DIVERSITY AND SEASONAL VARIETY IN RECLAIMED NATIVE GRASSLANDS[1]

by

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Abstract. Production and cover data from a 216 ha reclamation area were collected between 1982 and 1988 for purposes of determining vegetation success and to evaluate establishment and management practices. Nineteen site types were identified where vegetation differed due to seeding date, mulch type, and reconstructed soil characteristics. Diversity and seasonal variety changes over time are discussed for 3 sites relative to an on-site reference area standard. Data show proper seed mixtures, seeding date, glyphosate (Roundup) treatments, and the use of a native hay mulch can effect species composition and contribute to diverse productive reclaimed grasslands.

Additional key words: Native grassland restoration, grassland diversity and seasonal variety.

Introduction

Bond performance standards under SMCRA for native grassland reclamation require mine operators to demonstrate that established stands are diverse, effective and permanent. Also, they must have the same seasonal variety native to the area. These requirements make it necessary to know what establishment and management practices are available and effective to meet these goals.

Monitoring reclaimed grasslands is important in determining diversity and seasonal variety in relation to requirements for final bond release. Trend information should be obtained several years before the end of the liability period in order to prescribe management practices to direct plant community succession. These practices may include prescribed burning, mowing or grazing. However, if species diversity or seasonal variety is deficient in the initial stand, none of these are useful. Interseeding, combined with burning and/or non-selective herbicide (glyphosate) treatments, is effective (Nilson et al. 1985) but this restarts the 10 year liability period because interseeding is not considered a normal conservation practice.

Diversity and seasonal variety characteristics on reclaimed grasslands at the Glenharold Mine have been studied over the past 10

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years. Study sites have included reclamation areas where seed mix and seeding date varied, non-selective herbicide treatments were used, or where native hay was used as a mulch. Data have been collected to evaluate both the short term and long term benefits of these practices.

Information presented in this paper are from a 216 ha (534 ac) grassland area seeded between 1981 and 1983. This area is referred to as the Glenharold Mine (GHM) section 15 grassland reclamation area.

Study Area

The Glenharold Mine is located 88 km (55 miles) northeast of Bismarck, North Dakota in a landform known as the "Missouri Breaks". Native prairie consists of mixed grasses of the wheatgrass-stipa-grama association. Principle soils include mollisols and entisols underlain by sodic montmorillonitic clays which are typical in spoil material. Major range sites are shallow, silty, sandy and thin claypan sites.

Native soils for this area were somewhat atypical of the mine as a whole. Most of the area was dominated by sands and thin sands range sites. Premine soils were of the Lihen and Telfer series' which have loamy fine sand textures. Following topsoil removal, sandy clay and clayey subsoils were selectively stripped down to 25 feet in deposits of brown glacial till. This was done to avoid reconstruction of a droughty soil profile where sandy topsoil is placed over sandy subsoil material. Consequently, the reclamation area has two basic soil profiles with soil characteristics that affect reestablished plant communities. One is the mined disturbance area which had both topsoil and subsoil replaced and the other is the associated disturbance areas which retain their original subsoil soil characteristics.

Major forage species present prior to mining, as recorded from an on-site reference area, were needle-and-thread (Stipa comata), blue grama (Bouteloua gracilis), prairie sandreed (Calamovilfa longifolia), little bluestem (Andropogon scoparius), sand bluestem (Andropogon hallii) and sedges (Carex spp.).

Methods

The section 15 reclamation area was delineated into 19 vegetation site types designated A-V in Table 1. Vegetation differences in these sites were influenced by a number of factors but were due primarily to conditions resulting from different seeding dates between 1981 and 1983. Other factors included whether or not both subsoil and topsoil were replaced or if only topsoil was affected. Also, differences were observed where native hay and slough hay were used as mulch as well as areas where broadcast seeding was used instead of drill seeding.

All sites seeded in 1981 were seeded with the same seed mixture (Table 2). In 1982, alfalfa (Medicago sativa) was seeded instead of sweetclover (Melilotus officinalis) at approximately the same rate. Also, because of its aggressiveness, intermediate wheatgrass (Agropyron intermedium) was replaced by slender wheatgrass (Agropyron trachycaulum) on areas seeded in 1983.

This seed mix and seeding rate take into consideration the proper ratio of warm and cool season species in the number of pure live

Table 1. 1987 vegetative characteristics of 19 reclaimed grassland stands (site types) established on the Glenharold Mine between 1981 and 1983.

Site	Species Detected Total	Species Detected 3% LBC[b]	H'[c]	Relative % LBC[d] Warm	Relative % LBC[d] Cool[e]	Relative % Production Warm	Relative % Production Cool	Date Seeded	Seeding Oper.	Mulch Type	Dist. Type
				----- % -----							
A[a]	12	4	1.73	38	62	13	66	05/27/82	PD[f]	NH+SH[f]	MD[f]
B	13	8	1.92	28	55	10	66	05/18/81	PD	SH	MD
C	11	7	1.85	34	56	18	72	05/22/82	PD	NH+SH	MD
D	15	10	2.02	33	60	20	75	05/11/82	PD	NH+SH	MD
E	13	9	1.87	15	81	5	85	05/10/81	PD	NH+SH	MD
F	12	8	1.89	40	58	24	76	05/31/83	PD	SH	MD
G	12	8	1.91	53	46	29	71	06/07/83	BS	SH	MD
H	13	4	1.53	80	18	48	42	06/05/82	PD	NH	MD
I	13	8	1.90	48	33	23	50	06/10/81	PD	NH+SH	MD
J	14	7	1.95	27	73	20	79	05/21/82	PD	NH	MD
L	11	8	1.86	52	48	48	52	06/09/83	PD	NH	AS
N	13	10	1.99	38	45	10	68	05/22/82	PD	NH	MD
O	14	8	1.93	55	40	34	57	06/05/82	PD	NH	MD
P	13	8	1.89	27	69	32	68	05/23/82	PD	NH	MD
Q	10	10	1.83	34	66	10	90	06/01/83	BS	SH	MD
R	12	6	1.77	59	41	52	47	06/01/83	BS	SH	AS
S	10	4	1.74	38	62	5	95	10/10/83	PD	SH	MD
T	13	13	1.97	51	49	35	62	06/03/83	PD	SH	MD
V	17	9	1.95	65	32	31	55	06/02/82	PD	NH+SH	AS
Mean	13	8	1.87	43	52	25	67				
Min	10	4	1.53	15	18	5	42				
Max	17	13	2.02	80	81	52	95				

[a] Note: Sites K and U were merged with sites L and V respectively because of similar vegetative characteristics. Site M is a tamegrass hayland and therefore, was excluded.

[b] Total number of species detected at 3 percent or more relative live basal cover.

[c] H' = Shannon-Weiner Plant Species Diversity Index.

[d] LBC = Live basal cover.

[e] WARM = Warm Season Species, COOL = Cool Season Species.

[f] NH = Native hay, SH = Slough hay, PD = Press drill, BS = Broadcast seeded, AS = Associated disturbance, MD = Mine disturbance.

Table 2. Species and seeding rate for the Section 15 reclamation area.

Species	Scientific Name	Plant Type [a]	Kg/ha PLS [b]	PLS/M²
Western wheatgrass	Agropyron smithii	CN	5.6	151
Intermediate wheatgrass	Agropyron intermedium	CI	2.2	43
Big bluestem	Andropogon gerardii	WN	1.1	41
Sand bluestem	Andropogon hallii	WN	1.1	28
Little bluestem	Andropogon scoparius	WN	2.2	127
Sideoats grama	Bouteloua curtipendula	WN	2.2	95
Blue grama	Bouteloua gracilis	WN	1.1	202
Prairie sandreed	Calamovilfa longifolia	WN	1.1	74
Switchgrass	Panicum virgatum	WN	1.1	96
Sand dropseed	Sporobolus cryptandrus	WN	.6	654
Green needlegrass	Stipa viridula	CN	2.2	88
Sweetclover	Melilotus officinalis	F	1.1	64
TOTAL			21.6	1,663

[a] CN=Cool season native, CI=Cool introduced, WN=Warm season native, F=Forb (legume)
[b] PLS=Pure live seed

seeds (PLS) per square meter. Earlier studies by Williamson (1984) pointed out the importance of using a warm:cool ratio of 3:1 or greater, to establish seasonally balanced grasslands. The warm:cool ratio for this mix is 4.7:1, which includes 1,318 PLS/m² for the warm season group and 282 PLS/m² for the 3 cool season species.

All site types except site P were hayed on a regular basis for two reasons. First, haying was used to prevent litter accumulations which can be excessive, particularly the first few years following seeding. Second, intermediate wheatgrass dominated the stand and would eventually exclude other slower growing species. Consequently, mowing was timed to coincide with flowering and seed production in order to deplete carbohydrate reserves and reduce its competitive advantage.

Of the 19 site types, production and cover have been collected since 1982 on 3 sites identified as C, E and I. Study sites E and I were seeded in 1981 while site C was established in 1982. All sites were sampled in 1987 for bond release purposes. Production data were collected at community peak standing crop using a 0.25 m² frame. Live basal cover (LBC) measurements were obtained using the 10-point frame described by Cook and Bonham (1977). A minimum of 2,000 points were read and recorded at each site. Cover data were collected by species, then grouped into categories including cool season grasses, warm season grasses, sedges, forbs and shrubs. Where species richness is discussed, sedges, forbs and shrubs were each considered as one species. These groups, as well as individual species, were counted as one species when their relative total cover equalled or exceeded 3 percent.

Study sites C, E and I were selected for long term monitoring for several reasons. First, this reclamation area was one of the earliest attempts at the GHM to establish a broad species base including tall grasses and data was needed to evaluate their performance. Second, sites E and I were seeded in 1981 but at different dates in the spring; site E around May 10 and site I around June 10. Additionally, sites C and E were mulched with native hay obtained from range sites similar to those found in section 15 prior to mining. Finally, both C and E contain subplots that were established to study the effects of non-selective herbicide treatments and the contribution of native hay mulch toward species diversity and seasonal variety.

Results and Discussion

Site Type Differences

As of the end of the 1987 growing season, site types were 5 to 7 years of age. Of the 19 identified, native forbs were recorded on 15, 13 have sedges, and 2 have shrub species. The mean number of species detected, based on a 3 percent minimum relative cover value, is 8 and varied from 4 to 13. Figure 1 illustrates the relationship between species numbers and the Shannon-Weiner Plant Diversity Index (H') (Shannon and Weaver, 1973). This equation, using log base 10, is

$$H' = \Sigma \; Pi \; Log \; Pi$$

where Pi is the actual cover of species i divided by the total cover. Sites A, H and S had only 4 species and concurrently the species diversity index was lowest for these areas. Site H is dominated by little bluestem which provides 72 percent of the total live basal cover while sites A and S are dominated by Agropyron spp. where relative cover values are 57 and 62 percent respectively. Sites D, N, T and Q, on the other hand, had 10 or more species. These sites generally had the highest diversity values indicating a more even distribution of individuals among species.

Seasonal variety, expressed in terms of both relative cover and relative production of warm season species, averaged 43 and 25 percent respectively (Table 1 and Figure 2). Mean total warm season production in 1987 averaged 470 kg/ha (419 lbs/ac) across all sites which exceeded the reference area standard by 59 kg/ha (52 lbs/ac).

Relative cover and species richness recorded in 1988 for select site types and study plots discussed in the remainder of this paper are presented in Table 3.

Planting Date

When the goal is to establish seasonally balanced grassland stands, it is important to delay the seeding date to favor warm season species. Often it is tempting to get in the field as soon as conditions permit to take advantage of early spring rains. However, if an early planting date is chosen and normal rainfall and temperatures occur, chances are a stand will develop that is dominated by cool season species. Williamson (1984) pointed out the importance of a delayed seeding date on GHM grasslands established in 1979. Vegetation differences in the section 15 reclamation area also were obvious between early and late seeding dates (Figure 3).

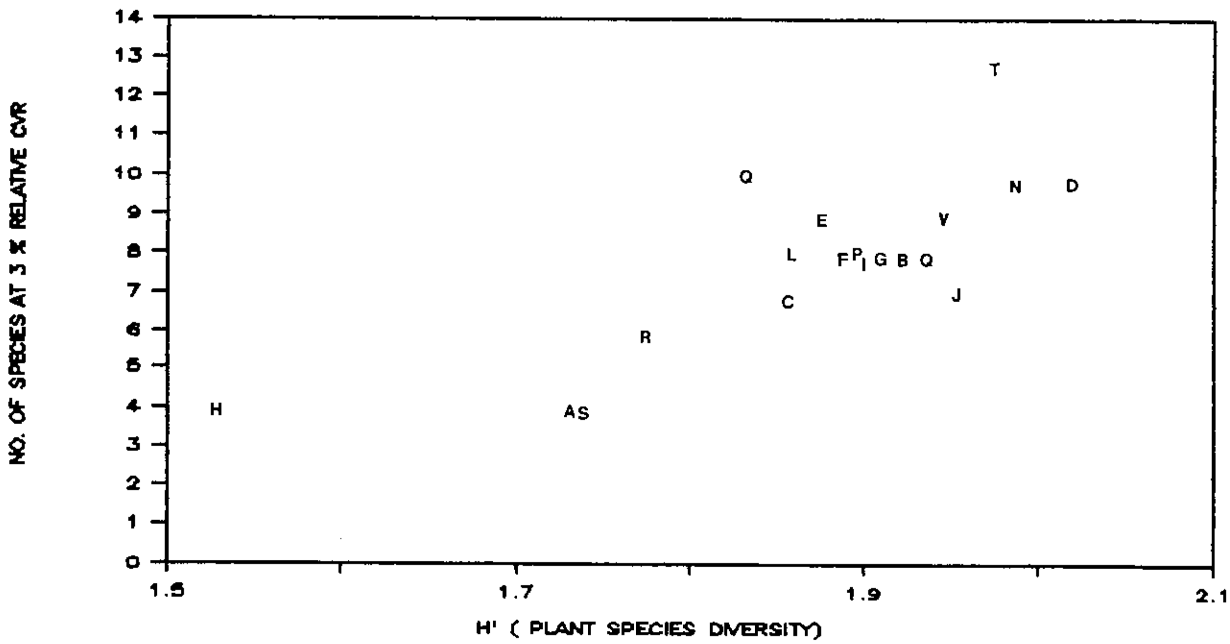

Figure 1. Number of species present and Shannon-Weiner diversity values (H') for 19 vegetation site types established on a single reclamation area between 1981 and 1983.

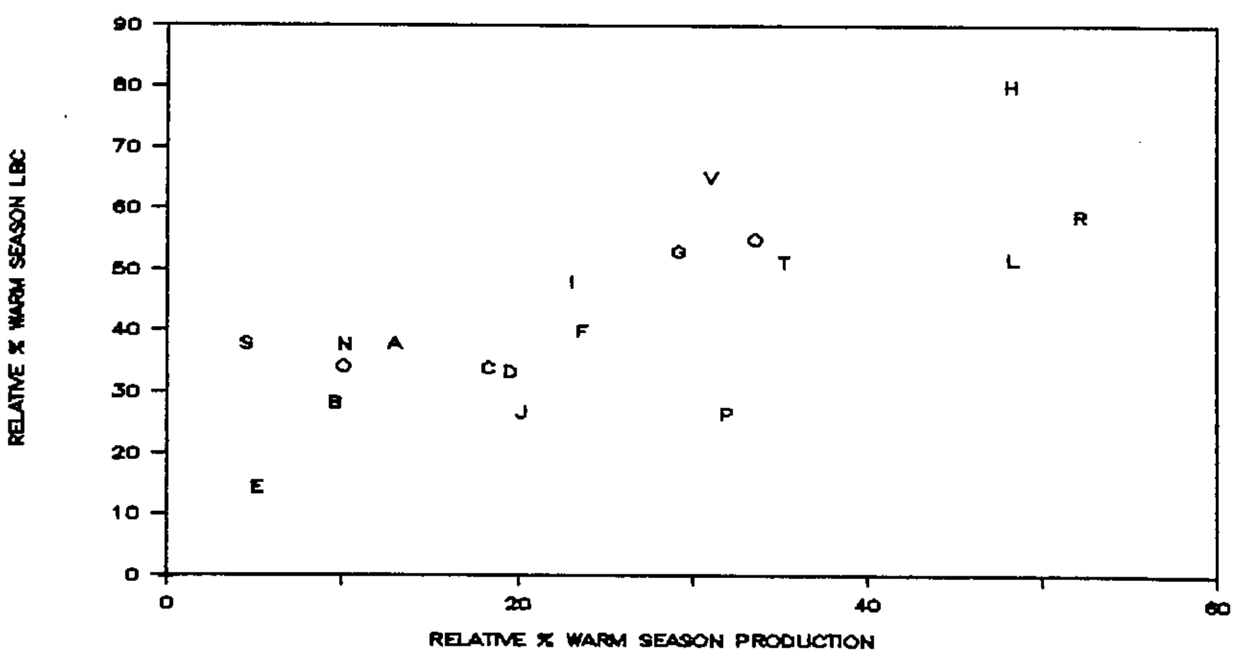

Figure 2. Relative cover and production of warm season species on 19 vegetation site types seeded between 1981 and 1983.

Table 3. Species composition based on relative LBC on select study sites within the Glenharold Mine section 15 reclamation area in 1988.

Species	Plant Type	Sands Reference Area	Reclamation Sites 15C	Herb-83	Herb-85	15-E	15-I	Native Mulch
Western wheatgrass *Agropyron smithii*	CN	3	30	2	8	16	16	3
Wheatgrass (other) *Agropyron* spp.	CI	0	16	2	0	28	23	0
Slender wheatgrass *Agropyron trachycaulum*	CN	0	1	2	0	7	7	0
Big bluestem *Andropogon gerardii*	WN	0	0	1	0	0	2	0
Sand bluestem *Andropogon hallii*	WN	5	2	2	0	0	0	0
Little bluestem *Andropogon scoparius*	WN	10	2	17	17	2	19	34
Sideoats grama *Bouteloua curtipendula*	WN	0	0	4	7	15	4	2
Blue grama *Bouteloua gracilis*	WN	11	20	16	27	5	5	20
Smooth bromegrass *Bromus inermis*	CI	0	8	3	2	15	0	0
Prairie sandreed *Calamovilfa longifolia*	WN	11	0	8	4	0	0	0
Canada wildrye *Elmus canadensis*	CN	0	0	0	0	0	0	1
Prairie junegrass *Koeleria pyramidata*	CN	1	0	0	0	0	0	0
Switchgrass *Panicum virgatum*	WN	0	0	26	12	0	0	7
Bluegrass *Poa* spp.	CI	3	3	1	0	6	1	14
Indiangrass *Sorghastrum nutans*	WN	0	1	3	5	0	0	0
Sand dropseed *Sporobolus cryptandrus*	WN	0	0	2	3	0	1	1
Needle-and-thread *Stipa comata*	CN	12	0	0	0	0	0	2
Green needlegrass *Stipa viridula*	CN	0	0	0	0	2	5	1
Other warm		2	0	0	0	1	0	0
Other cool		0	0	0	0	0	2	3
Forbs		9	17	5	14	2	13	6
Sedges *Carex* spp.	CN	25	0	6	0	0	2	6
Shrub		10	0	0	0	0	0	0
Total number of species & groups		12	10	16	10	11	13	13
Total number of species & groups => 3% relative LBC		10	6	9	9	7	8	8
Relative cool season LBC		43	58	15	10	75	55	29
Relative warm season LBC		39	25	80	76	23	32	65
Total forbs LBC		9	17	5	14	2	13	6
Total shrub LBC		10	0	0	0	0	0	0

Plant types are CN=Cool season native, CI=Cool introduced, WN=Warm season native.

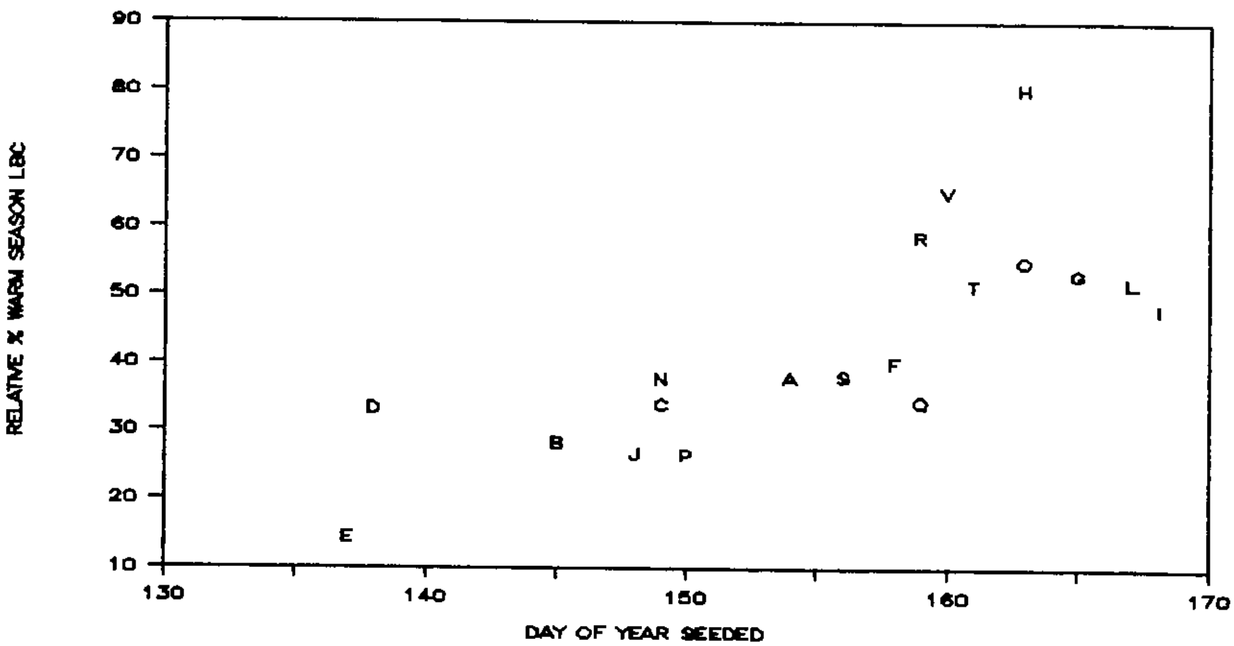

Figure 3. Relationship between the percent relative cover of warm season species and the day of year seeded.

Figures 4 and 5 illustrate differences in warm season grass production and cover beginning in 1985, the fifth growing season and continuing through 1988. Study site E was seeded in mid-May of 1981 while site I was seeded around mid-June.

Although total production on sites E and I was statistically equivalent in 1988 (Table 4), relative cover and production of the warm season component on site E remained below the reference area standard. However, this percentage continued to increase over the last 4 growing seasons and is expected to meet or exceed the standard by year 10.

Table 4. Comparison of 1988 total production on sites E, I and the sands reference area.

Study Site	Kg/ha	Lbs/ac
Site E	1,322	1,180
Site I	1,343	1,198
Sands RA	1,390	1,240

The 1988 yield on the sands reference area was only 64 percent of its natural capability (SCS, 1975) due to extreme drought conditions. This yield reduction corresponds with a 63 percent decrease in May-July precipitation. Total cool season grass yields on sites E

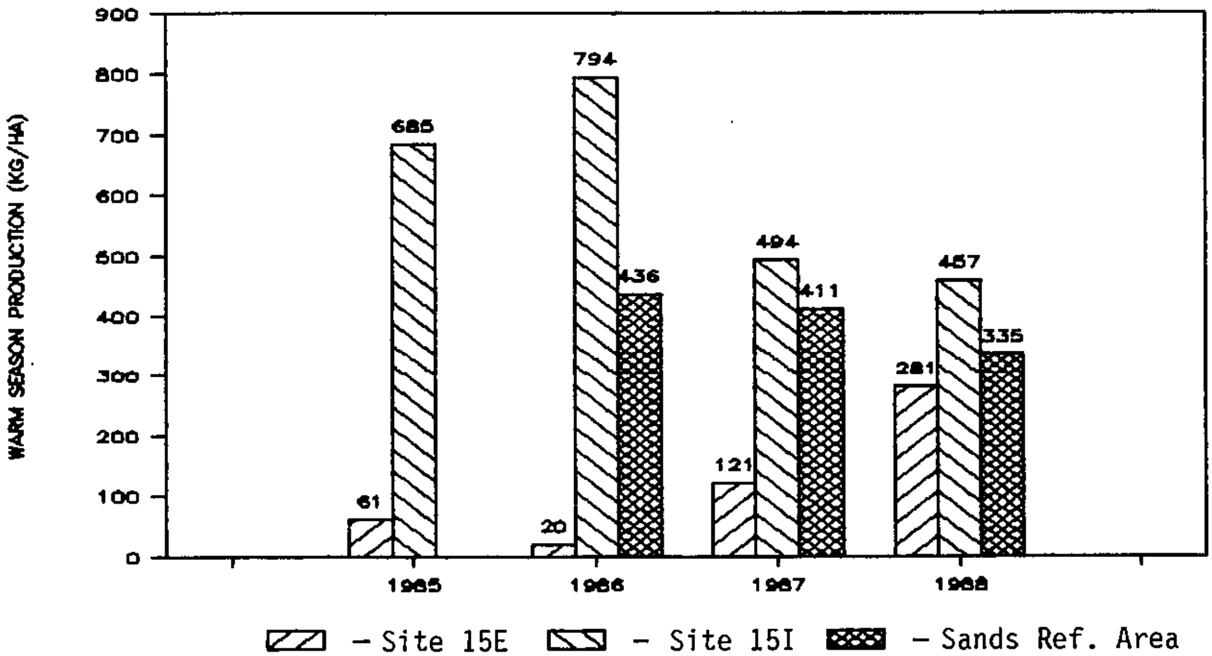

Figure 4. Comparison of warm season production over time on sites seeded early (15-E) and late (15-I) in the spring.

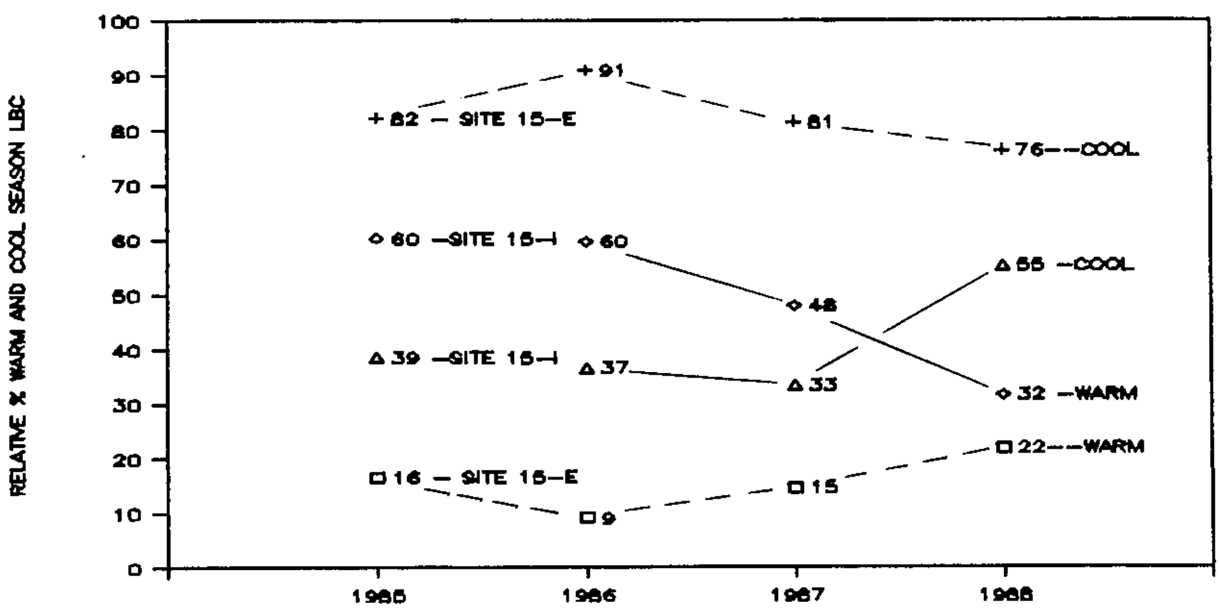

Figure 5. Comparison of relative cover on sites 15-E and 15-I seeded in early and late spring respectively.

and I declined 69 and 64 percent respectively between 1987 and 1988. In comparison, warm season production remained relatively stable on site I and increased from 121 kg/ha (108 lbs/ac) to 281 kg/ha (251 lbs/ac) on site E.

Herbicide Treatments

One of the more promising management techniques to emerge recently involves the use of glyphosate (Roundup) as a cool season suppressant. Although it is considered a non-selective herbicide, it only affects those species actively growing. Consequently, an early application prior to warm season emergence and growth can reduce or eliminate cool season competition. This technique was described by Waller and Schmidt (1983) as an effective way to increase warm season tall grass species on rangeland in eastern Nebraska.

To test its applicability to recently seeded rangeland, glyphosate was applied in early May of 1983 to three randomly selected subplots within site type C. A single application of .85 kg/ha of active ingredient was sprayed with 280 l of water. Later, in 1985, the same treatment was used on subplots either north or south of the 1983 treated areas.

Figure 6 illustrates changes in relative LBC of warm season species on treated plots relative to the control (site C) from 1982 through 1988. Warm season species present after one and three growing seasons responded dramatically to the suppression of the cool season group which was dominated by intermediate wheatgrass. Major species adversely affected by delaying a glyphosate treatment until 1985 were big bluestem, switchgrass and sand bluestem. The 1988 yield difference of 490 kg/ha (437 lbs/ac) between the two herbicide treatments is attributed to the absence of these species (Figure 7). Collectively, they contributed 460 kg/ha (410 lbs/ac) more forage on the 1983 glyphosate treated plots which resulted in significantly higher yields. Although 1988 was a drought year, total production on the 1983 and 1985 glyphosate treatments were higher than the sands reference area and site C. These yields are summarized in Table 5.

Table 5. Comparison of 1988 total production on sites C, 83 and 85 glyphosate treatments, and the sands reference area.

Study Site	Kg/ha [a]	Lbs/ac
Site C	1,362a	1,215
H-83	2,199b	1,962
H-85	1,709ab	1,525
Sands RA	1,390a	1,240

[a] Yields between sites followed by the same letter are not significantly different $P < .05$.

Along with an increase in relative cover and production, both the 83 and 85 herbicide treatments had an increase in species richness over site C (Table 6). After 8 growing seasons, species contributing 3 percent or more toward the total live basal cover totalled 9 in the herbicide study plots while site C had 6 and the sands reference area had 10.

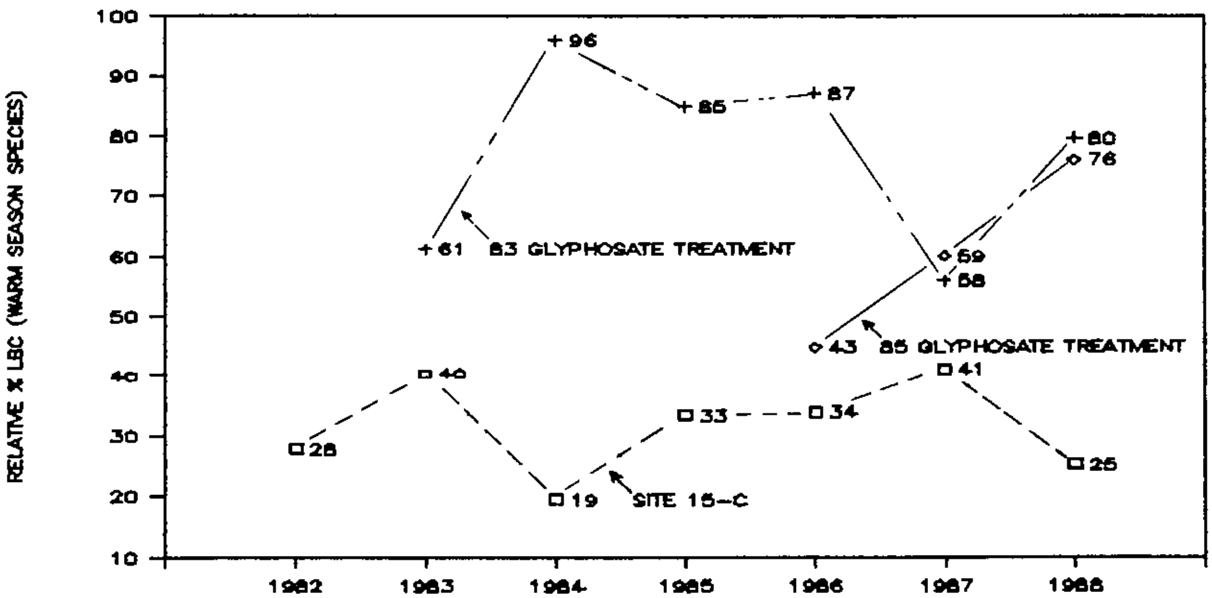

Figure 6. Relative cover of warm season species on plots treated with glyphosate relative to the control area (15-C).

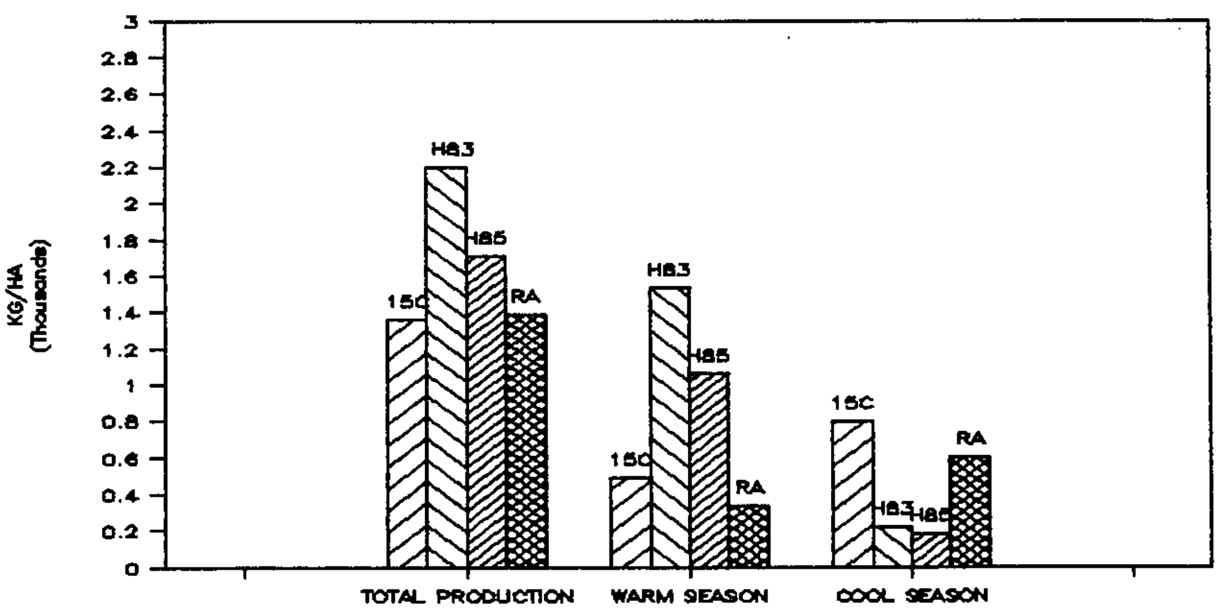

Figure 7. Comparison of 1988 production on 1983 (H83) and 1985 (H85) glyphosate treated plots relative to the control (15-C) and the sands range site reference area (RA).

Table 6. Comparison of species richness between 1983 and 1985.

Year	Reclamation Sites 15-C	H-83	H-85	Sands Ref. Area
	---------No. Species--------			
1982	7			
1983	10	10		
1984	7	6		
1985	7	7		
1986	5	9	8	11
1987	7	9	11	9
1988	6	9	9	10

Native Hay Mulch

The use of native prairie hay as a complimentary seed source has been reported by Ries and Hofmann (1982). In this publication, they discussed the viability of seed from stored hay after one year. Also Ries et al. (1980) evaluated seed quality and quantity relative to range condition and harvest date. Based on this research, native prairie hay was used on several sites following seeding in 1981 and 1982. Prairie hay was cut and baled during mid August from rangeland where sands and sandy range sites were common. A subplot within site E was mulched, but never seeded in order to observe and develop a better understanding of using this hay as a mulching source.

Cover and production data for 1988 comparing the mulched plot with the seeded and mulched control (site E) are presented in Figures 8 and 9. Relative cover by species are given in Table 3.

From these observations, it was concluded that competition from seeded cool season species, primarily intermediate wheatgrass, adversely affected the establishment and growth of species from the native hay mulch. In addition to a greater warm season component, species composition on the native hay mulch subplot included native forbs and sedges (Carex spp.). No significant difference ($P < .05$) in total production was found in 1988 when compared to either site E or the sands reference area. A comparison of species present and their relative cover on the native hay mulch subplot, site E, and the sands reference area is given in Table 3.

The importance of native prairie as a complimentary seed source deserves more attention for several reasons. First, the amount of seed detected per unit of mulch can be sufficient to warrant seed mix modifications to realize a cost savings. The potential seed source from native hay used on this reclamation area was described by Nilson et al. (1985). Native prairie hay cut in August of 1981 and mulched at 3,362 kg/ha (3,000 lbs/ac) in the spring of 1982 provided a seed source potential of 314 seeds per square meter. This is roughly 20 percent of the PLS density for the seed mix listed in Table 2. However, data from this reclamation study area and earlier research have demonstrated that with a good source, proper handling and harvesting, seeding may not be necessary. If seeding is done, care should be taken to minimize the affect of competition from aggressive cool season species.

Summary

Reclaimed native grassland established between 1981 and 1983 in west central North Dakota resulted in 19 grassland stands where vegetative characteristics differed due to establishment and management practices. Live basal cover and production data, collected in 1987

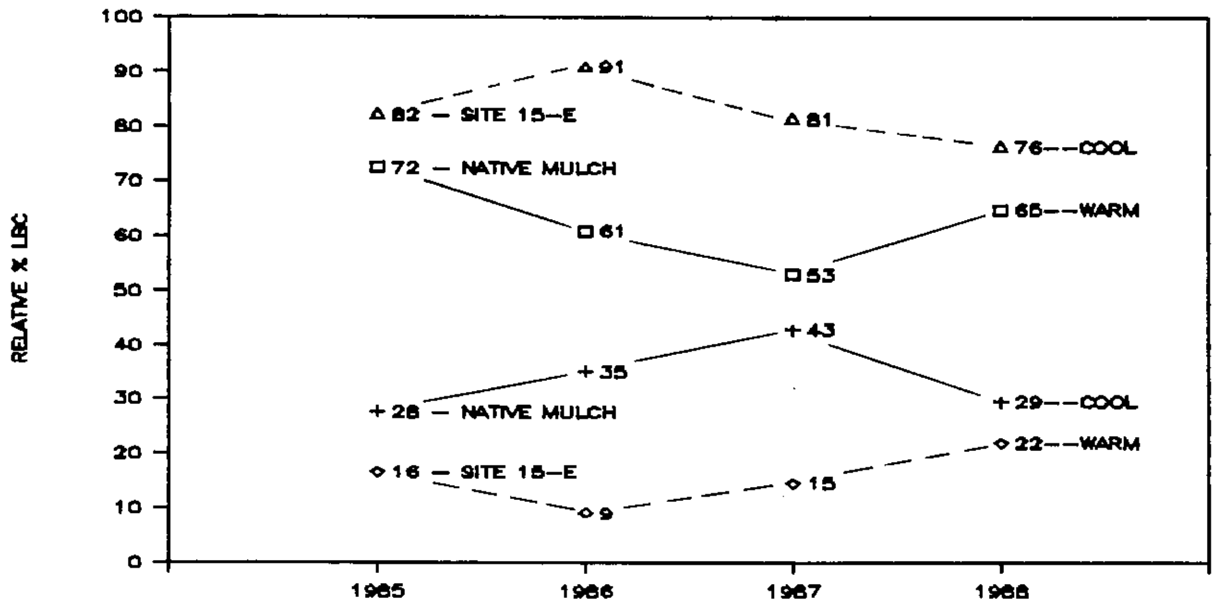

Figure 8. Changes in relative cover of cool and warm season species from 1985 through 1988 on the native hay mulch (NM) and control areas (15-E).

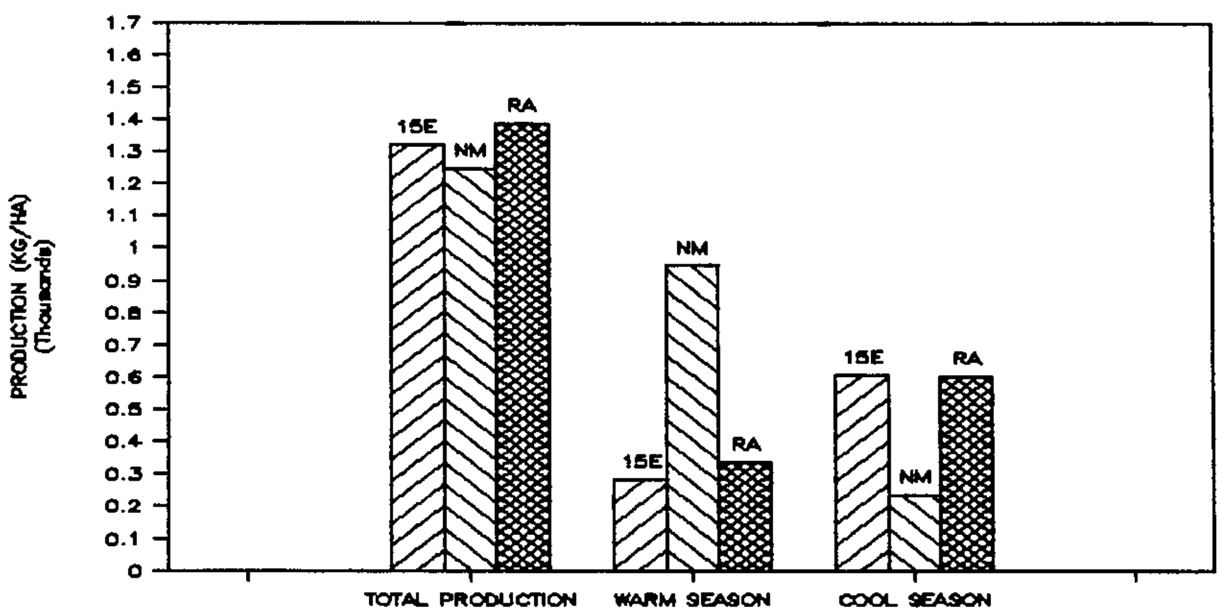

Figure 9. Comparison of 1988 productivity on the native hay mulch (NM), reclamation area 15-E and the sands reference area (RA).

for bond release purposes, indicate species richness and diversity (H') varied between sites. The mean number of species present was 13, but ranged from 10 to 17. When a 3 percent minimum relative cover value criteria is used, the average number of species detected was 8 with a minimum of 4 and a high of 13. Seasonal variety, expressed in terms of relative cover of warm season species, averaged 43 percent and ranged from 15 percent on an area seeded in mid May, to 80 percent on an area seeded in early June. The date of seeding was a primary factor affecting stand composition in this area as well as other reclamation grassland areas established since 1983.

Intermediate wheatgrass was an aggressive competitor the first few years excluding and often negating the contributory effect of the native hay mulch and diverse seed mixture. Where competition from this species was reduced, using glyphosate, the response of the warm season component was dramatic. Similarly, competition from this species affected diversity and seasonal variety on native hay mulched areas. A study site that was mulched but not seeded provided a comparison with an adjacent seeded and mulched area. Although production was equivalent, the native hay mulched area had higher number of species, including sedges and forbs, and higher relative cover and production of the warm season component.

Re-establishing native grasslands that are diverse, productive and qualify for bond release requires an understanding of species as well as community responses to different environmental conditions and establishment and management practices. Practices used will depend on this knowledge relative to prevailing weather conditions for the area. Establishment and management practices used at the Glenharold Mine have consistently produced diverse and productive grasslands that meet applicable bond release criteria.

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