2000 Billings Land Reclamation Symposium

THE USE OF LOCAL ECOTYPES FOR THE REVEGETATION OF ACID/HEAVY METAL CONTAMINATED LANDS IN WESTERN MONTANA

Leslie Marty[1]

ABSTRACT

Current reclamation efforts to revegetate abandoned mine sites in western Montana rely primarily on commercial seed sources and limited native seed collection. Very few species of commercially available seeds are adapted to acid/metalliferrous soil, or to western Montana. The Development of Acid Tolerant Plant Cultivars project seeks to address this problem by selecting plant ecotypes from western Montana that demonstrate superior tolerance to acid/heavy metal soil conditions. In 1995, two initial evaluation plots were constructed on the Anaconda Smelter Superfund Site in southwestern Montana. Plant materials in this study were assembled from wildland collections on degraded sites throughout western Montana and from commercial seed sources. The plots were replicated three times in a randomized complete block design and collectively tested 95 species consisting of 51 grass, 29 forb, 14 shrub, and 1 tree species. The entries were evaluated for percent survival, vigor, height, and seedhead production. After three growing seasons, the superior performing entries were identified. The best performing collections are presently being tested in a comparative evaluation planting near Anaconda with comparisons to other accessions and cultivars of the same species. Concurrently, 13 grass, 6 forb, and 7 shrub species are being grown at the Bridger Plant Material Center (BPMC) to determine cultural techniques and to increase seed. The results of the comparative evaluation planting and the success of seed production will provide valuable information for the selection of plant materials. Releases will be made through the Pre-Varietal Release process at the "Source-Identified" and "Selected" level. Foundation seed for the releases will be maintained at the BPMC for distribution through the Montana and Wyoming Crop Improvement Association to commercial seed producers.

[1] Deer Lodge Valley Conservation District in cooperation with the Bridger Plant Materials Center, Route 2, Box 1189, Bridger, MT 59014. (406) 662-3579.

INTRODUCTION

The legacy of Montana's mining past has left a wide range of problems and challenges for those charged with reclamation and associated activities in the next century. There are an estimated 6,000 abandoned hardrock and milling sites in Montana (Montana Department of State Lands 1994). Serious environmental and safety issues have been identified at 286 of these sites (Montana Department of State Lands 1995). Additionally, Montana has the largest Superfund site in the United States. The Upper Clark Fork Basin Superfund complex extends 225 km (140 mi) from Silver Bow Creek north of Butte to the Milltown Dam near Missoula. In the Clark Fork Basin alone, there are approximately 51.8 km^2 (20 mi^2) of tailing ponds; more than 453.2 km^2 (175 mi^2) of soils and vegetation contaminated by air pollution from smelting operations; at least 77.7 km^2 (30 mi^2) of unproductive agricultural land; over 241 km (150 mi) of contaminated river bed and riparian habitat; and millions of gallons of contaminated groundwater (Johnson and Schmidt 1988; Moore and Luoma 1990).

Metal mine and mill wastes are the most difficult and highly visible reclamation problems facing land rehabilitation specialists today (Munshower 1994, Neuman et al. 1993). At the Anaconda smelter site, 40 km (25 mi) northwest of Butte, copper ore milling, smelting, and refining operations took place between 1884 and 1980. Today, this 777 km^2 (300 mi^2) site contains large volumes of wastes, debris, and contaminated soil. Re-entrainment of these wastes continues to be a problem. Release mechanisms include air dispersion, surface water runoff, and wind erosion, resulting in secondary contaminant sources in surface and subsurface soils, sediments, surface water, and fugitive dust (CDM Federal 1997).

As global populations grow, the demand for natural resources accelerates. New mining and mineral extraction technology also has spurred a resurgence in the mining industry. Such developments can create severe disturbances that potentially threaten the integrity of watersheds including water quality, wildlife habitat, aesthetic resources, and other environmental concerns. These severe disturbances often suspend succession and thus intensify contamination problems. The resulting loss of vegetation decreases soil stability, soil shading, organic matter, nutrient cycling, and in turn, degrades wildlife habitat.

The arid and semi-arid climate prevalent in the Intermountain and Northern Great Plains region increases the time required for disturbances to rehabilitate naturally. Depending on soil conditions (rootzone characteristics), drastic disturbances may require hundreds or thousands of years to achieve functional plant communities. Hardrock minelands pose additional problems for revegetation, primarily: steep slopes; unfertile soil media (low cation exchange capacity, low water holding capacity, low organic matter); extreme moisture, temperature, and wind fluctuations; acidic soils; and heavy metal contamination. To accelerate rehabilitation, proper plant selection on these harsh sites is crucial.

Although the Surface Mining Control and Reclamation Act of 1977 allows the use of introduced species, State and Federal regulatory agencies recognizing the importance of adaptation and biological diversity, frequently require the re-establishment of a permanent vegetative cover of the same variety native to the area (Roundy et al. 1997). Scientists contend it is essential that indigenous native plant species be selected that are evolutionary products of that environment. Native indigenous species have a long history of genetic sorting and natural selection by the local environment. Over the long-term, these plants are often better able to survive, grow and reproduce under the environmental extremes of the local area than introduced plants originating in other environments (Brown 1997, Munshower 1994).

The utilization of tolerant races, even on amended or topsoiled sites, is suggested because the subsoil is often a major portion of the rootzone materials. Species exhibiting acid/heavy metal tolerances may also reduce the need for lime and are a precaution against poor mixing of amendments with acidic wastes. Populations of acid and metal-tolerant vegetation have been successfully selected, propagated and established on abandoned mine sites in Europe and Africa. Tolerant populations have been identified in North America but none have been propagated for seed production.

Improving the metal tolerance of plants is of interest to scientists internationally. Many papers have recently been published on developing transgenic metal tolerance (Hasegawa et al. 1997, Manual de la Fuente et al. 1997, Vatamaniuk et al. 1999). However, the biology is complex, poorly understood, and the technology needed to transfer genes to wildland plants is not well developed. Ethical and biological questions related to releasing genetically engineered organisms into the environment are also pertinent. Traditional plant breeding (plant selection) seems to be the best approach at present.

Except when extensive amelioration has been employed, reclamation efforts on hardrock minelands in western Montana have met with limited success. At the Anaconda Superfund Site, for example, the region’s plant cover and diversity remains low although revegetation efforts began in the 1940s (RRU 1993). The majority of native seed currently being used on metal mine reclamation projects in Montana were developed for coal strip-mine reclamation and range renovation in the dry, saline soils of eastern Montana. The few cultivars adapted to western Montana, where the bulk of reclamation occurs, were not selected for acid or heavy metal tolerance. The Development of Acid/Heavy Metal-Tolerant Cultivars (DATC) project seeks to identify, select and release naturally occurring acid/heavy metal-tolerant plant ecotypes desirable for reclamation and commercial seed production.

The project objective is to develop plants for use on lands where ameliorative and adaptive revegetation methods are implemented. In an agricultural approach the contaminated soil media is removed and replaced with hauled topsoil and typically planted using highly productive exotic species. The ameliorative/adaptive approach, in contrast, involves amending/shaping the soil in-situ, and identifying, specifying, and establishing plants that are ecotypically differentiated, or adapted, and tolerant of the site conditions. Although, this approach has been used in Europe since the 1960s, its use in the United States is relatively new (Morrey 1996). The ameliorative/adaptive reclamation method may be the preferred approach in the future due to diminishing economical topsoil resources, and available land for repositories. This approach also addresses concerns regarding biodiversity, self-sustaining plant communities, and the need for an alternative method on steep slopes.

METHODS AND MATERIALS

The project design is based on the assumption that the best plants for acid/heavy metal contaminated soils would be those found growing at such sites. Plants that are able to survive in nutrient poor, acidic rooting media contaminated with heavy metals such as copper, zinc, lead, cadmium, and arsenic are thought to possess inheritable genetic traits for tolerance to those conditions. This assumption is based on numerous studies. Jain et al. (1966) documented the existence of localized races or ecotypes each adapted to the particular environment conditions of its habitat. The study concluded that distances as low as 1-2 meters are sufficient to permit populations of certain species occupying contrasting habitats to become very distinct from one another. Bradshaw et al. 1965 found that *Agrostis tenuis*, a common perennial grass in temperate climates, evolved unique populations in old mine workings that exhibited tolerances to various heavy metals. Furthermore, these tolerances were not lost in cultivation in the absence of the metal, and were heritable. Surbrugg (1982) reported two cool season grass species growing on copper tailings at Anaconda that possessed tolerances to elevated levels of copper and zinc. Chambers et al. (1984) working in the Beartooth Mountains of southcentral Montana found that species colonizing severe disturbances exhibited an ability to establish on phytotoxic sites. Additionally, there is evidence that metal tolerant strains tend to be more drought tolerant and translocate fewer contaminates to their aerial portions than non-tolerant plants (Smith and Bradshaw 1972).

The process of developing plants for mineland revegetation encompasses a number of stages: 1) seed/plant collection from affected sites and assemblage of commercially available plant material, 2) initial evaluation of assembled germplasm, 3) secondary large-scale seed collection of better performing germplasm, 4) seed increase of superior collections, 5) field testing of superior germplasm, and 6) release of foundation quality seed to commercial seed producers. The project has concentrated on collecting and testing plant materials at the Anaconda Smelter Superfund site because of the extent of contamination, elevation, varied terrain, and cool, semi-arid climate.

Initial Evaluation Planting

The project was initiated in 1995 with 124 collections made at 26 mine impacted sites throughout western Montana. Seed and occasionally plants were collected from a range of elevations, precipitation zones, aspects, contamination types and concentrations, soil and plant community types. In addition, released cultivars and other commercially available plant materials were assembled. Three initial evaluation plantings (IEPs) were established - one plot near East Helena and two plots near Anaconda, Montana. The plots collectively tested 95 species (220 accessions). Only data from the Anaconda sites (Site 1 and Site 2) are presented, however, due to subsequent burial of the East Helena plot.

The soil at Site 1, located near the junction of Highways 1 and 48, has been impacted by aerial fallout from smelter emissions and the ongoing re-deposition of exposed hazardous substances. The site was sparsely vegetated and mostly devoid of topsoil due to severe wind and water erosion. Prior to plowing, the site had an average pH of 5.5. The plot site was deep plowed, cultivated with sweeps, and roller packed. After plowing, the pH increased due to a calcareous layer in the top 30 cm (1 ft) of the soil profile. Composite samples from the top 25.4 cm (0.83 ft) of the profiles indicated levels of cadmium, copper and zinc that exceeded the upper limits for phytotoxicity established by the EPA. The surface soil samples had metal concentrations several times greater in magnitude than the composite samples. Surface water runoff during storm events, soil crusting and stoniness were other factors observed at the site.

Site 2 is located on the Opportunity Ponds about 3 km (2 mi) northeast of Site 1. The Opportunity Ponds were used as a disposal site for mill tailings. During active disposal of smelter wastes, a portion of the ponds was covered with water, but has since been allowed to dewater. Very high levels of copper, lead, and zinc, in combination with extremely poor fertility, low pH and organic matter characterize Site 2. The site was devoid of vegetation except for sparse patches of *Agrostis gigantea*. The average pH prior to plowing was 3.0. Quick lime was incorporated at this site at three different rates: 0, 11, and 22 metric tons per ha (0, 30, and 60 tons per ac). The composite soil samples at the site contained extremely high levels of cadmium, copper and zinc. One sample contained cadmium concentrations 21 times, copper 53 times, and zinc 266 times greater than the upper limits established for phytotoxicity. Other growth factors include a hard surface crust, high winds and subsequent particle movement that can sand blast, bury, and defoliate plants. The site's total exposure to incoming solar radiation and associated high ground surface temperatures and reflectance also influences plant growth.

The sites were planted with a push type, single-row, belt seeder in rows 9 m (30 ft) long, with 0.45 m (1.5 ft) row spacing, approximately 1 cm (0.5 in) deep. Both sites were a randomized complete block design replicated 3 times. Of the 220 entries tested, 80 were released cultivars and 140 were wildland collections or common sources. Distribution of cultivar lifeforms was 59 grasses, 18 forbs, and 3 shrubs. Distribution of wildland collections and common sources was 69 grasses, 26 forbs, 35 shrubs, and 8 trees.

Comparative Evaluation Planting

A Comparative Evaluation Planting (CEP) was installed to test the wildland plant material that performed well in the IEP. The CEP is located on the Willow Glenn Road, approximately 3 km (2 mi) east of Anaconda. Soil contamination in this area is concentrated in the upper few centimeters of the profile and is the result of past stack emission fallout and the ongoing re-deposition of fugitive dust. The plot site is approximately 0.2 ha (0.5 acres) and had an average pH of 4.5 [0-15 cm (0-6 in) composite samples] after tillage to a depth of 15 cm (6 in). Most soil samples contained arsenic and copper concentrations exceeding EPAs upper range for phytotoxicity. Some samples had phytotoxic levels of zinc.

The CEP is testing multiple accessions of 6 forb species, 13 grass species and 6 forb/grass mixes. The plot contains 84 entries in a randomized complete block design, replicated 4 times. The entries were planted in May 1999, using a single row, push-type belt seeder based on a seeding rate of 82 PLS per m (25 PLS per ft). During the unusually dry growing season of 1999, the CEP was evaluated twice.

RESULTS AND DISCUSSION

Initial Evaluation Planting

The IEP plots have been evaluated annually since 1996 for height, integrated vigor (incorporates assessment of leafiness, basal area, tillering, and color), and percent stand/survival. The results are from 1999 at Site 1 and 1998 at Site 2, the fourth and third growing seasons, respectively. The entries were ranked using the scores for vigor and percent stand weighted equally. The top performing entries (up to the fifteenth rank if applicable) from each lifeform from Site 1 and Site 2 are listed below in tables 1 and 2.

None of the forbs, trees or shrubs planted at Site 2 survived. At both sites potted woody material was transplanted in early July during particularly hot weather. Transplant timing may have contributed to the mortality of the woody material at Site 2. The more sheltered position of Site 1 may have enabled the woody material to survive there. *Leymus racemosus* ND-691, which performed the best at Site 2, was not included in the entries at Site 1. Second ranking, *Leymus racemosus* 'Volga' ranked in the middle of the field at Site 1. *Pseudoroegneria* ssp. *inermis* 'Whitmar' performed very well at both sites. Other grasses that performed well at both sites include *Elymus lanceolatus* 'Sodar', *Elymus lanceolatus* ssp. *lanceolatus* 'Schwendimar', *Pseudoroegneria spicata* ssp. *spicata* 'Goldar', *Leymus angustus* 'Prairieland', and *Pascopyrum smithii* 'Rosana'. *Deschampsia cespitosa* performed well at both sites although the two high ranking entries were different accessions. Both accessions outperformed *Deschampsia cespitosa* 'Peru Creek', a released cultivar. *Elytrigia repens* X *Pseudoroegneria spicata* 'Newhy' was a top performer at Site 2 and also performed fairly well at Site 1, although not a top performer. *Poa alpina* 9016273 and *Festuca rubra* 'Penlawn' that were top performers at Site 2 did not fare well at Site 1.

Table 1. Anaconda Initial Evaluation Planting Site 1 Top Performing Species.

LIFEFORM	SPECIES	ACCESSION/ CULTIVAR	RANK	ORIGIN
Forb	*Potentilla hippiana*	9076289	1	Native
Forb	*Epilobium angustifolium*	9076267	2	Native
Forb	*Penstemon strictus*	Bandera	3	Native
Forb	*Heuchera parviflora*	9076279	4	Native
Forb	*Coronilla varia*	Chemung	4	Introduced
Forb	*Lotus corniculatus*	Kalo	5	Introduced
Forb	*Sphaeralcea coccinea*	9076283	6	Native
Forb	*Dalea purpurea*	Keneb	7	Native
Forb	*Lotus corniculatus*	Norcen	7	Introduced
Forb	*Aster chilensis*	9078675	8	Native
Forb	*Medicago sativa*	Spredor-3	8	Introduced
Forb	*Phacelia hastata*	9058019	9	Native
Forb	*Lathyrus sylvestris*	Lathco	10	Introduced
Grass	*Pseudoroegneria spicata* ssp. *spicata*	Secar	1	Native
Grass	*Pseudoroegneria spicata* ssp. *inermis*	Whitmar	2	Native
Grass	*Psathyrostachys juncea*	Bozoisky-Select	3	Introduced
Grass	*Elymus lanceolatus*	Sodar	4	Native
Grass	*Deschampsia cespitosa*	9076290	5	Native
Grass	*Psathyrostachys juncea*	Mankota	6	Introduced
Grass	*Leymus cinereus*	Magnar	7	Native
Grass	*Leymus cinereus*	Trailhead	8	Native
Grass	*Elymus lanceolatus* ssp. *lanceolatus*	Schwendimar	9	Native
Grass	*Pseudoroegneria spicata* ssp. *spicata*	Goldar	10	Native
Grass	*Elymus trachycaulus* ssp. *trachycaulus*	Pryor	11	Native
Grass	*Pascopyrum smithii*	Rodan	12	Native
Grass	*Elymus elymoides*	9040189	13	Native
Grass	*Leymus angustus*	Prairieland	14	Native
Grass	*Pascopyrum smithii*	Rosana	15	Native
Shrub	*Salix alba*	9078386	1	Introduced
Shrub	*Rosa woodsii*	9078385	2	Native
Shrub	*Lonicera* spp.	9081306	3	Native
Shrub	*Artemisia longifolia*	9076289	4	Native
Shrub	*Caragana* spp.	9078379	5	Introduced
Shrub	*Symphoricarpos albus*	9078388	6	Native
Shrub	*Shepherdia argentea*	9081334	7	Native
Shrub	*Atriplex canescens*	Rincon	8	Native
Shrub	*Rhus trilobata*	Bighorn	9	Native
Shrub	*Atriplex* X *aptera*	Wytana	10	Native
Tree	*Populus deltoides* ssp. *monilifera*	9078382	1	Native

Table 2. Anaconda Initial Evaluation Planting Site 2 Top Performing Species.

LIFEFORM	SPECIES	ACCESSION/ CULIVAR	RANK	ORIGIN
Grass	*Leymus racemosus*	ND-691	1	Introduced
Grass	*Leymus racemosus*	Volga	2	Introduced
Grass	*Pseudoroegneria spicata* ssp. *inermis*	Whitmar	3	Native
Grass	*Poa alpina*	9016273	4	Native
Grass	*Festuca rubra*	Pennlawn	5	Introduced
Grass	*Leymus arenarius*	ND-2100	6	Introduced
Grass	*Elytrigia repens* X *Pseudoroegneria spicata*	Newhy	7	Native
Grass	*Leymus angustus*	Prairieland	8	Unknown
Grass	*Deschampsia cespitosa*	9076280	9	Native
Grass	*Elymus lanceolatus* ssp. *lanceolatus*	Critana	10	Native
Grass	*Pseudoroegneria spicata* ssp. *spicata*	Goldar	11	Native
Grass	*Elymus lanceolatus* ssp. *lanceolatus*	Schwendimar	12	Native
Grass	*Pascopyrum smithii*	Rosana	13	Native
Grass	*Elymus lanceolatus*	Sodar	14	Native
Grass	*Poa secunda*	Canbar	15	Native

At both sites, cultivars, both native and introduced, overwhelmingly outperformed wildland collections. This may be due to the higher pure live seed (PLS) content of the cultivar seed. The wildland seed was not tested for viability or purity. All seed was sown at 25 PLS per ft when PLS was known. When unknown, the seed was sown at 25 seeds per foot. This variance may account for the seemingly superior performance of cultivars.

In general, grasses seemed to outperform forb, shrub and tree lifeforms. The wildryes and wheatgrasses, known for their drought tolerance, were the best performing grasses. Many of the best performing forbs were legumes and many also pioneering species

Comparative Evaluation Planting

The emergence rates in the CEP was extremely low. Less than half (42%) the entries emerged. The highest emergence rate was 15.7% for *Oryzopsis hymenoides* 'Nezpar'. A month later seedling survival had declined greatly and only 9% of the entries (table 3) contained live seedlings. In early November, the CEP was replanted in hopes that a more favorable growing season would result in better plant establishment. The pH of the site may prove to be too acidic for plant establishment unless plowed to a greater depth and/or amended.

Table 3. Anaconda Comparative Evaluation Planting Results. Planted May, 1999.

LIFEFORM	SPECIES	ACCESSION/CULTIVAR	% SURVIVAL
Grass	*Elymus trachycaulus*	9081620	0.33
Grass	*Elymus trachycaulus*	Pryor	0.33
Grass	*Oryzopsis hymenoides*	Nezpar	0.33
Grass	*Psuedorogeneria spicata*	Secar	0.33
Grass/Forb	Cultivated Plains	Seed Mix	0.17
Grass	*Agrostis gigantea*	9076266	0.05
Grass	*Agrostis gigantea*	9076276	0.05

Seed Increase

Seed increase of the promising collections has been initiated at the USDA NRCS Plant Materials Center at Bridger, Montana. The objective of seed production is to provide foundation seed and cultural information to commercial growers. Currently, there are approximately 1.4 ha (3.5 ac) of promising acid/heavy metal-tolerant plant materials in seed increase including 6 forb species, 13 grass species and 7 shrub species (table 4). Some of these native species have not previously been cultivated.

Table 4. Ecotypes in Production at the Bridger Plant Materials Center

LIFEFORM	SPECIES	COMMON NAME	ELEVATION*	ORIGIN
Forb	*Aster chilensis*	creeping aster	foothills to subalpine	Native
Forb	*Heuchera parviflora*	littleflower alumroot	montane to alpine	Native
Forb	*Penstemon eriantherus*	fuzzy-tongued penstemon	plains to montane	Native
Forb	*Phacelia hastata*	silverleaf phacelia	plains to alpine	Native
Forb	*Potentilla hippiana*	woolly cinquefoil	Foothills	Native
Forb	*Sphaeralcea coccinea*	scarlet globemallow	plains to montane	Native
Grass	*Agrostis gigantea*	redtop	plains to montane	Introduced
Grass	*Carex paysonis*	Payson's sedge	foothills to alpine	Native
Grass	*Deschampsia cespitosa*	tufted hairgrass	foothills to alpine	Native
Grass	*Elymus trachycaulus*	slender wheatgrass	plains to alpine	Native
Grass	*Juncus balticus*	Baltic rush	plains to subalpine	Native
Grass	*Leymus cinereus*	basin wildrye	plains to montane	Native
Grass	*Oryzopsis hymenoides*	Indian ricegrass	plains to foothills	Native
Grass	*Pascopyrum smithii*	western wheatgrass	plains to subalpine	Native
Grass	*Poa alpina*	alpine bluegrass	subalpine to alpine	Native
Grass	*Poa ampla*	big bluegrass	plains to montane	Native
Grass	*Poa compressa*	Canada bluegrass	plains to montane	Naturalized
Grass	*Poa* species	bluegrass species	foothills	Native
Grass	*Pseudoroegneria spicata*	bluebunch wheatgrass	plains to foothills	Native
Shrub	*Juniperus horizontalis*	creeping juniper	plains to subalpine	Native
Shrub	*Purshia tridentata*	antelope bitterbrush	plains to foothills	Native
Shrub	*Rosa woodsii*	Prairie rose	plains to subalpine	Native
Shrub	*Shepherdia argentea*	silver buffaloberry	plains to foothills	Native
Shrub	*Symphoricarpos albus*	common snowberry	plains to subalpine	Native
Shrub	*Symphoricarpos occidentalis*	western snowberry	foothills to montane	Native
Shrub	*Ribes* species	currant species	foothills to alpine	Native

* Kershaw et al. 1998

Planting begins with seedbed preparation that includes the isolation of accessions of the same or similar species to protect the genetic integrity of the accessions. Seed production fields are commonly established by seeding 1 m (3 ft) rows at 90 PLS per m (30 PLS per ft). Many of the forb and woody species require pre-treatments to break dormancy. In some cases, hard seeded species can be dormant fall planted without pretreatment. In the establishment year, weed control is difficult due to the generally slow establishment of native species. Weeds are controlled by timely mowing, tilling, and spraying with herbicides formulated for seedlings. Fields are fall fertilized to insure the slow release of nutrients and to initiate development of seedhead primordia.

Seed production usually begins in the second growing season. Many native grass species can be combine harvested. The forbs are often harvested using a swather equipped with a canvas catch basin. The woody species are usually hand stripped. To optimize seed yields, the harvested plant material is often left to afterripen and dry on tarps for 1-2 weeks. Specialized equipment is then utilized to clean the seed. Cleaning methods vary depending on the type, size, shape, and amount of debris in each harvest. Most commonly, the plant material is processed by running it through a hammermill, which liberates the seed by flailing the material. Next, the material is run over a seed mill which uses wind and vibrating screens to further separate the good seed from the chaff.

The end product of the project will be the release of indigenous, native plant materials that demonstrate superior tolerance to acidic conditions and heavy metal contamination. In addition, the plant material chosen for release will consider the following criteria: commercial production potential, heavy metal uptake in aerial plant tissues, and the ability to add to the ecosystem's resilience by initiating and/or accelerating the process of succession. Releases will be made through the Pre-Varietal Release certification process at the "Selected" and "Source-Identified" levels. The foundation seed will be maintained at the BPMC and distributed to commercial seed producers through the Montana and Wyoming Crop Improvement Association. Each release will have a companion Planting Guide that provides information such as plant adaptation, uses, compatibility, growing techniques, etc. Plant releases are anticipated to begin in 2001.

CONCLUSION

The results of the IEP suggest that there are a number of species that have not been released for revegetation purposes but have reclamation potential. These species include *Aster chilensis*, *Epilobium angustifolium, Heuchera parviflora, Potentilla hippiana, Sphaeralcea coccinea, Artemisia longifolia, Populus deltoides* ssp. *monilifera, Rosa woodsii*, *Symphoricarpos albus*, and *Symphoricarpos occidentalis*. Many of the cultivars that performed well originated from other regions. New ecotypic releases of these species may be of value. *Deschampsis cespitosa* Peru Creek, for example, is a cultivar originating from Colorado, however, at the IEP two collections from mine affected sites in western Montana outperformed Peru Creek. Some species that merit further investigation include *Deschampsia cespitosa*, *Elymus lanceolatus, Elymus trachycaulus*, *Leymus cinereus, Pascopyrum smithii*, *Poa alpina* and *Pseudoroegneria spicata*.

Many cultivars on the market performed well. The outstanding forb cultivars included *Penstemon strictus* 'Bandera', *Coronilla varia* 'Chemung' and *Lotus corniculatus* 'Kalo'. The outstanding grass cultivars include *Pseudoroegneria spicata* ssp. *inermis* Whitmar, *Elymus lanceolatus* Sodar, *Elymus lanceolatus* ssp. *lanceolatus* Schwendimar, and *Pseudoroegneria spicata* ssp. *spicata* Goldar. Although only a small sampling of shrub cultivars were tested, the best performers were *Atriplex canescens* 'Rincon', *Rhus trilobata* 'Bighorn' and *Atriplex* X *aptera* 'Wytana'.

Information on the performance of the entries at the CEP is forthcoming. Until more data from the CEP is collected it is impossible to make any conclusions on the performance of local ecotypes versus broadly adapted cultivars. The success of seed increase efforts at the BPMC will also help determine the potential of future releases.

REFERENCES

Bradshaw, A.D.; McNeilly, T.S.; Gregory, R.P.G. 1965. Industrialization, evolution and the development of heavy metal tolerance in plants. British Ecological Society Symposium 6: 327-343.

Brown, R.W.; Amacher, M.C. 1997. Selecting plant species for ecological restoration: a perspective for land managers. Revegetation with native species, pp.1-16 In: Proceedings, 1997 Society for Ecological Restoration Annual Meeting. U.S.D.A. Forest Service Rocky Mountain Research Station. Proceedings RMRS-P-8.

CDM Federal. 1997. Final baseline ecological risk assessment. Anaconda regional water, waste, and soil operable unit; Anaconda Smelter NPL Site, Anaconda, Montana, Vol. 1. Prepared for EPA, Region VIII, Montana Office. (October).

Chambers, J.C.; Brown, R.W.; Johnston, R.S. 1984. Examination of plant successional stages in disturbed alpine ecosystems: a method of selecting revegetation species. In: Proceedings: High Altitude Revegetation Workshop. No. 6 Information Series: 215-224.

Hasegawa, I.; Terada, E.; Sunairi, M.; Walota, H.; Shinmachi, F.; Noguchi, A.; Nakajima, M.; Yazaki, J. 1997. Genetic improvement of heavy metal tolerance in plants by transfer of the yeast metallothionein gene (CUP1). In: Plant and Soil 196: 277-281.

Jain, S.K.; Bradshaw, A.D. 1966. Evolutionary divergence among adjacent plant populations. Heredity, 21: 407-441.

Johnson, H.E.; Schmidt, C.L. 1988. Clark Fork Basin Project: status report and action plan. Prepared for the Office of the Governor, Helena, MT.

Kershaw, L; MacKinnon, A; Pojar, J. 1998. Plants of the Rocky Mountains. Lone Pine Publishing. 384 p.

Manual de la Fuente, J.; Ramires-Redriguez, V.; Cabrera-Ponce, J.L.; Herrera-Estrella, L. 1997. Aluminum tolerance in transgenic plants by alteration of citrate synthesis. Science Magazine Vol. 276 June 6, 1997:1566-1568.

Montana Department of State Lands, Abandoned Mine Reclamation Bureau. 1994. 1994 Summary report. (December).

Montana Department of State Lands, Abandoned Mine Reclamation Bureau. 1995. 1995 Summary report.

Moore, J.N.; Luoma, S. N. 1990. Hazardous waste from large-scale metal extraction: The Clark Fork Waste Complex, Montana. Prepared by the University of Montana, Missoula, MT, and the U.S. Geological Survey. 34 p.

Morrey, D. 1996. Vegetation on Barren Mining Land. Land and Water: 41-44.

Munshower, F.F. 1994. Practical handbook of disturbed land revegetation. CRC Press, Inc. 265 p.

Neuman, D.R.; Munshower, F. F.; and Dollhopf, D. J. 1993. Revegetation of mining wastes in Montana. Montana AgReseach Vol.1, Issue 1: 3-7.

Reclamation Research Unit (RRU). 1993. Arts Phase I Report. Anaconda Revegetation Treatability Studies Phase I: Literature Review, Reclamation Assessments, And Demonstration Site Selection. 28 P. Document No.: Asss-Arts-I-Fr-R1-102293.

Roundy, B.A.; Shaw, N.L.; Booth, D.T. 1997. Lessons from historical rangeland revegetation for today's restoration:1-8. In Proceedings: Using Seeds of Native Species on Rangelands. Society of Range Management 50th Annual Meeting. U.S.D.A. Forest Service Intermountain Research Station. General Tech. Report INT-GTR-372.

Smith R. A. H.; Bradshaw, A. D. 1972. Stabilization of toxic mine wastes by the use of tolerant plant populations. Trans. Inst. Min. Metall. 81 (A): 230-237.

Surbrugg, J.E. 1982. Copper and zinc tolerance in two Montana grass species growing on copper mill tailings. Montana State University master's thesis.

Vatamaniuk, O.K.; Mari, S.; Lu, Y.; Rea, P. 1999. AtPCS1, phytochelatin synthase from *Arabidopsis*: isolation and *in vitro* reconstitution. In: Proceedings of the National Academy of Science, Vol. 96, June, 1999: 7110-7115.