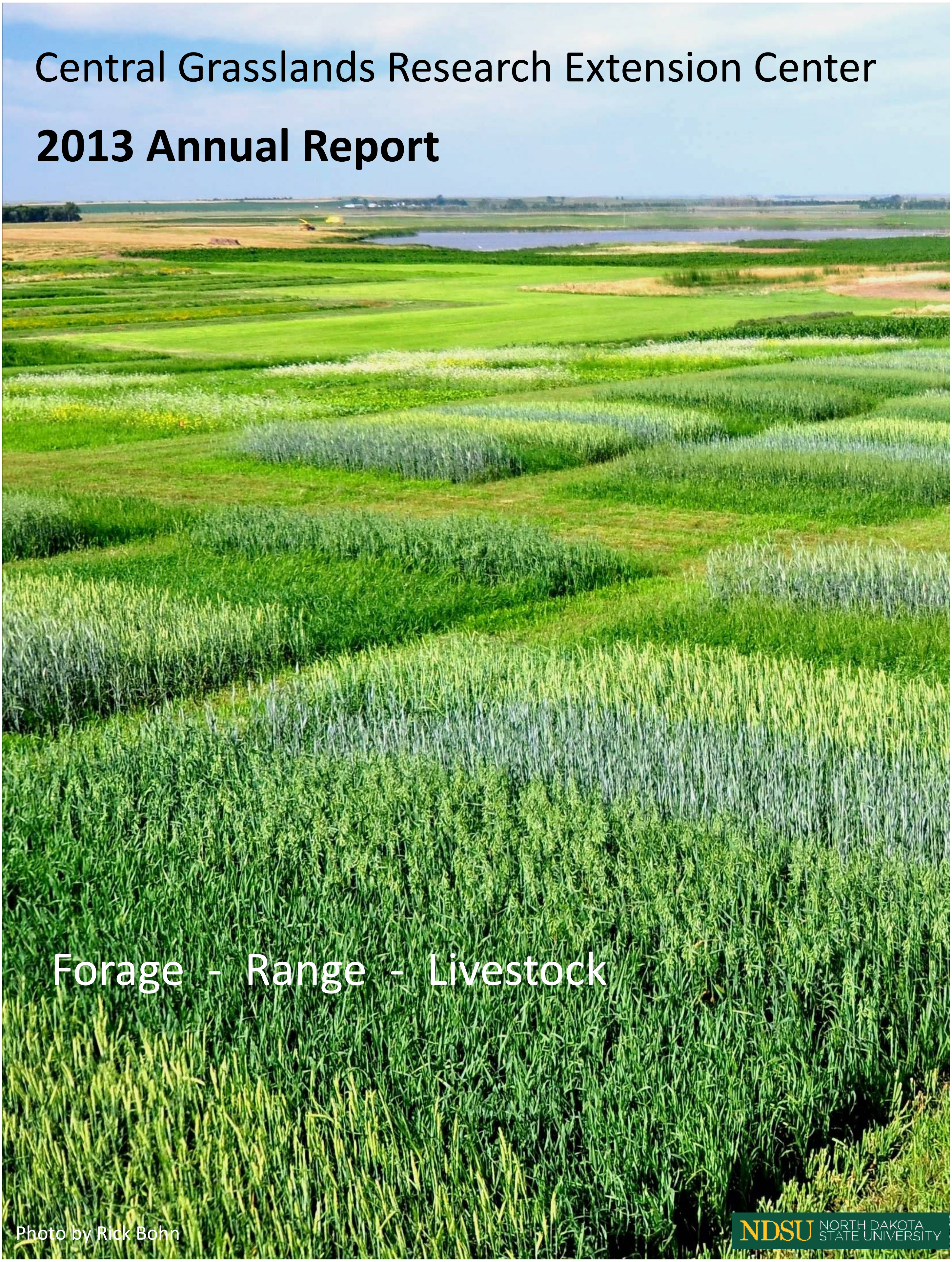
Central Grasslands Research Extension Center

2013 Annual Report



Forage - Range - Livestock

Photo by Rick Bohn

NDSU NORTH DAKOTA STATE UNIVERSITY

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Overview of the Central Grasslands Research Extension Center

Located six miles northwest of Streeter, N.D., the Central Grasslands Research Extension Center (CGREC) serves 18 counties in the Missouri Coteau, an area bounded by the Missouri River basin on the west and the James River basin on the east.

The center began operation in 1981 and is made up of 5,335 acres of mixed-grass prairie and cropland in Stutsman and Kidder counties. The staff is composed of 12 year-round employees and six or more summer employees. An 11-member advisory board that includes producers and community leaders from throughout the Coteau region provides input on research topics.

The center provides facilities for graduate students conducting research, and hosts an annual field day in the summer and a research review in the winter.

Studies at the center include:

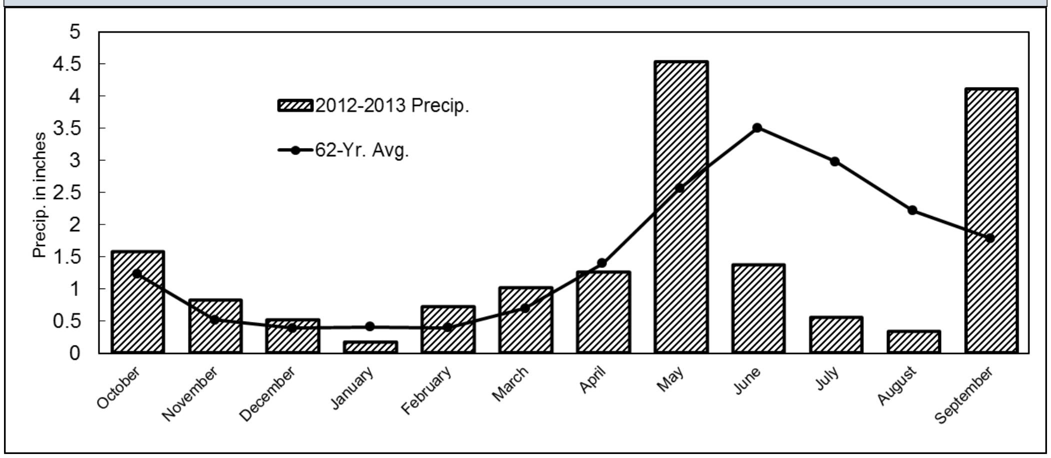
- Natural resource management
- Grazing systems and rangeland monitoring
- Cattle herd management and marketing
- Cattle nutrition and health
- Integrated forage/livestock/biofuels systems
- Biomass-for-ethanol crop trials

Central Grasslands Research Extension Center
4824 48th Ave. S.E., Streeter ND 58483

Phone: (701) 424-3606, Fax: (701) 424-3616
www.ag.ndsu.edu/CentralGrasslandsREC
www.facebook.com/NDSUCentralGrasslands

Director: Bryan Neville, bryan.neville@ndsu.edu
Administrative Secretary: Sandi Dewald,
sandi.dewald@ndsu.edu

Monthly Precipitation for the 2012-2013 Crop Year at CGREC

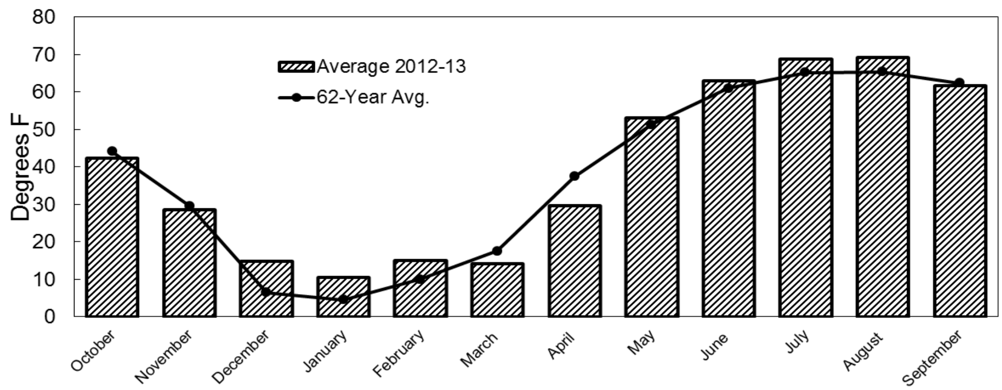


Month	2012-13 Precipitation (inches)	62-year Average Precipitation (inches)	Deviation From Average (inches)	2012-13 Accumulated Precipitation (inches)	Accumulated 62-year Average Precipitation (inches)	2012-13 Percent 62-year Accumulated Average
October	1.58	1.23	0.35	1.58	1.23	128.89
November	0.82	0.52	0.31	2.40	1.74	137.87
December	0.51	0.39	0.12	2.91	2.13	136.44
January	0.17	0.41	-0.24	3.08	2.54	121.31
February	0.72	0.40	0.32	3.80	2.93	129.51
March	1.01	0.70	0.31	4.81	3.63	132.53
April	1.25	1.40	-0.15	6.06	5.03	120.55
May	4.54	2.57	1.97	10.60	7.60	139.49
June	1.37	3.51	-2.14	11.97	11.10	107.80
July	0.55	2.98	-2.43	12.52	14.08	88.89
August	0.33	2.22	-1.89	12.85	16.30	78.82
September	4.12	1.79	2.33	16.97	18.09	93.80
Total	**16.97**	**18.09**	**-1.12**	**16.97**	**18.09**	**93.80**

Total snow depth in reporting period: 63.7 inches

Note: A graph of the monthly precipitation for the period 2010 through 2013 is located on page 48.

Average Monthly Temperatures for the 2012-2013 Crop Year at CGREC



Month	2012-13 Maximum Temperature (degrees F)	2012-13 Minimum Temperature (degrees F)	2012-13 Average Temperature (degrees F)	1951-2013 Average Temperature (degrees F)	2012-13 Deviation From 60-year Average (degrees F)
October	77	21	42.4	44.1	-1.7
November	61	3	28.5	29.6	-1.1
December	52	-13	14.8	6.5	8.3
January	41	-22	10.6	4.6	6.0
February	38	-22	15.1	10.0	5.1
March	43	-11	14.1	17.5	-3.4
April	69	3	29.7	37.4	-7.8
May	86	21	53.2	51.3	1.9
June	87	38	63.1	61.0	2.0
July	92	42	68.8	65.2	3.6
August	100	39	69.2	65.4	3.7
September	88	37	61.7	62.4	-0.7

Last spring frost: May 12, 2013 (27° F) — 62-year average last spring frost: May 13

First fall frost: Oct 7, 2013 (30°F) — 62-year average first fall frost: Sept. 22

148 frost-free days — 62-Year average frost-free days: 132 days

Long-term Grazing Intensity Research in the Missouri Coteau Region of North Dakota: Effects on Plant Production and Composition

Bob Patton and Anne Nyren
Central Grasslands Research Extension Center - NDSU, Streeter

The effects of grazing intensity on plant species and the sustainability of forage production have been monitored on 12 pastures at the CGREC since 1989. Plant responses to grazing fall into four groups: plants favored by no grazing, moderate or heavy grazing, and invaders. The optimum stocking rate depends on objectives, but the greatest forage production falls between a light stocking rate (35 percent utilization) and a moderate stocking rate (50 percent utilization).

Summary

This study began in 1989. Five treatments were included: no grazing, and light, moderate, heavy and extreme grazing. Our goal was to stock the pastures each year so when the cattle were removed in the fall, 65, 50, 35 and 20 percent of the forage produced in an average year remains on the light, moderate, heavy and extreme treatments, respectively.

Thus far, on loamy and loamy overflow ecological sites, the extreme grazing treatment produced the least forage ($P \leq 0.05$). On loamy ecological sites, the light treatment produced the most forage ($P \leq 0.05$). On loamy overflow ecological sites, the light and moderate treatments produced the most forage but were not significantly different from each other ($P \leq 0.05$).

Of the 166 plant species monitored on loamy ecological sites, 66 responded to grazing based on frequency, density or basal cover. Of the 177 plant species monitored on loamy overflow ecological sites, 53 responded to grazing.

Introduction

The question of how heavily to stock native range is complex. The answer primarily depends on how much forage is available, which varies each year, depending on the temperature and precipitation. If stocking rates are too low, profits will not be maximized, but if rates are too high, cattle performance will suffer and the resource will be damaged.

The optimum stocking rate varies with objectives, but we cannot know what stocking rate is optimum for any particular objective without knowing how cattle and rangeland respond to the stocking rate. Heavy stocking can damage the resource, reducing total forage production and shifting the species composition to species that are more resistant to grazing (Thurow 1991).

Procedures

This ongoing study began in 1989 at the Central Grasslands Research Extension Center in Kidder County northwest of Streeter, N.D. The site was divided into 12 pastures of approximately 30 acres each. Grazing intensities were light, moderate, heavy and extreme. The target was to leave 65, 50, 35 and 20 percent of the forage produced in an average year on the light, moderate, heavy and extreme treatments, respectively. Exclosures were used to provide a fifth, ungrazed treatment to determine how rangeland changes when it is not grazed.

Grazing began each year in mid-May, and cattle were removed when forage utilization on half of the pastures had reached desired grazing intensity (approximately mid-October). Table 1 presents the stocking history of the study and Figure 1 shows how much forage remained at the end of the grazing season each year.

Monitoring locations were on loamy and loamy overflow ecological sites in each pasture, as were six exclosures for the ungrazed treatment. Frequency of occurrence of all plant species was monitored each year to determine changes in the plant community. Plant density of shrubs, forbs and bunch grasses was sampled in conjunction with the frequency sampling. Forage production and utilization was determined using the paired plot cage comparison method.

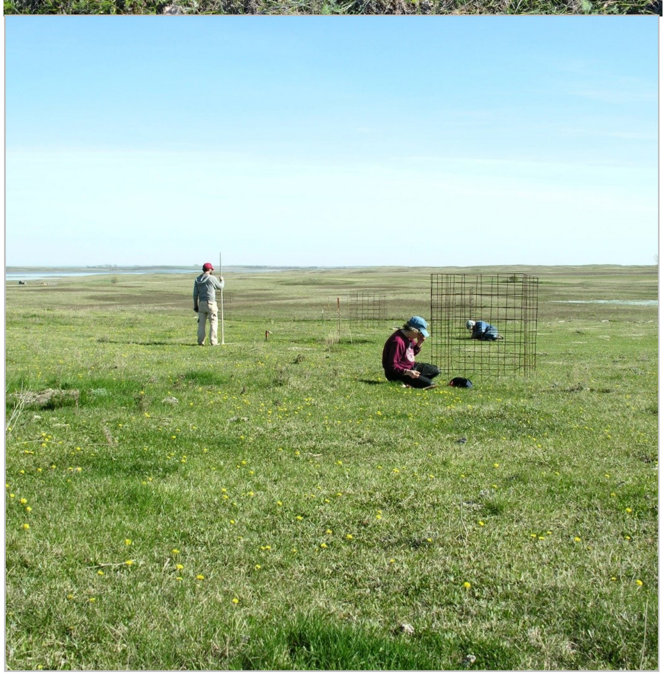


Table 1. Stocking history of the grazing intensity trial for 1989 through 2013 at Central Grasslands Research Extension Center, Streeter, N.D.

Year	Class of Animal	Stocking Date	Removal Date	Length of Grazing Season (Days)
1989	steers	May 22	Aug 22	92
1990	bred heifers	May 30	Nov 27	181
1991	bred heifers	May 29	Sept 25	119
1992	bred heifers	June 1	Aug 25	85
1993	bred heifers	May 29	Sept 26	120
1994	open heifers & steers	May 17	Nov 10	177
1995	open heifers	May 18	Oct 30	165
1996	open heifers	May 20	Sept 23	126
1997	open heifers	May 27	Nov 5[1]	162[1]
1998	open heifers	May 16	Oct 28	165
1999	open heifers	May 27	Nov 4	161
2000	open heifers	May 18	Sept 25	130
2001	open heifers	May 21	Sept 11	113
2002	open heifers	May 23	July 17	55
2003	open heifers	May 23	Sept 19	119
2004	open heifers	May 19	Sept 9	113
2005	open heifers	May 17	Oct 27	163
2006	open heifers	May 11	July 27	77
2007	open heifers	May 18	Oct 1	136
2008	open heifers	May 20	Aug 25	97
2009	open heifers	May 21	Sept 1	103
2010	open heifers	May 11	Sept 20	132
2011	open heifers	May 18	Oct 17	152
2012	open heifers	May 7	Sept 25	141
2013	open heifers	May 22	Aug 28	98

[1]Due to lack of forage, livestock were removed early (August 27) from the extreme grazing treatment, resulting in 92 days of grazing on that treatment.

Results

Forage production. Figure 2 shows the average production on the loamy and loamy overflow ecological sites during each year of the study and the total precipitation for the year. Monthly precipitation for 2010 through 2013 is shown on page 48.

The average forage production by treatment for the past 21 years is shown in Tables 2 and 3. On loamy ecological sites, the light grazing resulted in the highest production ($P \le 0.05$). On loamy overflow ecological sites, no difference ($P > 0.05$) in forage production was found on light, moderate and heavy treatments in end-of-the-season forage production. The ungrazed treatment produced significantly less forage than the light treatment on the loamy ecological site and less than the light, moderate and heavy treatments on the loamy overflow ecological site ($P \le 0.05$).The extreme grazing treatment produced the least forage ($P \le 0.05$) on both ecological sites.

Year x *treatment* interactions ($P \le 0.05$) have been found only at the beginning of the grazing season for both ecological sites. On loamy overflow ecological sites, the treatment with the most forage production at the beginning of the season was light, moderate or heavy, but different treatments produced the most forage in different years ($P \le 0.05$). On loamy ecological sites at the beginning of the grazing season, the treatment with the highest forage production was ungrazed, light or moderate in different years, with the extreme or heavy treatments always having the lowest forage production ($P \le 0.05$).

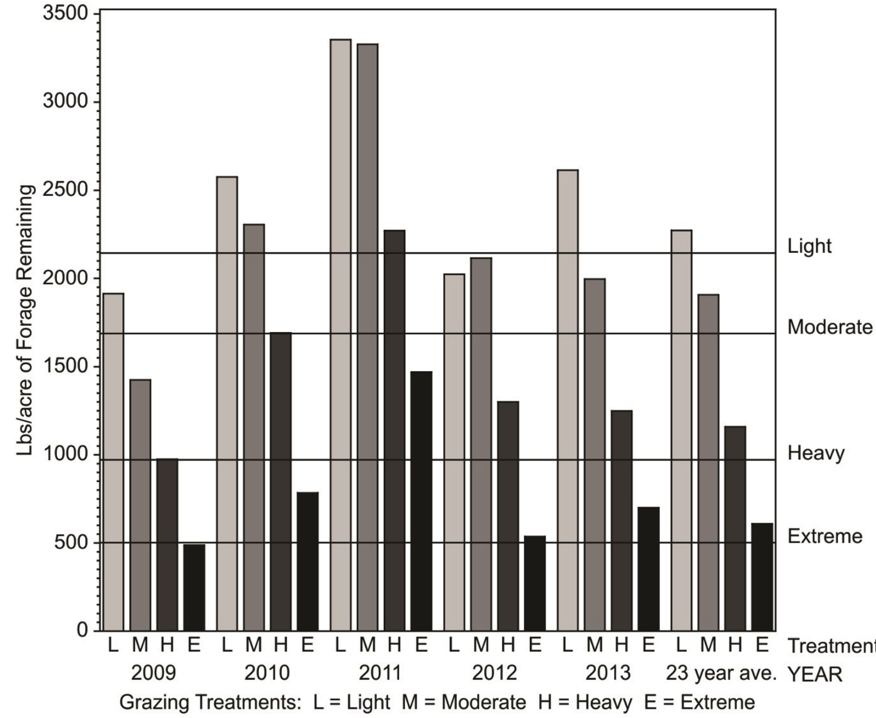


Figure 1. Forage remaining on each treatment at the end of the grazing season from 2009 to 2013 and the average forage remaining on each treatment over the last 23 years.

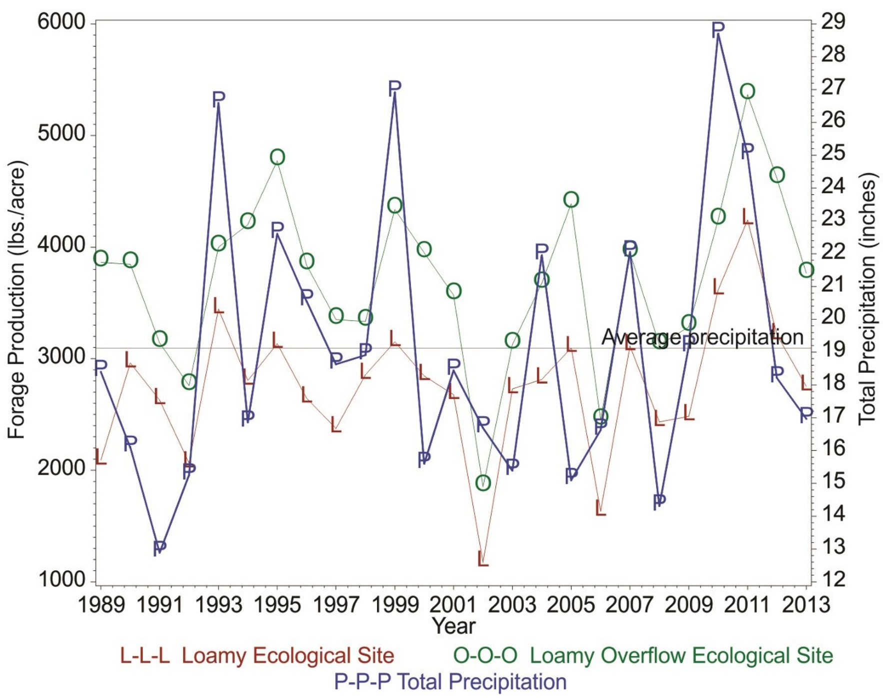


Figure 2. Total crop year precipitation (October 1 to September 30) and peak total above ground biomass production on loamy overflow and loamy ecological sites on the grazing intensity study from 1989 to 2013.

Table 2. Average above ground biomass production by grazing treatment on **loamy** ecological sites from 1992 to 2013.

Treatment	Above-ground biomass (lbs/acre)			
	Beginning of season	Middle of season	Peak yield	End of season
Ungrazed	1,273 b[1]	2,587 b	2,829 b	2,649 c
Light	1,352 a	2,906 a	3,297 a	3,172 a
Moderate	1,201 c	2,659 b	3,019 b	2,886 b
Heavy	938 d	2,261 c	2,510 c	2,416 d
Extreme	751 e	1,938 d	2,278 d	2,213 d
LSD (0.05)	61	166	205	221

[1]Means in the same column followed by the same letter are not significantly different at *P*=0.05.

Table 3. Average above ground biomass production by grazing treatment on **loamy overflow** ecological sites from 1993 to 2013.

Treatment	Above-ground biomass (lbs/acre)			
	Beginning of season	Middle of season	Peak yield	End of season
Ungrazed	1,005 b[1]	3,364 c	3,511 c	3,050 b
Light	1,177 a	4,127 a	4,407 a	4,156 a
Moderate	1,249 a	3,789 b	4,226 ab	4,067 a
Heavy	1,219 a	3,646 b	4,009 b	3,952 a
Extreme	819 c	2,310 d	2,703 d	2,633 c
LSD (0.05)	74	255	269	284

[1]Means in the same column followed by the same letter are not significantly different at *P*=0.05.

Plant community dynamics. Table 4 lists the 10 most dominant plants species on the loamy ecological site as determined by average frequency of occurrence in 25- by 25-centimeter (cm) frames across the 26 years and five treatments.

A total of 166 species have been found on the loamy ecological sites and 63 have shown a response to grazing treatment based on frequency, density or basal cover. Eight species are favored by no grazing (Table 5). Twenty-six species are favored by moderate grazing (Table 6). These are species that increase as grazing pressure increases from ungrazed to moderately grazed but decrease as grazing pressure increases from moderate to extreme. Twenty-seven species are favored by heavy grazing (Table 7). Five species are "invaders," or species that appear on the site only after heavy grazing (Table 8).

Table 9 lists the 10 most dominant plants species on the loamy overflow ecological site as determined by average frequency of occurrence in 25- by 25-cm frames across the 26 years and five treatments. Of the 177 species on the loamy overflow ecological sites, 53 have responded to grazing treatment. Six are favored by no grazing (Table 10), 16 by moderate grazing (Table 11), 26 by heavy grazing (Table 12) and five are "invaders" (Table 13).

Table 4. The dominant plant species on the **loamy** ecological site: those with the highest average frequency of occurrence in 25 cm by 25 cm frames over the 26 years on the five treatments and their average frequency of occurrence in 1988 and 2013.

Scientific name	Common name	1988 average (percent)	2013 average (percent)
Poa pratensis L.	Kentucky bluegrass	84	98
Pascopyrum smithii (Rydb.) A. Löve	western wheatgrass	51	69
Carex inops Bailey ssp. *heliophila* (Mackenzie) Crins	sun sedge	70	40
Symphyotrichum ericoides (L.) Nesom var. *ericoides*	heath aster	38	45
Artemisia ludoviciana Nutt.	cudweed sagewort	20	33
Nassella viridula (Trin.) Barkworth	green needlegrass	38	29
Carex obtusata Lilj.	obtuse sedge	13	37
Achillea millefolium L.	western yarrow	4	45
Taraxacum officinale F.H. Wigg.	common dandelion	0	49
Bouteloua gracilis (H.B.K.) Lag. ex Griffiths	blue grama	38	19

Table 5. Plant species which appear to have been favored by no grazing on the **loamy** ecological site.

Scientific name	Common name
Poa pratensis L.	Kentucky bluegrass
Lotus unifoliolatus (Hook.) Benth. var. *unifoliolatus*	deer vetch
Lactuca tatarica (L.) C.A. Mey. var. *pulchella* (Pursh) Breitung	blue lettuce
Helianthus pauciflorus Nutt. ssp. *pauciflorus*	stiff sunflower
Artemisia absinthium L.	wormwood
Tragopogon dubius Scop. - goat's beard	goat's beard
Pediomelum esculentum (Pursh) Rydb.	breadroot scurf-pea
Symphyotrichum lanceolatum (Willd.) G.L. Nesom ssp. *lanceolatum* var. *lanceolatum*	panicled aster

Table 6. Plant species which appear to have been favored by moderate grazing on the **loamy** ecological site.

Scientific name	Common name
Symphyotrichum ericoides (L.) Nesom var. *ericoides*	heath aster
Artemisia ludoviciana Nutt.	cudweed sagewort
Ambrosia psilostachya DC.	western ragweed
Dichanthelium wilcoxianum (Vassey) Freckmann	Wilcox dichanthelium
Hesperostipa curtiseta (Hitchc.) Barkworth	western porcupine grass
Cirsium flodmanii (Rydb.) Arthur	Flodman's thistle
Elymus repens (L.) Gould	quackgrass
Ratibida columnifera (Nutt.) Woot. & Standl.	prairie coneflower
Pediomelum argophyllum (Pursh) J. Grimes	silver-leaf scurf-pea
Solidago mollis Bartl.	soft goldenrod
Comandra umbellata (L.) Nutt.	comandra
Rosa arkansana Porter	prairie rose
Bromus inermis Leyss.	smooth brome
Artemisia dracunculus L.	green sagewort
Carex filifolia Nutt.	thread-leaved sedge
Anemone cylindrica A. Gray	candle anemone
Lithospermum incisum Lehm.	yellow puccoon
Calamagrostis montanensis (Scribn.) Scribn.	plains reedgrass
Sisyrinchium montanum Greene.	blue-eyed grass
Asclepias ovalifolia Dcne.	ovalleaf milkweed
Arabis hirsuta (L.) Scop. var. *pycnocarpa* (Hopkins) Rollins	rock cress
Erysimum asperum (Nutt.) DC.	western wallflower
Heterotheca villosa (Pursh) Shinners var. *villosa*	golden aster
Physalis virginiana Mill.	Virginia groundcherry
Erysimum inconspicuum (S. Wats.) MacM.	smallflower wallflower
Orthocarpus luteus Nutt.	owl clover

Table 7. Plant species which appear to have been favored by heavy grazing on the **loamy** ecological site.

Scientific name	Common name
Pascopyrum smithii (Rydb.) A. Löve	western wheatgrass
Carex inops Bailey ssp. *heliophila* (Mackenzie) Crins	sun sedge
Nassella viridula (Trin.) Barkworth	green needlegrass
Achillea millefolium L.	western yarrow
Taraxacum officinale F.H. Wigg.	common dandelion
Bouteloua gracilis (Willd. ex Kunth) Lag. ex Griffiths	blue grama
Artemisia frigida Willd.	fringed sagewort
Vicia americana Muhl. ex Willd.	American vetch
Grindelia squarrosa (Pursh) Dun.	curly-cup gumweed
Cerastium arvense L.	prairie chickweed
Astragalus agrestis Dougl. ex G. Don	field milk-vetch
Koeleria macrantha (Ledeb.) J.A. Schultes	Junegrass
Androsace occidentalis Pursh	western rock jasmine
Carex duriuscula C.A. Mey.	needle-leaved sedge
Oxalis stricta L.	yellow wood sorrel
Chamaesyce serpyllifolia (Pers.) Small ssp. *serpyllifolia*	thyme-leaved spurge
Hedeoma hispida Pursh	rough false pennyroyal
Plantago patagonica Jacq.	wooly plantain
Potentilla pensylvanica L.	Pennsylvania cinquefoil
Penstemon gracilis Nutt.	slender beardtongue
Geum triflorum Pursh	prairie smoke
Sphaeralcea coccinea (Pursh) Rydb.	scarlet globe mallow
Draba nemorosa L.	yellow whitlowort
Antennaria neglecta Greene	field pussy-toes
Bouteloua dactyloides (Nutt.) J.T. Columbus	buffalograss
Lepidium densiflorum Schrad.	peppergrass
Potentilla norvegica L.	Norwegian cinquefoil

Table 8. Plant species which only appear after heavy grazing on the **loamy** ecological site.

Scientific name	Common name
Medicago lupulina L.	black medic
Agrostis hyemalis (Walt.) B.S.P.	ticklegrass
Juncus interior Wieg.	inland rush
Trifolium repens L.	white clover
Polygonum ramosissimum Michx.	bushy knotweed

Table 9. The dominant plant species on the **loamy overflow** ecological site: those with the highest average frequency of occurrence in 25 cm by 25 cm frames over the 26 years on the five treatments, and their average frequency of occurrence in 1988 and 2013.

Scientific name	Common name	1988 average (percent)	2013 average (percent)
Poa pratensis L.	Kentucky bluegrass	66	97
Bromus inermis Leyss.	smooth brome	28	64
Symphoricarpos occidentalis Hook.	buckbrush	57	39
Oligoneuron rigidum (L.) Small var. *humile* (Porter) Nesom	stiff goldenrod	25	48
Symphyotrichum ericoides (L.) Nesom var. *ericoides*	heath aster	33	38
Artemisia ludoviciana Nutt.	cudweed sagewort	28	30
Carex obtusata Lilj.	obtuse sedge	20	26
Helianthus pauciflorus Nutt. ssp. *pauciflorus*	stiff sunflower	46	18
Achillea millefolium L.	western yarrow	5	38
Taraxacum officinale F.H. Wigg.	common dandelion	0	50

Table 10. Plant species which appear to have been favored by no grazing on the **loamy overflow** ecological site.

Scientific name	Common name
Bromus inermis Leyss.	smooth brome
Symphoricarpos occidentalis Hook.	buckbrush
Helianthus pauciflorus Nutt. ssp. *pauciflorus*	stiff sunflower
Rosa arkansana Porter	prairie rose
Sonchus arvensis L.	field sow thistle
Liatris ligulistylis (A. Nels.) K. Schum.	round-headed blazing star

Table 11. Plant species which appear to have been favored by moderate grazing on the **loamy overflow** ecological site.

Scientific name	Common name
Oligoneuron rigidum (L.) Small var. *humile* (Porter) Nesom	stiff goldenrod
Ambrosia psilostachya DC.	western ragweed
Solidago canadensis L.	Canada goldenrod
Glycyrrhiza lepidota Pursh	wild licorice
Solidago mollis Bartl.	soft goldenrod
Carex pellita Muhl. ex Willd.	wooly sedge
Anemone cylindrica A. Gray	candle anemone
Spartina pectinata Bosc ex Link	prairie cordgrass
Carex praegracilis W. Boott.	clustered field sedge
Muhlenbergia racemosa (Michx.) B.S.P.	marsh muhly
Juncus arcticus Willd. ssp. *littoralis* (Engelm.) Hultén	Baltic rush
Campanula rotundifolia L.	harebell
Sisyrinchium montanum Greene.	blue-eyed grass
Agrimonia striata Michx.	striate agrimony
Poa palustris L.	fowl bluegrass
Packera plattensis (Nutt.) W.A. Weber & A. Löve	prairie ragwort

Table 12. Plant species which appear to have been favored by heavy grazing on the **loamy overflow** ecological site.

Scientific name	Common name
Poa pratensis L.	Kentucky bluegrass
Symphyotrichum ericoides (L.) Nesom var. *ericoides*	heath aster
Artemisia ludoviciana Nutt.	cudweed sagewort
Carex obtusata Lilj.	obtuse sedge
Achillea millefolium L.	western yarrow
Taraxacum officinale F.H. Wigg.	common dandelion
Carex inops Bailey ssp. *heliophila* (Mackenzie) Crins	sun sedge
Oxalis stricta L.	yellow wood sorrel
Pascopyrum smithii (Rydb.) A. Löve	western wheatgrass
Cerastium arvense L.	prairie chickweed
Viola pedatifida G. Don	larkspur violet
Grindelia squarrosa (Pursh) Dun.	curly-cup gumweed
Elymus caninus (L.) L.	slender wheatgrass
Nassella viridula (Trin.) Barkworth	green needlegrass
Agrostis hyemalis (Walt.) B.S.P.	ticklegrass
Solidago missouriensis Nutt.	Missouri goldenrod
Androsace occidentalis Pursh	western rock jasmine
Astragalus agrestis Dougl. ex G. Don	field milk-vetch
Chamaesyce serpyllifolia (Pers.) Small ssp. *serpyllifolia*	thyme-leaved spurge
Conyza canadensis (L.) Cronq.	horse-weed
Geum triflorum Pursh	prairie smoke
Artemisia frigida Willd.	fringed sagewort
Erigeron philadelphicus L.	Philadelphia fleabane
Penstemon gracilis Nutt.	slender beardtongue
Erysimum inconspicuum (S. Wats.) MacM.	smallflower wallflower
Draba nemorosa L.	yellow whitlowort

Table 13. Plant species which only appear after heavy grazing on the **loamy overflow** ecological site.

Scientific name	Common name
Medicago lupulina L.	black medic
Trifolium repens L.	white clover
Polygonum ramosissimum Michx.	bushy knotweed
Lithospermum incisum Lehm.	yellow puccoon
Lepidium densiflorum Schrad.	peppergrass

On loamy sites, total forb density has become highest on the extreme treatment and lowest on the light and ungrazed treatments ($P \leq 0.05$). Total plant density (including forbs, bunchgrasses and shrubs, but not rhizomatous grasses) has increased more on the extreme treatment than on the ungrazed or light treatments ($P \leq 0.05$).

From 1994 to 2001, total grass density decreased on the ungrazed and light treatments and has not recovered on those treatments, while a steady increase has occurred in grass density on the moderate, heavy and extreme treatments ($P \leq 0.05$). Also, on loamy ecological sites, total plant basal cover decreased on all treatments, but it decreased less on the extreme than on the other treatments ($P \leq 0.05$). On loamy overflow sites, the total density of non-rhizomatous grasses has increased on the extreme grazing treatment and decreased on the ungrazed treatment ($P \leq 0.05$). Total forb density has increased with grazing intensity and has become greatest on the extreme treatment and least on the ungrazed ($P \leq 0.05$). Total plant density also has increased with grazing intensity ($P \leq 0.05$). Total plant basal cover has increased on the extreme and heavy treatments and decreased on the ungrazed and light treatments ($P \leq 0.05$).

In addition to the changes listed for plant species, litter has decreased on loamy ecological sites under heavy grazing, and bare ground has increased on loamy and loamy overflow ecological sites under heavy grazing ($P \leq 0.05$).

Discussion

During the past 24 years, forage production on our loamy ecological sites has averaged 2,759 pounds/acre. In a year with average production, 0.34 acre of this ecological site would be enough to supply this amount of forage for a month. However production has varied through the years from being able to supply this amount of forage with 0.22 acre to requiring 0.79 acre. This emphasizes the importance of knowing how productive pastures are and being able to predict weather trends early in the grazing season.

Differences in biomass production among treatments indicate that grazing reduces the amount of carbohydrate reserves the plants are able to carry over to the next season. This was evident more on the loamy sites than the loamy overflow sites (Tables 2 and 3).

So instead of season-long grazing, we recommend a rotational grazing system at a moderate stocking rate to take advantage of higher forage quality found on the extreme grazing treatment (Patton et al., 2002) and still give plants a rest, thereby avoiding reduced production.

Also, a light or moderate stocking rate is better than a period of rest that is too long. The low level of production on the ungrazed treatment likely is due to litter buildup that prevents rainfall and sunlight from reaching the ground.

We plan to continue this research for a number of years because changes in forage production and plant species composition still are apparent in response to grazing intensity and weather. These factors, in turn, will affect animal response to the grazing treatments.

Literature Cited

Patton, B.D., P.E. Nyren, B.S. Kreft and A.C. Nyren. 2002. Grazing intensity research in the Missouri Coteau of North Dakota. North Dakota State University Central Grasslands Research Extension Center 2001 Grass and Beef Research Review, Streeter, N.D. North Dakota State University - Central Grasslands Research Extension Center. P. 12-16. Available online at: www.ag.ndsu.edu/archive/streeter/2001report/Grazing_intensity_Intro.htm#TableofContents

Thurow, T.L. 1991. Hydrology and Erosion. In: Heitschmidt, R.K. and Stuth, J.W. (eds.). *Grazing Management: An Ecological Perspective*. Portland, Ore.: Timber Press. 259 pp.

Acknowledgements

We thank Dwight Schmidt, Rodney Schmidt, Rick Bohn and former staff members, along with nearly 100 summer employees, who have contributed to this study during the past 25 years.

Long-term Grazing Intensity Research in the Missouri Coteau Region of North Dakota: Livestock Response and Economics

Bob Patton and Anne Nyren
Central Grasslands Research Extension Center- NDSU, Streeter

The effects of grazing intensity on cattle performance, profitability and the sustainability of forage production have been monitored on 12 pastures at the CGREC since 1989. The optimum stocking rate depends on objectives, but the best compromise between profitability and sustainability falls between a moderate stocking rate (50 percent utilization) and a heavy stocking rate (65 percent utilization).

Summary
The question of how heavily to stock native range is complex. The answer primarily depends on how much forage is available, which varies each year, depending on the temperature and precipitation. If stocking rates are too low, profits will not be maximized, but if rates are too high, cattle performance will suffer and the resource will be damaged.

This study began in 1989. Five treatments were included: no grazing, and light, moderate, heavy and extreme grazing. Our goal was to stock the pastures each year so when the cattle were removed in the fall, 65, 50, 35 and 20 percent of the forage produced in an average year remains on the light, moderate, heavy and extreme treatments, respectively.

Average daily gain and animal body condition scores have decreased with increasing grazing intensity. This effect has been significant ($P \leq 0.05$) in most but not all years. Initially, gain/ton (total weight gain of all animals/ton of available forage) increased as the stocking rate increased, but a point was reached at which gains/ton decline.

In this study, at 2.54 animal unit months (AUMs)/ton of forage, average gain/ton from 1991 to 2013 would be 77.2 pounds/ton. If cattle prices were constant, then return/ton (dollars returned to the enterprise per ton of forage) would peak at a stocking rate somewhere below maximum gain/ton, with the exact point depending on carrying costs. The stocking rate with the maximum return/ton during the last 23 years would be 2.16 AUMs/ton, with an average annual return of $38.22/ton.

Introduction
At low stocking rates, individual animal performance is high, but total gains from the pasture will be low (Hart 1972). As stocking rates increase, individual performance goes down but gain/ton of forage will increase as long as the individual gain of the animal added exceeds the reduced gain of the other animals in the pasture. But gain/ton will decline as more animals are competing for less forage (Hart 1972). If cattle prices are steady, then return/ton would peak at a stocking rate somewhere below maximum gain/ton, with the exact point depending on input costs (Hart 1972).

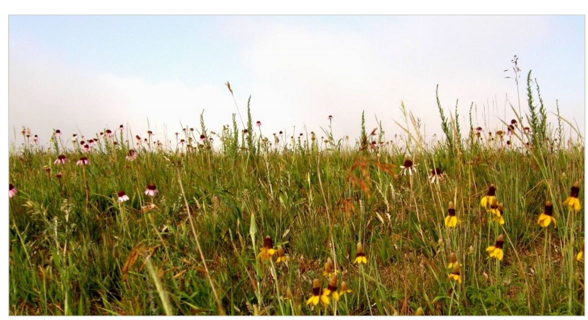
The optimum stocking rate varies with objectives, but we cannot know what stocking rate is optimum for any particular objective without knowing how cattle and rangeland respond to the stocking rate. Heavy stocking can damage the resource, reducing total forage production and shifting the species composition to species that are more resistant to grazing (Thurow 1991).

Stocking rate can be expressed two ways: on a land area or a forage basis. The land area basis states how many animals are on a given amount of land for a given length of time. The forage basis describes how many animals are grazing a given amount of forage during a given length of time.

The drawback of the land area basis is that forage production varies from year to year and place to place, so a year with half the normal forage production will require half the normal stocking rate by cutting animal numbers in half, cutting the time they graze in half or doubling the amount of land area.

To express stocking rate on a forage basis, the ratio of forage demand to forage supply remains constant. In a year with half of normal forage production, a producer still would have to cut animals numbers in half, cut grazing time in half or double the amount of land area, but the stocking rate would remain the same because the ratio of animals to available forage remains the same.

The unit used to express animal demand is the animal unit month (AUM). An AUM is defined as the forage required to sustain a 1,000-pound cow and her calf for one month, assuming they require 26 pounds of forage a day on a dry-matter basis. The animal unit is based on the metabolic weight of the animal, so a 1200-pound cow would be 1.147 animal units and a 700-pound steer or open heifer would be 0.765 animal unit.



A stocking rate of one AUM/acre allows the equivalent of one cow and calf to graze on an acre for one month. A stocking rate of 3 AUMs/acre holds the equivalent of three cows with calves on one acre for one month, but this is saying nothing about the amount of forage they will have to graze. A stocking rate of 1AUM/ton of forage allows the equivalent of one mature cow and calf to graze on one ton of available forage for one month or 66.6 pounds per day. A stocking rate of 3 AUMs/ton of forage holds the equivalent of three mature cows with calves on one ton of available forage for one month or 22.2 pounds per day. Table 1 gives examples of stocking rates in AUM/ton of available forage and their equivalent in AUM/acre, assuming that the area produces 2,759 pounds/acre, the average of the loamy ecological site in our study.

Table 1. Examples of stocking rates in AUM/ton of available forage and the acres of land required to provide that much forage for one month assuming an average year's forage production on a loamy ecological site (2,759 lbs/acre in an average year). Stocking rate in AUM/acre is

AUM/ton of Available Forage		Acres Required	Stocking Rate in AUM/acre
Average stocking rate on the light treatment	0.36	2.01	0.50
Average stocking rate on the moderate treatment	0.70	1.04	0.97
	0.72	1.00	1.00
	1.00	0.72	1.38
Average stocking rate on the heavy treatment	1.35	0.54	1.86
Stocking rate with the highest average return	2.16	0.34	2.98
Average stocking rate on the extreme treatment	2.40	0.30	3.31
Stocking rate with the highest average gain	2.54	0.29	3.50
	3.00	0.24	4.14

Procedures

This ongoing study began in 1989 at the Central Grasslands Research Extension Center in Kidder County northwest of Streeter, N.D. The site was divided into 12 pastures of approximately 30 acres each. Grazing intensities were light, moderate, heavy and extreme. The target was to leave 65, 50, 35 and 20 percent of the forage produced in an average year on the light, moderate, heavy and extreme treatments, respectively. Exclosures were used to provide a fifth, ungrazed treatment to determine how rangeland changes when it is not grazed. Grazing began each year in mid-May, and cattle were removed when forage utilization on half of the pastures had reached desired grazing intensity (approximately mid-October). Table 2 presents the stocking history of the study.

Table 2. Stocking history of the grazing intensity trial for 1989 through 2013 at Central Grasslands Research Extension Center, Streeter, N.D.

Year	Class of Animal	Stocking Date	Removal Date	Length of Grazing Season (Days)
1989	steers	May 22	Aug 22	92
1990	bred heifers	May 30	Nov 27	181
1991	bred heifers	May 29	Sept 25	119
1992	bred heifers	June 1	Aug 25	85
1993	bred heifers	May 29	Sept 26	120
1994	open heifers & steers	May 17	Nov 10	177
1995	open heifers	May 18	Oct 30	165
1996	open heifers	May 20	Sept 23	126
1997	open heifers	May 27	Nov 5[1]	162[1]
1998	open heifers	May 16	Oct 28	165
1999	open heifers	May 27	Nov 4	161
2000	open heifers	May 18	Sept 25	130
2001	open heifers	May 21	Sept 11	113
2002	open heifers	May 23	July 17	55
2003	open heifers	May 23	Sept 19	119
2004	open heifers	May 19	Sept 9	113
2005	open heifers	May 17	Oct 27	163
2006	open heifers	May 11	July 27	77
2007	open heifers	May 18	Oct 1	136
2008	open heifers	May 20	Aug 25	97
2009	open heifers	May 21	Sept 1	103
2010	open heifers	May 11	Sept 20	132
2011	open heifers	May 18	Oct 17	152
2012	open heifers	May 7	Sept 25	141
2013	open heifers	May 22	Aug 28	98

[1]Due to lack of forage, livestock were removed early (August 27) from the extreme grazing treatment, resulting in 92 days of grazing on that treatment.

Cattle performance was evaluated based on initial and final body weight, and body condition score. Economic return is determined by subtracting the initial value of each animal, interest on the initial value for the grazing period, death loss, and estimated costs per head for salt, mineral and veterinary fees from the final value of the animal when taken off pasture. Initial and final values of animals are based on weight using regression equations developed from sale prices at the Napoleon Livestock Auction during the same period.

Results

Forage production. Figure 1 shows how much forage remained at the end of the grazing season each year.

Figure 2 shows the average production on the loamy and loamy overflow ecological sites during each year of the study and the total precipitation for the year.

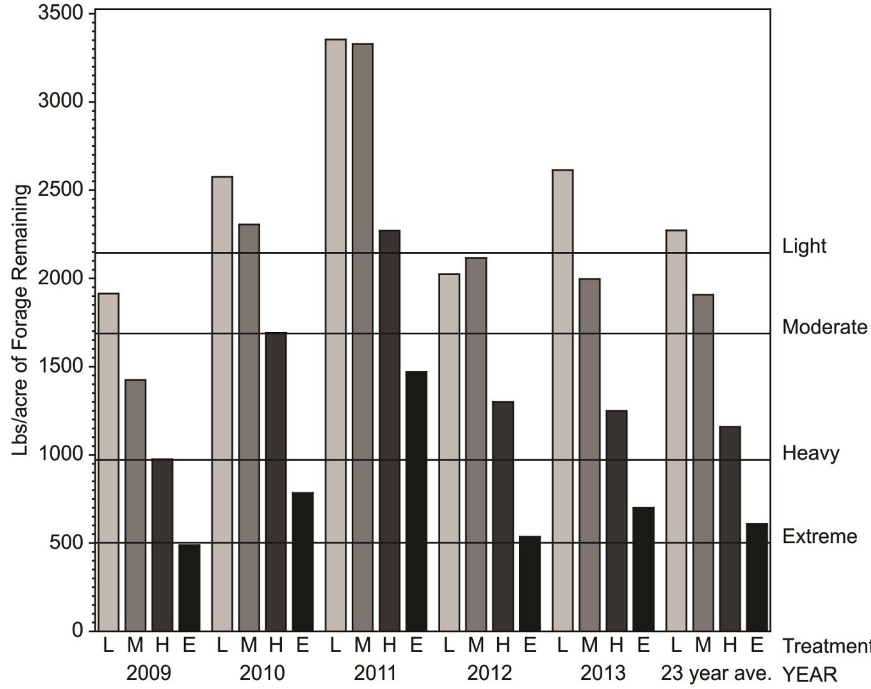


Figure 1. Forage remaining on each treatment at the end of the grazing season from 2009 to 2013 and the average forage remaining on each treatment over the last 23 years.

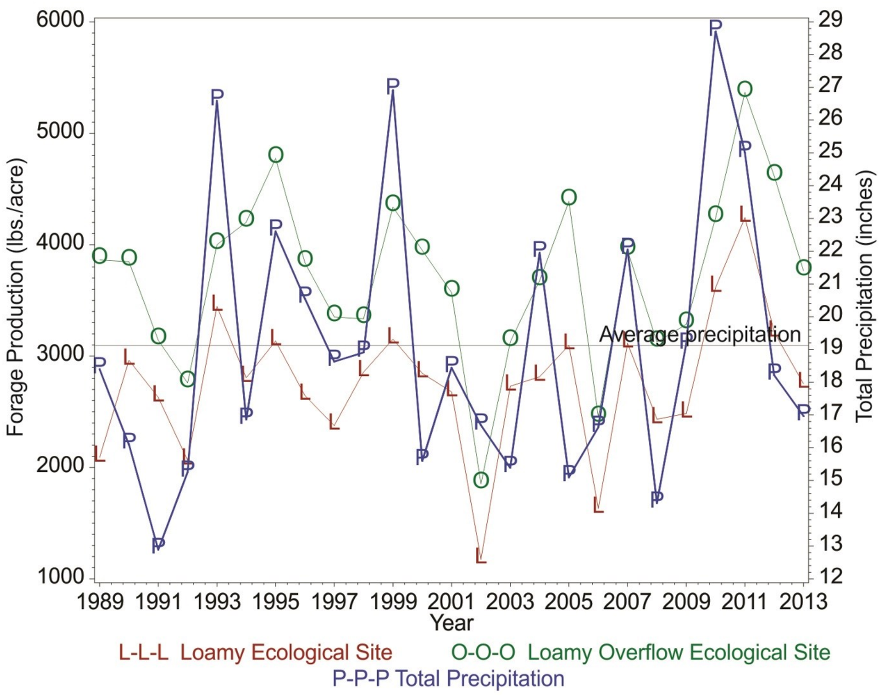


Figure 2. Total crop year precipitation (October 1 to September 30) and peak total above ground biomass production on loamy overflow and loamy ecological sites on the grazing intensity study from 1989 to 2013.

Livestock response. Table 3 shows the average daily gain, gain per acre, gain per ton of forage and body condition scores from the different grazing intensities. The relationships between stocking rate and average daily gain are illustrated in Figure 3 (next page). Initially, gain/ton of forage increased as the stocking rate increased, but a point is reached at which further increases in stocking rates result in reduced gain/ton (Figure 4). Average body condition score decreased with increased grazing intensity each year with few exceptions ($P \leq 0.05$).

Table 3. Average daily gains, gains per acre, gain per ton of forage and condition scores from different stocking intensities.

Desired Grazing Intensity	Average Daily Gains (lbs/head/day)					
	2009	2010	2011	2012	2013	Average 1991-2013
Light	2.05a[1]	1.54	1.59	1.21a	1.36	1.39a
Moderate	1.99a	1.29	1.32	1.12a	1.31	1.27b
Heavy	1.48b	1.09	1.30	0.98ab	1.09	1.11c
Extreme	1.09b	1.02	1.17	0.72b	1.01	0.87d
LSD (0.05)	0.42	NS[2]	NS	0.34	NS	0.12
	Average Gain (lbs/acre)					
	2009	2010	2011	2012	2013	Average 1991-2013
Light	47.37b	41.58	51.55c	36.81	30.33b	31.27d
Moderate	90.63a	68.95	83.22bc	62.85	53.27ab	56.66c
Heavy	92.72a	84.55	121.11ab	83.17	66.90a	78.27b
Extreme	90.79a	104.70	140.29a	80.16	80.60a	88.86a
LSD (0.05)	34.31	NS	54.49	NS	27.97	9.22
	Average Gain (lbs/ton of forage)					
	2009	2010	2011	2012	2013	Average 1991-2013
Light	33.80b	19.01c	21.69b	17.88b	17.20b	19.45d
Moderate	62.10ab	31.24bc	32.82b	33.08ab	37.44ab	35.09c
Heavy	77.54a	52.54ab	58.61a	54.07a	53.62a	58.72b
Extreme	92.90a	64.87a	74.00a	58.94a	69.77a	75.32a
LSD (0.05)	33.78	27.37	22.96	30.27	34.87	7.13
	Condition Score					
	2009	2010	2011	2012	2013	Average 1994-2013
Light	5.77	5.24	5.41	5.02a	4.81	5.41a
Moderate	5.52	5.19	5.33	4.88a	4.69	5.30ab
Heavy	5.46	5.16	5.42	4.78ab	4.57	5.19b
Extreme	4.97	5.05	5.25	4.57b	4.48	4.93c
LSD (0.05)	NS	NS	NS	0.24	NS	0.17

[1]Means in the same column followed by the same letter are not significantly different at $P=0.05$.

[2]Means not significantly different.

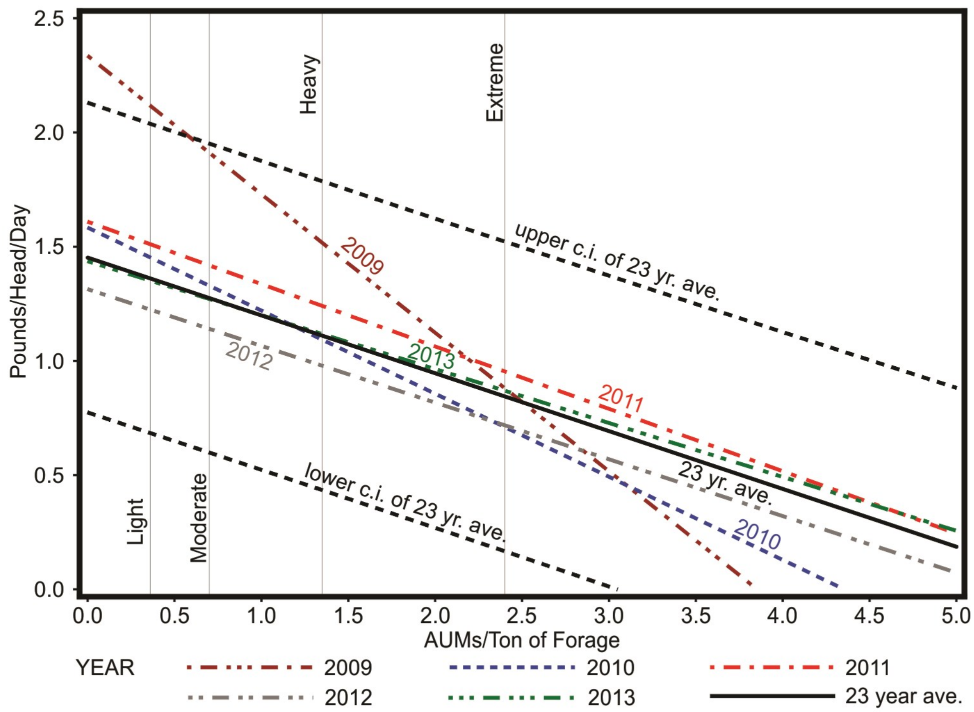


Figure 3. Relationships between average daily gain and stocking rate on the grazing intensity trial for 2009 to 2013 and the 23 year average with 95 percent confidence intervals.

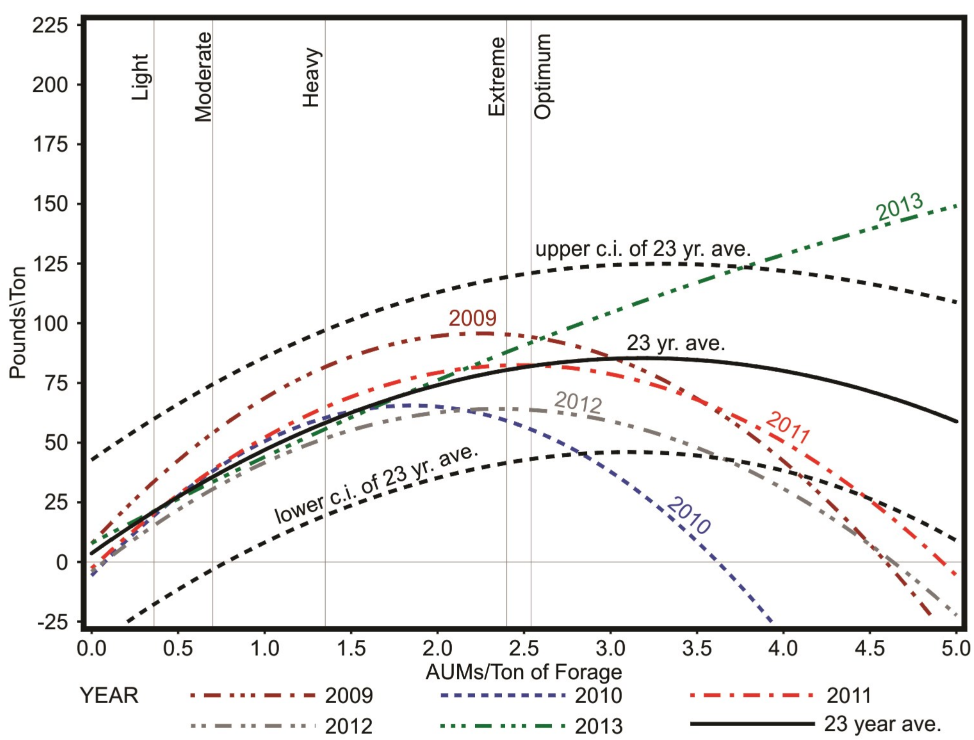


Figure 4. Relationships between gain/ton and stocking rate on the grazing intensity trial for 2009 to 2013 and the 23 year average with 95 percent confidence intervals.

Table 4A shows the stocking rate that would have resulted in the maximum gain/ton of forage in each year. The stocking rate with the maximum gain/ton from 1991 to 2013 would be 2.54 AUMs/ton ("Optimum" in Figure 4) (Values are based on regressions of gain on the stocking rate. All regressions were significant at least at the P=0.0068 level).

Table 4B shows what the gain/ton would have been each year if we had stocked at that rate. Stocking at 2.54 AUMs/ton each year, gain/ton would have ranged from 30.1 pounds/ton in 2004 to 152.1 pounds/ton in 1992, with an average of 77.2 pounds/ton.

Table 4C shows gain/ton if the stocking rate had been held constant at 0.70 AUM/ton, the average of the moderate treatment.

Economics. Figure 5 shows the relationship between stocking rate and economic return. Costs for land, labor and management are not included because these values vary greatly from one operation to another. If cattle prices were steady, then return/ton would peak at a stocking rate somewhere below maximum gain/ton, with the exact point depending on carrying costs. However, when cattle are worth more per hundred-weight in the spring than they are in the fall, the point of maximum return/ton occurs at a lower stocking rate (Hart 1987). When the cattle are worth more in the fall, the maximum return/ton occurs at a higher stocking rate.

Table 5 shows the optimum return/ton for each year if stocking rates were set for the optimum for that year, a constant optimum rate and the moderate rate. The peaks of the curves in Figure 5 correspond to these optimum stocking rates.

Table 4. Comparison of gain in pounds per ton of forage from selected stocking rates.

	A		B		C	
	Stocking rate in AUMs/ton of forage that would result in the maximum gain/ton in each year.		Stocking rate in AUMs/ton of forage that if held constant would result in the maximum gain/ton during the 23-year period.		Gain/ton over the 23-year period if stocking rate where held constant at 0.70 AUMs/ton of forage, the average of the moderate treatment during this period.	
Year	**AUMs/ ton of Forage**	**Gain/ ton**	**AUMs/ ton of Forage**	**Gain/ ton**	**AUMs/ ton of Forage**	**Gain/ ton**
1991	2.61	56.5	2.54	56.4	0.70	27.6
1992	3.84	171.9	2.54	152.1	0.70	56.7
1993	2.07	102.9	2.54	97.0	0.70	54.1
1994	1.83	40.1	2.54	34.3	0.70	25.2
1995	2.52	60.3	2.54	60.3	0.70	28.8
1996	2.52	58.7	2.54	58.7	0.70	26.6
1997	2.30	95.4	2.54	94.3	0.70	46.9
1998	2.10	75.6	2.54	72.2	0.70	40.4
1999	3.46	108.3	2.54	100.4	0.70	37.3
2000	2.75	70.9	2.54	70.5	0.70	30.6
2001		*	2.54	109.0	0.70	36.8
2002		*	2.54	109.1	0.70	39.1
2003		*	2.54	78.4	0.70	28.8
2004	1.50	80.1	2.54	30.1	0.70	49.9
2005	2.43	48.3	2.54	48.2	0.70	22.9
2006	3.08	35.9	2.54	34.8	0.70	15.4
2007		*	2.54	111.9	0.70	34.9
2008	1.89	80.4	2.54	70.1	0.70	46.3
2009	2.25	95.7	2.54	94.2	0.70	53.9
2010	1.85	65.6	2.54	55.6	0.70	38.0
2011	2.48	82.5	2.54	82.4	0.70	38.5
2012	2.35	64.1	2.54	63.7	0.70	30.5
2013		*	2.54	91.9	0.70	*
23-year Average	**2.43**	**77.4**	**2.54**	**77.2**	**0.70**	**36.8**

* The regressions for 2001, 2002, 2003, 2007 and 2013 were not suitable to project the peak in gain/ton.

The constant stocking rate with the maximum return/ton during the last 23 years would be 2.16 AUMs/ton. This is the point labeled "Optimum" in Figure 5. Last year (2012), cattle prices were higher in the spring than in the fall for cattle weighing less than 875 pounds. This, coupled with the lower rate of gain on the higher stocking rates, would put the maximum return for 2012 at $15.20/ton if stocked at 1.23 AUMs/ton.

This year, cattle prices were higher in the fall than they were in the spring, so the heavier you could stock, the more money you would have made, provided the cattle did not lose too much weight. Therefore our pastures were not stocked heavily enough to determine the stocking rate with the maximum return.

Although the average return/ton is higher under the optimum stocking rate, seven years had negative returns, while only two years had a negative return under the moderate stocking rate. Comparing Tables 4 and 5, the stocking rate with the greatest economic return was less than the rate with the greatest gain per ton of forage in all but three years (1996, 1999 and 2004).

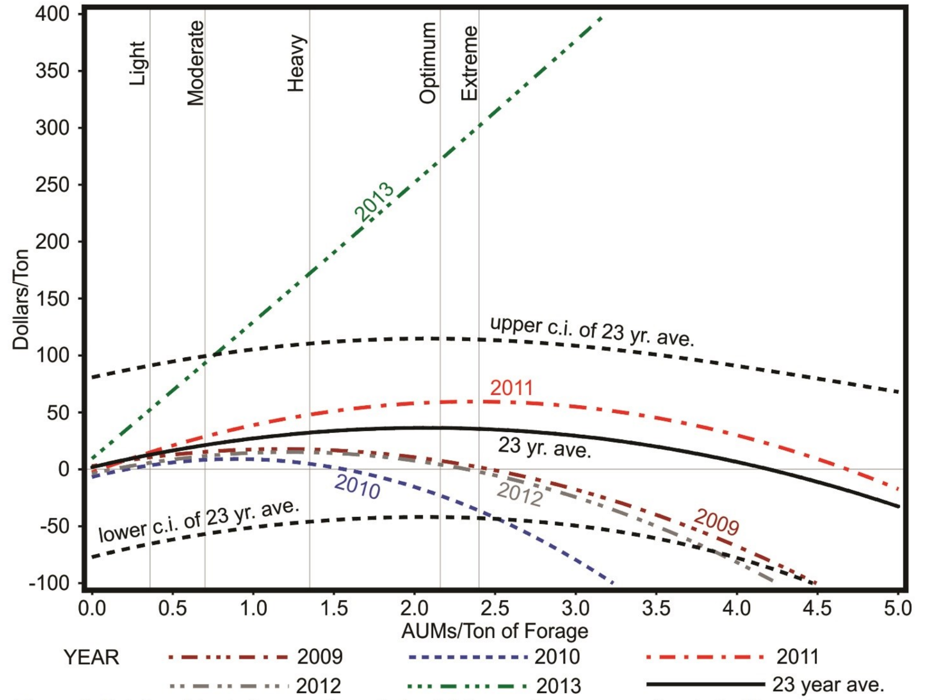


Figure 5. Relationships between returns to land, labor and management and stocking rate on the grazing intensity trial for 2009 to 2013 and the 23 year average with 95 percent confidence intervals.

Discussion

The objective of this study is to determine what stocking rate would result in the greatest economic return to the livestock producer in the long run. The slope of the decline in average daily gain with increase in stocking rate varies greatly from year to year. These differences may be due to variation in forage quality or quantity, the effect of weather on the animals, the animals' initial weights or their potential to gain.

Results indicate that for the past 23 years, the optimum stocking rate would have been 2.16 AUMs/ton of forage. This is equal to 926 pounds of forage for one animal unit, the equivalent of a 1,000-pound cow and calf, for one month.

During the past 24 years, forage production on our loamy ecological sites has averaged 2,759 pounds/acre. In a year with average production, 0.34 acre of this ecological site would be enough to supply this amount of forage for a month. However production has varied through the years from being able to supply this amount of forage with 0.22 acre to requiring 0.79 acre. This emphasizes the importance of knowing how productive pastures are and being able to predict weather trends early in the grazing season.

Although 2.16 AUMs/ton of forage would have provided the best economic return during the last 23 years, we found a number of reasons to consider a lighter stocking rate. First, the extreme and heavy pastures have been deteriorating in condition through the course of the study and may not be able to support the rates of gain we have seen in the past. Also, profits and losses are higher at higher stocking rates, depending on the difference between spring and fall livestock prices. The producer would experience more years with negative returns at the higher stocking rates.

The moderate stocking rate may be too conservative if maximizing profit is the objective. In only four out of 23 years, returns would have been higher with a stocking rate less than the moderate rate of 0.70 AUM/ton of forage. In all other years, a higher stocking rate would have resulted in higher returns. For a stocker operation in this area, the optimum stocking rate would fall in the range of 0.70 to 2.16 AUMs/ton of forage.

So instead of season-long grazing, we recommend a rotational grazing system at a moderate stocking rate to take advantage of higher forage quality found on the extreme grazing treatment (Patton et al., 2002) and still give plants a rest, thereby avoiding reduced production.

Also, a light or moderate stocking rate is better than a period of rest that is too long. The low level of production on the ungrazed treatment likely is due to litter buildup that prevents rainfall and sunlight from reaching the ground.

We plan to continue this research for a number of years because changes in forage production and plant species composition still are apparent in response to grazing intensity and weather. These factors, in turn, will affect animal response to the grazing treatments.

Table 5. Comparison of return to land, labor and management from selected stocking rates.

	A			B			C		
	Stocking rate in AUMs/ton of forage that would result in the maximum returns/ton to land, labor and management in each year.			Stocking rate in AUMs/ton of forage that if held constant would result in the maximum returns/ton to land, labor and management during the 23-year period.			Returns/ton to land, labor and management over the 23-year period if stocking rate where held constant at 0.70 AUMs/ton of forage, the average of the moderate treatment during this period.		
Year	**AUMs/ ton of Forage**	**Dollars/ ton**	**Gain/ ton**	**AUMs/ ton of Forage**	**Dollars/ ton**	**Gain/ ton**	**AUMs/ ton of Forage**	**Dollars/ ton**	**Gain/ton**
1991	0.41	1.77	18.0	2.16	(12.42)	54.90	0.70	1.37	27.55
1992		*		2.16	91.67	138.98	0.70	35.19	56.71
1993	1.41	59.10	91.8	2.16	42.71	102.61	0.70	44.11	54.10
1994	0.28	1.00	12.1	2.16	(20.32)	38.84	0.70	(0.06)	25.21
1995	0.85	0.38	33.9	2.16	(11.30)	59.06	0.70	0.22	28.83
1996	2.55	32.22	58.7	2.16	31.45	57.50	0.70	14.58	26.64
1997	1.12	15.27	68.9	2.16	(1.89)	95.04	0.70	12.54	46.90
1998	0.61	0.17	35.9	2.16	(17.44)	75.55	0.70	0.11	40.38
1999	3.50	54.24	108.3	2.16	46.01	92.59	0.70	18.21	37.30
2000	2.03	15.47	65.9	2.16	15.39	67.64	0.70	7.96	30.57
2001		*		2.16	46.95	96.51	0.70	18.16	36.78
2002	0.00	12.96	32.0	2.16	(21.31)	88.63	0.70	(4.31)	39.07
2003		*		2.16	92.90	67.03	0.70	34.54	28.79
2004	1.97	82.65	69.9	2.16	81.74	59.91	0.70	42.55	49.85
2005	1.44	10.76	39.9	2.16	7.85	47.66	0.70	7.72	22.88
2006		*		2.16	77.03	32.83	0.70	27.36	15.36
2007		*		2.16	64.61	97.70	0.70	23.33	34.94
2008	1.70	49.99	79.5	2.16	45.89	78.57	0.70	30.84	46.34
2009	1.18	17.84	75.9	2.16	7.49	95.61	0.70	15.35	53.94
2010	0.89	9.09	46.4	2.16	(23.11)	63.50	0.70	8.37	38.01
2011	2.37	59.50	82.3	2.16	59.04	81.06	0.70	28.74	38.53
2012	1.23	15.20	48.5	2.16	4.16	63.69	0.70	11.71	30.46
2013		*		2.16	271.99	80.98	0.70	93.18	33.50
23-year Average	**2.00**	**25.74**	**56.9**	**2.16**	**38.22**	**75.49**	**0.70**	**20.51**	**36.64**

* The regressions for 1992, 2001, 2003, 2006, 2007 and 2013 were not suitable to project the peak in returns to land, labor and management.

Literature Cited

Hart, R.H. 1972. Forage yield, stocking rate, and beef gains on pasture. Herbage Abstr. 42:345-353.

Hart, R.H. 1987. Economic analysis of stocking rates and grazing systems. p. 163-172. In: Proc. Beef Cow Symposium X. Coop. Ext. Serv. and Animal Sci. Dept., Univ. of Wyoming, South Dakota State Univ., Colorado State Univ., and Univ. of Nebraska.

Patton, B.D., P.E. Nyren, B.S. Kreft and A.C. Nyren. 2002. Grazing intensity research in the Missouri Coteau of North Dakota. North Dakota State University Central Grasslands Research Extension Center 2001 Grass and Beef Research Review, Streeter, N.D. North Dakota State University - Central Grasslands Research Extension Center. P. 12-16. Available online at: www.ag.ndsu.edu/archive/streeter/2001report/Grazing_intensity_Intro.htm#TableofContents

Thurow, T.L. 1991. Hydrology and Erosion. In: Heitschmidt, R.K. and Stuth, J.W. (eds.). *Grazing Management: An Ecological Perspective*. Portland, Ore.: Timber Press. 259 pp.

Acknowledgements

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Early Intensive Grazing Research in the Missouri Coteau Region of North Dakota: Year Three

Bob Patton, Bryan Neville and Anne Nyren
Central Grasslands Research Extension Center - NDSU, Streeter

*Early season intensive grazing is being tested as a means to control Kentucky bluegrass (*Poa pratensis* L.), an invasive grass species. After three years, initial results indicate that early grazing can reduce Kentucky bluegrass aerial cover and frequency. Removing cattle before the native grasses and forbs have received much grazing pressure should allow these species to increase in the community.*

Summary

Kentucky bluegrass is a perennial cool-season grass that begins growth in the spring earlier than our native species. Its forage quality is high in the spring but decreases through the season, resulting in reduced overall forage quality during the summer (Patton et al. 2001). By grazing heavily while Kentucky bluegrass is growing actively, we may be able shift the balance in the plant community to favor the native species.

Each of six pastures was assigned to one of two treatments: early intensive and season-long. On the early intensive treatment, the cattle are stocked as early as possible after Kentucky bluegrass greens up, ideally prior to the three-leaf stage, and removed when 30 percent of the native species have received some grazing. On the season-long treatment, the cattle are placed on pasture in mid-May and removed in mid-September.

Forage production was not significantly different between the early intensive and season-long grazing treatments in 2011, 2012 or 2013 ($P>0.05$). Kentucky bluegrass aerial cover ($P=0.001$) and frequency of occurrence ($P=0.003$) declined on the early intensive treatment during the period, while its aerial cover increased on the season-long treatment in 2012 and 2013.

Introduction

Kentucky bluegrass was introduced by early colonists along the East Coast and spread across America by settlers and natural dissemination (Carrier and Bort 1916). Kentucky bluegrass can be a problem throughout the tallgrass and mixed-grass prairies (Sather 1996).

A perennial cool-season grass, Kentucky bluegrass begins growth in the spring earlier than our native species and gains competitive advantage by using soil water and shading the later-emerging species.

Forage quality is high in the spring when green and actively growing, but decreases as the summer progresses, although it can green up again in the fall if adequate moisture is available (Patton et al. 2001, North Dakota Department Lands 2011). The dominance of Kentucky bluegrass in the plant community results in reduced forage quality of the pasture in the summer months.

The timing of grazing can have a great impact on plant species composition by reducing those species that are growing actively during the grazing period and releasing from competition those plants that are growing actively when grazing pressure is absent (Stephenson 2010).

In the Flint Hills of Kansas, researchers found that intensive early stocking reduced Kentucky bluegrass, compared with season-long stocking (Smith and Owensby 1978). We believe we can shift the balance to favor the native species with early, heavy grazing followed by summer rest.

Procedures

This study is being conducted at the Central Grasslands Research Extension Center in Kidder County northwest of Streeter, N.D. The pastures have been used for a variety of grazing experiments in the past but in recent years have received only light grazing in the summer months. In 2009 and 2010, these pastures were lightly stocked mid-May. Half of the animals were removed in late June or late July, and the rest remained until late September to mid-October.

Kentucky bluegrass has become dominant, with aerial cover averaging about 30 percent and frequency of occurrence (in 25- by 25-centimeter frames) averaging 90 percent in 2011 on the sites selected for vegetation monitoring.

Six pastures of about 40 acres each were assigned to one of two treatments: early intensive grazing and season-long grazing. Livestock were not rotated among pastures, and each pasture received the same treatment each year. On the early intensive treatment, 41 to 50 head of cattle were stocked in each pasture as early as possible after Kentucky bluegrass greens up (as early as mid-April) and removed when 30 percent of the native species receive some grazing (Table 1).

On the season-long treatment, 15 to 19 head were placed on each pasture in mid-May and removed between the end of August and mid-September, with the objective of grazing at a moderate stocking rate. The actual stocking rate was between 0.96 and 1.85 animal unit months (AUMs)/acre. The overall objective is to achieve a similar grazing pressure on the early intensive pastures as on the season-long pastures but in a shorter period of time (Table 1).

Changes in the plant community are monitored by sampling the frequency of occurrence, density per unit area and aerial cover of all the approximately 97 plant species, using nested frames along a transect, with 50 readings per pasture.

Fortunately, we began monitoring these same parameters on these sites in 2009 in connection with a previous experiment, although the stocking rates were much lower during these years. Still, this gave us two years of baseline data.

Forage production and utilization are determined using the cage comparison method, clipping three times per season. While clipping plots at peak production, an estimate is made of species percentage by weight. All samples are oven-dried and weighed.

Results

Total production and utilization. Forage production was not significantly different (P>0.05) between the early intensive and the season-long grazing treatments in 2011, 2012 or 2013 (Table 2). At the time the cattle were taken off the early intensive treatment, they had utilized 42 to 59 percent of the forage produced so far in the season, but only 20 to 33 percent of the forage produced during the entire growing season.

At the time the cattle were taken off the season-long treatment, they had utilized 45 to 63 percent of the forage produced during the growing season (Table 2). The differences in total utilization were significantly different between the early intensive and season-long treatments each year (P≤0.05).

Production by species and groups. Figure 1 shows total forage production on each treatment from 2011 to 2013 and the estimated production of selected species and species groups. The species shown produced at least 10 percent of the total biomass production on at least one treatment in one year.

Production of Kentucky bluegrass was not significantly different in any year, but the three-year average was greater on the season-long treatment: 2,998 vs. 2,343 pounds/acre on the early intensive treatment (P=0.017).

Shrub production declined between 2011 and 2012 and was significantly less on the early intensive treatment than on the season-long treatment in 2012

Table 1. Stocking history of the early intensive grazing trial for 2011 to 2013 at Central Grasslands Research Extension Center, Streeter, N.D.

Treatment	Year	Average Head/ pasture	Average Starting Weight (lbs)	Date On	Date Off	Days Grazed	Stocking Rate (AUM/ acre)
Early Intensive	2011	41.7	750	May 2	June 6	35	0.98
	2012	46.0	748	April 13	May 24	41	1.26
	2013	50.0	773	May 6	June 7	32	1.10
Season-long	2011	15.0	780	May 13	Sept. 15	125	1.30
	2012	18.3	865	May 9	Sept. 21	135	1.85
	2013	15.7	694	May 23	Aug. 28	97	0.96

Table 2. Total crop year precipitation (Oct. 1 to Sept. 30), peak total above ground biomass production, and percent of forage utilization on loamy overflow ecological sites on the early intensive and season-long grazing treatments from 2011 to 2013.

Year	Precipi-tation (inches)	Early Intensive			Season-long		Average Production (lbs/acre)
		Above ground biomass (lbs/ acre)	Utilization when removed (percent)	Utilization at end of season (percent)	Above ground biomass (lbs/acre)	Utilization at end of season (percent)	
2011	25.01	7847	59	20	6348	47	7098
2012	18.21	8387	49	31	6545	63	7466
2013	16.97	6314	42	33	5556	45	5935
3-year Avg.	**20.06**	**7516**	**50**	**28**	**6150**	**52**	**6833**

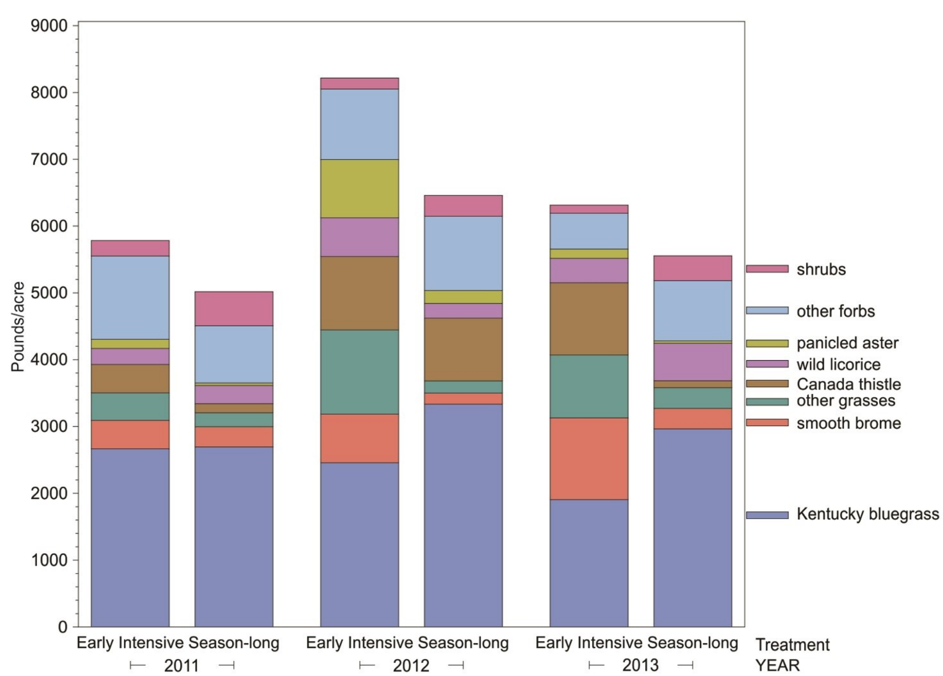


Figure 1. Total production and estimates of production of selected species and species groups on the early intensive and season-long grazing treatments from 2011 to 2013.

and 2013 ($P \leq 0.05$). Prairie rose (*Rosa arkansana* Porter) production was greater on the season-long than on the early intensive treatment in 2012: 35 vs. 9 pounds/acre (P=0.019). Buckbrush (*Symphori-carpos occidentalis* Hook.) production was greater on the season-long treatment than on early intensive treatment in 2013: 370 vs. 108 pounds/acre (P=0.022).

Green needlegrass (*Nassella viridula* [Trin.] Barkworth) was not found on the early intensive treatment in 2013, but 12 pounds/acre were produced on the season-long treatment (P=0.011).

Western ragweed (*Ambrosia psilo-stachya* DC.) originally was not different between treatments, but it has decreased on the early intensive treatment and now is most abundant on the season-long treatment with 85 pounds/acre as compared to 19 pounds/acre on the early intensive (P=0.001).

Although differences appear to occur in production of some of the other dominant species in Figure 1, they were not significantly different between treatments.

Frequency, density and aerial cover. Eight species showed responses to the grazing treatments with respect to frequency, density and aerial cover (Figures 2 through 10). Species of note: Kentucky bluegrass, for which aerial cover (P=0.001, Figure 2) and frequency (P=0.003, Figure 3) declined on the early intensive treatment and increased on the season-long treatment.

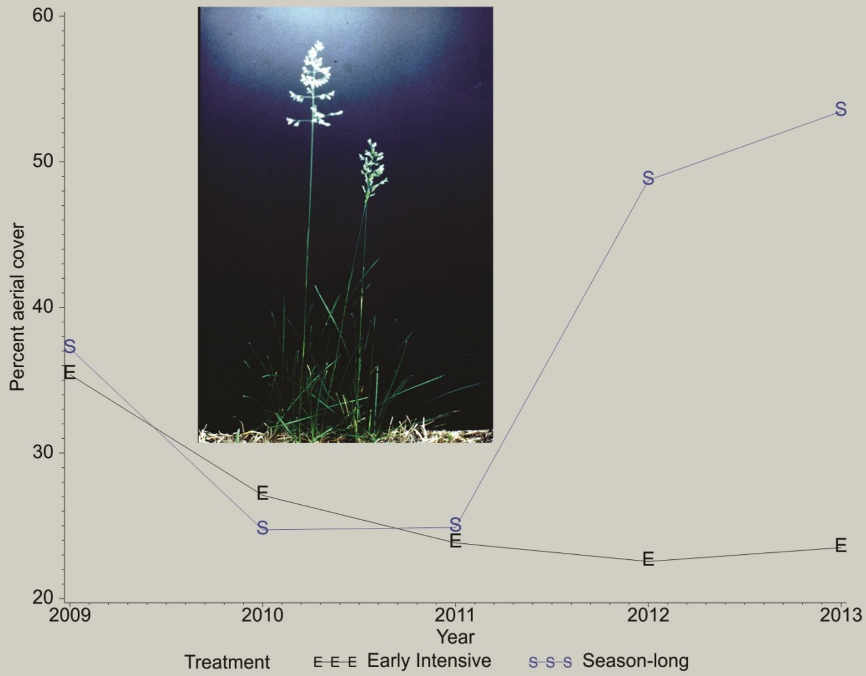


Figure 2. Aerial cover of Kentucky bluegrass (*Poa pratensis* L.) on the early intensive and season-long grazing treatments in 2009 to 2013.

Figure 3. Percent frequency of occurrence of Kentucky bluegrass (*Poa pratensis* L.) in 5 x 5 centimeter frames on the early intensive and season-long grazing treatments in 2009 to 2013.

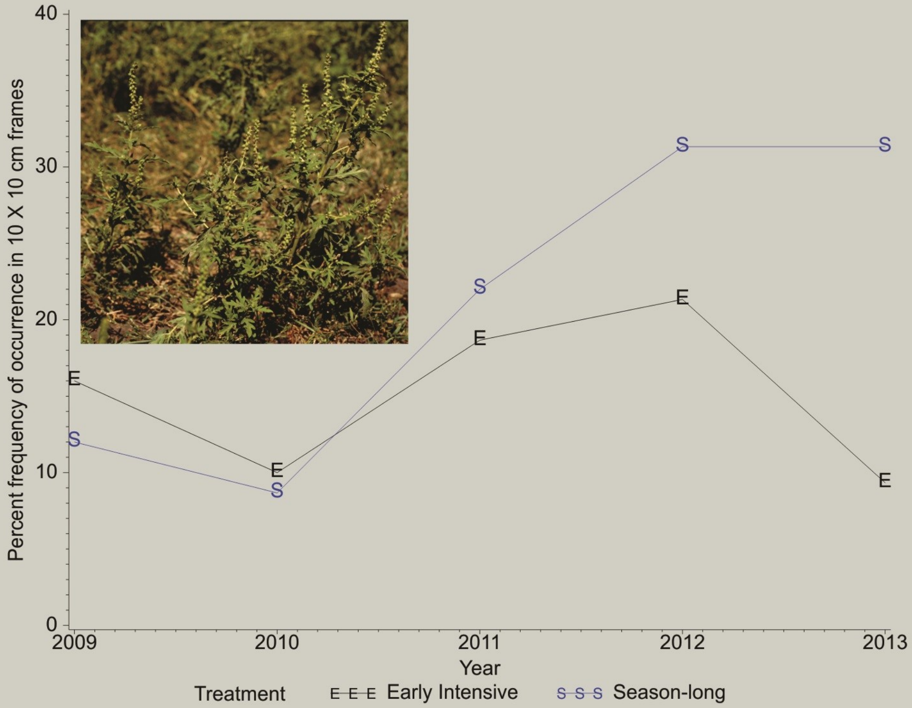


Figure 4. Percent frequency of occurrence of western ragweed (*Ambrosia psilostachya* DC.) in 10 x 10 centimeter frames on the early intensive and season-long grazing treatments in 2009 to 2013.

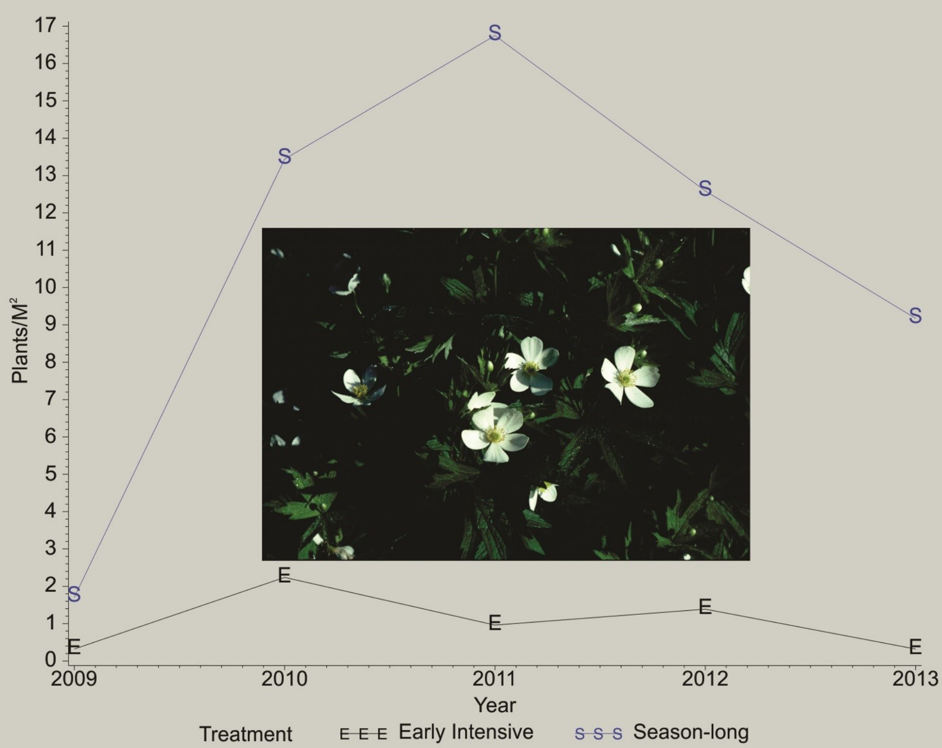


Figure 5. Density of meadow anemone (*Anemone canadensis* L.) on the early intensive and season-long grazing treatments in 2009 to 2013.

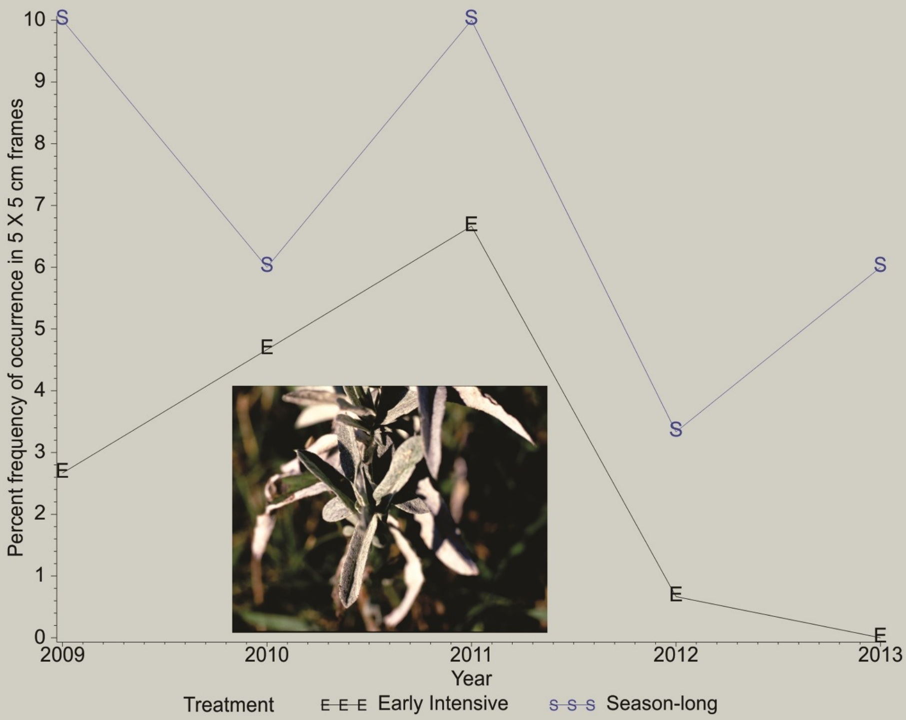


Figure 6. Percent frequency of occurrence of cudweed sagewort (*Artemisia ludoviciana* Nutt.) in 5 x 5 centimeter frames on the early intensive and season-long grazing treatments in 2009 to 2013.

Buckbrush frequency of occurrence decreased on the early intensive treatment from 2010 to 2012 ($P \leq 0.05$, Figure 7).

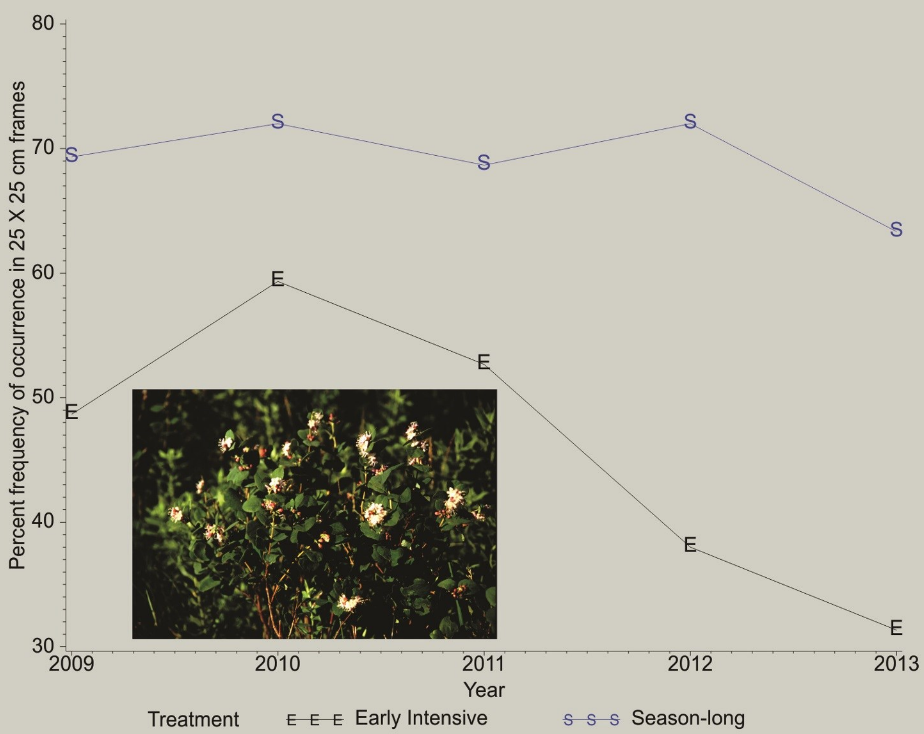


Figure 7. Percent frequency of occurrence of buckbrush (*Symphoricarpos occidentalis* Hook.) in 25 x 25 centimeter frames on the early intensive and season-long grazing treatments in 2009 to 2013.

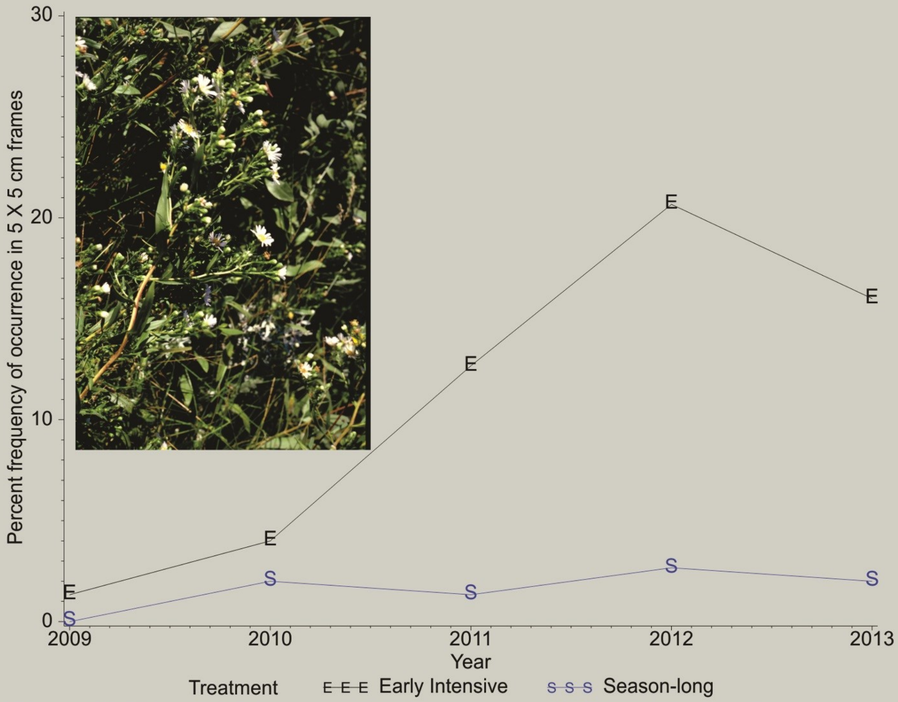


Figure 8. Percent frequency of occurrence of panicled aster (*Symphyotrichum lanceolatum* (Willd.) G.L. Nesom ssp. *lanceolatum* var. *lanceolatum*) in 5 x 5 centimeter frames on the early intensive and season-long grazing treatments in 2009 to 2013.

Smooth brome (*Bromus inermis* Leyss.) aerial cover increased on the early intensive treatment from 2011 to 2013 ($P \leq 0.05$, Figure 9).

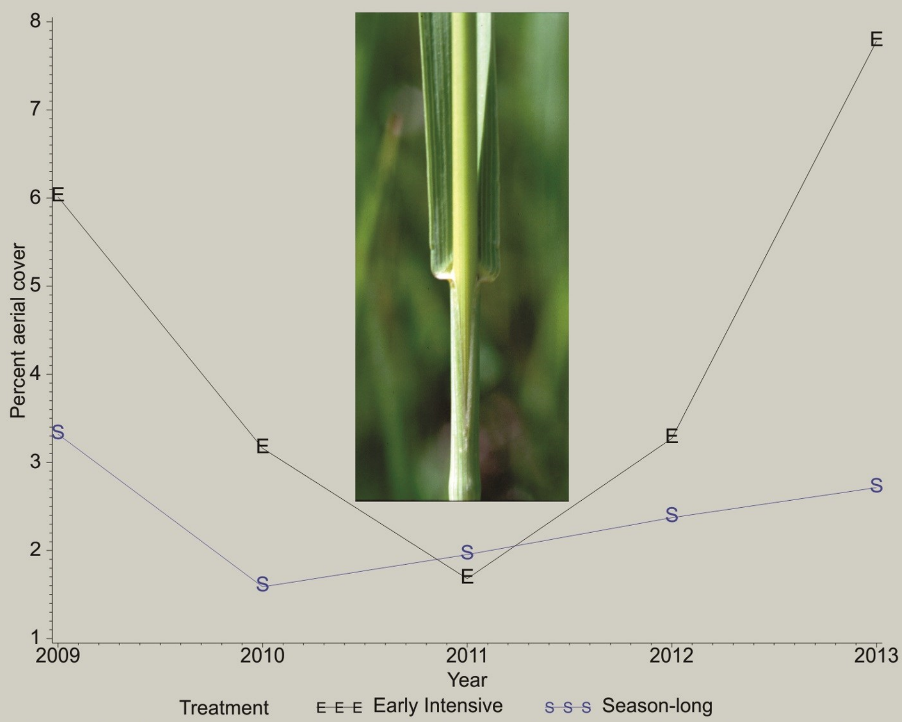


Figure 9. Aerial cover of smooth brome (*Bromus inermis* Leyss.) on the early intensive and season-long grazing treatments in 2009 to 2013.

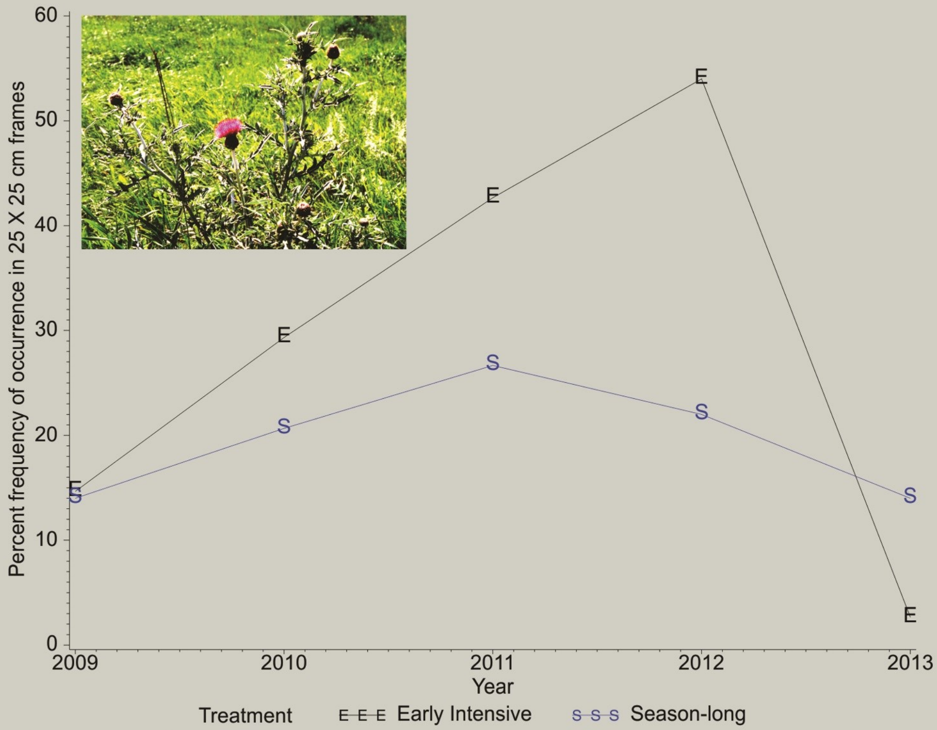


Figure 10. Percent frequency of occurrence of Flodman's thistle (*Cirsium flodmanii* (Rydb.) Arthur) in 25 x 25 centimeter frames on the early intensive and season-long grazing treatments in 2009 to 2013.

Litter decreased on the season-long treatment from 2009 to 2013. In contrast, on early intensive pastures, litter decreased from 2009 to 2010, then increased from 2010 to 2012 ($P \leq 0.001$, Figure 11).

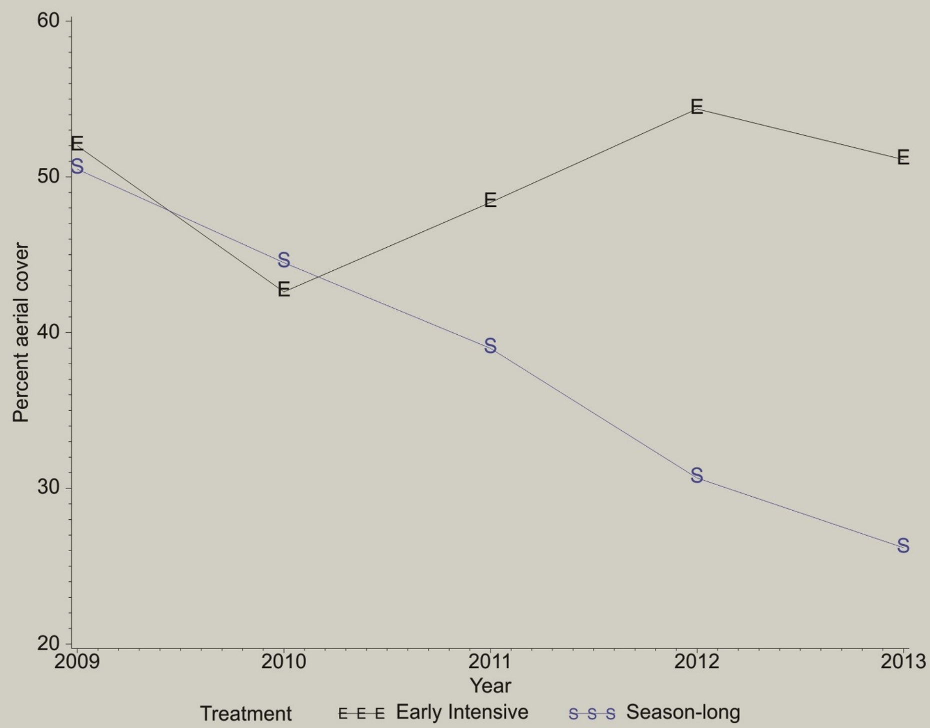


Figure 11. Percent aerial cover of litter on the early intensive and season-long grazing treatments in 2009 to 2013.

Discussion

Kentucky bluegrass begins growth early, and early grazing appears to reduce its abundance in the community and favor other grasses and forbs. However, five to 10 years of grazing treatments will be required to change the plant species composition fundamentally.

At this early stage in the project, Kentucky bluegrass still makes up a large part of the plant community, and if early grazing was to cease, Kentucky bluegrass would recover quickly.

Weather and the timing of precipitation can play as great as or greater role in determining plant species composition. The years 2011 and 2012 were wetter than average, and most of the precipitation in 2012 was in the early part of the growing season (see page 48). Although total precipitation was less than average in 2013, precipitation in May and September was well above average. This provided good growing conditions for Kentucky bluegrass, smooth brome and Canada thistle.

We will continue to monitor the impact of the early grazing treatment during the next several years.

Literature Cited

Carrier, L., and K.S. Bort. 1916. The history of Kentucky bluegrass and white clover in the United States. Agronomy Journal 8(4): 256-266.

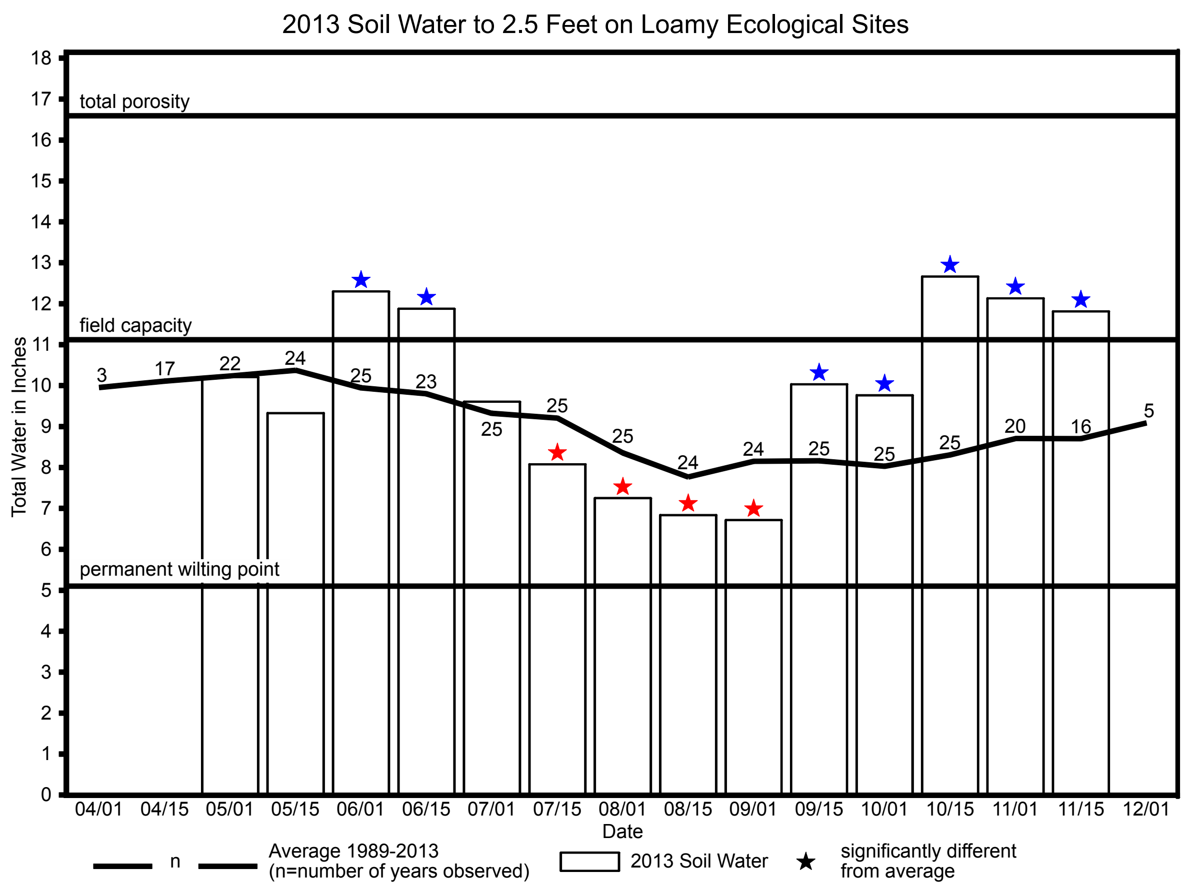
North Dakota Department of Lands. 2011. Kentucky bluegrass (*Poa pratensis*). The Land Line: Traditional Communication in a High-tech World. Vol. 29(4). http://land.nd.gov/Docs/Surface/2011SpringNewsletter.pdf

Patton, B.D., J.S. Caton and P.E. Nyren. 2001. Seasonal changes in forage quality. North Dakota State University - Central Grasslands Research Extension Center 2000 Grass and Beef Research Review, Streeter, N.D. North Dakota State University - Central Grasslands Research Extension Center. P. 6-7. www.ag.ndsu.edu/archive/streeter/2000report/seasonal_changes_in_forage_quality.htm

Sather, N. 1996. *Poa pratensis*. L. Connor and E. Carlson (Eds.). Center for Invasive Species and Ecosystem Health at the University of Georgia. http://wiki.bugwood.org/Poa_pratensis

Smith, E.F., and C.E. Owensby. 1978. Intensive early stocking and season-long stocking of Kansas Flint Hills range. J. of Range. Man. 31(1): 14-17.

Stephenson, M.B. 2010. Effect of Grazing System on Livestock Performance, Botanical Composition, and Standing Crop in the Nebraska Sandhills. M.S. Thesis. University of Nebraska, Lincoln. 113pp.



Total water in soil profile to the two and one half foot depth on loamy ecological sites at the Central Grasslands Research Extension Center in 2013.

Screening and Evaluation of Full-season Annual Forage Species in the Missouri Coteau Region of North Dakota

Guojie Wang, Matthew Danzl and Paul Nyren
Central Grasslands Research Extension Center - NDSU

Annual species can be used in forage production systems in the Missouri Coteau region. Annual forages add flexibility to row crop and livestock production. When a forage shortage or weather-limited row crop production occurs, annual crops can be harvested as high-quality forages by haying or grazing.

Annual forage species also can be used as cover crops to increase agricultural sustainability by improving soil fertility and quality; controlling soil water and wind erosion; suppressing weeds, pests and diseases; and increasing biodiversity and wildlife habitat.

In this study, annual legumes, warm-season grasses, cool-season grasses and brassicas were screened and evaluated in an extensively designed field trial. The information generated can be used for species selection for different management objectives.

Summary

Weed control is necessary for all annual forage species if weed pressure is high due to tillage and the weed seed bank. In this study, the species most competitive with common weeds (and without herbicide application) were forage pea, foxtail millet, oat and hybrid brassica from the legumes, warm-season grasses, cool-season grasses and brassicas, respectively. No-till with pre-planting glyphosate application, crop rotation and late seeding for annual warm-season grasses and legumes could be used to control the common weeds such as foxtails and pigweeds.

For full-season production, berseem clover, chickling vetch, peas and soybean are the promising annual legumes. Foxtail millet, sorghum and sorghum-sudan performed the best of the annual warm-season grasses. Barley, oat and triticale are the promising annual cool-season grasses, and among the brassicas, cabbage and radish produced well. The variability in all the species we screened and evaluated gives producers options for their management objectives.

Introduction

Interest in annual forage species has increased among agricultural producers in the Missouri Coteau region. Annual forage species can be used in row cropping systems to produce high-quality forages (McCartney et al., 2008; McCartney et al., 2009; McCartney and Fraser, 2010; Hansen et al., 2013). Due to their different phenology, annual forages can provide increased flexibility to agricultural production systems.

For example, in this region, a forage shortage is likely due to the conversion of grasslands to croplands, and annual forage species can be planted in the row cropping system to overcome this shortage. By doing so, switching back to row crop production is easy in a year-by-year manner.

Spring seeding in the last two years in the Missouri Coteau region was delayed due to the late spring and/or wet soils. A delayed seeding season could harm the cash crop production, and an alternative is to plant late-season annual forages.

Annual forage species include annual legumes (McCartney and Fraser, 2010) such as soybean (Sheaffer et al., 2001), peas and beans (Fraser et al., 2001); annual warm-season grasses (McCartney et al., 2009) such as sorghum (Jahanzad et al., 2013) and pearl millet (Rostamza et al., 2011); annual cool-season grasses (McCartney et al., 2008) such as barley (Nakano et al., 2013), oat (Coblentz et al., 2011) and triticale (Cazzato et al., 2011); annual brassicas (McCartney et al., 2009) such as rape (Keogh et al., 2011) and turnip (Neilsen et al., 2008). Different groups of annual forage species have different growth habits and agronomic requirements. Even within each group, wide variation occurs in species production and seasonality.

A monoculture or a mixture of annual forage species also can be used as cover crops (Hansen et al., 2013). Cover crops are known to provide agricultural sustainability by improving soil health, controlling erosion, suppressing weeds, pests and diseases; increasing biodiversity; and improving habitat for wildlife. However, information about annual forage species selection for a specific management objective is often anecdotal and incomplete. Therefore, we initiated this field trial to study annual forage species extensively. Weed suppression potential, weed control practices, species performance and species production seasonality were studied.

Procedures

The study was carried out at the Central Grasslands Research Extension Center from 2011 through 2013. Thirteen species/ cultivars of annual legumes, warm-season grasses and cool-season grasses, as well as nine species/cultivars of annual brassicas, were seeded in mid-May 2011 (Table 1). Each of these species/cultivars was drilled into field plots that were prepared by disking and harrowing. Each plot was 20 by 20 feet. For the 2011 seeding, neither fertilizer nor herbicides were applied to study the forage species' weed-suppression potential with low agronomic input.

In 2012, 13 species/cultivars (Table 1) were seeded in mid-May with four different herbicide application protocols. Each of these species/cultivars was no-till drilled into 20- by 5-foot plots. Herbicide application treatment A was a pre-plant glyphosate burn-down, treatment B was A plus a pre-germination glyphosate burn-down, Treatment C was A plus a post-emergence herbicide application, and treatment D was B plus a post-emergence herbicide application.

For annual legumes, Pursuit (imazethapyr) and Volunteer (clethodim) were used as post-emergence herbicides to control broadleaf and grass weeds, respectively. For annual warm-season and cool-season grasses, Detonate (diglycolamine salt of dicamba) was used as a post-emergence herbicide to control broadleaf weeds. Volunteer and Stinger (clopyralid) were used as post-emergence herbicides to control grass and broadleaf weeds for annual brassicas, respectively.

In 2013, 26 species/cultivars within all four groups were seeded. Annual cool-season grasses and annual brassicas were seeded in mid-May, while annual legumes and annual warm-season grasses were seeded in the early part of June. Each of these species/cultivars was no-till drilled into field plots. Each plot was 20 by 10 feet.

Pre-planting glyphosate was used to burn down all weeds two to three days before planting. Pre-emergence glyphosate also was used for some plots if weeds were apparent. Urea was applied at 56 pounds of nitrogen (N)/acre for all groups of species, and potash and superphosphate were applied at 20 pounds of potassium (K) and phosphorus (P)/acre for annual legumes.

Each plot was visually evaluated for seeded species establishment. The establishment scale was: failed (no seedlings of seeded species and covered by weeds), poor (sparse seedlings of seeded species and covered by weeds at least 50 percent), fair (regularly spaced seedlings of seeded species and covered by weeds at most 50 percent) and excellent (dense seedlings of seeded species and covered by weeds at most 25 percent). Each plot was harvested at the pod-filling stage for legumes, soft dough stage for grasses and purple-leaf stage for brassicas. Oven-dried subsamples were used to calculate forage production on a dry-matter basis.

Results

Seeded in 2011 with tillage and without any herbicide application, forage pea, foxtail millet, oat and hybrid brassica were the most successful species within their corresponding groups with respect to competition with common weeds (Tables 1 – 4). In 2012, four treatments of herbicide application were used with no-till seeding technology. The weed pressure was much less even with the pre-plant glyphosate application alone (Tables 1 – 4). In 2013, weed control was successful with no or minimal weed problems.

For full-season production, berseem clover (0.84 tons/acre), chickling vetch (0.41 tons/acre), peas (0.81 tons/acre) and soybean (0.42 tons/acre) were the most productive legumes (Table 5). The best warm-season grasses were foxtail millet (0.55 tons/acre), pearl millet (0.53 tons/acre), proso millet (0.75 tons/acre), sorghum (0.94 tons/acre), sudangrass (1.04 tons/acre) and sorghum-sudan (1.09 tons/acre) (Table 6). Barley (0.64 tons/acre), oat (0.42 tons/acre) and triticale (0.42 tons/acre) were the most productive cool-season grasses (Table 7). Cabbage (2.52 tons/acre), rape (2.14 tons/acre) and radish (3.27 tons/acre) were the most productive brassicas (Table 8).

Discussion

Weed control is necessary for all annual forage species if weed pressure is high due to tillage and the weed seed bank. Unfortunately, that was the case for our trial in 2011.

We disked and harrowed the plots before they were seeded. Tillage disturbs soil and favors weed germination. The weed seed banks in this area include foxtails, barnyard grass, wild barley, pigweeds, kochia and lamb's quarters. No-till with pre-planting glyphosate application helps suppress the common weeds in this region.

Furthermore, crop rotation (grass – broadleaf – grass rotation) can smother the broadleaf weeds in the grass plots, as well as the grass weeds in the broadleaf plots, with post-emergence herbicide application to control them.

Late seeding for annual warm-season grasses and legumes not only fits their warmer seedbed requirement (as compared with the cool-season grasses and brassicas) but also is beneficial for controlling the common weeds such as foxtails and pigweeds. These weeds germinate later and can be sprayed with glyphosate pre-planting. For the early seeded species, their competitive potential in the early season gives them a chance to suppress the common weeds.

We had a dry summer in 2013 (see page 48), and all the yields were low and the cool-season grasses were short. In comparison, because annual warm-season grasses are more drought-tolerant than cool-season grasses, they were a little more productive than the cool-season grasses. Surprisingly, annual brassicas were short and water-stressed in the early season. However, with rainfall in late August and early September, their regrowth was apparent and promising.

No simple recommendation is available for species selection. It depends on the management objectives and weather patterns. What we can do is study the diverse species pools to present different options in different situations.

References

Cazzato, E., V. Laudadio and V. Tufarelli. 2011. Effects of harvest period, nitrogen fertilization and mycorrhizal fungus inoculation on triticale (x Triticosecale Wittmack) forage yield and quality. Renewable Agriculture and Food Systems 27:278-286.

Coblentz, W.K., M.G. Bertram and N.P. Martin. 2011. Planting date effects on fall forage production of oat cultivars in Wisconsin. Agronomy Journal 103:145-155.

Fraser, M.D., R. Fychan and R. Jones. 2001. The effect of harvest date and inoculation on the yield, fermentation characteristics and feeding value of forage pea and field bean silages. Grass and Forage Science 56:218-230.

Hansen, M.J., V.N. Owens, D. Beck and P. Sexton. 2013. Suitability of cover crop monocultures for late-season forage in South Dakota. Canadian Journal of Plant Science 93:589-597.

Jahanzad, E., M. Jorat, H. Moghadam, A. Sadeghpour, M.R. Chaichi and M. Dashtaki. 2013. Response of a new and a commonly grown sorghum cultivar to limited irrigation and planting density. Agricultural Water Management 117:62-69.

Keogh, B., T. McGrath and J. Grant. 2011. The effect of sowing date and nitrogen on the dry-matter yield and nitrogen content of forage rape (Brassica napus L.) and stubble turnips (Brassica rapa L.) in Ireland. Grass and Forage Science 67:2-12.

McCartney, D., and J. Fraser. 2010. The potential role of annual forage legumes in Canada: a review. Canadian Journal of Plant Science 90:403-420.

McCartney, D., J. Fraser and A. Ohama. 2008. Annual cool-season crops for grazing by beef cattle: a Canadian review. Canadian Journal of Animal Science 88:517-533.

McCartney, D., J. Fraser and A. Ohama. 2009. Potential of warm-season annual forages and Brassica crops for grazing: a Canadian review. Canadian Journal of Animal Science 89:431-440.

Nakano, H., N. Kawada, I. Hattori, S. Morita and H. Araki. 2013. Yield and nutritive value responses of forage barley cultivars and lines. Agronomy Journal 105:1087-1093.

Neilsen, J.E., B.A. Rowe and P.A. Lane. 2008. Vegetative growth and development of irrigated forage turnip (Brassica rapa var. rapa). Grass and Forage Science 63:438-446.

Rostamza, M., M.R. Chaichi, M.R. Jahansooz, H.R. Mashhadi and H.R. Sharifi. 2011. Effects of water stress and nitrogen fertilizer on multi-cut forage pearl millet yield, nitrogen, and water use efficiency. Communications in Soil Science and Plant Analysis 42:2427-2440.

Sheaffer, C.C., J.H. Orf, T.E. Devine and J.G. Jewett. 2001. Yield and quality of forage soybean. Agronomy Journal 93:99-106.

Table 1. Full-season annual legume species/varieties screened and evaluated at the CGREC in 2011—2013.

Common name	Latin Name	Seeding Year[1]	Variety[2]	Seeding Rate[3]	Establishment[4]
Arrowleaf clover	*Trifolium vesiculosum* Savi	2012	Yuchi	21.81	NA
		2013	Yuchi	21.81	Excellent
Berseem clover	*Trifolium alexandrinum* L.	2011	VNS	17.01	Fair
		2012	VNS	21.81	NA
		2013	VNS	30.53	Excellent
Chickling vetch	*Lathyrus sativus* L.	2011	AC Greenfix	69.78	Fair
		2012	AC Greenfix	65.42	NA
		2013	AC Greenfix	87.22	Excellent
Common vetch	*Vicia sativa* L.	2012	VNS	39.25	NA
		2013	VNS	61.06	Fair
Cowpea	*Vigna unguiculata* (L.) Walp.	2011	Chinese Red	52.33	Poor
		2012	Iron & Clay	56.70	NA
		2013	Chinese Red	61.06	Fair
		2013	Iron & Clay	61.06	Fair
Crimson clover	*Trifolium incarnatum* L.	2011	VNS	19.97	Fair
		2012	VNS	30.53	NA
		2013	VNS	39.25	Excellent
Fava bean	*Vicia faba* L.	2011	VNS	162.24	Poor
Hairy vetch	*Vicia villosa* Roth	2011	Purple Bounty	32.32	Fair
		2012	Purple Bounty	39.25	NA
		2013	Purple Bounty	61.06	Excellent
Joint vetch	*Aeschynomene americana* L.	2013	VNS	69.78	Failed
Lablab bean	*Lablab purpureus* (L.) Sweet	2013	Rongiu	87.22	Fair
Lentil	*Lens culinaris* Medikus	2011	Indianhead	38.72	Fair
		2013	Indianhead	43.61	Excellent
Mung bean	*Vigna radiate* (L.) R. Wilczek	2011	VNS	48.50	Poor
Pea	*Pisum sativum* L.	2011	4010	82.47	Excellent
		2011	Austrian winter	58.92	Excellent
		2012	4010	91.59	NA
		2012	Austrian winter	91.59	NA
		2012	Midas	130.84	NA
		2013	4010	161.37	Excellent
		2013	Austrian winter	161.37	Excellent
		2013	Cruiser	161.37	Excellent
		2013	DS-Admiral	161.37	Excellent
		2013	Flex	161.37	Excellent
		2013	Majoret	161.37	Excellent
		2013	Mystique	161.37	Excellent
		2013	Perfection 326	161.37	Excellent
		2013	Vegas	161.37	Excellent
		2013	Viper	161.37	Excellent
Persian clover	*Trifolium resupinatum* L.	2011	Mihi	6.98	Fair
		2012	Mihi	21.81	NA
		2013	Mihi	13.08	Excellent
Soybean	*Glycine max* (L.) Merr.	2011	Derry	52.33	Fair
		2012	Eagle-RR	91.59	NA
		2013	Derry	87.22	Failed
		2013	Eagle-RR	87.22	Fair
Subterranean clover	*Trifolium subterraneum* L.	2013	VNS	21.81	Excellent
Sunn hemp	*Crotalaria juncea* L.	2011	VNS	45.36	Poor
		2012	VNS	47.97	NA
		2013	VNS	52.33	Poor

[1] Thirteen full-season annual forage legume species/varieties were seeded in 2011 and 2012, and 26 were seeded in 2013. The study plots were accidentally sprayed in 2012 with Milstone and none of the legume species germinated.
[2] VNS: variety not stated.
[3] Pounds pure live seed per acre.
[4] Establishment level was evaluated visually one year after seeding in the early spring on a scale of 0 – 3: 0 – failed (no seedlings found); 1 – poor (sparse seedlings found); 2 – fair (regularly spaced seedlings found); 3 – excellent (dense seedlings found and few or no weeds found).
NA: not available.

Table 2. Full-season annual warm-season grass species/varieties screened and evaluated at the CGREC in 2011 – 2013.

Common Name	Latin Name	Seeding Year[1]	Variety[2]	Seeding Rate[3]	Establishment[4]
Foxtail millet	*Setaria italica* (L.) P. Beasuv.	2011	Golden German	21.46	Excellent
		2012	Golden German	21.81	Excellent
		2013	Golden German	26.17	Excellent
Japanese millet	*Echinochloa esculenta* (A. Braun) H. Scholz	2011	VNS	28.52	Fair
		2012	VNS	21.81	Excellent
		2013	VNS	26.17	Excellent
Pearl millet	*Pennisetum glaucum* (L.) R. Br.	2011	PP102M	22.24	Fair
		2012	MS2500	21.81	Excellent
		2013	Gem-X	26.17	Excellent
		2013	MS2500	26.17	Excellent
Siberian millet	*Echinochloa frumentacea*	2011	Manta	20.93	Fair
		2012	Manta	21.81	Excellent
		2013	Manta	26.17	Excellent
Sorghum	*Sorghum bicolor* (L.) Moench	2012	Gene12	30.53	Excellent
		2012	MS7000	30.53	Excellent
		2013	Gene12 BMR	43.61	Excellent
		2013	LFS601	43.61	Excellent
		2013	LFS901 BMR	43.61	Excellent
		2013	MS7000	43.61	Excellent
		2013	Rox Orange Cane	43.61	Excellent
		2013	Sweetie	43.61	Excellent
		2013	Sweetie BMR	43.61	Excellent
		2013	WGF Grain	43.61	Excellent
Sudangrass	*Sorghum sudanense* (Piper) Stapf	2011	Piper	26.35	Fair
		2011	Pro-Max BMR	26.35	Fair
		2012	Hayking	30.53	Excellent
		2012	Piper	30.53	Excellent
		2013	Hayking	34.89	Excellent
		2013	Higest	34.89	Excellent
		2013	Piper	34.89	Excellent
Sorghum-Sudan	*Sorghum bicolor × S. sudanese*	2011	22053 BMR	24.42	Fair
		2011	Black Hawk BMR	24.42	Fair
		2011	Special Effort	24.42	Fair
		2011	Sweet Thing	24.42	Fair
		2011	Sweet Thing BMR	24.42	Fair
		2012	Cow Conditioner	39.25	Excellent
		2012	Sweet Thing	39.25	Excellent
		2012	Sweet Thing BMR	39.25	Excellent
		2013	Cow Conditioner	43.61	Excellent
		2013	Graze X2	43.61	Excellent
		2013	GW300 BMR	43.61	Excellent
		2013	MS9000	43.61	Excellent
		2013	Super Honey	43.61	Excellent
		2013	Sweet Thing	43.61	Excellent
		2013	Sweet Thing BMR	43.61	Excellent
Teff	*Eragrostis tef* (Zuccagni) Trotter	2011	Tiffany	11.95	Fair
		2012	Tiffany	10.47	Excellent
		2013	Tiffany	13.08	Excellent
		2011	Red	27.74	Fair
		2012	White	30.53	Excellent
		2013	Red	34.89	Excellent
		2013	White	34.89	Excellent

[1] Thirteen full-season annual forage warm-season grass species/varieties were seeded in 2011 and 2012, and 26 were seeded in 2013.
[2]VNS: variety not stated. [3] Pounds pure live seed per acre.
[4] Establishment level was evaluated visually one year after seeding in the early spring on a scale of 0 – 3: 0 – failed (no seedlings found); 1 – poor (sparse seedlings found); 2 – fair (regularly spaced seedlings found); 3 – excellent (dense seedlings found and few or no weeds found).

Table 3. Full-season annual cool-season grass species/varieties screened and evaluated at the CGREC in 2011 – 2013.

Common name	Latin Name	Seeding Year[1]	Variety[2]	Seeding Rate[3]	Establishment[4]
Barley	*Hordeum vulgare* L.	2011	Haybet	88.90	Fair
		2011	Hayes	88.90	Fair
		2011	Lavina	88.90	Fair
		2012	Haybet	91.59	Excellent
		2012	Stockford Hay	91.59	Excellent
		2013	Haybet	126.48	Fair
		2013	Robust	126.48	Fair
		2013	Stockford Hay	126.48	Fair
Black oat	*Avena strigosa* Schreb.	2011	Soil Saver	45.10	Excellent
Italian ryegrass	*Lolium multiflorum* Lam.	2011	VNS	18.14	Fair
		2012	Feast II	21.81	Excellent
		2012	Gulf	21.81	Excellent
		2012	Tetilia	21.81	Excellent
		2012	Tetraploid	21.81	Excellent
		2013	Crusader	26.17	Excellent
		2013	Feast II	26.17	Excellent
		2013	Green Spirit	26.17	Excellent
		2013	Gulf	26.17	Excellent
		2013	Tetilia	26.17	Excellent
		2013	Tetraploid	26.17	Excellent
Naked oat	*Avena nuda* L.	2011	Paul	95.60	Excellent
		2013	Streaker	87.22	Fair
Oat	*Avena sativa* L.	2011	Everleaf126	75.80	Excellent
		2011	Hifi	75.80	Excellent
		2011	Kona	75.80	Excellent
		2012	Everleaf126	109.03	Excellent
		2012	Morgan	109.03	Excellent
		2012	Shelby 427 SD	109.03	Excellent
		2013	Athacasca	126.48	Fair
		2013	Colt	126.48	Fair
		2013	Everleaf126	126.48	Fair
		2013	Jim	126.48	Fair
		2013	Kona	126.48	Fair
		2013	Monida	126.48	Fair
		2013	Morgan	126.48	Fair
		2013	Rockford	126.48	Fair
		2013	Shelby 427 SD	126.48	Fair
		2013	Souris	126.48	Fair
Regreen	*Triticum aestivum* × *Elytrigia elogata*	2012	VNS	109.03	Excellent
		2013	VNS	43.61	Fair
Rye	*Secale cereale* L.	2011	Rymin	109.03	Fair
		2013	Rymin	126.48	Fair
Triticale	*Triticum aestivum* × *Secale cereale*	2011	Trical 141	112.47	Fair
		2011	Trical Mertin	112.47	Fair
		2012	Pronghorn	109.03	Excellent
		2012	Trical 141	109.03	Excellent
		2013	Pronghorn	126.48	Fair
		2013	Trical 141	126.48	Fair
		2013	Tyndal	126.48	Fair
Wheat	*Triticum aestivum* L.	2011	Hard Red Winter	109.03	Fair
		2012	Hard Red Spring	109.03	Excellent
		2013	Hard Red Spring	126.48	Fair

[1] Thirteen full-season annual forage cool-season grass species/varieties were seeded in 2011 and 2012, and 26 were seeded in 2013.
[2]VNS: variety not stated. [3] Pounds pure live seed per acre.
[4] Establishment level was evaluated visually one year after seeding in the early spring on a scale of 0 – 3: 0 – failed (no seedlings found); 1 – poor (sparse seedlings found); 2 – fair (regularly spaced seedlings found); 3 – excellent (dense seedlings found and few or no weeds found).

Table 4. Full-season annual brassica species/varieties screened and evaluated at the CGREC in 2011 – 2013.

Common Name	Latin Name	Seeding Year[1]	Variety[2]	Seeding Rate[3]	Establishment[4]
Cabbage	*Brassica oleracea* L.	2011	Ethiopian	3.66	Excellent
		2012	Ethiopian	6.98	Excellent
		2013	Ethiopian	8.72	Excellent
Canola	*Brassica napus* L.	2011	Sumner Winter	6.37	Fair
		2012	Sumner Winter	6.11	Excellent
		2013	Kronos	8.72	Excellent
Hybrid brassica	*Raphanus sativus* L.	2011	Hunter	3.66	Excellent
		2011	Winfred	3.66	Excellent
		2012	Hunter	6.98	Excellent
		2012	Pasja	6.98	Excellent
		2012	Vivant	6.98	Excellent
		2013	Hunter	8.72	Excellent
		2013	Pacer	8.72	Excellent
		2013	Pasja	8.72	Excellent
		2013	Vivant	8.72	Excellent
		2013	Winfred	8.72	Excellent
Kale	*Brassica oleracea* L.	2013	Dwarf Siberian	8.72	Excellent
		2013	Kestrel	8.72	Excellent
		2013	Siberian	8.72	Excellent
Mustard	*Brassica juncea* L.	2012	AC Pennant	6.11	Excellent
		2013	AC Pennant	11.34	Excellent
Radish	*Raphanus sativus* L.	2011	Graza	10.90	Fair
		2012	Bio Till	11.34	Excellent
		2012	Daikon	11.34	Excellent
		2012	Graza	11.34	Excellent
		2012	Soil Buster	11.34	Excellent
		2013	Bio Till	13.08	Excellent
		2013	Daikon	13.08	Excellent
		2013	Graza	13.08	Excellent
		2013	Ground Hog	13.08	Excellent
		2013	Jack Hammer	13.08	Excellent
		2013	Soil Buster	13.08	Excellent
Rape	*Brassica napus* L.	2011	Dwarf Essex	6.37	Fair
		2012	Dwarf Essex	6.98	Excellent
		2013	Athena	8.72	Excellent
		2013	Barnapoli	8.72	Excellent
		2013	Barsica	8.72	Excellent
		2013	Dwarf Essex	8.72	Excellent
Sugar beet	*Beta vulgaris* L.	2011	VNS	3.66	Poor
Swede	*Brassica napus* L.	2013	Major Plus	8.72	Excellent
Turnip	*Brassica rapa* var. *rapa* L.	2011	New York	6.37	Fair
		2011	Purple Top	6.37	Fair
		2012	New York	6.11	Excellent
		2012	Purple Top	6.11	Excellent
		2013	Appin	8.72	Excellent
		2013	Barkant	8.72	Excellent
		2013	New York	8.72	Excellent
		2013	Purple Top	8.72	Excellent

[1]Nine full-season annual forage brassica species/varieties were seeded in 2011, 13 were seeded in 2012, and 26 in 2013.
[2] VNS: variety not stated. [3] Pounds pure live seed per acre.
[4]Establishment level was evaluated visually one year after seeding in the early spring on a scale of 0 – 3: 0 – failed (no seedlings found); 1 – poor (sparse seedlings found); 2 – fair (regularly spaced seedlings found); 3 – excellent (dense seedlings found and few or no weeds found).

Table 5. Forage yield (tons/acre) of full-season annual legume species/varieties at the CGREC seeded in 2011 and 2013.

Species	Variety	Year	
		2011	2013
Arrowleaf clover	Yuchi		0.21g[1]
Berseem clover	VNS	2.63	0.84a-d
Chickling vetch	AC Greenfix	2.57	0.41d-g
Common vetch	VNS		0.27g
Cowpea	Chinese Red	2.23	0.61b-g
	Iron & Clay		0.40e-g
Crimson clover	VNS	2.75	0.25g
Fava bean	VNS	2.99	
Hairy vetch	Purple Bounty	2.61	0.20g
Joint vetch	VNS		0.35fg
Lablab	Rongiu		0.45c-g
Lentil	Indianhead	1.38	0.48c-g
Mung bean	VNS	2.30	
Pea	4010	2.33	1.09a
	Austrian Winter	2.57	0.93ab
	Cruiser		0.57b-g
	DS-Admiral		0.61b-g
	Flex		0.84a-e
	Majoret		0.85a-d
	Mystique		0.87a-c
	Perfection326		0.53b-g
	Vegas		0.81ae
	Viper		0.96ab
Persian clover	Mihi	2.77	0.32fg
Soybean	Derry	2.14	0.42d-g
	Eagle-RR		0.34fg
Subterranean clover	VNS		0.46c-g
Sunn hemp	VNS	2.42	0.75a-f

[1] Forage yields within a column followed by same letter are not statistically different at $p \leq 0.05$.

Table 6. Forage yield (tons/acre) of full-season annual warm-season grass species/varieties at the CGREC in 2011 – 2013.

Species	Variety	Year 2011	2012 Herbicide Treatment[1] A	2012 B	2012 C	2012 D	2013
Foxtail millet	Golden German	2.39	3.05	3.78	3.14	2.47	0.55hi[2]
Japanese millet	VNS	2.65	2.48	2.55	2.69	2.06	0.39i
Pearl millet	Gem-X						0.58g-i
	MS2500		2.78	2.68	2.33	2.72	0.48hi
	PP102M	2.75					
Red proso	VNS	2.82					0.75e-h
Siberian millet	Manta	2.76	3.19	3.37	3.40	3.05	0.67f-i
Sorghum	Gene12		3.34	3.54	3.60	4.12	
	Gene12 BMR						1.16ab
	LFS601						0.88c-e
	LFS901 BMR						0.83d-g
	MS7000		3.02	2.89	3.90	2.69	0.95b-e
	Rox Orange Cane						0.87c-f
	Sweetie						1.10a-d
	Sweetie BMR						1.11a-d
	WGF Grain						0.65f-i
Sudangrass	Hayking		3.92	3.21	3.51	3.23	1.10a-d
	Higest						0.96b-e
	Piper	3.20	3.18	3.09	3.30	2.88	1.07a-d
	Pro-Max BMR	3.06					
Sorghum-Sudan	22053 BMR	2.92					
	Black Hawk BMR	3.56					
	Cow Conditioner		3.55	3.26	3.25	2.63	1.03a-d
	Graze X2						1.13a-c
	GW300 BMR						0.98a-e
	MS9000						1.16ab
	Special Effort	3.17					
	Super Honey						1.06a-d
	Sweet Thing	3.43	5.17	3.98	4.13	3.91	1.24a
	Sweet Thing BMR	3.31	3.28	3.52	3.63	3.11	1.05a-d
Teff	Tiffany	2.86	3.30	2.83	3.20	2.57	0.44i
White proso	VNS		3.25	2.82	3.21	3.16	0.75e-h

[1] A: Pre-seeding glyphosate application
B: A + Pre-emergence glyphosate application
C: A + post-emergence Detonate application
D: B + post-emergence Detonate application.
[2] Forage yields within a column followed by same letter are not statistically different at $p \leq 0.05$.

Table 7. Forage yield (tons/acre) of full-season annual cool-season grass species/varieties at the CGREC in 2011 – 2013.

Species	Variety	Year					
		2011	2012				2013
			Herbicide Treatment[1]				
			A	B	C	D	
Barley	Haybet	2.68b-d[2]	2.45b-d	2.61ab	2.30b-d	2.15a-d	0.66ab
	Hayes	3.07a-c					
	Lavina	2.48b-d					
	Robust						0.56a-c
	Stockford Hay		3.05ab	3.01a	2.70ab	2.69a	0.70a
Black oat	Soil Saver	2.80bc					
Italian ryegrass	Crusader						
	Feast II						0.13fg
	Green Spirit		1.84c-e	1.39e	1.86d-f	1.60cd	0.14e-g
	Gulf						0.14e-g
	Tetilia		1.89c-e	2.11b-d	1.95d-f	1.91b-d	0.17d-g
	Tetraploid		1.91c-e	1.80c-e	1.76d-f	1.90b-d	0.13fg
	VNS		1.65de	1.81c-e	1.50f	1.79b-d	0.16d-g
Naked oat	Paul	2.93a-c					
	Streaker						0.48a-d
Oat	Athacasca						0.42a-g
	Colt						0.19d-g
	Everleaf126	3.67a	3.08ab	2.71ab	2.76ab	2.73a	0.37b-g
	Hifi	2.57b-d					
	Jim						0.24c-g
	Kona	3.19ab					0.67ab
	Morgan		2.63a-c	2.75a	2.73ab	2.36ab	0.28c-g
	Monida						0.66ab
	Rockford						0.43a-f
	Shelby427 SD		1.97c-e	2.18b-d	2.12c-e	2.27a-c	0.38a-g
	Souris						0.47a-e
Regreen	VNS		1.56e	1.73de	1.66ef	1.46d	0.17d-g
Rye	Rymin	1.69ef					0.11g
Triticale	Pronghorn		3.08ab	2.45a-c	2.64a-c	2.84a	0.40a-g
	Trical141	2.35c-e	3.28a	2.89a	2.90a	2.51ab	0.37b-g
	Trical Mertin	2.53b-d					
	Tyndal		3.08ab	2.45a-c	2.64a-c	2.84a	0.44a-f
Wheat	Hard Red Spring		2.92ab	2.56ab	2.91a	2.22a-d	0.53a-c
	Hard Red Winter	1.46f					

[1] A: Pre-seeding glyphosate application;
B: A + Pre-emergence glyphosate application;
C: A + post-emergence Detonate application;
D: B + post-emergence Detonate application.

[2] Forage yields within column followed by same letter are not statistically different at $p \leq 0.05$.

Table 8. Forage yield (tons/acre) of full-season annual brassica species/varieties at the CGREC in 2011 – 2013.

Species	Variety	Year							
		2011	2012				2013		
			Herbicide Treatment[1]				First and Second Harvests		
			A	B	C	D	August	October	Total
Cabbage	Ethiopian	3.50a[2]	1.88a	1.88ab	1.29a-c	1.48ab	0.34c-g	2.19bc	2.52bc
Canola	Kronos						0.19e-i	1.34d-h	1.54f-j
	Sumner Winter	2.69ab	1.34b-e	1.17d-f	0.79d	0.77e			
Hybrid	Hunter	2.54a-c	1.24c-e	1.26c-f	0.71d	1.01b-e	0.25d-i	1.29d-h	1.54f-j
brassica	Pacer						0.10g-i	1.39d-g	1.50f-j
	Pasja		1.60a-d	1.29c-e	0.84cd	0.99c-e	0.16f-i	1.22e-i	1.38g-j
	Vivant		1.42a-e	1.14ef	1.00a-d	0.78de	0.28d-i	1.23e-i	1.51f-j
	Winfred	2.21b-d					0.36c-g	1.47d-f	1.83d-i
Kale	Dwarf Siberian						0.34c-g	1.62c-e	1.97c-g
	Kestrel						0.40b-f	1.49d-f	1.90c-h
	Siberian						0.46a-d	1.40d-g	1.86c-i
Mustard	AC Pennant		1.67a-c	2.01a	1.46a	1.26b-d	0.32c-h	0.86g-i	1.18ij
Radish	Bio Till		1.41a-e	1.36c-e	1.37ab	1.46a-c	0.57a-c	2.81a	3.38a
	Daikon		1.73ab	1.55bc	1.43ab	1.18b-e	0.68a	2.48ab	3.16ab
	Graza	2.45a-c	1.23c-e	1.17d-f	0.69d	0.75e	0.04i	1.71c-e	1.75e-i
	Ground Hog						0.42a-f	2.08bc	2.50b-d
	Jack Hammer						0.30d-i	1.87cd	2.17c-f
	Soil Buster		1.79a	2.11a	1.46a	1.84a	0.67ab	1.67ce	2.34c-e
Rape	Athena						0.32c-h	1.41d-g	1.73e-i
	Barnapoli						0.45a-e	1.69c-e	2.15c-f
	Barsica						0.45a-e	1.67c-e	2.12c-f
	Dwarf Essex	2.27b-d	1.51a-e	1.49b-d	0.95b-d	0.91de	0.34c-g	1.33d-h	1.67e-i
Sugar beet	VNS	3.33ab							
Swede	Major Plus						0.22d-i	1.01f-i	1.23h-j
Turnip	Appin						0.21d-i	0.97f-i	1.19ij
	Barkant						0.26d-i	1.45d-g	1.71e-i
	New York	1.13d	1.05e	1.10ef	0.80d	0.69e	0.17f-i	0.69i	0.86j
	Purple Top	1.43cd	1.12de	0.96f	0.71d	0.86de	0.06hi	0.81hi	0.87j

[1] A: Pre-seeding glyphosate application
B: A + Pre-emergence glyphosate application
C: A + post-emergence Volunteer and Stinger application
D: B + post-emergence Volunteer and Stinger application.
[2] Forage yields within a column followed by same letter are not statistically different at $p \leq 0.05$.

Establishment, Persistence and Production of Perennial Cool-season Grasses in the Missouri Coteau Region of North Dakota

Guojie Wang, Matthew Danzl and Paul Nyren
Central Grasslands Research Extension Center - NDSU

Smooth brome (Bromus inermus Leyss.) is the dominant species in most hayland in the Missouri Coteau region. This perennial cool-season grass is productive early in the growing season; however, due to its low drought tolerance, its production decreases through the summer.

Furthermore, the forage quality of smooth brome is lower than other perennial cool-season grasses, especially when smooth brome is harvested after the late-anthesis stage. Other perennial cool-season grasses may be preferable for livestock producers. Therefore, to evaluate perennial cool-season grasses for diverse management goals, field plots of 17 species were established at the CGREC in 2011.

The comparison of selected species/cultivars with regard to their establishment, persistence and production is presented here to fill the information gap and then diversify forage production systems in this region.

Summary

All 17 screened and seeded perennial cool-season grasses showed successful establishment in the Missouri Coteau region. They were: meadow brome, smooth brome, meadow fescue, tall fescue, reed canarygrass, creeping foxtail, green needlegrass, orchardgrass, perennial ryegrass, timothy, crested wheatgrass, hybrid wheatgrass, intermediate wheatgrass, slender wheatgrass, western wheatgrass, tall wheatgrass and Russian wildrye.

However, perennial ryegrass did not survive one year after seeding, probably due to winterkill. Green needlegrass, western wheatgrass and Russian wildrye plots were invaded by Kentucky bluegrass one year after seeding.

One year after seeding, tall wheatgrass (4.84 tons/acre) was the most productive species, followed by smooth brome (4.34 tons/acre). Two years after seeding, smooth brome produced 3.25 tons/acre, followed by meadow brome (2.71 tons/acre). Meadow brome would be a good alternative to smooth brome because of its evenly distributed production through the growing season. Intermediate wheatgrass, tall wheatgrass and hybrid wheatgrass also could be used as perennial cool-season grass forages.

Introduction

Smooth brome, a perennial cool-season grass, is the dominant species in most hayland in the Missouri Coteau region. Its dominance comes from intentional seeding historically, but mostly from more recent invasions (DiAllesandro, 2011). It is productive, especially in the early growing season (Dillemuth, 2012).

However, it is not very drought-tolerant, with production showing an apparent summer depression (Sedivec et al., 2007). Furthermore, due to its low forage quality in midsummer, it is less preferred compared with other grasses, especially with regards to in vitro digestibility when harvested after the late-anthesis stage (Coleman et al., 2010).

Perennial cool-season grasses are of interest to livestock producers in the Missouri Coteau region for several reasons. These grasses can be used to renovate abused and degraded natural prairie vegetation, extend the grazing season in the late fall and early spring, and supplement forage resources for livestock in the winter (Coleman et al., 2010). Therefore, a long-term study of perennial cool-season grasses was initiated in 2011 at the CGREC near Streeter, N.D. Specific objectives were to establish and monitor perennial cool-season grass species for their establishment, persistence and productivity.

Procedures

The study was carried out at the Central Grasslands Research Extension Center from 2011 through 2013. Nineteen perennial cool-season grass species/cultivars were seeded in mid-May 2011 (Table 1). Each species/cultivar was drilled into 20- by 20-foot field plots that were prepared by disking and harrowing.

Each plot was harvested in a multi-cut system when smooth brome was at the early anthesis stage. Oven-dried samples were collected to calculate forage production on a dry-matter basis. During establishment, mowing was employed to control common weeds. Herbicide (2,4-D) was applied to the plots to control undesirable broadleaf weeds when necessary.

Each plot was evaluated visually for seeded species establishment. The establishment scale was: failed (no seedlings of seeded species present and plots covered by weeds), poor (sparse seedlings of seeded species and plots covered by weeds at least 50 percent), fair (regularly spaced seedlings of seeded species and covered by weeds at most 50 percent) and excellent (dense seedlings of seeded species and covered by weeds at most 25 percent).

Results

All 17 perennial cool-season grasses showed successful establishment at the CGREC. They were: meadow brome, smooth brome, meadow fescue, tall fescue, reed canarygrass, creeping foxtail, green needlegrass, orchardgrass, perennial ryegrass, timothy, crested wheatgrass, hybrid wheatgrass, intermediate wheatgrass, slender wheatgrass, western wheatgrass, tall wheatgrass and Russian wildrye (Table 1).

However, perennial ryegrass did not survive one year after seeding, probably due to winterkill. Green needlegrass, western wheatgrass and Russian wildrye plots were invaded by Kentucky bluegrass one year after seeding.

We found no significant differences among all species evaluated for the June 2012 harvest (Table 2). However, for the September 2012 harvest, tall wheatgrass (3.17 tons/acre) produced the most biomass (Table 2). We only have one year's data for the multi-harvest regime.

From the results, meadow brome, meadow fescue, tall fescue, reed canarygrass, hybrid wheatgrass and intermediate wheatgrass appear to have had an even distribution of production through the growing season (Table 2). However, smooth brome, creeping foxtail, timothy, slender wheatgrass and crested wheatgrass had their most production early in the season.

In comparison, orchardgrass and tall wheatgrass had their most production late in the growing season. In 2013, a dry year (see page 48), meadow fescue, tall fescue, reed canarygrass and orchardgrass production decreased significantly from 2012. Crested wheatgrass and smooth brome, the early season growing species, produced well, however.

Discussion

It is well-known that perennial cool-season grasses are easy to establish in the northern Great Plains (Sedivec et al., 1997). The only concern that arose in our study was the invasion by perennial cool-season grass "weeds" such as Kentucky bluegrass. Seedbed preparation is very critical to control these weeds. Glyphosate should be used before seeding to control any weeds in the plots.

Green needlegrass and western wheatgrass establishment in our study was only marginal successful compared with other species. We seeded these two species in other plots in 2013, and their establishment was excellent, so we suspect that weed competition was the cause for their poor establishment in 2011. The difficulty we had establishing Russian wildrye may relate with low seeding rates or seed quality. The literature shows mixed results for wildrye establishment. Perennial ryegrass is a very popular forage species in the southern part of the United States. It can establish well in the seeding year, however, it did not overwinter in our study.

The perennial cool-season grasses showed little variability in production. Even though there is some significant difference between species, the magnitude is not great. However, different species showed considerable variety in growth pattern through the growing season. We can classify perennial cool-season grasses into different categories based on their phenology. Livestock producers can use this information to design their production systems to fit their specific management objectives. Furthermore, although production totals may not be different, quality may be. Further studies will focus on evaluating quality parameters.

References

Coleman, S.W., S.C. Rao, J.D. Volesky and W.A. Phillips. 2010. Growth and nutritive value of perennial C3 grasses in the southern Great Plains. Crop Science 50:1070-1078.

DiAllesandro, A.J.L. 2011. The invasion of smooth bromegrass and Kentucky bluegrass in restored grasslands as a function of species diversity. MS. Thesis, North Dakota State University.

Dillemuth, F.P. 2012. Invasion of smooth broom into North American tall-grass prairies: impact on native plant/herbivore species and mechanisms responsible for successful invasion. PhD. Dissertation, Louisiana State University.

Sedivec, K.K., D.A. Tober, W.L. Duckwitz, D.D. Dewald and J.L. Printz. 2007. Grasses for the Northern Plains: Growth Patterns, Forage Characteristics and Wildlife Values. Volume I - Cool-season. North Dakota State University, Fargo. 89 pp.

Table 1. Perennial cool-season grass species/varieties screened and evaluated at the CGREC seeded in 2011 and evaluated in 2012 and 2013.

Common Name	Latin Name	Variety[1]	Seeding Rate[2]	Establishment[3]
Crested wheatgrass	*Agropyron cristatum* (L.) Gaertn.	Fairway	13.08	Excellent
Creeping foxtail	*Alopecurus arundinaceus* Poir.	Garrison	6.98	Excellent
Meadow brome	*Bromus biebersteinii* Roem. & Schult.	Paddock	17.44	Excellent
Smooth brome	*Bromus inermis* Leyss.	VNS	26.17	Excellent
Orchardgrass	*Dactylis glomerata* L.	Pennlate	20.93	Excellent
Hybrid wheatgrass	*Elymus hoffmannii* K. B. Jensen & K. H. Asay	NewHy	19.19	Excellent
Slender wheatgrass	*Elymus trachycaulus* (Link) Gould ex Shinners	Revenue	26.17	Excellent
Perennial ryegrass	*Lolium perenne* L.	Linn	52.33	Excellent
Green needlegrass	*Nassella viridula* (Trin.) Barkworth	Lodorm	8.72	Fair
Western wheatgrass	*Pascopyrum smithii* (Rydb.) Å. Löve	Flintlock	17.44	Fair
Western wheatgrass	*Pascopyrum smithii* (Rydb.) Å. Löve	Recovery	17.44	Fair
Reed canarygrass	*Phalaris arundinacea* L.	Palaton	17.44	Excellent
Timothy	*Phleum pratense* L.	Kootenai	17.44	Excellent
Russian wildrye	*Psathyrostachys juncea* (Fisch.) Nevski	Bozoisky	6.98	Fair
Tall fescue	*Schedonorus arundinaceus* (Schreb.) Dumort.	VNS	26.17	Excellent
Meadow fescue	*Schedonorus pratensis* (Huds.) P. Beauv.	VNS	60.06	Excellent
Intermediate wheatgrass	*Thinopyrum intermedium* (Host) Barkworth & D. R. Dewey	Oahe	13.08	Excellent
		Manska	19.19	Excellent
Tall Wheatgrass	*Thinopyrum ponticum* (Podp.) Z.-W. Liu & R.-C. Wang	Alkar	34.89	Excellent

[1] VNS: variety not stated.
[2] Pounds pure live seed per acre.
[3] Establishment level was evaluated visually one year after seeding in the early spring on a scale of 0 – 3: 0 – failed (no seedlings found); 1 – poor (sparse seedlings found); 2 – fair (regularly spaced seedlings found); 3 – excellent (dense seedlings found and few or no weeds found).

Table 2. Forage yield (tons/acre) of established perennial cool-season grass species/varieties at the CGREC seeded in 2011.

Species	Variety	2012			2013
		June	Sept.	Total	June
Meadow brome	Paddock	1.83	1.96bc[1]	3.76	2.71ab
Smooth brome	VNS	2.92	1.42b-e	4.34	3.25a
Meadow fescue	VNS	1.69	1.78b-d	3.47	1.62cd
Tall fescue	VNS	1.30	1.29b-e	2.59	0.97d
Reed canarygrass	Palaton	1.89	1.98bc	3.86	2.05bc
Creeping foxtail	Garrison	1.30	0.76de	2.06	2.18bc
Orchardgrass	Pennlate	0.91	2.07b	2.98	1.61cd
Timothy	Kootenai	1.82	0.71de	2.53	2.30bc
Crested wheatgrass	Fairway	1.41	0.67e	2.08	2.61ab
Hybrid wheatgrass	NewHy	1.99	1.77b-d	3.75	2.68ab
Intermediate wheatgrass	Manska	1.74	1.15b-e	2.89	2.39abc
	Oahe	1.13	1.90bc	3.04	2.75ab
Slender wheatgrass	Revenue	1.45	0.95c-e	2.40	2.12bc
Tall wheatgrass	Alkar	1.67	3.17a	4.84	2.58ab

[1] Forage yields in column followed by same letters were not statistically different at $p \leq 0.05$.

Establishment, Persistence and Production of Perennial Legumes in the Missouri Coteau Region of North Dakota

Guojie Wang, Matthew Danzl and Paul Nyren
Central Grasslands Research Extension Center - NDSU

Alfalfa, a perennial legume, is the "queen" in the forage realm. However, it has some problems with winterkill, soil salt intolerance, pest infestation such as alfalfa weevil and root cutworms, and causing livestock bloating. Therefore, research on the various cultivars of alfalfa, along with other adapted perennial legumes, is of interest to livestock producers in the Missouri Coteau region.

However, information about the selection, establishment, winter hardiness, phenology, productivity and quality of perennial legumes is scattered and not site-specific. Therefore, 42 field plots were used to screen and evaluate perennial legumes at the Central Grasslands Research Extension Center (CGREC) in the Missouri Coteau region of North Dakota. The comparison of selected species/varieties with regard to their establishment and production is presented here to fill the information gap and then diversify forage production systems in this region.

Summary

Several perennial legumes showed successful establishment at the CGREC: alfalfa, birdsfoot trefoil, Canadian milkvetch, cicer milkvetch, crownvetch, sainfoin, alsike clover, kura clover, red clover and white clover. In contrast, the crownvetch, alsike clover, red clover and white clover stands lasted only two to three years. Cultivar effect was minimal on production except for 'Falcata' alfalfa and 'Empire' birdsfoot trefoil; their production was lower than other selected cultivars.

For short-lived perennial legumes, white clover (1.66 tons/acre) produced less forage than alfalfa (2.39 tons/acre) in 2011, while alsike clover (2.70 tons/acre) and crownvetch (2.48 tons/acre) were comparable. Red clover (4.05 tons/acre) production was higher than alfalfa in 2011.

For long-lived perennial legumes, the three-year average forage production (2011 through 2013) of birdsfoot trefoil (2.43 tons/acre) and cicer milkvetch (2.52 tons/acre) were comparable with alfalfa (2.30 tons/acre), while sainfoin (1.71 tons/acre) was lower. In 2013 alone, however, a dry year, cicer milkvetch (1.63 tons/acre) and sainfoin (1.60 tons/acre) produced more forage than alfalfa (1.09 tons/acre) and birdsfoot trefoil (1.09 tons/acre). Canadian milkvetch and kura clover production varied significantly from year to year and needs further investigation.

Introduction

Legumes, especially perennial legumes, are considered very critical forage species for several reasons. The ability of perennial legumes to fix nitrogen biologically can improve forage production and quality without intensive fertilization (Carlsson and Huss-Danell, 2003). The use of perennial legumes with various seasonalities of production and quality can extend the grazing season in the late fall or early spring (Butler and Muir, 2012; Suriyagoda et al., 2013).

Some perennial legumes are drought-tolerant due to their deep tap roots (Pang et al., 2011). Also, because their root system, perennial legumes can be used to improve soil health such as in saline soil alleviation (Nichols et al., 2012).

Among perennial legume species, alfalfa has a long history of playing a very important role in forage production (Bouton, 2012). Due to its own biological characteristics and historical development, alfalfa is the "queen" of the forage realm. In North Dakota, more than half of the hayland is occupied by alfalfa alone and in mixture with other species.

However, it has some problems with winterkill, soil salt intolerance, pest infestation such as alfalfa weevil and root cutworms, and causing livestock bloating. Efforts to expand the use of alfalfa have drawn Considerable interest; however, a need also exists for alternative perennial species to increase biodiversity and fill niches where alfalfa is less suited (Dear et al., 2003).

Farmers and scientists have embraced the use of new perennial legume species (Dear et al., 2003; Real et al., 2011; Nichols et al., 2012). While "old" species such as alfalfa, white clover and red clover still play an important role in forage production systems, "new" species such as birdsfoot trefoil (McKenzie et al., 2004; Marley et al., 2005), sainfoin (Peel et al., 2004), cicer milkvetch (Loeppky et al., 1996; Acharya et al., 2006), kura clover (Sheaffer and Marten, 1991) and crownvetch (Burns and Cope, 1974) have expanded the range of legume options to produce high-quality forage.

Recently, several producers in the Missouri Coteau region contacted us regarding perennial forage legume species related to their ranch- or farm-specific situations. These phone calls demonstrate the need to study other species as well as alfalfa for forages in our region. Therefore, a long-term study of perennial legumes was initiated in 2010 at the CGREC.

Specific objectives are to establish and monitor perennial legume species for their establishment success and productivity.

Procedures

The study was carried out at the CGREC from 2010 through 2013. Twenty-eight legume species/cultivars were seeded in mid-May, 2010 (Table 1). Each of these species/cultivars was drilled into field plots that were prepared by disking and harrowing. Each plot was 20 by 20 feet. In 2011, 11 more perennial legume species/cultivars were added to the trial (Table 1).

Due to stand failure in 2010, several selections were reseeded in 2011. They were: black medic, Canada milkvetch, kura clover, mountain goldenbanner, silvery lupine, strawberry clover, Utah sweetvetch, white prairie clover and purple prairie clover (Table 1).

Each plot was evaluated visually for seeded species establishment. The establishment scale was: failed (no seedlings of seeded species and plots covered by weeds), poor (sparse seedlings of seeded species and covered by weeds at least 50 percent), fair (regularly spaced seedlings of seeded species and covered by weeds at most 50 percent) and excellent (dense seedlings of seeded species and covered by weeds at most 25 percent). Each plot was harvested when the alfalfa reached the 10 percent blooming stage in a multi-cut system started in 2011. Oven-dried samples were collected to calculate forage production by dry-matter basis.

During establishment, several schedules of mowing were employed to control common weeds. Generic select herbicide (Volunteer [clethodim] at 6 to 8 ounces/acre) was applied to the plots each year to control undesirable grasses.

Results

Establishment. Nineteen out of 28 plots of perennial legumes were established from the 2010 seeding: alsike clover, alfalfa (five cultivars), birdsfoot trefoil (five cultivars), cicer milkvetch (two cultivars), crown vetch, red clover, sainfoin (three cultivars) and white clover (Table 1). Nine species had stand failure (black medic, Canada milkvetch, kura clover, mountain goldenbanner, purple prairie clover, silvery lupine, strawberry clover, northern sweetvetch and white prairie clover) and were reseeded in mid-May of 2011 (Table 1). Based on establishment success, more cultivars of alfalfa (six), red clover (three) and white clover (two) were seeded in 2011 to broaden the scope of cultivars of the well-established species (Table 1). All of these added varieties were well-established in 2012 (Table 1).

Canada milkvetch and kura clover had a successful establishment in 2012 (Table 1). However, silvery lupine and Utah sweetvetch experienced stand failure again in 2012 (Table 1). Black medic, mountain goldenbanner, purple prairie clover, strawberry clover and white prairie clover stands were sparse, and more viable seeds were added to the plots during the growing season in 2012 after a solid rainfall. This re-seeding did not improve these stands by 2013.

Persistence. Crownvetch, alsike clover, red clover and white clover seeded in 2010 had stand thinning from 2011 to 2012. This pattern also was observed for red clover and white clover (seeded in 2011) from 2012 to 2013. Alfalfa, Canadian milkvetch, cicer milkvetch and kura clover showed stand improvement during the second and third year after seeding. Birdsfoot trefoil and sainfoin stands stayed fairly steady through the three years.

Production. Cultivar effect was minimal on production except for 'Falcata' alfalfa and 'Empire' birdsfoot trefoil, which showed lower productivity than other selected cultivars (Tables 2 and 3). For short-lived perennial legumes, white clover (1.66 tons/acre) produced less forage than alfalfa (2.39 tons/acre), while alsike clover (2.70 tons/acre) and crownvetch (2.48 tons/acre) production was comparable to that of alfalfa. Red clover (4.05 tons/acre) produced more forage than alfalfa one year after seeding in 2010.

For long-lived legumes, the three-year averages of forage production of birdsfoot trefoil (2.43 tons/acre) and cicer milkvetch (2.52 tons/acre) were comparable to alfalfa (2.30 tons/acre), while sainfoin (1.71 tons/acre) was lower. However, in 2013, a dry year, (see Figure 1, page 48) cicer milkvetch (1.63 tons/acre) and sainfoin (1.60 tons/acre) produced more forage than alfalfa (1.09 tons/acre) and birdsfoot trefoil (1.09 tons/acre). Canadian milkvetch and kura clover production varied significantly from year to year and needs further investigation.

Discussion

Establishment of these perennial legume forage species is the first step of this study and is a key for their production and field management. Two comments warrant a mention: First, this study includes the objective of screening available perennial legume forage species. Due to winterkill, drought, diseases, soils and other factors, not all the species we screened established well. Second, field management can play a critical role for species establishment. Different seeding strategies and weed control measures can contribute to stand establishment.

Selection of the seeding time and tillage type can alleviate weed infestation. The common weeds in our field plots are foxtails, Canada thistle and redroot pigweeds. The annual grass weeds could be controlled easily by herbicides such as Select; however, broadleaf weeds are difficult to control. The herbicide Pursuit is an option, but its efficiency was not as good as expected.

With the same field management protocol, alfalfa, alsike clover, birdsfoot trefoil, Canadian milkvetch, cicer milkvetch, crownvetch, kura clover, red clover, sainfoin and white clover can be established in the Missouri Coteau region, and they deserve more detailed study of their growth phenology, nutrition and effects on soil fertility.

More species or cultivars will be added to this trial based on the screening results. The difficult part after the screening process is seed availability on the commercial scale, and this constrains the use of "new" perennial forage legume species.

Species with various stand longevities can be utilized in specific situations or agronomic practices. Crownvetch, alsike clover and red clover are short-lived and quite productive in the year after seeding. Further research should focus on improving their production in the seeding year. These short-lived species can be used as a rotation crop in row crop production systems for soil health benefits and short-term forage production. They also can be used as a cover crop component, and all of these need further study to develop appropriate production systems.

Stands of our long-lived species - alfalfa, Canadian milkvetch and cicer milkvetch - improved year by year. This is typical for these species due to their slow process of establishment. Furthermore, Canadian milkvetch and cicer milkvetch have a high proportion of hard seeds, sometimes more than 80 percent. These hard seeds serve as insurance to increase stand density if the initial stand is sparse. We seeded alfalfa at low seeding rate due to a seed problem, which may explain their extensive branching in the later years. Birdsfoot trefoil and sainfoin stands were fairly constant, and their longevity needs further study.

Our results showed that for these perennial legumes, seasonality production varied by species. For example, alsike clover and red clover are early season species with fair regrowth potential. Canadian milkvetch, cicer milkvetch and crownvetch are late-season species with less regrowth, and an early season harvest will hurt their total production. Sainfoin and birdsfoot trefoil are midseason species with less regrowth potential.

We also found that species varied in drought tolerance. Cicer milkvetch and sainfoin are more drought-tolerant than alfalfa and birdsfoot trefoil. The variability in different species can be employed by livestock producers to design their grazing systems and their whole-farm production for different purposes, such as grazing, haying, green manure and cover crops.

Future Research

In 2014, all perennial legumes, including well-established and newly seeded species, will be monitored with regard to their phenology, morphology, production and quality. Soil samples were collected in 2011 and will be collected again in 2015 to study the effect that these species have on soil health, especially soil fertility.

References

Acharya, S.N., J.P. Kastelic, K.A. Beauchemin and D.F. Messenger. 2006. A review of research progress on cicer milkvetch (Astragalus cicer L.). Canadian Journal of Plant Science 86:49-62.

Bouton, J.H. 2012. An overview of the role of lucerne (Medicago sativa L.) in pastoral agriculture. Crop & Pasture Sci. 63:734-738.

Burns, J.C., and W.A. Cope. 1974. Nutritive value of crownvetch forage as influenced by structural constituents and phenolic and tannin compounds. Agronomy Journal 66:195-200.

Butler, T.J., and J.P. Muir. 2012. Perspective on forage legume systems for the tallgrass and mixed-grass prairie of the southern Great Plains of Texas and Oklahoma. Crop Science 52:1971-1979.

Carlsson, G., and K. Huss-Danell. 2003. Nitrogen fixation in perennial forage legumes in the field. Plant and Soil 253:353-372.

Dear, B.S., G.A. Moore and S.J. Hughes. 2003. Adaptation and potential contribution of temperate perennial legumes to the southern Australian wheatbelt: a review. Australian Journal of Experimental Agriculture 43:1-18.

Loeppky, H.A., S. Bittman, M.R. Hiltz and B. Fricks. 1996. Seasonal changes in yield and nutritional quality of cicer milkvetch and alfalfa in northeastern Saskatchewan. Canadian Journal of Plant Science 76:441-446.

McKenzie, D.B., Y.A. Papadopoulos and K.B. McRae. 2004. Harvest management affects yield and persistence of birdsfoot trefoil (*Lotus corniculatus* L.) in cool summer climates. Canadian Journal of Plant Science 84:525-528.

Marley, C.L., R. Fychan and R. Jones. 2005. Yield, persistency and chemical composition of Lotus species and varieties (birdsfoot trefoil and greater birdsfoot trefoil) when harvested for silage in the UK. Grass and Forage Science 61:134-145.

Nichols, P.G.H., C.K. Revell, A.W. Humphries, J.H. Howie, E.J. Half, G.A. Sandral, K. Ghamkhar and C.A. Harris. 2012. Temperate pasture legumes in Australia - their history, current use, and future prospects. Crop & Pasture Science 63:691-725.

Pang, J., J. Yang, P. Ward, K.H.M. Siddique, H. Lambers, M. Tibbett and M. Ryan. 2011. Contrasting responses to drought stress in herbaceous perennial legumes. Plant Soil 348:299-314.

Peel, M.D., K.H. Asay, D.A. Johnson and B.L. Waldron. 2004. Forage production of sainfoin across an irrigation gradient. Crop Science 44:614-619.

Real, D., G.D. Li, T.O. Albertsen, S. Clark, M.D. Denton, R.C. Hayes, M.F. D'Antuono and B.S. Dear. 2011. Evaluation of perennial forage legumes and herbs in six Mediterranean environments. Chilean Journal of Agricultural Research 71:357-369.

Sheaffer, C.C., and G.C. Marten. 1991. Kura clover forage yield, forage quality, and stand dynamic. Canadian Journal of Plant Science 71:1169-1172.

Suriyagoda, L.D B., D. Real, M. Renton, H. Lambers and M.H. Ryan. 2013. Establishment, survival, and herbage production of novel summer-active perennial pasture legumes in the low-rainfall cropping zone of Western Australia as affected by plant density and cutting frequency. Crop & Pasture Science 64:71-85.

Figure 1. Monthly precipitation during the four-year period of 2010 through 2013.

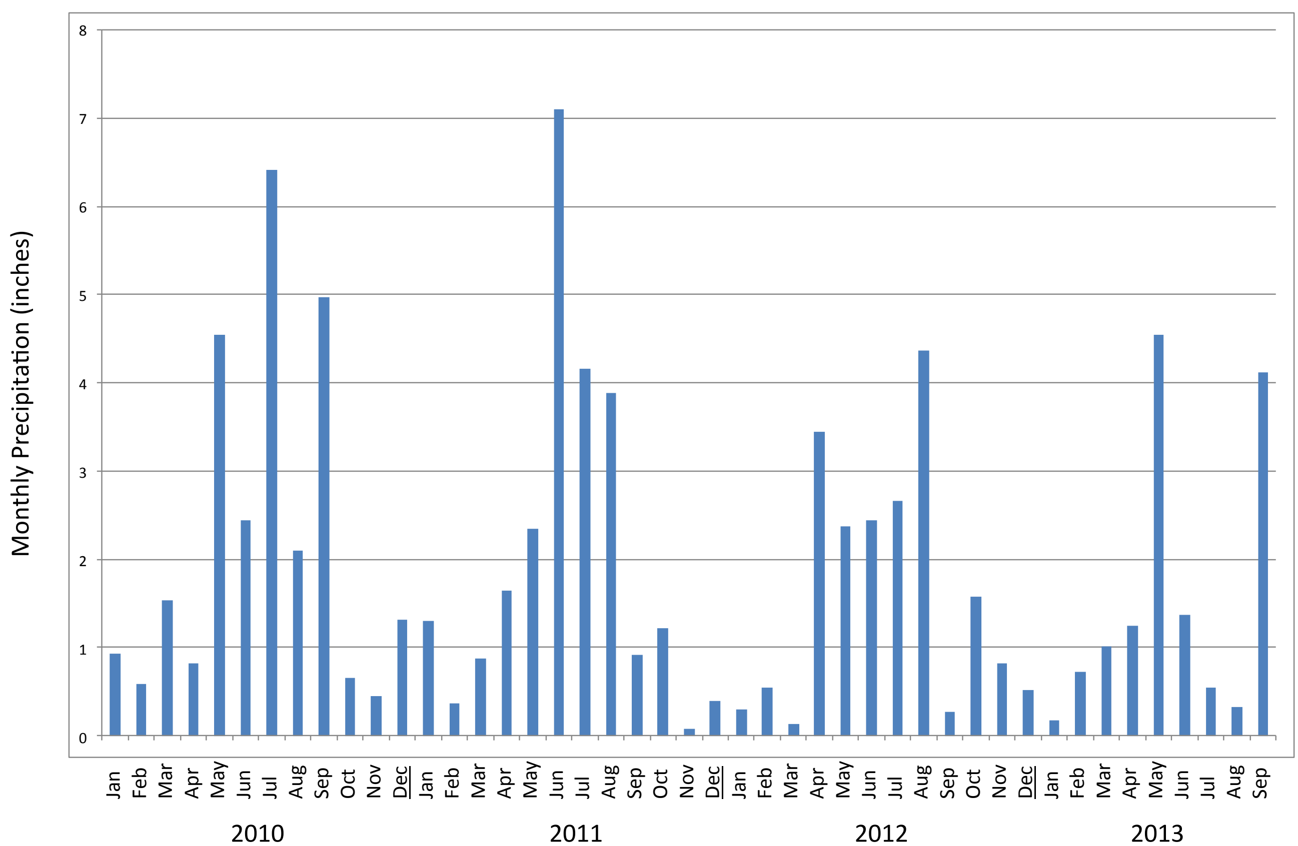


Table 1. Perennial legume species/varieties screened and evaluated at the CGREC 2010 through 2013. (Footnotes on next page.)

Common Name	Latin Name	Seeding Year[1]	Variety[2]	Seeding Rate[3]	Establishment[4]
Alfalfa	*Medicago sativa* L.	2010	Pioneer	5.57	Fair
		2010	PGI427	5.57	Fair
		2010	Rugged	5.57	Fair
		2010	TS4002	5.57	Fair
		2010	Vernal	5.57	Fair
		2011	Falcata	15.70	Excellent
		2011	Multileaf	15.70	Excellent
		2011	Ameristand 433T-RR	15.70	Excellent
		2011	Graze N Hay 3.10-RR	15.70	Excellent
		2011	Maxi-Pro 3.01-RR	15.70	Excellent
		2011	WL 355-RR	15.70	Excellent
		2013	Rhirst Extra Hybrid	17.44	NA
		2013	Vernal	17.44	NA
Alsike clover	*Trifolium hybridum* L.	2010	VNS	8.71	Excellent
		2013	VNS	13.08	NA
Birdsfoot trefoil	*Lotus corniculatus* L.	2010	Empire	6.98	Excellent
		2010	Leo	6.98	Excellent
		2010	Norcern	6.98	Excellent
		2010	Pardee	6.98	Excellent
		2010	Viking	6.98	Excellent
		2013	Languille	8.72	NA
Black medic	*Medicago lupulina* L.	2010	CT Organic	8.71	Failed
		2011	CT Organic	13.08	Poor
Canadian milkvetch	*Astragalus canadensis* L.	2010	MN Native	6.98	Failed
		2011	MN Native	10.90	Fair
		2013	MN Native	130.84	NA
Cicer milkvetch	*Astragalus cicer* L.	2010	Monarch	17.44	Excellent
		2010	Lutana	17.44	Excellent
		2013	OxleyII	21.81	NA
		2013	Veldt	21.81	NA
Crown vetch	*Coronilla varia* L.	2010	Penngift	13.11	Excellent
		2013	Penngift	21.81	NA
Kura clover	*Trifolium ambiguum* M. Bieb.	2010	VNS	6.98	Failed
		2011	VNS	13.96	Excellent
		2013	VNS	8.72	NA
Mountain goldenbanner	*Thermopsis montana* Nutt.	2010	VNS	26.15	Failed
		2011	VNS	47.36	Poor
Purple prairie clover	*Dalea purpurea* Vent.	2010	VNS	5.23	Failed
		2011	VNS	15.70	Poor
Red clover	*Trifolium pretense* L.	2010	Medium	8.71	Excellent
		2011	Arlington	9.16	Excellent
		2011	Mammoth	9.16	Excellent
		2011	Marathon	9.16	Excellent
		2013	Cinnamon Plus	13.08	NA
Sainfoin	*Onobrychis viciifolia* Scop.	2010	Eski	34.87	Excellent
		2010	Remont	34.87	Excellent
		2010	Shoshone	34.87	Excellent
		2013	Melrose	52.33	NA
		2013	Nova	52.33	NA
Silvery lupine	*Lupinus argenteus* Pursh	2010	VNS	26.15	Failed
		2011	VNS	27.26	Failed
Strawberry clover	*Trifolium fragiferum* L.	2010	O'Conners	13.11	Failed
		2011	O'Conners	15.70	Poor
Utah sweetvetch	*Hedysarum boreale* Nutt.	2010	Timp CT	15.69	Failed
		2011	Timp CT	21.81	Failed
White clover	*Trifolium repens* L.	2010	New Zealand	3.49	Excellent
		2011	Dutch	3.49	Excellent
		2011	Ladino	3.49	Excellent
		2013	Alice	6.98	NA
White prairie clover	*Dalea candida* Michx. ex Wild.	2010	Slider	5.23	Failed
		2011	Antelope	15.70	Poor

Footnotes for **Table 1**.

[1] Twenty-eight perennial forage legume species/varieties were seeded in 2010. Nine species failed to establish and they were reseeded in the same plots in 2011. Another 11 promising species/varieties were seeded also in 2011 to test different varieties of well-established species from the 2010 seeding. When evaluated in 2012, two out of those nine species seeded in 2010 and reseeded in 2011 established well. In 2013, 11 promising species/varieties were seeded in the seven failed plots seeded in 2010 and 2011.

[2] VNS: variety not stated.

[3] Pounds pure live seed per acre.

[4] Establishment level was evaluated visually one year after seeding in the early spring in a scale of 0 – 3: 0 – failed (no seedlings found); 1 – poor (sparse seedlings found); 2 – fair (regularly spaced seedlings found); 3 – excellent (dense seedlings found and few or no weeds found).

Table 2. Forage yield (tons/acre) of established perennial legume species/varieties at the CGREC seeded in 2010.

Species/Variety	2011			2012				2013		
	July	August	Total	June	July	Sept.	Total	June	July	Total
Alfalfa										
Pioneer	1.27b-e[1]	1.16d-g	2.43c-g	0.95a-d	1.72a-d	0.87a	3.54ab	0.69e	0.49a	1.17a-d
PGI427	1.22be	1.21c-g	2.44b-g	0.98a-d	1.55b-e	0.70ab	3.23ab	0.56e-g	0.33a-d	0.90c-e
Rugged	1.30b-e	1.10e-g	2.40c-g	1.13a-c	2.14a-c	0.61bc	3.88a	0.86c-e	0.43ab	1.28a-d
TS4002	1.20b-e	1.09fg	2.30d-g	0.83cd	2.15a-c	0.62bc	3.60ab	0.59ef	0.34a-c	0.93b-d
Vernal	1.20b-e	1.20c-g	2.40c-g	0.70c-e	1.61b-e	0.55bc	2.86a-d	0.82de	0.37a-c	1.18a-d
Alsike clover										
VNS	1.55b-d	1.15d-g	2.70b-f	0.27e-g	1.16d-f	0.07ef	1.49ef	NA	NA	NA
Birdsfoot trefoil										
Empire	1.19b-e	1.47b-e	2.66b-f	0.07fg	1.35c-f	0.27de	1.69e-f	NA	NA	NA
Leo	1.58b-d	1.50b-d	3.08b-e	0.87b-d	2.20ab	0.04ef	3.11ab	0.75e	0.11de	0.86de
Norcern	1.42b-e	1.88a	3.30a-c	0.59c-f	1.82a-d	0.09ef	2.50b-e	0.73e	0.17c-e	0.91c-e
Pardee	1.80ab	1.57a-c	3.37ab	0.84cd	2.26ab	0.07ef	3.17ab	0.95c-e	0.30a-d	1.25a-d
Viking	1.61bc	1.52a-d	3.13a-d	0.89b-d	2.51a	0.19d-f	3.60ab	0.99c-e	0.37a-c	1.35a-d
Cicer milkvetch										
Monarch	0.79e	1.37b-f	2.16e-g	1.46a	1.87a-d	0.14ef	3.47ab	1.59ab	0.00e	1.59ab
Lutana	0.91de	1.49b-d	2.40c-g	1.39ab	2.32ab	0.15ef	3.85a	1.67a	0.00e	1.67a
Crown vetch										
Penngift	1.23b-e	1.25c-g	2.48b-g	0.09fg	1.80a-d	0.02f	1.90c-f	NA	NA	NA
Red clover										
Medium	2.41a	1.63ab	4.05a	0.59c-f	1.96a-d	0.43cd	2.98a-c	0.12fg	0.14c-e	0.26ef
Sainfoin										
Eski	1.43b-e	0.91g	2.34d-g	0.87b-d	0.83ef	0.04ef	1.75e-f	1.37a-c	0.22b-e	1.59a
Remont	1.20b-e	1.04fg	2.24d-g	0.55d-g	0.65f	0.12ef	1.32f	1.31a-d	0.36a-c	1.67a
Shoshone	0.96c-e	0.88g	1.84fg	0.25e-g	0.67f	0.14ef	1.06f	1.09b-e	0.43ab	1.53a-c
White clover										
New Zealand	0.76e	0.90g	1.66g	0.05g	0.65f	0.03ef	0.73f	0.05g	0.00e	0.05f

[1] Forage yields within columns followed by same letters were not statistically different at $p \leq 0.05$.

Table 3. Forage yield (tons/acre) of established perennial legume species/varieties at the CGREC seeded in 2011.

Species/Variety	2012				2013		
	June	July	Sept.	Total	June	July	Total
Alfalfa							
Falcata	0.42bcde[1]	1.20ef	0.01c	1.63de	1.33abc	0.00e	1.33bcd
Multileaf	0.99a	1.35def	0.76b	3.10ab	0.84de	0.51abc	1.35bcd
Ameristand 433T-RR	0.82ab	1.97abcd	1.09a	3.88a	1.41ab	0.69a	2.10a
Graze N Hay 3.10-RR	0.63abc	1.69abcde	0.71b	3.03abc	1.03bcde	0.55ab	1.58ab
Maxi-Pro 3.01-RR	0.79abc	1.59abcdef	0.85ab	3.22ab	1.21abcd	0.62a	1.83ab
WL 355-RR	0.67abc	1.50cdef	0.58b	2.76abcd	1.03bcde	0.49abcd	1.51abc
Canadian milkvetch							
MN Native	0.19de	0.98f	0.03c	1.20e	0.89cde	0.00e	0.89cde
Kura clover							
VNS	0.38cde	1.41def	0.10c	1.88cde	1.64a	0.00e	1.64ab
Red clover							
Arlington	0.63abcd	2.22ab	0.62b	3.47ab	0.33fg	0.26cde	0.60ef
Mammoth	0.84ab	2.17abc	0.09c	3.10ab	0.62ef	0.22de	0.85de
Marathon	0.85ab	2.25a	0.77ab	3.87a	0.28fg	0.30bcd	0.58ef
White clover							
Dutch	0.68abc	1.81abcde	0.04c	2.54bcd	0.19fg	0.00e	0.19f
Ladino	0.08e	1.55bcdf	0.16c	1.79de	0.07g	0.00e	0.07f

[1] Forage yield number followed by same letters was not statistically different at $p \leq 0.05$.

Establishment, Persistence, Yield and Harvest Regime of Perennial Forage Species for Bioenergy Production Across Central and Western North Dakota

Guojie Wang[1], Matthew Danzl[1], Paul Nyren[1], Ezra Aberle[2], Eric Eriksmoen[3], Tyler Tjelde[4], John Hendrickson[5], Rick Warhurst[6] and Anne Nyren[1]

[1]Central Grasslands Research Extension Center, North Dakota State University (NDSU);
[2]Carrington Research Extension Center - NDSU;
[3]Hettinger and North Central Research Extension Centers - NDSU;
[4]Williston Research Extension Center - NDSU;
[5]Northern Great Plains Research Laboratory, U.S. Department of Agriculture - Agricultural Research Service;
[6]Ducks Unlimited, Great Plains Regional Office.

Switchgrass, a perennial warm-season grass, has been declared a "model" bioenergy crop in the U.S. However, its establishment and persistence remain questionable across central and western North Dakota due to its soil moisture requirements.

Therefore, several cultivars of switchgrass, along with other promising perennial species, as well as some mixtures, were evaluated across central and western North Dakota. The effects of harvest regimes (annual vs. biennial, high-stubble vs. low-stubble) on stand persistence and biomass yield also were investigated from the perspective of conservation and production. The results from this study can be used to develop appropriate bioenergy production systems to match site-specific situations in North Dakota.

Summary

To develop bioenergy production systems appropriate to specific locations, four species were studied at seven sites across central and western North Dakota from 2006 to 2013. These species were switchgrass, prairie cordgrass, intermediate wheatgrass and tall wheatgrass, and several mixtures. They were evaluated with regard to establishment, persistence, biomass yield and harvest regimes.

Annual vs. biennial harvest regimes were evaluated at the Carrington, Hettinger, Minot, Streeter and Williston study sites, which were seeded in 2006. Study sites at Mandan and Wing were added in 2009. Low-stubble vs. high-stubble harvest regimes also were evaluated at Streeter and Wing, which also were seeded in 2009. All plots were dryland, although an irrigated set of plots was added at Williston.

One year after seeding (2007 and 2010), intermediate wheatgrass, tall wheatgrass, a binary mixture of tall wheatgrass and intermediate wheatgrass, and a binary mixture of tall wheatgrass with 'Sunburst' switchgrass (dominated by tall wheatgrass) established soundly at all seven sites. 'Sunburst' switchgrass and its binary mixture with big bluestem established well at Carrington and Williston (irrigated land) and failed at Hettinger and Williston (dryland). Meanwhile, their successful establishment took two to three years after seeding at Mandan, Minot, Streeter and Wing.

Comparing the seven-year average of production by species within each site, and with annual harvest, 'Sunburst' switchgrass produced the highest biomass at Carrington (4.36 tons/acre), Streeter (2.95 tons/acre) and Williston (irrigated land, 5.74 tons/acre), while intermediate wheatgrass was the highest at Hettinger (2.23 tons/acre) and Williston (dryland, 1.36 tons/acre). The mixture of tall wheatgrass with 'Sunburst' switchgrass had the highest yield at Minot (3.31 tons/acre) during the seven years, with an annual harvest.

Biennial harvest at Carrington and Williston (irrigated land only) accounted for approximately 50 percent of those two annual harvest totals. The high-stubble harvest produced approximately 70 percent of the biomass of the low-stubble harvest for the most promising species or mixtures.

Introduction

The northern Great Plains has been identified as an important area for biomass production. In particular, North Dakota is ranked first in the nation for its potential to produce perennial grasses and other dedicated bioenergy crops (Milbrandt, 2005). After evaluating 34 annual and perennial species in multistate field trials, switchgrass (*Panicum virgatum* L.) was declared a "model" crop for bioenergy production in the U.S.

Switchgrass is native to the tall-grass prairie of North America. However, the northern Great Plains region is a mixed ecoregion with tall-grass prairie on the east and midgrass prairie on the west. In North Dakota, the transition zone occurs at approximately 98°W longitude. Therefore, switchgrass performance remains questionable in this area from an ecological standpoint.

Other promising perennial forage species should be tested in the field if switchgrass cannot perform well in western North Dakota. Furthermore, switchgrass cultivars of southern origin such as 'Alamo,' 'Kanlow,' 'Cave-in-Rock' and 'Blackwell' have uncertain winter hardiness 300 miles north of their origin.

If switchgrass can be established in western North Dakota, further evaluation and selection of adapted cultivars of switchgrass is important.

Producing perennial biomass for bioenergy can help mitigate the negative impacts of fossil fuel on our economy and energy security, as well as provide environmental benefits such as improving soil health, water quality and wildlife habitat. However, these benefits can be realized only with appropriate agronomic practices, in particular, using selected harvest frequencies and stubble heights.

Therefore, the objectives of this study were to compare the performance of two different cultivars of switchgrass and species of intermediate wheatgrass, tall wheatgrass and prairie cordgrass monocultures, as well as mixtures of 1) intermediate wheatgrass and tall wheatgrass, 2) intermediate wheatgrass, tall wheatgrass, alfalfa and yellow sweetclover, 3) switchgrass and tall wheatgrass, 4) switchgrass and Altai wildrye, 5) switchgrass and big bluestem, 6) Altai wildrye and basin wildrye and 7) switchgrass and prairie cordgrass across central and western North Dakota.

Several questions were asked: 1) Could switchgrass establish and persist in central and western North Dakota west of the 980 W longitude? 2) If so, which cultivar would be most productive? 3) If not, what is the alternative to switchgrass? 4) Are monocultures and mixtures similar in production or which is superior? 5) What is the best species or mixtures in each site for biomass production? 6) Do harvest regimes affect the performance of the selected monocultures and mixtures?

Procedures

Field study was conducted at the North Dakota State University Research Extension Centers at Carrington, Hettinger, Minot, Streeter and Williston during 2006 to 2013. The growing-season 30-year average precipitation is: Carrington, 15.2 inches; Streeter, 13.7 inches; Minot, 13.1 inches; Hettinger, 12.1 inches; and Williston, 11.6 inches. At Williston, a side-by-side site comparison of irrigation effect was conducted and included dryland and irrigated sites. Irrigated plots received approximately 6 to 10 inches of water every year as necessary.

The 10 experimental entries of monocultures and mixtures are shown in Table 1. Each field plot measured 30 feet long and 15 feet wide and contained 30 rows spaced 6 inches apart. In 2006, all plots across all sites were seeded the week of May 15, starting in Hettinger (the western-most site) and ending with Carrington (in the east), following seedbed preparation with disking and harrowing. The seeding rate for each experimental entry is shown in Table 1.

The field plots at each site were maintained by different mowing agendas, and herbicides were used for weed control if necessary. The plots were not harvested in 2006 but were mowed at the end of the growing season. Since 2007, plots were harvested every year in the second or third week of September, depending on the weather. A 4-foot-wide strip in the center of each plot was cut to a 3-inch stubble height and weighed.

Dry-matter content of biomass from each plot was measured from a 1- to 2-pound grab sample that was dried at 150 degrees Fahrenheit and used to adjust plot yields to a dry-matter basis. Beginning in 2007, nitrogen (N) fertilizer (56 pounds N/acre) was applied in May to all plots except those containing legumes. The biennial harvests were conducted in 2007, 2009, 2011 and 2013.

Two sites, one at the USDA-ARS station at Mandan and the other on the Ducks Unlimited Coteau farm near Wing, were added to the existing trial in 2009. Agronomic practices such as seedbed preparation, seeding, fertilization, weed control and harvest at these two sites were the same as the others except that in the list of experimental entries, wildryes were replaced by prairie cordgrass due to their poor performance at the other sites in 2007 and 2008.

Also in 2009, two more sets of plots at Wing and Streeter were added to the existing trial to evaluate the effect of harvest stubble height on species performance. Two stubble heights were included: 3-inch and 10-inch. The corresponding agronomic practices were the same as in the existing trial.

Results

Establishment and Persistence. In general, establishment was successful for the cool-season grasses, intermediate wheatgrass and tall wheatgrass in monoculture, as well as their mixture with others, seeded in 2006 at Carrington (Table 2), Hettinger (Table 3), Minot (Table 4), Streeter (Table 5) and Williston (Tables 6 and 7). The same was true for plots seeded in 2009 at Mandan (Table 8), Streeter (Table 10) and Wing (Tables 9 and 11).

However, the persistence of tall wheatgrass seeded in 2006 showed a sharp decrease in 2013 at Carrington (Table 2), in 2012 at Minot (Table 4), in 2011 at Streeter (Table 5) and in 2012 at Williston irrigated land (Table 7). Tall wheatgrass persistence fluctuated through the years at Williston dryland (Table 6) seeded in 2006. More time is needed to detect the same trend for tall wheatgrass persistence at Mandan, Streeter and Wing seeded in 2009.

On the other hand, the establishment of warm-season grasses, switchgrass and big bluestem was complex and varied from site to site. At Carrington and Williston irrigated land, they established well in the first year after seeding in 2006 (Tables 2 and 7). However, their establishment at Minot and Streeter took one and two years after seeding in 2006, respectively

Table 1. Experimental entries of species monocultures and mixtures and the corresponding seeding rate for evaluating biomass yield for bioenergy across central and western North Dakota seeded in May 2006 and 2009.

Species or Mixtures	Abbreviation	Species Traits[1]	Seeding Rate[2]
'Sunburst' switchgrass	Sunburst	C_4 Grass	10
'Trailblazer' switchgrass[3]	Trailblazer	C_4 Grass	10
'Dacotah' switchgrass[3]	Dacotah	C_4 Grass	10
'Alkar' tall wheatgrass	Alkar	C_3 Grass	11
'Haymaker' intermediate wheatgrass[4]	Haymaker	C_3 Grass	10
'Manifest' intermediate wheatgrass[4]	Manifest	C_3 Grass	10
'SD Native' prairie cordgrass[5]	SD Native	C_4 Grass	2
CRP mix 1			
'Haymaker' intermediate wheatgrass[4]	CRP1	C_3 Grass	5
'Manifest' intermediate wheatgrass[4]		C_3 Grass	5
'Alkar' tall wheatgrass		C_3 Grass	6
CRP mix 2			
'Haymaker' intermediate wheatgrass[4]		C_3 Grass	4
'Manifest' intermediate wheatgrass[4]		C_3 Grass	4
'Alkar' tall wheatgrass	CRP2	C_3 Grass	4.5
'Vernal' alfalfa		Legume	1
'Blossom' yellow sweetclover		Legume	0.5
$C_4 + C_3$ 1[1]			
'Sunburst' switchgrass	$C_4C_3$1	C_4 Grass	5
'Alkar' tall wheatgrass		C_3 Grass	5
$C_4 + C_3$ 2			
'Sunburst' switchgrass	$C_4C_3$2	C_4 Grass	7
'Mustang' Altai wildrye		C_3 Grass	11
$C_4 + C_4$ 1			
'Sunburst' switchgrass	$C_4C_4$1	C_4 Grass	7
'Sunnyview' big bluestem		C_4 Grass	2.5
$C_4 + C_4$ 2			
'Sunburst' switchgrass	$C_4C_4$2	C_4 Grass	7
'SD Native' prairie cordgrass		C_4 Grass	1
C_3 combination			
'Mustang' Altai wildrye	C_3C_3	C_3 Grass	11
'Magnar' basin wildrye		C_3 Grass	5

[1] C_4: warm-season species; C_3: cool-season species.
[2] Pounds pure live seed/acre.
[3] 'Trailblazer' switchgrass was seeded at Hettinger, Streeter, and Carrington, while 'Dacotah' switchgrass was seeded at Williston and Minot.
[4] 'Haymaker' intermediate wheatgrass was seeded in 2006, while 'Manifest' intermediate wheatgrass was seeded in 2009.
[5] Prairie cordgrass was seeded in 2009 at Mandan, Streeter and Wing instead of wildryes.

(Tables 4 and 5). Their establishment at Hettinger and Williston dryland failed (Tables 3 and 6). Furthermore, the persistence of well-established switchgrass decreased through the years and plots were invaded by cool-season grasses: smooth brome, quackgrass and/or crested wheatgrass.

Switchgrass did not establish well until three, three and two years after seeding in 2009 at Mandan, Wing and Streeter, respectively (Tables 8 – 11). At Williston irrigated land seeded in 2006, all the plots containing wheatgrasses were invaded by Canada thistle and smooth brome; therefore, wheatgrass persistence decreased through the years.

In general, harvest regimes (annual vs. biennial, low-stubble vs. high-stubble) did not have a significant effect on stand establishment or persistence.

Biomass Yield. The highest yielding monocultures or mixtures varied from site to site, year to year and also with harvest regimes (Tables 12 – 21). For the annual harvest regime seeded in 2006, 'Sunburst' switchgrass produced the highest biomass consistently from 2007 to 2013 at Carrington and Williston irrigated land, with average yields of 4.36 tons/acre and 5.74 tons/acre, respectively (Tables 12 and 17).

At Williston dryland and Hettinger, intermediate wheatgrass was consistently the highest from 2007 to 2013, with an average yield of 1.36 and 2.23 tons/acre, respectively (Tables 13 and 16). At Minot, tall wheatgrass and its mixtures had the highest yield in 2007, 2008 and 2012.

From 2009 to 2011, all the entries were similar, while switchgrass mixed with big bluestem produced the highest amount of biomass in 2013 (Table 14). As a result, the seven-year average was highest for tall wheatgrass and its mixtures (3.31 tons/acre). Results from the Streeter site showed a similar trend as from the Minot site: From 2007 to 2008, the cool-season grasses produced higher biomass than warm-season grasses.

All entries were similar in 2009 and 2010, while from 2011 to 2013, 'Sunburst' switchgrass produced the highest biomass. The seven-year average yield of 'Sunburst' switchgrass was the highest at 2.95 tons/acre.

For the biennial harvest regime seeded in 2006, 'Sunburst' switchgrass mixed with 'Mustang' wildrye produced the highest biomass at Carrington (Table 12), Minot (Table 14) and Williston (Tables 16 and 17), while 'Sunburst' switchgrass alone produced the highest at Streeter (Table 15). By comparison, the biennial harvest in a specific year accounted for 45 to 67 percent, 43 to 112 percent, 32 to 87 percent, 50 to 98 percent and 40 to 103 percent of the two annual harvest combined totals at Carrington, Minot, Streeter, Williston dryland and Williston irrigated land, respectively (Tables 12, 14 – 17).

For the annual harvest regime seeded in 2009, intermediate wheatgrass consistently produced the highest biomass at Mandan and averaged 3.13 tons/acre (Table 18). Tall wheatgrass produced the highest biomass at Wing and averaged 3.77 tons/acre (Table 19). For the biennial harvest regime seeded in 2009, tall wheatgrass mixed with switchgrass produced 5.05 tons/acre at Mandan, which is 90 percent of the yield of the two annual harvest combined totals (Table 18). As for the Wing site, the two wheatgrass mixtures produced 5.36 tons/acre under the biennial harvest, or 84 percent of the yield of the two annual harvest combined totals (Table 19).

Switchgrass mixed with big bluestem produced 2.80 tons/acre on average under the low-stubble harvest regime, while 'Trailblazer' switchgrass produced 2.11 tons/acre on average under the high-stubble harvest regime at Streeter seeded in 2009 (Table 20). However, tall wheatgrass produced the highest at both harvest heights at Wing (Table 21). In general, the biomass yield of high-stubble harvested warm-season grass increased in comparison with low-stubble harvest during the study years at both sites (Table 20 and 21).

Discussion

Several factors can contribute to stand failure in establishing perennial grasses; for example, moisture stress (Sanderson et al., 1999), improper seeding strategies (McGinnies, 1960), poor seed quality (Panciera and Jung, 1984) and poor weed control (Martin et al., 1982; Mitchell et al., 2010). The stand failure of the warm-season grasses at the Williston dryland site, as compared with the success at the nearby irrigation site, suggest that establishment was constrained by the available soil water in the seeding year. This is in spite of the fact that these stands were the same with respect to seed batch, seeding strategy, weed control and soil characteristics.

At Hettinger, warm-season grasses seeded in 2006 showed stand failure in 2007, a warmer and drier than average year, followed by another stand failure in 2009, a wetter and colder year, of plots reseeded in 2008.

We see two possible explanations. First, the Hettinger area simply cannot support tall-statured warm-season grasses unless extra moisture is available due to topography or irrigation. Second, soil variability may contribute to stand failure due to problems with soil texture and salinity. Fortunately, intermediate wheatgrass may serve as an alternative for biomass production in these dry areas from the establishment perspective.

At Streeter and Minot, weed control was crucial to establishing warm-season grasses. For weed control in switchgrass and big bluestem stands, atrazine can be used pre-emergence (Hintz et al., 1998), and glyphosate can be used before spring growth of the warm-season grasses. During the course of the six-year study period, warm-season grasses' composition increased, which may indicate the need to allow more time for these grasses to achieve optimum site occupancy.

Biomass yield of switchgrass in this region is highly variable: 1.4 to 5.6 tons/acre at Mandan and Dickinson, N.D. (Berdahl et al., 2005). 4.4 to 5.8 tons/acre in northeastern South Dakota (Boe and Lee, 2007), 0.9 to 4.0 tons/acre in central South Dakota (Lee and Boe, 2005). 3.0 to 5.8 tons/acre in southern Iowa (Lemus et al., 2002) and 3.6 to 8.9 tons/acre in Texas (Sanderson et al., 1999).

The cultivars of switchgrass we studied are all of the upland type but from different origins. Normally, southern-origin, later-maturing cultivars would produce more than northern-origin, early maturing cultivars (Casler et al., 2004). The more southern-origin cultivars may suffer from winterkill (Berdahl et al., 2005). However, the cultivar 'Dacotah' developed in North Dakota did not show superior stand establishment or production when compared with 'Sunburst,' a cultivar from South Dakota. 'Trailblazer,' also a southern cultivar, did show some stand decrease through the years at Streeter and Carrington where it was used. Its production was higher than 'Sunburst' only in 2007 at Carrington.

A trade-off occurs among different harvest regimes. A lower biomass yield would be expected with a biennial harvest regime, compared with annual harvests totaled for two years due to lodging and decomposition in the year without harvest. It is possible that the biennial harvest in a specific year will not necessarily be equal to the annual harvest in the same year due to biomass accumulation from the preceding year, residue effects on stand longevity and soil fertility, and soil water conservation.

Another aspect concerning annual vs. biennial harvest is the harvest cost and efficiency. The cost of two annual harvests is obviously higher than a biennial harvest. If we can improve the harvester to pick up more lodged material, the biennial harvest biomass yield will be higher than with the current machinery.

The primary reason for evaluating stubble height and its effect on biomass yield in this study was wildlife habitat. The best scenario is to select the appropriate species or mixtures that minimize yield lost due to high-stubble harvest while improving wildlife habitat. Also, researchers have shown that harvesting big-statured warm-season grasses at a very low-stubble height has a negative impact on their winter hardiness and the following year's biomass yield.

In the northern Great Plains, we harvest all forages with about a 3-inch stubble height to harvest the shorter forages. This may be too low for the selected switchgrass and big bluestem grass species. The question now is to decide how much producers would be affected by biennial or high-stubble harvesting and weighing that with environmental benefits when they grow bioenergy crops.

References

Berdahl, J.D., A.B. Frank, J.M. Krupinsky, P.M. Carr, J.D. Hanson and H.A. Johnson. 2005. Biomass yield, phenology, and survival of diverse switchgrass cultivars and experimental strains in western North Dakota. Agronomy Journal 97:549-555.

Boe, A., and D.K. Lee. 2007. Genetic variation for biomass production in prairie cordgrass and switchgrass. Crop Science 47:929-934.

Casler, M.D., K.P. Vogel, C.M. Taliaferro and R.L. Wynia. 2004. Latitudinal adaptation of switchgrass populations. Crop Science 44:293-303.

Hintz, R.L., K.R. Harmony, K.J. Moore, J.R. George and E.C. Brummer. 1998. Establishment of switchgrass and big bluestem in corn with atrazine. Agronomy Journal 90:591-596.

Lee, D.K., and A. Boe. 2005. Biomass production of switchgrass in central South Dakota. Crop Science 45:2583-2590.

Lemus, R., E.C. Brummer, K.J. Moore, N.E. Molstad, C.L. Burras and M.F. Barker. 2002. Biomass yield and quality of 20 switchgrass populations in southern Iowa, USA. Biomass & Bioenergy 23:433-442.

Martin, A.R., R.S. Moomaw and K.P. Vogel. 1982. Warm-season grass establishment with atrazine. Agronomy J. 74:916-920.

McGinnies, W.J. 1960. Effects of planting dates, seeding rates, and row spacings on range seeding results in western Colorado. Journal of Range Management 13:37-39.

Milbrandt, A. 2005. A geographic perspective on the current biomass resource availability in United States. Washington, D.C.

Mitchell, R.B., K.P. Vogel, J. Berdahl and R.A. Masters. 2010. Herbicides for establishing switchgrass in the central and northern Great Plains. Bioenergy Research 3:321-327.

Panciera, M.T., and G.A. Jung. 1984. Switchgrass establishment by conservation tillage: planting date responses of 2 varieties. Journal of Soil and Water Conservation 39:68-70.

Sanderson, M.A., R.L. Reed, W.R. Ocumpaugh, M.A. Hussey, G. Van Esbroeck , J.C. Read, C. Tischler and F.M. Hons. 1999. Switchgrass cultivars and germplasm for biomass feedstock production in Texas. Bioresource Technology 67:209-219.

Table 2. Seeded monoculture and mixture stand canopy cover (percent) at harvest (annual vs. biennial) of ten experimental entries for evaluating biomass yield for bioenergy at **Carrington**, North Dakota 2006 through 2013.

Harvest Year	Entries[1]									
	Sun-burst	Trail-blazer	Alkar	Haymaker	CRP1	CRP2	C_4C_3 1	$C_4C_3$2	$C_4C_4$1	C_3C_3
	Annual Harvest									
2007	100a[2]	100a	100a	100a	96a	87b	100a	100a	100a	96a
2008	100a	99ab	100a	99ab	97ab	82c	100a	100a	97ab	88abc
2009	100	100	100	100	100	100	100	100	100	100
2010	95	68	100	100	100	100	100	72	73	90
2011	70	70	100	100	100	100	100	100	100	98
2012	50	57	100	100	100	100	100	63	67	90
2013	60	53	63	100	97	93	87	53	70	60
	Biennial Harvest									
2009	100	100	100	100	100	100	100	100	100	100
2011	80	73	100	100	100	100	100	100	100	100
2013	47bc	30c	63abc	100a	97a	93a	57abc	80ab	37bc	80ab

[1] Experimental entry lists and abbreviations are shown in Table 1.
[2] Within rows for each harvest, means followed by the same letter are not significantly different according to LSD (0.05) for species yield.

Table 3. Seeded monoculture and mixture stand canopy cover (percent) at harvest (annual) of ten experimental entries for evaluating biomass yield for bioenergy at **Hettinger**, North Dakota 2006 through 2013.

Harvest Year	Entries[1]									
	Sunburst	Trailblazer	Alkar	Haymaker	CRP1	CRP2	$C_4C_3$1	$C_4C_3$2	$C_4C_4$1	C_3C_3
	Annual Harvest									
2007	2c[2]	2c	80ab	86a	87a	78ab	70b	9c	4c	8c
2009	0c	7c	63ab	100a	100a	100a	83a	23bc	0c	40bc
2010	0d	0d	92a	82ab	70abc	67bc	50c	0d	0d	2d

[1] Experimental entry lists and abbreviations are shown in Table 1.
[2] Within rows for each harvest, means followed by the same letter are not significantly different according to LSD (0.05) for species yield.

Table 4. Seeded monoculture and mixture stand canopy cover (percent) at harvest (annual vs. biennial) of ten experimental entries for evaluating biomass yield for bioenergy at **Minot**, North Dakota 2006 through 2013.

Harvest Year	Entries[1]									
	Sunburst	Dacotah	Alkar	Haymaker	CRP1	CRP2	$C_4C_3$1	$C_4C_3$2	$C_4C_4$1	C_3C_3
	Annual Harvest									
2007	35c[2]	18c	100a	100a	100a	100a	100a	67b	40bc	20c
2008	99a	83b	100a	100a	100a	100a	100a	95a	95a	93a
2009	100	83	100	100	100	100	100	100	100	100
2010	100	13	100	100	100	100	100	100	100	98
2011	100	60	98	100	100	100	100	97	100	100
2012	77bc	43d	73c	100a	100a	97ab	83abc	73c	83abc	63cd
2013	97a	57bc	43c	67abc	100a	100a	73abc	87ab	100a	50bc
	Biennial Harvest									
2009	100	83	100	100	100	100	100	100	100	100
2011	97	63	100	100	100	100	100	97	100	100
2013	97a	47b	83a	100a	100a	100a	77a	93a	100a	80a

[1] Experimental entry lists and abbreviations are shown in Table 1.
[2] Within rows for each harvest, means followed by the same letter are not significantly different according to LSD (0.05) for species yield.

Table 5. Seeded monoculture and mixture stand canopy cover (percent) at harvest (annual vs. biennial) of ten experiment entries for evaluating biomass yield for bioenergy at **Streeter**, North Dakota 2006 through 2013.

Harvest Year	Entries[1]									
	Sunburst	Trailblazer	Alkar	Haymaker	CRP1	CRP2	$C_4C_3$1	$C_4C_3$2	$C_4C_4$1	C_3C_3
	Annual Harvest									
2007	33b[2]	2c	100a	100a	100a	100a	98a	10bc	15bc	3c
2008	33b	0b	100a	100a	100a	100a	100a	32b	37b	8b
2009	72a	0b	100a	100a	100a	100a	100a	73a	73a	0b
2010	93a	40bc	100a	100a	97a	100a	100a	80a	67ab	18c
2011	100a	80ab	67b	83ab	100a	100a	100a	100a	97a	0c
2012	100a	75ab	33bc	100a	100a	83a	75ab	60ab	100a	0c
2013	100a	93a	33d	90ab	87ab	83abc	63c	70bc	100a	0e
	Biennial Harvest									
2009	40c	2d	100a	100a	100a	100a	100a	73ab	60bc	0d
2011	100a	70ab	100a	63b	83ab	98a	100a	87ab	100a	0c
2013	100a	93ab	67bc	63bc	67bc	77ab	43c	43c	100a	0d

[1] Experimental entry lists and abbreviations are shown in Table 1.
[2] Within rows for each harvest, means followed by the same letter are not significantly different according to LSD (0.05) for species yield.

Table 6. Seeded monoculture and mixture stand canopy cover (percent) at harvest (annual vs. biennial) of ten experiment entries for evaluating biomass yield for bioenergy at **Williston - dry land**, North Dakota 2006 through 2013.

Harvest Year	Entries[1]									
	Sunburst	Dacotah	Alkar	Haymaker	CRP1	CRP2	C_4C_31	C_4C_32	C_4C_41	C_3C_3
					Annual Harvest					
2007	32b[2]	28b	100a	100a	98a	100a	87a	15b	13b	17b
2008	3c	7bc	22b	88a	87a	99a	8bc	2c	0c	2c
2009	20b	20b	100a	100a	100a	100a	100a	20b	20b	20b
2010	33b	13bc	17bc	93a	100a	100a	5c	20bc	38b	0c
2011	53b	25bc	58ab	98a	98a	100a	33bc	33bc	35bc	0c
2012	63b	40b	7c	97a	100a	100a	40b	47b	57b	0c
2013	53bc	33cd	0e	90a	97a	90a	13de	40cd	77ab	0e
					Biennial Harvest					
2009	20b	20b	100a	100a	100a	100a	100a	20b	20b	20b
2011	33cd	33cd	42bc	100a	100a	98a	48bc	77ab	70abc	0d
2013	60bc	17d	7d	93ab	100a	90ab	23cd	57bc	83ab	0d

[1] Experimental entry lists and abbreviations are shown in Table 1.
[2] Within rows for each harvest, means followed by the same letter are not significantly different according to LSD (0.05) for species yield.

Table 7. Seeded monoculture and mixture stand canopy cover (percent) at harvest (annual vs. biennial) of ten experiment entries for evaluating biomass yield for bioenergy at **Williston - irrigated land**, North Dakota 2006 through 2013.

Harvest Year	Entries[1]									
	Sunburst	Dacotah	Alkar	Haymaker	CRP1	CRP2	C_4C_31	C_4C_32	C_4C_41	C_3C_3
					Annual Harvest					
2007	100	100	100	100	100	100	100	100	100	100
2008	100	100	100	100	100	100	100	100	100	100
2009	100	100	100	100	100	100	100	100	100	100
2010	100a[2]	100a	100a	100a	100a	100a	100a	100a	100a	50b
2011	100	100	100	100	100	100	100	100	100	100
2012	100a	100a	67b	97a	90ab	93ab	66b	100a	100a	27c
2013	100a	100a	0c	83a	50b	33b	93a	100a	100a	33b
					Biennial Harvest					
2009	100	100	100	100	100	100	100	100	100	100
2011	100a	100a	100a	87b	93ab	87b	100a	100a	100a	100a
2013	100a	87ab	3d	43bcd	37cd	23d	77abc	100a	100a	43bcd

[1] Experimental entry lists and abbreviations are shown in Table 1.
[2] Within rows for each harvest, means followed by the same letter are not significantly different according to LSD (0.05) for species yield.

Table 8. Seeded monoculture and mixture stand canopy cover (percent) at harvest (annual vs. biennial) of ten experiment entries for evaluating biomass yield for bioenergy at **Mandan**, North Dakota 2009 through 2013.

Harvest Year	Entries[1]									
	Sunburst	Trailblazer	Alkar	Manifest	CRP1	CRP2	$C_4C_3$1	$C_4C_4$1	$C_4C_4$2	SD Native
	Annual Harvest									
2010	3b[2]	7b	90a	92a	77a	67a	72a	13b	0b	0b
2012	100a	100a	100a	100a	100a	100a	100a	87a	53b	0c
2013	100a	100a	100a	100a	100a	100a	100a	87b	30c	0d
	Biennial Harvest									
2013	100a	97a	100a	100a	100a	100a	100a	100a	37b	0c

[1] Experimental entry lists and abbreviations are shown in Table 1.
[2] Within rows for each harvest, means followed by the same letter are not significantly different according to LSD (0.05) for species yield.

Table 9. Seeded monoculture and mixture stand canopy cover (percent) at harvest (annual vs. biennial) of ten experimental entries for evaluating biomass yield for bioenergy at **Wing**, North Dakota 2009 through 2013.

Harvest Year	Entries[1]									
	Sunburst	Trailblazer	Alkar	Manifest	CRP1	CRP2	$C_4C_3$1	$C_4C_4$1	$C_4C_4$2	SD Native
	Annual Harvest									
2010	0b[2]	7b	83a	70a	93a	93a	73a	3b	2b	0b
2011	10bc	32b	100a	100a	100a	100a	100a	0c	20bc	0c
2012	63bc	83ab	100a	100a	100a	100a	100a	50cd	27de	0e
2013	67bc	90ab	100a	100a	100a	100a	100a	60c	30d	3d
	Biennial Harvest									
2011	20bc	7c	98a	67ab	100a	100a	100a	32bc	35bc	7c
2013	77ab	43bcd	100a	73abc	100a	100a	67abc	67abc	23cd	7d

[1] Experimental entry lists and abbreviations are shown in Table 1.
[2] Within rows for each harvest, means followed by the same letter are not significantly different according to LSD (0.05) for species yield.

Table 10. Seeded monoculture and mixture stand canopy cover (percent) at harvest (high vs. low stubble height) of ten experimental entries for evaluating biomass yield for bioenergy at **Streeter**, North Dakota 2009 through 2013.

Harvest Year	Entries[1]									
	Sunburst	Trailblazer	Alkar	Manifest	CRP1	CRP2	C_4C_31	C_4C_41	C_4C_42	SD Native
	3-inch Low Stubble Harvest									
2010	67	62	35	93	73	50	75	40	48	3
2011	100a[2]	82ab	100a	100a	100a	100a	100a	83ab	60b	3c
2012	100a	90b	100a	100a	100a	100a	100a	100a	57c	0d
2013	100a	90a	93a	100a	100a	100a	100a	93a	57b	0c
	10-inch High Stubble Harvest									
2010	67abc	57abc	52abc	93a	87ab	72ab	83ab	45bcd	27cd	5d
2011	97a	98a	73b	100a	100a	93a	100a	97a	96a	2c
2012	100a	100a	100a	100a	97a	93a	100a	100a	68b	0c
2013	100a	100a	100a	100a	100a	100a	100a	100a	60b	0c

[1] Experimental entry lists and abbreviations are shown in Table 1.
[2] Within rows for each harvest, means followed by the same letter are not significantly different according to LSD (0.05) for species yield.

Table 11. Seeded monoculture and mixture stand canopy cover (percent) at harvest (high vs. low stubble height) of ten experimental entries for evaluating biomass yield for bioenergy at **Wing**, North Dakota 2009 through 2013.

Harvest Year	Entries[1]									
	Sunburst	Trailblazer	Alkar	Manifest	CRP1	CRP2	C_4C_31	C_4C_41	C_4C_42	SD Native
	3-inch Low Stubble Harvest									
2010	7de[2]	3de	95a	43cd	93ab	57bc	100a	7de	0e	0e
2011	57b	30c	100a	100a	100a	100a	100a	53b	7d	2d
2012	90a	57b	100a	100a	100a	100a	100a	83ab	20c	8c
2013	100a	60b	100a	100a	100a	93a	100a	90a	17c	7c
	10-inch High Stubble Harvest									
2010	3b	3b	87a	87a	100a	97a	100a	0b	0b	0b
2011	60b	57b	100a	100a	100a	100a	100a	20c	30bc	0c
2012	83a	83a	100a	100a	100a	100a	100a	83a	10b	0b
2013	87a	87a	100a	100a	100a	100a	100a	60b	0c	3c

[1] Experimental entry lists and abbreviations are shown in Table 1.
[2] Within rows for each harvest, means followed by the same letter are not significantly different according to LSD (0.05) for species yield.

Table 12. Yield (ton/acre) at harvest (annual vs. biennial) of ten experiment entries for evaluating biomass yield for bioenergy at **Carrington**, North Dakota 2006-2013.

Harvest Year	Entries[1]									
	Sunburst	Trailblazer	Alkar	Haymaker	CRP1	CRP2	$C_4C_3$1	$C_4C_3$2	$C_4C_4$1	C_3C_3
					Annual Harvest					
2007	5.36abc[2]	**6.21a**[3]	4.66bcde	4.45cde	4.16de	4.93bcd	5.29abc	5.18bc	5.48ab	3.86e
2008	**5.13a**	4.57abc	4.37abc	3.35cd	3.75 bcd	3.79bcd	4.00abcd	4.96ab	4.86ab	3.12d
2009	**4.91a**	3.69cde	3.95bcd	3.22e	3.42de	3.23e	3.99bcd	4.43ab	4.21bc	3.11e
2010	4.04ab	3.39cde	**4.13a**	2.96de	3.23de	3.28de	3.47bcd	3.42bcd	3.95abc	2.76e
2011	4.19	4.28	4.54	3.53	**4.70**	4.33	4.19	4.19	4.26	3.61
2012	4.01	3.51	4.14	3.43	3.69	3.48	3.92	4.01	**4.23**	3.03
2013	2.85	2.11	2.28	2.87	2.79	2.52	2.25	2.92	**3.02**	2.51
7-year Average	**4.36a**	3.96ab	4.01ab	3.39cd	3.68 bcd	3.65bcd	3.88abc	4.16ab	4.29a	3.14d
					Biennial Harvest					
2009	5.36ab	4.02bc	4.04bc	3.42c	3.47c	3.18c	4.11bc	**5.76a**	5.24ab	3.08c
2011	4.66	4.85	4.82	4.38	3.83	3.88	4.84	5.13	**5.24**	3.84
2013	3.54	3.08	3.43	2.93	3.06	3.14	3.39	**4.48**	3.33	3.37
3-year Average	4.52ab	3.98bc	4.10bc	3.58c	3.45c	3.40c	4.11bc	**5.12a**	**4.61ab**	3.43c
					Ratio of Biennial/Annual					
2009/ 2008+2009	0.53	0.49	0.49	0.52	0.48	0.45	0.51	0.61	0.58	0.49
2011/ 2010+2011	0.57	0.63	0.56	0.67	0.48	0.51	0.63	0.67	0.64	0.60
2013/ 2012+2013	0.52	0.55	0.53	0.47	0.47	0.52	0.55	0.65	0.46	0.61
Average	0.54	0.55	0.52	0.55	0.48	0.49	0.57	0.64	0.56	0.57

[1] Experimental entry lists and abbreviations are shown in Table 1.
[2] Within rows for each harvest, means followed by the same letter are not significantly different according to LSD (0.05) for species yield.
[3] Bold number is the highest biomass yield within a year.

Table 13. Yield (ton/acre) at harvest (annual vs. biennial) of ten experiment entries for evaluating biomass yield for bioenergy at **Hettinger**, North Dakota 2007 through 2010.

Harvest Year	Entries[1]									
	Sunburst	Trailblazer	Alkar	Haymaker	CRP1	CRP2	$C_4C_3$1	$C_4C_3$2	$C_4C_4$1	C_3C_3
	Annual Harvest									
2007	1.64d[2]	1.64d	2.32abcd	2.68ab	2.59ab	**2.86a**[3]	2.49abc	1.79cd	1.64d	1.93bcd
2009	1.51	1.06	1.11	1.64	1.34	**1.68**	1.52	1.60	1.43	1.30
2010	2.04	**2.43**	2.12	2.37	2.23	2.25	2.25	2.18	2.15	1.57
3-year Average	1.73	1.71	1.85	2.23	2.05	**2.26**	2.09	1.86	1.74	1.60

[1] Experimental entry lists and abbreviations are shown in Table 1.
[2] Within rows for each harvest, means followed by the same letter are not significantly different according to LSD (0.05) for species yield.
[3] Bold number is the highest biomass yield within a year.

Table 14. Yield (ton/acre) at harvest (annual vs. biennial) of ten experiment entries for evaluating biomass yield for bioenergy at **Minot**, North Dakota 2007 through 2013.

Harvest Year	Entries[1]									
	Sunburst	Dacotah	Alkar	Haymaker	CRP1	CRP2	$C_4C_3$1	$C_4C_3$2	$C_4C_4$1	C_3C_3
	Annual Harvest									
2007	2.39b[2]	2.32b	4.19a	3.67a	4.47a	4.12a	**4.58a**[3]	2.29b	2.14b	2.35b
2008	1.63c	1.32c	4.10a	**4.13a**	3.58ab	3.23ab	4.09a	3.57ab	1.68c	2.47bc
2009	2.23	2.36	3.13	2.45	2.04	2.80	**3.25**	3.09	2.04	2.72
2010	3.48	**4.02**	3.32	2.73	2.10	2.88	3.45	3.22	3.82	2.77
2011	3.11	3.46	2.57	2.96	2.49	3.05	3.48	3.26	**3.58**	2.99
2012	1.90bc	1.96bc	1.38c	2.21bc	1.35c	**3.30a**	1.52bc	2.01bc	2.39ab	1.64bc
2013	2.72bc	2.63c	2.86bc	3.67ab	2.93bc	3.49abc	2.79bc	3.04bc	**4.30a**	3.24bc
7-year Average	2.49d	2.58cd	3.08abcd	3.12abc	2.71bcd	3.27ab	**3.31a**	2.93abcd	2.85abcd	2.60cd
	Biennial Harvest									
2009	4.33	3.21	**5.42**	3.76	4.08	4.19	5.33	4.38	3.59	4.20
2011	4.48ab	4.38ab	3.65bc	2.46d	2.69d	3.22cd	3.84bc	4.15b	**5.18a**	3.85bc
2013	4.33	3.48	2.35	3.11	2.68	3.54	2.56	3.30	**4.42**	3.12
3-year Average	4.38	3.69	3.81	3.11	3.15	3.65	3.91	3.95	**4.40**	3.73
	Ratio of Biennial/Annual									
2009/(2008+2009)	1.12	0.87	0.75	0.57	0.73	0.69	0.73	0.66	0.97	0.81
2011/(2010+2011)	0.68	0.59	0.62	0.43	0.59	0.54	0.55	0.64	0.70	0.67
2013/(2012+2013)	0.94	0.76	0.55	0.53	0.63	0.52	0.59	0.65	0.66	0.64
Average	0.87	0.70	0.66	0.51	0.65	0.58	0.63	0.65	0.74	0.71

[1] Experimental entry lists and abbreviations are shown in Table 1.
[2] Within rows for each harvest, means followed by the same letter are not significantly different according to LSD (0.05) for species yield.
[3] Bold number is the highest biomass yield within a year.

Table 15. Yield (ton/acre) at harvest (annual vs. biennial) of ten experiment entries for evaluating biomass yield for bioenergy at **Streeter**, North Dakota 2007 through 2013.

Harvest Year	Entries[1]									
	Sunburst	Trailblazer	Alkar	Haymaker	CRP1	CRP2	C_4C_31	C_4C_32	C_4C_41	C_3C_3
	Annual Harvest									
2007	1.89c[2]	1.71c	3.42a	2.70b	3.38a	2.56b	**3.94a**[3]	1.79c	1.59c	1.67c
2008	1.66de	1.37e	2.63abc	2.74ab	2.67abc	1.65de	**3.09a**	2.10bcd	1.98cde	1.51de
2009	1.98	1.83	2.32	**3.31**	2.69	2.06	2.53	2.37	1.86	1.83
2010	2.72	2.70	**2.91**	2.82	2.58	2.36	2.75	2.18	2.19	2.15
2011	**4.34a**	2.33bc	2.38bc	2.64bc	2.80bc	2.57bc	2.62bc	3.39ab	2.83bc	2.24c
2012	**3.83a**	2.95b	1.06d	1.57cd	1.42cd	1.68cd	1.46cd	1.77c	3.30ab	1.08d
2013	**4.23a**	2.59b	1.50c	2.21bc	2.10bc	2.02bc	2.01bc	2.18bc	3.55a	1.39c
7-year Average	**2.95a**	2.21bc	2.32bc	2.57abc	2.52abc	2.13cd	2.63ab	2.25bc	2.47abc	1.70d
	Biennial Harvest									
2009	1.63ef	1.24f	4.02ab	2.86cd	3.55bc	2.99bcd	**4.75a**	2.78cd	2.77cd	2.51de
2011	3.97ab	2.50de	3.87abc	1.72e	2.83bcde	2.68bcde	**4.20a**	2.76bcde	3.73abcd	2.62cde
2013	**6.55a**	2.87c	2.23cd	1.69cd	2.07cd	2.61c	2.70c	1.87cd	4.62b	1.32d
3-year Average	**4.05a**	2.20d	3.37abc	2.09d	2.82bcd	2.76bcd	3.88a	2.47cd	3.71ab	2.15d
	Ratio of Biennial/Annual									
2009/ 2008+2009	0.45	0.39	0.81	0.47	0.66	0.81	0.85	0.62	0.72	0.75
2011/ 2010+2011	0.56	0.50	0.73	0.32	0.53	0.54	0.78	0.50	0.74	0.60
2013/ 2012+2013	0.81	0.52	0.87	0.45	0.59	0.71	0.78	0.47	0.67	0.53
Average	0.65	0.48	0.79	0.41	0.59	0.67	0.81	0.53	0.71	0.63

[1] Experimental entry lists and abbreviations are shown in Table 1.
[2] Within rows for each harvest, means followed by the same letter are not significantly different according to LSD (0.05) for species yield.
[3] Bold number is the highest biomass yield within a year.

Table 16. Yield (ton/acre) at harvest (annual vs. biennial) of ten experiment entries for evaluating biomass yield for bioenergy at **Williston dry land**, North Dakota 2007 through 2013.

Harvest Year	Entries[1]									
	Sunburst	Dacotah	Alkar	Haymaker	CRP1	CRP2	C_4C_31	C_4C_32	C_4C_41	C_3C_3
	Annual Harvest									
2007	0.83d[2]	0.91bcd	0.96bcd	**1.23a**[3]	1.04abc	0.87cd	1.06ab	0.87cd	0.90bcd	0.83d
2008	0.50	0.60	0.70	**0.79**	0.72	0.62	0.68	0.75	0.69	0.61
2009	0.93bc	0.84bc	1.05ab	**1.27a**	1.05ab	0.78c	0.93bc	0.85bc	1.00bc	0.90bc
2010	1.03	1.13	1.08	**1.32**	1.15	1.14	1.05	0.99	1.07	1.00
2011	1.95	1.92	1.62	**2.08**	1.72	1.97	1.58	1.75	1.93	1.69
2012	**1.45a**	1.09bcd	0.77e	1.09bcd	1.02cde	0.83de	0.92cde	1.11bc	1.30ab	0.91cde
2013	2.16a	1.34c	1.37c	1.75b	1.56bc	1.43bc	1.64bc	1.56bc	**2.24a**	1.42bc
7-year Average	1.26	1.12	1.08	**1.36**	1.18	1.09	1.12	1.13	1.30	1.05
	Biennial Harvest									
2009	1.35	1.16	1.16	1.22	**1.40**	0.95	1.24	1.31	1.15	1.22
2011	2.18	2.05	1.93	2.22	2.24	1.84	1.92	**2.68**	2.34	2.13
2013	1.81bcd	2.13ab	1.53d	1.66cd	1.75bcd	1.73bcd	1.73bcd	**2.53a**	2.03bc	1.48d
3-year Average	1.78	1.78	1.54	1.70	1.80	1.50	1.63	**2.17**	1.84	1.61
	Ratio of Biennial/Annual									
2009/(2008+2009)	0.94	0.81	0.66	0.59	0.79	0.68	0.77	0.82	0.68	0.81
2011/(2010+2011)	0.73	0.67	0.71	0.65	0.78	0.59	0.73	0.98	0.78	0.79
2013/(2012+2013)	0.50	0.88	0.71	0.58	0.68	0.77	0.68	0.95	0.57	0.64
Average	0.67	0.77	0.70	0.61	0.75	0.67	0.72	0.93	0.67	0.74

[1] Experimental entry lists and abbreviations are shown in Table 1.
[2] Within rows for each harvest, means followed by the same letter are not significantly different according to LSD (0.05) for species yield.
[3] Bold number is the highest biomass yield within a year.

Table 17. Yield (ton/acre) at harvest (annual vs. biennial) of ten experiment entries for evaluating biomass yield for bioenergy at **Williston irrigated land**, North Dakota 2007 through 2013.

Harvest Year	Entries[1] Sunburst	Dacotah	Alkar	Haymaker	CRP1	CRP2	C_4C_31	C_4C_32	C_4C_41	C_3C_3
					Annual Harvest					
2007	5.83a[2]	4.31bc	4.98ab	4.20bc	4.50bc	3.72c	5.61a	**5.85a**[3]	4.92ab	4.19bc
2008	**7.28a**	4.91c	3.16e	3.35e	3.24e	2.80e	4.27d	5.69b	5.87b	3.06e
2009	**5.76a**	4.09b	3.84b	3.72b	2.80c	3.48bc	3.92b	5.72a	5.02a	3.31bc
2010	5.33a	4.25bc	3.23def	2.51f	3.41cde	2.75ef	3.95cd	**5.44a**	5.11ab	3.43cde
2011	**5.62a**	3.93cd	3.08de	3.08de	3.21de	2.68e	4.67bc	5.59a	5.48ab	3.69d
2012	5.35a	3.67c	2.33ef	2.50ef	2.83de	1.89f	4.54b	**5.50a**	5.16ab	3.36cd
2013	5.02ab	3.24cd	2.51e	2.75de	2.75de	2.34e	4.52b	**5.33a**	5.01ab	3.71c
7-year Average	**5.74a**	4.06d	3.30e	3.16ef	3.25e	2.81f	4.50c	5.59ab	5.22b	3.54e
					Biennial Harvest					
2009	6.96a	5.43bc	5.48bc	3.93d	4.18cd	3.82d	6.12ab	**7.09a**	7.06a	6.57ab
2011	6.67a	5.22b	3.71d	3.40d	4.09bcd	3.77cd	4.94bc	**7.20a**	6.80a	4.58bcd
2013	**5.76a**	3.95c	2.13d	2.24d	2.21d	2.24d	4.45bc	5.32ab	5.58ab	4.38bc
3-year Average	6.46a	4.87b	3.77c	3.19c	3.49c	3.28c	5.17b	**6.54a**	6.48a	5.18b
					Ratio of Biennial/Annual					
2009/(2008+2009)	0.53	0.60	0.78	0.56	0.69	0.61	0.75	0.62	0.65	1.03
2011/(2010+2011)	0.61	0.64	0.59	0.61	0.62	0.69	0.57	0.65	0.64	0.64
2013/(2012+2013)	0.56	0.57	0.44	0.43	0.40	0.53	0.49	0.49	0.55	0.62
Average	0.56	0.61	0.62	0.53	0.57	0.62	0.60	0.59	0.61	0.76

[1] Experimental entry lists and abbreviations are shown in Table 1.
[2] Within rows for each harvest, means followed by the same letter are not significantly different according to LSD (0.05) for species yield.
[3] Bold number is the highest biomass yield within a year.

Table 18. Yield (ton/acre) at harvest (annual vs. biennial) of ten experiment entries for evaluating biomass yield for bioenergy at **Mandan**, North Dakota 2010 through 2013.

Harvest Year	Entries[1]									
	Sunburst	Trailblazer	Alkar	Manifest	CRP1	CRP2	$C_4C_3$1	$C_4C_4$1	$C_4C_4$2	SD Native
	Annual Harvest									
2010	2.45	2.28	**3.27**[3]	3.23	3.26	2.80	3.21	2.65	2.51	2.95
2012	1.52bc[2]	1.53bc	2.14a	**2.32a**	2.06a	1.88ab	2.06a	1.41bc	1.51bc	1.36c
2013	3.11	2.92	3.55	**3.85**	3.43	3.36	3.53	2.70	2.87	2.63
3-year Average	2.36	2.24	2.99	**3.13**	2.91	2.68	2.94	2.25	2.30	2.31
	Biennial Harvest									
2013	3.65b	3.52b	3.65b	3.49b	3.44b	3.35b	**5.05a**	3.01bc	2.93bc	2.30c
	Ratio of Biennial/Annual									
2013/ (2012+2013)	0.79	0.79	0.64	0.57	0.63	0.64	0.90	0.73	0.67	0.58

[1] Experimental entry lists and abbreviations are shown in Table 1.
[2] Within rows for each harvest, means followed by the same letter are not significantly different according to LSD (0.05) for species yield.
[3] Bold number is the highest biomass yield within a year.

Table 19. Yield (ton/acre) at harvest (annual vs. biennial) of ten experiment entries for evaluating biomass yield for bioenergy at **Wing**, North Dakota 2010 through 2013.

Harvest Year	Entries[1]									
	Sunburst	Trailblazer	Alkar	Manifest	CRP1	CRP2	$C_4C_3$1	$C_4C_4$1	$C_4C_4$2	SD Native
	Annual Harvest									
2010	1.42bc[2]	0.94c	2.13ab	1.24c	1.44bc	**2.36a**[3]	2.29a	0.94c	0.85c	1.08c
2011	1.72d	0.97d	**4.54a**	3.03c	3.88abc	3.38bc	4.33ab	1.35d	1.13d	0.83d
2012	1.89	2.14	**3.47**	2.55	2.70	2.86	3.27	1.25	1.50	1.68
2013	3.73abcd	3.97abcd	4.96ab	4.35abc	4.69abc	**5.11a**	5.07ab	2.78d	3.33cd	3.65bcd
4-year Average	2.19bcd	2.01cd	**3.77a**	2.79abc	3.18ab	3.43a	3.74a	1.58d	1.71d	1.81cd
	Biennial Harvest									
2011	1.14c	1.22bc	4.13a	2.52b	4.67a	4.65a	**4.75a**	1.75bc	1.24bc	1.00c
2013	3.89bc	3.37c	3.96bc	3.64c	**6.05a**	5.65ab	5.63ab	4.18bc	3.44c	2.56c
2-year Average	2.52c	2.30c	4.04ab	3.08bc	**5.36a**	5.15a	5.19a	2.96bc	2.34c	1.78c
	Ratio of Biennial/Annual									
2011/(2010+2011)	0.36	0.64	0.62	0.59	0.88	0.81	0.72	0.76	0.63	0.52
2013/(2012+2013)	0.69	0.55	0.47	0.53	0.82	0.71	0.68	1.04	0.71	0.48
Average	0.57	0.57	0.54	0.55	0.84	0.75	0.69	0.94	0.69	0.49

[1] Experimental entry lists and abbreviations are shown in Table 1.
[2] Within rows for each harvest, means followed by the same letter are not significantly different according to LSD (0.05) for species yield.
[3] Bold number is the highest biomass yield within a year.

Table 20. Yield (ton/acre) at harvest (high vs. low stubble height) of ten experiment entries for evaluating biomass yield for bioenergy at **Streeter**, North Dakota 2010 through 2013.

Harvest Year	Entries[1]									
	Sunburst	Trailblazer	Alkar	Manifest	CRP1	CRP2	C_4C_31	C_4C_41	C_4C_42	SD Native
	3-inch Low Stubble Harvest									
2010	0.74bcd[2]	0.94abc	0.96abc	0.95abc	1.05abc	**1.17a**[3]	1.14ab	0.67cd	0.64cd	0.35d
2011	3.29ab	2.72bc	3.31ab	2.72bc	2.71bc	2.65bc	**3.70a**	3.10ab	2.17cd	1.55d
2012	3.00a	2.95a	1.56b	1.66b	1.70b	2.01b	1.85b	**3.57a**	1.51b	1.25b
2013	**3.88a**	2.84b	2.21bc	2.69b	2.49bc	2.38bc	2.45bc	3.88a	2.11bc	1.71c
4-year Average	2.73ab	2.36abc	2.01bc	2.01bc	1.99bcd	2.06abc	2.29abc	**2.80a**	1.61cd	1.22d
	10-inch High Stubble Harvest									
2010	0.39	0.29	0.25	**0.70**	0.33	0.47	0.42	0.17	0.30	0.08
2011	2.43a	2.37a	1.66ab	2.40a	1.55b	1.52b	**2.46a**	2.13ab	2.18ab	0.70c
2012	2.44ab	**2.86a**	0.71c	0.98c	0.69cd	1.14c	0.82c	2.25b	0.81c	0.21d
2013	2.77a	**2.90a**	1.34b	1.69b	1.62b	1.67b	1.40b	2.61a	1.17b	0.58c
4-year Average	2.01ab	**2.11a**	0.99de	1.44bcd	1.05de	1.20cd	1.27cd	1.79abc	1.12d	0.39e
	Ratio of High Stubble/Low Stubble									
2010	0.53	0.31	0.26	0.74	0.31	0.40	0.37	0.25	0.47	0.23
2011	0.74	0.87	0.50	0.88	0.57	0.57	0.66	0.69	1.00	0.45
2012	0.81	0.97	0.46	0.59	0.41	0.57	0.44	0.63	0.54	0.17
2013	0.71	1.02	0.61	0.63	0.65	0.70	0.57	0.67	0.55	0.34
4-year Average	0.74	0.89	0.49	0.72	0.53	0.58	0.56	0.64	0.69	0.32

[1] Experimental entry lists and abbreviations are shown in Table 1.
[2] Within rows for each harvest, means followed by the same letter are not significantly different according to LSD (0.05) for species yield.
[3] Bold number is the highest biomass yield within a year.

Table 21. Yield (ton/acre) at harvest (high vs. low stubble height) of ten experiment entries for evaluating biomass yield for bioenergy at **Wing**, North Dakota 2010 through 2013.

Harvest Year	Entries[1]									
	Sunburst	Trailblazer	Alkar	Manifest	CRP1	CRP2	C_4C_31	C_4C_41	C_4C_42	SD Native
	3-inch Low Stubble Harvest									
2010	1.25d[2]	1.23d	**2.97a**[3]	1.54bcd	2.35abc	2.41ab	2.75a	1.09d	1.44cd	0.87d
2011	1.11d	1.82d	**4.75a**	3.14c	3.64bc	3.11c	4.50ab	1.44d	1.15d	1.29d
2012	2.21	1.78	2.83	1.85	2.01	**2.83**	2.31	1.83	1.77	1.75
2013	4.63ab	2.89c	4.82a	3.27bc	3.69abc	3.88abc	**4.90a**	3.62abc	3.25bc	2.76c
4-year Average	2.30cd	1.93d	**3.84a**	2.45cd	2.92bc	3.06abc	3.62ab	2.00d	1.91d	1.66d
	10-inch High Stubble Harvest									
2010	0.59b	0.66b	**2.00a**	1.20ab	1.23ab	1.86a	1.68a	0.70b	0.54b	0.45b
2011	1.07bc	0.89c	**3.78a**	1.92b	3.19a	3.35a	3.04a	0.45c	0.44c	0.41c
2012	1.32bc	1.19bc	1.58ab	1.49abc	1.62ab	**2.22a**	1.54abc	0.90bc	0.92bc	0.77c
2013	3.33abc	2.38bcd	**3.81a**	2.18cd	2.86abcd	2.88abcd	3.40ab	2.13d	1.80d	1.93d
4-year Average	1.58cde	1.28de	**2.79a**	1.70bcd	2.23abc	2.58a	2.42ab	1.05de	0.93e	0.89e
	Ratio of High Stubble/Low Stubble									
2010	0.47	0.54	0.67	0.78	0.52	0.77	0.61	0.64	0.38	0.52
2011	0.96	0.49	0.80	0.61	0.88	1.08	0.68	0.31	0.38	0.32
2012	0.60	0.67	0.56	0.81	0.81	0.78	0.67	0.49	0.52	0.44
2013	0.72	0.82	0.79	0.67	0.78	0.74	0.69	0.59	0.55	0.70
4-year Average	0.69	0.66	0.73	0.69	0.76	0.84	0.67	0.52	0.49	0.53

[1] Experimental entry lists and abbreviations are shown in Table 1.
[2] Within rows for each harvest, means followed by the same letter are not significantly different according to LSD (0.05) for species yield.
[3] Bold number is the highest biomass yield within a year.

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Central Grasslands Research Extension Center

4824 48th Ave. SE, Streeter, ND 58483

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