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PLANT MATERIALS TECHNICAL NOTE

Seed Mixes for Acid and Heavy Metal Contaminated Sites in the Anaconda, Montana Area

Joe LeFebvre, Project Leader,
Integration of Selected Native Plant Materials for Enhanced Restoration Activities in the UCFRB
Jim Jacobs, Plant Materials Specialist, USDA-NRCS, Bozeman, Montana

Four-row Cone Seeder

Introduction

The development of appropriate seed mixes for the re-vegetation of disturbed sites is a critical and challenging step in the restoration and reclamation process. Species and seed source selection, and their relative proportions in the mix, are particularly important. Practical issues such as availability and cost cannot be overlooked, although long-term success must be considered in any cost analysis. Numerous combinations of species and seeding rates may prove successful, and vary with factors such as soil texture, aspect, slope, project goals, degree of disturbance, method of seeding, cost, and other factors. Although this Technical Note presents potential seed mixes for re-vegetating or restoring native plant communities on smelter-impacted sites in the Anaconda-Butte area of Montana, the goal of the publication is to also provide the reader with the basic decision-making tools when developing custom mixtures.

Mix formulations for the smelter-impacted sites are based in part on seed mixes developed at the USDA-NRCS Plant Materials Center near Bridger, Montana, as well as the experience and testing of others. These mixes were successfully established on lime-amended, acid/heavy metal contaminated soils on Stucky Ridge near Anaconda, Montana. Results of those mixture-testing studies are presented herein. The establishment and survival of some of the species used in the experimental mixes were collected from Anaconda Superfund site and also tested in monoculture studies on Stucky Ridge. The results show they were able to tolerate the acid and heavy metal conditions of the soil there. The results are summarized in Montana Plant Materials Technical Note, MT-97, *Acid and Heavy Metal Tolerant Plants for Restoring Plant Communities in the Upper*

Clark Fork River Basin (LeFebvre, 2014). That document should be used as a companion to this Technical Note when selecting appropriate species for developing seed mixes for this application. The recommended mixes and species contained herein do not constitute a comprehensive list of well-adapted materials, but are provided as examples.

I. Stucky Ridge Seed Mix Study

Plants able to survive in nutrient poor, acidic soil, contaminated with heavy metals such as copper, zinc, lead, cadmium, and arsenic, are thought to possess heritable genetic traits for tolerance to those conditions (Sainger et al., 2011). From this we assume the best plants for acid/heavy metal contaminated soils would be progeny from those found growing naturally at such sites. This was tested by comparing the establishment and persistence of seed mixtures composed of progeny from plant species found growing on the contaminated soils of Stucky Ridge with mixtures of commercially available seed of similar species. The hypothesis is; the progeny from Stucky Ridge seed will have greater establishment and persistence than the progeny from a commercial seed source when planted at Stucky Ridge.

In May 2003 the Stucky Ridge test plot was established to test four different seed mixtures for survival and establishment success. Stucky Ridge is located in Deer Lodge County two miles northeast of Anaconda, Montana. Quaking aspen, *Populus tremuloides*; Woods' rose, *Rosa woodsii*; currant, *Ribes* spp.; rabbitbrush, *Ericameria nauseosa*; redtop, *Agrostis gigantea*; and basin wildrye, *Leymus cinereus* were sparsely growing on the site. The average annual precipitation at the site ranges from 10 to 13 inches with most of the precipitation occurring in late spring to early summer. The average frost-free period is 90 to 105 days. The parent material is alluvium. The soil has a gravelly loam texture and is well drained. The slope at the plot site averages 5 to 10 percent. Prior to planting, 22 tons per acre of lime kiln dust was disked to a 6-inch depth in November 2002. In the spring of 2003, commercial fertilizer (12% N, 16% P_2O_5, 30% K_2O) was applied at a rate of 500 bulk pounds per acre and incorporated to 6 inches using a chisel plow.

Four seed mixtures were drill-seeded at 50 Pure Live Seeds (PLS) per linear row foot, at 14-inch row spacing in a randomized complete block design with four replications. Species for the seed mixes were chosen based on their predicted performance and potential ability to create a diverse plant community and formulated for two distinct applications. The “Upland” blends (see Tables 1 and 2) were designed for sloping areas with acid/heavy metal soil and generally low water infiltration, in order to provide site stabilization and wildlife habitat. The “Waste Management Area” (WMA) blends (see Tables 3 and 4) were designed to provide vegetative cover for areas with highly acidic soils and high heavy metal concentrations (native and non-native species). “Developed” seed mixes were formulations composed of commercially available cultivars (native and non-native, see Tables 2 and 4). “Experimental” mixes attempted to utilize local, native ecotypes of the same species used in the Developed mixes, when possible (see Tables 1 and 3). In a few cases, non-indigenous seed sources, and even one non-native (redtop) species, had to be utilized in the Experimental mix. Only three local, native seed source selections used in the WMA - Experimental mixes were available as cultivars or selections for the WMA - Developed mix. Seeding rates were based on Plant Materials Technical Note, MT-46 (Rev. 4), *Seeding Rates for Conservation Species for Montana* (Majerus et al., 2013).

I. Stucky Ridge Seed Mix Study (continued)

Table 1. Upland Areas – Experimental Seed Mix Formulation - Mix 1

Scientific Name	Common Name	Accession or Variety	Origin	% Mix PLS by Weight	Full Stand Seeding Rate *PLS lb./acre*
Grasses					
Achnatherum hymenoides	Indian ricegrass	9081629	Deer Lodge Co., MT	15.0	5.0
Elymus trachycaulus	slender wheatgrass	Copperhead	Deer Lodge Co., MT	15.0	7.0
Leymus cinereus	basin wildrye	Washoe	Deer Lodge Co., MT	15.0	7.0
Pascopyrum smithii	western wheatgrass	9081968	Deer Lodge Co., MT	5.0	10.0
Poa alpina	alpine bluegrass	9016273	Gallatin Co., MT	10.0	13.0
Poa secunda (*ampla*)	big bluegrass	Opportunity	Deer Lodge Co., MT	15.0	2.0
Pseudoroegneria spicata	bluebunch wheatgrass	9081636	Deer Lodge Co., MT	15.0	7.0
Forbs					
Symphyotrichum chilense	Pacific aster	9078675	Deer Lodge Co., MT	2.5	2.0
Penstemon eriantherus	fuzzytongue penstemon	Old Works	Deer Lodge Co., MT	5.0	3.0
Potentilla hippiana	woolly cinquefoil	9076274	Silverbow Co., MT	2.5	NA

Table 2. Upland Areas – Developed Seed Mix Formulation - Mix 2

Scientific Name	Common Name	Accession or Variety	Origin	% Mix PLS by Weight	Full Stand Seeding Rate *PLS lb./acre*
Grasses					
Achnatherum hymenoides	Indian ricegrass	'Nezpar'	White Bird, ID	5.0	5.0
Elymus lanceolatus	thickspike wheatgrass	'Critana'	Hill County, MT	15.0	7.0
Elymus trachycaulus	slender wheatgrass	'Revenue'	SK, Canada	15.0	7.0
Festuca ovina	sheep fescue	'Covar'	central Turkey	10.0	2.0
Leymus cinereus	basin wildrye	'Magnar'	SK, Canada	15.0	7.0
Pascopyrum smithii	western wheatgrass	'Rosana'	Rosebud Co., MT	10.0	10.0
Poa secunda (*ampla*)	big bluegrass	'Sherman'	Sherman Co., OR	14.5	2.0
Pseudoroegneria spicata	bluebunch wheatgrass	'Goldar'	Asotin Co., WA	10.0	7.0
Forbs					
Achillea millefolium	western yarrow	Great Northern	Flathead Co., MT	2.5	0.5
Artemisia frigida	fringed sagebrush	9082258	unknown	0.5	0.3
Linum lewisii	Lewis flax	'Appar'	Custer Co., SD	2.5	3.5

Table 3. Waste Management Areas - Experimental Seed Mix Formulation - Mix 3

Scientific Name	Common Name	Accession or Variety	Origin	% Mix PLS by Weight	Full Stand Seeding Rate *PLS lb./acre*
Grasses					
Agrostis gigantea	redtop	9076276	Deer Lodge Co., MT	15.0	0.5
Deschampsia cespitosa	tufted hairgrass	9076290	Silverbow Co., MT	10.0	0.8
Elymus trachycaulus	slender wheatgrass	9081620	Deer Lodge Co., MT	15.0	7.0
Leymus cinereus	basin wildrye	Washoe	Deer Lodge Co., MT	15.0	7.0
Pascopyrum smithii	western wheatgrass	9081968	Deer Lodge Co., MT	5.0	10.0
Poa secunda (*ampla*)	big bluegrass	9081633	Deer Lodge Co., MT	10.0	10.0
Hesperostipa comata	needle & thread grass	9078314	Deer Lodge Co., MT	10.0	9.0
Forbs					
Symphyotrichum chilense	Pacific aster	9078675	Deer Lodge Co., MT	10.0	2.0

Table 4. Waste Management Areas - Developed Seed Mix Formulation - Mix 4

Scientific Name	Common Name	Accession or Variety	Origin	% Mix PLS by Weight	Full Stand Seeding Rate *PLS lb./acre*
Grasses					
Thinopyrum intermedium	intermediate wheatgrass	'Greenar'	Former USSR	10.0	10.0
Bromus inermis	smooth brome	'Manchar'	Manchuria, China	15.0	8.0
Elymus lanceolatus	thickspike wheatgrass	'Critana'	Hill County, MT	10.0	7.0
Elymus trachycaulus	slender wheatgrass	'Revenue'	SK, Canada	15.0	7.0
Leymus cinereus	basin wildrye	'Magnar'	SK, Canada	15.0	7.0
Poa secunda (*ampla*)	big bluegrass	'Sherman'	Sherman Co., OR	10.0	2.0
Nassella viridula	green needlegrass	9082255	Washington	10.0	6.0
Forbs					
Medicago sativa	alfalfa	'Ladak'	Kashmir, India	15.0	5.0

II. Stucky Ridge Seed Mixture Evaluations

Establishment and survival were measured by counting seeded plant density from 10.76 ft^2 sample frames in June and August of 2003, by estimating the percent foliar cover of the seeded species, the relative vigor of species on a scale of 1 to 9, the height of the tallest plant, and biomass of seeded species clipped from a one square meter sample frame in each treatment plot in year 2004, 2005, 2006, and 2007 (see Addendum 1). Density data were analyzed using a split-plot in time analysis of variance model with density as the dependent variable, mixture as the whole-plot independent variable, and sample date as the sub-plot independent variable. Cover, vigor, height and biomass data were dependent variables in a split-plot in time analysis of variance model with mix as the whole-plot independent variable and year as the sub-plot independent variable.

III. Stucky Ridge Seed Mixture Trial Results

Table 5. Mean densities (plants per square foot) of mixes at two sampling dates during the establishment year at Stucky Ridge. A split plot in time analysis of variance model found no significant differences among seed mixtures or sampling dates (p>0.1).

Date	Upland Exp.	Upland Dev	WMA Exp.	WMA Dev
24 June 2003	10.3	14.9	10.0	16.8
26 August 2003	11.9	11.2	11.1	17.4

Seeded plant densities during the establishment year, 2003, are listed in Table 5. The analysis found no significant differences among mixes or between sampling dates (p>0.1) suggesting the experimental and development mixes established equally well at both sites and establishing plants survived the first year.

Table 6. Mean percentage foliar cover. When comparing means for statistical differences among columns and rows, different letters following the means indicate differences (Tukey HSD comparison test α=0.05).

Year	Upland Exp.	Upland Dev.	WMA Exp.	WMA Dev.
2004	61 AB	26 B	60 AB	28 B
2005	50 AB	36 AB	65 A	38 AB
2006	28 B	27 B	34 AB	26 B
2007	51 AB	43 AB	56 AB	65 A

The effect of the seed mixture treatment on plant foliar cover depended on the year sampled (P=0.0207). This interaction is mainly the result of the WMA Developed mix which had low cover in 2004 and 2006 (28% and 26%, respectively) and increased significantly to 65% in 2007 suggesting the cover resulting from this mix increased over time (see Table 6). However, there were no differences in cover among mixes in any year. The WMA Experimental mix had higher cover (65%) in 2005 than the other mixes in 2006, and the Upland Developed mix in 2004. Its cover was not significantly different than the cover resulting from other mixes in 2005 or its cover in other years (see Table 6). Averaged over all mixtures, cover was lower (p<0.0001) in 2006 (29%) than in 2004 (44%), 2005 (47%) and 2007 (54%). Averaged over all years, the WMA Experimental mix (54%) had greater cover (p=0.0366) than the Upland Developed mix (33%) but not the Upland Experimental mix (47%) or the WMA Experimental mix (40%).

Table 7. Mean vigor rating. A vigor rating of 1 is the highest rating and a vigor rating of 9 is the lowest rating. When comparing means for statistical differences among columns and rows, different letters following the means indicate differences (Tukey HSD comparison test α=0.05).

Year	Upland Exp.	Upland Dev.	WMA Exp.	WMA Dev.
2004	2.6 CD	4.3 ABCD	2.3 D	4.1 ABCD
2005	4.2 ABCD	4.4 ABC	3.8 ABCD	4.1 ABCD
2006	5.1 AB	4.4 ABC	5.3 AB	5.3 A
2007	3.6 ABCD	4.2 ABCD	3.3 BCD	3.4 ABCD

The effect of seed mixture treatment on plant vigor depended on the year sampled (p=0.0311). This is the result of the Experimental mixes having different ratings over time on both the Upland and WMA sites. In the Upland Experimental mix plots, plant vigor declined from a rating of 2.6 in 2004 to 5.1 in 2006, but vigor in both those years were not rated differently than the vigor in 2005 or 2007 (see Table 7). In the WMA Experimental mix plots, plant vigor declined from 2.3 in 2004 to 5.3 in 2006, but was not different than vigor in 2005 or 2007 (see Table 7). Estimated plant vigor did not differ statistically among seed mixes in each year. Averaged over all years, the WMA Experimental mix (3.6) had greater (p=0.0366) vigor than the Upland Developed mix (4.3) but not the Upland Experimental mix (3.9) or the WMA Developed mix (4.2). Averaged over all mixtures, vigor ratings were highest (p<0.0001) in 2004 (3.3), followed by 2007 (3.6) and 2005 (4.1) and lowest in 2006 (5.0).

Table 8. Mean plant height in inches. There is no seed mix by year interaction (p>0.1) thus no statistical comparisons are presented on the table.

Year	Upland Exp.	Upland Dev.	WMA Exp.	WMA Dev.
2004	31.1	18.5	32.7	22.5
2005	29.6	22.9	29.9	28.4
2006	26.8	28.0	26.4	26.8
2007	28.4	21.7	29.2	28.8

Mean plant heights of the tallest plant by mixture and year are presented in Table 8. The mixture treatment did not interact with year (p=0.1169), nor did heights averaged over the four mixtures change over the four years of sampling (p>0.1). However, the tallest plant height was affected by the mixture seeded (p=0.0022). Averaged over all years, the tallest plants in the Upland Experimental seed mix plots reached 28.9 inches tall and were taller than the tallest plants in the Upland Developed mix which were 22.7 inches tall. The tallest plants in the WMA Experimental mix were 29.6 inches tall, they were also taller than the tallest plants in the Upland Developed mix, but were not significantly taller than the tallest plants in the WMA Developed mix (26.8 inches).

Table 9. Mean plant biomass (pounds/acre). When comparing means for statistical differences among columns and rows, different letters following the means indicate (Tukey HSD comparison test α=0.05).

Year	Upland Exp.	Upland Dev.	WMA Exp.	WMA Dev.
2004	5,303.5 AB	1,795.8 BC	7,978.1 A	4,013.1 ABC
2005	1,220.7 C	1,592.2 BC	3,666.7 BC	2,956.7 BC
2006	968.0 C	1,503.8 BC	1,582.4 BC	1,240.4 BC
2007	1,195.7 C	1,469.0 BC	1,811.0 BC	1,746.7 BC

The effect of seed mixture on biomass produced was dependent on the year sampled (p=0.0177). In 2004, the WMA Experimental mix had greater biomass than the Upland Developed mix (see Table 9). Mixtures did not differ in biomass in other years. Biomass in the Experimental mix on the Upland site declined from 2004 to 2005, 2006 and 2007 (see Table 9). The Experimental mix on the WMA site declined from 2004 to subsequent years also (see Table 9). Averaged over all years, the biomass sampled from the WMA Experimental mix plots (3,759.5 pounds/acre) was greater (p=0.0135) than biomass sampled from the Upland Developed mix plots (1,590.4 pounds/acre), but neither of these biomasses were different than biomass sampled from the Upland Experimental (2,171.8 pounds/acre) or WMA Developed mix plots (2,489.2 pounds/acre). Averaged over all mixtures, biomass declined (p<0.0001) from 2004 (4,772.2 pounds/acre) to 2005 (2,359.3 pounds/acre), 2006 (1,323.4 pounds/acre), and 2007 (1,555.6 pounds/acre).

Biomass may have been strongly influenced by one or two species in each mix. The Experimental mixes were dominated by Copperhead slender wheatgrass, while the Developed mixes were dominated by 'Revenue' slender wheatgrass and 'Critana' thickspike wheatgrass.

The analysis of the Stucky Ridge study provides little support for the assumption that progeny of locally collected plants establish and survive better on the remediated site conditions than progeny of plants developed through standard plant materials selection and testing for cultivar development. Initial establishment densities in 2003 did not differ between the Experimental and Developed mixes at either the Upland or WMA sites (see Table 5). Cover, vigor, height, and biomass in subsequent years also did not differ between mixtures when compared by site or year (see Tables 6, 7, 8 and 9). It is possible soil remediation may have reduced any advantage locally collected plant materials may have had in establishment and survival. Additionally, plants developed through the testing and selection process of cultivar development may be adapted to a wide range of soil conditions including acid and heavy metal soil extremes.

The greater biomass production of the WMA Experimental mix on the WMA site compared to the WMA Developed mix (see Table 9) provides some support for the local adaptation assumption, but these mixtures where designed for, and applied to different site conditions and therefore is not a good comparison. Cover, vigor, and biomass results (WMA Experimental mix was greater than Upland Developed mix) when averaged over all years provides similar support. The height results when averaged over all years provides the strongest support for the assumption under the Upland site conditions where plants in the Upland Experimental plots were taller than plants in the Upland Developed mix.

The remainder of this technical note is a step-by-step guide dedicated to explaining the seed mix development process in a manner that allows custom design of seed mixes.

IV. Seed Mix Design Process

A. Species Selection

Species selection is often the biggest challenge when developing a seeding mix. For this project, mixtures were constructed of species and rates based on NRCS Plant Materials Program protocols for establishing various vegetative conservation practices (Majerus et al., 2013, NRCS 2013). Species selected for the mixes tested on Stucky Ridge were chosen based on the species proven or anticipated functional performance in a plant community and compatibility with other species in the mix. A typical herbaceous conservation mix often includes one grass species known for rapid establishment, one rhizomatous grass species for site stabilization, other grasses for diversity and as structural components, one or more wildflowers (forbs) for diversity and as a source of pollinator and beneficial insect habitat, and one or more woody plants for vertical strata and wildlife habitat.

Recommended mixes may vary if the restoration site is high versus low elevation, northerly versus southerly exposure, or if soils or climatic conditions vary widely over the target site. Mixes also vary with the intended purpose of the conservation planting, the method of seeding, and the severity of the site disturbance.

The success of re-establishment of a vegetative community on a severely disturbed site is dependent on many factors. Seeding a disturbed site with a mix of seeds from several different species is valuable for the following reasons:

1. Ecosystem stability depends in part on the degree of diversity among plants inhabiting the area. There is a direct relationship between ecosystem stability and plant diversity. More diverse communities establish faster, require fewer nutrients, provide better soil cover, and grow more vigorously. More diverse communities are also better able to resist weed invasion, prevent erosion and tolerate drought and disease, resulting in lower maintenance requirements for that site.

A. Species Selection (continued)

Sowing a mix of seeds increases the plant diversity and, therefore, can result in an increase the stability of the ecosystem.

2. When erosion control is a primary goal of the re-seeding, a rapidly establishing species is an important component of the seed mix. Such species typically establish quickly the first year and then fade over time. Their function in mixes includes rapid soil stabilization, shade, wind protection, and moisture and nutrient retention until slower growing native species can establish and mature. Species such as slender wheatgrass, *Elymus trachycaulus* and cereal grains (for temporary cover) are rapid establishing.

3. In severely impacted areas, such as land in close proximity to the Anaconda smelter, species or selections with demonstrated tolerance to acid and heavy metal laden soils, and capable of re-seeding, are necessary in the seed mix. As previously noted, a description of these species appears in Montana Plant Materials Technical Note, MT-97, *Acid and Heavy Metal Tolerant Plants for Restoring Plant Communities in the Upper Clark Fork River Basin*.

4. Species that are drought tolerant, winter hardy, heavy root producers, and/or have excellent seedling vigor (such as thickspike wheatgrass, *Elymus lanceolatus*) are well suited for seed mixes on severely impacted mined sites. Re-establishing a vegetative cover on severely disrupted sites requires plant species capable of tolerating numerous severe growing conditions.

5. The ability to withstand grazing or browsing pressures from cattle or wildlife is important to the long-term productivity of the reclaimed site. Palatable species capable of recovering well following animal utilization (such as western wheatgrass, *Pascopyrum smithii*) should be a part of the seed mix.

6. Species providing cover for wildlife are important. The interactions between wildlife and the plant communities they live in are important to the stability of the area. Including species that are important food sources for pollinators and other wildlife ensures species diversity, and therefore improves the likelihood of restoration success. Seed mixes should include tall stature species providing wildlife cover (such as basin wildrye, *Leymus cinereus*), as well as food and habitat for pollinators (such as silverleaf phacelia, *Phacelia hastata*). Reference Addendum 2, "Important Characteristics of Plants in A Mine Reclamation Seed Mix", for a summary of the characteristics exhibited by the plants in the tested seed mixes.

Potential species for inclusion in mixes are often generated from NRCS soils surveys, Ecological Site Descriptions, local botanical surveys, and other sources. Use Montana Plant Materials Technical Note, MT-97, *Acid and Heavy Metal Tolerant Plants for Restoring Plant Communities in the Upper Clark Fork River Basin* (LeFebvre, 2014) for descriptions of well-adapted species and selections.

Additional considerations when developing a seed mix include commercial availability and cost, problems incurred when combining highly competitive and non-competitive species, and species compatibility. Seed cost is an important consideration on large-scale reclamation projects and, in some cases; it may be possible to substitute less expensive species. That said, management objectives, species function, and long-term success should always be the determining factors in species selection. Aggressive species may dominate and crowd out other species in a mix and should be used sparingly or replaced with a similar functioning, but less aggressive option. In addition to competitiveness, other plant attributes such as seed size and shape, speed of seedling emergence, plant stature, tolerance to site conditions such as soil pH or salinity, may also affect compatibility and should be considered.

B. Seeding Rates

All suggested seeding rates should be calculated on a Pure Live Seed (PLS) basis. The value takes into account seed lot impurities such as inert material, other crops seeds, weed seeds, and the germination (viability) of the lot. The result is a calculation based on actual live seeds put in the ground. Seeding rates, the amount of live seed planted per unit area, are based on Montana Plant Materials Technical Note, MT-46 (Rev. 4), *Seeding Rates for Conservation Species for Montana,* (Majerus et al., 2013), which recommends the number of PLS pounds of seed to plant per acre in order to obtain a full (solid or single species) stand of that species when sown with a drill planter. Individual species seeding rates are therefore adjusted downward in seeding mixtures, since seldom is one species used to create a solid stand. Rates of seeding of each species are based on their relative percentage in the mix.

Table 10 illustrates seeding rate calculations when drill seeding a mix on a good site with 12-inch row spacing. The species listed in the table are provided primarily for demonstration purposes. The table and procedures described may be used to calculate the seeding rates for other appropriate species, as long as the columns in the tables are adjusted for the recommended percentage of each species in the mix, and the drilled full stand seeding rate in PLS pounds per acre for each species is selected. Reference the Montana Plant Materials Technical Note, MT-46 (Rev. 4), *Seeding Rates for Conservation Species for Montana* (Majerus et al., 2013) for that information.

The following explanations describe how to calculate the values in each of the columns in Table 10 below. Follow along on the table with the explanation for each column. A more detailed explanation of planting practices to improve seeding success can be found in the Montana Plant Materials Technical Note, MT-46 (Rev. 4), *Seeding Rates for Conservation Species for Montana* (Majerus et al., 2013).

Table 10. Seeding Rates for Conservation Plant Species When Drill Seeding A Mix on A Good Site.

1 **Species**	2 **Preferred Selection**	3 **Alternative Selection**	4 **Function**	5 **Recommended Percentage in Mix** *(decimal)*	6 **PLS Seeds per Pound** *PLS/lb.*	7 **Drilled Full Stand Seeding Rate** *PLS lb./acre*	8 **Drilled Mix Good Site Seeding Rate** *PLS lb./acre*	9 **Mix Resultant PLS Seeds Per Square Foot** *PLS/ft²*
slender wheatgrass	Copperhead	Pryor	rapid establishment	0.2	140,000	7.0	1.4	4.5
Nevada Sandberg bluegrass	Opportunity	local ecotypes	cover, longevity	0.2	1,029,000	2.0	0.4	9.4
basin wildrye	Washoe	Trailhead	vertical height, cover	0.2	144,000	7.0	1.4	4.6
Indian ricegrass	Rimrock	local ecotypes	diversity, wildlife food	0.1	235,000	5.0	0.5	2.7
fuzzy-tongue penstemon	Old Works	local ecotypes	diversity, pollinator	0.1	358,000	3.0	0.3	2.5
yarrow	Great Northern	local ecotypes	diversity, pollinator	0.1	2,850,000	0.5	0.05	3.3
winterfat	Open Range	local ecotypes	winter forage	0.1	93,000	3.0	0.3	0.6
			Totals:	**1.0**	**NA**	**NA**	**4.4**	**27.6**

B. Seeding Rates (continued)

Species listed in column 1 should be chosen based on their proven ability to work well in the intended conservation practice in Montana and Wyoming. Seed of each species must be commercially available, cost-effective, and able to be direct seeded. Certified seed is always recommended and preferred (Scianna et al., 2011).

The Preferred Selection (see column 2) is usually a selection that has been tested in the local ecosystem or environment and has proven to establish well under those specific conditions. Preferred selection status is often based on choosing seed sources whose origin was in the closest proximity to the intended planting site.

The Alternative Selection (see column 3) usually consists of selections made from parent plants found growing outside the local area, but have proven to establish and grow well under the intended conditions and environment.

For more information on appropriate selections and seed sources, see Montana Plant Materials Technical Note, MT-67, *Seed Source Selection, Use of Certified Seed, and Appropriate Seed Release Class Improve Conservation Planting Success* (Scianna et al., 2011), and Montana Plant Materials Technical Note, MT-69, *Standard and Preferred Forage and Reclamation Plants for Use in Montana and Wyoming* (Hybner et al., 2011).

Column 4 indicates the function each species performs when it is included in a seed mix. As explained previously, the best seed mix will have a combination of species that together will perform most of the functions described in the table.

The next step is to determine the percentage of each species to use in the mixture (see column 5). This decision is based on several factors, including species function, competitiveness, speed of establishment, as well as the experience and expertise of the restorationist.

The only time the mix would consist of 100% of an individual species would be if a pure stand of a single species was desired. The recommended planting rate of each species should reflect its specific percentage in the total mixture. Other plants within the mix will make up the remaining percentage of the mixture (100% total). The final percentage used for each species is based on the conservation objective of the planting (e.g., wildlife versus erosion control). Adjust the percentage used for each species, with the greatest percentage of the mix consisting of the species that best meet your management objective.

The values in column 6 have been calculated from the average of numerous seed lots of the species and its selections, and are provided in Plant Materials Technical Note MT-46 (Rev.4), *Seeding Rates for Conservation Species for Montana* (Majerus et al., 2013).

The number of Pure Live Seed (PLS) pounds per acre (see column 7) recommended for each species are based on planting a desired number of target seeds per linear foot or square foot, depending on whether the seed is drilled in rows (linear) or broadcast (area). The standard rule of thumb is to sow 20 to 30 PLS seeds per linear or square foot for most plantings; although this number varies with seed size (number of seeds per pound), seedling vigor, type of seeding equipment, and conservation practice. It is important to note the recommended number of PLS pounds per acre for a full drill seeding are based on 12-inch row spacing, and must be adjusted when the row spacing is greater than 12 inches. The target-seeding rate per foot (based primarily on seed size) is listed in Table 11. Small seeds are seeded at higher rates because they generally have less carbohydrate reserves and perish more easily than large seeds, and have a greater potential to be planted too deep. Large-seeded plants often produce larger, more competitive seedlings that tend to survive well. The seeds from large-stature plants can be difficult to sow in high numbers because of their large size.

B. Seeding Rates (continued)

Table 11. Target Number of Seeds per Foot Based on Seed Size

Seed Size Class	Number of PLS per Pound	Target Number of PLS per Foot
small	>800,000	30 to 50
medium	80,000 to 800,000	20 to 25
large	<80,000	15 to 20

The values in column 8 (see Table 10) were simply calculated by multiplying the Drilled Full Stand Seeding Rate PLS value (see column 7) times the Recommended Percentage in Mix value (see column 5). This value represents how many PLS pounds per acre of each species are needed for the seeding mixture when using a drill and planting on a “good” site. Unfortunately, most sites in the Butte-Anaconda area do not qualify as “good”. Column 9 lists how many seeds of each species will be sown per square foot at the recommended rate and percentages specified in the mix. It is calculated by multiplying the number of PLS seeds per pound value (see column 6) times the Drilled Good Site Mix Seeding Rate PLS value (see column 8), and then dividing the product by 43,560 (the number of square feet in an acre).

The recommended seeding rate also varies with the planting method. The seeding rate when broadcasting is twice the drilled seeding rate. The seeding rate can also vary with the type of conservation practice. For broadcast or hydro-seeded Critical Area Plantings, the seeding rate is up to twice the recommended rate for broadcast seeding on a good site, and up to 4 times the rate of drill seeding on a good site.

B. Seeding Rates (continued)

Table 12 demonstrates seeding rate calculations when drill seeding a mix in a critical area, whereas Table 13 demonstrates seeding rate calculations when broadcast seeding a mix in a critical area. In Table 12, to calculate the seeding rate for a drill planted, critical area (see column 8), multiply the Recommended Percentage in Mix value (see column 5) times the Drilled Full Stand Seeding Rate PLS value (see column 7), and then multiply the product by 2.

Table 12. Seeding Rates for Conservation Plant Species When Drill Seeding A Mix in A Critical Area

1 **Species**	2 **Preferred Selection**	3 **Alternative Selection**	4 **Function**	5 **Recommended Percentage in Mix** *(decimal)*	6 **PLS Seeds per Pound** *PLS/lb.*	7 **Drilled Full Stand Seeding Rate** *PLS lb./acre*	8 **Drilled Critical Area Mix Seeding Rate** *PLS lb./acre*	9 **Mix Resultant PLS Seeds Per Square Foot** *PLS/ft^2*
slender wheatgrass	Copperhead	Pryor	rapid establishment	0.2	140,000	7.0	2.8	9.0
Nevada Sandberg bluegrass	Opportunity	other local ecotypes	cover, longevity	0.2	1,029,000	2.0	0.8	18.9
basin wildrye	Washoe	Trailhead	vertical height, cover	0.2	144,000	7.0	2.8	9.3
Indian ricegrass	Rimrock	local ecotypes	diversity, wildlife food	0.1	235,000	5.0	1.0	5.4
fuzzy-tongue penstemon	Old Works	other local ecotypes	diversity, pollinator	0.1	358,000	3.0	0.6	4.9
yarrow	Great Northern	local ecotypes	diversity, pollinator	0.1	2,850,000	0.5	0.1	6.5
winterfat	Open Range	local ecotypes	winter forage	0.1	93,000	3.0	0.6	1.3
			Totals:	**1**	**NA**	**NA**	**8.7**	**55.3**

B. Seeding Rates (continued)

To calculate the seeding rate (see Table 13) for a broadcast planted, critical area (see column 8), multiply the Recommended Percentage in Mix value (see column 5) times the Drilled Full Stand Seeding Rate PLS value (see column 7), and then multiplying the product by 4.

Table 13. Seeding Rates for Conservation Plant Species When Broadcast Seeding a Mix in a Critical Area

1 Species	2 Preferred Selection	3 Alternative Selection	4 Function	5 Recommended Percentage in Mix *(decimal)*	6 PLS Seeds per Pound *PLS/lb.*	7 Drilled Full Stand Seeding Rate *PLS lb./acre*	8 Broadcast Critical Area Mix Seeding Rate *PLS lb./acre*	9 Mix Resultant PLS Seeds Per Square Foot *PLS/ft²*
slender wheatgrass	Copperhead	Pryor	rapid establishment	0.2	140,000	7.0	5.6	18.0
Sandberg bluegrass	Opportunity	other local ecotypes	cover, longevity	0.2	1,029,000	2.0	1.6	37.8
basin wildrye	Washoe	Trailhead	vertical height, cover	0.2	144,000	7.0	5.6	18.5
Indian ricegrass	Rimrock	local ecotypes	diversity, wildlife food	0.1	235,000	5.0	2.0	10.8
fuzzy-tongue penstemon	Old Works	other local ecotypes	diversity, pollinator	0.1	358,000	3.0	1.2	9.9
yarrow	Great Northern	local ecotypes	diversity, pollinator	0.1	2,850,000	0.5	0.2	13.1
winterfat	Open Range	local ecotypes	winter forage	0.1	93,000	3.0	1.2	2.6
			Totals:	**1**	**NA**	**NA**	**17.4**	**110.7**

Summary

Other seed mixes have been developed for reclamation of the Anaconda Superfund Site. Richard Prodgers, Bighorn Environmental Sciences, developed eight seed mixes for the Natural Resources Damage Program, and Warren Keammerer, Ecological Consultants, Inc., developed a seed mix for ARCO. The mixes were very similar in their basic species composition to each other and to the Bridger Plant Materials Center mixes.

Each of the seed mixes was evaluated on whether it contained the essential components of a good seed mix. The essential components of a seed mix, as discussed earlier, include rapid rate of establishment, longevity, at least one rhizomatous grass, drought tolerance, acid tolerance, and provides food and cover for wildlife, including pollinators.

The component missing most often from the NRDP and ARCO mixes was the inclusion of a forb or shrub species to serve as a food source for pollinators. The mixes also differed in the rate at which the seed was applied, the percentage composition of each of the species in the mix, and the percentage composition of seed originating from local sources.

The mixes developed by the Bridger Plant Materials Center differed from the mixes developed by the others by including species grown from seed that originated at the Anaconda Superfund site.

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Addendum 1. Comparative Evaluation Planting − Stucky Ridge / Moto-X Replicated Mixture Trial

	6/03	8/03	6/04	9/04	8/05	8/06	8/07	2004	2005	2006	2007	2004	2005	2006	2007
Species	**Density** *No./ft²*	**Density** *No./ft²*	**Stand** *%*	**Stand** *%*	**Stand** *%*	**Stand** *%*	**Stand** *%*	**Height** *in*	**Height** *in*	**Height** *in*	**Height** *in*	**Biomass** *lb./acre*	**Biomass** *lb/acre*	**Biomass** *lb/acre*	**Biomass** *lb/acre*
Upland Experimental	6.4	7.4	39.4	45.9	60.6	49.7	27.8	18.1	31.1	29.7	26.8	705.5	5,303.5	1,220.7	967.4
Upland Developed	9.3	7.0	17.3	24.4	25.9	35.9	27.2	5.8	18.6	22.7	27.8	192.0	1,795.8	1,592.2	1,503.2
Waste Mgmt. Area Experimental	6.3	6.9	38.1	46.9	59.7	65.0	34.1	17.7	32.5	30.1	26.4	1,077.0	7,977.2	3,666.7	1,582.6
Waste Mgmt. Area Developed	10.5	8.0	15.0	23.8	28.4	38.1	26.3	7.8	22.3	28.5	26.8	273.3	4,013.1	2,956.7	1,240.3

Addendum 2. Important Characteristics of Plants in a Mine Reclamation Seed Mix

Grasses	Seedling Vigor	Rate of Establishment	Cover Longevity	Drought Tolerance	Soil Texture Requirement Coarse, Fine, Medium	pH Min / Max	Salinity Tolerance	Pollinator Food Source	Wildlife Food Source	Winter Forage	Regrowth Rate	Height Wildlife Cover
Achnatherum hymenoides Indian ricegrass	medium	moderate	medium	high	C, M	6.6 - 8.6	low	N/A	high	high	moderate	high
Agrostis gigantea redtop	high	rapid	medium	low	F, M	4.5 - 8.0	low	N/A	high	high	moderate	high
Bromus inermis smooth brome	high	rapid	high	medium	F, M	5.5 - 8.0	medium	N/A	high	high	slow	low
Deschampsia cespitosa tufted hairgrass	low	slow	high	low	C, F, M	3.5 - 7.5	low	N/A	high	high	slow	low
Elymus lanceolatus thickspike wheatgrass	medium	moderate	high	high	C, F, M	6.0 - 9.5	medium	N/A	high	low	moderate	high
Elymus trachycaulus slender wheatgrass (Copperhead)	high	rapid	low	high	F, M	5.6 - 9.0	medium	N/A	high	medium	moderate	high
Festuca ovina sheep fescue	low	moderate	high	high	C, M	5.5 - 7.5	low	N/A	medium	high	moderate	low
Hesperostipa comata needle & thread grass	low	rapid	high	high	C, M	6.6 - 8.4	none	N/A	high	high	slow	low
Leymus cinereus basin wildrye (Washoe)	medium	moderate	high	high	C, F, M	5.6 - 9.0	high	N/A	high	medium	moderate	high
Nassella viridula green needlegrass	high	slow	medium	low	F, M	6.6 - 8.4	medium	N/A	medium	high	moderate	high
Pascopyrum smithii western wheatgrass	medium	moderate	high	high	F, M	4.5 - 9.0	high	N/A	medium	medium	moderate	high
Poa alpina alpine bluegrass	high	moderate	high	medium	C	5.0 - 7.2	none	N/A	medium	high	slow	low
Poa secunda (ampla) Sandberg bluegrass (Opportunity)	low	moderate	high	medium	C, M	6.0 - 8.0	low	N/A	medium	medium	slow	high
Pseudoroegneria spicata bluebunch wheatgrass	high	moderate	high	high	C, F, M	6.6 - 8.4	low	mid season	high	high	moderate	high
Thinopyrum intermedium intermediate wheatgrass	high	rapid	low	medium	C, F, M	5.6 - 8.4	low	N/A	high	medium	slow	high

Addendum 2. Important Characteristics of Plants in a Mine Reclamation Seed Mix (continued)

Forbs	Seedling Vigor	Rate of Establishment	Cover Longevity	Drought Tolerance	Soil Texture Requirement Coarse, Fine, Medium	pH Min / Max	Salinity Tolerance	Pollinator Food Source	Wildlife Food Source	Winter Forage	Regrowth Rate	Height Wildlife Cover
Achillea millefolium western yarrow	low	moderate	medium	medium	C, M	6.0 - 8.0	low	early season	low	high	moderate	high
Artemisia frigida fringed sagebrush	high	rapid	medium	high	C, F, M	7.0 - 9.0	medium	late season	high	fair	slow	high
Aster chilensis Pacific aster	low	slow	medium	medium	F, M	5.9 - 8.0	high	high	low	high	slow	low
Linum lewisii Lewis flax	high	moderate	high	medium	C, M	5.6 - 8.4	low	mid season	medium	high	slow	medium
Medicago sativa alfalfa	medium	rapid	medium	high	F, M	6.0 - 8.5	medium	all season	high	low	rapid	low
Penstemon eriantherus fuzzytongue penstemon (Old Works)	low	slow	medium	high	C, F, M	4.5 - 8.3	low	early/mid season	high	low	moderate	low
Potentilla hippiana woolly cinquefoil	low	moderate	high	medium	C, F, M	6.4 - 7.0	medium	all season	low	low	slow	low
Phacelia hastata silverleaf phacelia	medium	moderate	high	high	C, M	6.1 - 7.3	none	mid season	low	low	slow	low
Shrubs												
Juniperus horizontalis horizontal juniper	low	moderate	high	low	M	5.5 - 7.8	none	N/A	low	low	slow	high
Krascheninnikovia lanata winter fat	high	moderate	high	high	C, F, M	6.6 - 8.5	high	early season	high	high	moderate	high
Rosa woodsii Woods' rose	medium	moderate	high	medium	C, M	5.0 - 8.0	low	mid season	medium	low	slow	high
Shepherdia argentea silver buffaloberry (Mill Creek)	medium	moderate	high	medium	C, M	5.3 - 8.0	high	early/mid season	medium	low	slow	high
Symphoricarpos albus common snowberry (Prospectors)	medium	slow	high	medium	C, F, M	6.0 - 7.8	medium	mid season	high	high	slow	high