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Summaries of Forage Research

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SUMMARIES OF FORAGE RESEARCH

Edited by
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FORWARD

February 5, 1990

Dear Reader:

South Dakota has a great history of productive research regarding forage crops. Niels E. Hansen brought alfalfa, smooth bromegrass, and crested wheatgrass to the Northern Great Plains nearly a century ago. Most of the modern winterhardy alfalfa cultivars sold today have genetic ties to Professor Hansen's introductions from Asia.

Research of forage crops continues in the Plant Science Department at South Dakota State University. This report contains summaries of 30 research projects recently conducted within or in cooperation with the Plant Science Department. A listing of 96 recent scientific publications is also included. Twenty-two scientists and support personnel contributed to this report.

The scope of research presented in this publication is extensive. New forage species are being investigated. Major issues related to forage quality are receiving attention. Forage production and management research has traditionally been a strength in the Plant Science Department and a wide spectrum of topics in these areas are being addressed. Experiments in basic biology of forage species, such as tissue culture and dry matter partitioning are also being conducted. Forage research at SDSU is well balanced between basic science and topics that immediately impact forage producers in our state and region.

South Dakota livestock and wildlife industries depend upon forages. Beef and dairy cattle, sheep and horses derive most of their nutrients from forages. Forage crops have no equal in economic importance to South Dakota. I estimate that forages contributed about $1.3 billion to South Dakota's agriculture economy in 1987, 46.5% of the total crop and livestock receipts. Economic values of soil conservation, wildlife habitat and attractive landscapes are difficult to appraise, but these aspects are also important assets provided to our state by forages.

Future concerns in crop production include Low-input Sustainable Agriculture (LISA) and environmental improvement. Modern agriculture will rely on forage to provide nitrogen, soil organic matter and erosion protection in crop rotations. Forages will be needed to maintain a sustainable livestock industry that serves health conscience consumers.

Our goal is to make SDSU a valuable center in the study of forage crops. We are developing strong teaching and research programs for graduate and undergraduate students. Enthusiasm generated by our extension program has led to creation of the South Dakota Forage and Grassland Council. New research on environmental and agronomic influences on forage quality have been initiated in the Plant Science Department using modern analytical techniques (e.g. near infrared reflectance spectroscopy). This technology has been used in SDSU's Agricultural Experiment Station Biochemistry Laboratory to assist South Dakota forage producers for several years. Breeding programs are underway to improve forage quality of alfalfa and switchgrass, improve seed production of big bluestem and side-oats grama, and increase the potential of Canada milkvetch as a forage legume.

Forages are the foundation to the economy of South Dakota and they protect and rejuvenate our environment. We are pleased to provide this collection of summaries which illustrates progress in understanding this valuable plant resource.

Kevin D. Kephart
Assistant Professor
Forage Crops
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RESEARCH ON

ALTERNATIVE OR NEW FORAGE CROPS

ALTERNATIVE FORAGES FOR DAIRY CATTLE

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Identification of alternative crops capable of producing high quality forage in conditions not conducive for alfalfa or perennial grass production would be desirable. The production of high quality forages in large quantities is the basis of any successful dairy enterprise. This will reduce the necessity of purchasing expensive supplemental grain and protein sources. Certain warm-season annual grasses and legumes, when harvested at the proper stage of maturity, are capable of producing high quality forage in large quantities where conditions are not suitable for alfalfa production. The objective was to evaluate the forage production and chemical composition at two cutting dates of four warm-season annual grasses and two annual legumes at two locations.

Four grasses (German millet, Siberian millet, Sudangrass, and teff) and an annual legume (cowpea) were grown at two locations (Brookings and Highmore, SD) in the summer of 1986. Forages were harvested at two dates, 36 and 57 days after planting at Brookings and 41 and 57 days after planting at Highmore, to evaluate changes in nutrient composition as affected by maturity. Forage material was harvested, weighed, and analyzed for dry matter, crude protein, neutral-detergent fiber (NDF), acid-detergent fiber (ADF), lignin, and in vitro dry matter digestibility (IVDMD). Chickpeas were also included in this study, but plots were completely destroyed by *Ascochyta* blight.

Warm-season Annual Grasses

Dry matter content was greatest for teff and Siberian millet, intermediate for Sudangrass, and lowest for German millet (Table 1). Crude protein and NDF concentrations were higher for teff than for the other grasses. No significant differences in ADF and lignin concentration were found among the four grasses. In vitro dry matter digestibility was greater for German millet than other grasses. German millet headed later than the other three grass species. Therefore, its greater IVDMD may be related to maturity differences. This study indicated that these grasses had good concentrations of crude protein and high concentrations of fiber, but still are readily digestible by ruminants.

All grasses had acceptable forage yields. Forage yields ranged from 7.8 tons per acre (17368 kg DM per ha) for Sudangrass to 2.6 tons per acre (5865 kg DM per ha) for teff. A significant interaction of location by grass type was detected (Figure 1). Sudangrass yields were over 100% greater at Highmore than at Brookings. The yield advantage at Highmore was not as large for the other grasses. Annual precipitation at Highmore was 7.7 in. above normal and one 5-in. rain was received shortly after planting. This improved early growing conditions and increased forage yields (Figure 1).

A significant difference was found between locations (Table 2) for chemical composition by increasing crude protein and lignin concentration and decreasing NDF, ash, and IVDMD when grasses were grown at Highmore. Highmore location 6 more growing days for the early harvest than Brookings, which may have been sufficient time to affect nutrient composition. Harvesting forage at a later date (early versus late cutting, Table 2) will increase dry matter and fiber concentrations, but will also reduce crude protein and IVDMD of the four grasses. Harvesting at a later stage of maturity (late cutting date) dramatically increased forage yields, but reduced crude protein concentration and dry matter digestibility. In summary, grasses can be acceptable alternative forages with high forage yield, nutrient composition, and dry matter digestibility when harvested at the proper time. Delaying harvest (even by 6 days) may result in greater forage yields, but will result in lower crude protein and increased concentrations of fiber with a reduction in dry matter digestibility.

Cowpeas

Cowpeas contained high concentrations of crude protein and ash and low concentrations of fiber, as measured by NDF and ADF, and had a high IVDMD (Table 3). These data indicate cowpea forage was comparable to alfalfa hay harvested at the late vegetative to early bloom stage. Forage yield was greater than 2.5 tons per acre (5,600 kg DM per ha) and the possibility exists to harvest two crops of cowpeas per year, which would likely increase forage yields. Cowpeas appear to be a very high quality source of forage for dairy cattle because of high crude protein, low fiber, and high dry matter digestibility.

Cowpeas grown at Highmore contained more crude protein and ash, but lower IVDMD. Forage yield was greater at Highmore than Brookings, which is probably related to the amount and timing of rainfall. Harvesting cowpeas at a later date will decrease crude protein content and increase dry matter and fiber content with a corresponding reduction in IVDMD. Forage yield can be increased by more than 3 tons per acre by harvesting at a later date, but will result in a slight decrease in forage quality. Even when harvested at a later date, however, with associated reductions in forage quality, cowpeas are a higher quality alternative legume forage than the warm-season annual grasses evaluated in this study.

In summary, German millet, Siberian millet, Sudangrass, teff, and cowpeas appear to have potential as alternative forages. These species could work well in emergency situations to produce forage where conditions are not conducive to alfalfa production. Further research with growing and/or lactating cattle is needed to ascertain their potential benefit and limitations in production systems.

Table 1. Chemical composition in vitro dry matter digestibility (IVDMD) and forage yield of four warm-season annual grasses grown for forage[1].

Measurement	German millet	Siberian millet	Sudan-grass	Teff
	--------------- % ---------------			
Dry matter (DM)	23.1c	28.8a	25.7b	29.2a
	--------------- (% of DM) ---------------			
Crude protein	10.9b	11.2b	10.8b	15.0a
NDF	66.0b	66.5b	66.3b	68.2a
ADF	40.2	39.9	39.6	37.3
Lignin	5.2	5.1	5.3	5.3
Ash	11.7a	11.5a	9.4b	10.6ab
IVDMD	63.1a	56.4b	55.3b	53.9b
	--------------- kg DM / ha ---------------			
Forage yield	8854ab	8092ab	17368a	5865b

[1] Means within rows with unlike letters differ by LSD at the 0.05 level of probability.

Table 2. Effect of location and cutting date on chemical composition, in vitro dry matter digestibility (IVDMD) and forage yield of four warm-season annual grasses grown for forage.

Measurement	Location		Cutting date	
	Brookings	Highmore	Early	Late
	--------------- % ---------------			
Dry matter (DM)	25.4	28.0**	22.0	31.5**
	--------------- (% of DM) ---------------			
Crude protein	10.3	13.7**	13.8	10.2**
NDF	67.4	66.1*	64.9	68.6**
ADF	39.3	39.3	37.2	41.4**
Lignin	4.4	6.1**	4.8	5.6**
Ash	11.1	10.4**	11.4	10.2**
IVDMD	59.4	54.8**	60.3	53.9**
	--------------- kg DM / ha ---------------			
Forage yield	7824	12264**	6248	13841**

*,** Means within locations or cutting dates significantly differ at the 0.05 and 0.01 levels of probability, respectively.

Table 3. Chemical composition, in vitro dry matter digestibility (IVDMD) and forage yield of cowpeas when grown as a forage at two locations and two cutting dates.

Measurement	Average	Location: Brookings	Location: Highmore	Cutting date: Early	Cutting date: Late
	%				
Dry matter (DM)	18.0	15.6	20.3*	13.9	22.0**
	% of DM				
Crude protein	22.0	20.4	23.7*	24.4	19.7**
NDF	35.2	34.6	35.9	32.2	38.3*
ADF	27.2	26.4	27.9	25.7	28.6*
Lignin	6.1	6.5	5.8	5.5	6.8*
Ash	13.1	12.2	13.9*	13.8	12.4
IVDMD	71.1	73.1	69.1*	72.9	69.2*
	kg DM/ha				
Forage yield	5622	4965	6279*	3641	7603**

*,** Means within locations or cutting dates differ at 0.05 and 0.01 level of probability, respectively.

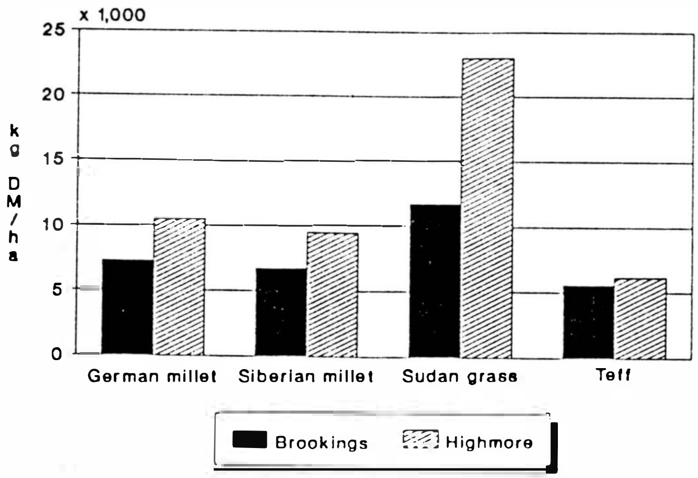

Figure 1. Forage yield of four annual warm-season grasses grown at two locations.

FORAGE PRODUCTION AND QUALITY OF AMERICAN SLOUGHGRASS

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Natural stands of American sloughgrass [*Beckmannia syzigachne* (Steud.) Fern.] have been used for forage in the northern USA and Canada, and it has been grown for forage in the USSR. Our objectives were to evaluate populations of American sloughgrass from the Northern Great Plains for growth habit, seed and forage production, and forage quality over a 2-year period at Brookings, South Dakota.

The two Montana and two South Dakota populations were similar for seed yield (505 lb. per acre). Forage yield at early head was significantly greater for a northeastern South Dakota population (2.3 tons per acre) than for two Montana populations (1.8 tons per acre) and yield of forage was greater in the establishment year (2.5 tons per acre) than the second year of production (1.5 tons per acre). No significant differences among populations were detected for forage quality, but dry matter digestibility was higher and fiber concentrations were lower during the establishment year than the second production year (Table 1).

This study indicated that Amaerican sloughgrass can be successfully grown for at least 2 years for either forage or seed in eastern South Dakota, and suggested it should be further investigated as an alternative forage crop in short-term rotations with conventional crops in tilled seasonal or temporary wetlands.

Future research will focus on interspecific hybridization attempts between American sloughgrass and European sloughgrass (*Beckmannia eruciformis* Host). American sloughgrass is a good seed producer, but European sloughgrass appears to have stronger vegetative reproduction, more disease resistance, and better persistence.

Table 1. Forage quality parameters of American sloughgrass harvested for forage at early head.

Measurement	Year 1985	Year 1986
	--- (% of DM[1]) ---	
Crude protein	13.5	12.2
Neutral-detergent fiber	64.0	69.0**
Acid-detergent fiber	37.0	41.1**
Ash	8.1	9.9**
Total nonstructural carbohydrates	12.7	6.6**
In vitro DM digestibility	60.2	46.4**

** Yearly means significantly different at the 0.01 level of probability.

CULTURAL PRACTICE EFFECTS ON COWPEA AND MUNGBEAN FORAGE PRODUCTION

Arvid Boe, Edward K. Twidwell, and Kevin D. Kephart
Plant Science Department

Cowpeas [*Vigna unguiculata* (L.) Walp.] and mungbeans [*Vigna radiata* (L.) Wilczek] are summer-annual legumes which have potential as forages in South Dakota during mid-summer when cool-season grass pastures decline in productivity. The objective of this study was to evaluate forage yield and growth response of these species when grown under different row spacings and planting rates.

'Victor' cowpeas and 'Berken' mungbeans were planted at 200,000 pure live seed (PLS) per acre in row spacings of 10, 20, and 30 in. at two South Dakota locations in 1987. In 1988 the legumes were planted at rates of either 100,000 or 200,000 PLS per acre in the same row spacings at three locations.

Cowpeas produced higher forage yields than mungbeans at all locations in both years (Table 1, 1987 data not shown). Yield of both species responded negatively to increased row-spacing (Table 2). Species did not differ in plant weight, but plants per unit of harvested area were greater for cowpeas than mungbeans (Table 1). Forage yield was not significantly affected by planting rate at any location in 1988. Plant weight, leaflets per plant, and leaf area per plant, however, were significantly higher for the low rate, suggesting that forage yield remains relatively constant across wide variations in plant population.

Results suggested that both cowpeas and mungbeans could be used as summer-annual forage crops. However, the consistently higher forage production of cowpeas indicated that they are better adapted to South Dakota and, consequently, should be a better forage crop.

Table 1. Forage yield, plant density, and plant weight of cowpeas and mungbeans grown at Highmore (HM), Beresford (BF), and Brookings (BK), SD in 1988. Values are means of two planting rates and three row-spacings.

Location	Yield			Plant density			Plant weight		
	HM	BF	BK	HM	BF	BK	HM	BF	BK
	-- tons/acre --			- plants/ft^2 -			--- g/plant ---		
Cowpeas	2.7	4.5	2.6	3.5	3.8	3.6	17.4	27.3	16.5
Mungbeans	1.7	3.2	2.4	2.6	3.3	3.1	15.1	22.2	18.2
LSD (0.05)		0.2			0.2			1.9	

Table 2. Forage yield of cowpeas and mungbeans planted in three row spacings in 1987 and 1988.

	Yield				
	1987		1988		
Row spacing	Brookings	Beresford	Brookings	Beresford	Highmore
- in. -	-----------------		tons/acre ------------------		
10	3.8	2.9	2.9	4.3	2.5
20	2.8	2.4	2.4	3.9	2.0
30	2.8	2.0	2.1	3.3	2.0
LSD (0.05)	0.3	0.4	0.2	0.6	0.4

CANADA MILKVETCH HARVEST MANAGEMENT

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Plant Science Department

Alfalfa is the most important forage legume grown in the USA. Despite its high potential for yield, forage quality, and intake by ruminant livestock, alfalfa is not well suited for grazing and stands often deteriorate with time.

Two legume species in the genus *Astragalus* may be well-suited for use in pastures in the North Central Region of the USA. Cicer milkvetch (*A. cicer* L.) and Canada milkvetch (*A. canadensis* L.) are being investigated for forage production and quality characteristics.

Cicer milkvetch has been used as a pasture legume in the Rocky Mountain Regions of the USA and Canada. It is strongly rhizomatous, lacks major disease and insect problems, is winterhardy, yields well, and stands often improve with age. These characteristics make cicer milkvetch well suited for pasture use; however, severe palatability problems have been reported in Minnesota. Although seedling growth is not as rapid as that for alfalfa, cicer milkvetch is less sensitive to soil pH and nutrient deficiencies.

Canada milkvetch is native to North America and is not a major agronomic forage. Recently, however, a breeding program was initiated at South Dakota State University for Canada milkvetch seedling growth improvement. Canada milkvetch has many of the desireable qualities found in cicer milkvetch and has a more erect growth habit. Essentially no agronomic information exists for this species.

A field experiment was established near Aurora, South Dakota to compare responses of alfalfa, cicer milkvetch, and Canada milkvetch to height and frequency of harvest. Species will be harvested twice or three times per growing season at two levels above the soil surface. Forage yield will be determined and samples will be obtained for measurements of digestibility, crude protein, cell wall composition, and ruminal escape protein.

ORCHARDGRASS AND TALL FESCUE FORAGE PRODUCTION EVALUATION

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Plant Science Department

Orchardgrass (*Dactylis glomerata* L.) and tall fescue (*Festuca arundinacea* Schreb.) are popular cool-season forage grasses in the upper Midwest and Pacific Northwest Regions of the USA. Considerable interest exists among forage producers and soil conservationists in eastern South Dakota. Indeed, some producers in Brookings County have used orchardgrass pastures for several years.

Desirable characteristics of orchardgrass include exceptionally high forage quality and palatability, good yield potential, and its rate of maturation complements that of alfalfa better than any other grass species. Orchardgrass is not widely used in the Northern Great Plains Region because most cultivars are not adequately drought tolerant or winterhardy. Cultivars recently developed in Canada and in the Rocky Mountain Region possess improved resistance to drought and freezing.

Tall fescue also has good forage quality because leaves comprise a high proportion of the herbage. Peak forage production periods are typically during late-spring and early autumn months. Tall fescue withstands trampling from grazing livestock and persists well in high traffic areas.

The objective of this research is to evaluate the forage production, maturation, and longevity of these cool-season grasses when grown in northeastern South Dakota.

A field experiment was established at the Northeastern Research Station near Watertown, South Dakota in September, 1989. Entries include three winterhardy orchardgrass cultivars (Kay, Chinook, and Paiute), three standard orchardgrass cultivars (Potomac, Sterling, and Latar), and seven tall fescue cultivars (Sexauer, Phoenix, Carefree, Astro, Fawn, Tempo, and Bonanza). 'Regar' meadow bromegrass (*Bromus biebersteinii* Roem & Schult.), a bunch-type bromegrass, was also included. Measurements in 1990 and 1991 will include forage yield, quality, maturity, and stand persistence.

RESEARCH ON
IMPROVING FORAGE QUALITY

ARCHITECTURE EFFECTS ON MORPHOLOGY AND YIELD OF ALFALFA

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Genetic improvement of alfalfa forage quality has often resulted from changed morphology of a population. For example, breeding for low lignin concentration in total herbage may actually result from increased leaf-to-stem ratio. Succulent stem tops are intermediate in digestibility to leaves and stem bases. Although leaves are the highest quality plant part, they are also susceptible to loss during senescence and harvest, whereas stem tops are less susceptible to these losses. Increasing the proportion of stem tops and branches to stem bases may improve forage quality by diluting stem bases. The objective of this research is to determine the relationship of alfalfa stem architecture with other plant morphological characteristics.

Experimental Procedures

Two dissimilar alfalfa cultivars were investigated; DeKalb '120' (DK-120) and 'Travois'. Fifty plants of each cultivar were established in the greenhouse. Data were collected from three harvests obtained at flowering maturities. Measurements on each plant included:

- total plant dry weight
- mean shoot length
- mean maturity stage [(Kalu and Fick, 1983) mean-stage-by-count]
- mean node number on main stem
- mean leaf-to-stem ratio
- mean ratio of axillary- to main-stems.

Table 1. Means, ranges, and least significant differences (LSD;0.05) for morphological characteristics of 48 genotypes of two alfalfa cultivars.

	DK-120			Travois			
	Mean	Min	Max	Mean	Min	Max	LSD[1]
Plant Dry Weight (g)	2.8	0.8	4.9	1.6	0.3	3.7	1.7
Length (cm)	46.9	28.4	62.4	33.2	14.9	48.6	16.0
Maturity	4.3	1.5	5.7	2.7	0.4	4.9	2.4
Node no.	12.2	9.5	14.7	10.8	8.3	12.8	2.7
Leaf-to-stem Ratio	0.9	0.6	1.3	1.2	0.6	2.0	0.6
Axillary-to-main-stem ratio	0.3	0.01	1.1	0.2	0.01	0.5	0.4

[1] Among all genotypes

Table 2. Correlation coefficients between morphological characteristics of two alfalfa cultivars (n=48)[1].

	Cultivar	
	DK-120	Travois
Leaf-to-stem ratio versus:		
Plant dry weight	-0.29*	-0.49**
Stem length	-0.69**	-0.74**
Maturity	-0.55**	-0.63**
Node no.	-0.20	-0.51**
Plant dry weight versus:		
Stem length	0.57**	0.78**
Axillary-to-main-stem ratio versus:		
Plant dry weight	0.07	0.52**
Stem length	-0.01	0.50**
Maturity	0.56**	0.76**
Node no.	-0.01	0.41**
Leaf-to-stem ratio	-0.33*	-0.44**

*, ** Significant at P=0.05 and 0.01, respectively.
[1] Genotype means over three harvests were correlated.

Results

When averaged over genotypes and harvests, DK-120 had 75% greater plant dry weight than Travois (Table 1). DK-120 also had greater stem length, maturity, and mean node number than Travois. Ranges within cultivars for length, maturity, and node number were similar for the two cultivars; however, DK-120 had 21 and 122% greater range in plant dry weight and axillary-to-main-stem ratio than Travois. Travois had a two-fold greater range in leaf-to-stem ratio than DK-120.

Leaf-to-stem ratio was negatively correlated with plant dry weight and stem length (Table 2). Conversely, plant dry weight and stem length were positively correlated. The negative relationship between leaf-to-stem ratio and plant dry weight is likely caused by the negative relationship between leaf-to-stem ratio and stem length. Plants with relatively short stems also have high leaf-to-stem ratio. Since stems represent an important yield component, reduced plant dry weight results from shortened stem length. (1989).

Leaf-to-stem ratio was also negatively correlated with maturity and node number, however, these correlation coefficients were not as great as the correlation coefficients between leaf-to-stem ratio and stem length (Table 2).

In contrast to leaf-to-stem ratio, correlations between axillary-to-main-stem ratio and plant dry weight, stem length, and node number were positive for Travois and were not significant for DK-120 (Table 2). Correlation coefficients between axillary-to-main-stem ratio and maturity were positive for both cultivars.

Nutritive value of alfalfa has been shown to be largely influenced by leaf-to-stem ratio and cell-wall characteristics of the stem. Unfortunately, genetic improvement of alfalfa forage quality has often resulted in reduced yield. Results of a negative correlation between leaf-to-stem ratio and herbage yield agree with previous research.

A primary mechanism of increasing leaf-to-stem ratio is by reducing stem length, thereby reducing herbage yield. Improved forage quality may also be realized by increasing the proportion of succulent stem tops. Results of this greenhouse study suggest that an increased proportion of branch stems will not result in reduced yield.

FORAGE YIELD AND QUALITY OF SUMMER ANNUAL CROPS AS INFLUENCED BY PLANTING DATE

Edward K. Twidwell, Arvid Boe, and Kevin D. Kephart
Plant Science Department

In South Dakota cool-season pastures decline in productivity during the late summer such that forage supplies are usually diminished. Crops that are normally used to augment low forage supplies in late summer include warm-season perennial grass pastures or warm-season annual pasture, hay, and silage crops. Previous research also indicates that summer annual legumes such as cowpeas and mungbeans are adapted to South Dakota conditions and can produce adequate forage yields. At present it is not well understood how the productivity of these summer annual grasses and legumes is influenced by planting date. In drought conditions producers often plant summer annual crops during early to mid-summer and hope that they can produce adequate forage yields in a short period of time. Identification of the best species and optimum planting dates to use would be beneficial information. The objective of this study was to determine the forage yield and quality of four summer annual species planted on three dates at two South Dakota locations.

Materials and Methods

Cowpeas, mungbeans, soybeans, and Siberian millet were planted in mid-May, mid-June, and mid-July, 1989 at Beresford and Highmore, South Dakota. Plot size was 3.3 ft. x 10 ft. and row spacing was 10 inches. On each harvest date the center two rows of each plot were harvested for yield determination. The forage was weighed and a 1 lb. subsample was taken for dry matter determination and future forage quality determinations. At Highmore the millet planted in mid-May was harvested on July 28. The other species were harvested on August 15. All species from the mid-June and mid-July plantings were harvested on August 15 and September 14, respectively. At Beresford, millet planted in mid-May was harvested on July 26. The other three species were harvested on August 14. All species from the mid-June and mid-July plantings were harvested on August 14 and September 15, respectively.

Results and Discussion

There were dramatic differences between locations as the mean yield for all species was 1.6 tons per acre at Highmore and 2.7 tons per acre at Beresford. The lower yields at Highmore were caused by the dry weather conditions present throughout the growing season. Averaged across locations, the species x planting date interaction was significant ($P<0.01$; Table 1). For the first planting date, differences among cowpeas, soybeans, and millet were not significant, however, they all produced at least 1.8 tons per acre more forage than mungbeans. Millet produced the highest forage yield when planted in mid-June, followed by cowpeas. Yields of mungbeans and soybeans were significantly lower, averaging 1.3 and 1.5 tons per acre, respectively (Table 1). For the mid-July planting cowpeas and millet produced similar yields, both of which were significantly higher than mungbeans or soybeans.

Data from the first year of this study indicate that, from a forage production standpoint, cowpeas or millet would be the preferred species. Samples will be analyzed for crude protein, neutral-detergent fiber, and in vitro dry matter digestibility. These data will allow yield and forage quality information to be combined such that pounds of protein or digestible dry matter per acre can be calculated. This entire study will be conducted again in 1990 at Highmore and Beresford.

Table 1. Forage yield of four species planted on three different dates. Values are means of two locations[1].

	Planting date in 1989		
Species	Mid May	Mid June	Mid July
	tons per acre		
Cowpeas	3.1	2.3	2.1
Millet	3.2	2.9	2.4
Mungbeans	1.2	1.3	1.5
Soybeans	3.0	1.5	1.4

[1] For comparison of any two means, the LSD (0.05) value is 0.4 tons per acre.

ALFALFA GROWTH AND FORAGE QUALITY RESPONSES TO ENVIRONMENT

Kevin D. Kephart and Edward K. Twidwell
Plant Science Department

Most studies of environmental effects on alfalfa growth and forage quality have used controlled growth conditions. Additionally, attempts are made to relate instantaneous measurements of environmental conditions to long-term growth responses. For example, prediction of forage yield is often attempted on the basis of leaf photosynthetic rate measured during only a few minutes. Yield and forage quality result from plant responses during relatively long time periods. Consequently, it is difficult to relate short-term phenomenon to long-term processes.

In this experiment, integrated measurements of environmental conditions will be related to alfalfa growth and forage quality in a natural field setting. Four alfalfa cultivars are being used which differ in growth characteristics: two cultivars with rapid regrowth rate; Pioneer 5432 and Cimarron, and two cultivars with slow regrowth rate; Spredor II and Travois. The study was established in 1988 near Aurora, South Dakota. All plots were sampled weekly for 6 weeks during two growth periods in 1989. Forage yield and maturity were measured and samples were prepared for future determination of cell wall components and digestibility. Alfalfa growth and forage quality are being related to days of growth, degree days, and cumulative solar radiation.

1989 Results

Degree days and solar radiation accumulated linearly during both growth periods (Fig. 1 and 2). Forage yield and maturity responses to degree days and solar radiation were similar, therefore only responses to degree days are shown (Fig. 3 and 4).

Cultivars did not significantly differ in growth rate response to degree days for either growth period (Fig. 3a and 4a). Spredor II had the greatest average yield during the first growth period (P=0.05), whereas Cimarron and 5432 produced the greatest average yield for the second growth period.

Notably, results suggest that cultivars differ more in response of maturity than in response of yield to degree days. Clearly, Travois matured less rapidly during both growth periods than the other cultivars (Fig. 3b and 4b). Cimarron and 5432 matured more rapidly than Spredor II and Travois during the second growth period (Fig. 4b).

This research will continue in 1990 and samples will be obtained for carbon isotope discrimination to have an integrated measurement of water stress.

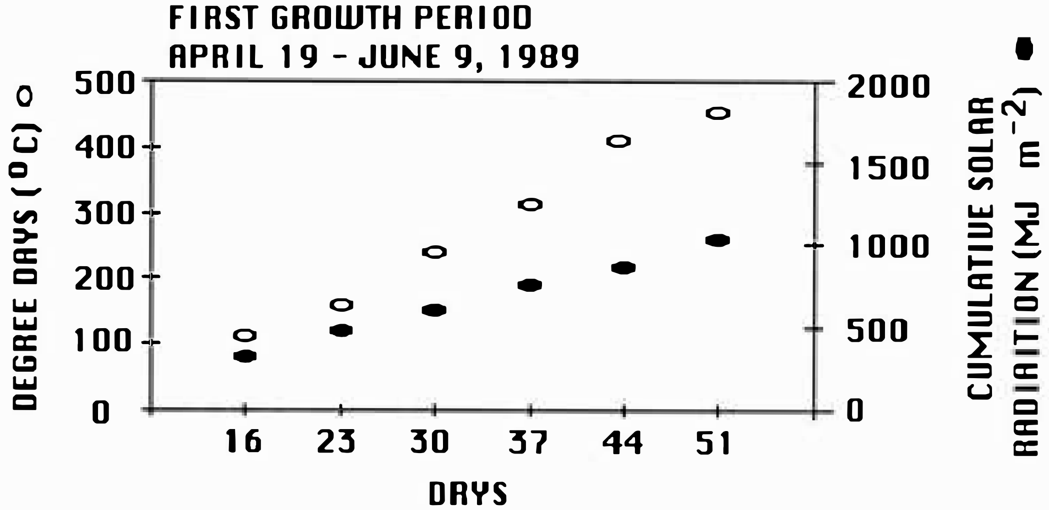

Figure 1. Accumulation of degree days and solar radiation during first alfalfa growth period, 1989.

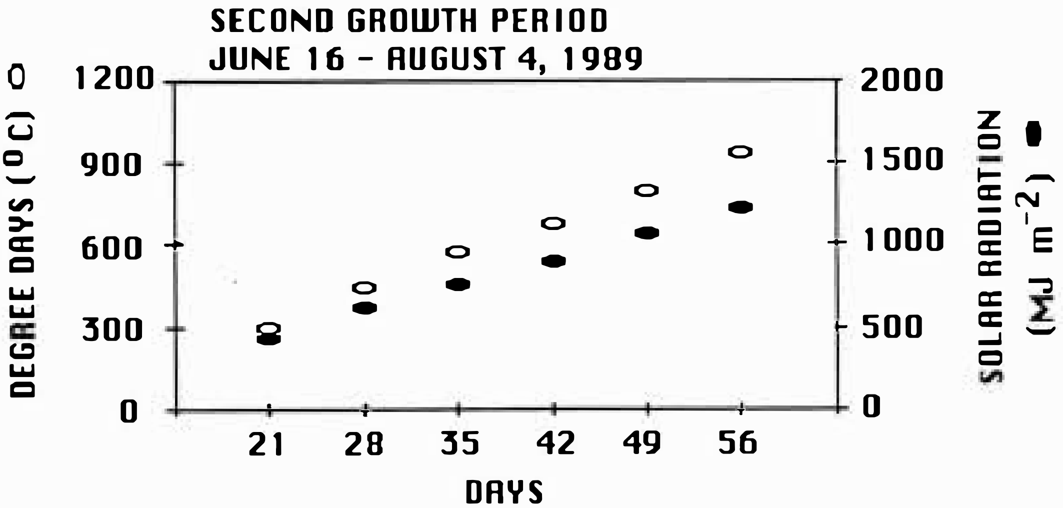

Figure 2. Accumulation of degree days and solar radiation during second alfalfa growth period, 1989.

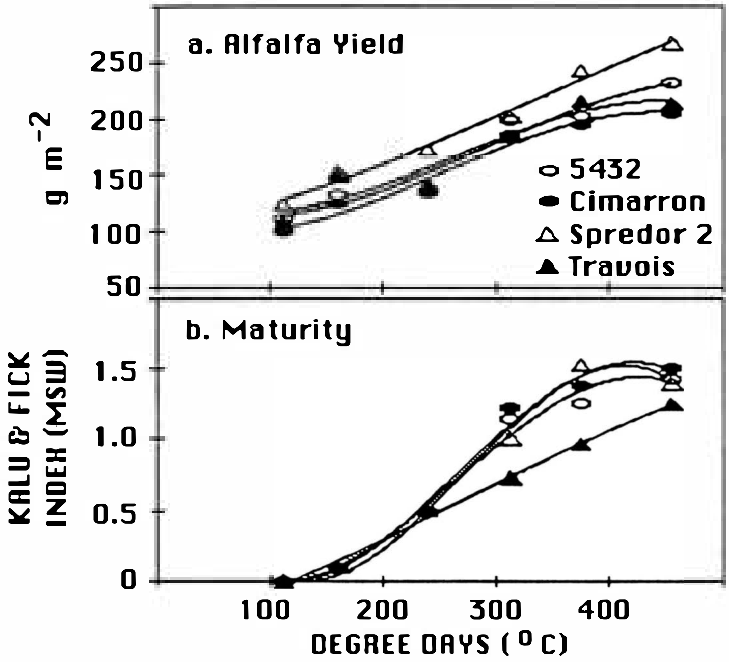

Figure 3. Response of forage yield and maturity to cumulative degree days during the first alfalfa growth period, 1989.

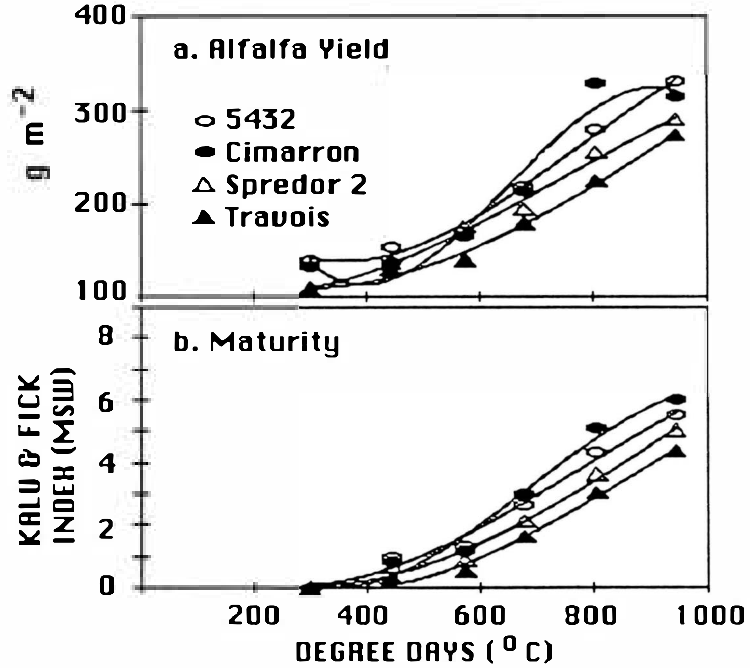

Figure 4. Response of forage yield and maturity to cumulative degree days during the second alfalfa growth period, 1989.

DIVERGENT SELECTION FOR YIELD COMPONENTS IN SWITCHGRASS

Arvid Boe and Kevin Kephart
Plant Science Department

The quality of switchgrass forage is related to changes in proportion and composition of the stem fraction with maturation. The superior forage quality of leaf blade compared to stem tissue, along with a tendency for cattle to selectively graze leaf blades of switchgrass, suggests development of cultivars that maintain a high proportion of leaf blade tissue as maturation proceeds should enhance performance of livestock grazing switchgrass or fed switchgrass hay.

The objective of this research is to develop, by divergent selection, populations that exhibit wide differences in leaf blade weight, leaf sheath weight, stem weight, and leaf-to-stem ratio. The first phase of this research involved evaluating 120 plants each of 'Sunburst' and 'Summer' for forage yield components over a 3-year period. The second phase, which is underway, involves the evaluation of progenies of plants from phase-I that were selected for high or low leaf blade weight, stem weight, or leaf-to-stem ratio. These progenies will be evaluated for morphological characteristics and forage quality for 3 years at 2 locations (Brookings and Highmore, SD). Progeny performance will provide a data base to aid in selection of elite genotypes to be used in development of cultivars with improved forage quality.

FORAGE PROTEIN CHARACTERIZATION AND UTILIZATION FOR BEEF CATTLE

Kevin D. Kephart, Arvid Boe, and Edward K. Twidwell
Plant Science Department

Not all protein in the forage diet is available to absorption by ruminant livestock. Two major categories of forage protein that are available to the animal include protein synthesized by rumen microbes and passed to the small intestine (microbial protein) and that which escapes microbial digestion in the rumen and passes intact to the small intestine (escape or bypass protein). Availability of microbial protein is closely linked with a balanced availability of nitrogen and energy. Either may limit microbial protein synthesis. High amounts of digestible escape protein are desireable because availability of this type of protein is less dependent upon energy availability. Often, livestock with high protein requirements, such as growing calves, may be nutritionally deficient in protein even though they are consuming high-quality forage because inadequate amounts of escape protein exist.

Little knowledge exists on the effects of species, environment, agronomic management, and maturity on escape protein characteristics of forages. A regional cooperative research project was recently initiated to investigate these effects on escape protein. The research committee is comprised of rumen nutritionists and forage agronomists in the North Central Region of the USA.

Two field experiments have been initiated at Brookings, South Dakota. The objective of the first experiment is to compare bloat provocative and non-bloat provocative legumes for escape protein responses to maturity. It is suspected that bloat provocative species, such as alfalfa, have less available escape protein than non-bloat provocative species. Thus, livestock on an alfalfa diet may possibly be deficient in metabolizable protein. Legume species in the experiment include 'Cimarron' alfalfa (bloat provocative) and cicer and Canada milkvetches (non-bloat provocative). Effects of harvest regime and maturity are being investigated.

The objective of the second experiment is to compare cool-season and warm-season grasses for escape protein. Warm-season grasses are often characterized as having lower digestibility than cool-season grasses because of differences in leaf anatomy. Yet, animal performance on warm-season grass pasture is often equal or superior to cool-season grass pastures. This unexplained response may be related to differences in escape protein relationships with leaf anatomy. Cool-season species in this experiment include 'Regar' meadow bromegrass and intermediate wheatgrass, and the two warm-season species include big bluestem and switchgrass.

Both experiments will be sampled in 1990. Forage samples will be shipped to the University of Nebraska for analysis of escape protein.

RESEARCH ON
MANAGEMENT AND CULTURAL PRACTICES
OF FORAGE CROPS

SCARIFICATION EFFECTS ON GERMINATION OF SWITCHGRASS

Arvid Boe and Nancy Jensen
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Germination and seedling emergence of neoteric (freshly-harvested) seed lots of switchgrass (*Panicum virgatum* L.) are often delayed because of seed dormancy. The objective of this study was to determine the effect of mechanical scarification (abrasion) on germination and seedling emergence of neoteric (1-to 18-month-old) switchgrass seed.

Scarification for 15 or 30 seconds in a Forsberg cylinder scarifier equipped with 2/0 emery cloth significantly ($P < 0.01$) increased germination percentage and seedling emergence in the greenhouse 14 days after planting for five cultivars (Table 1). Overall mean germination percentage for five cultivars harvested in September 1983 and tested in October and November 1983 and January 1984 at two temperature regimes (30 °C for 8 h / 15 °C for 16 h and constant 20 °C) without prechill were 8.7, 39.4, and 39.9% for 0-, 15- and 30-sec scarification treatments, respectively. Four-month- and 18-month-old seed lots of 'Sunburst' and a North Dakota ecotype (NDE) kept in either cold storage (7 °C, 43% relative humidity) or at room temperature and humidity also exhibited significant ($P < 0.01$) increases in germination after scarification. Overall mean germination percentages for three lots of 'Sunburst' and two lots of NDE were 30.5, 50.5, and 53.7% for 0-, 15-, and 30-sec scarification treatments, respectively. Significant ($P < 0.01$) differences were found between scarified and nonscarified lots for seedling emergence in the greenhouse but the magnitude of the increase in emergence due to scarification was not consistent across cultivars.

Mechanical scarification has potential for improving initial germination and seedling emergence in neoteric seed lots of switchgrass. Field studies are needed to determine the feasibility of such a procedure as a seed treatment prior to planting.

Table 1. Greenhouse emergence at 14 days of nonscarified and scarified neoteric seed of five switchgrass cultivars.

	Scarification time (sec)		
Cultivar	0	15	30
	% Emergence		
Sunburst	3.3	32.7	26.7
Pathfinder	20.0	58.7	33.3
Summer	7.3	8.7	5.3
Dacotah	0.0	6.0	10.0
Forestburg	4.0	20.0	18.8
LSD (0.05) = 12.4			

CHEMICAL CONTROL OF COMPANION CROP IN ALFALFA ESTABLISHMENT

Bill S. Curran, Kevin D. Kephart, and Edward K. Twidwell
Plant Science Department

Two major techniques for establishment of alfalfa (*Medicago sativa* L.) include companion cropping, and clear-seeding. Use of an oat (*Avena sativa* L.) companion crop benefits alfalfa establishment by providing erosion control, weed suppression, and in the seeding year can be used as a forage in addition to the alfalfa. Companion crops, however, compete with alfalfa seedlings for water, soil nutrients, and solar radiation. Optimum alfalfa stands often result in the seeding year by clear-seeding. Conversely, potential for soil erosion is greatly increased because of prolonged soil exposure. Also, weed control with pre-plant incorporated herbicides has been inconsistent. To minimize inhibition of alfalfa seedling growth, a companion crop can be used for soil erosion control, followed by sethoxydim treatment when competition becomes excessive.

The objectives of this study are to: 1) compare three alfalfa establishment techniques; i) companion crop; ii) clear-seeding; iii) chemical control of companion crop. 2) determine growth rate kinetics of alfalfa seedlings for the three establishment techniques. 3) determine morphological adaptations of alfalfa seedlings to different establishment techniques.

Experimental Procedures

This field based experiment was conducted at two eastern South Dakota locations: 1) SDSU Agronomy Farm at Brookings, and 2) Crop Improvement Research Farm near Aurora. The experimental treatments include: i) oat companion crop with sethoxydim applied at 2 inches of oat growth; ii) oat companion crop with sethoxydim applied at 6 inches of oat growth; iii) oat companion crop removed at boot stage; iv) oat companion crop removed at dough stage; v) clear-seeding with EPTC; vi) weed-free treatment; vii) control.

Measurements include herbage dry matter yield of alfalfa, oats and weeds, alfalfa plant density, alfalfa maturity, weight and length of alfalfa stems and roots, and weight and area of alfalfa leaves.

Results

Alfalfa established with an oat companion crop and sprayed with sethoxydim at the 2-inch stage of growth provided similar alfalfa yields to the weed-free treatment in the seeding year (Fig. 1).

Treatments with progressively lower alfalfa yields included clear-seeding with EPTC, oat companion crop with sethoxydim applied at 6-inches, oats clipped at boot stage, oats clipped at dough stage, and the control, respectively. Plant densities were statistically similar for all establishment methods.

Weed yields ranged from 0 to 299 g m^{-2}. The control had the greatest weed yield followed by oat companion removed at dough stage, oat companion removed at boot stage, clear-seeded with EPTC, oat companion with sethoxydim applied at 6-inches, and oat companion with sethoxydim applied at 2-inches (Table 1).

The largest component of weed yield was annual grasses comprised of green foxtail [*Setaria viridis* (L.) Beauv.], yellow foxtail [*Setaria gluaca* (L.) Beauv.], and barnyard grass [*Echinochloa crusgalli* (L.) Beauv.]. Annual broadleaf weeds included common lambsquarters (*Chenopodium album* L.), redroot pigweed (*Amaranthus retroflexus* L.), prostrate pigweed (*Amaranthus blitoides* S. Wats.) and russian thistle (*Salsola kali* L.).

Control of the annual grasses and broadleaf weeds increases alfalfa yield nearly 25 fold over the alfalfa yield in the control treatment. Total herbage yield, however, was 106% lower for the sethoxydim applied at 2-inches when compared to the control.

Results suggest that oats, annual grass, and broadleaf weeds hinder seedling growth of alfalfa. Clear-seeding establishment had an 15% yield advantage over sethoxydim applied at 2-inches, but oats provided adequate early season erosion control, whereas the clear-seeded treatment allowed no erosion control until alfalfa emergence. More data are being analyzed at a second location with the study continuing at both locations to investigate stand persistence and alfalfa forage yield in subsequent years.

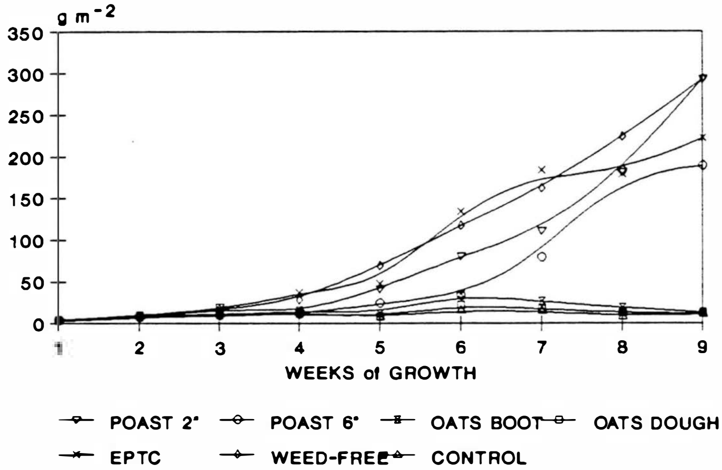

Figure 1. Alfalfa forage yield response to establishment treatments during the first 9 weeks of growth of the seeding year.

Table 1. Effect of establishment method on alfalfa and weed yield in the seeding year.

Treatment	Yield component				
	Alfalfa	Grass	Broadleaf	Oat	Total
	--------------		$g\ m^{-2}$		-------------
1 Oat companion at 2-in. and sethoxydim[1]	293.5	13.0	37.7	0	344.2
2 Oat companion at 6-in. and sethoxydim[1]	188.7	28.7	28.3	9.0	254.6
3 Oat companion clipped at boot stage	13.2	416.5	92.4	7.1	529.2
4 Oat companion clipped at dough stage	12.0	371.8	156.2	25.8	565.8
5 Clear-seeded with EPTC[1]	222.4	131.1	43.1	---	396.6
6 Weed free	292.9	0	0	---	292.9
7 Control	11.3	495.9	202.2	---	709.4
LSD (0.05) =	27.9	35.7	44.3	9.9	33.8

[1]Sethoxydim applied at 0.22 kg ai. per ha and EPTC applied at 0.56 kg ai. per ha.

EFFECT OF PREVIOUS LEGUME CROP ON ALFALFA PRODUCTION

Robin Bortnem and Arvid Boe
Plant Science Department

Several field studies in the central and eastern USA have demonstrated reduced yields from reseeded alfalfa compared with stands established on land that previously supported other crop species. Little information exists on variability among alfalfa cultivars for forage production on land previously cropped to alfalfa and other forage legumes. The objective of this study was to evaluate forage production of alfalfa cultivars planted into land previously cropped to alfalfa, red clover, and birdsfoot trefoil.

Three diverse alfalfa cultivars; Heinrichs, Cimarron, and Vernal, were clear-seeded into residues from adjacent 3-year-old 0.1 ha stands of alfalfa, red clover, and birdsfoot trefoil. Treatments included a summer 1987 tillage and planting (87T/87P), a summer 1987 tillage and spring 1988 planting (87T/88P), and spring 1988 tillage and planting (88T/88P). No significant differences were found among cultivars for total forage yields in 1988 and 1989.

The lack of significant cultivar X residue and cultivar X tillage/plant interactions indicated forage yields of the three cultivars were similarly influenced by residues of the preceding crop. A highly significant residue X year interaction indicated total forage yields for the 87T/87P plots in the three residues ranked differently across years. Total forage yields were significantly higher in birdsfoot trefoil residue in 1989, but production was similar in all residues in 1988. In 1988, the autotoxic effect might have been expected to be greatest because of below normal precipitation. Since total production was similar for residues in 1988, the influence of autotoxic factors on forage yield was not indicated.

Highly significant year X residue and year X tillage/plant interactions in the red clover and alfalfa residues indicated residue and tillage/plant effects varied over time. The 1988 forage yields were similar for alfalfa grown in alfalfa or red clover residues but yields in 1989 showed production in alfalfa residue (1.60 T/A) to be significantly higher than that of red clover (1.42 T/A). The effect of tillage/plant combinations in 1988 showed 87T/87P alfalfa (0.43 T/A) yielded significantly greater than 87T/88P and 88T/88P alfalfa (0.18 and 0.20 T/A, respectively). Greater 1988 forage yield in the 87T/87P alfalfa was expected since the stand was established in summer 1987. Tillage 30 days prior to planting compared to 9 months prior to planting did not reduce forage yield of alfalfa planted into alfalfa and red clover residues in 1988. Residues and tillage/plant combinations did not seem to influence establishment year forage yields under these conditions.

SEEDING RATE EFFECTS ON ALFALFA PLANT GROWTH

Kevin D. Kephart and Edward K. Twidwell
Plant Science Department

Seeding rate effects on alfalfa forage yield have been studied extensively in order to assist forage producers in planting decisions. While modern alfalfa cultivars possess improved disease and pest resistance, they are also more expensive than obsolete and common types. Seed prices for new cultivars often exceed $3.00 per lb., making seed one of the most expensive components in establishing a new alfalfa stand.

The amount of seed planted per acre may also influence forage yield and stand characteristics during the entire life of an alfalfa stand. Understandably, forage producers wish to minimize seeding rates without compromising forage production. The objective of this research is to determine effects of seeding rate on alfalfa yield components several years after stand establishment.

Experimental Procedures

Alfalfa seeding rate experiments were established at Brookings and Highmore, South Dakota in spring of 1985. Cultivars included Pioneer 532 and Big-10 and seeding rates ranged from 2 to 30 lb. pure live seed (PLS) per acre in 2 lb. PLS per acre increments.

Total forage yield was measured in 1985 at Brookings and in 1986 and 1987 at both locations. In 1988 and 1989, plots were sampled for alfalfa yield component analysis. Components included alfalfa plant density (plants per ft^2), shoot number per plant, and shoot weight. Yield of broadleaf and grass weeds were also measured. Plots were sampled twice at Brookings and once at Highmore in 1988 and once at both locations in 1989.

Results

Optimum seeding rate at Brookings was approximately 12 lb. PLS per acre for the first 3 years (Fig. 1). Similarly, 12 lb. PLS per acre was also the optimum seeding rate at Highmore in 1986, a year with abundant precipitation. Harvest did not occur in 1985 at Highmore because of poor seedling growth resulting from drought. Additionally, forage yield did not respond to seeding rate at Highmore in 1987, also because of limited soil moisture.

Common to previous seeding rate experiments, effects of seeding rate on alfalfa yield were modest after the seeding year. At Brookings, alfalfa yield responses to seeding rate were observed 4 years after planting, demonstrating that seeding rate decisions influence alfalfa growth for several years.

Alfalfa yield responses may be related to changes in three yield components: plant density, number of shoots per plant, and shoot weight. Seeding rate effects were observed on alfalfa plant density 4 years after establishment at both locations (Fig. 2b and 3b). Differences in alfalfa yields were modest even though plant density increased with seeding rate. Alfalfa plant densities were approximately 5 plants per ft^2 at the 2 lb. PLS per acre seeding rate and were as high as 25 plants per ft^2 for 26 lb. PLS per acre at Highmore and 19 plants per ft^2 for 24 lb. PLS per acre at Brookings.

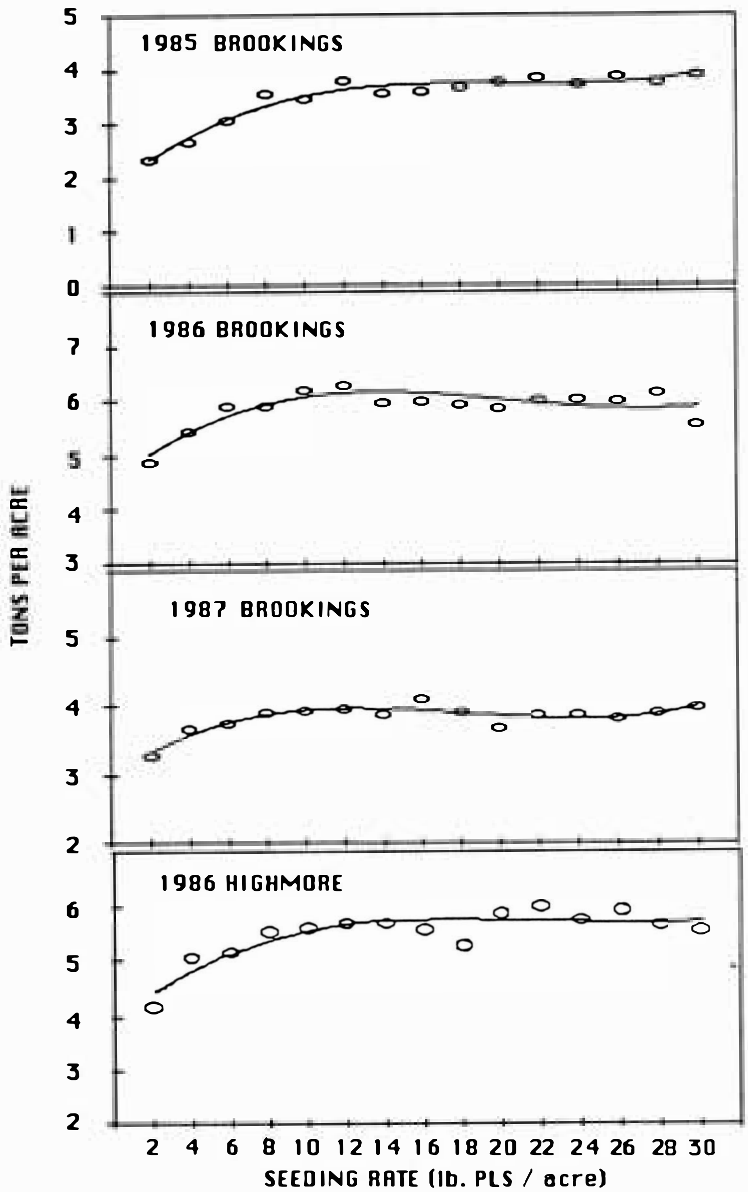

Figure 1. Total season forage yield responses to seeding rate for alfalfa spring-planted at two South Dakota locations in 1985.

Number of shoots per plant were also affected by seeding rate 4 years after establishment (Fig. 2c and 3c). The greatest number of shoots per plant were observed with the lowest seeding rate and numbers declined until approximately 16 and 14 lb. PLS per acre at Brookings and Highmore, respectively. Clearly, shoot number per plant and plant density negatively interact resulting in great yield plasticity.

The third major yield component, shoot weight, also responded to seeding rate for as long as 4 years after establishment (Fig. 2d and 3d). Shoot weight did not significantly differ among seeding rate treatments at Brookings in 1988, however, a negative response of shoot weight to seeding rate was observed at Brookings in 1989 and at Highmore in 1988 and 1989. The negative response was greatest during extreme drought.

Seeding rate decisions can influence alfalfa growth during the entire life of a stand. Yield is not always influenced because of interactions among yield components; however, efficiency in use of water, soil nutrients, solar radiation, and economic inputs may be influenced. Future research is needed to determine seeding rate responses to available soil moisture.

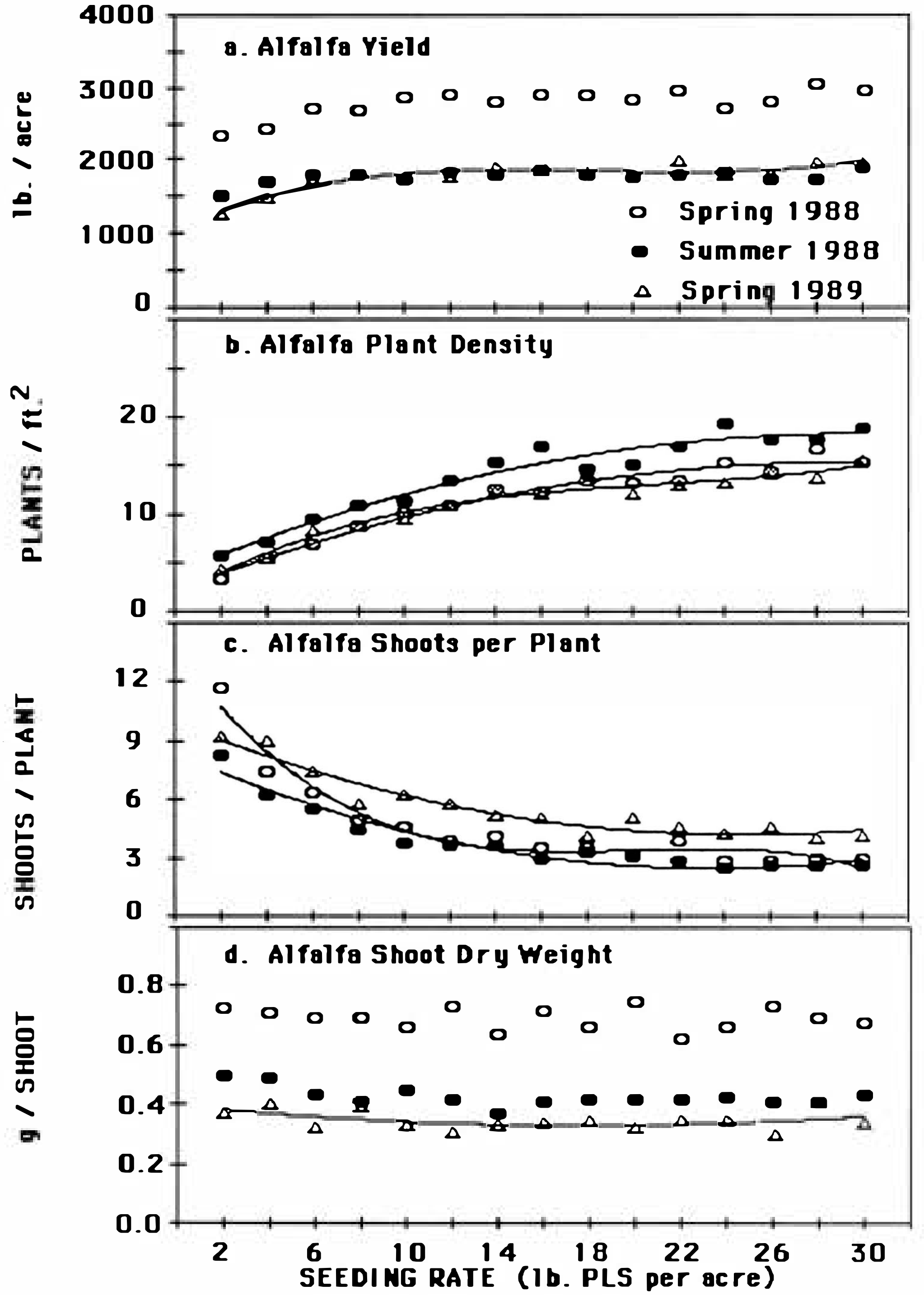

Figure 2. Responses of forage yield, plant density, shoot number per plant, and shoot weight to seeding rate for alfalfa planted at Brookings, South Dakota in 1985.

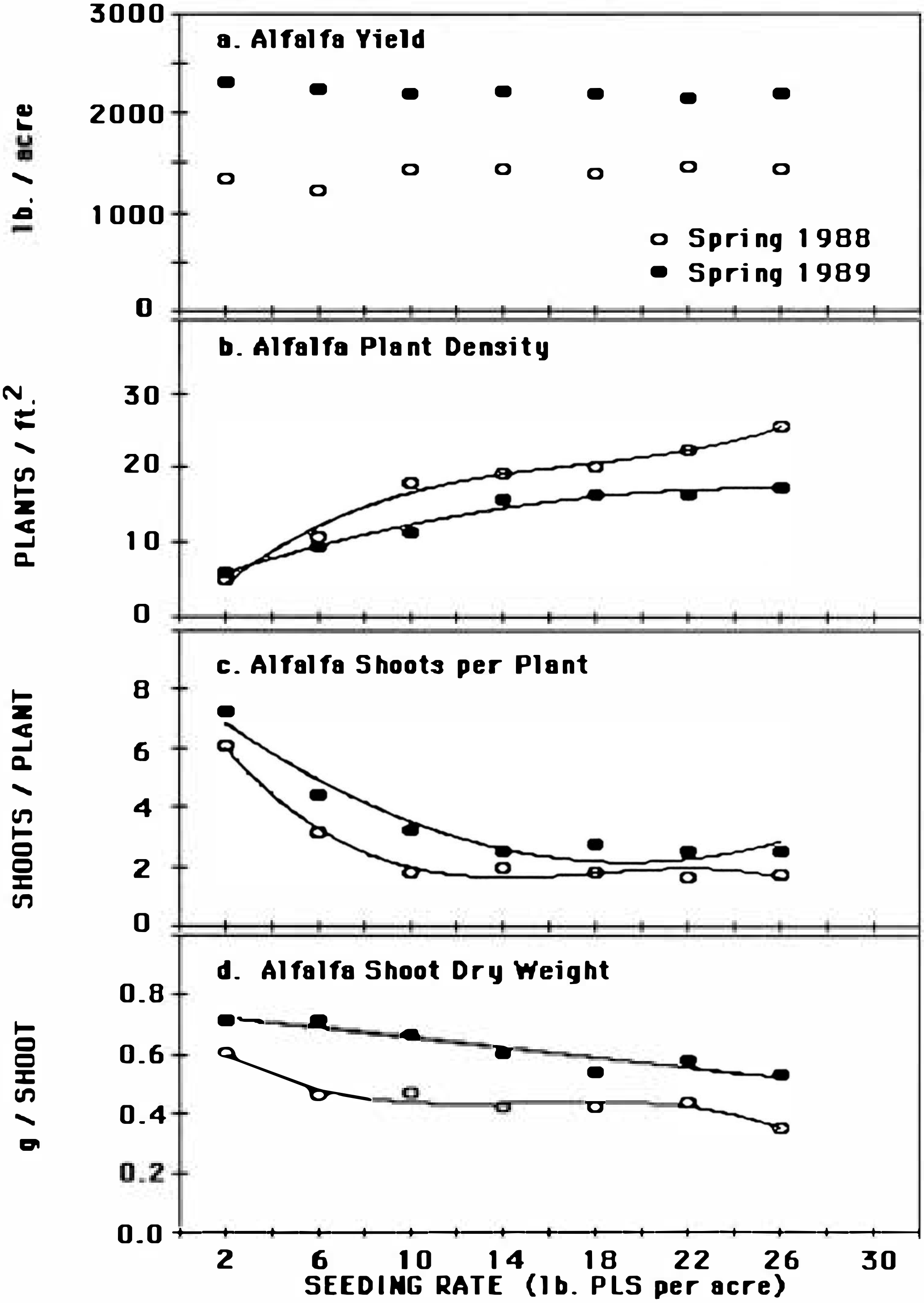

Figure 3. Responses of forage yield, plant density, shoot number per plant, and shoot weight to seeding rate for alfalfa planted at Highmore, South Dakota in 1985.

SEEDLING EVALUATION OF INTERSEEDED ALFALFA

Robin Bortnem and Arvid Boe
Plant Science Department

Several researchers have suggested that failures to improve alfalfa stand density by interseeding are related to germination inhibition caused by existing plants. The objective of this study was to assess emergence and stand establishment of interseeded alfalfa cultivars.

No significant differences in seedling counts were found among eight alfalfa cultivars planted at 67 pure live seed (PLS) per ft. between rows of 3-year-old stands of alfalfa at Chester, Beresford, and Highmore, South Dakota. A significant difference in seedling counts was found between 1 and 6 weeks after planting. Seedling counts were 24.5 seedlings per ft. 1 week after planting compared to 12.2 seedlings per ft. 6 weeks after planting.

A highly significant treatment X location interaction for seedling counts indicated the effect of clipped (existing stand trimmed to 2 in.) versus unclipped (existing stand not trimmed) treatments, averaged between 1 and 6 weeks, varied with location. At Chester, higher seedling counts were found in clipped than unclipped treatments (24.1 and 13.2 seedlings per ft., respectively). At Beresford and Highmore, on the other hand, no significant differences were found between clipped and unclipped treatments.

A highly significant date X treatment X location interaction was detected for 1-week and 6-week seedling count means (Table 1). Six-week seedling counts for clipped and unclipped treatments at Chester were significantly higher than at Highmore. The 6-week seedling count in the clipped treatment was significantly higher at Chester than at Beresford but no significant difference was found between unclipped treatments at the two locations. Precipitation received during June at Chester was approximately twice that of Beresford and Highmore, therefore competition between the existing stand and the new seedings was most likely most severe at Beresford and Highmore. However, the lack of significant differences between unclipped treatments at Chester and Beresford indicated factors other than moisture likely decreased seedling counts in unclipped treatments at Chester. Alfalfa germination and seedling emergence were not severely inhibited by existing stands of alfalfa. However, seedling mortality was high between 2 and 6 weeks after planting.

Table 1. Mean seedling counts of eight alfalfa cultivars for clipped and unclipped treatments at three locations in eastern South Dakota.

Location	Weeks after planting	Stand treatment Clipped	Unclipped
		----seedlings/m----	
Chester	1	59.0	41.4
	6	85.9	38.0
Beresford	1	125.9	140.8
	6	39.3	29.1
Highmore	1	50.0	23.4
	6	9.2	18.1
		LSD (0.01) = 11.0	

NO-TILL STAND ESTABLISHMENT OF ALFALFA AND GRASSES

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In the semi-arid climates of western South Dakota establishment of alfalfa and grasses is difficult. Producers may make several seeding attempts before obtaining a satisfactory stand. Nurse crops such as oats or other small grains provide shade for seedling alfalfa and grasses but tend to compete for plant available moisture. The results of using oats as a nurse crop in many cases has been less than satisfactory. Planting alfalfa alone or with soil incorporated herbicides generally does not leave adequate residue on the soil surface to protect against wind erosion or provide any shade for the small alfalfa seedling. The use of non-residual herbicides to control weeds in standing small grain stubble provides a dead nurse crop. This standing dead stubble provides wind erosion protection and shade while not using soil moisture. Seeding into winter wheat stubble was a concern because of potential allelopathy on the seedling alfalfa and grass. This concept needed to be studied in western South Dakota where the need for available moisture is critical during the establishment period for alfalfa and grasses.

Research

1984:

Experiments using no-till establishment of alfalfa were conducted. The 1984 methods of stand establishment were successful with all treatments exceeding 20 plants per ft^2. Both Paraquat and Roundup herbicides were effective in controlling volunteer winter wheat and broadleaf weeds.

1985:

The spring of 1985 was very dry. Limited precipitation was received during April and May. The 1985 no-till seeding attempt was unsuccessful. Alfalfa seed did not germinate in the dry soil until August.

1986:

No-till plots of alfalfa and intermediate wheatgrass were established near Rapid City. The spring of 1986 was very wet and herbicide application was delayed until April 21. Plots were seeded using a disk press drill on April 25, 1986. The plots had alternating 6-inch spaced rows of wheatgrass and alfalfa. Post-planting spraying was done on April 29, 1986. The weeds on April 29 were pennycress at two leaf to 8-

in. tall, tansy mustard at 3- to 8-in. tall, and volunteer winter wheat 6-in. tall. The weeds grew rapidly because of early season rains. Yield of the previous years winter wheat crop exceeded 30 bu. per acre and residue was undisturbed at the time of seeding. There was no problem with the residue plugging the disk press drill. Evaluation of weed control and stands were made visually on May 21, 1986. Roundup, Landmaster and tillage effectively controlled weeds and volunteer winter wheat. Paraquat did not control volunteer winter wheat and regrowth competed with alfalfa and wheatgrass (Table 1). Yield was measured on August 4 and 5, 1986. The yield samples were separated into four major components; alfalfa, wheatgrass, volunteer wheat and weeds. Yields at 12.5% moisture are presented in Table 2. The alfalfa and wheatgrass components were reduced when volunteer winter wheat and weeds were not controlled. Plots that received cultivation or Roundup treatments prior to planting had excellent stands.

The 1986 plots were maintained through 1987 and yield was measured. The yields of alfalfa and wheatgrass were better in plots that had control of volunteer winter wheat and weeds in the first season (Table 3).

Table 1. No-till alfalfa and grass - summary of weed control and stand establishment on May 21, 1986 - Pennington County (Spring Creek area) 1986

TREATMENT	RATE OF PRODUCT	TANSY-MUSTARD	VOLUNTEER WHEAT	ALFALFA[1]	GRASS[1]
	- oz./acre -	-- % control --		-- % stand --	
Pre-plant					
Roundup	8	99	99	99	100
Roundup	12	99	97	86	65
Landmaster	40	99	99	54	79
Paraquat	16	83	45	81	71
Paraquat	24	86	53	100	72
Cultivated	check	99	86	53	62
Uncultivated	check	0	0	45	26
Post-plant					
Roundup	8	92	97	87	69
Roundup	12	99	97	84	58
Landmaster	40	99	99	70	33
Paraquat	16	75	25	75	68
Paraquat	24	79	50	76	63
LSD (.05)		4	11		
C.V.		4	11		

[1]Percent of top plot. (100% = top plot) Notes taken May 21, June 16 and 17, and July 1, 1986.

Table 2. No-till alfalfa and grass - summary of production - Pennington County (Spring Creek), 1986

TREATMENT	RATE OF PRODUCT	ALFALFA[1]	VOLUNTEER GRASS	VOLUNTEER W. WHEAT	VOLUNTEER WEEDS	ALFALFA AND GRASS
	- oz./ acre	---------------		lb./acre		----------------
Pre-plant						
Roundup	8	1078	197	0	1121	1275
Roundup	12	1145	209	0	1123	1354
Landmaster	40	1041	168	0	1551	1209
Paraquat	16	413	68	1809	688	481
Paraquat	24	496	79	2147	724	575
Cultivated	check	1034	354	702	581	1388
Uncultivated	check	214	123	547	607	337
Post-plant						
Roundup	8	700	72	36	1415	772
Roundup	12	995	215	15	840	1210
Landmaster	40	719	58	490	1208	777
Paraquat	16	143	13	4626	320	156
Paraquat	24	351	154	2241	430	505
LSD (.05)		464	168	1073	719	535
C. V.		46	82	71	56	44

[1] Plots harvested on August 4-5, 1986

Table 3. No-till alfalfa and grass - summary of production - Pennington County (Spring Creek), 1987

TREATMENT	RATE OF PRODUCT	ALFALFA[1]	VOLUNTEER GRASS	VOLUNTEER W. WHEAT	VOLUNTEER WEEDS	ALFALFA AND GRASS
	- oz./acre -	---------------		lb./acre		---------------
Pre-plant						
Roundup	8	1360	3464	284	262	4824
Roundup	16	1301	4707	577	257	6008
Landmaster	40	815	3019	1472	193	3834
Paraquat	16	502	2133	1133	324	2635
Paraquat	24	903	2920	1060	550	3823
Cultivated	check	680	3188	1178	283	3868
Uncultivated	check	530	2837	1571	791	3367
Post-plant						
Roundup	8	1226	4261	337	272	5487
Roundup	16	1042	4411	761	477	5453
Landmaster	40	905	3975	472	334	4880
Paraquat	16	959	4251	671	80	5210
Paraquat	24	1063	3633	1425	457	4696
LSD (.05)		529	1859	1148	-	-
C.V.		39	36	87	-	-

[1] Plots harvested on June 24-29, 1987

1987:

In April of 1987, two experiments were established. There was limited moisture at planting time, but 10 days later the site received 0.33 in. of rain. Two separate experiments evaluated herbicides to replace tillage in establishing a mixture of alfalfa and crested wheatgrass, and establishing cool- and warm-season grasses. Alfalfa and crested wheatgrass were drilled in alternately spaced 6-in. rows into tilled and untilled winter wheat stubble. Alfalfa germinated and established a satisfactory stand by mid-May. Crested wheatgrass had limited germination and there were not enough plants to evaluate the stand by mid-May; therefore, evaluation was delayed until 1988 (Table 4). All plots were mowed in late May 1987 to control larger weeds.

The experiment with cool- and warm-season grasses used western wheatgrass and sideoats grama planted in alternately spaced 6-in. rows. No early summer germination was detected for either grass. By mid-summer, limited numbers of sideoats grama plants appeared to be established. Plots were evaluated in 1988 to determine if there were significant stand differences due to methods of establishment. Field bindweed badly infested this trial preventing statistical comparisons. Treatments consisted of various combinations of Roundup, Glean, and Ally in addition to cultivation and direct drill treatments without herbicides. By 1988, western wheatgrass stands ranged from 9 to 25%; with direct drilling being 9%. All treatments have the potential to eventually be satisfactory because western wheatgrass is rhizomatous. Sideoats grama stands ranged from 25 to 30% except for the cultivated-without-tillage treatment which was 17%. Sideoats grama seemed to be established better with the use of herbicides than with the cultivated-no-herbicide treatment.

TABLE 4. NO-TILL ALFALFA AND GRASS - SUMMARY OF % STAND ESTABLISHMENT - PENNINGTON COUNTY (MARTY PRINTZ) 1988

TREATMENT	RATE OF PRODUCT	ALFALFA[1]	GRASS[1]
	- oz./acre -	----- % stand	----
Pre-plant			
Roundup	8	91	64
Roundup	12	90	75
Post-plant			
Roundup	8	91	68
Roundup	12	84	62
Touchdown	16	92	61
Cultivated		87	65
Direct Drilled		60	22
LSD (0.05)		22.8	31.9
STANDARD DEVIATION		14.8	20.7
C.V.		12.4	24.8

[1] Notes taken June 22, 1988

1988:

April 14, 1988 an experiment was established in Meade County similar to the ones in Pennington County in 1987. The treatments were preplant herbicides or tillage to establish a seedbed. The pretreatments were to be combined with post emergence treatments of mowing or herbicide applications. The plots were planted April 20, 1988. The first set of notes were taken on the stands of alfalfa and crested wheatgrass on June 22, 1988 (Table 5). The farmer cooperator had the field sprayed with Landmaster. The pilot did not see our plots and the plots were accidentally sprayed 2 days before the notes were taken. The post emergence treatments were not applied and no further notes were taken. The plots which had Roundup applied prior to seeding had a significantly better stand of alfalfa than the plots that were directly seeded into wheat stubble without a spring treatment. The plots that were disked to prepare a seedbed had a significantly poorer stand of both alfalfa and crested wheatgrass.

Table 5. No-till alfalfa and grass establishment - summary of percent stand estimates - Meade County (Jim Madsen Farm) 1988

TREATMENT[1]	RATE OF PRODUCT	ALFALFA[2]	GRASS[2]
	- oz./acre -	---- % stand	---
Roundup & mowing	12	85	83
Roundup	12	94	91
Roundup & 2,4-DB	12	89	85
Roundup & Bromoxynil	12	88	83
Control		71	73
Control & 2,4-DB		70	73
Control & Bromoxynil		71	65
Disked		50	84
LSD (0.05)		11.9	13.1
STANDARD DEVIATION		8.1	8.9
C.V.		10.5	11.3

1 Mowing, 2,4-DB and Bromoxynil were not applied, therefore, the four Roundup treatments were similar and the three control treatments were similar.

2 Notes taken May 27,1988.

Summary

Spring no-till establishment of alfalfa and cool-season grasses is somewhat variable. Herbicides improve the chances of success but there are no guarantees. In 1985 because of the extreme drought the alfalfa stand was not satisfactory. During 1984, 1986, 1987 and 1988 when volunteer winter wheat, downy bromegrass and other winter annual weeds were controlled, no-till stand establishment of alfalfa was excellent. No-till establishment of cool-season grasses is very dependent on moisture. More research into no-till stand establishment of cool- and warm-season grasses is needed to determine best planting times and methods of seeding.

South Dakota producers have tried the no-till springtime method of alfalfa and grass establishment. In general it has worked well with 12 fluid ounces of Roundup, a wetting agent and 2% by weight ammonium sulfate in a 5 gallon per acre spray solution applied prior to planting. Volunteer wheat or downy bromegrass must be actively growing and completely non-dormant. Herbicides are generally most effective when applied after April 15. A word of caution should be given to producers considering no-till. Insects, particularly grasshoppers, are also favored by no-till. A producer in the Rapid City area lost a no-till field to grasshoppers when the alfalfa plants were less than 3 inches tall. There was no evidence of allelopathy on the alfalfa or wheatgrasses in any of the studies.

QUACKGRASS CONTROL IN ALFALFA AS INFLUENCED BY TIMING OF SETHOXYDIM APPLICATION

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In the northeastern part of South Dakota, alfalfa stands are frequently infested by quackgrass. Quackgrass lowers the production and quality of alfalfa, and causes producers to destroy these stands sooner than intended. Quackgrass is a difficult grass to control because of its rhizomatous growth habit. Chemical control of quackgrass is limited to herbicides that will selectively control the grass and not harm the alfalfa. Of these herbicides available, little research has been conducted with sethoxydim (Poast), which has only recently been labeled for use in alfalfa. Sethoxydim has been shown to give excellent control of annual grasses in alfalfa. The effect of sethoxydim on perennial grasses has been slight. Preliminary research conducted in South Dakota in 1989, however, indicates that timing of sethoxydim application may play a key role in the effectiveness of this chemical for quackgrass control in alfalfa.

The objective of this study is to determine the effect of different timing schemes of sethoxydim application on quackgrass control in alfalfa. Schemes range from one application of sethoxydim in the fall to four applications throughout the year. Parameters of interest include: forage yield, crude protein, in vitro dry matter digestibility, and determination of the proportion of alfalfa and quackgrass components. The experimental site is located near Clear Lake, South Dakota and was identified through the efforts of SDSU Extension Agricultural Agent Dale Wiitala. Treatments that will be applied are listed below. The fall treatments were applied on October 6, 1989. Data will be collected beginning in 1990.

Treatments

1. Check
2. Fall only (0.5 lb. ai.[1] per acre)
3. Spring only (0.5 lb. ai. per acre)
4. Fall (0.3 lb. ai. per acre) + spring (0.2 lb. ai. per acre)
5. Fall (0.2 lb. ai. per acre) + spring (0.2 lb. ai.per acre) + after 1st cutting (0.2 lb. ai. per acre)
6. Fall (0.2 lb. ai. per acre) + spring (0.2 lb. ai. per acre) + after 2nd cutting (0.2 lb. ai. per acre)
7. Spring (0.3 lb. ai. per acre) + after 2nd cutting (0.2 lb. ai. per acre)
8. After 2nd cutting only (0.5 lb. ai. per acre)
9. Fall (0.2 lb. ai. per acre) + spring (0.2 lb. ai. per acre) + after 1st cutting (0.2 lb. ai. per acre) + after 2nd cutting (0.2 lb. ai. per acre)

[1] Active ingredient; Sethoxydim.

ASSESSMENT OF FORAGE DESTRUCTION BY GRASSHOPPERS AND ECONOMIC INJURY LEVEL OF COOL-SEASON MIXED GRASS RANGELAND

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Objectives

1. Establish forage destruction levels per grasshopper feeding day for *Melanoplus confusus*, *Melanoplus sanguinipes*, *Aulocara elliotti*, *Amphitornus coloradus* and *Trachytachys kiowa* on cool-season mixed-grass rangeland in 0.25 m^2 cages. Grasshopper densities of 0, 4, 8, 16 and 32 females per m^2 per species and mixed species of *sanguinipes* and *coloradus* on a 1:1 basis with *elliotti*.

2. Assess forage destruction levels by uncaged, natural grasshopper populations in replicated 2-ha blocks.

3. Estimate forage consumption rates under laboratory conditions by the above grasshopper species during their nymphal and adult stages. The information derived, along with the data from the above field studies, will be used to develop methods for predicting potential forage losses and establish economic injury level of rangeland.

4. Determine developmental rates, survival and fecundity of *Melanoplus sanguinipes* when confined to a specific food source.

5. Evaluate nutritional values of forage plants damaged by grasshopper feeding.

Methods

1. Field collected populations of *Melanoplus confusus*, *M. sanguinipes*, *Aulocara elliotti*, *Amphitornus coloradus* and *Trachyrachys kiowa* will be stocked in 0.25 m^2 cages at population of 0, 4, 8, 16, 32 adult females per m^2. Mixed species evaluation will include 1:1 mixture of *confusus*, *sanguinipes*, *coloradus* and *kiowa*. Each treatment will have 25 replicates with preinfestation forage samples obtained adjacent to each cage in addition to the 0 population treatments. Collected forage will be dried, sorted to species and weighed. Twenty-five specimens of each species will be weighed at initiation and conclusion of the experiment.

2. The forage destruction by uncaged grasshoppers will be assessed in six, replicated 2-ha blocks. Check plots will be maintained with malathion ground applied, at 10 day intervals or when grasshopper numbers exceed 3 per m^2 on plot borders. Prior to hatch, 3-m long stripes, 56-cm wide subsamples of forage will be collected from each replicate. Forage samples will be

obtained at a 4-cm height, dried, weighed and stored for further analysis on TDN values important to ruminants. Grasshopper density, species age and composition will be determined by 40 0.1 m^2 rings in the central one third of each block. Forage samples will be collected at 10 day intervals for a 60 day period, estimated to begin May 20.

3. Grasshoppers will be reared from the first instar on rye grass, western wheatgrass and blue grama. Each food source will be supplemented by oat bran when grasshoppers reach the third instar. A known amount of fresh food will be supplied daily to each feeding tube and consumption rates observed.

4. Grasshoppers will be reared on fresh rye foliage plus dry oats (standard diet), fresh foliage of western wheatgrass and yellow sweetclover, and fresh foliage of blue grama and yellow sweetclover. Developmental rates, survival and fecundity of the grasshoppers will be observed.

5. At conclusion of each experiment on forage destruction by caged grasshoppers, remaining portion of forage plants in each cage will be clipped, dried and sorted to species. Raw plant materials of each samples will be prepared by a two-stage grinding process. There will be 5 samples per treatments after consolidation of blocks. Two subsamples of 1-mm screen will be taken for analysis on percent content acid-detergent fiber, neutral-detergent fiber and crude protein. This analysis will be done only for three dominant host plant groups: western wheatgrass, blue grama and buffalo grass combined, and Japanese bromegrass and downy bromegrass combined.

ALFALFA AUTUMN HARVEST MANAGEMENT EFFECTS ON STAND LONGEVITY

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Alfalfa is a widely used forage legume because it has a rapid crop growth rate, it is a long-lived perennial, and it is adapted to many regions of North America. Modern cultivars have resistance to several insect and disease pests. Alfalfa cultivars vary in winterhardiness characteristics; therefore, management regimes vary with prevailing environmental conditions and the cultivar being used. For example, winterhardy cultivars are not used in the southwestern USA because fall dormancy is undesirable, whereas winterhardiness is important for cultivars used in northern states.

For the last 25 to 30 years, the recommendation for late-season management of alfalfa is to avoid harvest during a 4 to 6 week period before the average date of the "first killing frost", thus allowing adequate levels of carbohydrates to accumulate in root and crown storage tissues. This definitive recommendation may be obsolete because it was based on cultivars which were susceptible to bacterial wilt and other diseases. Additionally, intensive pest and soil nutrient management practices were not widely utilized during that time. Recent research suggests that use of disease resistant cultivars and intensive pest and fertility management results in healthier plant stands which endure late-season harvesting. Forage producers are interested in information related to autumn harvesting and consequences of early harvest during the autumn season.

Hardening of alfalfa occurs during autumn as a preparation for winter. Environmental factors such as photoperiod, temperature, and soil moisture significantly influence alfalfa hardening. In this research, several environments and alfalfa cultivars differing in fall dormancy will be investigated for growth in autumn periods. Yield component analysis will be employed. Spring growth of herbage and roots will be related to environmental conditions, cultivar characteristics and harvest management used the previous autumn. The effect of soil and air temperature, precipitation, photoperiod, and solar radiation on spring growth will be determined.

The objective of this research is to determine the effect of environmental factors on fall dormancy, morphological development and winterhardiness of alfalfa. This research will provide a fundamental understanding of environmental and plant related influences on alfalfa fall dormancy and winterhardiness. Coordinated field-based experiments were established during 1989 in South Dakota, Montana and Wyoming which will investigate several environments per growing season.

MANAGEMENT PRACTICE IMPACTS ON GRAZING ALFALFA

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In western South Dakota, 'Travois' alfalfa is used for grazing and in some areas for single cutting hay. It is believed that grazing-type alfalfas used for hay production, may have benefits over more productive hay types in terms of persistence and flexibility for dual use (grazing and haying). By 1980 several new grazing varieties were available. However, there was no regional testing to compare characteristics of production, hardiness, and persistence. Eight public and two private alfalfa cultivars were obtained in 1981 for testing.

Objectives

Compare alfalfa cultivars for the following characteristics.

1) Persistence and production under spring grazing with steers.
2) Persistence and production under mowing.
3) Hay production and persistence when fall grazed.

Experimental Methods

Ten grazing-type alfalfa cultivars and two hay-types ('Ladak 65' and 'Vernal') were planted on a clayey range site at the Cottonwood Station in Haakon County in May 1981. Entries were strip-planted with crested wheatgrass. Alfalfa cultivars were Daneb, D-2, Drylander, Ladak 65, Maverick, Rambler, Rangelander, Roamer, Spredor II, Teton, Travois, and Vernal. The three management treatments are presented in Table 1. Stands were estimated by basal intercept along rows with each gap of 6 in. equalling 0.5% less than a full stand. Forage yield was determined by sampling from multiple 2 ft. x 4.8 ft. plots and oven drying. Samples were sorted into grass, alfalfa and weed components. Grazing was done by steers with forage use estimated as animal-unit-months (AUM's) consumed.

Results

In general, production and persistence differences among cultivars were minor and are not reported here. The value of grazing, in terms of AUM's of forage consumed is not completed, and thus, is not reported.

Persistence

Table 2 summarizes stand changes during the trial for all three treatments. In all years, the dual use treatment (Treatment I) damaged stands of grass and alfalfa, particularly during the early years. By 1986 both haying treatments (Treatments I and III) tended to reduce alfalfa and grass stands more than grazing (Treatment II). Alfalfa stands decreased and grass stands increased during the entire study, except during the drought year of 1985. Drought appeared to greatly reduce both alfalfa and grass stands, after which alfalfa did not regain its pre-drought prominence.

Production

Table 3 summarizes hay production for Treatments I and III. Although differences exist between treatments, especially in 1983 and 1984, yearly differences are more variable. Dormant season grazing prior to 1984 and 1985 haying seasons substantially reduced grass yield, with variable responses for alfalfa. By the end of the trial in 1986, no differences were observed.

Conclusions and Implications

1. Dormant season grazing of hay grounds did not reduce hay production. In fact, the AUM's provided as dormant season grazing represents substantial additional production from that practice. Soil surface was typically dry during dormant season grazing.
2. Dormant season grazing does not appear to be a factor in declining alfalfa stands, drought is likely a greater factor.
3. Haying appears to have greater stand reducing effects than grazing.
4. Grazing-type alfalfa cultivars, except D-2, when grown with crested wheatgrass produced as much hay as the two hay types (Ladak 65 and Vernal), and appear equally persistent, thus all can be successfully used for hay production in a single cutting environment.

Table 1. Schedule of management practices.

Date	Treatment I Dormant Grazing Plus Haying	Treatment II Spring Grazing	Treatment III Only Haying
1981 May	Seeded	Seeded	Seeded
July	Mowed Weeds	Mowed Weeds	Mowed Weeds
1982 July	Hayed	Hayed	Hayed
1983 March	Grazed		
May		Grazed	
June	Hayed		Hayed
1984 March	Grazed		
May		Grazed	
June	Hayed		Hayed
1985 March	Grazed		
May		Grazed	
	Summer drought, no hay production		
1986 May	Grazed		
June	Hayed		Hayed
October	Grazed	Grazed	

Table 2. Percent stand of alfalfa and crested wheatgrass determined from basal intercept in three grazing/haying management regimes[1].

	Alfalfa			Grass		
Treatments	I	II	III	I	II	III
	% stand					
1982	46	46	46	57	57	57
1983	60.9b	72.4a	65.9ab	55.7b	67.6ab	68.8a
1984	65.9b	70.0b	76.0a	64.2c	79.3a	73.7b
1985	21.8ns	29.4ns	28.0ns	42.9b	60.5a	55.5a
1986	30.3ns	38.0ns	25.4ns	63.6c	82.2a	74.4b

[1] In comparing treatments components within a year, values followed by the same letter are not significantly different (P=0.05), Duncan-Waller K-ratio T test.

Table 3. Forage yield components for three grazing/haying management regimes[1,2].

	Alfalfa[3]	Grass	Combined
	--------- lb. DM per acre --------		
1983 Tr I	1937*	914*	2851ns
Tr III	1585*	1433*	3018ns
1984 Tr I	482ns	1014*	1496*
Tr III	608ns	1447*	2055*
1986 Tr I	900ns	2384ns	3284ns
Tr II	567ns	2349ns	2916ns

1 Data not presented for 1982, establishment year.

2 Data not presented for 1985, no hay production because of drought.

3 Alfalfa data averaged over cultivars.

, ns In comparing alfalfa, grass, or combined in Tr I versus Tr III, numbers followed by "" are different (P=0.05), those by "ns" are not different.

WEST RIVER HAY STORAGE PROJECT

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A hay storage experiment is being conducted at the request of the Antelope Range and Livestock Research Station's advisory board. The objectives of this study are to:

1> acquire information on how large round bales deteriorate over time,
2> determine the amount of storage loss,
3> evaluate the most economical method for storing prairie hay in western South Dakota.

Most of the studies on hay storage have been completed in the Midwestern Region of the USA using high or premium grade alfalfa. These areas typically have a much greater amount of precipitation than Western South Dakota. The Antelope Station's advisory board asked for a study that reflected Western South Dakota hay production and storage methods, including the way hay storage is handled by local producers.

The project includes 186 large round bales stored under eight storage methods. Three stacks of 62 small square bales are also included in the project. A total of 106 tons of hay are used in the study. All hay was harvested in 1989 from Conservation Reserve Program acreage near Redig, South Dakota. The project will conclude in 1992.

The storage methods of large round bales include:

1> bales placed in rows with their round ends pushed together,
2> bales in rows, covered with plastic,
3> bales arranged separately with at least 18 in. space around them,
4> pyramid stacks of 18 bales,
5> pyramid stacks of 14 bales,
6> stacks of eight bales where four bales are placed vertically with ends on the ground and four additional bales stacked horizontally on top,
7> bales in rows with the round edges pushed together,
8> bales stored in a pole shed.

The storage methods of small square bales include:

1> hay stacked outside, uncovered,
2> hay stacked outside and covered with plastic,
3> hay stored in a shed.

Samples of each large round bale were taken as the hay was placed in storage. One third of the hay will be sampled at the end of each year to determine storage losses caused by weathering. The sampled hay will be fed to livestock at the Antelope Station. Storage loss data will be combined with cost data to determine which outdoor storage method is the most economical and the economic feasibility of constructing hay sheds.

This hay storage project is a joint effort between the SDSU Cooperative Extension Service, the SDSU College of Agriculture and Biological Sciences, and the SDSU West River Agricultural Research and Extension Center. Participating individuals and their respective university departments include: Martin Beutler - Economics; Ed Twidwell and Kevin Kephart - Plant Science; Bob Durland - Agricultural Engineering; Jim Males and Terry Goehring - Animal and Range Science; and Ron Swan - Antelope Station Manager. County Extension Agents include: Ken Nelson - Harding County; Vince Gunn - Perkins County; and John Skoberg - Butte County. A scale to weight the hay was provided by L-8 Products, Inc. of Rapid City.

The hay storage project may be viewed at the Antelope Station, 14 miles east of Buffalo, South Dakota on Highway 20.

UNDERSTORY VEGETATION PRODUCTION ON LIMESTONE SOILS OF THE SOUTH DAKOTA BLACK HILLS

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The limestone plateau in the Black Hills of South Dakota provides grazing habitat for livestock and wildlife. Paleozoic-age limestones and limy sandstones have formed a broad plateau approximately 500,000 acres in size. Well developed forest soils (Alfisols) have formed on the plateau. Both frigid and cryic soil temperature regimes occur on the limestone plateau because of differences in elevation.

A 2 year study was conducted across the limestone plateau to:
1> determine the annual understory production on the dominant limestone derived soils under a range of forest canopy covers,
2> develop a statistical model for predicting understory production based upon soil, forest density and climatic factors, and
3> evaluate differences in nitrogen concentration of understory vegetation related to soil and forest parameters.

Kjeldahl nitrogen concentration of the grass, forb and shrub components were determined on vegetation samples collected during June and August of 1988 and 1989. Nitrogen concentration of the vegetation was determined on only the two non-skeletal (non rocky) soils, Stovho and Citadel. Biomass production was based upon data collected in August from five soil series (Table 1). The understory was dominated by cool-season grasses, a mixture of forbs and low growing shrubs.

Canopy cover and understory forage production were negatively related. All soils responded in a similar manner except for the Paunsaugunt series which was shallow to bedrock. Multiple linear regression models were developed to predict grass (R^2=0.72), forb (R^2=0.44) and total vegetation production (R^2=0.72) from soil and forest canopy cover data. The variability was found to be too great to allow the development of a meaningful model to predict shrub production. Precipitation and soil nutrient content parameters along with canopy cover were found to significantly contribute in the prediction of understory production once the data were sorted by soils. Paunsaugunt soils were approximately six-times less productive than deeper soils.

Nitrogen concentration of the vegetation components decreased significantly (P=0.01) between June and August. Grasses and forbs growing on the Stovho soil had significantly greater (P=0.01) nitrogen concentrations than when the same species were grown on Citadel soils at lower elevations.

Within soils, plant nitrogen concentration decreased as the timber basal area increased in the lower elevation soils; the reverse was true for the higher elevation soils. The relationship was strongest for grasses (P=0.01).

In the Citadel soils, plants grown under greater basal areas had lower nitrogen concentrations, because of the less favorable growing conditions. Plants had greater nitrogen concentrations on Stovho soils with greater basal areas. Plants under the forest canopy were relatively younger than plants in open areas and therefore, had greater nitrogen concentration. The same interpretation explains the difference in plant nitrogen concentration that existed between soil series. High elevation (cold soil temperature regime) has the same effect on plant nitrogen concentration as increased overstory shading.

These data demonstrate the importance of considering soil survey information in the development of woodland grazing plans. Differences in total production and plant nitrogen concentration were documented.

Table 1. Classification and landscape position of Limestone Plateau soils.

SERIES	GREAT GROUP	ELEVATION	LANDSCAPE POSITION
		-- ft. --	
Citadel	Eutroboralfs	less than 6,200	summit
Vanocker	Eutroboralfs	less than 6,200	backslope
Stovho	Cryoboralfs	higher than 6,200	summit
Trebor	Cryoboralfs	higher than 6,200	backslope
Paunsaugunt	Haploborolls	less than 6,200	summit/ backslope

MANAGEMENT OF SOIL FERTILITY FOR MAXIMUM FORAGE PRODUCTION

ALFALFA RESPONSE TO APPLICATION OF PHOSPHORUS POTASSIUM, SULFUR AND ZINC FERTILIZATION

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Alfalfa is considered to be a heavy user of phosphorus (P) and potassium (K). Yield responses to P and K fertilizers have been good where soil tests have indicated a need. Some producers have indicated that their alfalfa also responds to sulfur (S) and zinc (Zn) fertilization. The objectives of this research are two-fold:

1> determine response of alfalfa to added rates of P, and
2> determine if alfalfa responds to fertilizer K, Zn or S on soils testing high in these elements.

Methods

The research was conducted on two sites in western South Dakota. An irrigated site was east of Vale in Butte County, South Dakota. The soil is a Haverson loam which is a moderately coarse textured soil. The P soil test indicated medium, with high K, Zn and S levels (Table 1). The second site was located 1.75 miles west of the Deadwood turnoff on Interstate 90 in Lawrence County, South Dakota. This site was non-irrigated and located on a Nevee silt loam. The soil tests at this site indicated a low P level and high levels of K and S (Table 1). The Zn level was considered low (0.44 ppm) for Zn sensitive crops.

Table 1. Soil Tests for Butte and Lawrence County Sites, Alfalfa 1989.

		Soil Test					
Site	Depth	P	K	S	Zn	pH	O.M.
	inches	---lb/A---		--- ppm ---			%
Butte	0-6	16	400	103	2.28	7.9	1.8
	6-12	10	340	129	2.00	7.8	1.7
Lawrence	0-6	10	510	21	0.44	6.5	3.5
	6-12	4	440	21	0.18	6.4	2.1

Fertilizer treatments applied are listed in Table 2. Two studies were done at each location to meet the listed objectives. One study evaluated rates of P fertilizer, the other compares the addition of K, S and Zn fertilizer to a check treatment.

Fertilizer was broadcast by hand on alfalfa on November 17, 1988. The sources of nutrients used were: P_2O_5 - 0-46-0, K_2O - 0-0-60, S - elemental S (88%), Zn - zinc sulfate (as 35% Zn). Each treatment was replicated four times. Harvests were completed on June 14, July 26 and August 30, 1989. Only two harvests were taken at the Lawrence County site.

Results

Yields for both sites and all treatments are displayed in Table 2. Data for Butte County indicates no yield response to added P and yields were excellent. The lack of response is somewhat surprising as the soil test is medium in P. There were moderate levels of P in the 6- to 12-inch layer. Evidently, adequate soil P was available to provide for alfalfa yields exceeding 6 tons per acre at this site.

The addition of K, S or Zn did not significantly affect alfalfa yield at the Butte County site. This was not unexpected as soil tests were high.

Yields for the Lawrence County site indicated a slight yield response to added P for the first harvest. The response was approximately 500 lb. for the 120 lb. P_2O_5 rate and was not an economical response. Drought likely caused the low yields and may have caused the slight response to P_2O_5. The residual P response will be measured in subsequent years.

As with the Butte County site there were no significant yield differences, due to the addition of K, S or Zn at this site. The residual yield responses from these treatments will be monitored next year.

Table 2. Dry Matter Alfalfa Yields for Fertilizer Study in Butte and Lawrence Counties, South Dakota, 1989.

Fertilizer	Butte County				Lawrence County		
Treatment	1	2	3	Total	1	2	Total
lb./ acre	----	lb./acre	--	ton/acre	-- lb./acre --		ton/acre
P_2O_5							
0	4252	5233	3266	6.38	2202B	992	1.60
30	4229	4088	3047	5.98	2472AB	896	1.68
60	4146	4800	2994	5.97	2384 B	999	1.69
90	4451	5108	3253	6.41	2363 B	993	1.68
120	4336	4864	3426	6.30	2757A	879	1.82
240	4331	4791	3201	6.30	2473AB	1100	1.79
Sig[1] (0.05)	NS[2]	NS	NS			NS	
Check [3]	4336	4864	3426	6.30	2757	879	1.82
100 K_2O [3]	4326	4981	3431	6.30	2645	944	1.79
50 S [3]	4201	5031	3155	6.20	2445	807	1.63
10 Zn [3]	4357	4709	3236	6.20	2545	895	1.72
Sig (0.05)	NS	NS	NS		NS	NS	

[1] Yields followed by the same letter are not significantly different at the 0.05 level of probability.

[2] NS = non-significant

[3] Received 120 lb. P_2O_5 per acre.

YIELD OF CRESTED WHEATGRASS TREATED WITH NITROGEN

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There is about 26 million acres of grassland in South Dakota and it is estimated that less than 5% of this grassland is fertilized. Past research in South Dakota indicates forage yields have nearly doubled with ample nitrogen applications on some cool-season grasses. Cool-season grasses such as crested wheatgrass produce most of their growth during the early spring and respond well to late-fall or early-spring nitrogen applications. This work was done to demonstrate the effectiveness of nitrogen applications for cool-season grass forage production.

Methods

The study was done on the Mike Cowan farm in Hyde County. The site had a good stand of crested wheatgrass estimated to be at least 15 years old. Very little manure or fertilizer has been applied which is typical of many grass stands. The soil at this site is classified as a Highmore series. It is a typical medium textured (silt loam) soil found in this area. Nitrogen was hand-applied to the experimental areas as urea (46-0-0) on September 14, 1988. The rates of nitrogen used were 0, 30, 60, 90, 120 and 150 lb. per acre of actual nitrogen applied.

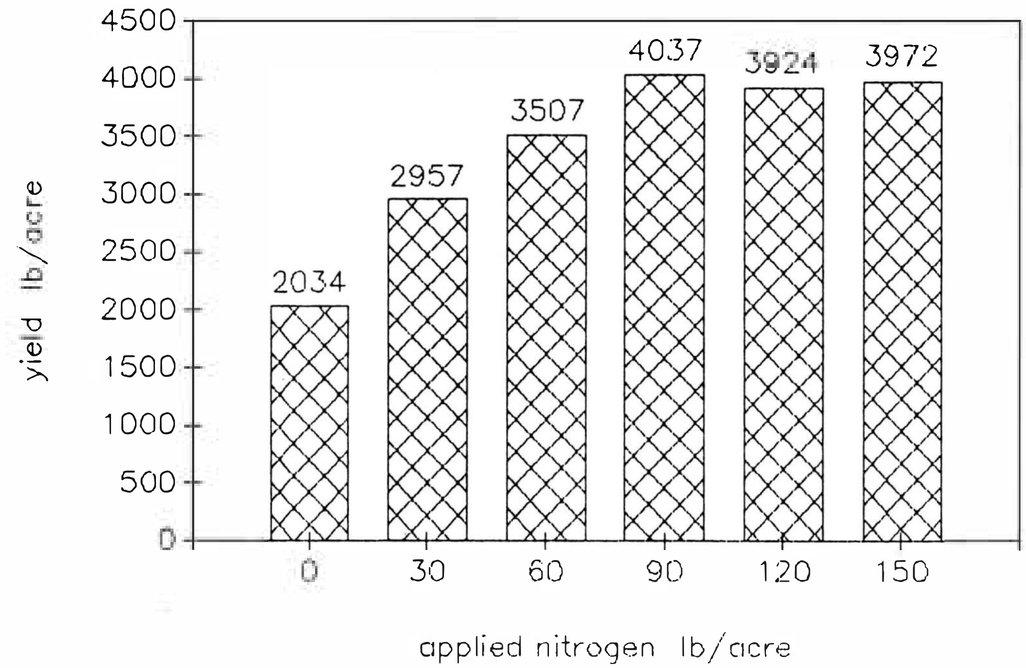
Phosphorus was spread over the entire experiment at a rate of 60 lb. P_2O_5 per acre to eliminate phosphorus as a limiting variable. Soil moisture was considered very low at application time. The following spring the soil was moist to 30 inches in depth. A total of 5.6 inches of rainfall was measured at the site from time of application through forage harvest on June 13, 1989. The low amount of precipitation severely limited forage production.

Results and Discussion

Dry matter yields are presented in Figure 1. Yields increased up to the 90 lb. nitrogen per acre rate. After that rate the yields are statistically similar. Even during drought, addition of 90 lb. nitrogen per acre increased forage production by 1 ton per acre over the check. Considering grass hay that is valued at $40 per ton, this extra yield would be worth $40.00 at a cost $18.00 per acre (90 lb. N x $0.20 per lb.). A total profit of $22.00 per acre was be realized by fertilizing with nitrogen. Protein concentrations are currently being determined and these economic returns do not consider the increased protein which usually occurs with nitrogen fertilization. For the producer who is feeding cattle during a year with limited hay availability, fertilizing with nitrogen means purchasing less hay and minimizing reductions in cow herds.

In summary, the addition of 90 lb. N per acre produced an extra ton of crested wheatgrass forage per acre in a very dry season.

Fig. 1. Influence of applied nitrogen on dry matter yield of crested wheatgrass, Hyde Co., 1989.



YIELD OF CRESTED WHEATGRASS TO PHOSPHORUS APPLICATION

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Cool-season grass response to phosphorus (P) fertilization has been documented in research at SDSU. However, more research is needed to determine if soil test P is well correlated to yield response from P fertilizers. The following work was done to meet that need. In addition, the residual forage response one year after application was also measured.

Methods

The study was done on the Mike Cowan farm in Hyde County. The site has a good stand of crested wheatgrass estimated to be at least 15 years old. Very little manure or fertilizer has been applied during this time which is typical of many grass stands. The soil at this site is classified as a Highmore series and is a typical medium-textured (silt loam) soil for this area. The P soil test in the 0 to 3 and the 3 to 6 in. soil layers was 12 and 5 lb. P per acre, respectively. This is considered a low P test but is not unusual for soils under long-time grass stands.

The P fertilizer was hand spread on March 28, 1988. Rates of P were 0, 30, 60, 90 and 180 lb. P_2O_5 per acre as 0-46-0 (Triple Super Phosphate). Sixty lb. nitrogen per acre (as urea) was applied over the whole plot to eliminate nitrogen as a limiting variable. In 1989, an additional 90 lb. nitrogen per acre was applied to the experiment area. No additional P was applied for the 1989 season. Forage harvest was completed on June 12, 1988 and June 13, 1989.

Results and Discussion

The results show rather poor yields in 1988 and 1989. Rainfall received during the growing season for the two years was identical at 5.6 inches. However, the 1988 growing season was characterized by extremely high temperatures in May and June which probably limited forage yields of the cool-season grass. Forage response to P was limited in 1988 with better responses to residual P in 1989. The 2 year total indicates an average response of 500 to 600 lb. dry matter per acre to 30 to 90 lb. P_2O_5 per acre. The very high rate of 180 lb. P per acre provided a response of about 1400 lb. dry matter per acre over the check for the 2 year period. These results indicate poor efficiency of P uptake. This is probably caused by the limited rainfall and the limited mobility of P in the soil. Since the P was placed on the surface of the soil and moves very little, root uptake of the fertilizer was limited probably because of dry conditions. A method of placing phosphorus deeper in the soil, such as spoke injection or knifing may provide more efficient utilization of P by crested wheatgrass.

Table 1. Influence of applied phosphorus on forage yield of crested wheatgrass, Hyde County, 1988.

Rate of P_2O_5	Forage Yield 1988	1989(residual)	2 Year Total
	------- lb. Dry Matter per acre -------		
0	2019	2767	4786
30	2038	3398	5436
60	2200	2928	5128
90	2054	3406	5460
180	2317	3892	6209

RESEARCH OF FACTORS INFLUENCING FORAGE SEED PRODUCTION

SEED YIELD COMPONENTS IN SIDE-OATS GRAMA

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Side-oats grama [*Bouteloua curtipendula* (Michx.) Torr] is an important component of grass mixtures planted for conservation and forage throughout the Great Plains region of the USA, but little research has been conducted on improving seed yield and quality in germplasm adapted to the northern Great Plains. The objective of this study was to determine relationships between seed yield and its components in 'Pierre' side-oats grama.

In May 1984, 70 seedlings of Pierre were transplanted to a field nursery and data were obtained for number of seedhead-bearing stems (culms), number of spikes per culm, number of spikelets per spike, seed set, seed size, and seed yield for individual plants in 1985 and 1986. Highly significant (P=0.01) differences were observed between years for seed yield and all its components other than number of reproductive culms per plant (Table 1). Mean seed yields per plant were 8.3 g in 1985 and 6.4 g in 1986. Mean numbers of culms per plant were 176.1 in 1985 and 187.1 in 1986. Highly significant positive relationships were found between number of culms and seed yield in both years. Significant positive relationships were found between seed set and seed yield in both years.

This study provides information that indicates selection for increased number of culms, which can be easily determined visually, and seed set should result in improved seed yield in this germplasm. Progenies of selected genotypes will be evaluated for seed production in rows and solid stands to determine the amount of progress in seed yield that can be made from selection for number of culms.

Table 1. Annual seed yield and component means for 'Pierre' side-oats grama space-plants evaluated at Brookings, SD.

Year	Culms per plant	Spikes per culm	Spikelets per spike	Seed size	Seed set	Seed yield
	----------	no.	----------	- mg -	-%-	-g-
1985	176.1	21.0**	8.6**	82.9**	32.0**	8.3**
1986	187.1	25.9	6.2	85.7	25.0	6.4

** Annual means significantly different at the 0.01 level of probability.

SEED SET AND SEED SIZE STUDIES IN ANDROMONOECIOUS AND HERMAPHRODITIC GENOTYPES OF BIG BLUESTEM

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Seed set is an important component of seed yield and seed size strongly influences seedling vigor in big bluestem (*Andropogon gerardii* Vitman). Objectives of current research are to determine the effects of sex expression and spikelet type on seed set and seed size in this valuable warm-season grass.

The seedhead of big bluestem contains two types of spikelets, those that are attached directly to axes of seedhead branches (sessile spikelets) and those that are attached to seedhead axes by short stalks (pedicellate spikelets). Spikelets occur in pairs, one sessile and one pedicellate spikelet, at each node of the seedhead axes.

The most common form of sex expression in big bluestem is andromonoecy. In andromonoecious plants, the sessile spikelets contain both male and female reproductive structures and thus are capable of producing seeds, while pedicellate spikelets produce only pollen or are neuter. Hermaphroditic genotypes are less abundant than andromoneocious genotypes but are of potential value for improving seed yields because they possess female structures in both sessile and pedicellate spikelets. Therefore, they have the potential to produce seeds in all their spikelets while andromonoecious genotypes can produce seed in sessile but not pedicellate spikelets.

A recent study of two andromonoecious and two hermaphroditic genotypes over a three-year period at Brookings produced some interesting results regarding the effect of sex expression (hermaphrodism versus andromonoecy) on seed set and size in big bluestem. Percent total (sessile plus pedicellate) spikelet seed set was 59% for hermaphroditic compared to 36% for andromonoecious genotypes, but andromonoecious genotypes had 11% higher seed set in sessile spikelets. Sessile and pedicellate spikelet seed sets of hermaphroditic genotypes were 61 and 57%, respectively (Table 1). Seeds from sessile spikelets were 46% heavier than those from pedicellate spikelets of hermaphroditic genotypes (Table 1). Because hermaphroditic genotypes had higher total spikelet seed set, hermaphrodism offers excellent potential for increasing seed yield in big bluestem.

Table 1. Caryopses set and weight means for sessile and pedicellate spikelets of two hermaphroditic genotypes of big bluestem.

Spikelet Type	seed set			seed weight		
	1984	1985	1986	1984	1985	1986
	-------- % ---------			---- mg/50 seeds -----		
Sessile	62.3	59.1	61.1	72.1	98.0	101.1
Pedicellate	57.6	50.0	64.5	50.6	68.0	67.5
LSD (0.05)		3.6			3.7	

Future studies will focus on determining the mode of inheritance of hermaphrodism and selection for large seeds in pedicellate spikelets. The long-range goal of this research is development of a cultivar with improved seed yield and quality characteristics.

BASIC BIOLOGICAL RESEARCH

ALFALFA DRY MATTER PARTITIONING RESPONSES TO PHOTOSYNTHATE AVAILABILITY DURING INITIAL REGROWTH

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Cell walls in alfalfa herbage limit forage quality by reducing potential intake and digestibility. Few physiological studies have been conducted from the standpoint that the cell wall represents a major photosynthate pool and plays a role in source/sink relationships.

Crop growth may be discussed in terms of photosynthate partitioning. Major sinks for alfalfa include the shoot apical meristems, axillary meristems, root storage tissue, active nodules, and the main stem. Photosynthates stored in roots are used for initiation of regrowth and for maintenance energy during dormancy. Soluble photosynthates are used for cell division, cell differentiation, and energy in meristematic tissues.

Recent work suggests that abundant photosynthates exist for storage and meristematic activities in alfalfa during reproductive stages of maturity, a period of rapid secondary cell wall development and lignin synthesis. Data of some scientific literature suggests that the extent of secondary cell wall development and lignification may be positively related to photosynthate availability when sink limitations to growth exist. The objective of this research is to determine the effect of source-limitations on growth, dry matter and carbohydrate partitioning in alfalfa.

Two cultivars planted at Brookings in this field study include Pioneer 5432 and Vernal. Treatments include differing frequencies of defoliation during the spring-growth period. Herbage was removed once, twice, or three times to a 3-inch height with a rotary mower. Defoliation treatments are intended to deplete storage carbohydrates and influence the source availability during the early-summer growth period. Samples for growth and shoot weight measurements were obtained weekly for 6 weeks on second (early-summer) growth herbage. Stem bases will be analyzed for cell-wall components, non-structural carbohydrates, and crude protein. This research will be repeated in 1990.

TISSUE CULTURE OF FORAGE GRASSES

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The objectives of this research are to:

1> develop somatic tissue culture techniques for rapid cloning of selected forage grass genotypes thereby speeding up release of new varieties, and,

2> explore anther culture techniques of selected forage grasses and test the variability of the culture products.

In somatic tissue culture, Linsmaier and Skoog's RM basal medium supplemented with 2,4-D at concentrations ranging from 5 to 10 mg per liter has been adopted for culturing young inflorescence segments. Calli initiated from the explants were isolated and grown on RM medium with 2,4-D removed or reduced to one-tenth of the callus initiation medium for plant regeneration. Kinetin at 0.1 to 1 mg per liter was occasionally added to the regeneration medium to enhance differentiation. Plant species regenerated from these media include:

crested wheatgrass	*Agropyron cristatum* (L.) Gaertn.
intermediate wheatgrass	*Agropyron intermedium* (Host). Beauv.
western wheatgrass	*Agropyron smithii* Rydb.
creeping foxtail	*Alopecurus arundinaceus* Poir.
smooth bromegrass	*Bromus inermis* Leyss.
European sloughgrass	*Beckmannia erucaeformis* (L.) Host
orchardgrass	*Dactylis glomerata* L.
reed canarygrass	*Phalaris arundinacea* L.
green needlegrass	*Stipa viridula* Trin.
big bluestem	*Andropogon gerardii* Vitman.
little bluestem	*Schizachyrium scoparium* (Michx.) Nash.
switchgrass	*Panicum virgatum* L.
indiangrass	*Sorghastrum nutans* (Michx.) Nash.

In anther culture, plant regeneration has been achieved in anthers of field-grown 'Oahe' intermediate wheatgrass cultured on Tsay's, N6, Yu-pei and 85D12 media supplemented with various concentrations of kinetin and 2,4-D or NAA. Of 9480 anthers cultured on the four media, 270 (2.85%) calli were initiated and 53 (0.53%) plantlets were regenerated. A total of 45 plantlets evolved through a callus phase while eight appeared to develop directly from microspores. Tsay's medium demonstrated the best performance in plant regeneration but all plantlets recovered from the anthers cultured on the four media were albino. Further experimentation with other genotypes, various pollen stages and culture conditions which may result in the production of green plants are being conducted. Androgenesis started with symmetrical divisions of pollen nuclei immediately followed by cytokinesis, or, alternatively, by the formation of multinucleate pollen grains, which were later partitioned through repeated cytoplasmic divisions.

Initiation of sporophytic growth was observed in big bluestem anthers during the first 3 weeks of culturing on N6 or Yu-pei medium supplemented with 1 or 2 mg per liter 2,4-D and 60 to 120 g per liter sucrose, but plant regeneration has not been achieved.

ALFALFA SEED CHALCID POPULATION BIOLOGY

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The alfalfa seed chalcid (ASC) (*Bruchophagus roddi*) is a serious pest of alfalfa seed production in South Dakota. The diversity of uses (e.g. pasture, hay, conservation, wildlife habitat and seed production) for alfalfa in South Dakota promotes flowering and seed pod set from June through September. This extended reproductive period enables the ASC to reduce seed yields in managed and opportunistic seed fields across the state.

Objectives of this research are to determine influences of stand management (i.e. harvesting to control date of pod set) on the population dynamics of the ASC and its chalcidoid parasites.

Emergence patterns of overwintering and growing season generations of the ASC and its parasites are being studied at Brookings and Highmore, South Dakota from seed crops that have matured from July through September. Rates of seed predation by the ASC and parasitism of ASC by *Mesopolobus bruchophagi*, *Pteromalus medicaginis*, *Liodontomerus perplexus*, *Trimeromicrus maculatus*, *Eupelmella vesicularis*, *Eupelmus* sp., and *Tetrastichus bruchophagi* are being studied.

LIST OF PUBLICATIONS

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