Long-term Plant Establishment on Mined Lands in Southeastern Montana

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Abstract

Research was conducted on strip mined lands at Colstrip, Mon., over a 6-year period to evaluate germination, survival and cover characteristics of fairway crested wheatgrass *(Agropyron cristatum)*, critana thickspike wheatgrass *(Agropgron dasystachyum)*, ranger alfalfa *(Medicago sativa)*, and fourwing saltbush *(Atriplex canescens)*. All 4 species showed good initial establishment and long-term survival/growth even though subjected to 2 consecutive years of drought when growing season precipitation was less than 50% of the mean. Nitrogen and phosphorus fertilizer application after emergence had no effect on initial or long-term survival of any species. However plant canopy and litter cover were increased for all species except fourwing saltbush by fertilizer application. There was little invasion of native species into the study area. Critana thickspike wheatgrass is a native species that appears well suited for seeding mixtures on mined lands in the study area. However, because of aggressiveness, the use of fairway crested wheatgrass is not recommended in mixtures from which a diversity of native species is the vegetation goal.

In recent years reclamation of lands altered by coal strip mining in the Northern Great Plains has become a major concern. Fertilization and plant species suitability are 2 subject areas of great importance. Critana thickspike wheatgrass *(Agropyron dasystachyum)* fairway crested wheatgrass *(Agropyron cristatum)*, ranger alfalfa *(Medicago sativa)*, and fourwing saltbush *(Atriplex canescens)* have shown good initial establishment when planted in mixtures and as monocultures on strip mine spoils at Colstrip, Mon. (Holechek 1980; Holechek et al. 1981; Holechek 1982; Depuit and Coenenberg 1979; Depuit et al 1978; Sindelar et al. 1974). Critana thickspike wheatgrass and fourwing saltbush are species native to the Colstrip area. However, the long-term persistence and vigor of these 4 species has not been evaluated. The primary objective of this study was to determine the survival and vigor of the 4 previously-mentioned species over a 6-year period when fertilized and when not fertilized with nitrogen and phosphorus. A secondary objective was to study the invasion rate of species from the surrounding area into the experimental units.

Methods

In late winter of 1975, 24 experimental units, 9 × 10 m, were established on strip mines spoils at Colstrip, Mon., that had been previously graded, ripped and topsoiled. A randomized block experimental design was used with three blocks of 8 treatments (4 species × 2 fertilizer levels). Fourwing saltbush, critana thickspike wheatgrass, ranger alfalfa, and fairway crested wheatgrass were randomly assigned to each block. Experimental units were seeded on the basis of pure live seed per square meter (PLS) in April 4. All seed used in the study had been recently tested for germination. Fourwing saltbush seed was dewinged. Crested wheatgrass, thickspike wheatgrass, and ranger alfalfa were broadcast seeded at 538 PLS per square meter. The relatively heavy seeding rate was used to compensate for the uneven depth of broadcast seeding (Vallentine 1971). Fourwing saltbush was seeded at a reduced rate (108 PLS/m^2) to lower intraspecific competition. Seeds were incorporated into the soil material by a cultipacker. Nitrogen and phosphorus fertilizer was randomly applied to one half the experimental units seeded to each species immediately after emergence. The rates of application were 37 kg/ha of elemental nitrogen and 94 kg/ha of phosphorus (P_2O5).

Plant density data were collected June 8, 1975, August 15, 1975, and July 9, 1980, using 20 × 20 cm square quadrats. At least 16 randomly placed frames were read on each experimental unit on each sampling date. Plant canopy and litter cover were estimated using the methods of Daubenmire (1970) on August 17, 1975, and July 10, 1980. At least 14, 20 × 50-cm frames were measured on each experimental unit on each sampling date. The standard *t*-test was used to compare differences between fertilizer treatments for each species. Analysis of variance was used to compare cover and density differences between species. Newman-Keuls test was used to rank treatment means where appropriate. The procedures of Steel and Torrie (1960) were used in all statistical tests.

The average chemical composition of soil samples from the study area at Colstrip is given in Table 1. Approximately, 20 cm of topsoil with a sandy loam texture was applied over the raw spoils. The topsoil exhibited low (approx. 0.5%) organic matter, and was deficient in nitrogen and phosphorus. The pH averaged 8.5. The spoils material beneath the topsoil was variable in texture, and had less than 0.2% organic matter. The pH was between 8.2 and 8.4 and deficiencies in nitrogen and phosphorus were evident.

The mean annual precipitation for the Colstrip area is 40.1 cm (Depuit and Coenenberg 1979). The annual precipitation totals for the years of 1975 through 1979 at Colstrip were 44.37, 40.77, 39.06, 57.76 and 22.3 cm, respectively. Conditions were very favorable for plant growth in 1976 because spring precipitation was 140% of the mean. Both 1979 and 1980 were years of severe spring drought. Precipitation totals during the growing seasons in 1979 and 1980 were 35 and 49% of the mean, respectively.

Results and Discussion

Plant density results from 1975 and 1980 are presented Table 2. There was no significant difference ($P>.05$) between fertilized and unfertilized experimental units for any species on any sampling date. Other investigators have also reported little effect of nitrogen and phosphorus on grass, legume, or shrub densities on mined lands in the region (Farmer et al. 1974; Depuit and Coenenberg 1979; Holechek 1980; Holechek et al. 1981). Plant density of all species showed drastic decreases between 1975 and 1980. Much of this decrease may be attributed to the severe drought conditions that existed during the 1979 and 1980 growing seasons. However intra-specific competition probably also accounts for a certain

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Table 1. Average chemical composition of soil samples from the study area at Colstrip, Montana.[1]

	No. of samples	pH	NO_3-N (ppm)	PO_4-P (ppm)	K (ppm)	Ca (meq/100g)	Mg (meq/100g)	Na (meq/100g)	E.C. (mmhos/cm)
Depth									
(0–20 cm) (topsoil)	3	8.50	2.20	.60	54.17	29.36	2.18	.13	.41
(21–60 cm) (spoil)	3	8.35	5.27	.53	56.67	21.20	2.21	.13	.75
(61–90 cm)(spoil)	3	8.23	3.86	.45	55.83	19.78	2.32	.13	.80
(91–120 cm) (spoil)	3	8.23	4.52	.47	56.67	19.87	2.12	.13	.80

[1]Soil samples were collected on November 17, 1974, prior to treatment application.

Table 2. Plant density of seeded species in 1975 and 1980.

Species	Plant/m^2 June 8, 1975	Fertilized plants/m^2 August 15, 1975	Unfertilized plants/m^2 August 15, 1975	Fertilized plants/m^2 July 9, 1980	Unfertilized plants/[2] July 9, 1980
Critana thickspike wheatgrass	312	244	254	88	82
Fairway crested wheatgrass	259	212	208	65	60
Ranger alfalfa	257	220	234	34	37
Fourwing saltbush	48	42	46	12	8

amount of this decrease. This is because as the more vigorous individuals develop in a seeding they tend to exclude the weaker plants until the population comes into balance with the physical resources (Donald 1951, 1954; Harper et al. 1961; Yoda et al. 1963).

Emergence and initial survival values of all four species were much higher than those for long-term survival (Table 3). As previously mentioned, this is attributed to intraspecific competition and the severe drought in 1979 and 1980.

Cover data also provide a useful appraisal of species establishment because it shows soil stabilization effectiveness and plant vigor. Plant cover data collected in 1975 and 1980 are presented in Table 4. Canopy cover for all species was significantly ($P<.05$) higher on fertilized compared to unfertilized plots in 1980. However fertilizer application had no significant ($P>.05$) effect on canopy cover of any species during the first growing season. All species except fourwing saltbush had a significantly higher ($P<.05$) canopy cover in 1980 than 1975. The relatively poor canopy cover of fourwing saltbush in 1980 is attributed to severe cold during the winter of 1978 which caused much top growth winter-kill of this species in the Colstrip vicinity (Depuit et al. 1980). Ranger alfalfa had significantly more ($P<.05$) canopy and litter cover than crested and thickspike wheatgrass in 1980 when data were pooled across fertilizer treatments. However there was no significant difference ($P>.05$) between the two wheatgrasses. These data suggest that ranger alfalfa is a legume species well suited to conditions on mined lands at Colstrip. Holechek et al. (1981) reported good long term establishment of this species at Colstrip. Considering the climatic conditions of the past 2 years, the persistence and vigor of fairway crested wheatgrass, critana thickspike wheatgrass and fourwing saltbush indicate they are also well suited to conditions Colstrip.

The density of invading species on seeded plots in 1975 and 1980 is shown in Table 5 while Table 6 presents data on composition of density of invading species in 1980. The relatively high densities of invading species on fourwing saltbush plots is probably due to its low density and vigor compared to other species, which would tend to reduce competitive pressure on invading species. Densities of invading species did not differ significantly ($P>.05$) between fertilized and unfertilized treatments when data were pooled across

Table 3. Plant germination and survival of seeded species pooled across fertilizer treatments in 1975 and 1980.

Species[1][2]	% emergence	% survival between June 8, 1975 and August 15, 1975	% survival between August 15, 1975 and July 9, 1980	% survival between June 8, 1975 and July 9, 1980
Critana thickspike wheatgrass	58^a	80^a	34^a	27^a
Fairway crested wheatgrass	48^b	81^a	30^{ab}	24^a
Ranger alfalfa	48^b	88^a	16^b	14^b
Fourwing saltbush	44^b	93^a	23^b	21^a

[1]All statistical comparisons are valid only within column.
[2]Treatments with different letters are significantly different ($P<.05$) using New-Keuls Test.

Table 4. Plant cover in 1975 and 1980.

	Canopy cover 1975		Canopy cover 1980		Litter cover 1980	
Species[1][2][3]	F	U	F	U	F	U
Critana thickspike wheatgrass	21^a	15^a	30^a	20^b	40^a	5^b
Fairway crested wheatgrass	16^a	10^a	37^a	23^b	40^a	13^b
Ranger alfalfa	17^a	20^a	43^a	28^b	75^a	23^b
Fourwing saltbush	6^a	4^a	10^a	2^b	35^a	5^b

[1]Statistical comparisons are valid only across columns within years for each parameter.
[2]Treatments with different letters are significantly different ($P<.05$) using Newman-Keuls Test.
[3]Litter cover includes invading species.

Table 5. Density of invading species on seeded plots in 1975 and 1980 pooled across fertilization treatments.

Seed species	Invading plants/m²[1] Aug. 15, 1975	Invading plants/m²[1] July 19, 1980	Difference[2] (1975-1980)
Fairway crested wheatgrass	23[a]	2[c]	-21*
Critana thickspike wheatgrass	17[a]	5[c]	-12*
Ranger alfalfa	16[a]	17[b]	+ 1
Fourwing saltbush	29[a]	27[a]	- 2

[1]Values with different letters are significantly different ($P<.05$) using Newman-Keuls Test.
[2]Differences significant at $P<.05$ using the standard t-test.

species in either 1975 or 1980.

Crested and thickspike wheatgrass were the primary seeded species invading plots seeded to other species in 1980. Differentiation between these two species in 1980 was difficult in some cases because drought had retarded phenological development. However, on the basis of those plants that could be identified, crested wheatgrass comprised at least 75% of the invading wheatgrass density on plots seeded to other species. This species appears to be very aggressive on mined lands at Colstrip on the basis of this and other studies (Depuit et al. 1977, Depuit et al. 1978, Depuit and Coenenberg 1979).

Ranger alfalfa demonstrated little invasion into other plots. Research conducted at Colstrip and other locations in Montana has shown this species to be relatively nonaggressive (Ditterline et al. 1976, Depuit et al. 1978, Holechek et al. 1981).

No fourwing saltbush plants were encountered on plots where it was not seeded. Although this species has shown good initial establishment on mined lands at Colstrip, it has not reproduced itself where seeded or invaded surrounding areas even when both sexes of this dioecous species were seeded. This may be a limitation to its long-term persistence in mine spoils revegetation.

Lincoln smooth brome *(Bromus inermis)* and lutana cicer milkvetch *(Astragalus cicer)* were the primary nonseeded, perennial species that invaded the study. These two species were seeded in a mixture that was used to stabilize the area around the study. This mixture is described by Depuit and Coenenberg (1979). Smooth brome appears to be a relatively aggressive species on mined lands at Colstrip (Depuit et al. 1978). Cicer milkvetch, in contrast, has shown moderate aggressiveness (Meyn et al. 1976, Holechek et al. 1982).

In 1975 the dominant invading species on the study in both density and cover was Russian thistle *(Salsola kali)* followed by annual bromes *(Bromus tectorum* and *japonicus)* and annual sunflower *(Helianthus annuus)*. These weedy pioneer species were nearly absent from the study in 1980 probably because of the drought and intraspecific competition from seeded and nonseeded perennial species.

Less than 0.5 native nonseeded, perennial plants/m² occurred on the study in 1980 when data were pooled across species and fertilizer treatments. Native perennial species occurring on the study in trace amounts included western wheatgrass *(Agropyron smithii)*, green needlegrass *(Stipa viridula)*, needle-and-thread grass *(Stipa comata)*, Indian ricegrass *(Oryzopsis hymenoides)*, and soapweed yucca *(Yucca glauca)*. All these species except soapweed yucca were seeded in the mixture used to stabilize the surrounding area. Native rangeland dominated by needle-and-thread grass, prairie sandreed grass *(Calamovilfa longifolia)*, blue grama *(Bouteloua gracilis)*, western wheatgrass *(Agropyron smithii)*, prairie junegrass *(Koeleria cristata)*, little bluestem *(Schizachyrium scoparium)*, soapweed yucca, and silver sagebrush *(Artemisia cana)* existed approximately 70 m south of the study and 100 m north of the study. However, with the exception of soapweed yucca, only native perennial species seeded in the area surrounding the study occurred on the study plots. Therefore it appears that invasion of perennial species from the surrounding native rangeland was almost nonexistent during the first five years following seeding.

Conclusions

The following conclusions may be drawn for mine spoils in the Colstrip area based on the results from this study. They may necessarily have to be modified if applied to sites in the same region with differing conditions.

1) All four species (fairway crested wheatgrass, critana thickspike wheatgrass, ranger alfalfa, fourwing saltbush) are adapted for mined land revegetation at Colstrip.

2) An initial light rate of nitrogen and phosphorus fertilizer application can be used to improve the canopy cover and subsequent soil stabilization effectiveness of fairway crested wheatgrass, critana thickspike wheatgrass, ranger alfalfa, and fourwing saltbush on mined land at Colstrip.

3) The application of an initial light rate of nitrogen and phosphorus fertilizer had no effect on short or long term plant survival of the four species under investigation.

4) Fairway crested wheatgrass is a highly aggressive species on mined land at Colstrip on the basis of this and other research.

5) Critana thickspike wheatgrass is a native species well suited for use in seeding mixtures at Colstrip because of germination, survival, persistence, and soil stabilization characteristics.

6) Ranger alfalfa appears well suited to grass-legume mixtures at Colstrip because it establishes well but lacks aggressiveness.

7) Very little invasion of native species from outside the study occurred during the 5 years after seeding even though a seed source was available. This suggests that natural succession may be very slow on mined lands in the Colstrip area.

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Table 6. Density of invading species on seeded plots in 1980 pooled across fertilizer treatments.

Species seeded	*Agropyron*[1] spp.	Non seeded species density (plants/m²) *Bromus inermis*	*Salsola kali*	*Astragalus cicer*	*Medicago sativa*	Other
Fairway crested wheatgrass	1[2]	<1	<1	<1	<1	<1
Critana thickspike wheatgrass	2[3]	3	<1	<1	1	<1
Ranger alfalfa	12	<1	<1	0	-	<1
Fourwing saltbush	20	3	2	<1	1	<1

[1]Primarily *Agropyron cristatum.*
[2]*Agropyron dasystachyum* plants found in *Agropyron cristatum* plots.
[3]*Agropyron cristatum* plants found in *Agropyron dasystachyum* plots.

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