# TECHNIQUES USED TO ESTABLISH, MAINTAIN AND ENHANCE GRASSLAND SEASONAL VARIETY ON THE GLENHAROLD MINE IN NORTH DAKOTA[1]

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A summary of revegetation techniques used on several rangeland reclamation areas and supporting vegetative data relative to diversity and seasonal variety are presented. Techniques used to improve these characteristics include a late spring seeding period, improved seed mix ratios and the use of native hay mulch. Management and enhancement techniques include prescribed burning, time-specific applications of non-selective herbicides and interseeding with warm season grasses.

## INTRODUCTION

The Surface Mining Control and Reclamation Act of 1977 (SMCRA, Pl. 95-87) requires that reclaimed native grassland have a diverse, effective and permanent vegetative cover of the same seasonal variety native to the area. In the strictest interpretation, this could mean that at the end of the reclamation liability period, a reestablished grassland must have the same species composition and community structure that existed prior to mining. However, experience has shown that regardless of how well the revegetation process is planned and implemented, the diversity and seasonal variety characteristics of an initial stand can vary considerably.

Reestablishing native grasslands with these characteristics is dependent upon many variables. Those addressed in the reclamation plan that may be considered controllable include (1) post-mine topography and grading plans, (2) topsoil and subsoil removal and respreading techniques, (3) seedbed preparation, (4) seed availability, quality and seed mix plans, (5) seeding and mulching techniques, (6) soil water management including irrigation, and (7) management during and following establishment.

Other variables less predictable or not controllable include (1) soil quanity and quality, (2) weather, and (3) competition from invading cool season perennials such as quackgrass (*Agropyron repens*), bluegrass (*Poa* spp.), smooth brome (*Bromus inermis*) and foxtail barley (*Hordeum jubatum*). Because of these variables, it may be necessary to employ one or several management techniques to maintain or modify diversity and seasonal variety during the reclamation liability period.

Choosing a particular establishment and management plan necessarily requires justification that it will produce the results expected given the proper set of variables. Failure to manipulate the controllable variables may result in additional material, labor, and bonding costs if performance standards are not met at the end of the liability period. When considering the latter, it is important to recognize deficiencies early, particularly if management procedures cause reinitiation of the ten-year liability period.

Grassland reclamation efforts at the Glenharold Mine have shown that seasonal variety and diversity may not be attained unless special establishment and management techniques are implemented. In order to develop these techniques and to better understand their effects, several establishment and management strategies have been implemented on old reclamation areas in preparation for the more stringent requirements outlined in SMCRA.

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## AREA DESCRIPTION

The Glenharold Mine is located in mixed grass prairie of eastern Mercer County, North Dakota, approximately 80 km (50 miles) northwest of Bismarck. It is owned by Basin Cooperative Services, a subsidiary of Basin Electric Power Cooperative. Mining and reclamation activities occur within the Missouri Breaks, topographically bordered by the gently rolling Upland Plateau to the south and west, and the low lying Missouri River floodplain on the northeast.

Soils include mollisols and entisols underlain by sodic montmorillonitic clays. Major range sites include shallow, silty, thin claypan and sandy sites. Up to 5 feet of soil, removed in 2 lifts, is stockpiled for reclamation.

Mean annual precipitation averages 44 cm (17.3 inches) with 9 cm (3.5 inches) occurring during June and 7.6 cm (3 inches) in July. Native grassland reclamation as related to precipitation indicates adequate June moisture and temperatures to be critical for establishing a stand with good seasonal variety. Based on several years of data from two onsite weather stations, the mean June precipitation averaged 7.4 cm (2.9 inches) with the low 4.6 cm (1.9 inches) occurring in 1980 and the high 12.2 cm (4.8 inches) occurring in 1982. Total growing season precipitation (May-September) from 1979 through 1984 show deficits occurring in 1983 -9.4 cm (3.7 inches) and 1984 -16.5 cm (6.5 inches). However, despite these deficiencies, adequate rainfall in June resulted in successful stands both years.

## VEGETATION MONITORING AREAS

Vegetation monitoring and research data summarized in this paper were obtained from three reclamation areas. Area A, seeded in 1975; Area B seeded in 1979; and Area C which was seeded over a three year period from 1981 through 1983. Various establishment and management techniques have been applied to large parcels and trial plots within these areas since 1979.

### Area A

The seed mixture used on area A (Table 1) was developed for mined land reclamation by the Soil Conservation Service (SCS) and was used until May 3, 1978 when state regulations required diversity and seasonal variety. Data collected in 1983 show sideoats grama (*Bouteloua curtipendula*) to be the only warm season species present comprising only 4 percent of the total live basal cover.

Table 1.--Species and seeding rate for the SCS spoilbank mixture used in Area A.

| Species | Seeding Rates | |
|---|---|---|
| | Kg/ha (PLS)[1] | PLS/$m^2$ |
| Western wheatgrass | 6.7 | 161 |
| Intermediate wheatgrass | 1.7 | 32 |
| Green needlegrass | 4.5 | 176 |
| Sideoats grama | 3.4 | 140 |
| Little bluestem | 2.2 | 127 |
| Sweetclover | 1.1 | 65 |
| Total | 19.6 | 701 |

[1]PLS - pure live seed.

### Area B

The seed mixture used on area B (Table 2) included a higher proportion of warm season species. Based on the amount of pure live seed (PLS) per $m^2$, the ratio of cool to warm PLS was increased from 1.4:1 on area A to 1:3.4 on area B. This site, described as Area 1 by Williamson (1984), is one of three study sites used to assess seed mix ratios and establishment techniques to improve seasonality on reestablished rangelands. In 1983, this area was one of three stands selected for a prescribed burning study which is described in more detail later in this paper.

Table 2.--Species and seeding rate for Area B.

| Species | Seeding Rates | |
|---|---|---|
| | Kg/ha (PLS)[1] | PLS/$m^2$ |
| Sideoats grama | 10.1 | 419 |
| Little bluestem | 4.5 | 247 |
| Blue grama | 1.1 | 172 |
| Slender wheatgrass | 2.2 | 75 |
| Western wheatgrass | 3.4 | 86 |
| Green needlegrass | 2.2 | 86 |
| Sweetclover | 1.1 | 65 |
| Total | 24.6 | 1,151 |

[1]PLS - pure live seed.

### Area C

Major portions of area C were seeded over a period of three years from 1981 through 1983 to the same seed mixture (Table 3). The proportion of cool:warm season PLS/$m^2$ was changed from 1:3.4 (area B) to 1:4.7 and included five additional warm season species. Selected stands were subjected to different mulch treatments and management trials including burning and the use of non-selective herbicides. Data presented in this paper were collected from stands established in 1981 and 1982.

Table 3.--Species and seeding rate for Area C.

| Species | Seeding Rates Kg/ha (PLS)[1] | PLS/$m^2$ |
|---|---|---|
| Western wheatgrass | 5.6 | 151 |
| Intermediate wheatgrass | 2.2 | 43 |
| Green needlegrass | 2.2 | 88 |
| Sideoats grama | 2.2 | 95 |
| Blue grama | 1.1 | 202 |
| Little bluestem | 2.2 | 127 |
| Sand bluestem | 1.1 | 28 |
| Big bluestem | 1.1 | 41 |
| Prairie sandreed | 1.1 | 74 |
| Switchgrass | 1.1 | 96 |
| Sand dropseed | .6 | 654 |
| Sweetclover | 1.1 | 64 |
| Total | 21.6 | 1,663 |

[1]PLS - pure live seed.

## SAMPLING METHODS

Frequency, productivity and cover data have been collected on reclamation areas and stands of special interest since 1979. Frequency and production data were collected using randomly placed 0.25 $m^2$ quadrats. Productivity quadrats were clipped in July during community peak standing crop and samples were oven dried to a constant weight.

Total cover measurements were obtained using the 10-point intercept frame described by Cook and Bonham (1977). Frames were placed randomly on large areas or trial plots during late July and early August. Live basal cover is expressed as a percentage based on total live hits recorded from the total number of points taken. Bare ground and litter were recorded simultaneously to obtain percent total ground cover.

All data were collected by species then grouped into categories including cool season, warm season, other grasses, sedges and forbs. Frequency data are presented by major species and groups, while cover and productivity data are summarized by groups.

Computer analyses comparing cover and productivity means utilized the Statistical Analyses System Program TTEST (SAS, 1982) and Northwest Analytical, Inc. STATPAK Program MTESTS: Ordinary t-statistic (NWA, 1984).

## GRASSLAND ESTABLISHMENT

### Seeding Practices

Establishment techniques utilized the past seven years include seeding into a firm seedbed or interseeding into a cover crop stubble on areas respread with topsoil the previous year. Interseeding is generally preceeded by an application of a non-selective herbicide to minimize competition from weeds and undesirable annual and perennial grasses. Rangeland areas are seeded to native grass mixtures containing warm and cool season species. Williamson (1984) describes in more detail establishment techniques that have resulted in seasonally balanced stands since 1979. In summary, his study and subsequent field operations support the importance of proper seedbed preparation, and seed placement. Additionally, three techniques substantially improved initial stand establishment and diversity. These are (1) supplemental irrigation if necessary, (2) weighting the seed mix to include a high percentage of warm season pure live seed, and (3) seeding in late spring.

The importance of seeding during the proper period was demonstrated in Williamson's study and has been apparent in the establishment of subsequent stands at the mine. Two adjacent areas within study area C seeded in 1981 to the same mixture (Table 3) show frequency and live basal cover differences that have been experienced between an early and late spring seeding date (Table 4).

Table 4.--Species frequencies and percent live basal cover by group for two adjacent sites in Area C seeded in mid May and mid June of 1981.

| Species | 1983 May | 1983 June | 1985 May | 1985 June |
|---|---|---|---|---|
| | ---------- | % | ---------- | |
| Sideoats grama*[1] | 77 | 90 | 50 | 67 |
| Blue grama* | 3 | 13 | 3 | 17 |
| Little bluestem* | 33 | 65 | 20 | 47 |
| Sand bluestem* | 20 | 35 | 3 | 27 |
| Big bluestem* | 10 | 10 | 0 | 17 |
| Prairie sandreed* | 3 | 18 | 0 | 17 |
| Switchgrass* | 0 | 45 | 0 | 50 |
| Sand dropseed* | 50 | 35 | 17 | 47 |
| Percent Warm LBC[2] | N/A[3] | N/A | .6 | 2.5ab[4] |
| Western wheatgrass* | 100 | 100 | 93 | 100 |
| Intermediate wheatgrass* | 97 | 55 | 47 | 40 |
| Green needlegrass* | 80 | 50 | 80 | 73 |
| Prairie junegrass | 7 | N/A | 0 | 0 |
| Smooth brome | 17 | N/A | 40 | 20 |
| Quackgrass | 3 | N/A | 0 | 3 |
| Percent Cool LBC | N/A | N/A | 2.9ab | 1.6 |
| Other grasses[5] | 17 | N/A | 30 | 23 |
| *Carex* spp. | 0 | N/A | 7 | 13 |
| Forbs | 3 | N/A | 43 | 60 |
| Total Percent LBC | N/A | N/A | 3.7 | 4.2 |

[1]Species marked with an asterisk were seeded.
[2]LBC = Live basal cover.
[3]N/A = Data not available.
[4]Significance as follows: (a) means within groups that were significantly ($p<.05$) greater between seeding dates; (b) means between groups that were significantly ($p<.05$) greater within each seeding date.
[5]Other grasses include Canada wildrye, Kentucky bluegrass, Indiangrass, and porcupine grass.

Live basal cover data collected in 1985 show significant ($p<.05$) differences between cool season and warm season groups due to the different seeding dates. The ratio of cool season to warm season species was 5.6:1 on the mid May seeding and 1:1.6 on the June seeding. No differences in total live basal cover or total ground cover (live + dead) were found in 1985. Total ground cover exceeded 90 percent in 1985.

In addition to the late spring seeding period it is important to weight the seed mixture to include a higher percentage of warm season pure live seed. This has contributed to good seasonal variety over seven growing seasons on area B. Tables 5 and 6 summarize live basal cover and productivity by groups for this area from 1980 through 1985. Invading perennial grasses that fall in the "other" category include smooth brome, quackgrass and bluegrass.

Based on live basal cover measurements, the proportion of cool to warm season species changed from 1:4.3 in the year following seeding to approximately 1:1 in 1985. Major changes were attributed to a gradual replacement of slender wheatgrass (*Agropyron trachycaulum*) which contributed 80 percent of the total cool season live basal cover in 1981, with western wheatgrass (*Agropyron smithii*), which contributed 82 percent of the total by 1985. Total cool season live cover increased significantly ($p<.05$) from 1980 through 1985. Warm season live basal cover increased from 1980 through 1982 primarily due to increases in sideoats grama and blue grama (*Bouteloua gracilis*) but decreased significantly ($p<.05$) from a high of 4.3 and 1.9 percent respectively in 1982 to 1.7 and 0.1 in 1985. Also, there was a significant ($p<.05$) decrease in warm season cover from 1980 to 1985. Total live basal cover increased from 1980 to 1982 then declined until 1985. Although changes in cool and warm season live cover occurred, no significant changes in total live basal cover were recorded between 1980 and 1985.

Productivity ratios between cool and warm season groups changed from approximately 1:1 the year following establishment to 2:1 in 1982 and remained proportionally the same through 1985. Productivity changes for major cool season species were relative to changes in live basal cover. In 1981 and 1982, slender wheatgrass comprised 85-95 percent of the total cool season productivity while in 1985, western wheatgrass made up 85 percent of this total. Although warm season productivity declined from 1980 to 1985 due to declines in *Bouteloua* spp., this decrease was not significant.

When compared to the silty reference area in 1984 and 1985, production ratios of major cool and warm season species were similar. Silty reference area cool:warm season ratios were 3:1 in 1984 and 2:1 in 1985. Area B ratios were 2.8:1 in 1984 and 2:1 in 1985.

Table 5.--Percent live basal cover on reestablished rangeland (Area B) by species groups for 1980-1985.

| Group | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|---|
| | % | | | | | |
| Cool season | 1.0 | 2.4a[1] | 2.5 | 1.2a | 2.0a | 2.0c |
| Warm season | 4.3b | 6.1ab | 6.3b | 3.9ab | 2.6a | 1.9c |
| Other grasses | - | 0.1 | 0.3 | 0.0 | 0.1 | 0.0 |
| Total LBC[2] | 5.3 | 8.6a | 9.1 | 5.1a | 4.7 | 3.9 |
| Relative % cool | 18.9 | 27.9 | 27.5 | 23.5 | 42.6 | 51.3 |
| Relative % warm | 81.1 | 70.9 | 69.2 | 76.5 | 55.3 | 48.7 |
| Relative % other | - | 1.2 | 3.3 | 0.0 | 2.1 | 0.0 |

[1]Significance as follows: (a) means within groups that were significantly ($p<.05$) different when compared to a previous year; (b) means between groups that were significantly ($p<.05$) greater; (c) means that changed significantly ($p<.05$) when comparing 1980 to 1985.

[2]LBC = live basal cover.

Table 6.--Productivity on reestablished rangeland (Area B) by species groups for 1980-1985.

| Group | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|---|
| | kg/ha | | | | | |
| Cool season | 840 | 2212 ab[1] | 2756ab | n/d[2] | 1475ab | 1457bc |
| Warm season | 900 | 1120 | 1428a | n/d | 524a | 712 |
| Other grasses | 212 | 0 | 60 | n/d | 95 | 140 |
| Forb | 96 | 0.4 | 12 | n/d | 64 | 64 |
| Total | 2048 | 3332.4a | 4256a | - | 2158a | 2373a |
| Relative % cool | 41.0 | 66.4 | 64.8 | - | 68.4 | 61.4 |
| Relative % warm | 43.9 | 33.6 | 33.6 | - | 24.3 | 30.0 |
| Relative % other | 10.4 | 0 | 1.4 | - | 4.4 | 5.9 |
| Relative % forb | 4.7 | tr | .2 | - | 2.9 | 2.7 |

[1]Significance as follows: (a) means within groups that were significantly ($p<.05$) different when compared to a previous year; (b) means between groups that were significantly ($p<.05$) greater; (c) means that changed significantly ($p<.05$) from 1980 to 1985.

[2]n/d = No data collected in 1983.

## Mulching Practices

Seeding is followed by a mulch application of either slough or native prairie hay. Slough hay, obtained from seasonal wetlands, may consist of whitetop (*Scolochlou festucacea*), sloughgrass (*Beckmannia syzigachne*), reed canarygrass (*Phalaris arundinacea*), common spikerush (*Eleocharis palustris*), and lowland sedges (*Carex* spp.). Slough hay is preferred over straw mulch because of its stem length and durability. Also competition from wetland species is less likely to be a problem on upland grassland areas. All rangeland is mulched to maximize infiltration, and to minimize seedling losses due to wind and water erosion.

During 1981 and 1982, native prairie hay mulch was used following seeding in area C to explore its capability as a mulch and potential seed source. Earlier studies (Ries et.al. 1980) were favorable for its application to mine land reclamation. In 1981, native hay was cut during mid-August from prairie where sands and sandy range sites were common along with low lying areas influenced by a high water table. This mulch was applied on portions of area C where premine range sites were similar. Hay samples collected from bales were taken for germination tests at the Agricultural Research Station in Mandan. Based on the results of these tests[3], perennial grass seed per 100 grams of mulch and potential seed per square meter using a 3,362 kg/ha (3,000 lb/ac) mulch application are presented in Table 7.

[3]Reis, R.E. 1982. Personal Correspondence. USDA Agricultural Research Service, Mandan, North Dakota 58554.

Table 7.--Potential seed from native hay mulch used on Area C reclamation areas in 1982.

| Species | Mean no. of Seedlings[1] Per 100 gms of mulch | Potential Seed/m² from 3362 kg/ha |
|---|---|---|
| Blue grama | 32.2 | 108 |
| Needle and thread | .3 | 1 |
| Big bluestem | .3 | 1 |
| Sand dropseed | 25.1 | 84 |
| Kentucky bluegrass | 5.3 | 18 |
| Little bluestem | 26.2 | 88 |
| Prairie Junegrass | 3.2 | 11 |
| Porcupine grass | .9 | 3 |
| Total perennial grass seed | 93.5 | 314 |

[1]Mean derived from four replications.

Other perennial grasses found on native hay mulched areas since 1981 included Canada wildrye (*Elymus canadensis*), plains muhly (*Muhlenbergia racemosa*), sandberg bluegrass (*Poa secunda*), Indiangrass (*Sorghastrum nutans*), smooth brome, and crested wheatgrass (*Agropyron cristatum*). Perennial forbs, half shrub and shrubs include horsetail (*Equisetum kansanum*), prairie wildrose (*Rosa arkansana*), wild sunflower (*Helianthus maximiliani*), round-headed blazing star (*Liatris scariosa*), white sage (*Artemisia ludoviciana*), sand sunflower (*Helianthus petiolaris*), green sage (*Artemisia glauca*), fringed sage (*Artemisia frigida*), marestail (*Hippuris vulgaris*), spiderwort (*Tradescantia occidentalis*), western wallflower (*Eryismum asperum*) and torch flower (*Geum triflorum*).

Since establishment, however, competition from cool season species, primarily intermediate wheatgrass (*Agropyron intermedium*), have reduced frequencies, species richness and live basal cover of native warm season species and forbs. The dominance of intermediate wheatgrass was obvious the second growing season and consequently management plans were implemented to decrease its competitive advantage.

## MANAGEMENT AND ENHANCEMENT

### Herbicide Applications

Native grassland stands have been established where aggressive introduced cool season species have affected diversity and seasonal variety in subsequent years. These species were either included in the seed mix or became voluntarily established from stockpiled soil or mulch sources. In 1983, trial plots were selected on the 1982 native hay mulched stand of area C to test the effects of suppressing cool season competition using a non-selective herbicide. This technique was used successfully by Waller and Schmidt (1983) to improve seasonality on tall grass range in eastern Nebraska. A single application of glyphosate (Roundup) was applied at .85 kg/ha using a water solution of 280 l/ha during early May prior to growth initiation of warm season species. Frequency data by species and percent live basal cover by groups are presented in Table 8.

Eliminating competition from intermediate wheatgrass resulted in significant ($p<.05$) increases in warm season live basal cover on spray plots each year from 1983 through 1985. During the same period, live basal cover of warm season species on the control declined significantly ($p<.05$) while live basal cover of cool season species remained the same. Cool season live cover on the spray plots declined following spraying in 1983, remained the same in 1984, then increased significantly ($p<.05$) in 1985. This increase is attributed to a significant ($p<.05$) increase in western wheatgrass.

Table 8.—Species frequencies and percent live basal cover by group for control and glyphosate treated trial plots on a 1982 seeded/native hay mulch reclamation grassland area (Area C).

| Species[1] | 1982 Control[2] | 1983 Control | 1983 Spray | 1984 Control | 1984 Spray | 1985 Control | 1985 Spray |
|---|---|---|---|---|---|---|---|
| | | | % | | | | |
| Little bluestem* | 45 | 0 | 43 | 37 | 43 | 20 | 47 |
| Big bluestem* | 43 | 0 | 40 | 33 | 27 | 17 | 23 |
| Sand bluestem* | - | 10 | 53 | 17 | 63 | 7 | 53 |
| Switchgrass* | 25 | 33 | 50 | 23 | 60 | 23 | 60 |
| Sand dropseed* | 40 | 37 | 33 | 33 | 47 | 7 | 47 |
| Blue grama* | 65 | 83 | 90 | 80 | 97 | 63 | 67 |
| Sideoats grama* | 35 | 0 | 43 | 30 | 33 | 13 | 40 |
| Prairie sandreed* | 5 | 13 | 13 | 23 | 27 | 0 | 33 |
| Percent LBC | 1.1 | 1.1 | 1.5b[3] | 0.4c | 2.4abc | 0.3c | 4.0abcd |
| Western wheatgrass* | 100 | 97 | 43 | 100 | 73 | 97 | 97 |
| Green needlegrass* | 20 | 20 | 0 | 13 | 0 | 3 | 3 |
| Intermediate wheatgrass* | 100 | 100 | 0 | 100 | 10 | 100 | 50 |
| Slender wheatgrass | 35 | 17 | 0 | 3 | 7 | 37 | 13 |
| Canada wildrye | 8 | 13 | 0 | 0 | 0 | 0 | 0 |
| Smooth brome | 10 | 0 | 13 | 27 | 0 | 70 | 3 |
| Percent LBC | 1.4 | 2.1 | 0.4a | 1.4b | 0.1ac | 2.1b | .7ac |
| *Poa* spp. | 13 | 27 | 0 | 23 | 0 | 13 | 3 |
| Minor grasses | 13 | 17 | 10 | 10 | 0 | 50 | 3 |
| *Carex* spp. | 5 | 3 | 0 | 10 | 3 | 3 | 7 |
| Forbs | 45 | 27 | 63 | 20 | 50 | 20 | 40 |
| Total percent LBC | 2.8 | 3.2 | 2.2a | 1.8c | 2.5 | 2.8c | 4.8acd |

[1]Species marked by an asterisk were seeded.
[2]Control = native hay mulched area.
[3]Significance as follows: (a) means within groups that were significantly ($p\leq.05$) different than the control; (b) means between groups that were significantly ($p<.05$) greater within treatments; (c) means within species groups that were significantly ($p<.05$) different when compared to the same treatment of the previous year; (d) 1985 means within species groups that were significantly ($p<.05$) different when compared to the same treatment in 1983.

At the end of the fourth growing season total live basal cover on treated areas was significantly ($p<.05$) greater than the control due primarily to increases in warm season species. By 1985, the ratio of cool:warm season grasses based on live basal cover was 7:1 on the control and 1:5.7 on the spray plots.

### Prescribed Burning

In 1983 Basin Cooperative Services entered into a cooperative agreement with North Dakota State University to conduct a prescribed burning study on seeded native grassland areas. The objectives were (1) to document physical and biological conditions prior to each burn to evaluate their effects on individual species, and (2) to obtain quantitative data on established species relative to several different burn dates. Additionally, this study and subsequent data collected as part of annual monitoring procedures will be used to develop future fire prescriptions.

Study plots were arbitrarily selected on areas A and B and from a 1981 seeded stand in area C. Burn dates on each of the three areas included May 1, May 23, June 30, August 1 and October 23. Specific data relative to species response by aspect and burn conditions are described in more detail by Haupt[4].

In summary, live basal cover ratios of cool to warm season species improved on the May 23 burn plots from 1983 to 1984 in all three areas and particularly in areas B and C where several warm season species were initially present. Favorable changes also occurred on the June 30 burns but results were less consistent between north and south aspects and between areas. May 1, August 1 and October burns resulted in a higher live basal cover of cool season species due to increases in western and intermediate wheatgrass. Because of the scarcity of warm season species on area A at the time burning was initiated, no significant improvements were recorded.

Based on 1983 and 1984 data, prescribed burning in late May and early June is applicable to reestablished native grassland stands. Although emphasis was placed on improving seasonal variety, burning may also be used to remove litter, improve live basal cover and production of cool season species, particularly western wheatgrass.

### Burn/Interseed/Herbicide Application

In some reclamation areas, native grassland stands may become established that are dominated by cool season or problem perennial grasses. Stands containing overly aggressive cool season species, specifically crested and intermediate wheatgrass, or problem species such as quackgrass and smooth brome will reduce diversity and possibly eliminate warm season species within a few years following establishment. Species composition on eight to ten year old stands seeded to the SCS spoil bank mixture (Table 1) show this to be the case. If this occurs, interseeding with native warm season species is necessary to improve diversity and seasonality. However, this alone will not produce favorable results particularly in the older, well established stands. Consequently, a combination of management applications are necessary to reduce cool season grass competition for a sufficient time to allow warm season species to become established. Once established, interseeding should be followed by continued proper management through the liability period.

A combination of management practices implemented on a trial basis in 1983 involved the use of burning followed by interseeding the same year and an early spring application of glyphosate in 1984. This management strategy was performed on May 23 and June 30 burn plots in area A.

Visual observations following treatment in 1983 indicated considerable competition from cool season regrowth on the May 23 burn-interseed areas and consequently warm season species were less successful during the establishment year than on the June 30 plots. Although a June 30 seeding date is later than recommended for warm season species, these trial areas had the best initial seedling response. A comparison of frequency and live basal cover data for groups on the June 30 burn-interseed and June 30 burn-interseed-spray trial areas are presented in Table 9.

Changes in live basal cover and seasonal variety occurred following successful interseeding of warm season species on the June 30 burn-interseed and the June 30 burn-interseed-spray areas. When compared to control in 1984 and 1985, both treatments had significant ($p<.05$) increases in warm season live basal cover. The lack of improvement on the burn-interseed areas from 1984 to 1985 is attributed to competition from cool season species which had increased significantly ($p<.05$) in 1985. However, suppressing cool season competition using glyphosate in 1984 resulted in a 120 percent increase in warm season live cover in 1985 on the spray-burn-interseed areas. Consequently fire alone does not adequately reduce competition from cool season species for a long enough period to allow warm season establishment. The use of glyphosate, however, will suppress cool season species and provide a vacancy for warm season establishment.

The results of glyphosate applications on areas A and C show a differential affect on intermediate and western wheatgrass. This difference was also noted on smooth brome and quackgrass on other grassland and woodland reclamation sites where this chemical was used for management or maintenance purposes. Similarly, Waller and Schmidt (1983) reported tolerance differences between Kentucky bluegrass and smooth brome.

Another factor that may have affected resistance levels, is the age of the stand at the time treatment was imposed. Intermediate wheatgrass frequencies and live basal cover data from area C, where spraying occurred in the year following estab-

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[4]Haupt, Michael L., Prescribed burning on reestablished grasslands on reclaimed land in western North Dakota. Masters Thesis (in preparation).

Table 9.--Species frequencies and live basal cover by species groups on the control, June 30 burn-interseed, and June 30 burn-interseed-spray trial areas located in Area A.

| Species | 1984 Control | 1984 BI[1] | 1984 BIS[1] | 1985 Control | 1985 BI | 1985 BIS |
|---|---|---|---|---|---|---|
| | % | | | | | |
| Blue grama | 0 | 50 | 15 | 0 | 33 | 30 |
| Sideoats grama*[2] | 15 | 55 | 65 | 25 | 65 | 55 |
| Little bluestem* | 0 | 15 | 25 | 0 | 0 | 18 |
| Switchgrass* | 0 | 20 | 55 | 0 | 0 | 15 |
| Sand bluestem* | 0 | 0 | 0 | 0 | 0 | 3 |
| Warm Season LBC | .03 | .4a[3] | .5a | .05 | .3a | 1.1acd |
| Western wheatgrass | 85 | 95 | 75 | 65 | 80 | 75 |
| Intermediate wheatgrass | 100 | 100 | 60 | 100 | 100 | 80 |
| Green needlegrass | 40 | 60 | 10 | 38 | 43 | 10 |
| *Poa* spp. | 0 | 25 | 20 | 3 | 40 | 13 |
| Smooth brome | 38 | 5 | 25 | 23 | 10 | 78 |
| Quackgrass | 15 | 0 | 20 | 5 | 3 | 0 |
| Cool Season LBC | 1.8b | 1.6bd | .7a | 2.1b | 2.4bc | 1.9c |
| Forbs | 8 | 25 | 50 | 10 | 23 | 40 |
| Green foxtail | 0 | 10 | 80 | 0 | 5 | 15 |
| Total live basal cover | 2.0 | 2.0 | 1.4 | 2.2 | 2.7 | 3.1ac |

[1]BI = burn-interseed, BIS = burn-interseed-spray.

[2]Species marked with an asterisk were interseeded, species underlined were seeded in 1975.

[3]LBC significance as follows: (a) group means within years that were significantly ($p<.05$) different than the control; (b) means between groups that were significantly ($p<.05$) greater within each treatment; (c) group means within treatments that changed significantly ($p<.05$) from 1984 to 1985; (d) means within groups that were significantly ($p<.05$) greater between burn-interseed and burn-interseed-spray plots.

lishment, exhibited less tolerance than in area A. In the year following treatment this species occurred in 10 percent of the quadrats in area C, and 60 percent in area A. Western wheatgrass occurred in 75 percent of the quadrats on both areas. Also 1985 cover measurements show significantly ($p<.05$) less cool season live basal cover on area C when compared to the control while no significant ($p\leq.05$) difference was detected in area A. If apparent differences are due to the age of the stand, higher rates may be necessary in order to attain a suppression effect for more than three years.

The potential for using glyphosate as a selective herbicide to enhance seasonality on reestablished grasslands warrants further investigation. Information regarding application rates, stand age, and application period relative to problem cool season species would further facilitate its use.

## SUMMARY AND CONCLUSIONS

Reestablishing a native grassland community with diversity and seasonal variety requires special establishment and management practices. These practices in addition to soil characteristics, and regrading and soil distribution plans will significantly affect plant community characteristics not only during the establishment phase, but throughout the liability period. Knowledge of species and/or group responses to various establishment and management strategies is paramount to attaining a diverse and seasonally balanced stand.

Native grassland reclamation practices studied and implemented on the Glenharold Mine have resulted in stands with improved diversity and seasonality since 1979. Establishment procedures important to attain these characteristics include (1) seeding in late spring from late May to mid June, (2) supplemental irrigation and soil water conservation practices such as seeding into a dead, standing stubble, and (3) weighting the seed mixture to include a higher percentage of warm season pure live seed, preferably a 1:3 cool:warm season ratio. Adhering to these procedures has resulted in successful initial stands seven consecutive years despite precipitation deficits during the growing season and below normal June rainfall five out of seven years.

Efforts to establish a diverse and seasonally balanced stand can be enhanced by using a native hay mulch. Present use has been limited to approximately 100 acres in area C while evaluations were being performed. Species recorded on these areas since 1982 and potential seed observed from germination tests justify its use on reclamation rangeland areas. Of particular importance is the capability of broadening the genetic variability and introducing locally adapted seed of sedges, grasses and forbs that are not available commercially.

Based on our data and field observations since 1981, it is important that competitive introduced cool season species be excluded from the seed mix to realize the full benefit from the native hay mulch. Also efforts should be made to avoid obtaining mulch from native grasslands where these species are present.

Experience has shown that proper establishment procedures will minimize management costs and expedite development of an economically viable grassland. Area B shows good seasonality after seven growing seasons even though special management techniques were not employed. Comparisons of cool and warm season productivity between the silty reference area and reclamation area B in 1984 and 1985 were similar. In 1984, warm season grasses made up 33 percent of the total grass production on the silty reference area and 28 percent of the total on area B. In 1985, warm season species comprised 50 percent of the total on the reference area and 49 percent on area B.

Management following establishment may be necessary to maintain or enhance plant community characteristics. Vegetation monitoring in the early development stages is necessary in order to initiate corrective action before serious problems develop. Factors affecting diversity and seasonality include weather, soils, and competition from undesirable cool season species. Management techniques implemented on grassland areas have included prescription mowing, burning, grazing, interseeding with warm season species, and non-selective herbicide applications. Discussed in this paper were burning, interseeding and non-selective herbicides.

Prescribed burning remains an effective and economical method of managing reclamation grasslands. Preliminary results of a burn study conducted in 1983 and 1984 indicate controlled burning during late May and early June to be the most effective period for improving stand seasonality. Additionally, controlled burning may be used for other purposes including but not limited to (1) stimulation of cool season productivity, (2) manipulation of soil temperatures, (3) removal of excessive litter, (4) weed control, and (5) facilitating supplemental seeding of warm season species.

In some cases, more intensive management strategies may be necessary in order to meet vegetation performance standards. Supplemental seeding of warm season grasses, and glyphosate treatments following burning demonstrated considerable potential on trial areas. Results from our studies show this combination to be a viable method for improving or introducing the warm season component into an established stand and simultaneously suppress or eliminate cool season competition. Frequency and live basal cover data collected from two different stands show significantly greater proportions of warm season species up to three years following treatment.

Results from reclamation procedures used on the Glenharold Mine have contributed to our knowledge and confidence in reestablishing diverse and seasonally balanced native grassland communities. In comparison with grasslands containing introduced cool season species, these grasslands (a) are more tolerant of stress caused by grazing or drought, (b) have greater productivity in soils with inherently low fertility, (c) are ecologically compatable with native forbs, shrubs and adjacent native rangelands, (d) provide better forage quality and quantity during the summer, and (e) meet vegetation performance criteria.

Continued monitoring of stands and trial areas subjected to techniques discussed in this paper will add to our present knowledge of native grassland reclamation. Application of new establishment and management practices as well as the discovery and implementation of old ideas is a continuing process requiring coordination between research scientists, reclamation specialists, and regulatory agencies. Significant technological advances have been made since 1977 and undoubtedly will continue as surface mining progresses in the West.

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