SUMMARY
EROSION CONTROL AND REVEGETATION DEMONSTRATION PROJECT REPORT, HORSESHOE BEND HILL, IDAHO STATE HIGHWAY 55

This demonstration project sought to demonstrate the comparative benefits of using commercially available products and technologies to help in the rapid and successful establishment of desired vegetation on disturbed sites to control erosion. The site is precipitous, .1 to 1 or steeper; the surface medium is decomposed granite strewn with rocks and boulders. Six different seed mixes were used with three different organic or compost based mulches to determine which would perform best under these difficult conditions. Replication of the natural succession process in using early seral stage plants that inhabit disturbed sites was the selection criteria for species. Dormant seeding was conducted.

Mycorrhizal associations (fungal colonies) are present in the root systems of most indigenous plant species on semiarid land. Loss of significant portions of the bacterial biomass, or loss of fungi and microorganisms such as nitrifying bacteria, severely limit the ability of a site to support vegetative cover. In the subject region, over 95% of the dominant indigenous plant species are dependent on mycorrhizal associations. Nutrient cycling is in large part controlled by mycorrhizal bacteria and their relative interactions with local biomass. These root-inhabiting fungi colonize both inside and outside the root system. The host plant supplies the mycorrhizal fungi with simple carbohydrates (sugars) from photosynthesis. In return, the fungi, using energy derived from the host plant, extend hyphal strands (feeding tubes) far into the soil, increasing the feeding area of the roots to improve water and nutrient absorption for its host. Reestablishment of mycorrhizae and associated microorganisms at disturbed sites in the semiarid West is essential to be successful in reestablishing vegetation to control erosion. Redistribution of topsoil collected on site is the most effective method to reestablish mycorrhizal colonies required for revegetation following construction. Managing excavation projects to include topsoil retention for revegetation purposes in the American West is both necessary and cost effective. The physical and biological properties of topsoil have characteristics necessary to grow vegetation that are not present in other construction materials, such as subsoil or borrow material. Topsoil reclamation needs to be recognized as a high priority in road building construction projects. Absent topsoil reclamation, the use of organic soil amendments and time release organic mulch compounds are necessary to initiate the soil building process necessary for revegetation and erosion control.

Comparison of the various seed mixes and soil amendment mulch products used at the Horseshoe Bend Hill demonstration site show that those products that accelerated development of soil organisms enhanced plant growth and establishment. Kiwi Power organic soil amendment and Kiwi Fertile-Fibers time release organic mulch out performed the other compost products, using criteria of plant density and establishment. Plant species that performed well include Intermediate wheatgrass, Siberian wheatgrass, Bluebunch wheatgrass, Canby bluegrass, Yarrow, Lewis blueflax, Sainfoin, Rabbitbrush, and Farewell to spring. These are early seral stage plants; pioneer species that act as soil builders that will enable higher seral stage plants to inhabit the site at a later time. The seed for this undertaking was obtained from areas similar in elevation and rainfall to the subject site. Seeding was conducted in early winter, the dormant period, enabling the seeds to germinate and begin establishment during the spring when more moisture is available. The vegetative cover, especially the shrubs, helps reduce water erosion and hold slopes through absorption of water and by slowing the transport of water off a given site by reducing kinetic energy. Further analysis of these sites will help focus future revegetation efforts at this and other similar sites in the region.

EROSION CONTROL AND REVEGETATION DEMONSTRATION PROJECT REPORT, HORSESHOE BEND HILL, IDAHO STATE HIGHWAY 55

October 23, 1997

The Horseshoe Bend Hill Erosion Control Demonstration Project sought to illustrate the feasibility and economics of using products, technologies and methods that have demonstrated propensities toward helping in the rapid and successful establishment of desired vegetation on disturbed sites. Of special concern to this undertaking were sites where growing conditions for plants are extremely poor and subject to erosion. The Horseshoe Bend Hill site is an excellent example of erosive and unattractive environmental conditions at a roadside site. The 12 cut slopes are .1 to 1 or steeper; the surface medium is decomposed granite strewn with rocks and small boulders, and parts of the slope continue to erode. The absence of topsoil and uneven decomposed granite particle size, low liquid holding capacity and low plasticity index make this site highly erosive and extremely difficult to vegetate. Weather conditions range from minus-zero winter conditions, to summer surface temperatures reaching 120 degrees. Typical precipitation ranges from 12 to 20 inches per year, mostly in the form of snow during the winter months.

The objective in this demonstration project was to evaluate a number of commercially available products to assess their effectiveness in helping stop erosion by reestablishing vegetation at the subject site. Different seed mixes were selected for side by side comparison in an effort to determine which species would perform best under these difficult conditions. Replicating the natural succession process by using plants that inhabit disturbed sites was the primary objective in choosing species for these mixes, understanding that early seral stage plants would be most applicable to this undertaking. Early seral stage plants aid in the reestablishment of soil microbes to build soils and promote growth and balance of organisms necessary for plant establishment and development. The parent material at the Horseshoe Bend Hill site was not exposed to air or sunlight prior to excavation, this material has little of the physical or biological components necessary for plant life, and yet the objective is to provide long term vegetative cover.

Annual grasses often are recommended for erosion control on disturbed sites because they are cheap, fast, and are able to establish on relatively non-fertile soils. With sufficient fertilizer, water and the appropriate climate, a suitable vegetative cover can be maintained with annual grasses. In the semiarid West this prescription does not work given the dry climate and extremes of temperature. Furthermore, plant species native to the semiarid West are dependent upon mycorrhizal fungi associations to survive with stresses from extreme temperatures, drought, and soil infertility. The use of annual grasses as vegetative cover is not a natural component of the indigenous revegetation process in this region. Annual grasses are generally counter productive to the long-term objective of establishing shrub, perennial grasses and forb species best suited for erosion control and soil stabilization in this region.

Soils in the shrub-steppe habitat in southwestern Idaho tend to be low in organic matter, low in available P and N, and have limited available water. Mycorrhizal associations (fungal colonies) are present in the roots systems of most indigenous plant species on semiarid lands. The role of mycorrhizae in this habitat appears related to their role in acquisition of nutrient resources for plants. Within the individual root system, the abundance of mycorrhizal colonization will vary depending upon a host of issues, including climate, establishment duration of the colony, and soil types. It is imperative to understand that grass, forb and shrub species indigenous to the semiarid West are dependent upon mycorrhizal fungi associations to exist. Beneficial mycorrhizae solubilize mineral elements, such as phosphorus, for uptake by plant roots. The plant roots utilize the fungus that surrounds them. The root systems of these plants grow in a sheathe of mycorrhizae (fungus) in a mutualistic symbiosis between plant and fungus. That is, energy in the form of organic carbon compounds moves primarily from fungus to plant and inorganic resources (principally phosphate) move from mineral to the fungus.[1] Mycorrhizal fungus plays a vital role in the root systems of dominant species of indigenous vegetation in the subject region. To be successful using vegetation for erosion control in this area, it is imperative that the focus be directed toward species, products and techniques that facilitate the development and maintenance of mycorrhizae.

Mycorrhizal associations are found in a broad range of habitats, including semiarid shrub steppe areas. For example, in the semiarid rangelands of the subject region, 95% of the dominant native species have mycorrhizae, as much as 96% of the root length can be colonized.[2] These root-inhabiting fungi colonize both the inside and the outside of the root system. The host plants supply the mycorrhizal fungi with simple carbohydrates (sugars) from photosynthesis. In return, the fungi, using energy derived from the host plant, extend hyphal strands (feeding tubes) far into the soil, increasing the surface area of the roots to improve water and nutrient absorption for its host. Plants with abundant mycorrhizae have a much larger, physiologically active, root fungus area for nutrient and water absorption than plants with few or no mycorrhizae. [3] Extensive research has shown that mycorrhizae development is energy efficient for plants. It would require approximately 100 times more photosynthate for a plant to produce roots to probe the same soil volume covered by mycorrhizal hyphal growth.[4] Through these hyphae, mycorrhizae absorb and accumulate more nitrogen, phosphorous, potassium and calcium more rapidly and for longer periods of time than nonmycorrhizal roots. Mycorrhizae have been found to increase tolerance of plants to: (1) drought, (2) high soil temperatures, (3) heavy metals, (4) soil salinity, (5) soil toxins (organic and inorganic), (6) extremes of soil-acidity caused by high levels of sulfur or aluminum, (7) fungal and bacterial root pathogens, and (8) parasitic nematodes. More than 30 years of research worldwide has proven the roles of mycorrhizal fungi and beneficial bacteria in plant survival. Research has also shown that 75 percent of a given plants survival potential lies within its root system. Yet roadside revegetation efforts in the semiarid West typically begin with growth medium absent topsoil containing pre-disturbance mycorrhizae, and, further, fail to take into account development of soil mycorrhizae as a requisite component of the revegetation process. Generic soil inoculates to introduce soil mycorrhizae are commercially available, however, research has proven they are ineffective in the semiarid West given the site specific adaptations of fungi common to this region.

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[1] Wicklow-Howard, Marcia C. 1994. Mycorrhizal Ecology of Shrub-Steppe Habitat. Proceedings – Ecology and Management of Annual Rangelands, Boise, ID. May 18, 1992. US Forest Service Intermountain Research Station General Technical Report INT-GTR-313

[2] Christensen, M: Williams, S.E. 1977. Occurrence of vesicular-arbuscular mycorrhizae on shrubs and grasses in strip-mine regions of Wyoming. Abstract in: Proceedings of the North American conference on mycorrhizae; 1977 August; Atlanta.

[3] Read, J.J. 1991. Mycorrhizal Fungi in Natural and Semi-Natural Plant Communities. Ecophysiology of Ectomycorrhizae of Forest Trees. Pp.27-53. Marcus Wallenberg Foundation Symposia Proceedings. 7. Stockholm, Sweden.

[4] Rousseau, J.V.D. 1994. Contributions of Ectomycorrhizae to the Potential Nutrient Absorbing Surface of Pine. New Physiologist 128:639-644.

On disturbed sites absent topsoil containing mycorrhizal colonies, one must address the process required to introduce plant species that will aid in reestablishment of said colonies, and be able to grow in a low nutrient, low organic environment. There are a limited number of such plant families, including Chenopodiaceae, Brassicaceae, Amaranthceae, and Zygophyllaceae [5] Selecting species from these families of plants, which naturally invade disturbed sites, is a prerequisite for effective roadside revegetation and erosion control on sites absent topsoil. In addition, having knowledge of plants commonly found in association with species of these families is important to establishing a sustainable plant community. Such plant communities are somewhat site specific and will vary widely depending upon parent mineral conditions, slope, aspect, precipitation, elevation, and surrounding plant communities. Careful analysis of these circumstances lays the foundation for decision making about species selection for a given site.

Species selected for inclusion in the seed mixes for use at the Horseshoe Bend Hill site were chosen based on: (a) commercial availability; (b) applicability to the aforementioned mycorrhizae criteria; (c) knowledge of the given species having been successfully used in revegetation efforts at mine and/or mountainous roadside sites of similar condition; (d) aesthetic considerations; and (e) affordability. The application rates were somewhat higher than normal, this given the many unknowns at the subject site. The varieties of grasses, forbs and shrubs selected were based on previous successful use of these species working at similar decomposed granite sites at mines and roadsides in the region. Establishing early seral stage plants that have a propensity toward developing mycorrhizal colonization, and that also have deep roots to help prevent erosion and help stabilize soils were the objectives of this demonstration project.

Methodology

Six different seed mixes were selected for revegetation purposes and used with three different soil amendment products. A listing of the seed mixes is included below. Cereal grain was included as a cover crop in some of the mixes with the objective of providing (1) initial cover, (2) a canopy to shelter small indigenous species from the harsh sun during their first year of growth, and (3) provide leaf-litter, the base material for decomposition providing cycling of nutrient in the parent mineral to sustain native perennial vegetation, and also to increase water holding capacity. The success with the use of cereal grain as a cover crop at this site will be determined later; side by side comparison of plants seeded with and without cereal grain is a comparative element of this project. The seed application techniques were two: (a) one step hydroseeding including seed, composted mulch and organic soil amendment, and (b) broadcast seeding followed by mechanically applied composted mulch over the seed. The hydroseeding was conducted January 23, 1997 when there was approximately 3 inches of snow covering the site. The ground was frozen. Ambient temperature at the time of application was 22 degrees F. The broadcast seeding with blown mulch top-dressing was conducted about one month later. Live planting of container stock was conducted at the demonstration area in the autumn of 1996, including 240 Big sage, 224 Rabbitbrush, 144 Bitterbrush. The objective of this live planting was to monitor the performance of container stock vrs. seed grown shrubs at this site. Previous attempts to establish shrubs from seed had proven unsuccessful.

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[5] Trappe, J.M. 1981 Mycorrhizae and productivity of arid and semi-arid range lands. In Manassah, J.T.; Briskey, E. J. , eds. Advances in Food Producing Systems for Arid and Semi-arid Lands. New York Academic Press: 581-599.

Seed mixes (PLS – Pure Live Seed)

Site 71, Wheatgrass Dryland Blend

SPECIES	%Mix
Ephraim crested wheatgrass	24.03
Thickspike wheatgrass	20.81
Canby bluegrass	5.01
Steptoe barley	21.03
Yarrow	5.26
Lewis blueflax	5.31
Small burnet	9.02
Rubber Rabbitbrush	.60
Louisiana sage	.93
Total	40 LB PLS

Site 72, Complex Dryland Blend

SPECIES	%Mix
Steptoe barley	19.97
Ephraim wheatgrass	17.12
Canby bluegrass	5.01
Covar sheep fescue	5.57
Lewis blueflax	5.05
Yarrow	4.99
Indian blanketflower	13.28
Small burnet	8.03
Sainfoin	15.56
Sherman bluegrass	6.05
Louisiana sage	.88
Rubber rabbitbrush	.57
Total	20.87 LB PLS

Site 73, No Wheatgrass Blend

SPECIES	%Mix
Steptoe barley	16.87
Covar sheep fescue	11.37
Sherman bluegrass	6.60
Sand dropseed	12.98
Bottlebrush squirreltail	2.71
Prostrate bitterbrush	7.61
Lewis blueflax	4.86
Yarrow	4.81
Indian blanketflower	6.42
Small burnet	10.18
Sainfoin	1.15
Rubber Rabbitbrush	4.59
Louisiana sage	1.15
Total	21.81 LB PLS

Site 74, Wildrye Blend

SPECIES	% Mix
Magnar wildrye	14.39
Covar sheep fescue	10.38
Bottlebrush squirreltail	6.97
Sand dropseed	12.06
Secar bluebunch wheatgrass	15.57
Small burnet	9.92
Sainfoin	8.86
Lewis blueflax	4.70
Yarrow	4.65
Louisiana sage	.85
Rubber rabbitbrush	.53
Total	22 LB PLS

Site 75, Ephriam Wheatgrass Blend

SPECIES	lbs/acre
Ephraim wheatgrass	2.5
Sand dropseed	2.5
Lewis blueflax	3
Palmer penstemon	1
Farewell to spring	1
Total	12 LB PLS

Site 76, Siberian Wheatgrass Blend

SPECIES	lbs/acre
Siberian wheatgrass	2.5
Sand dropseed	2.5
Lewis blueflax	3
Palmer penstemon	1
Farewell to spring	1
Total	12 LB PLS

Products

Sites 71, 72, 73 & 74 were hydroseeded in a one step process using products from Quattro Environmental including 5 gal/acre Kiwi Power, 2,000 lb/acre Fertile-fiber, and 100-lb/acre Cliffhanger tack (5% of the dry weight of total mulch mix). The Kiwi Power was used as an organic soil amendment to provide essential soil enzymes, humic acid, Cytogin and Sarsapogenin – all necessary for plant life in sterile soil conditions. This product has a demonstrated capacity to promote the development of species that are mycorrhizal dependent, indicating that it speeds the development of desirable soil microorganisms. Fertile-fiber, a composted poultry based mulch, was added to provide an organic based balanced NPK and carbon to build the fundamental compounds of soil. Cliffhanger takifier was used as a tackifier to anchor these products and the seed against erosion from wind and water. Site 75 was broadcast seed, and composted yard waste including soft wood shavings from Castlewood Products was blown on top at a rate of approximately 33.5 cu yd per acre at approximately 850 LB per yd. Site 76 was broadcast seeded, and composted bovine manure from Compost West was blown on top at a rate of 33.5 cu yd per acre at approximately 850 LB per yd.

The cost of the Kiwi products as listed (including 100-lb takifier per acre at $65.00 per acre) was approximately $640.00 per acre. Cost of transport and hydroseed application was $415 per acre. Aggregate cost per acre of Kiwi products and application, minus seed cost, was $1,055.00 per acre. The base price for Castlewood products was $335.01 per acre. Application costs to have this material blown onto the Horseshoe Bend Hill site was $40.00 per yard, including transportation. Aggregate cost per acre for the Castlewood products and application, not including seed, was $1,675.01 per acre. The base price for Compost West bovine compost was $427.13 per acre, plus $40.00 per yard for transport and application. The aggregate cost for the Compost West product and application, not including seed, was $1,767.13 per acre. The Castlewood and Compost West applications did not include takifier, which if added would have raised the cost of these compost products by $75.00 to $150.00 per acre. However, this cost comparison is deceiving given that Kiwi Fertile-fiber used in this trial was poultry based, which is roughly *five* times more potent in soil accessible nutrient on a per pound basis than bovine based compost. It takes five tons of compost derived from cattle waste to equal one ton of poultry based compost. Compost derived from yard waste and wood product waste generally has fewer nutrients than compost derived from cattle waste. When taken in balance, including evaluation of the cost of transport and the time and cost of application, and evaluating nutrient delivered on a pound per pound basis, Kiwi products are more cost effective. Costs for the above Kiwi and compost products were for the demonstration project only. Economies of scale would apply to larger undertakings; bulk shipment and application would lower cost for each of the products mentioned above in differing ways. More cost study needs to be done for comparative purposes.

Weather

The precipitation at the site during the winter was higher than normal, both as rain and snow. However, the spring rainfall was below average – the period most important for germination and establishment of the subject species. May had only two rainy days, these in the fourth week of the month. June had more than typical rainfall for this part of Idaho.

Performance

In general, all areas hydroseeded with Kiwi products did well. These areas, 71, 72, 73 & 74, developed solid stands of vegetative cover. Those seeded with the cereal grain appeared denser in cover. However, when measured to determine plant density per square foot, there was only a modest difference. The Kiwi products are noted for aiding plant germination and rapid establishment on very poor soil conditions, and for stimulating development of soil microorganisms. Based on previous experiences at mine sites in the arid and semiarid West, stimulation of soil microbial activity with these products is not short lived, the results being recognizable for over four years following application. A slowly available nutrient supply with organic products such as those contained in the Kiwi products is desirable for plant germination and establishment, as opposed to the rapid release characteristics of elemental or chemical fertilizers. The presence of cereal grain byproducts, safflower meal and cottonseed meal, contained in Fertile-fiber mulch, produces slow release NPK supply for establishing plants. In addition, the organic boost provided by the composted chicken manure and humic acid provide organic inputs that create a viable topsoil environment for plant establishment in otherwise harsh and inhospitable decomposed granite conditions at this site. The best performance at the Horseshoe Bend Hill site was visible on the areas treated with Kiwi products from Quattro Environmental. The plant density at sites 71,72,73, &74 was approximately 20 to 30 per square foot.

Sites 75 and 76 did display some germination and growth, though demonstratively less than sites 71, 72,73 &74. Site 75 was the poorest performer of the group, though it had germination rates similar to Site 76, the plant establishment appears to be marginal. There did not appear to be adequate nutrients available to allow the plants to grow. There is a striking difference between these two. By contrast Site 76 did appear to have better-established plants than did Site 75, though less so than site 71-74. Site 76 was contaminated by topsoil riddling down from undisturbed areas up slope. This contamination brought in seed, plants, nutrients and mycorrhizae to site 76. It is assumed the organic boost from the bovine compost was providing NPK in sufficient levels to encourage plant growth. Experience at other disturbed sites clearly demonstrates that the benefits provided by bovine compost are short lived – similar in many respects to elemental fertilizer. [3] [6]It is also important to note that Site 76 had a sizable number of plants, about 45-50%, growing that were not contained in the seed mix planted as a part of this demonstration project, presumably these were volunteers from vegetation in the area up slope of this site. These volunteers were primarily rabbitbrush and big sage, and bunch grasses, though cereal grain of unknown origin was also present, as well as Cheat grass, ***Bromus tectorum***. Site 76 also had the highest number of weeds of all the demonstration sites, the seeds of which may have been carried in the bovine compost, or come from other outside sources. Cattle are herbivorous, consuming a wide range of plant material, and their digestive process does not damage many common weed seeds. Site 76 was in a natural drainage which, with heavy winter rainfalls, probably contributed to the deposits of topsoil riddling down from undisturbed areas above, thus contaminating the site. These topsoils are presumed to contain both annual and perennial seed and mycorrhizae. The plant density at both sites 75 and 76 was approximately 7 to 8 per square foot, though the plants on site 76 were larger. and better established.

The species that did perform exceptionally well were Steptoe barley, Yarrow, Rubber rabbitbrush, Sainfoin, Intermediate wheatgrass, Ephraim wheatgrass, Bluebunch wheatgrass, Canby bluegrass and Farewell to spring. In the moderate performance category were Sherman bluegrass, Indian blanketflower, Palmer penstemon, Siberian wheatgrass, Covar sheep fescue and Magnar wildrye. Species that should have done well but did not include Sand dropseed, Bottlebrush squirreltail, and Small burnet. The best performance density of all seeded species was demonstrated by Canby bluegrass, Yarrow and Louisiana sage, with Steptoe barley and Ephraim wheatgrass also doing well. Sainfoin was also in abundance where it was applied – this species is especially noted for erosion control given its extensive root system once established.

Further evaluation will be required to determine the results of this demonstration over time. Experience has proved that success in revegetation efforts is demonstrated when evaluated two or three years following application. When working in parent materials deficient in organic content and very low to non-existent nutrient content, long-term, sustained plant establishment is the criteria by which results can best be evaluated. A diversified plant community of early seral stage species will help to build soils and attendant microorganisms that will enable self-sustaining plant communities to continue at the subject site.

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[6] McKell, Cyrus. 1991. Native Plant Establishment Techniques. Cyrus McKell, Dennis Hansen, Stephen Clark, LaGrande Hobbs. Weber State University Press, July 1, 1991 Utah Department of Transportation.

Soil ecology – Microbial activity

The benefits of using compost and other organics in erosion control and revegetation projects have yet to be thoroughly established through sound empirical research. The extensive body of research available regarding such uses in agriculture and horticulture may not prove of relevance to revegetation on severely disturbed sites where the mycorrhizae and topsoil have been removed as overburden. In general, the organic content of a soil is an indicator of its fertility, ability to support microbial populations, retention of elements, and water retention. This is an important issue in the semi-arid west, especially given the symbiotic relationship of species native to these areas mycorrhizal fungus and other soil organisms. Soil organisms perform many processes, often with varying degrees of redundancy. In healthy soil, there are usually several organisms that perform any particular process, and in highly disturbed soils these organisms may be lacking or sufficiently impacted to dramatically limit the success of revegetation. Unless topsoil is returned to disturbed site, compost or organic mulches typically must be used so that early seral stage plant life can be reestablished at near sterile conditions. Disturbed soils and especially soils that have been mined generally have low diversity and depending upon the site may be relatively depauperate and poorly colonized with indigenous microbial and fungal populations. To mitigate for this one must artificially initiate the soil building process by importing organic compounds. One of the questions this demonstration project sought to evaluate is how different commercially available products function in this capacity on badly degraded sites such as Horseshoe Bend Hill. Products such as Kiwi Power that supply microorganisms and enzymes to activate soil microbial activity and improve soil fungal development are of necessary importance. Humic acid activates soil microbes and improves its physical properties, and aids in water retention. In addition, cytogin, an organic growth hormone, serves to stimulate root growth and the development of essential microorganisms. Large scale mine revegetation projects using these products in Wyoming, Montana and Idaho during the past four years demonstrate that, on severely disturbed sites, the combination of the Kiwi products has out-performed other soil amendment combinations. In depth comparative research trials are being conducted at the University of California, Davis and at Weber State in Utah to scientifically document these occurrences and their causes. Additional evaluation at Horseshoe Bend Hill will be necessary to document whether the same holds true in this circumstance.

Mycorrhizae and land disturbance

In mycorrhizal association with plants, the fungus is considered as the obligate symbiont, and hence, any disturbance affecting the plant will result in a fungal response.[7] Studies have shown that most successful pioneer plants on disturbed sites and new soils are non-mycorrhizal plants, and that many indigenous plants may require mycorrhizal infection in order to colonize disturbed lands. [8] Non-mycotrophic weeds, such as Russian thistle, *Salsola kali*, Halogeton, *Halogeton glomeratus*, and Cheat grass, *Bromus tectorum* can invade disturbed sites rapidly and compete with desired species for water and nutrients. Without mycotrophic host plants the mycorrhizae may not be able to persist.

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[7] Miller. R.M. 1979 Some Occurrences of Vascular Arbuscular Mycorrhizae in Natural and Disturbed Ecosystems of the Red Desert. Canadian Journal of Botany. 57: 619-623

Disturbed sites, invaded by and subsequently dominated by weeds, have reported no mycorrhizae for up to 10 years. [4] Non-mycotrophic weeds, such as Cheat grass, are annual in nature and typically shallow rooted, making a given site highly susceptible to erosion and fire.

One of the most successful land management methods for disturbed sites has been the retention of topsoil to reestablish mycorrhizae. Concurrent reclamation techniques re-spread stockpiled topsoil to reestablish mycorrhizae, followed by re-seeding the desired early seral stage species. In addition, use of inorganic fertilizers, especially those containing super-phosphate, should be discouraged since they can drastically inhibit mycorrhizae formation. Even the addition of relatively small amounts of topsoil (1 to 2 inches in depth) to a site results in improved mycorrhizal infection and subsequent establishment of indigenous shrub and forb species - species superior for erosion control and stabilization [9]. In the absence of topsoil reclamation on road and bridge construction projects, the use of soil amendments that facilitate initial plant establishment and mycorrhizal development appears to be necessary. Mycorrhizal inoculation products, roots dips and similar applications have proven unsuccessful in the semi arid West for reasons having to do with the site specific nature of indigenous soil fungi in this region. While many fungi are cosmopolitan, the unique character of the fungal community specific to biomass has been demonstrated, as exemplified by the successional patterns of fungi on decaying leaf litter material and in wood. There are substantial differences in these microorganisms that make it difficult to commercially reproduce them. Soil microorganisms in the semi-arid West region are not generic in nature, they are adapted to the specifics of given soils chemistry, aspect, elevation and climate.

Transplanting native and introduced species as container stock at roadside construction projects is common, and often met with failure. Frequently such transplants struggle and do not flourish for various reasons, among the most common in the semi arid West is dysfunctional root systems missing necessary indigenous mycorrhizae and associated microorganisms to obtain adequate moisture and nutrient to grow and develop. Nutrient cycling is in large part controlled by bacteria and the relative growth rates of the active fractions of the bacterial biomass, including root algae. Loss of significant portions of bacterial biomass, or loss of certain nitrogen fixers or nitrifying bacteria, severally limit the productivity of a site. Other problems include construction damage, reduced root volume, soil compaction, low organic matter and fertility, adverse soil pH and competition from grasses. In these cases, colonization of plant roots by mycorrhizal fungi and the introduction of beneficial bacteria to the soil would greatly reduce plant mortality.[3]

Topsoil

Managing excavation projects to include topsoil retention for revegetation purposes in the American West is an embryonic enterprise. Reclamation planers and engineers responsible for scheduling, equipment and budgeting operating activities realize that managing topsoil resources can be expensive and may conflict with other seemingly more critical activities. The physical and biological properties of topsoil have characteristics necessary to grow vegetation that are not present in other construction materials, such as sub-soils or imported borrow-material. The characteristics of topsoil are complex and, like all living things, require care to maintain their health. Topsoil can be stockpiled

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[8]Allen, E.B.; Allen, M.F. 1980. Natural re-establishment of vesicular-arbuscular mycorrhizae following strip mining in Wyoming. Journal of Applied Ecology. 17: 139-147

[9] Danielson, R. M. 1985 Mycorrhizae and Reclamation of Stressed Terrestial Environments. In: Tate, R. L., III; Klein, D.A

for short duration's of time - up to six months without appreciable loss of mycorrhizae, and efforts should be made to include in the stockpile process existent vegetative cover. Grubbing and clearing of sites should not waste these plant materials; they should be included in the topsoil stockpile. The water holding capabilities of topsoil is both physically and biologically very important to the revegetation process. The physical structure of topsoil is such that root development and establishment is possible, which is critical to the success of vegetation efforts. Although some operations have integrated soil management into excavation plans, many still struggle through a "last minute approach" which begins a few days before excavation equipment begins a new lay back. Schedules are not generally coordinated to salvage topsoil; the value of this material is not uniformly appreciated. Educational programs to instruct project designers and resident engineers as to the value of tops soil should be considered to stop the process of using topsoil as fill material. Topsoil reclamation needs to be recognized as a high priority in road building construction projects.

An average of 1 foot of topsoil over 1 acre of ground yields approximately 1,613 cubic yards of salvageable soil materials. Assuming a nearby stockpile site is available, it is likely that an operation will spend approximately $5,000.00 per disturbed acre to remove and replace the soil resources at this 1 foot deep level (based upon $1.50 per cubic yard from the stockpile). If one is only reapplying 6 inches of topsoil the cost drops to about $2,500.00 per acre. (Research by Wiclow-Howard indicates that even as little as 2 inch of topsoil provides a base level of essential mycorrhizae to help reestablish species dependant upon these soil microorganisms to live.) This magnitude of cost combined with the acres impacted annually by a highway agency suggests that road builders should be very interested in a carefully developed topsoil management plan. At $1.03 to as low as$.26 per square yard to have topsoil collected, stockpiled and returned to an excavated site, cost must be evaluated in light of the erosion control, environmental and aesthetic benefits resultant from the expenditure. The value of topsoil can not be measured strictly in economic terms, especially in the semiarid west when it takes up to 20 years to rebuild soil microorganisms sufficient for plant life to begin growing. The physical, biological and microbiological characteristics of topsoil are difficult and expensive to reestablish on disturbed sites. Roadside scars produced by road and bridge building create ongoing public relations problems for highway agencies and their employees.

Soil amendment products begin to build some of the organic processes common to topsoil, though these products can do little to compensate for the structural inadequacies of non-topsoil materials. Each project and each site is different with regard to topsoil and/or the so-called growth medium available for revegetation. There are no standard formulas that can be applied to determine what soil amendment or composted materials will function best in a given circumstance. Analysis of individual site characteristics, soils (NPK testing), slope, aspect, elevation and average rainfall will provide a basis for the decision making process. Notwithstanding, products commonly used in residential lawn revegetation, such as wood fiber or paper mulch, have a demonstrated propensity toward not aiding plant establishment at roadside sites where soils are poor. These products are very low in available organic content and do not carry soil-building nutrients necessary for plant establishment; their primary function is to hold moisture and prevent wind and water erosion. Many indigenous plants that are quite valuable for erosion control have very small seeds that can not grow through thick mulch blankets or bonded fiber matrix materials. Vigilance should be exercised to avoid such products in revegetation efforts. Comparison of the relative merits of compost materials such as yard waste or dairy waste in the Castlewood and Compost West products, as opposed to Fertile-fiber derived from composted poultry waste mixed with cereal grain meal, and soil amendments such as Kiwi Power is complex and, again, a site-specific undertaking. With composts, it is demonstrated that the addition of cereal meal to the organic mulch adds a time release element that is valuable as these materials provide organic nutrient material to the soil/plant life cycle. Poultry compost is five times more valuable on a pound per pound basis than bovine compost, and bovine compost is slightly more potent than yard waste or wood fiber composts[10].

Available topsoil resources are generally defined during the pre-excavation environmental base line survey. In some cases surveys have been completed by the Natural Resource Conservation Service (NRCS), a local office of the U.S. Department of Agriculture, or are completed by soil scientists working for an engineering or environmental company designing the road project. Included in this soil survey is a discussion of depth of salvageable topsoil within the unit, which at first may seem like sufficient information to develop a topsoil management plan. However, the range and depth of suitable soil within a soil-mapping unit will vary plus or minus 5 to 25% depending upon the site. The soil management plan must be site specific and is therefore dependent upon accurate soils data. Use of average soil depth information to guide a topsoil-salvaging plan will almost always result in the following negative outcomes:

- Unsuitable soils and/or rock materials will be placed in the stockpile at considerable expense.
- Salvageable soils will be left for fill materials and thus be unavailable for reclamation.
- Unnecessary costs will be incurred to handle poor materials and to salvage deeper suitable materials, which were not identified prior to the salvage operation.

Other problems, which often result from the lack of a topsoil management plan, include (1) no accounting system to keep track of the quantity of topsoil needed vrs. the quantity in the stockpile; (2) missed opportunities to direct-haul salvaged soils to reclamation sites and avoid stockpiling costs; (3) misplaced topsoil stockpiles, which can result in soil resources being stored at the opposite end of the site from where they are needed or, worse, being stored over next years phase 2 construction area; and (4) salvageable topsoil during the wrong season, resulting in difficult operating conditions.

The way to avoid endless challenges (opportunities) is to develop a topsoil management plan as an integral part of the road excavation process. This plan would fit with the planning horizons developed by the engineering group and is kept alive and current by the planning, operations, and environmental managers.

Conclusions

Comparison of the plant growth and establishment to date would indicate that the Kiwi products of Quattro Environmental could be valuable tools in revegetation for erosion control at badly disturbed sites absent topsoil. The demonstrated capacity of these products to spur the fungal growth of mycorrhizal organisms in poor soils is advantageous when revegetating using species dependant on a symbiotic relationship with these soil fungi. The expense of these products must be considered in balance with the bigger picture of the project objectives, and the relative quality, or lack thereof, of the parent material being revegetated. Given that poultry based compost is five times more effective than cattle based compost on a cost per effective pound basis, its more effective than the alternatives.

[10] Brenzel, Kathleen Norris. 1996. Sunset Western Landscape Book. Sunset Books Inc. Menlo Park, CA.

The addition of cereal grain meal to poultry compost adds a substantial time release NPK not available in other organic products. Carefully selecting species for seeding that are by nature early succession plants is also very important to the revegetation process. In addition, if at all possible selecting and obtaining seed form a similar elevation, similar rainfall environment in relatively close proximity to the subject site is of critical importance for optimal success. Early seral stage plants are soil builders, species designed to adapt and succeed in poor conditions. These early seral stage plants build soils, both physically and biologically so that higher seral stage species can grow on the site at a later date when soil conditions permit. Putting the seed down at the appropriate time of year (dormant seeding), the autumn or early winter is desirable so that the spring moisture regime may be available to germinate and help establish species. Vegetative cover, especially shrubs species, helps reduce water erosion and hold slopes through absorption of water and by slowing the transport of water off a given site and thus reducing kinetic energy. Deep rooting shrubs and legumes should be purposefully selected for these reasons. The natural selection process will eliminate less resolute plants at the Horseshoe Bend Hill site. Further evaluation will determine those species included in the mixes which have proven most successful. Once these species have been selected out, this information will make it possible to use seed applications that lay down as few as twenty to thirty seeds per square foot to achieve desired results. At this juncture it would appear that the areas treated with Quattro Environmental Kiwi products did quite well, and that the areas seeded with Yarrow, Louisiana sage, Rabbitbrush, Sainfoin, Ephraim wheatgrass, Thickspike and Intermediate wheat grass, Canby bluegrass and Steptoe barley did substantially better than the other areas. The demonstration plots continue to grow and, as time passes, further analysis will help focus future revegetation efforts at this and other similar sites in Southern Idaho.