NATIVE PLANTS ALLIANCE

"Growing Soil":

establishing sustainable native plant growth on drastically disturbed soils in harsh environments

by

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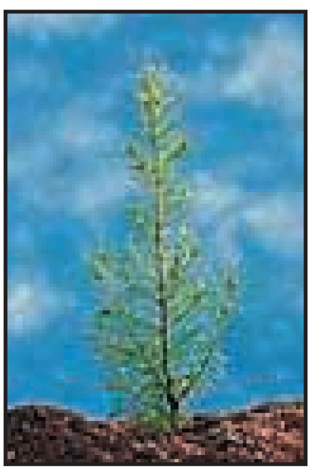
If native plants are so hardy, how come they are so difficult to grow on a sustainable basis?

Short answer: absent topsoil comprising an intact soil food web, native plants are not so hardy, and ultimately fail for much the same reasons ornamental and agronomically-based plants have historically failed to endure on drastically disturbed soils.

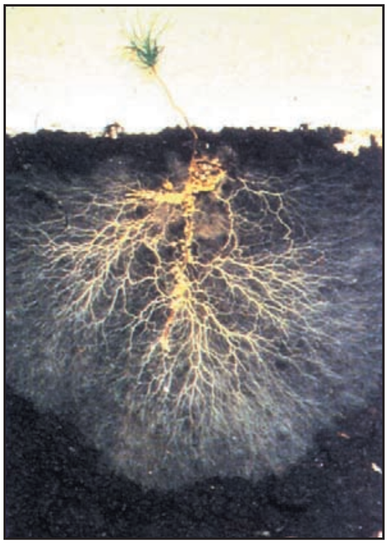


Annual grasses are often recommended for erosion control on disturbed sites because they are cheap, fast growing, and are able to grow on relatively non-fertile soils. With sufficient fertilizer, water and a benign climate, a suitable vegetative cover can be quickly accomplished with annual grasses. Unfortunately, in the semiarid West such traditional efforts based upon an agronomic model of plant establishment, even when seeding with native plant species, have consistently met with disappointing results in the field. Monocultures of shallow-rooted and drought-susceptible grasses, or worse, strongly-competitive weed growth, is the norm versus the hoped for diverse species of deep-rooted native shrubs, perennial grasses and forb species best suited for erosion control and soil stabilization in this region.

"Growing soil" as a strategy for establishing sustainable native plant growth on drastically disturbed (sterile) soils.

The strategy recognizes that the key to establishing native plant growth is to re-build sterile soils into vibrant organic matter, rich in living organisms. The objective is to fire up the natural cycling processes of the soil's "biological engine". Rather than merely growing plants per se, this amounts to setting the stage for the natural re-establishment of mycorrhizal fungi, soil bacteria and other beneficial soil organisms necessary to grow early seral stage plants -- pioneer species that act as soil builders. This is accomplished through the incorporation of certain organic complexes of enzymes and bacteria, along with protein-rich, organic fiber nutrients into the seed bed. We are growing soil organisms first and foremost, in order to sustain vegetative cover on site through the stages of plant succession in our efforts to ultimately re-establish climax native plant species.

The rationale for pursuing the re-establishment of soil microbes is predicated upon the recognition that grass, forb and shrub species indigenous to the semiarid West are dependent upon mycorrhizal fungi associations to exist.



Mycorrhizal associations (fungal colonies) are found in a broad range of habitats, being present in the root systems of most indigenous plant species on arid and semiarid lands, as well as higher rainfall areas with coniferous forests. In regions with low rainfall, where soils tend to be low in organic matter, and low in available P and N, mycorrhizal fungus plays a vital role in assisting the root systems of dominant species of indigenous vegetation to access moisture and nutrients from the soil. By way of example, 95% of the dominant native species in the Great Basin have mycorrhizae, and 96% of the root length can be colonized (Christensen, 1977).

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 roots to improve water and nutrient absorption for its host. Beneficial mycorrhizae solubilize mineral elements, such as phosphorus, for uptake by plant roots. 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 (Reed, 1991). 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 (Rousseau, 1994). Through these hyphae, mycorrhizae absorb and accumulate more nitrogen, phosphorous, potassium and calcium more rapidly and for longer periods of time than non-mycorrhizal roots.

Mycorrhizae have been found to increase the 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% of a given plant's survival potential lies within its root system. Yet revegetation efforts on drastically disturbed soils in the semiarid West typically begin with growth medium absent topsoil containing pre-disturbance mycorrhizae, and, further, fail to provide for the restoration of soil mycorrhizae as a requisite component of the revegetation process. To be successful using native species for revegetation and erosion control, it is imperative to focus on plant species, soil amendment materials and techniques that facilitate the natural re-establishment and maintenance of site specific mycorrhizae fungi and associated soil microbes. Generic soil inoculates attempting to introduce soil mycorrhizae have proven to be disappointingly ineffective in the semiarid West given the site specific adaptations of fungi common to this region.

"Setting the stage":

On disturbed sites absent topsoil containing mycorrhizal colonies, the objective is to introduce plant species that will aid in re-establishment of said colonies, and be able to grow in a low nutrient, low organic environment. To do nothing invariably results in non-mycotrophic weeds invading the disturbed sites rapidly and competing with desired species for water and nutrients. Attempts to grow native plant climax species with industrial fertilizer invariably meet with a similar fate. Without mycotrophic host plants present on the site to colonize, airborne spores of indigenous mycorrhizae are unable to persist. Disturbed sites, invaded by and subsequently dominated by weeds, have reported no mycorrhizae for up to 10 years (Rousseau, J.V.D. 1994).

A seed blend of early seral stage indigenous bunch grasses, forbs and shrubs should be selected for use as pioneer species at disturbed sites. There are a limited number of such plant families, including Chenopodiaceae, Brassicaceae, Amaranthceae, and Zygophyllaceae (Trappe, J.M. 1981). Selecting species from these families of plants, which both naturally invade disturbed sites and have a demonstrated propensity toward building soils (by aiding in the establishment of soil microorganisms and mycorrhizae), is a prerequisite for effective revegetation 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.

Advances in soils research and technology have led to development of organic soil amendments that stimulate the development of soil microorganisms, most notably mycorrhizae and beneficial bacteria. Use of such additives in revegetation efforts greatly speeds the establishment of indigenous vegetation at difficult sites, as exemplified by Idaho Transportation Department's Horseshoe Bend Hill demonstration site. The twelve cut slopes are 1:1 or steeper. The surface medium is decomposed granite strewn with rocks and small boulders. The absence of topsoil and uneven decomposed granite particle size, low moisture holding capacity and low plasticity index make this site highly erosive and extremely difficult to vegetate. Weather conditions range from minus-zero degrees in winter, 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 Beartrack Mine in central Idaho is another example of a difficult site where cut and fill slopes along the US Forest Service National Forest Service Highway road leading into the mine were successfully revegetated, as well as areas internal to the mine with difficult growth medium. In each case, the essential soil chemistry was found to contain minimal silt loam with decomposed granite and cobble, high pH, low CEC, low calcium, low sulfur, and low organic content. These soils tended to easily move off slopes. Beartrack Mine had been attempting a revegetation program at their forest road site for three consecutive years with only modest success.

At both the Horseshoe Bend Hill ITD site and Beartrack Mine site soil testing was conducted, a series of seed blends were developed, and organic soil amendments were prescribed that would biocatalytically improve soil structure, aid nutrient availability, import soil enzymes and bacterial activators along with cytokinins growth hormone (Kiwi Power). A high-protein organic mulch was added at a rate of 1 ton per acre to supply a nutrient energy source for soil microorganisms, which in turn would deliver a sustained, slow release of balanced nutrient to the soil via biological decomposition over time (Fertil-Fibers NutriMulch). These materials, along with the site-specific seed blends, were hydroseeded onto the barren hillsides in tandem with a clay-based, light-duty tackifier (Cliffhanger Tack).

On both projects, the seeding was conducted during the dormant period of winter (as late as January 23, 1997, in the case of Horseshoe Bend Hill, when there was approximately 3 inches of snow covering the site), and by the following late spring desired vegetation all but covered the treated slopes. These plants were well established by the end of the first growing season. Importantly, microscopic examination of the roots of these plants revealed an abundance of mycorrhizae sheath material surrounding them. This was accomplished in growth medium that was all but sterile as determined by laboratory analysis. While the Fertil-Fibers NutriMulch cereal meal provided the initial nutrient "lifepak" for the enzymes and bacteria in the soil, the biomass from the decaying foliage of what was seeded will help establish the nutrient cycling necessary for plant life to become self-sustaining at these sites.

Seeding efforts utilizing this growing soil technique over the past six years have demonstrated a remarkable consistency of success on a wide variety of terrain spanning Idaho, Wyoming, Montana, Nevada, California, Oregon and Washington. Large scale mine and roadside revegetation projects that have initially not responded favorably to traditional seeding treatments of seed + wood fiber mulch + fertilizer, have been successfully revegetated by the common application of this technique incorporating site specific seed blends and site specific treatments of the Quattro Advantage soil amendments at each site. Beginning in the fall 1996, steeper and longer slopes have been revegetated with the aid of the heavy-duty soil binder Atlas SoilLok developed by Henkel Corporation. Closely linked to Cognis Corporation's worldwide-recognized Terra-Control binder, the Atlas SoilLok technology forms a flexible, lattice-like membrane in the top-most layer of soil that is permeable to rain and oxygen and will not impair vegetative growth. Use of this environmentally-friendly binder in recent years has greatly facilitated the establishment of native plant growth on slopes approaching the vertical.

"Kick starting" nutrient cycling to rebuild organic matter:

The thin lens of topsoil common to the earth's crust is in fact rich in bacterial biomass and mycorrhizae. Nutrient cycling, and thereby sustainability of plant growth, 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, severely limit the vegetative productivity of a site. Consequently, loss of this thin lens of topsoil during road construction or other disturbance makes it difficult to reestablish vegetation on the exposed subsoil. For this reason, cut and fill slopes exposed during construction will usually not fully revegetate and thus remain sparsely populated.

Rebuilding the lens of biomass necessary for successful vegetation to establish can take many decades if left to Nature alone. Though the airborne spores of indigenous mycorrhizae may be present, the absence of hospitable conditions for reestablishing biomass makes it difficult for soil conditions to improve. Physical conditions compound the problem. The steep slopes are poor for holding moisture and whatever organic matter may come to settle there, making life difficult for emergent microflora. Sheet runoff from upslope areas on to these angle of repose slopes, and subsequent erosion, further compounds the problem of reestablishing a lens of biomass sufficient to support sustainable vegetation. Yet in the absence of early vegetative recovery, erosion and resultant sedimentation will occur.

Role of organic matter:

The organic content of a soil is an indicator of its fertility, its ability to support microbial populations, retention of mineral elements, and water retention. Organic matter is the part of the soil that is derived from living organisms. Although it constitutes a relatively small (1% - 5%) percentage of most soils, it is vitally important for soil as a medium for plant growth. Soil organic matter provides several benefits resulting from its unique physical and chemical properties. These benefits include:

1. Nutrients through mineralization;
2. Increased water holding capacity;
3. Heating soil by absorption of sunlight;
4. Increased soil aggregation;
5. Increased cation exchange capacity;
6. Increased soil buffering capacity;
7. Stimulation of plant growth and seed germination by plant growth regulator activity of humic substances.

Soil organic matter provides benefits far out of proportion to the percentages present in the soil, accounting for 2% -6% by weight of most soils. In semiarid regions the percentage is usually less than 2%. In a typical agricultural soil, organic matter contributes 50% of the cation exchange, water holding and buffering capacity of soil (MacCarthy et al., 1990). In sandy soils, organic matter may account for up to 90% of the absorptive and adsorptive capacity (Janick et al., 1974). Increased water holding capacity benefits plant growth by maintaining soil moisture for a longer period of time. This is particularly true for seeding on disturbed sites in semiarid regions. Relatively small amounts of organic matter may provide the amount of moisture retention needed to germinate the seeds and sustain young seedlings until root systems are able to extract water from a large volume of soil. Organic matter has a profound effect on soil structure. It is the "glue" that binds soil particles into aggregates. These soil aggregates are responsible for the crumbly, friable nature of productive soils. Soils with good structure have much less tendency for crusting, an occurrence that is a frequent cause of a poor vegetative stand. Seedling roots elongate more rapidly through a soil with good structure, allowing establishment of young plants with strong root systems that will withstand the rigors of the coming dry season. Cation exchange capacity is important because it measures the ability of the soil to bind nutrient cations and prevent their loss by leaching.

The Soil Food Web:

Most soil organic matter is derived from decomposed plant tissues, residues of top foliage and roots. As these residues are incorporated into the soil, they provide food for a community of soil organisms that constitute the soil food web. This community includes burrowing animals, worms, bacteria, protozoa and various beneficial fungi. The soil food web is a complex system with direct and indirect relationships among the soil biota. An example of a direct interaction would be a soil animal feeding on bacteria and fungi. Animals that feed on plant residue could exemplify an indirect interaction. The plant material is physically shredded and consumed portions are chemically altered in the animal's digestive tract. This hastens decomposition by providing more surface area for microbes to work on and providing partially degraded biopolymers. Since native plants are especially dependent upon a healthy soil environment, the existence of an intact soil food web is vital to maintaining the primary production that feeds the entire ecosystem.

Organic matter contains a variety of organic compounds which vary greatly in their digestibility. Sugars, starches and simple proteins are easily utilized by soil microbes and are rapidly oxidized to provide energy for microbial decomposers. More resistant molecules such as cellulose, lignin's and waxes are not utilized by most organisms, but may be decomposed at a slow rate by microbes with specialized enzymes. When much of the readily decomposed organic matter has been consumed, microbial activity declines and inorganic nutrients such as sulfate and nitrate are released to the soil solution. The process by which nutrients such as sulfur and nitrogen are changed from an organic to an inorganic form is called mineralization. This is important to plants because the inorganic forms are available to higher plants. These processes occur in both natural ecosystems and agroecosystems. However, the community of soil microbial decomposers may differ greatly in different environments.

The ratio of fungal to bacterial biomass has been used as a measure of ecosystem processes. Productive agricultural soils usually have a ratio of 1:1. Healthy grassland soils have a ratio less than 1 since they are dominated by bacteria, while fungal dominated forest soils have ratios greater than 1, sometimes greater than 10. In many natural ecosystems and agroecosystems under reduced tillage, fungi tend to be the primary decomposers. This results in relatively rapid nutrient cycling and the buildup of a large slow/passive organic pool. This pool includes humic substances. The organic matter remaining is humus, a heterogeneous dark-colored colloidal substance (Coleman et al., 1992; Hendrix et al., 1986; Ingham and Horton, 1987).

Humic Substances:

Humic substances are classified as humic acid, fulvic acid and humin based on water solubility as a function of pH. In general, humic substances may be characterized as complexes of macromolecules with amino acids, amino sugars, peptides, aliphatic acids and other aliphatic groups. The building blocks of humic substances are amphiphilic units with hydrophilic functional groups, linked to hydrophobic functional groups.

Humic substances are important to the soil-plant system because of their function as plant nutrient reservoirs, holding up to 50% of all available soil nutrients. Studies of biostimulant activity have shown humic substances stimulate seed germination, root growth and shoot growth. Studies have demonstrated that humic substances derived from leonardite increased plant growth rates and treatments produced a proliferation of stout healthy roots. The hormone-like activity of humic and fulvic acids involves action at the root cell membrane or enhancement of active metabolism. While the biology and chemistry of humic substances in the soil is exceedingly complex, the use of humic substances at sites where the soil is devoid of adequate microbial activity has demonstrated that a bloom of soil microbes results.

In relation to the systematic application of the Quattro Advantage materials to disturbed soil sites, the Kiwi Power complex of enzymes and bacteria both incorporates and stimulates a bloom of soil microbial activity which requires sustenance. The Fertil-Fibers NutriMulch combination of seedmeal/ feathermeal proteins and poultry compost nutrient package has been designed to sustain the soil microbes through their initial stages of life, until such time as plant residues are available through decomposition to provide for their ongoing sustenance. It is this dual-action delivery of a humic substance hormonal stimulus, in tandem with the life-sustaining nourishment of a protein-rich nutrient source, which enables the Quattro Advantage plant growth materials to reestablish soil microorganisms and native plant growth in a self-sustaining manner at disturbed sites.

Unless topsoil is returned to a disturbed site, composted organic wastes and protein-rich organic mulches typically must be utilized to reestablish early seral stage plant life to the site. It is the diminutive quantity of humic substances in compost, complex amino acids and amino sugars that stimulate protein synthesis necessary for microbial life in soil. It should be noted that use of industrial fertilizers, especially those containing super-phosphate, should be discouraged since they can drastically inhibit mycorrhizae formation. These products, so commonly used in domestic agriculture, are salt- and acid-based and as such will effectively inhibit the development of soil microbes. Further, use of fertilizer with native plantings will not promote establishment objectives; rather it will result in weeds and non-native species occupying the site in question. By contrast, even the addition of relatively small amounts of topsoil (1 to 2 inches in depth) to a site results in improved mycorrhizal inoculation and subsequent establishment of indigenous grass, forb and shrub species -species superior for erosion control and soil stabilization.

Mycorrhizal inoculation products, root dips and similar treatments have consistently proven disappointing in the Western U.S. for reasons having to do with the site specific nature of indigenous soil fungi and bacteria in this region. While many bacteria are cosmopolitan, the unique character of the fungal community composition 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 them difficult to reproduce commercially. Soil microorganisms in the West are not generic in nature, but are adapted to the specifics of given soil chemistry, plant cover type, aspect, elevation and climate.

Despite the existence of winning techniques and formulated materials to implement such "growing soil" efforts in harsh environments, true native plant establishment on sterile soils continues to be elusive owing to Nature's intolerance of, and our industry's lack of attention to, the "weak link" factor.

The "weak link" factor is simply that one's level of plant establishment success will correspond to the weakest link in the process of design, supply and field implementation of a revegetation project. For a variety of reasons, the sabotaging influence of the weak link factor pervades our industry and is largely responsible for the industry's high level (80% +) of total seeding efforts that are ultimately judged "disappointing".

Nature's intolerance of a weak link is nowhere more apparent than on federal and/or state contractor bid seeding projects, where the "low bid" mandate prevails. The fragmented make-up of the industry notwithstanding, and the perceived handicap of the federal/state government "low bid" mandate, strategies are successfully being implemented to keep the weak link at bay, and achieve revegetation success.

Efforts to counter "weak link":

- ❑ Team relationships: Native Plants Trust; client-developed team relationships
- ❑ Constant supervision (Federal Highway Administration)
- ❑ Minimizing what is "left to chance": soil analysis
    - ❑ Seed testing prior to mixing
    - ❑ Supervision of seeding application
    - ❑ Education of designers, project engineers

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Handouts: Erosion Control Demonstration Project (Horseshoe Bend Hill), Idaho Transportation Dept. Research Paper, 1997

Quattro Advantage Briefing Folder

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