SEED VIABILITY AND SEEDLING VIGOR IN SELECTED PRAIRIE PLANTS

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The tallgrass prairie as mapped by Weaver and Clements (1938) does not exist in Montana; however, on ideal sites small isolated stands of prairie species occur. These stands are unique because they are on the margin of their range, of scattered occurrence, and of very limited extent. Concern for the continued existence of tall prairie species within southwestern Montana is spurred by the encroachment of surface coal mines and the number of stands already lost to all types of land disturbance. We would suspect that the reestablishment of species on the margin of their range would be very difficult due to the loss of many special microsites through soil and subsoil redistribution and new topographic characteristics concomitant with strip mine reclamation processes.

The use of indigenous species is required by law in Montana, but the biological characteristics of southwestern Montana ecotypes are unknown. Because of this concern for restoration of prairie species to strip mine reclamation lands, a project was begun in 1975 to evaluate seed and seedling biology for a large number of indigenous plant species. The objective of the research was to improve the potential for restoring each species into its original habitat. We are also concerned with the possibility that some species, due to very narrow site requirements, may not be capable of reestablishment.

METHODS

Seed collections were made from an area of the Fort Union Basin roughly outlined by Decker, Colstrip, and Alzada, Montana, and Gillette and Sheridan, Wyoming. Species from which seeds were collected included Andropogon gerardii Vitman, Andropogon hallii Hack., Elymus canadensis L., Dalea enneandra Nutt., Ratibida columnifera (Nutt.) Wooton & Standl., Panicum virgatum L., Schizachyrium scoparium Nash., Spartina pectinata Link, and Sporobolus cryptandrus (Torr.) A. Gray. One to several seed sources were obtained and seeds were stored in paper bags under dark conditions, 20°C. Of the species collected Andropogon gerardii, A. hallii, Dalea enneandra, Panicum virgatum, and Spartina pectinata are very limited in their distribution; the remainder of species are of common occurrence.

Seed Viability

To determine germination requirements seeds were placed on moist cellulose, treated with Captan fungicide (N-(trichloromethylthio)-4-Cyclohexene-1, 2-dicarboximide), and germinated in darkness at 5, 10, 15, 20, 25, and 30°C with and without 5°C cold 1, 2, or 3 month stratification. Four replicates of 25 seeds each were used per treatment. Germination was checked every 2 days for a 30-day period. Germination rate (days to 50 percent of final total germination) and total germination were calculated. All comparisons were made using a pairwise t-test.

Seedling Vigor

The seedling vigor of each prairie plant was tested by setting up probable field conditions: an early spring rain saturating the soil followed by a drought during the crucial period of seedling establishment. A control with adequate soil moisture was also included.

A loam topsoil screened through a 5-mm mesh was loosely packed into 500 or 700 ml root trainer columns, then saturated to field capacity (moisture content of 37.4 percent). Following optimal pretreatment freshly germinated seeds were transplanted into the rooting columns. Equal-aged individuals were utilized to eliminate variables caused by factors other than those being tested. Each set of seedlings for a particular species was tested over a 4-week period. Two treatments were applied: (1) control—soils kept moist throughout 4 weeks (continuous wet cycle) and (2) moisture stress—soils allowed to dry, no additional watering (drying cycle). Depending upon the species, eight to sixteen replicates were utilized for each treatment with additional replicates included to determine the weekly gravimetric soil moisture content.

The experiment was conducted under 25°C greenhouse conditions with a 16-hour light period. Measurements of the "above ground" growth or the photosynthetic area were taken each week. At the end of the fourth week "below ground" measurements were made after soil had been washed from the root systems. Mean, standard deviation, t-test for two means, skewness, and kurtosis values were computed for the above measurements.

RESULTS

Seed Viability

Analysis of the germination data for the nine species yields no apparent response patterns, rather each species is unique when all factors are considered (Table 1). On a factor by factor basis some groups are discernable. Andropogon gerardii and A. hallii are quite different from Sporobolus cryptandrus. Also, Schizachyrium scoparium and Dalea enneandra are somewhat different from each other.

Most significant results are those dealing with the temperature requirements. For germination, Sporobolus cryptandrus was most sensitive to cold temperatures, with Andropogon hallii germination occurring very poorly even when prestratification exceeded 30 days. All species germinated rapidly except Elymus canadensis which was the last to initiate germination and had the lowest overall germination rate.

Very High Seedling Vigor

The response of Dalea enneandra was characterized by no significant difference between the control and moisture stress groups (Table 2) with slightly increased growth under stress conditions (Fig. 1).
Table 1. Germination characteristics of some indigenous plants of southeastern Montana.

<table>
<thead>
<tr>
<th>Species</th>
<th>Seed Fill</th>
<th>After Ripening (months)</th>
<th>5°C Stratification Effects on Germination</th>
<th>Germination Rate</th>
<th>Range in Germination Percent at Optimum Temperature (%)</th>
<th>Optimum Germination Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Andropogon gerardii</td>
<td>Fair</td>
<td>12</td>
<td>30 days promoted, 60 days eliminated</td>
<td>Medium</td>
<td>12-94</td>
<td>Stratification followed by 25° or 30°</td>
</tr>
<tr>
<td>A. hallii</td>
<td>Good</td>
<td>12</td>
<td>30 days promoted, 90 days inhibited</td>
<td>Rapid</td>
<td>68-93</td>
<td>10° to 30°, 30°-20°, or 20°-5°</td>
</tr>
<tr>
<td>Dalea enneandra</td>
<td>Excellent</td>
<td>2</td>
<td>Variable</td>
<td>Rapid</td>
<td>62-91</td>
<td>20°, 30°-20°, 20°-5°, or stratification followed by 10°, 20°, or 30°</td>
</tr>
<tr>
<td>Elymus canadensis</td>
<td>Good</td>
<td>1</td>
<td>Develops short inhibition period</td>
<td>Slow</td>
<td>60-99</td>
<td>20° or 20°-5°</td>
</tr>
<tr>
<td>Panicum virgatum</td>
<td>Good</td>
<td>3</td>
<td>Promoted except in older seed</td>
<td>Medium</td>
<td>70-90</td>
<td>20° or 30°</td>
</tr>
<tr>
<td>Ratibida columnifera</td>
<td>Excellent</td>
<td>2</td>
<td>Older seed inhibited</td>
<td>Rapid</td>
<td>80-99</td>
<td>20° or 30°</td>
</tr>
<tr>
<td>Schizachyrium scoparium</td>
<td>Poor</td>
<td>10</td>
<td>30-60 days required</td>
<td>Slow</td>
<td>85-98</td>
<td>Stratification followed by 20°, 30°, or 30°-20°</td>
</tr>
<tr>
<td>Spartina pectinata</td>
<td>Excellent</td>
<td>4</td>
<td>Promoted</td>
<td>Rapid</td>
<td>70-91</td>
<td>20°, 30°, or 20°-5°</td>
</tr>
<tr>
<td>Sporobolus cryptandrus</td>
<td>Excellent</td>
<td>6</td>
<td>60 days required</td>
<td>Rapid</td>
<td>90-99</td>
<td>30°-20°</td>
</tr>
</tbody>
</table>

1 Days to initial germination/days to 50 percent of final total germination.

Under the moisture stress treatment, both above and below ground tissue displayed insignificant signs of stress at the end of 4 weeks (Table 2). This stress suggests very low requirements for additional water during initial establishment and excellent potential for vigorous establishment during desiccative periods of 4 weeks or more.

High Seeding Vigor

Panicum virgatum, Spartina pectinata, Andropogon hallii, and Elymus canadensis exhibited high seeding vigor in both the control and moisture stress treatments (Table 2). However, a reduction in growth under moisture stress did occur (Fig. 2) though no signs of stress were evident at the end of the 4-week desiccative period. Data indicate a high potential for survival under moisture stress conditions of 4 weeks or longer.

Relatively Low Seeding Vigor

Ratibida columnifera, Andropogon gerardii, and Schizachyrium scoparium showed a significant reduction in both above and below ground growth with increasing moisture stress when compared to their control (Table 2, Fig. 3). Additional water would be necessary for continued stable growth at the end of 2 weeks; therefore, the potential for vigorous establishment during a 4-week drought for these species is comparatively low (Fig. 3).

Very Low Seeding Vigor

Sporobolus cryptandrus exhibited great variance between the control and moisture stress treatments (Table 2, Fig. 4). Photosynthetic and root tissue were necrotic and suberized at the end of 3 weeks indicating high requirements for additional water and very poor potential for establishment during a desiccative period beyond 2 weeks.

Interspecific comparisons are compiled in Table 2 with six main factors averaged to determine a survival index (Column 18) of the nine species tested. This index indicates the following arrangement of seedling vigor response during moisture stress on a relative basis: excellent (Panicum virgatum, Elymus canadensis, and Andropogon hallii), good (Dalea enneandra and Spartina pectinata), moderate (Ratibida columnifera), poor (Andropogon gerardii), and very poor (Schizachyrium scoparium and Sporobolus cryptandrus).

CONCLUSIONS

Andropogon gerardii appears to have a low potential for reestablishment on disturbed areas based on low and variable germination, low probability of optimal germination temperatures occurring naturally, and poor seedling vigor. Best establishment should be expected from seeds over 1 year old. McWilliams (1950) found seeds reached peak germination at 4 years for a North Dakota seed source. Also, seed lots should be checked for high seed fill and vigor. Planting appears to be best in spring when soil temperature is cool but with a high probability of significant warming in 30 days or less. Maintenance of good soil moisture conditions appears to be necessary.

Andropogon hallii possesses many characteristics indicating high reestablishment potential. These characteristics are good seed fill, a broad range of optimal germination temperatures, pronounced seed vigor, and high seedling vigor even with soil drought. High seed vigor was also reported by Tolstaud (1941). We found seeds should be afterripened for at least 1 year and it may retain high germination up to 7 years (McWilliams, 1950). Plantings appears to be best anytime in the spring.

Dalea enneandra has excellent potential for reestablishment on disturbed land. We found high seed fill, vigorous seed germination at a wide range of temperatures, and excellent seedling vigor with strong resistance to soil drought. Consistently high losses of seedlings immediately after germination, however, pose a problem. Plantings should be successful both in the fall and spring.

Elymus canadensis possesses excellent seedling vigor; however, it was slow to germinate being quite variable in total germination and somewhat restricted in its germination requirements. Germination was generally high; a result also obtained by Greene and Curtis (1950) and McWilliams (1950). McWilliams also noted that germination re-
Table 2. Interspecific ranking of species based on seedling growth characteristics as an index to their potential survival under moisture stress conditions. Rankings are based only on moisture stress data except columns 2, 6, and 11 which have been adjusted to a control before interspecific comparisons were made. All rankings are derived from measurements at the end of four weeks except columns 1, 16, 17, and 18.

| Rank | Initial Establishment | Variance of Reaction-Control | Cumulative Leaf-Stem Length | Plant Height | Above Ground Biomass | Above Ground Biomass Control vs. Moisture Stress | Composite Above Ground Rating Average of Columns 3,4,5,6, & 7 | Primary Root Length | Below Ground Biomass | Below Ground Biomass Control vs. Moisture Stress | Composite Below Ground Rating Average of Columns 9,10,11, & 12 | Total Biomass of Control | Final Establishment | Soil Moisture Utilization Index | Potential for Extended Stress Period | Survival Index (Average of Columns 2,8,13, 15, 16, & 17) |
|------|----------------------|------------------------------|----------------------------|-------------|---------------------|-----------------------------------------------|-------------------------------------------------|------------------|------------------|-----------------------------------------------|-----------------------------------------------|------------------|------------------|-------------------------------|---------------------------------|
| 1    | Andropogon gerardii  | 5                            | 3                          | 3            | 2                   | 2                                             | 2.4                                             | 3                | 2                | 2                                             | 2.2                                            | 2                | 5                | 3                             | 1.26                             |
| 2    | A. hallii            | 5                            | 3                          | 5            | 4                   | 4                                             | 4.3                                             | 4                | 4                | 4                                             | 4                                             | 3                | 5                | 4                             | 4.0                              |
| 3    | Dalea enneandra      | 2                            | 3                          | 5            | 4                   | 4                                             | 4.6                                             | 4                | 5                | 4                                             | 4.5                                            | 3                | 4                | 4                             | 3.8                              |
| 4    | Elymus canadensis    | 5                            | 5                          | 5            | 5                   | 3                                             | 4.0                                             | 4                | 3                | 3                                             | 3.8                                            | 5                | 5                | 5                             | 3.8                              |
| 5    | Panicum virgatum     | 5                            | 5                          | 5            | 5                   | 5                                             | 4.4                                             | 5                | 5                | 5                                             | 5.0                                            | 5                | 5                | 5                             | 4.4                              |
| 6    | Ratibida columnifera | 3                            | 2                          | 2            | 2                   | 1                                             | 2.4                                             | 5                | 3                | 4                                             | 3.5                                            | 4                | 5                | 3                             | 3.5                              |
| 7    | Schizachyrium scoparium | 3                          | 2                          | 2            | 2                   | 1                                             | 1.8                                             | 3                | 2                | 1                                             | 2.2                                            | 4                | 2                | 1                             | 1.8                              |
| 8    | Spartina pectinata   | 3                            | 3                          | 5            | 5                   | 4                                             | 4.6                                             | 4                | 5                | 4                                             | 4.5                                            | 4                | 4                | 4                             | 3.7                              |
| 9    | Sporobolus cryptandrus | 3                          | 3                          | 1            | 1                   | 1                                             | 1.0                                             | 1                | 1                | 1                                             | 1.0                                            | 1                | 1                             | 1                             | 1.7                              |

Ranking by column number
1. Percent survival after 1 week of growth: 1 = 0-24 percent, 2 = 25-49 percent, 3 = 50-74 percent, 4 = 75-99 percent, and 5 = 100 percent.
2. Average of greatest root and shoot variance expressed by skewness and kurtosis values: 1 = highly significant**, 3 = significant difference at 95 percent*, and 5 = not significant (NS).
3. 1 = 0-24 mm, 2 = 25-49 mm, 3 = 50-74 mm, 4 = 75-99 mm, and 5 = 100+ mm.
4. 1 = 0-9 mg, 2 = 10-24 mg, 3 = 25-49 mg, 4 = 50-74 mg, and 5 = 75-100+ mg.
5. 1 = 0-0.9 mg, 2 = 1-2.9 mg, 3 = 3-4.9 mg, 4 = 5-5.9 mg, and 5 = 6-10+ mg.
6. Significant difference at 95 percent*, highly significant**, not significant (NS), and magnitude of calculated t value (t’ = 2.6-2.56):
   1 = **/6-10+, 2 = **/3.5-5.9, 3 = */2.51-3.49, 4 = NS/2-2.5, and 5 = NS/1.99-0.5.
7. Visual: 1 = necrotic, 2 = chlorotic and wilted, 3 = stable, 4 = moderate, and 5 = vigorous.
8. Composite average.
9. 1 = 0-24 mm, 2 = 25-49 mm, 3 = 50-74 mm, 4 = 75-99 mm, and 5 = 100-150+ mm.
10. 1 = 0-0.9 mg, 2 = 1-2.9 mg, 3 = 3-4.9 mg, 4 = 5-5.9 mg, and 5 = 6-10+ mg.
11. Significant difference at 95 percent*, highly significant**, not significant (NS), and magnitude of calculated t value (t’ = 2.16-3.35):
    1 = **/6+, 2 = **/3.5-5.9, 3 = */2.51-3.49, 4 = NS/2-2.5, and 5 = NS/1.99-0.5.
13. Composite average.
14. 1 = 1 mg, 2 = 1-4.9 mg, 3 = 5-9.9 mg, 4 = 10-14.9 mg, and 5 = 15-20+ mg.
15. Percent survival after 4 weeks of growth which includes loss after initial establishment and loss due to moisture stress:
    1 = 0-24 percent, 2 = 25-49 percent, 3 = 50-74 percent, 4 = 75-99 percent, and 5 = 100 percent.
16. Percent H2O used weeks active growth: 1 = very poor, 2 = poor, 3 = moderate, 4 = good, and 5 = excellent.
17. Visual: 1 = very poor, 2 = poor, 3 = moderate, 4 = good, and 5 = excellent.
18. 1 = very poor, 2 = poor, 3 = moderate, 4 = good, and 5 = excellent.
Figure 1. Dalea enneandra. Mean cumulative shoot and primary root growth at the end of four weeks.

Figure 2. Elymus canadensis. Mean cumulative shoot and primary root growth at the end of four weeks.

Figure 3. Schizachyrium scoparium. Mean cumulative shoot and primary root growth at the end of four weeks.

Figure 4. Sporobolus cryptandrus. Mean cumulative shoot and primary root growth at the end of four weeks.

maintained high up through 3 years of seed age. Spring planting in warm moist soil appears to be best due to an inhibition period developed from cold stratification. Additional soil moisture appears necessary after 3 weeks of growth to maintain maximum seedling vigor.

Panicum virgatum germinated well and exhibited exceptional seedling vigor, although with moisture stress shoot growth was reduced. It should do well in reestablishment efforts. Limitations appear to be a slower rate of germination and high germination temperature requirements. We found both a shorter afterripening period and higher germination than did McWilliams (1950) and Robocker et al. (1953). Our results indicate both fall and spring planting should be acceptable.

Ratibida columnifera appears to possess only moderate potential for reestablishment. Sorensen and Holden (1974) were able to obtain germination only by puncture of the seed coat; however, we consistently obtained high germination without doing so. Although Jacobsen (1974) rated both seedling vigor and seed quality as excellent we rank seedling vigor as only moderate. Seed quality and production, however, was high for our seed sources. Afterripening and stratification response indicate both fall and spring plantings of new seed would be acceptable. Jacobsen (1974) indicated spring planting was required.

Schizachyrium scoparium appears to possess very poor seed and seedling vigor. Although we obtained very high germination from seedlots roughly 1 year old, McWilliams (1950) found peak germination in seeds 7-8 years of age. Coukos (1944) found dormancy began to break at 18 months for Missouri seed while ours required only 10 months for complete dormancy breaking. Fall planting of seed a year or more old appears best based on our data.

Spartina pectinata seed germinated rapidly and seedlings grew vigorously, even under soil moisture stress, to 4 weeks of age. The main limiting factor was early seedling mortality. Our data indicate that fall planting would be the most successful.

Sporobolus cryptandrus would not be expected to do well in reestablishment efforts. Seed required stratification, as reported by Tolstead (1941) and Toole (1941), and restricted temperatures to germinate. Seedlings were of low vigor and required constant high soil moisture. Our results suggest fall planting as being the best possible procedure.
**Sporobolus cryptandrus** may be a problem species in reestablishment, but we suspect other factors compensate for those limitations observed in the laboratory experiments. For example, excellent seed production and seed quality increase its probability of success as evidenced by field observation.

We foresee considerable difficulty in reestablishment of *Andropogon gerardii* and *Schizachyrium scoparium* on disturbed lands by direct seeding. The problems we observed may be overcome by use of adaptable varieties as Wilson (1972) tentatively recommended or by ecotypic selection of native materials. An alternative would be propagation of seedlings which Nuzzo (1976) found successful on Wisconsin roadsides. Based on species-site relationships both *Andropogon hallii* and *Dalea enneandra* show good potential for use on uplands, while *Panicum virgatum*, *Elymus canadensis*, and *Spartina pectinata* show good potential for swale sites.

**SUMMARY**

Tallgrass prairie species are present in isolated stands in southeastern Montana. A number of such stands have already been lost through surface coal mining activities and those remaining are endangered by the expanding industry. Wherever possible, destruction must be prevented, and, in addition, the tallgrass prairie species must be reestablished on mined lands. Reestablishment requires an understanding of their regeneration characteristics, particularly seed vitality and seedling vigor.

Nine common tallgrass prairie species were studied and their seed vitality and seedling vigor determined. Five of these species are very limited in their distribution though they are frequently abundant in small localized stands. Seed germination rate and total was measured at temperatures ranging from 5°C to 30°C with and without preceding stratification. Seedlings were also grown under artificial drought conditions to determine root and shoot response.

*Andropogon gerardii* and *Schizachyrium scoparium* both possess poor seed viability and poor seedling vigor. Considerable difficulty is foreseen in reestablishment on coal mine spoils. *Sporobolus cryptandrus* possesses very low seeding vigor under moisture stress conditions. Therefore reestablishment would be expected from *Ratibida columnifera* since germination and seedling vigor are only fair under stress conditions. Reestablishment of *Dalea enneandra* and *Spartina pectinata* is expected to be limited only by early seedling mortality. Vigor of seed and seedlings appears quite high. *Elymus canadensis* should reestablish well, however limitations in germination and an apparent necessity for fair moisture conditions may give poor results in some years. Both *Panicum virgatum* and *Andropogon hallii* possess excellent seed and seedling vigor. Reestablishment is expected to be consistently successful.

Since some species possess inherent reestablishment difficulties, well-designed studies are needed to select the adaptable genotypes for perpetuation of the species on the reclaimed coal mines in southeastern Montana.

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**LITERATURE CITED**


