Initiation Date and Nitrogen Rate for Stockpiling Smooth Bromegrass in the North-Central USA

Gregory J. Cuomo,* Margot V. Rudstrom, Paul R. Peterson, Dennis G. Johnson,
Av Singh, and Craig C. Sheaffer

ABSTRACT

Increasing costs associated with winter feeding have renewed interest in extending the grazing season in the North-Central USA. A factorial design with three N treatments was applied to existing smooth bromegrass (*Bromus inermis* Leyss.) pastures to evaluate initiation dates and N fertilization rates for stockpiling forage. Stockpile initiation dates were 1 June, 15 June, 1 July, 15 July, 1 August, and 15 August. Nitrogen fertilization treatments were 0, 56, or 112 kg ha^{-1}. Data collected included forage mass in October, residual forage mass the subsequent April, leaf concentration, and forage nutritive value. October forage availability was generally greater from earlier stockpile initiation dates (2.58, 2.44, 1.98, 1.28, 0.78, and 0.65 Mg dry matter ha^{-1} for 1 June, 15 June, 1 July, 15 July, 1 August, and 15 August stockpile initiation dates, respectively; LSD at 0.05 = 0.19). Leaf mass available in October was similar through the 15 July stockpile initiation date. October forage mass was greater with 56 kg N ha^{-1} than with 0 N fertilization, averaging 1.26, 1.75, and 1.85 Mg ha^{-1} (LSD at 0.05 = 0.14) for 0, 56, and 112 kg N ha^{-1}, respectively, when averaged across stockpile initiation dates and years. Trends in April forage mass for stockpile initiation date and N fertilization tended to be similar to October. Crude protein tended to increase and acid detergent fiber and neutral detergent fiber tended to decrease as stockpile initiation was later in the season. These results indicate that initiating stockpiling of smooth bromegrass–dominated pastures about 1 July with 56 kg N ha^{-1} optimizes stockpiled smooth bromegrass in the North-Central region.

PASTURE-BASED livestock production in the North-Central USA has often been limited to a 5-mo (May through September) growing season. Increased costs associated with winter-feeding hay or silage has generated renewed interest in extending the grazing season in the region. Stockpiling is managing a pasture or hay land to accumulate forage produced during the growing season to be grazed at a later time. Extending the grazing season with stockpiled forage in autumn has been shown to be an economical way to maintain livestock in the mid-Atlantic region of the USA (Poore et al., 2000). The practice of accumulating cool-season grasses, particularly tall fescue (*Festuca arundinacea* Schreb.), for stockpiled forage has been well investigated in the Midsouth (Taylor and Templeton, 1976; Rayburn et al., 1979; and Burns and Chamblee, 2000a) and Midwest (Wedin et al., 1967; Gerrish et al., 1994; and Riesterer et al., 2000) regions of the USA. The applicability of this practice and more specifically the stockpiling of smooth bromegrass (*Bromus inermis* Leyss.) in the North-Central USA have not been thoroughly evaluated.

Smooth bromegrass is the predominant cool-season grass in much of the North-Central USA. Widespread adaptation (Vogel et al., 1996), winterhardiness (Limin and Fowler, 1987), and high palatability make smooth bromegrass a well-adapted forage crop for hay or pasture in this region. Smooth bromegrass produces the majority of its growth in early spring (Engel et al., 1987; Moore et al., 1991). Relatively slow regrowth after defoliation and summer growth rate raises questions regarding the suitability of smooth bromegrass for stockpiling (Carlson and Newell, 1983). In a multilocation trial in Wisconsin, Riesterer et al. (2000) evaluated seven cool-season grasses under varying levels of fertility and determined that smooth bromegrass stockpiled beginning in early August produced inadequate forage dry matter (DM) to be considered suitable for stockpiling in the Upper Midwest USA. Despite this, many pastures in the North-Central USA consist of smooth bromegrass, and management strategies to improve its potential for extending the grazing season would be desirable.

Research suggests that earlier stockpiling initiation dates in the summer result in greater forage yield but lower forage quality (Matches et al., 1973; Taylor and Templeton, 1976; Burns and Chamblee, 2000a). When stockpiled from 15 August until 1 December in Kentucky, fertilizing with 50 kg N ha^{-1} increased tall fescue forage mass 64% and Kentucky bluegrass (*Poa pratensis* L.) forage mass 131% compared with unfertilized pastures (Taylor and Templeton, 1976). Several studies (Collins and Balasko, 1981; Fribourg and Bell, 1984; Burns and Chamblee, 2000b) in the Midsouth have shown that later stockpile initiation dates (August–September) result in higher forage nutrient concentrations during the winter than earlier dates (June–July).

Nitrogen fertilization has also been shown to increase stockpile forage mass. In Maryland, tall fescue forage production increased 1.01 Mg ha^{-1} when fertilized with 100 kg N ha^{-1} compared with unfertilized tall fescue when stockpiled 100 d (Archer and Decker, 1977). In a study of N rates (0, 45, 90, or 135 kg ha^{-1}) and timing of N application (0, 14, or 28 d after hay cutting) for stockpiling tall fescue, Gerrish et al. (1994) reported the

---

G.J. Cuomo, M.V. Rudstrom, and D.G. Johnson, Univ. of Minnesota West Central Res. and Outreach Cent., State Hwy. 329, Morris, MN 56267; P.R. Peterson and C.C. Sheaffer, Dep. of Agron. and Plant Genet., Univ. of Minnesota, St. Paul, MN 55108; and A. Singh, Organic Agric. Cent. of Canada, Nova Scotia Agric. College, P.O. Box 550, Truro, NS, Canada B2N-5E3. This research was supported by the Minnesota Agric. Exp. Stn. Received 4 June 2004. *Corresponding author (cuomogj@mrs.umn.edu).

Published in Agron. J. 97:1194–1201 (2005).
Pasture Management
doi:10.2134/agronj2004.0149

677 S. Segoe Rd., Madison, WI 53711 USA

Abbreviations: ADF, acid detergent fiber; CP, crude protein; DM, dry matter; NDF, neutral detergent fiber; NIRS, near infrared reflectance spectrophotometry.

most efficient response to N occurred using 45 kg ha^{-1} at time of harvest.

Both forage yield and forage nutrient concentrations of stockpiled grasses have been shown to decline as winter progresses (Poore et al., 2000). Taylor and Templeton (1976) showed that from December to February, forage mass declined by 21, 26, and 5% for 0, 50, and 100 kg N ha^{-1}, respectively.

Fribourg and Bell (1984) associated susceptibility to weathering as a primary cause in forage quality changes over winter. In their study, September-accumulated tall fescue with 140 g kg^{-1} crude protein (CP) declined to 120 g kg^{-1} by January in Tennessee.

Stockpiling has not been as widely used in the North-Central USA as it has in other more temperate regions of the USA. Much different growing and dormant season conditions may require that different management strategies are needed in this area. In the North-Central USA, most forage, including smooth bromegrass, senesces by mid-October. If desirable management strategies can be identified, stockpiled smooth bromegrass has the potential to increase the length of the grazing season and decrease the length of the hay or silage feeding in this region. The objective of this study was to identify stockpile initiation dates and N fertilization rates that optimize stockpile yield and quality of smooth bromegrass–dominated pastures in the North-Central USA.

MATERIALS AND METHODS

The experimental site was located at the University of Minnesota's West Central Research and Outreach Center near Morris, MN. Average precipitation is 60 cm yr^{-1} with about 40 cm falling during the growing season. The experiment was conducted on a Doland silt loam (fine loamy, mixed, Udic Haploboroll) soil that is an undulating, well-drained soil formed in silty material underlain by glacial till. The A horizon extends to about 25 cm with glacial till beginning at about 60 cm. At the beginning of the study, soil pH was 7.9, organic matter was 4.0%, NO_3–N was 10 kg ha^{-1} in the top 60 cm of the soil, Olsen P (Olsen et al., 1954) was 37, and soil test K was 408 on the experimental site.

A randomized complete block design with four replications was applied to existing cool-season grass pastures to evaluate initiation dates and N fertilization rates for stockpiling smooth bromegrass–dominant pasture in adjacent sites during the 1996 and 1998 growing seasons. Stockpile initiation dates were 1 June, 15 June, 1 July, 15 July, 1 August, and 15 August. Nitrogen fertilization treatments were 0, 56, or 112 kg ha^{-1} applied as ammonium nitrate on the date of stockpile initiation for each treatment. Individual treatment plots were 4 by 10 m. The experimental area for each stockpile initiation date treatment was mowed to leave a stubble height of 7.5 cm on the initiation date for that treatment. Electric fence was used to exclude cattle from the area.

For at least 30 yr before 1994, the experimental pasture had been grazed with little rotation by beef cattle from May through September. Beginning in 1995 until the initiation of stockpiling treatments, lactating dairy cattle grazed flexibly sized paddocks for 12 h at a stocking rate of 56 000 kg of lactating Holstein cow ha $^{-1}$ five or six times per 5-mo grazing season. Grazing was generally initiated when forage height was 25 to 40 cm. When the trial was initiated in 1996, the pasture consisted of primarily smooth bromegrass with minor amounts of quackgrass [*Elytrigia repens* (L.) Nevski.] and Kentucky bluegrass.

Data collected included biomass and leaf concentration and forage CP, acid detergent fiber (ADF), and neutral detergent fiber (NDF) concentrations. Data were collected in October in the year treatments were applied and in the following April to assess the value of stockpiled forage that overwintered. Biomass data were collected in October by harvesting a 0.9- by 10-m swath through each plot with a flail-type forage harvester. Biomass data in April were collected by hand clipping residual biomass with a 30- by 60-cm frame. Biomass was hand-clipped in two locations in each plot in spring. Samples for CP, ADF, and NDF concentrations were hand-clipped in two additional locations in each plot in an effort to reduce loss of plant material that might be associated with flail harvesting smooth bromegrass residue that is desiccated, light, and fluffy.

Crude protein, ADF, and NDF of whole herbage were analyzed using near infrared reflectance spectrophotometry (NIRS). Spectra for NIRS analysis were collected with NIRS Systems (Silver Springs, MD) Model 6500 scanning monochrometer using the 400- to 2500-nm spectral range. Equations for predicting CP, ADF, and NDF were developed from a similar spectral population using Infrasoft International (ISI, Port Matilda, PA) NIRS 3.0 version 4.0 software program Calibrate with the modified partial least squares regression option (Shenk and Westerhaus, 1991). A monitoring subset of samples from this study was analyzed using the Kjeldahl procedure for CP and procedures of Goering and Van Soest (1970) for ADF and NDF. Calibration statistics (standard error of cross validation, SECV) for NIR equations were SECV = 9.6 g kg^{-1} (R^2 = 0.90) for CP, SECV = 22.3 g kg^{-1} (R^2 = 0.79) for ADF, and SECV = 27.8 g kg^{-1} (R^2 = 0.88) for NDF.

Leaf concentration was also estimated using NIRS. Leaf and stem composition were determined by clipping a 30- by 60-cm sample and hand-separating leaves from stems and inflorescences. At the first harvest in fall 1996, all 72 plots from the trial were clipped and hand-separated. In following harvests, one plot from each treatment combination (6 stockpile initiation dates × 3 N fertilization rates) was randomly selected and clipped for separating into leaf and stem components. Leaf data were used to develop a predictive equation for leaf percentage for each treatment at the fall and spring harvest dates. Calibration statistics for leaf concentration were SECV = 67.8 g kg^{-1} (R^2 = 0.85).

The experiment was analyzed as a factorial ANOVA (Steel and Torrie, 1980) using the GLM procedure of SAS (SAS Inst., 1996). The model for biomass, forage nutritive value, and leaf concentration included effects due to stockpile initiation date, N treatment, year, and their interactions. Residual mean squares were used as the error terms. Means were compared using the method of LSD and considered significantly different at a $P < 0.05$.

RESULTS AND DISCUSSION

Climate Data

Monthly temperature and total precipitation data for April 1996 through April 1999 and 117-yr averages for Morris, MN are presented in Table 1. Temperatures were near normal throughout the experiments. During the 1996 growing season, precipitation was below normal in June and August. During the 1998 growing season, precipitation was at or above normal except for September, which was very dry.

Table 1. Average temperature and precipitation data for April 1996 through April 1999 and 117-yr average for Morris, MN.

Year		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1996	Average temp., °C				4	12	20	20	20	15	8	−7	−13
	Precipitation, mm				21	83	60	85	47	62	137	59	19
1997	Average temp., °C	−15	−10	−5	4	11	21	21	20	17	9	−4	−4
	Precipitation, mm	57	8	56	69	40	64	130	100	33	56	13	5
1998	Average temp., °C	−11	−3	−3	10	17	18	22	22	19	10	0	−3
	Precipitation, mm	26	30	29	46	80	146	106	91	9	130	32	6
1999	Average temp., °C	−13	−4	0	8								
	Precipitation, mm	32	5	42	35								
117 yr	Average temp., °C	−13	−10	−3	6	14	19	22	21	16	8	−1	−9
	Precipitation, mm	18	17	30	58	75	100	94	77	57	44	25	17

Stockpile Forage Availability

Generally, forage mass availability in October and the following April increased with earlier stockpile initiation dates and with N fertilization to 56 kg ha^{-1}. However, two-way interactions were detected for stockpiled forage mass available in both October and April for stockpile initiation date × N fertilization rate (Fig. 1), N fertilization rate × year (Fig. 2), and stockpile initiation date × year (Fig. 3).

October Forage Mass

Stockpiled forage mass available in October was similar and greatest when stockpiling was initiated 1 or 15 June, declined through July stockpile initiation dates, and was similar and lowest for 1 and 15 August stockpile initiation dates (Fig. 1). Smooth bromegrass may have approached its growth potential when stockpiling was initiated in June, thus resulting in similar October forage mass availability for June stockpile initiation dates. This trend is more evident at 0 and 56 kg N ha^{-1} than at 112 kg N ha^{-1}. Additionally, with the short growing season at this latitude and the dry August in 1996 and September in 1998 (Table 1), smooth bromegrass may not have had enough time for adequate regrowth to detect differences among August stockpile initiation dates before senescence in October. When averaged across N fertilization rates and years, stockpiled forage mass averaged 2.58, 2.44, 1.98, 1.28, 0.78, and 0.65 Mg ha^{-1} for 1 June, 15 June, 1 July, 15 July, 1 August, and 15 August stockpile initiation dates, respectively (LSD at 0.05 = 0.19).

Nitrogen fertilization increased October forage mass availability over no N fertilization (Fig. 1). Available forage mass in October was greater with 56 kg N ha^{-1} than with 0 N fertilization. Further forage mass increase was generally not detected with 112 kg N ha^{-1} compared with 56 kg N ha^{-1}. This is in agreement with stockpiling research with tall fescue in Missouri that indicated an economic response to N fertilizer at rates above 56 kg N ha^{-1} was unlikely (Gerrish et al., 1994). When averaged across stockpile initiation dates and years, forage mass in October averaged 1.26, 1.75, and 1.85 Mg ha^{-1} (LSD at 0.05 = 1.4) for 0, 56, and 112 kg N ha^{-1}, respectively.

Nitrogen fertilization rate × year interactions were detected (Fig. 2). Increasing N fertilization rate increased stockpiled yield in both years, but the extent of yield response varied with year. As N rate increased from 0 to 112 kg N ha^{-1}, stockpiled yield averaged over all harvests increased by 71% in 1996 while only increasing 19% in 1998. Widely contrasting June through Sep-

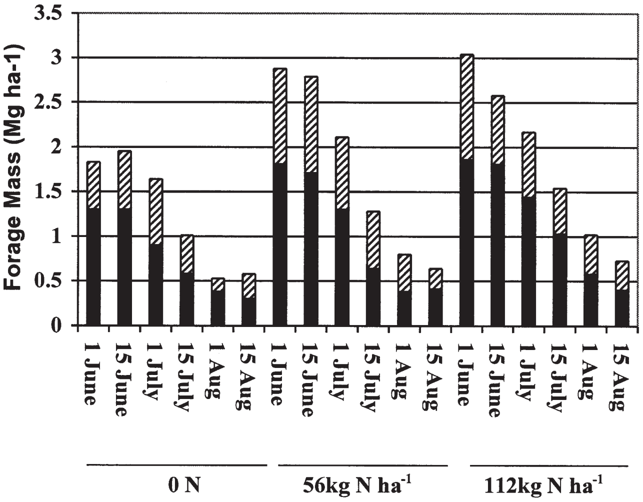

Fig. 1. Stockpile date and N management of stockpiled smooth bromegrass in the north central USA. October forage mass availability for a given stockpile initiation date and N fertilization management strategy is represented by an entire bar, April forage mass by the black portion of a bar, and forage mass disappearance over winter by the hashed portion of a bar. Data presented are averaged over years. LSD(0.05) is 0.34 Mg ha^{-1} for October forage mass availability, 0.24 Mg ha^{-1} for April forage mass availability, and 0.26 Mg ha^{-1} for forage mass disappearance over winter.

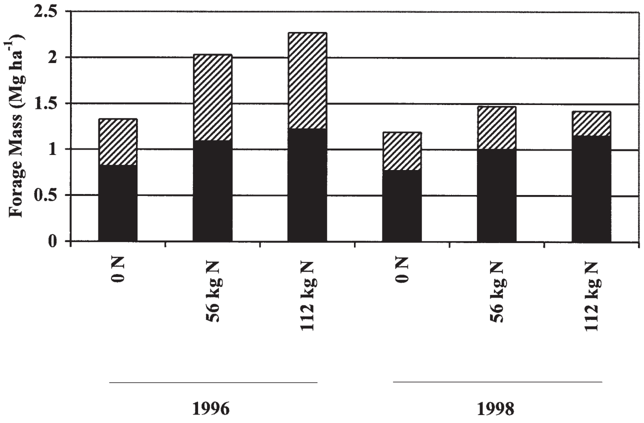

Fig. 2. N management and year of stockpiled smooth bromegrass in the north central USA. October forage mass availability for a given stockpile initiation date and N fertilization management strategy is represented by an entire bar, April forage mass by the black portion of a bar, and forage mass disappearance over winter by the hashed portion of a bar. Data presented are averaged over stockpile initiation dates. LSD(0.05) is 0.2 Mg ha^{-1} for October forage mass availability, 0.14 Mg ha^{-1} for April forage mass availability, and 0.2 Mg ha^{-1} for forage mass disappearance over winter.

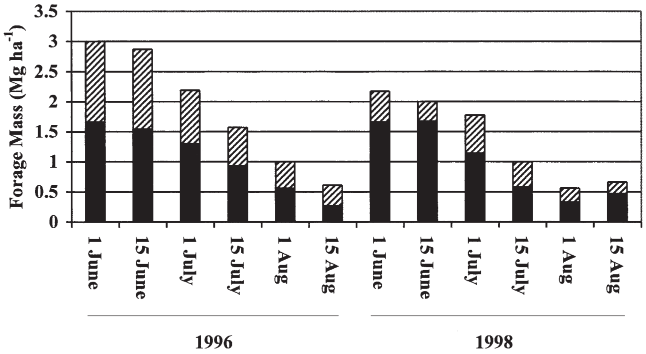

Fig. 3. Initiation date and year interactions of stockpiled smooth bromegrass in the north central USA. October forage mass availability for a given stockpile initiation date and N fertilization management strategy is represented by an entire bar, April forage mass by the black portion of a bar, and forage mass disappearance over winter by the hashed portion of a bar. Data presented are averaged over N fertility management strategies. LSD(0.05) is 0.28 Mg ha^{-1} for October forage mass availability, 0.2 Mg ha^{-1} for April forage mass availability, and 0.29 Mg ha^{-1} for forage mass disappearance over winter.

tember precipitation patterns in 1996 and 1998 may have influenced this response. Despite above-normal precipitation in June through August 1998, a very dry September appears to have limited stockpile forage available in October.

Stockpile initiation date × year interactions (Fig. 3) were likely the result of October forage mass availability being greater in 1996 than in 1998 for all stockpile initiation dates except the 15 August date. The short regrowth period between the 15 August stockpile initiation date and senescence may have masked environmental differences between years.

April Residual Stockpile Forage Mass

In the North-Central region, forage stockpiled for fall grazing may become inaccessible as a result of snow. Thus, the availability and nutritive value of stockpiled forage the following spring is of importance when evaluating the applicability of stockpiling forage in the North-Central region of the USA.

Stockpile initiation date × N fertilizer rate interactions for forage mass remaining in April were detected (Fig. 1). Similar to stockpiled forage mass in October, these interactions resulted from inconsistencies in the general trend toward greater forage availability with earlier stockpile initiation dates and with increasing N fertilization.

Forage mass that disappeared over winter tended to decrease as stockpile initiation date was delayed (Fig. 1; 0.93, 0.83, 0.76, 0.53, 0.33, and 0.28 Mg ha^{-1} for 1 June, 15 June, 1 July, 15 July, 1 August, and 15 August stockpile initiation dates when averaged over N fertilization rates and years, respectively; LSD at 0.05 = 0.2). However, percentage forage mass loss over winter was similar among stockpile initiation dates and averaged 36%.

Forage mass losses over winter were greater with N fertilization following the 1996 growing season than following the 1998 growing season (Fig. 2). The combination of greater October forage availability in 1996 and greater forage mass losses over winter following the 1996 growing season resulted in no year × N fertilization interactions for forage residue availability in April. In April, forage residue availability averaged 0.8, 1.05, and 1.19 Mg ha^{-1} for 0, 56, and 112 kg of N ha^{-1}, respectively (LSD at 0.05 = 0.14).

Percentage DM losses with N fertilization compared with 0 N tended to be greater following the 1996 growing season than the 1998 growing season (36, 46, and 46% for 0, 56, and 112 kg ha^{-1} of N fertilizer in 1996, respectively, and 36, 32, and 20% for 0, 56, and 112 kg ha^{-1} of N fertilizer in 1998 when averaged across stockpile initiation dates and years; LSD at 0.05 = 11.2). Thus, forage losses over winter were more variable with N fertilization compared with no N. Relatively similar late-fall and winter environmental conditions following the 1996 and 1998 growing season do not appear to account for differences in DM losses over winter (Table 1). This contrasts with findings of Balasko (1977), who reported that 0 N fertility had significantly more losses in forage mass of tall fescue than high-fertility treatments.

Stockpile initiation date × year interactions for April forage mass availability resulted from differences in trends with stockpile initiation dates that were later in the growing season between years (Fig. 3). When averaged over N fertility rates, DM losses over winter tended to be greater following the 1996 growing season (0.8 Mg ha^{-1}, 43% of forage mass available in October) than the 1998 growing season (0.39 Mg ha^{-1}, 30% of forage mass available in October). These losses in smooth bromegrass forage mass were somewhat more than the 19 to 29% losses in tall fescue forage mass reported when harvest was delayed from December to February in North Carolina (Poore et al., 2000).

Leaf Concentration

Under grazing, leaf material is often consumed more readily than stem material. As such, stockpile initiation date and N management strategies that optimize available leaf mass may be desirable. Interactions with stockpile initiation date for leaf mass were not detected. When averaged across N fertility rates and years, leaf mass available in October was similar from 1 June through 1 July stockpile initiation dates, declined through July, and was similar and least for 1 and 15 August (1.51, 1.73, 1.57, 1.11, 0.63, and 0.57 Mg ha^{-1} for 1 June, 15 June, 1 July, 15 July, 1 August, and 15 August, respectively; LSD at 0.05 = 0.23). The same trend held true for residual leaf mass available the following April (1.0, 1.08, 0.97, 0.55, 0.63, and 0.28 Mg ha^{-1} for 1 June, 15 June, 1 July, 15 July, 1 August, and 15 August, respectively; LSD at 0.05 = 0.22). These trends for available leaf forage mass across stockpile initiation dates are similar to those for whole herbage mass availability (Fig. 1 and 3).

N fertilization rate × year interactions were detected for October leaf mass. Interactions were the result of leaf mass increasing with N fertilization in 1996 but not during the 1998 growing season (0.94, 1.56, 1.74, 0.93, 0.98, and 1.0 Mg ha^{-1} for 0, 56, and 112 kg N ha^{-1} for

Table 2. Stockpile initiation date × N fertilization management interactions for crude protein (CP), CP mass per hectare, acid detergent fiber (ADF), and neutral detergent fiber (NDF) concentrations of stockpiled forage in October and residual forage in April averaged over 2 yr.

Stockpile initiation date	N rate	CP		CP mass		ADF		NDF	
		Oct.	April	Oct.	April	Oct.	April	Oct.	April
	kg N ha^{-1}	g kg^{-1}		kg ha^{-1}		g kg^{-1}			
1 June	0	80	77	150	100	450	500	670	720
1 June	56	84	84	240	150	450	510	680	720
1 June	112	95	93	280	170	440	500	660	710
15 June	0	85	88	170	120	440	480	660	700
15 June	56	94	89	260	160	430	490	670	720
15 June	112	107	109	270	200	430	480	640	700
1 July	0	104	107	170	100	430	470	640	690
1 July	56	114	123	230	150	420	450	630	660
1 July	112	121	119	270	170	420	470	640	690
15 July	0	123	122	130	60	410	460	610	680
15 July	56	119	127	160	80	420	450	630	680
15 July	112	140	141	210	160	400	440	600	660
1 Aug.	0	111	116	60	50	420	470	620	690
1 Aug.	56	164	135	130	50	360	440	540	650
1 Aug.	112	176	173	170	80	350	410	560	620
15 Aug.	0	143	127	80	40	380	450	570	660
15 Aug.	56	167	134	110	50	370	440	550	650
15 Aug.	112	189	168	140	70	350	410	530	620
LSD at 0.05		15	18	22	20	32	27	41	NS

1996 and 1998, respectively; LSD at 0.05 = 0.16). This interaction was not detected for residual leaf mass in April as a result of greater leaf mass loss following the 1996 growing season compared with the 1998 growing season. Residual leaf mass in spring was greater when N was applied to smooth bromegrass compared with 0 N (0.55, 0.71, and 0.85 Mg ha^{-1} for 0, 56, and 112 kg N ha^{-1}; LSD at 0.05 = 0.15). Percentage of October leaf mass that remained in spring was greater [LSD(0.05) = 4.9%] with 112 kg N ha^{-1} (76%) than 0 (68%) or 56 (69%) kg N ha^{-1}. In other research with tall fescue, Balasko (1977) suggested N fertilization reduced the rate of senescence and thereby increased tolerance to weathering over winter.

Stockpile Forage Nutritive Value

Generally, CP tended to increase and ADF and NDF tended to decrease as stockpile initiation was later in the season (Tables 2 and 3). This is in agreement with Collins and Balasko (1981), who reported that tall fescue stockpiled later in the growing season had greater forage nutritive value than forage stockpiled beginning earlier in the growing season. Increased CP concentration in stockpiled forage with N fertilization in this study also supported earlier research findings (Taylor and Templeton, 1976; Archer and Decker, 1977; Collins and Balasko, 1981; Gerrish et al., 1994).

However, stockpile initiation date × N fertility rate interactions were detected for many forage nutritive value parameters (Table 2). These interactions were the result of variability in the rate of change of forage nutritive value parameters with stockpile initiation dates and N fertility rates. Through the 15 July stockpile initiation date, an increase in N fertility from 0 to 112 kg N ha^{-1} had a corresponding increase in October CP concentration that ranged from 16 to 26%. With the August stockpile initiation dates, as N fertility increased from 0 to 112 kg N ha^{-1}, CP increased 32 and 59%.

Although CP tended to increase with later stockpile initiation dates, forage mass availability tended to decrease (Fig. 1 and 3). One way to consider both forage production and forage nutritive value is through kilograms of CP produced per hectare (kg CP ha^{-1}). As with forage mass, CP mass (kg CP ha^{-1}) available in October was stable through the 1 July stockpile initiation date and greater than at later stockpile initiation dates [220, 230,

Table 3. Stockpile initiation date × year interactions for crude protein (CP), CP mass per hectare, acid detergent fiber (ADF), and neutral detergent fiber (NDF) concentrations of stockpiled forage in October and residual forage in April averaged over three N rates.

Stockpile initiation date	Stockpile initiation year	CP		CP Mass		ADF		NDF	
		Oct.	April	Oct.	April	Oct.	April	Oct.	April
		g kg^{-1}		kg ha^{-1}		g kg^{-1}			
1 June	1996	80	71	240	120	420	490	600	660
1 June	1998	93	99	200	170	480	520	740	770
15 June	1996	93	80	270	130	390	470	580	650
15 June	1998	97	111	200	190	470	500	740	760
1 July	1996	116	103	260	130	390	460	560	630
1 July	1998	109	129	190	150	460	470	710	730
15 July	1996	126	110	200	110	390	450	560	640
15 July	1998	129	151	130	90	430	450	670	710
1 Aug.	1996	133	118	140	60	370	450	540	620
1 Aug.	1998	170	165	100	60	380	440	610	690
15 Aug.	1996	159	131	100	30	370	430	540	590
15 Aug.	1998	173	156	110	70	360	440	560	690
LSD at 0.05		12	15	18	16	26	22	34	25

Table 4. Stockpile initiation date × N fertilization rate interactions for the value of stockpiled forage mass and crude protein (CP) available in October and April when compared with grass hay with 140 g kg^{-1} CP valued at \$95 dry matter Mg^{-1} and fertilizer N valued at \$0.50 kg^{-1}. Data presented are averaged over 2 yr.

N rate	Stockpile initiation date	October forage value	April forage value	October CP value	April CP value	Cost of N
kg ha^{-1}		\$ ha^{-1}				
0	1 June	33.80	9.78	19.66	13.11	0
0	15 June	35.73	11.86	20.97	15.73	0
0	1 July	30.13	13.56	22.28	13.11	0
0	15 July	18.52	7.87	15.73	9.18	0
0	1 Aug.	9.71	2.70	6.55	5.24	0
0	15 Aug.	10.57	5.16	10.49	6.55	0
56	1 June	52.71	19.56	31.46	19.66	28
56	15 June	51.07	19.77	34.08	20.97	28
56	1 July	38.85	14.92	30.15	18.35	28
56	15 July	23.60	11.80	20.97	9.18	28
56	1 Aug.	14.66	7.73	15.73	6.55	28
56	15 Aug.	11.73	4.17	13.11	7.87	28
112	1 June	55.77	21.64	36.70	24.91	56
112	15 June	47.44	14.17	35.39	27.53	56
112	1 July	39.86	13.43	34.08	22.28	56
112	15 July	28.23	9.29	27.53	19.66	56
112	1 Aug.	18.61	8.00	22.28	11.80	56
112	15 Aug.	13.40	6.04	18.35	9.18	56

220, 170, 120, and 110 kg CP ha^{-1} for the 1 June, 15 June, 1 July, 15 July, 1 August, and 15 August stockpile initiation dates when averaged across N fertility management strategies and years, respectively; LSD(0.05) = 18].

Decreases in CP mass averaged about 70 kg CP ha^{-1} over winter. Changes in CP over winter tended to be relatively small compared with changes in DM over winter. As such, trends in CP mass disappearance over winter were similar to those of forage mass with greater losses at early stockpile initiation dates [140, 160, 140, 100, 60, and 50 kg CP ha^{-1} for the 1 June, 15 June, 1 July, 15 July, 1 August, and 15 August stockpile initiation dates when averaged over N fertility rates and years, respectively; LSD(0.05) = 24]. Differences in the proportion of CP mass that disappeared over winter for stockpile initiation dates were not detected and averaged 36%.

Fiber concentration also tended to improve (decrease) with N fertility. Both ADF [424, 406, and 398 g kg^{-1} for 0, 56, and 112 kg N ha^{-1} when averaged across stockpile initiation dates and years, respectively; LSD (0.05) = 9 g kg^{-1}] and NDF [628, 615, and 606 g kg^{-1} for 0, 56, and 112 kg N ha^{-1} when averaged across stockpile initiation dates and years, respectively; LSD (0.05) = 12 g kg^{-1}] concentrations decreased between 0 and 56 kg N ha^{-1} but not between 56 and 112 kg N ha^{-1}. In tall fescue, Archer and Decker (1977) and Gerrish et al. (1994) both reported a tendency toward lower levels of NDF when N was applied.

Stockpile initiation date × year interactions were detected for CP and fiber parameters (Table 3). Fiber concentration in October tended to be greater in 1998 than 1996 through the 15 July stockpile initiation date. However, fiber concentration over winter tended to increase less in 1998 than 1996. When averaged across N fertility management strategies and years, ADF increased 40 to 64 g kg^{-1} while NDF increased 45 to 89 g kg^{-1}.

Stockpile initiation date × year interactions were detected for change in CP concentration over winter (Table 3). Through the 15 July 1998 stockpile initiation date, CP increased over winter. In 1996, CP decreased over winter for all stockpile initiation dates.

Economics

Stockpiled forage has both value and costs associated with it. If forage is not stockpiled for use in fall, it could be grazed during the growing season or baled into hay. For comparison to stockpiled forage, 140 g kg^{-1} CP grass hay at a cost of \$97 Mg^{-1} DM (from Minnesota hay auction data, www.stearnsdhialab.com/Auct-Hay.htm; verified 25 Apr. 2005) would result in a hay value of \$0.0183 kg^{-1} of forage mass and \$0.131 kg^{-1} of CP. Forage mass (Mg ha^{-1}) is a measure of productivity, but it does not incorporate quality considerations. Crude protein mass (kg CP ha^{-1}) is a composite measure that incorporates both quantity and quality of forage.

For this study, a cost of \$0.50 kg^{-1} of fertilizer N was used. This assumes a commercial cost of \$230 Mg^{-1} for 46% ammonium nitrate. Thus, applying 56 kg results in a cost of \$28 ha^{-1} and 112 kg of N is \$56 ha^{-1}.

Increasing productivity does not necessarily translate into higher returns (Table 4). If the value of the stockpiled forage exceeds the cost of the fertilizer, fertilization makes economic sense. When no N fertilizer is applied, the value of the forage and CP are less than those for the fertilized treatments. This is due to the lower quantity and quality of forage produced when no N is applied.

While increased productivity, as measured by Mg DM ha^{-1}, occurred by adding N, not all levels of fertilization are profitable. With 112 kg N ha^{-1}, the value of the October forage was less than the cost of the N fertilizer for every initiation date. At the rate of 56 kg ha^{-1}, N fertilization is profitable for initiation dates before 15 July.

The same results were observed when CP mass was assessed (Table 4). Stockpiling initiated before 15 July resulted in the value of CP being higher than the cost of N when it was applied at a rate of 56 kg ha^{-1}. While the value of the CP is higher at the 112 kg ha^{-1} application rate, it is less than \$56 ha^{-1} cost of the N.

The goal of stockpiling is to have forage available to graze in the fall of the year. Should fall grazing of the stockpiled forages not be possible, quantity and quality losses occur over the winter. These losses result in unprofitable levels of forage and CP production (Table 4).

If the smooth bromegrass stockpiling began 1 July, forage grown in June could be utilized before the initiation of stockpiling. Cuomo et al. (unpublished data, 2005), working on a similar soil in the same pasture series and at the same location, found forage production before June was 1.4, 1.7, and 1.8 Mg ha^{-1} with 0, 56, and 112 kg ha^{-1} of N applied, respectively. Thus, in June, daily forage production averaged 46, 57, and 60 kg d^{-1} for 0, 56, and 112 kg ha^{-1} of N applied, respectively. Assuming forage intake of a 550-kg cow is 2% of body weight (Natl. Res. Counc., 1987), June grazing would support 4.2, 5.2, and 5.5 cows ha^{-1} for 0, 56, and 112 kg ha^{-1} of N, respectively. Assuming the cost of pasturing dry cows is \$12 animal unit^{-1} mo^{-1} (Univ. of Minnesota Ext. Serv., 2003), the additional income potential by initiating stockpiling 1 July instead of 1 June would be \$50, \$62, and \$66 for 0, 56, and 112 kg ha^{-1}, respectively. Initiating stockpiling 1 July offers both optimal stockpile forage availability in fall and forage for grazing in June.

It is possible to increase returns by fertilizing smooth bromegrass at the rate of 56 kg ha^{-1} of N. The 112 kg ha^{-1} rate of N was not profitable. By not initiating stockpiling until 1 July, it would be possible to graze or cut the forage in June and have positive returns to stockpiling forage over N cost at 56 kg ha^{-1}.

CONCLUSIONS

Smooth bromegrass often dominates pastures in the North-Central region of the USA. In this region, smooth bromegrass produces the majority of its seedheads by mid- to late June (Smith, 1981). Data from the current study indicate that if stockpiling is initiated shortly after seedheads are produced (1 July), forage and leaf mass available in October is optimized. By initiating stockpiling 1 July instead of 1 June, there was no reduction in forage mass available in October, and the pasture could be used for an additional month (June) during summer. This makes for more efficient use of forage than stockpiling at earlier dates. Initiating stockpiling at later dates reduced the availability of October forage but may be an option depending on seasonal forage needs of a given operation.

Data from this trial indicate that applying 56 kg N ha^{-1} results in optimal levels of forage and leaf mass. Applying 112 kg N ha^{-1} did not further increase fall forage mass or improve forage nutritive value appreciably.

Stockpiling for fall and winter grazing by livestock in the North-Central USA can have several potentially beneficial economic and environmental effects. Maintaining livestock on pasture longer in the season reduces the need for stored feed, thereby reducing the many costs associated with storing feed (i.e., machinery, fuel, labor, and storage). Moreover, extending the grazing season is a cost-effective way of redistributing manure rather than scraping lots, transporting, and mechanically spreading manure back onto pasture.

Kind and class of livestock are also an important factor when considering stockpiled forage. Stockpiled forage in this study was of moderate nutritive value, and high fiber concentrations may limit intake. Stockpiled forage may not be nutritionally adequate for growing or lactating animals. However, forage nutritive value of stockpiled smooth bromegrass in this study would be adequate for maintaining dry cows or ewes (Natl. Res. Counc., 1987) and may be an economical alternative to reduce the need for feeding stored forage.

REFERENCES

Archer, K.A., and A.M. Decker. 1977. Autumn-accumulated tall fescue and orchardgrass: I. Growth and quality as influenced by nitrogen and soil temperature. Agron. J. 69:605–609.

Balasko, J.A. 1977. Effects of N, P, and K fertilization on yield and quality of tall fescue forage in winter. Agron. J. 69:425–428.

Burns, J.C., and D.S. Chamblee. 2000a. Summer accumulation of tall fescue at low elevations in the humid Piedmont: I. Fall yield and nutritive value. Agron. J. 92:211–216.

Burns, J.C., and D.S. Chamblee. 2000b. Summer accumulation of tall fescue at low elevations in the humid piedmont: II. Fall and winter changes in nutritive value. Agron. J. 92:217–224.

Carlson, I.T., and L.C. Newell. 1983. Smooth bromegrass. p. 198–206. *In* M.E. Heath, R.F Barnes, and D.S. Metcalfe (ed.) Forages: The science of grassland agriculture. Iowa State Univ. Press, Ames.

Collins, M., and J.A. Balasko. 1981. Effects of N fertilization and cutting schedules on stockpiled tall fescue: II. Forage quality. Agron. J. 73:821–826.

Cuomo, G.J., M.V. Rudstrom, D.G. Johnson, J.E. Anderson, A. Singh, P.R. Peterson, and C.C. Sheaffer. 2005. Nitrogen fertilization impacts on stand dynamics and productivity of rotationally stocked cool-season grass-legume pastures [Online]. Forage Grazinglands (in press).

Engel, R.K., L.E. Moser, J. Stubbendieck, and R.S. Lowery. 1987. Yield accumulation, leaf area index and light interception of smooth bromegrass. Crop Sci. 27:316–321.

Fribourg, H.A., and K.W. Bell. 1984. Yield and composition of tall fescue stockpiled for different periods. Agron. J. 76:929–934.

Gerrish, J.R., P.R. Peterson, C.A. Roberts, and J.R. Brown. 1994. Nitrogen fertilization of stockpiled tall fescue in the Midwestern USA. J. Prod. Agric. 7:98–104.

Goering, H.K., and P.J. Van Soest. 1970. Forage fiber analysis: Apparatus, reagents, procedures, and some applications. USDA Agric. Handb. 379. U.S. Gov. Print. Office, Washington, DC.

Limin, A.E., and D.B. Fowler. 1987. Cold hardiness of forage grasses grown on the Canadian Prairies. Can. J. Plant Sci. 67:1111–1115.

Matches, A.G., J.B. Tevis, and F.A. Martz. 1973. Yield and quality of tall fescue stockpiled for winter grazing. p. 54–57. *In* Research in agronomy. Misc. Publ. 73–5. Univ. of Missouri, Columbia.

Moore, K.J., L.E. Moser, K.P. Vogel, S.S. Waller, B.E. Johnson, and J.F. Pederson. 1991. Describing and quantifying growth stages of perennial forage grasses. Agron. J. 83:1073–1077.

National Research Council. 1987. Predicting feed intake of food-producing animals. Natl. Academy Press, Washington, DC.

Olsen, S.R., C.V. Cole, F.S. Watanabe, and L.A. Dean. 1954. Estimation of available phosphorous in soils by extracting with sodium bicarbonate. Circ. 939. USDA, Washington, DC.

Poore, M.H., G.A. Benson, M.E. Scott, and J.T. Green. 2000. Review of research on stockpiled fescue for beef cattle. p. 45–57. *In* Proc. Southern Pasture and Forage Crop Improvement Conf., 55th, Raleigh, NC. 12–14 June 2000.

Rayburn, E.B., R.E. Blaser, and D.D. Wolf. 1979. Winter tall fescue yield and quality with different accumulation periods and N rates. Agron. J. 71:959–963.

Riesterer, J.L., D.J. Undersander, M.D. Casler, and D.K. Combs. 2000. Forage yield of stockpiled perennial grasses in the Upper Midwest USA. Agron. J. 92:740–747.

SAS Institute. 1996. SAS systems for Windows. Release 6.12. SAS Inst., Cary, NC.

Shenk, J.S., and M.O. Westerhaus. 1991. Population structuring of near infrared spectra and modified partial least squares regression. Crop Sci. 31:1548–1555.

Smith, D. 1981. Forage management in the North. 2nd ed. Kendall/Hunt Publ. Co., Dubuque, IA.

Steel, R.G.D., and J.H. Torrie. 1980. Principles and procedures of statistics. 2nd ed. McGraw-Hill, New York.

Taylor, T.H., and W.C. Templeton, Jr. 1976. Stockpiling Kentucky bluegrass and tall fescue forage for winter pasturage. Agron. J. 68:235–239.

University of Minnesota Extension Service. 2003. Land rental survey 2003–2004 [Online]. Available at www.extension.umn.edu/county/Nicollet/news/landrentsurvey2003-2004.pdf (verified 25 Apr. 2005). Univ. of Minnesota Ext. Serv., St. Paul.

Vogel, K.P., K.J. Moore, and L.E. Moser. 1996. Bromegrasses. p. 535–568. *In* L.E. Moser, D.R. Buxton, and M.D. Casler (ed.) Cool-season forage grasses. Agron. Monogr. 34. ASA, CSSA, and SSSA, Madison, WI.

Wedin, W.F., I.T. Carlson, and R.L. Vetter. 1966. Studies on nutritive value of fall-saved forage, using rumen fermentation and chemical analyses. p. 424–428. *In* Proc. Int. Grassl. Congr., 10th, Helsinki, Finland. 7–16 July 1966. Int. Grassl. Congr., Helsinki, Finland.