PROMISING NATIVE FORBS FOR SEEDING ON MINE SPOILS[1]

by

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Abstract. Twenty nine species of perennial forbs and 2 biennial forbs were directly seeded into coal mine spoil materials at Dickinson, North Dakota to determine which species would be most successful for direct seeding into coal mine spoil. Those which showed exceptionally good emergence and vigorous growth of seedlings in a two year study were: white prairie clover (*Petalostemum candidum*), wild licorice (*Glycyrrhiza lepidota*), prairie coneflower (*Ratibida columnifera*), blazing star (*Liatris punctata*) and long-leaved milkvetch (*Astragalus ceramicus*). Species with lesser but acceptable germination only were: white upland aster (*Aster ptermicoides*), purple coneflower (*Echinacea angustifolia*), early goldenrod (*Solidago missouriensis*), green milkvetch (*Astragalus striatus*), purple prairie-clover (*Petalstemum purpureum*) and evening star (*Metzelia decapetala*). Other species tested showed little to no germination and hence difficult to establish by direct seeding into coal mine spoil.

Additional Key Words: forbs, seeding, reclamation, revegetation.

Introduction

Forbs are herbaceous or semi-woody plants such as fringed sagewort (*Artemisia frigida*) or winter fat (*Eurotia lanata*) (Stevens 1963, Thornburg 1982, Wasser 1982). Other herbaceous plants include grasses, sedges and rushes. Forbs are the most numerous group of plants but are seldom dominant and almost always occur in mixtures. They may be perennials, biennials (live two years) or annuals which may be fall or spring annuals i.e., seed germination occur in fall or spring time of the year. Forbs, due to persistant high level of nutrients, are an important part of the diet of wildlife, including big game animals and birds, and livestock. However, they are usually of limited abundance whereby animals need to select for these forbs in order to ingest sufficient amounts to supplement nitrogen and phosphorous need in the diets (Alexander et al. 1983, Peterson 1989).

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Grazing systems are generally focused around the graminoid component of the grassland ecosystem and it is this component that has received the greatest attention by managers and researchers. This has been done with studies which dealt with floristics (Peterson 1989), community descriptions (Hanson and Whitman 1938, Hirsch 1985, Girard et al. 1989), seasonal nutritional composition of grasses and shrubs (Whitman et al. 1951, Jefferies and Rice 1969, Williamson 1979), and phenology of selected range plants (Peterson 1989). Results of these studies show forbs as merely a minor component of the environment and added mainly structure, increased diversity and enhanced aesthetic qualities. Forbs were recognized as indicators of range condition and mesotrophism (Weaver and Albertson 1943). They were also noted to be the first to take great advantage of reduced cover following the great drought of the 1930's (Weaver and Albertson 1944), in other words they were the pioneers to rehabitate the site during early successional stages.

The forb component and their management remains to be understood and described, even though its importance was recognized 15 years ago (Ferguson and Monsen 1974). This problem continues because we do not know which forbs are most promising and the cultural practices required or the site conditions most conducive to their establishment. Previous studies indicate severe problems with the germination is a major deterant to forb establishment (Blake 1935, Tolstead 1941, McDonough 1969, Sorensen and Holden 1974, Voigt 1977).

The objectives of the study were to (1) determine optimum seed storage and germination environments for 29 species of perennial forbs common in western North Dakota (Hanson and Whitman 1938), (2) determine the germination of these forbs seeded in mine spoil material under actual field conditions, and (3) compare the height growth of plants seeded with those propagated by the use of containerized seedlings.

Procedures

Seed collection on native ranges in western North Dakota began as soon as seed appeared in seed dispersal stage, usually late June for cool season forbs and as late as October for warm season forbs (Table 1). The recognition of forbs as with grasses according to season of growth, ie. cool or warm season, provides extended periods of growth when appropriately mixed to provide balancing of these species (Thornburg 1982, Wasser 1982). This was recognized in the selection of species used in this study (Table 1).

The forb seeds were stored in glass bottles at room temperature during the summer, threshed-out by hand rubbing and hand-screening and returned to the glass bottles. Most seeds threshed relatively clean but some appendages or portions of appendages remained attached. This occurred with yarrow (*Achillea lanulosa*), sagewort wormwood (*Artemisia caudata*), white upland aster (*Aster ptarmicoides*), wild buckwheat (*Eriogonum multiceps*), butterfly weed (*Gaura coccinea*) skeleton weed (*Lygodesmia juncea*) golden aster (*Chrysopsis villosa*), the goldenrods (*Solidago spp.*) and goatsbeard (*Tragopogon dubius*).

Three storage treatments were applied to separate lots of the forb seed. These treatments were (1) dry storage at room temperature, (2) dry-cold storage with seed subjected to normal outdoor winter temperature fluctuations, and (3) wet-cold storage with moisture weekly monitored

Table 1.--List of species collected near Dickinson, North Dakota used in experiment on forb es tablishment and season of growth.

Scientific name	Season of growth*
Achillea lanulosa	C
Artemisia caudata	W
Aster ptarmicoides	W
Astragalus ceramicus	C
Astragalus flexuosus	C
Astragalus striatus	C-W
Campanula rotundifolia	C-W
Chrysopsis villosa	W
Echinacea angustifolia	C
Eriogonum multiceps	C
Gaillardia aristata	C-W
Gaura coccinea	C-W
Glycyrrhiza lepidota	C
Helianthus rigidus	W
Liatris punctata	W
Linum lesisii	C
Lygodesmia juncea	C-W
Mentzelia decapetala	W
Penstemon angustifolius	C
Petalostemum candidum	W
Petalostemum purpureum	W
Psoralea esculenta	C
Ratibida columnifera	W
Solidago missouriensis	W
Solidago mollis	W
Solidago rigida	W
Sphaeralcea coccinea	C
Suaeda fruticosa	W
Tragopogon dubius	C
Vicia americana	C

* C=Cool Season, W=Warm Season

and added to keep seed maintained in moist conditions at approximately 4 C in a refrigerator. The seed storage period began on December 1.

All germination trials were conducted using a Seedburo Model 3516 germinator maintained at a temperature of 21 °C. Triplicate lots of 25 seeds each, tested for viability using the tetrazolium test (Ferguson and Monsen 1974) were germinated on moist chromatography paper in square petri dishes. Germination trials of room temperature and cold-dry stored seed were begun on the 9th of January and subsequent trials of each species thus treated were begun on the approximate same day of the month each month thereafter through May. Germination trials of the wet-cold treated seed were begun on January 16 and were continued for the rest of the 5-month period beginning on the approximate same day of each month. The germination period allowed for each trial was 60 days, after which the ungerminated seed of each trial lot remaining in the petri dishes was discarded. Germination was considered to have taken place when the radicle appeared, and the germinated seeds were removed from the petri dishes at that time.

Germination of pretreated forb seeds was also tested on spoil piles, constructed from raw coal spoil material hauled to the Dickinson Experiment Station from North American Coal Corporation's Indianhead Mine near Zap, North Dakota. The sandy clay loam texture and void of organic matter material was from a depth of 9-12 meters (30-40 feet). The spoil material was spread to a depth of 30 cm (14 inches). The surface was rototilled before seeding.

Each spoil pile was divided into plots 1.2 x 1.2 m (4 x 4 feet) in size. The seedings were made in two replications per treatment from each species. Seed was broadcast by hand and raked. Application rate was considered to be heavy when compared to seeds of similar size of tested seeding rates (Thornburg 1982). Plots were seeded the first week of June.

Container-grown seedlings used for height growth rate comparison were germinated starting the previous December and transplanted into the spoil the first week of June. After the completion of the transplanting and seeding of the plots, all plots were watered with a fine-spray as needed to keep the surface damp.

Results and Discussion

While the results of this trial show some inconsistencies, all species showed some germination under all treatments. Cluster analyses using ISODATA showed some species benefited by cold treatment and showed increased germination under this treatment than when stored at room temperature. Included in this group were *Chrysopsis villosa*, *Ratibida columnifera*, *Solidago missouriensis*, *S. mollis*, *S. rigida*, *Aster ptarmicoides* and *Mentzelia decapetala* (Table 2).

A few species had less germination under the dry cold treatment than under room temperature storage. Included in this group were *Echinacea angustifolia*, *Gaillardia aristata*, *Glycyrrhiza lepidota*, *Linum lewisii*, and *Suaeda fruticosa*.

The wet-cold storage treatment was especially beneficial to *Mentzelia decapetala* and *Penstemon angustifolus*. *Mentzelia* continued to increase in percent germination throughout the period of wet-cold storage with May trial showing 92 percent germination, the highest germination shown by any perennial species in the trial. *Penstemon* showed satisfactory germination only under the wet-cold treatment, reaching 76 percent in the February test, but declining thereafter.

Table 2.--Percent germination of forb seeds collected in the summer, stored under three different conditions and tested in the winter and spring.[1]

Species	Room temp. storage					Dry cold storage					Wet cold storage				
	Jan.	Feb.	Mar.	Apr.	May	Jan.	Feb.	Mar.	Apr.	May	Jan.	Feb.	Mar.	Apr.	May
Glycyrrhiza lepidota	65	80	75	77	79	57	71	61	56	60	77	52	69	75	55
Tragopogon dubius	56	57	72	80	93	51	83	87	89	31	28	4	19	93	49
Liatris punctata	51	63	16	71	67	68	35	57	69	72	36	65	41	73	64
Solidago rigida	4	21	24	15	32	41	31	44	48	21	41	51	55	25	17
Solidago mollis	17	52	60	16	32	33	55	44	36	29	9	31	23	3	12
Aster ptarmicoides	9	20	15	36	35	11	31	28	39	29	5	65	29	45	32
Chrysopsis villosa	20	25	32	17	16	17	37	24	22	29	32	36	12	33	40
Solidago missouriensis	23	13	47	24	15	40	45	32	29	23	64	25	5	20	7
Linum lewisii	16	23	36	33	79	4	25	16	13	43	14	25	1	41	20
Mentzelia decapetala	0	1	12	4	1	7	1	1	4	17	29	81	53	83	92
Petalostemum candidum	13	33	25	12	11	36	23	21	23	8	36	23	16	19	25
Artemisia caudata	16	40	16	15	8	25	15	19	20	12	15	16	36	11	24
Ratibida columnifera	11	20	20	0	16	29	25	13	17	17	1	17	16	5	9
Gaillardia aristata	23	19	24	11	15	7	12	5	7	8	5	16	16	13	23
Astragalus striatus	16	21	7	21	11	8	7	12	13	12	11	16	35	12	13
Petalostemum purpureum	12	21	29	1	5	12	3	13	11	4	11	11	4	8	8
Echinacea angustifolia	11	15	13	27	12	9	5	12	7	1	5	9	13	0	7
Vicia americana	5	20	16	7	3	3	11	5	11	4	9	21	15	11	4
Penstemon angustifolius	0	3	0	0	3	1	0	3	0	5	19	76	8	12	0
Suaeda fruticosa	0	7	11	23	5	3	0	1	8	4	0	20	24	12	8
Thermopsis rhombifolia	9	21	5	0	8	7	8	3	5	7	20	8	7	11	4
Astragalus flexuosus	5	15	4	8	0	0	3	1	8	4	7	5	8	3	3
Astragalus ceramicus	5	3	7	5	0	7	0	0	11	3	5	9	9	3	0
Achillea lanulosa	8	0	3	0	0	3	0	3	4	0	24	0	13	3	0
Campanula rotundifo	4	0	0	28	1	0	0	9	8	0	4	5	8	5	1
Eriogonum multiceps	0	13	3	27	12	3	1	0	1	1	1	2	1	0	3
Lygodesmia juncea	1	4	0	0	0	4	0	0	0	1	5	13	3	0	1
Gaura coccinea	7	1	4	3	0	3	3	5	0	1	4	0	0	0	0
Helianthus rigidus	1	3	3	4	1	1	1	0	0	3	0	12	7	8	4
Sphaeralcea coccinea	4	5	1	1	0	1	1	1	0	0	0	7	3	0	1
Psoralea esculenta	9	-	-	-	-	3	-	-	-	-	5	7	-	-	-

[1] Storage period for all treatments was considered to have begun on Dec. 1. Germination tests began on the 10th of the month indicated and each lot of seeds was observed for 60 days thereafter except for the May trials.

Other species which showed small to moderate benefit from the wet-cold storage treatment included Aster ptarmicoides, Astragalus ceramicus, Chrysopsis villosa, Helianthus rigidus, Lygodesmia juncea, Petalostemum candidum Suoeda fruticosa, Thermopsis rhombifolia, and Vicia Americana. Achilles lanulosa apparently benefitted from a short period of cold-wet storage, but prolonged storage under these conditions appeared to be detrimental.

From the results of this germination trial the requirement for a cold treatment before most of the forbs will show satisfactory germination rates seems to be somewhat in doubt. This requirement may be related to previous seasonal growing conditions and the conditions under which the seed matured. In a normal field situation, most forb seed will receive either a dry-cold or a wet-cold treatment during the winter after the seed is produced. Whether this treatment is essential during storage before direct seeding into mine spoil for satisfactory germination now seems somewhat doubtful.

Germination of the 29 forb species direct seeded on the mine spoil took place over a relatively long period of time. Twenty-three species showing some germination and seedling emergence within 120 days, by the end of August (Table 3). Six species that did not germinate under natural mine spoil conditions were: Penstemon angustifolius, Solidago rigida, Helianthus rigidus, Campanula rotundifolia, Suaeda fruticosa and Lygodesmia juncea. The species that showed exceptionally good emergence of seedlings and subsequent vigorous growth included: Petalostemum candidum, Glycyrrhiza lepidota, Ratibida columnifera, Liatris punctata, and Astragalus ceramicus.

Fourteen species of the container-grown seedlings were successfully transplanted and height growth measurements on the unheaded stalks were taken (Table 4). These transplants were started from seed

Table 3.--Estimated number of seed lings per square meter produced in one growing season on mine spoil plots seeded June 9 and estimates made in August and listed according to highest number per square meter.

Species	No. seedlings/m^2
Astragalus striatus	356
Petalostemum candidum	335
Mentzelia decapetala	302
Tragopogon dubius	280
Glycyrrhiza lepidota	248
Liatris punctata	204
Astragalus ceramicus	140
Petalostemum purpureum	140
Chrysopsis villosa	97
Linum lewisii	43
Echinacea angustifolia	32
Astragalus flexuosus	21
Solidago mollis	21
Sphaeralcea coccinea	21
Thermopsis rhombifolia	11
Ratibida columnifera	11
Aster ptarmicoides	11
Eriogonum multiceps	11
Achillea lanulosa	T*
Artemisia caudata	T
Solidago missouriensis	T
Gaillardia aristata	T
Gaura coccinea	T
Penstemon angustifolius	0
Solidago rigida	0
Helianthus rigidus	0
Campanula rotundifolia	0
Suaeda fruticosa	0
Lygodesmia juncea	0

*T = Seedlings present but averaging less than $1/m^2$.

in December and transplanted into the spoil in June. All container grown seedlings survived transplanting and grew successfully on the spoil material until heights were measured on August 30 (Table 4). Solidago rigida, Mentzelia, Campanula, Liatris, and Penstemon remained in the rosette growth form throughout the season. In this form they appeared vigorous and developed well but did not make height growth. Those species which grew the most included the two Petalostemum species, Ratibida, Glycyrrhiza.

Some seedlings and transplants grew more vigorously than others (Table 4). In general the transplants of the species reached greater heights by the end of first growing season than did the plants of the same species grown directly from seed. However, the plants grown directly from seed did remarkably well with four producing flower stalks by August 30 of the first growing season (Table 5). Container-grown seedlings of the same species produced flower stalks of similar heights the first growing season.

Numerous newly emerged seedlings from the previously direct seeded forbs were observed the following June. Seedlings from previous year planted seeds were especially abundant on plots of Solidago mollis, Mentzelia decapetala, Thermopsis rhombifolia, Helianthus rigidus, Penstemon angustifolus, Aster ptarmicoides, and Echinacea angustifolia. The inference is that

Table 4.--Average heights of plants, seeded and container-grown transplants in mine spoil material at Dickinson, North Dakota at end of first growing season.

Species	Average Plant Height (cm) Seeded	Container
Suaeda fruticosa	19 ± 1.3[1]	--[3]
Glycyrrhiza lepidota	17 ± 0.4	15 ± 2.4
Astragalus ceramicus	16 ± 3.8	--
Petalostemum candidum	10 ± 2.6	34 ± 1.2
Artemisia caudata	6[2]	--
Mentzelia decapetala	6[2]	9 ± 1.7
Liatris punctata	5 ± 1.9	3 ± 0.8
Echinacea angustifolia	5 ± 0.0	3 ± 0.8
Thermopsis rhombifolia	5 ± 0.0	10 ± 1.7
Astragalus striatus	5[2]	2 ± 0.0
Ratibida columnifera	4 ± 0.6	25 ± 3.9
Aster ptarmicoides	4 ± 0.0	11 ± 0.6
Eriogonum multiceps	2 ± 0.0	--
Solidago rigida	2 ± 0.0	11 ± 1.0
Helianthus rigidus	1	12 ± 4.0
Solidago missouriensis	1	--
Campanula rotundifolia	--	4 ± 1.6
Penstemon angustifolia	--	5 ± 0.9

[1]± standard error.
[2]± mean per plot, no replication.
[3] Not included.

Table 5. End of growing season average heights of flower stalks developed on container transplants and on plants seeded on mine spoil material at the Dickinson Station.

	Average flower stalk height (cm)	
Species	Container	Seeded
Petalostemum purpureum	20	25
Petalostemum candidum	24	31
Helianthus rigidus	-	50
Ratibida columnifera	17	29
Thermopsis rhombifolia	25	-

seed will lie dormant for several years and overwintering under natural conditions will promote germination and emergence of seedlings from previously dormant seed. The fall rains and winter conditions on the northern Great Plains would provide a wet-cold treatment.

Summary and Conclusions

Thirty one species of highly valued forbs on the northern Great Plains were selected for evaluations as to their suitability for seeding on coal mine spoils in North Dakota. Two biennials, Artemisia caudata and Tragopogon dubius, were included due to their high visibility and availability of seed to reclamation specialists. All thirty one species showed some germination under all treatments. However, germination of Chrysopsis villosa, Ratibida columnifera, Solidago missouriensis, S. rigida, Aster ptarmicoides, and Mentzelia decapetala was increased when receiving the dry-cold treatment compared to storage at room temperature. The wet-cold storage treatment was beneficial to Mentzelia decapetala and Penstemon angustifolius. Therefore, these species should be fall seeded, or if placed in dry winter storage the proper treatment should be applied for maximizing germination prior to spring seeding. Species tested which had special germination problems requiring further investigation include Achillea lanulosa, Astragalus ceramicus, Astragalus flexuosus, Campanula rotundifolia, Eriogonum multiceps, Gaura coccinea, Lygodesmia juncea, Psoralea esculenta, and Sphaeralcea coccinea. Those perennial forbs which demonstrated exceptional promise for direct seeding in seed mixtures on mine spoils were: Petalostemum candidum, Ratibida columnifera, Glycyrrhiza lepidota, Liatris punctata and Astragalus ceramicus.

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