S**	**N**
C (52.45%)		Y	
S (59.54%)	Y		Y†
N (51.79%)		Y†	

Y = significant difference (P=0.05)
†Test between N and S is a non-parametric Mann-Whitney Rank Sum Test.

Organic Amendment Treatments. When vegetation cover was grouped according to organic amendment treatment on the portion of plots on which fertilizer and Kiwi Power™ were not reapplied, plots treated with organic matter had significantly higher cover than plots treated with Kiwi Power™ (Table 4). There was no significant difference between control plots and plots treated with organic matter or plots treated with Kiwi Power™.

Seeding Treatments. When vegetation cover was grouped according to seeding treatment on the portion of plots on which fertilizer and Kiwi Power™ were not reapplied, there was no statistically significant effect of higher (mean cover 57.20%) versus lower (mean cover 54.13%) seeding rates.

Table 4. Montana Borrow Area, vegetation cover analysis: grouped by organic amendments, fertilizer/Kiwi Power™ not reapplied.

Treatment (Mean % Vegetation Cover)	**C**	**K**	**O**
C (52.45%)			
K (53.66%)			Y
O (57.66%)		Y	

Y = significant difference (P=0.05)

Reapplication vs. No Reapplication. Vegetation cover data for the northern half of the plots on which fertilizer and Kiwi Power™ were reapplied were grouped and compared using a parametric T-Test with vegetation cover data for the southern half of the plots on which fertilizer and Kiwi Power™ were not reapplied. Vegetation cover was not significantly different between the northern half and the southern half of the plots. Mean vegetation cover on the northern halves of the plots on which amendments had been reapplied was 52.72%. Mean vegetation cover on the southern halves of the plots on which amendments had not been reapplied was

55.31%. Reapplication of amendments also was examined on plots grouped according to organic amendment (i.e., Kiwi Power™ plots where Kiwi Power™ plots had not been reapplied [mean cover 53.66%] were compared with plots where Kiwi Power™ had been reapplied [mean cover 51.45%]). Also, organic material plots with no reapplication (mean cover 57.66%) were compared with plots where fertilizer was reapplied (56.18%). There was no statistically significant difference in vegetation cover when the plots were grouped in this manner.

Cover of Robust Species

It was visually apparent during monitoring that four species that were not seeded, but that commonly colonized the revegetation test plots, appeared to have higher cover on some test plots than on others. These species generally are larger and more robust than other species that either were seeded, or that had colonized naturally. Robust species include slender wheatgrass (*Elymus trachycaulus*), yarrow (*Achillea millefolium*), false dandelion (*Agoseris glauca*), and dandelion (*Taraxacum officinale*). Table 5 lists vegetation cover of robust species on the Montana Borrow Area test plots.

Data on cover of robust species were analyzed using Kruskall-Wallis non-parametric ANOVA and Dunn's multiple pairwise comparisons, which compares the median of each treatment rather than the mean. Cover of robust species generally does not coincide with total vegetation cover (total vegetation cover was highest on plots treated with topsoil) (Table 2). Plots with the highest median percent cover of robust species include OVHN (27.50%), C (27.50%), KHN (25.00%), C-R (22.00%), and KHN-R (22.00%). Plots with the lowest median percent cover of robust species include OHS (10.00%), KVHS (10.00%), and OHS-R (11.00%). There were significant differences in median percent cover of robust species between the following treatments: KHN v. OHS, OHS-R, and KVHS; C v. OHS, OHS-R, and KVHS; OVHN v. OHS, OHS-R, and KVHS. From this data, it appears that plots without topsoil yielded higher cover of robust species than plots with topsoil, which contrasts with vegetation cover data for all species. With the exception of OVHN, it also appears that plots not treated with composted organic matter had higher median percent cover of robust species than plots treated with composted organic matter.

Species Richness

Species richness of each treatment was examined using ANOVA (Table 6). The analysis detected no statistically significant difference (P=0.05) between test plot treatments, with the exception of KVHN v. KVHS. This difference is probably an anomaly, and does not appear to be related to seeding rate. This difference was not detected in previous years.

The lack of a significant difference in species richness among treatments may be because the sample size is too small to detect a difference or because only a few species are capable of voluntarily establishing at a high elevation site. Although some plots or treatments may have more individuals, or more of a given species, all of the plots could have one or two individuals of this same set of species, making it difficult to detect a significant difference.

Table 5. Montana Borrow Area vegetation cover analysis: robust species, all treatments, fertilizer/Kiwi Power™ reapplied, and fertilizer/Kiwi Power™ not reapplied.

Treatment (Median % Vegetation Cover)†	C (27.50%)	KHS (15.00%)	KVHS (10.00%)	KHN (25.00%)	KVHN (20.00%)	OHS (10.00%)	OVHS (15.00%)	OHN (15.00%)	OVHN (27.50%)
C-R (22.00%)									
KHS-R (20.00%)									
KVHS-R (15.00%)									
KHN-R (22.00%)									
KVHN-R (21.00%)									
OHS-R (11.00%)	Y			Y					Y
OVHS-R (17.50%)									
OHN-R (15.00%)									
OVHN-R (15.00%)									
C									
KHS				Y					
KVHS	Y			Y					Y
KHN									
KVHN									
OHS	Y			Y					Y
OVHS									
OHN									
OVHN									

†Robust species include slender wheatgrass (*Elymus trachycaulus*), yarrow (*Achillea millefolium*), false dandelion (*Agoseris glauca*), and dandelion (*Taraxacum officinale*).

R= fertilizer and Kiwi Power™ reapplied. Y = significant difference (P=0.05)

Eight species were seeded on the Montana Borrow Area revegetation test plots in 1999. All seeded species have become established on the revegetation test plots, with the exception of woolly pussytoes (*Antennaria lanata*). Species richness ranges from 9 to 14 species per plot, indicating that species other than the ones seeded are colonizing the test plots.

Table 6. Montana Borrow Area species richness.

Treatment	Median (Mean # of Species)	Treatment	Mean Species Richness (Mean # of Species)
C	10.50	OHS	11.50
KHS	10.50	OVHS	10.50
KVHS	9.50†	OHN	11.00
KHN	11.50	OVHN	11.00
KVHN	13.00†		

†KVHS had significantly lower species richness than KVHN.

Soil Laboratory Analysis

Results from soil laboratory analyses at the Montana Borrow Area were grouped according to treatment, and parametric and non-parametric ANOVA were performed on the data. Soil samples taken from plots where amendments had been reapplied were compared with those taken from plots where amendments had not been reapplied. In addition, soil samples taken from plots where amendments had been reapplied were compared to one another, and soil samples taken from plots where amendments had not been reapplied were compared to one another. The variables tested were organic matter, phosphorous, potassium, and nitrate.

Amendments Not Reapplied v. Amendments Reapplied. Soil nutrients were compared on plots where soil amendments had been reapplied and plots where soil amendments had not been reapplied using a non-parametric ANOVA, which compares medians rather than means. In this comparison, organic matter percent was not significantly different between treatments. For all other nutrients (N, P, K), nutrient levels were statistically higher on plots where amendments had been reapplied v. plots on which amendments had not been reapplied (Table 7).

Table 7. Montana Borrow Area soil laboratory analysis and vegetation cover: amendments not reapplied

Organic Amendment Treatment	OM (Median %)	NO_3 (Median %)	K (Median ppm)	P (Median ppm)
No Reapplication	7.00	1.80†	213.25‡	48.20*
Reapplication	5.85	6.95†	363.10‡	115.65*

†Nitrate is significantly higher on plots where soil amendments were reapplied than on plots where amendments were not reapplied.

‡Potassium is significantly higher on plots where soil amendments were reapplied than on plots where were not reapplied.

*Phosphorous is significantly higher on plots where soil amendments were reapplied than on plots where were not reapplied.

Amendments Not Reapplied — Organic Matter. Non-parametric ANOVA of soil data from plots on which soil amendments had not been reapplied indicated that percent organic matter varied significantly between treatments. Dunn's pairwise comparisons showed that organic matter was significantly higher on plots treated with composted organic material than on control plots and on plots treated with Kiwi Power™ (Table 8). Vegetation cover is noticeably higher on plots treated with organic material and plots treated with topsoil, both of which have significantly higher organic matter than plots treated with Kiwi™ products and control plots.

Table 8. Montana Borrow Area soil laboratory analysis and vegetation cover: amendments not reapplied.

Organic Amendment Treatment	**Veg. Cover (Mean %)[1]**	**OM (Median %)**	**NO_3 (Median ppm)**	**K (Median ppm)**	**P (Median ppm)**
C	52.45	2.65[*]	2.05	175.53[†]	37.95[§]
O	57.66	14.65[*,**]	1.55	448.58[†,‡]	143.30, [§,§§]
K	53.66	3.20[**]	2.60	175.53[‡]	34.75[§§]
Soil Treatment					
S	59.54	39.25	3.05[+]	111.98	266.90
NS	51.79	3.30	1.80	82.90	170.35

[1]VNon-parametric ANOVA was used to compare soil nutrients, so the results list the median of each nutrient. Vegetation cover is listed as mean percent cover because it is not

[*]Organic matter is significantly higher on plots treated with composted organic material than on control plots.

[**]Organic matter is significantly higher on plots treated with composted organic material than on plots treated with Kiwi Power™.

[†]Potassium is significantly higher on plots treated with composted organic material than on control plots.

[‡]Potassium is significantly higher on plots treated with composted organic material than plots treated with Kiwi Power™.

[§]Phosphorous is significantly higher on plots treated with composted organic matter than on control plots

[§§]Phosphorous is significantly higher on plots treated with composted organic matter than on plots treated with Kiwi Power™.

[+]Nitrate is significantly higher on plots treated with topsoil than on plots not treated with topsoil.

Amendments Not Reapplied — Nitrates. There were no significant differences in nitrate levels on the revegetation test plots where amendments were not reapplied, except that plots treated with topsoil had significantly higher nitrate levels than plots not treated with topsoil (Table 8). Nitrate levels were highest on plots treated with topsoil and on plots treated with organic material, and lowest on plots treated with Kiwi Power™ and plots with no topsoil. Vegetation cover is highest on plots treated with topsoil, which also had the highest nitrate levels.

Amendments Not Reapplied — Potassium. ANOVA and Tukey's tests revealed significant differences in potassium concentrations in treatments. Potassium was significantly higher on plots treated with composted organic material than on plots treated with Kiwi Power™ or control plots (Table 8). No statistically significant difference was apparent in potassium levels between plots treated with topsoil, which have the highest percent vegetation cover, and plots not treated with topsoil, which have the lowest percent vegetation cover. There is no apparent relationship between vegetation cover and potassium levels.

Amendments Not Reapplied — Phosphorous. ANOVA on Ranks conducted on phosphorous data (Table 8) revealed significant differences among treatments. Dunn's pairwise comparisons showed phosphorous levels were significantly higher on plots treated with composted organic material than control plots and plots treated with Kiwi Power™; however, there is no clear relationship between phosphorous and vegetation cover.

Conclusions

Vegetation Cover Analyses

In 2001 and 2002, the portions of plots where amendments were reapplied had significantly higher vegetation cover than the portions of plots where amendments were not reapplied, but this difference was not apparent in 2003 (ERO 2002; ERO 2003). Fertilizer and Kiwi Power™ have not been reapplied since 2001. The effects of amendments did not last more than 1 year following reapplication of fertilizer. In 2002, cover on C-R plots was 66%. In 2003, however, C-R cover decreased to about 43%, the lowest cover of all the plots (ERO 2003). This may indicate that an overabundance of nitrate caused high vegetation cover, which could not be sustained once reapplication of the additional nitrate source was discontinued. It appears that C-R plots did not establish a nitrogen cycle, which reinforces the need for topsoil in revegetating alpine disturbances.

ANOVAs conducted on the Montana Borrow Area test plots showed that plots treated with topsoil had higher cover than plots not treated with topsoil. The effect of organic amendments on vegetation cover was apparent, but was not as noticeable as the effect of topsoil. Seeding rate did not apparently influence vegetation cover.

Species Richness

There was no significant treatment effect on species richness, which may be due to the limited number of species capable of colonizing the plots or because of the high variability within treatments.

Soil Laboratory Analyses

Organic Matter. Topsoil and organic material (compost) are important sources of organic matter Munshower 1994). Because organic matter is known to reduce bulk density and increase available water holding capacity, treatments that increase organic matter may be important for increasing soil moisture. Organic matter also helps support nitrogen cycling in the soil. Topsoil used in this experiment was obtained from a borrow site about 100 m (300 ft.) south of the revegetation test plots. Not surprisingly, plots with the highest organic matter were treated with composted organic material. Plots treated with topsoil had a higher mean organic matter percent than plots that were not treated with topsoil, but the organic matter percent was not significantly higher than on plots without topsoil.

Nitrates. Plots on which fertilizer was reapplied had the highest levels of nitrates. Plots on which Kiwi Power™ was reapplied did not have higher levels of nitrates than control plots or plots on which amendments were not reapplied.

Phosphorous. Generally, plots with the highest phosphorous content were treated with organic matter or topsoil, and plots with the lowest phosphorous were not treated with organic matter or topsoil. Plots on which Kiwi Power™ had been reapplied had significantly higher levels of phosphorous than plots on which Kiwi Power™ was not reapplied.

Potassium. Potassium levels were generally higher on plots treated with composted organic material than on plots treated with Kiwi Power™ or on control plots. Plots where Kiwi Power™ was reapplied had higher levels of potassium than plots where Kiwi Power™ was not reapplied.

Additional Studies Being Conducted on the Beartooth Plateau

Extensive data have been collected at the Montana Borrow Area and in other studies as part of the Beartooth Highway Reconstruction Project. In addition to revegetation tests placed in 1999, FHWA contracted with ERO to design and place revegetation test plots in 2000 and 2001, to examine additional revegetation variables. All revegetation test plots were placed in existing disturbances along the Beartooth Highway. In summer 2000, the second set of test plots was placed at the West Summit of the Beartooth Highway and at a pullout near the Gardner Headwall. Variables tested in 2000 were soil amendments (BioSol Mix™, Kiwi Power™, and Fertil-Fibers™), seed source (locally collected v. commercial), slope, and aspect. Variables tested at the West Summit in 2001 were seeding density, surface mulch (70:30 straw:coconut fiber erosion control blankets, wood chips, and bonded fiber matrix), sod transplants, and organic amendments. All revegetation test plots were created to assist in project planning and to help identify revegetation techniques applicable for reclaiming areas disturbed by construction activities in alpine areas.

Two seed growout experiments also are being conducted. One tests the practicality of collecting and growing seed of forb and sedge species for direct seeding or transplanting onto alpine disturbances. Another will examine the practicality of a large seed growout to obtain enough seed for a road reconstruction project in alpine and subalpine areas.

Data on soil moisture have been collected in previous monitoring years; however, because of recent storms at the time of 2003 monitoring, soil moisture monitoring data in 2003 were not considered reliable. In past monitoring years, plots treated with organic matter and/or topsoil had higher soil moisture than plots without topsoil (ERO 2003).

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