Final Report
Evaluation of Containerized Legumes and Forbs As Potential Revegetation Species for Molycorp Overburden Piles– 1995 Trial of Commercially Available and Molycorp Germplasm

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By
David R. Dreesen
New Mexico Plant Materials Center
U.S. Department of Agriculture
Natural Resources Conservation Service
1036 Miller St. SW
Los Lunas, NM 87031

Executive Summary:

The objective of this experimental planting in 1995 was to evaluate 27 legume and 3 forb species to determine which species exhibit superior survival and growth on overburden to enable cost effective large-scale reclamation. At this site, superior species must be adapted to south aspects, steep slopes, and rocky substrates that are the predominant site conditions encountered on the overburden piles. Site factors evaluated included 2 planting sites and 3 blocks per site representing a variety of overburden types differentiated by particle size distribution, ripping depth, overburden chemistry, and rock type.

Results indicate that the native herbaceous legumes in the *Petalostemum* genus would probably be better suited for more xeric situations based on their better performance at the Spring Gulch site. *Thermopsis montanus* and *Thermopsis rhombifolia* seem to hold some promise for persistence and spreading by rhizomes. Although *Hedysarum boreale* had relatively poor survival, the vigor of the few plants that survived would make it a reasonable selection to include in a legume species mix. Two species with relatively good early performance but only poor to fair later performance, *Dalea aurea* and *Astragalus missouriensis*, could only be recommended under the presumption that they could set and disseminate viable seed before their demise. The native woody legume *Amorpha fruticosa* showed good overall performance except for flowering and seedhead production. Still unresolved is the long-term performance of *Amorpha fruticosa* because the Molycorp environment is outside its typical area of adaptation (i.e., lower elevation and riparian). *Robinia neomexicana* tested in early trials exhibited excellent growth and vigor but highly variable survival (Dreesen 2001). Thus, *Robinia neomexicana* would be the better woody legume to include in a revegetation species mix. The other woody species tested can not be recommended; *Amorpha canescens* and *Caragana arborescens* for their poor vigor and growth and *Robinia fertilis* for its poor survival. The forb species *Penstemon barbatus* and *Solidago sp.* would be recommended; however, this *Penstemon* may behave more like a “short-lived” species with a decline in vigor and survival after several years. The introduced herbaceous legume *Astragalus cicer* had good performance at both sites and would be recommended for inclusion in revegetation specifications if exotic species are deemed appropriate. *Medicago sativa* appears to be another worthwhile exotic species on more mesic sites like the Blind Gulch site.

Objective:

The objective of this experimental planting was to evaluate legumes and forbs for their potential to survive and grow when planted as containerized transplants directly into overburden. The 3 forb (herbaceous) species (*Asclepias sp.*, *Solidago sp.*, and *Penstemon barbatus*) were grown from seed collected in the vicinity of the Molycorp mine. Of the 27 legume species tested, 23 are commercially available. Four of the legume species were woody shrubs with the remainder being herbaceous. The majority of the species are native to the western U.S.; 5 entries are introduced species. Factors evaluated included 2 planting sites and 3 blocks per site; these blocks represented a variety of overburden types distinguished by differences in particle size distribution, ripping depth, overburden chemistry, and rock type. No fertilizer was applied to the legume seedlings at planting or later to assess nitrogen fixation potential. The forb species received a controlled release fertilizer application at planting as well as broadcast fertilizer in subsequent years.

Introduction and Application:

The Molycorp open pit molybdenum mine near Questa, NM operated an open pit from 1965 to 1983 that required the removal of 300 million metric tons of overburden. The overburden piles are situated at elevations from 8,000 to 9,800 ft with surrounding vegetation of ponderosa pine, mixed conifer, and mountain shrub communities. Southerly aspects and steep slopes are the predominant natural site features and overburden pile characteristics. The overburden piles

consist of mixed volcanic rocks (rhyolitic and andesitic types sometimes referred to as acid rock) as well as black andesite and aplite intrusives (referred to as neutral rock) (Steffen, Robertson, and Kirsten, Inc. 1995). The mixed volcanic rocks are highly fractured and weathered typically with low pH and high salinity from pyrite oxidation. The mixing of rock types during overburden pile construction has resulted in heterogeneous substrates with a range of pH and soluble salt levels.

Several herbaceous and suffretescent species have invaded the mine overburden piles and road cuts (*Eriogonum sp., Artemisia frigida, Penstemon sp*., and *Solidago sp.*) and many herbaceous species are components of the surrounding mountain shrub community and mixed conifer forest. No native legume species have invaded overburden areas; however, yellow sweet clover (*Melilotus officinalis*) has established on spots where lowland topsoil has been brought in and placed on the overburden. The surrounding natural plant communities contain a paucity of legume species. An occasional *Lupinus sp*. has been observed. A woody legume, *Robinia neomexicana*, was installed in earlier species trials and was one of the few species that showed good vigor without nutrient additions. This lack of nitrogen in the overburden materials is assumed from the results of earlier studies which showed the general poor growth of transplants that did not receive nutrient additions at planting (Dreesen 2001). The establishment of legumes capable of nitrogen fixation through symbiosis with *Rhizobium sp.* would provide a natural mechanism for introducing nitrogen into the nutrient cycle of revegetated plant communities on the overburden. The poor germination of seed broadcast or incorporated into overburden suggests that species trials established from seed are not suitable for this site. Therefore, containerized transplants were used to establish the species evaluation plots to determine which species and ecotypes have superior survival and growth characteristics sufficient to justify their use in cost effective large scale reclamation efforts.

Methods:

The planting took place on August 8, 1995 at 2 sites (Blind Gulch 9300 ft. and Spring Gulch 9000 ft.) on the flat top of overburden deposits. The Blind Gulch overburden surface materials are a heterogeneous mix of acidic mixed volcanic rock and neutral aplite and black andesite. One of the row plots was situated where approximately one-half of the surficial material was low pH overburden. The other two plots were primarily neutral rock. The Spring Gulch plots were all situated on neutral rock. The Blind Gulch site is more mesic due to greater precipitation (higher elevation and orographic influences) as well as generally having overburden with a higher proportion of fines. The ripped rows were watered immediately before and after planting. The rows were watered before planting to prevent the collapse of the dibbled holes. Dibbles specifically designed for Ray Leach Super Cell containers (10 cubic inch) were used. Planting holes were placed approximately 8 to 12 inches apart in the ripped row. The species plots were installed in random order in each row, except the 3 forb species which were planted at the end of the row to isolate the effect of the fertilizer application. The fertilizer application for the forbs involved the placement of one heaping teaspoon (~6 g) of Sierra 17-6-12 controlled release fertilizer with minor nutrients (3-4 month release at 70^{o}F) in each planting hole. On July 23, 1996, approximately 6 g of slow release fertilizer was top-dressed on each forb plant using an EZ Feeder Chemical Applicator. The fertilizer applied to the forbs in 1996 and 1997 was Scotts 17-17-17, a polymer encapsulated sulfur-coated urea with ammoniated phosphate and potassium chloride (6.5% ammonium N, 10.5% urea N, and 4% free sulfur). On July 31,1997, Scotts 17-17-17 was hand scattered on each forb plot. On July 29, 1998, July 7, 1999, and August 1, 2000, a fertilizer blend with an average composition of 23-14-10 was hand scattered on each forb plot. This fertilizer was a mix of 50% Scotts Turf Starter (16-25-12) and 50% Scotts Turf Fertilizer Plus 2% Iron (30-3-9).

In late April 1997, 3 superior plants of *Pentemon barbatus* were dug from these plots to establish seed stock plants. The analysis of survival data in this report assumes that these 3 plants would have survived until the year 2000 because of their superior size at the time of harvesting. In August 1996, August 1997, and August 1998 the vigor, survival, and presence of seedheads were recorded. The vigor ratings based on visual comparisons were scaled as follows: 4 = excellent, 3 = good, 2 = fair, 1 = poor, and 0 = dead. In 1997 the maximum height and crown width of the largest plant in each row plot was also estimated. In August 2000, the number of live plants, individual heights, and individual crown widths were recorded. The height and width were estimated by observation.

The species included in the 1995 planting are listed in Table 1 along with the origin, seed source, number of row plots, and number of seedlings per row plot.

Table 1. Species tested at Blind Gulch and Spring Gulch overburden piles.

Genus	**Species**	**Plant Type**	**Origin (Seed Source)**	**Number of Plants at Blind Gulch**	**Number of Plants at Spring Gulch**
				(rows x reps.)	(rows x reps.)
Amorpha	*canescens*	Legume Woody Shrub	Native (Wind River Seed Co.)	3 x 7	3 x 7
Amorpha	*fruticosa*	Legume Woody Shrub	Native (Corrales bosque, NM)	3 x 7	3 x 7
Asclepias sp.	*sp.*	Forb Herbaceous	Native (Molycorp Headframe Hill)	3 x 7	3 x 7
Astragalus	*cicer*	Legume Herbaceous	Introduced (Granite Seed Co. – 'Monarch')	3 x 7	3 x 7
Astragalus	*drummondii*	Legume Herbaceous	Native (Desert Legume Program Univ. of Arizona – 90-0281)		1 x 2
Astragalus	*kentrophyta*	Legume Herbaceous	Native (Desert Legume Program Univ. of Arizona – 90-0283)		1 x 2
Astragalus	*lonchocarpus*	Legume Herbaceous	Native (Plants of the Southwest)		3 x 7
Astragalus	*missouriensis*	Legume Herbaceous	Native (Plants of the Southwest)	3 x 7	3 x 7
Astragalus	*shortianus*	Legume Herbaceous	Native (Desert Legume Program Univ. of Arizona – 90-0285)		1 x 1
Caragana	*arborescens*	Legume Woody Shrub	Introduced (Granite Seed Co.)	3 x 7	3 x 7

Genus	**Species**	**Plant Type**	**Origin (Seed Source)**	**Number of Plants at Blind Gulch**	**Number of Plants at Spring Gulch**
				(rows x reps.)	(rows x reps.)
Coronilla	*varia*	Legume Herbaceous	Introduced (Ernst Crownvetch Seed Co. – 'Chemung')	3 x 7	3 x 7
Dalea	*aurea*	Legume Herbaceous	Native (Plants of the Southwest)	2 x 7	3 x 7
Hedysarum	*boreale*	Legume Herbaceous	Native (Granite Seed Co.)	3 x 7	3 x 7
Lathyrus	*eucosmus*	Legume Herbaceous	Native (Plants of the Southwest)		3 x 7
Lathyrus	*sylvestris*	Legume Herbaceous	Introduced (Ernst Crownvetch Seed Co. – 'Lathco')	3 x 7	3 x 7
Lotus	*corniculatus*	Legume Herbaceous	Introduced ('Empire')		3 x 7
Lotus	*oroboides*	Legume Herbaceous	Native (Desert Legume Program Univ. of Arizona – 91-0410)	2 x 7	2 x 7
Lupinus	*alpestris*	Legume Herbaceous	Native (Granite Seed Co.)	3 x 7	3 x 7
Lupinus	*palmeri*	Legume Herbaceous	Native (Desert Legume Program Univ. of Arizona – 91-0187)		2 x 5 + 1
Lupinus	*perennis*	Legume Herbaceous	Native (Granite Seed Co.)	3 x 7	3 x 7
Medicago	*sativa*	Legume Herbaceous	Introduced (Granite Seed Co. – "Spredor')	3 x 7	3 x 7
Oxytropis	*lambertii*	Legume Herbaceous	Native (Plants of the Southwest)	3 x 7	3 x 7
Oxytropis	*sericeus*	Legume Herbaceous	Native (Plants of the Southwest)		3 x 7
Penstemon	*barbatus*	Forb Herbaceous	Native (Molycorp Goat Hill Gulch)	3 x 7	3 x 7
Petalostemum	*candidum*	Legume Herbaceous	Native (Prairie Moon Nursery)	3 x 7	3 x 7
Petalostemum	*purpureum*	Legume Herbaceous	Native (Granite Seed Co.)	3 x 7	3 x 7

Genus	Species	Plant Type	Origin (Seed Source)	Number of Plants at Blind Gulch	Number of Plants at Spring Gulch
				(rows x reps.)	(rows x reps.)
Robinia	*fertilis*	Legume Woody Shrub	Native (Ernst Crownvetch Seed Co.)	3 x 7	3 x 7
Solidago sp.	*sp.*	Forb Herbaceous	Native (Molycorp Above Blind Gulch)	3 x 7	3 x 7
Thermopsis	*montana*	Legume Herbaceous	Native (Granite Seed Co.)	1 x 7	3 x 7
Thermopsis	*rhombifolia*	Legume Herbaceous	Native (Wind River Seed Co.)		3 x 7

Results:

The vigor of live plants and survival percentages for plantings at the Blind Gulch site are presented in Table 2. The species in the left half of Table 2 are listed in descending order based on the overall average vigor of 21 plants (7 or 14 for 3 species) evaluated in 1998 after 3 years growth. The best performers (vigor > 2.9) included 4 introduced herbaceous legumes (*Medicago sativa, Coronilla varia, Astragalus cicer,* and *Lathyrus sylvestris*), the 3 native forbs (*Asclepias sp., Penstemon barbatus,* and *Solidago sp.*), 2 native woody legumes (*Amorpha fruticosa* and *Robinia fertilis*), and 4. native herbaceous legumes (*Hedysarum boreale, Petalostemum candidum, Astragalus missouriensis,* and *Thermopsis montana*). *Dalea aurea* showed a substantial decline in vigor between 1996 and 1998, whereas, *Lathyrus sylvestris* had an appreciable increase in vigor. The survival percentages for plants evaluated from 1996 to 2000 are reported in right half of Table 2; the species are listed in descending order based on survival in 2000. In 2000, six species had survival greater than 48% compared with 9 species in 1998, 11 species in 1997, and 14 species in 1996. The species which had 1996 survival greater than 48% and showed a decline in survival between 1996 and 2000 less than 30% include *Thermopsis montana, Amorpha fruticosa, Caragana arborescens, Amorpha canescens, Medicago sativa, Petalostemum candidum,* and *Asclepias sp.* Species showing declines greater than 30% at Blind Gulch include *Astragalus cicer, Petalostemum purpureum, Petalostemum candidum, Solidago sp., Penstemon barbatus, Coronilla varia, Astragalus missouriensis,* and *Dalea aurea*.

A similar analysis of plantings at Spring Gulch shows 9 species with vigor greater or equal to 2.5 in the 1998 evaluation; these superior performers include the 3 native forbs (*Penstemon barbatus, Asclepias sp.*, and *Solidago sp.*), 4 native herbaceous legumes (*Hedysarum boreale, Astragalus missouriensis, Astragalus lonchocarpus,* and *Petalostemum purpureum*) as well as cicer milkvetch (*Astragalus cicer*) and bristly locust (*Robinia fertilis*). In earlier evaluations, a number of other species exhibited good vigor (>=2.5): *Amorpha fruticosa, Petalostemum candidum, Thermopsis rhombifolia, Lupinus palmeri, Thermopsis montana, Amorpha canescens, Dalea aurea*, and *Astragalus kentrophyta*. Survival percentages in 2000 greater or equal to 48% were found for 2 native woody legumes (*Amorpha fruticosa* and *Amorpha canescens*), 4 native herbaceous legumes (*Petalostemum purpureum, Petalostemum candidum, Thermopsis rhombifolia, Thermopsis montana*), 3 native forbs (*Penstemon barbatus, Solidago sp.*, and *Asclepias sp.*) and cicer milkvetch (*Astragalus cicer*). Declines in survival between 1996 and 2000 greater than 30% were observed for 9 species: *Caragana arborescens, Lotus corniculatus,*

Astragalus missouriensis, *Medicago sativa*, *Coronilla varia*, *Astragalus lonchocarpus*, *Lathyrus eucosmus*, *Lathyrus sylvestris*, and *Dalea aurea*. The following 5 species exhibited greater than 60% decrease in survival over this same time period: *Astragalus missouriensis*, *Medicago sativa*, *Coronilla varia*, *Lathyrus eucosmus*, and *Dalea aurea*. The reported increases in survival for *Amorpha canescens* and *Caragana arborescens* between evaluations probably result from leafless but live plants being recorded as dead.

Tables 4 and 5 present overall ratings and percentage of plants with seedheads at Blind Gulch and Spring Gulch, respectively. The overall rating is intended to reflect a simultaneous measure of vigor and survival and is calculated by multiplying the mean vigor of live plants by the survival expressed in decimal fraction. Five species at Blind Gulch had superior ratings (i.e., greater than 1.50) in 1996 through 1998: *Amorpha fruticosa*, *Thermopsis montana*, *Astragalus cicer*, *Solidago sp.*, and *Medicago sativa*. Four species (*Amorpha canescens*, *Penstemon barbatus*, *Petalostemum purpureum*, and *Dalea aurea*) had superior ratings for two years and *Coronilla varia*, *Caragana arborescens*, and *Petalostemum candidum* had superior ratings for one year. *Coronilla varia* showed a large increase in rating for 1998, while *Dalea aurea* showed a steady decline in ratings from 1996 to 1998.

There were differences in ratings between the sites; 8 species at Spring Gulch showed superior ratings (greater than 1.50) for all 3 years of evaluation: *Astragalus cicer*, *Penstemon barbatus*, *Amorpha fruticosa*, *Petalostemum purpureum*, *Solidago sp.*, *Thermopsis montana*, *Petalostemum candidum*, and *Thermopsis rhombifolia*. *Asclepias sp.* and *Astragalus missouriensis* had superior ratings for 1996 and 1997 while *Lotus corniculatus*, *Amorpha canescens*, *Coronilla varia*, and *Dalea aurea* had superior ratings for 1996. Dramatic declines in ratings were noted for *Astragalus missouriensis*, *Amorpha canescens*, *Coronilla varia*, and *Dalea aurea* at Spring Gulch.

Seven species at Blind Gulch showed flowering or seedheads for all 3 evaluations: *Astragalus missouriensis*, *Penstemon barbatus*, *Medicago sativa*, *Solidago sp.*, *Petalostemum candidum*, *Hedysarum boreale*, and *Thermopsis montana*. The only flowering for *Petalostemum purpureum* and *Dalea aurea* were noted in 1996 while the only flowering of *Astragalus cicer* and *Coronilla varia* were observed in 1998. Three species showed consistent flowering in all 3 years at Spring Gulch: *Penstemon barbatus*, *Solidago sp.*, and *Astragalus missouriensis*. Two species had substantial flowering in 1996 but little in 1997 or 1998: *Petalostemum candidum* and *Petalostemum purpureum*. Appreciable flowering was noted for one or two years for *Hedysarum boreale*, *Medicago sativa*, *Dalea aurea*, *Astragalus cicer*, *Lotus oroboides*, and *Lotus corniculatus* at Spring Gulch.

Tables 6 and 7 show the maximum survival within individual planting rows. Because of variation in rock type and chemistry, ripping depth, and fraction of fines among rows, the row with maximum survival may give a better indication of the survival that might be expected in a more uniform overburden. At Blind Gulch, 10 species had better than 50 % survival in 2000 in the maximal row: two native woody legumes (*Amorpha fruticosa* and *Amorpha canescens*), 3 native herbaceous legumes (*Petalostemum purpureum*, *Thermopsis montana*, and *Petalostemum candidum*), 2 introduced herbaceous legumes (*Astragalus cicer* and *Medicago sativa*), 2 forbs (*Solidago sp.* and *Penstemon barbatus*) and the introduced woody legume *Caragana arborescens*. In prior years, *Coronilla varia*, *Asclepias sp.*, *Astragalus missouriensis*, and *Dalea aurea* had high survival in the maximal row. A similar assessment of survival at Spring Gulch revealed 15 species with maximal row survival greater than 50% in 2000: 2 native woody legumes (*Amorpha fruticosa* and *Amorpha canescens*), 4 introduced herbaceous legumes (*Astragalus cicer*, *Lotus corniculatus*, *Medicago sativa*, and *Coronilla varia*), 5 native herbaceous legumes (*Petalostemum candidum*, *Thermopsis montana*, *Thermopsis rhombifolia*, *Petalostemum purpureum*, and *Astragalus missouriensis*), 3 forbs (*Solidago sp.*, *Asclepias sp.*, and *Penstemon*

barbatus), and the woody introduced legume (*Caragana arborescens*). Species with high maximal survival in one or more prior years include *Astragalus lonchocarpus, Lathyrus eucosmus, Lupinus palmeri, Lathyrus sylvestris,* and *Dalea aurea*.

Table 8 and 9 present overall average height and crown width and maximum mean row and maximum individual values in 2000; in 1997 only maximum individual height and width in each row plot were recorded. The species in Tables 8 and 9 are ranked according to calculated canopy (i.e., the maximum height times maximum width value). Maximum individual heights greater that 50 cm for the Blind Gulch planting were observed for *Astragalus cicer, Robinia fertilis, Amorpha fruticosa,* and *Medicago sativa*; maximum crown widths greater than 50 cm were found for the previous 4 species as well as *Lathyrus sylvestris, Thermopsis montana* and *Petalostemum candidum*. The maximum mean row heights show 7 species with mean heights at least 25 cm for *Astragalus cicer, Robinia fertilis, Amorpha fruticosa, Medicago sativa, Lathyrus sylvestris, Thermopsis montana,* and *Petalostemum candidum*; a similar assessment of rows had the same species with 25 cm or greater maximum mean crown widths. Overall average height in 2000 greater than 20 cm was observed for *Astragalus cicer, Robinia fertilis, Amorpha fruticosa, Medicago sativa, Lathyrus sylvestris, Thermopsis montana,* and *Petalostemum candidum*. This same group along with *Coronilla varia* had average crown widths greater than 20 cm. The results in Table 9 show maximum individual heights at Spring Gulch of 25 cm or greater for *Hedysarum boreale, Astragalus cicer, Thermopsis montana,* and *Penstemon barbatus*. Maximum individual crown widths greater than or equal to 25 cm were observed for *Hedysarum boreale, Astragalus cicer, Thermopsis montana, Petalostemum candidum, Penstemon barbatus, Medicago sativa, Solidago sp., Lotus corniculatus, Coronilla varia,* and *Thermopsis rhombifolia*. Maximum mean row heights greater than or equal to 20 cm were found for *Hedysarum boreale, Astragalus cicer, Thermopsis montana,* and *Penstemon barbatus*. Maximum mean row crown widths of at least 20 cm were noted for *Hedysarum boreale, Astragalus cicer, Medicago sativa, Solidago sp., Lotus corniculatus,* and *Astragalus lonchocarpus*. The species with overall average heights of at least 20 cm were *Hedysarum boreale* and *Penstemon barbatus* and the species with overall average widths of 20 cm or greater were *Hedysarum boreale, Astragalus cicer, Medicago sativa,* and *Lotus corniculatus*.

Conclusions:

In an effort to summarize these results and to rate species according to their revegetation potential for Molycorp overburden, Tables 10 and 11 have been produced with grades for each attribute for both early (1996 and 1997) and late (1998 and 2000) evaluations. The species listed in both Tables 10 an 11 had superior overall performance or had superior performance for a specific attribute. The species are discussed individually below in groups with similar performance.

Species with superior performance at both sites:

Astragalus cicer - This introduced herbaceous legume had good to excellent grades for all attributes except flowering/seedhead production. At Blind Gulch *Astragalus cicer* produced appreciable flowers and seedheads by the late evaluation periods.

Amorpha fruticosa – This native woody legume shrub is typically found as a riparian species at elevations below 7,000 feet. It's survival and growth at 9000 feet on xeric overburden sites was unexpected. This species exhibited good to excellent survival and growth on both sites but exhibited poor seedhead/flower production.

Solidago sp. – This Molycorp ecotype forb had good to excellent performance including flowering. At Blind Gulch, below average height and width growth was noted for the final evaluations.

Species with some good or better attributes at both sites:

Petalostemum candidum – This native herbaceous legume showed poor survival and growth at Blind Gulch in the early evaluations, but had generally good scores for most other traits except flowering.

Thermopsis montana - A native herbaceous legume with good or better scores except flowering and vigor at Spring Gulch.

Penstemon barbatus - The Molycorp ecotype forb had declining survival and growth at Blind Gulch and poor early survival at Spring Gulch.

Petalostemum purpureum - This native herbaceous legume showed poor vigor at Blind Gulch and poor height and growth in late evaluations as well as overall poor to fair flowering.

Species with good scores at only one site:

Medicago sativa – An introduced herbaceous legume had good to excellent performance at Blind Gulch, but only poor to fair scores at Spring Gulch.

Thermopsis rhombifolia – This native herbaceous legume was not tested at Blind Gulch but did well at Spring Gulch other than vigor and seedhead/flowering.

Species with a few good attributes at one site:

Robinia fertilis – A woody legume native to the eastern U.S. had good vigor and height and width growth at Blind Gulch, but poor survival.

Caragana arborescens – This introduced woody legume had good survival at Blind Gulch but poor vigor and height and width growth. Typically, this species was defoliated at the time of evaluation; it is not known whether this defoliation resulted from herbivory or environmental stresses.

Asclepias sp. – A Molycorp ecotype forb had good early vigor and growth at Spring Gulch.

Hedysarum boreale - This native herbaceous legume showed good to excellent vigor and growth at Spring Gulch but poor to fair survival.

Lotus corniculatus – This introduced herbaceous legume had good growth but poor survival at Spring Gulch.

Coronilla varia – This introduced herbaceous legume had only good early survival and good late growth at Spring Gulch.

Species with good early grades but exhibiting a substantial decline in performance by the later evaluations:

Dalea aurea – This native herbaceous legume exhibited good early survival but experienced great mortality before the later evaluations at Blind Gulch.

Astragalus missouriensis – A native herbaceous legume exhibited good survival, vigor, flowering, and growth at Spring Gulch in the early evaluations, but declined dramatically in later evaluations.

Amorpha canescens - showed good early survival and vigor in early evaluations but scores decreased substantially by later evaluations.

Based on these results, the forb species *Penstemon barbatus* and *Solidago sp.* would be recommended. However, while *Penstemon barbatus* is a perennial based on performance at these sites, it appears to function as a “short-lived” species with a decline in vigor and survival after several years.

The native herbaceous legumes in the *Petalostemum* genus would probably be better suited for more xeric situations based on their better performance at Spring Gulch. The *Thermopsis* species seem to hold some promise for persistence and spreading by rhizomes. Although *Hedysarum boreale* had relatively poor survival, the vigor of the few plants that survived would make it a reasonable choice to include in a legume species mix in light of the fact there are few legume candidates for this site. Two species with relatively good early performance but only poor to fair later performance, *Dalea aurea* and *Astragalus missouriensis*, could only be recommended under the presumption that they could set and disseminate viable seed before their demise.

The native woody legume *Amorpha fruticosa* showed good overall performance other than flowering and seedhead production. Uncertainty remains regarding its long-term performance because the Molycorp environment is outside its typical area of adaptation (i.e., lower elevation and riparian). *Robinia neomexicana* tested in early trials exhibited excellent growth and vigor but highly variable survival (Dreesen 2001). All things considered, *Robinia neomexicana* would be the better woody legume to include in a revegetation species mix. The other woody legume species tested can not be recommended; *Amorpha canescens* and *Caragana arborescens* for their poor vigor and growth and *Robinia fertilis* for its poor survival.

The introduced herbaceous legume *Astragalus cicer* had good performance at both sites and would be recommended for inclusion in revegetation specifications, if exotic species are deemed appropriate. *Medicago sativa* appears to be a worthwhile species on more mesic sites like Blind Gulch.

The establishment of these legumes and forbs from seed drilled directly into overburden is problematic. The high soil moisture resulting from snowmelt in late spring may produce soil moisture conditions conducive for germination. The question is whether the seedlings can persist through the soil moisture deficits from late May to early July as well as hard frosts that may occur in early spring. Cool season grasses have shown some ability to establish under these conditions; therefore, it is possible that legumes may establish in years with optimal moisture and temperature conditions. The alternative would be to seed scarified seed in mid-summer to try to achieve legume germination during the July and August rainy season. The seedlings would have to develop and harden-off sufficiently to tolerate the moisture stress of late September and October as well as early hard freezes. Most of the legume species tested can be established from containerized transplants. A number of species (in particular the *Lupinus* species) had very poor transplant survival. The planting of dormant stock in mid-spring might provide a better chance of establishment for these species than a mid-summer, non-dormant planting. Whether herbaceous legumes established from transplants will produce viable seed and whether this seed can germinate and establish seedlings sufficient to produce a nitrogen fixing vegetation component remain as questions.

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Table 2: Overall Vigor and Survival at Spring Gulch

Species	Site	Number Planted	1996 Eval. Overall Average Vigor of Live Plants	1997 Eval. Overall Average Vigor of Live Plants	1998 Eval. Overall Average Vigor of Live Plants	Species	Site	Number Planted	1996 Eval. Overall Survival (%)	1997 Eval. Overall Survival (%)	1998 Eval. Overall Survival (%)	2000 Eval. Overall Survival (%)
MESA	BG	21	2.8	2.9	3.7	THMO	BG	7	100	100	100	100
COVA	BG	21	2.0	2.4	3.6	AMFR	BG	21	100	100	100	90
ASCI	BG	21	3.2	2.9	3.4	ASCI	BG	21	100	90	57	67
Asclepias	BG	21	2.9	3.1	3.4	CAAR	BG	21	90	57	76	62
AMFR	BG	21	3.3	2.9	3.2	AMCA	BG	21	67	48	81	48
ROFE	BG	21	2.9	2.8	3.2	MESA	BG	21	76	67	48	48
PEBA	BG	21	3.6	3.3	3.1	PEPU	BG	21	71	67	57	33
Solidago	BG	21	3.6	3.3	3.1	PECA	BG	21	62	43	43	33
HEBO	BG	21	3.4	2.9	3.0	Solidago	BG	21	76	62	62	29
PECA	BG	21	2.5	2.8	3.0	PEBA	BG	21	67	57	43	29
ASMI	BG	21	2.2	2.4	3.0	Asclepias	BG	21	48	38	38	19
LASY	BG	21	1.8	2.0	3.0	ROFE	BG	21	38	24	24	19
THMO	BG	7	2.9	3.0	2.9	COVA	BG	21	67	57	71	14
PEPU	BG	21	2.5	2.5	2.3	ASMI	BG	21	62	33	19	14
AMCA	BG	21	2.7	2.1	2.2	HEBO	BG	21	38	33	19	14
DAAU	BG	14	3.1	2.1	2.0	LASY	BG	21	24	14	14	5
CAAR	BG	21	1.3	1.3	2.0	DAAU	BG	14	86	79	36	0
LOOR	BG	14	0.0	1.0	0.0	LOOR	BG	14	0	7	0	0
LUAL	BG	21	0.0	0.0	0.0	LUAL	BG	21	0	0	0	0
LUPE	BG	21	0.0	0.0	0.0	LUPE	BG	21	0	0	0	0
OXLA	BG	21	0.0	0.0	0.0	OXLA	BG	21	0	0	0	0

Table 3: Overall Vigor and Survival at Spring Gulch

Species	Site	Number Planted	1996 Eval. Overall Average Vigor of Live Plants	1997 Eval. Overall Average Vigor of Live Plants	1998 Eval. Overall Average Vigor of Live Plants
PEBA	SG	21	3.7	3.7	3.4
HEBO	SG	21	3.0	2.5	3.3
ASCI	SG	21	3.2	2.8	3.0
ROFE	SG	21	2.3	1.5	3.0
Asclepias	SG	21	3.1	3.3	2.7
ASMI	SG	21	2.7	2.5	2.7
ASLO	SG	21	1.3	2.6	2.5
PEPU	SG	21	3.5	2.4	2.5
Solidago	SG	21	3.5	3.5	2.5
MESA	SG	21	1.4	1.6	2.3
AMFR	SG	21	3.1	2.6	2.2
PECA	SG	21	2.8	2.3	2.1
THRH	SG	21	2.7	1.9	2.1
LUPA	SG	11	1.7	3.0	2.0
OXLA	SG	21	2.0	2.0	2.0
LASY	SG	21	1.5	1.2	2.0
THMO	SG	21	2.7	1.9	2.0
LOCO	SG	21	2.2	1.9	1.8
AMCA	SG	21	2.9	2.4	1.8
COVA	SG	21	1.8	1.6	1.3
LAEU	SG	21	1.9	1.1	1.3
CAAR	SG	21	1.3	1.0	1.0
DAAU	SG	21	3.1	1.6	0.0
LOOR	SG	14	1.3	0.0	0.0
OXSE	SG	21	1.0	0.0	0.0
LUAL	SG	21	0.0	0.0	0.0
LUPE	SG	21	0.0	0.0	0.0
ASKE	SG	2	2.0	2.5	2.5
ASSH	SG	1	2.0	2.0	2.0

Species	Site	Number Planted	1996 Eval. Overall Survival (%)	1997 Eval. Overall Survival (%)	1998 Eval. Overall Survival (%)	2000 Eval. Overall Survival (%)
AMFR	SG	21	100	100	100	100
PEPU	SG	21	100	95	86	90
AMCA	SG	21	100	48	38	90
PECA	SG	21	100	86	86	86
THRH	SG	21	90	86	86	76
PEBA	SG	21	71	67	67	76
THMO	SG	21	90	90	95	71
ASCI	SG	21	95	81	81	71
Solidago	SG	21	81	81	81	62
Asclepias	SG	21	71	57	48	48
CAAR	SG	21	86	71	81	29
LOCO	SG	21	71	67	62	24
ASMI	SG	21	100	71	43	24
MESA	SG	21	100	43	38	19
HEBO	SG	21	43	29	29	19
COVA	SG	21	90	71	14	19
ASLO	SG	21	57	24	10	10
OXLA	SG	21	14	14	10	5
LAEU	SG	21	67	38	29	0
LUPA	SG	11	27	9	9	0
LASY	SG	21	52	29	5	0
ROFE	SG	21	29	19	5	0
DAAU	SG	21	100	24	0	0
LOOR	SG	14	21	0	0	0
LUAL	SG	21	0	0	0	0
LUPE	SG	21	0	0	0	0
OXSE	SG	21	5	0	0	0
ASKE	SG	2	100	100	100	100
ASSH	SG	1	100	100	100	100

Species	Site	Number Planted	1996 Eval. Overall Average Vigor of Live Plants	1997 Eval. Overall Average Vigor of Live Plants	1998 Eval. Overall Average Vigor of Live Plants	Species	Site	Number Planted	1996 Eval. Overall Survival (%)	1997 Eval. Overall Survival (%)	1998 Eval. Overall Survival (%)	2000 Eval. Overall Survival (%)
ASDR	SG	2	0.0	0.0	0.0	ASDR	SG	2	0	0	0	0

Table 4. Overall Rating (Vigor x Survival) and Percentage of Live Plants with Seedheads at Blind Gulch

Species	Site	Number Planted	1996 Eval. Overall Average Rating	1997 Eval. Overall Average Rating	1998 Eval. Overall Average Rating		Species	Site	Number Planted	1996 Eval. Overall Percentage of Plants with Seedheads (%)	1997 Eval. Overall Percentage of Plants with Seedheads (%)	1998 Eval. Overall Percentage of Plants with Seedheads (%)
AMFR	BG	21	3.29	2.90	3.24		ASMI	BG	21	38	43	100
THMO	BG	7	2.86	3.00	2.86		PEBA	BG	21	93	100	67
COVA	BG	21	1.33	1.38	2.57		MESA	BG	21	31	43	60
ASCI	BG	21	3.19	2.62	1.95		Solidago	BG	21	88	100	46
Solidago	BG	21	2.71	2.05	1.90		PECA	BG	21	38	11	33
AMCA	BG	21	1.81	1.00	1.76		ASCI	BG	21	0	0	33
MESA	BG	21	2.14	1.95	1.76		HEBO	BG	21	25	14	25
CAAR	BG	21	1.19	0.71	1.52		ROFE	BG	21	0	0	20
PEBA	BG	21	2.43	1.86	1.33		THMO	BG	7	14	43	14
PEPU	BG	21	1.81	1.67	1.29		COVA	BG	21	0	0	13
PECA	BG	21	1.57	1.19	1.29		PEPU	BG	21	53	7	0
Asclepias	BG	21	1.38	1.19	1.29		DAAU	BG	14	83	0	0
ROFE	BG	21	1.10	0.67	0.76		AMCA	BG	21	0	0	0
DAAU	BG	14	2.64	1.64	0.71		AMFR	BG	21	0	0	0
HEBO	BG	21	1.29	0.95	0.57		Asclepias	BG	21	0	0	0
ASMI	BG	21	1.38	0.81	0.57		CAAR	BG	21	0	0	0
LASY	BG	21	0.43	0.29	0.43		LASY	BG	21	0	0	0
LOOR	BG	14	0.00	0.07	0.00		LOOR	BG	14	0	0	0
LUAL	BG	21	0.00	0.00	0.00		LUAL	BG	21	0	0	0
LUPE	BG	21	0.00	0.00	0.00		LUPE	BG	21	0	0	0
OXLA	BG	21	0.00	0.00	0.00		OXLA	BG	21	0	0	0

Table 5. Overall Rating (Vigor x Survival) and Percentage of Live Plants with Seedheads at Spring Gulch

Species	Site	Number Planted	1996 Eval. Overall Average Rating	1997 Eval. Overall Average Rating	1998 Eval. Overall Average Rating		Species	Site	Number Planted	1996 Eval. Overall Percentage of Plants with Seedheads (%)	1997 Eval. Overall Percentage of Plants with Seedheads (%)	1998 Eval. Overall Percentage of Plants with Seedheads (%)
ASCI	SG	21	3.00	2.29	2.43		PEBA	SG	21	87	86	64
PEBA	SG	21	2.67	2.48	2.29		Solidago	SG	21	100	100	47
AMFR	SG	21	3.10	2.57	2.24		ASMI	SG	21	76	47	44
PEPU	SG	21	3.52	2.29	2.14		HEBO	SG	21	0	17	33
Solidago	SG	21	2.81	2.86	2.00		MESA	SG	21	0	0	25
THMO	SG	21	2.48	1.71	1.86		PECA	SG	21	38	6	6
PECA	SG	21	2.81	2.00	1.81		PEPU	SG	21	62	5	6
THRH	SG	21	2.43	1.62	1.76		DAAU	SG	21	90	40	0
Asclepias	SG	21	2.19	1.86	1.29		ASCI	SG	21	0	12	0
LOCO	SG	21	1.57	1.29	1.14		LOOR	SG	14	67	0	0
ASMI	SG	21	2.67	1.81	1.14		LOCO	SG	21	27	0	0
HEBO	SG	21	1.29	0.71	0.95		AMCA	SG	21	0	0	0
MESA	SG	21	1.38	0.67	0.86		AMFR	SG	21	0	0	0
CAAR	SG	21	1.14	0.71	0.81		Asclepias	SG	21	0	0	0
AMCA	SG	21	2.86	1.14	0.67		ASLO	SG	21	0	0	0
LAEU	SG	21	1.29	0.43	0.38		CAAR	SG	21	0	0	0
ASLO	SG	21	0.76	0.62	0.24		COVA	SG	21	0	0	0
COVA	SG	21	1.67	1.14	0.19		LAEU	SG	21	0	0	0
OXLA	SG	21	0.29	0.29	0.19		LASY	SG	21	0	0	0
LUPA	SG	11	0.45	0.27	0.18		LUAL	SG	21	0	0	0
ROFE	SG	21	0.67	0.29	0.14		LUPA	SG	11	0	0	0
LASY	SG	21	0.81	0.33	0.10		LUPE	SG	21	0	0	0
DAAU	SG	21	3.10	0.38	0.00		OXLA	SG	21	0	0	0
LOOR	SG	14	0.29	0.00	0.00		OXSE	SG	21	0	0	0
OXSE	SG	21	0.05	0.00	0.00		ROFE	SG	21	0	0	0
LUAL	SG	21	0.00	0.00	0.00		THMO	SG	21	0	0	0
LUPE	SG	21	0.00	0.00	0.00		THRH	SG	21	0	0	0
ASKE	SG	2	2.00	2.50	2.50		ASDR	SG	2	0	0	0
ASSH	SG	1	2.00	2.00	2.00		ASKE	SG	2	0	0	0
ASDR	SG	2	0.00	0.00	0.00		ASSH	SG	1	0	0	0

Table 6. Maximum Survival in an Individual Planting Row at Blind Gulch

Species	Site	Number Planted	1996 Eval. Maximum Row Survival (%)	1997 Eval. Maximum Row Survival (%)	1998 Eval. Maximum Row Survival (%)	2000 Eval. Maximum Row Survival (%)
AMFR	BG	21	100	100	100	100
PEPU	BG	21	100	100	100	100
THMO	BG	7	100	100	100	100
AMCA	BG	21	100	86	100	100
ASCI	BG	21	100	100	100	86
Solidago	BG	21	100	100	100	86
CAAR	BG	21	100	86	86	86
PEBA	BG	21	86	86	86	86
MESA	BG	21	100	100	71	86
PECA	BG	21	100	86	86	71
COVA	BG	21	86	71	86	43
Asclepias	BG	21	100	71	71	43
ASMI	BG	21	86	71	57	43
ROFE	BG	21	71	43	43	29
HEBO	BG	21	43	43	29	29
LASY	BG	21	57	43	43	14
DAAU	BG	14	100	100	43	0
LOOR	BG	14	0	14	0	0
LUAL	BG	21	0	0	0	0
LUPE	BG	21	0	0	0	0
OXLA	BG	21	0	0	0	0

Table 7. Maximum Survival in an Individual Planting Row at Spring Gulch

Species	Site	Number Planted	1996 Eval. Maximum 1996 Eval. Maximum Row Survival (%)	1997 Eval. Maximum 1997 Eval. Maximum Row Survival (%)	1998 Eval. Maximum 1998 Eval. Maximum Row Survival (%)	2000 Eval. Maximum 2000 Eval. Maximum Row Survival (%)
AMFR	SG	21	100	100	100	100
ASCI	SG	21	100	100	100	100
PECA	SG	21	100	100	100	100
THMO	SG	21	100	100	100	100
THRH	SG	21	100	100	100	100
PEPU	SG	21	100	100	86	100
AMCA	SG	21	100	71	71	100
Solidago	SG	21	100	86	100	86
Asclepias	SG	21	100	100	86	86
PEBA	SG	21	86	86	86	86
LOCO	SG	21	100	86	86	71
ASMI	SG	21	100	86	71	71
CAAR	SG	21	100	86	86	57
MESA	SG	21	100	86	86	57
COVA	SG	21	100	100	29	57
HEBO	SG	21	43	43	43	29
ASLO	SG	21	86	43	29	14
OXLA	SG	21	43	29	14	14
LAEU	SG	21	71	43	29	0
LUPA	SG	11	60	20	20	0
LASY	SG	21	86	57	14	0
ROFE	SG	21	29	29	14	0
DAAU	SG	21	100	29	0	0
LOOR	SG	14	29	0	0	0
OXSE	SG	21	14	0	0	0
LUAL	SG	21	0	0	0	0
LUPE	SG	21	0	0	0	0
ASKE	SG	2	100	100	100	100
ASSH	SG	1	100	100	100	100
ASDR	SG	2	0	0	0	0

Table 8. Overall Average, Maximum Row, and Maximum Individual Plant Height and Width at Blind Gulch

Species	Site	Number Planted	2000 Eval. Overall Average Height (cm)	2000 Eval. Maximum Row Height (cm)	1997 Eval. Maximum Individual Height (cm)	2000 Eval. Maximum Individual Height (cm)	2000 Eval. Overall Average Width (cm)	2000 Eval. Maximum Row Width (cm)	1997 Eval. Maximum Individual Width (cm)	2000 Eval. Maximum Individual Width (cm)	2000 Eval. Maximum Individual Height x Width Rank
ASCI	BG	21	37	53	38	61	62	80	76	127	1
ROFE	BG	21	36	48	25	71	50	66	36	102	2
AMFR	BG	21	30	48	46	61	41	65	38	91	3
MESA	BG	21	28	29	46	61	37	41	61	76	4
LASY	BG	21	25	25	5	25	91	91	10	91	5
THMO	BG	7	30	30	36	46	30	30	46	51	6
PECA	BG	21	22	28	20	36	36	44	38	61	7
HEBO	BG	21	15	15	25	25	17	18	30	30	8
CAAR	BG	21	14	18	15	20	18	19	8	36	9
PEPU	BG	21	14	14	25	20	18	18	25	25	10
Solidago	BG	21	13	13	25	20	19	19	30	25	10
AMCA	BG	21	8	9	10	15	14	17	15	25	12
COVA	BG	21	8	8	8	10	24	24	25	30	13
ASMI	BG	21	5	5	5	5	17	17	38	25	14
Asclepias	BG	21	9	15	30	15	5	5	15	5	15
PEBA	BG	21	3	3	61	3	7	7	61	10	16
DAAU	BG	14	0	0	10	0	0	0	20	0	19
LOOR	BG	14	0	0	3	0	0	0	5	0	19
LUAL	BG	21	0	0	0	0	0	0	0	0	19
LUPE	BG	21	0	0	0	0	0	0	0	0	19
OXLA	BG	21	0	0	0	0	0	0	0	0	19

Table 9. Overall Average, Maximum Row, and Maximum Individual Plant Height and Width at Spring Gulch

Species	Site	Number Planted	2000 Eval. Overall Average Height (cm)	2000 Eval. Maximum Row Height (cm)		1997 Eval. Maximum Individual Height (cm)	2000 Eval. Maximum Individual Height (cm)		2000 Eval. Overall Average Width (cm)	2000 Eval. Maximum Row Width (cm)		1997 Eval. Maximum Individual Width (cm)	2000 Eval. Maximum Individual Width (cm)		2000 Eval. Maximum Individual Height x Width Rank
HEBO	SG	21	36	56		38	56		43	61		51	76		1
ASCI	SG	21	14	20		20	25		33	44		46	61		2
THMO	SG	21	12	20		15	41		11	15		25	30		3
PECA	SG	21	6	10		46	25		9	12		76	41		4
PEBA	SG	21	21	32		91	41		13	18		61	25		5
MESA	SG	21	10	10		15	15		30	30		15	41		6
Solidago	SG	21	9	10		30	20		16	20		38	30		6
LOCO	SG	21	11	11		10	15		22	22		25	30		8
COVA	SG	21	7	7		8	15		15	15		15	25		9
THRH	SG	21	7	9		20	15		9	11		25	25		9
ASLO	SG	21	13	15		20	15		15	20		15	20		10
PEPU	SG	21	5	6		46	15		5	6		46	15		11
AMFR	SG	21	7	9		30	10		9	10		20	15		12
Asclepias	SG	21	9	10		25	15		6	8		20	10		12
CAAR	SG	21	12	15		20	15		4	4		3	5		13
AMCA	SG	21	3	3		10	5		6	8		15	10		14
ASMI	SG	21	3	3		5	3		8	8		30	10		16
OXLA	SG	21	3	3		20	3		5	5		25	5		17
LUPA	SG	11	0	0		25	0		0	0		13	0		25
LAEU	SG	21	0	0		15	0		0	0		15	0		25
DAAU	SG	21	0	0		8	0		0	0		8	0		25
ROFE	SG	21	0	0		8	0		0	0		8	0		25
LASY	SG	21	0	0		5	0		0	0		5	0		25
LOOR	SG	14	0	0		0	0		0	0		0	0		25
LUAL	SG	21	0	0		0	0		0	0		0	0		25
LUPE	SG	21	0	0		0	0		0	0		0	0		25
OXSE	SG	21	0	0		0	0		0	0		0	0		25
ASKE	SG	2	3	3		3	3		10	10		10	15		15
ASSH	SG	1	3	3		5	3		3	3		10	3		18
ASDR	SG	2	0	0		0	0		0	0		0	0		25

Table 10. Summary grades for species with superior overall performance at Blind Gulch.

Evaluation Species	Early Vigor	Early Survival	Early Rating	Early Seedheads	Early Row Survival	Early Height and Width	Late Vigor	Late Survival	Late Rating	Late Seedheads	Late Row Survival	Late Height and Width
Amorpha fruticosa	+	++	++	--	++	++	+	++	++	--	++	++
Astragalus cicer	+	++	++	--	++	++	++	+	++	+	++	++
Thermopsis montana	+	++	++	-	++	++	-	++	++	--	++	+
Medicago sativa	+	+	+	-	++	++	++	+	+	+	+	+
Solidago sp.	++	+	++	++	++	+	+	+	+	+	++	-
Petalostemum candidum	-	-	-	-	++	+	+	+	-	+	+	+
Petalostemum purpureum	-	+	+	-	++	+	--	+	+	--	++	-
Penstemon barbatus	++	+	+	++	-	++	+	-	+	++	+	--
Robinia fertilis	+	--	--	--	--	+	+	--	--	--	-	++
Caragana arborescens	--	+	--	--	++	-	--	++	+	--	+	-
Dalea aurea	-	++	+	-	++	-	--	--	--	--	--	--

Table 11. Summary Grades For Species With Superior Overall Performance At Spring Gulch

Evaluation Species	Early Vigor	Early Survival	Early Rating	Early Seedheads	Early Row Survival	Early Height and Width	Late Vigor	Late Survival	Late Rating	Late Seedheads	Late Row Survival	Late Height and Width
Astragalus cicer	++	+	++	--	++	++	++	+	++	--	++	++
Solidago sp.	++	+	++	++	++	++	+	+	++	++	+	+
Penstemon barbatus	++	-	++	+	-	++	++	+	++	++	+	++
Petalostemum candidum	+	++	+	--	++	++	-	++	+	-	++	+
Amorpha fruticosa	++	++	++	--	++	+	+	++	++	--	++	-
Petalostemum purpureum	++	++	++	--	++	++	+	++	++	-	++	-
Thermopsis montana	-	+	+	--	++	+	--	+	+	--	++	+
Thermopsis rhombifolia	-	+	+	--	++	+	-	+	+	--	++	+
Asclepias sp.	++	-	+	--	--	+	--	-	+	--	--	-
Hedysarum boreale	+	--	-	-	-	++	++	-	-	+	--	++
Lotus corniculatus	-	-	-	--	++	+	--	-	+	--	-	+
Astragalus missouriensis	+	++	+	+	++	-	-	-	-	+	-	-
Medicago sativa	--	+	-	--	++	-	+	-	-	-	-	+
Amorpha canescens	+	+	+	--	+	-	--	+	-	--	+	-
Coronilla varia	-	+	-	--	++	-	--	--	--	--	--	+