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Potassium Management for Brown Midrib Sorghum × Sudangrass as Replacement for Corn Silage in the North-eastern USA

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With 1 figure and 3 tables

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Abstract

In recent years, there has been a growing interest in brown midrib (BMR) sorghum (*Sorghum bicolor* (L.) Moench.) × sudangrass (*Sorghum sudanense* Piper) hybrids (SxS) as a replacement for silage corn (*Zea mays* L.) in the north-eastern USA. Recent studies suggest it is suitable for both rotational grazing and as a hay crop and could compete with corn harvested for silage in years when wet spring conditions prevent the timely planting of corn. However, little is known about its suitability as forage for non-lactating cows that require low potassium (K) forages to prevent health problems. Our objective was to evaluate the impact of K fertilizer management (0, 112 or 224 kg K_2O ha^{-1} cut^{-1}) under optimum N management (112–168 kg N ha^{-1} cut^{-1}) on yield, quality and K concentrations of BMR SxS over a 2-year period. Field trials were established on a fine loamy, mixed, active, mesic Aeric Fragiaquepts with medium K-supplying capacity and characteristic of a large region in New York. Potassium application did not affect dry matter yields in either of the 2 years. Averaged over 2 years, neutral detergent fibre (NDF) significantly increased with K addition with similar but non-significant trends observed in each of the years individually. The digestibility of NDF was unaffected by K application. Crude protein (CP) concentrations showed a significant decrease with K application in 2002 and similar trends were observed in 2003, although differences were not significant at $P \leq 0.05$. The changes in NDF and CP did not significantly impact forage quality expressed as milk production per megagram of silage. Potassium application increased forage K concentration up to 13 mg K kg^{-1} dry matter (in the first cut in 2003). Forage Ca and Mg concentrations decreased with K addition except for the first cut in 2002 where differences between 112 and 224 kg K_2O ha^{-1} treatments were not significant. Without K addition in the 2-year period, K concentrations in the forage decreased from 23 g kg^{-1} for the first cutting in 2002 to 15 g kg^{-1} for the second cut in 2003. Low K forage was obtained for all second-cut forage unless 224 kg K_2O ha^{-1} cut^{-1} had been added. First-cut forage was suitable only when no additional K had been applied. These results suggest low K BMR SxS forage can be harvested from initially high K soils without loss in dry matter yield as long as no additional K is added.

Key words: brown midrib — dry matter yield — non-lactating cows — north-eastern USA — potassium — sorghum sudangrass

Introduction

It is known that perennial grasses will accumulate potassium (K) in excess of plant requirements depending upon soil K availability and K addition in the form of fertilizer or manure (Cherney et al. 2003). High K forages can cause pregnant cows to develop metabolic health problems including ketosis, metritis, retained placenta and displaced abomasums (Beede 1996, Goff and Horst 1997, Cherney et al. 1998). It is recommended to only feed grass forage with less than 25 g kg^{-1} dry matter to non-lactating cows based on research by Goff and Horst (1997).

In recent years, there has been a growing interest in brown midrib (BMR) sorghum (*Sorghum bicolor* (L.) Moench.) × sudangrass (*Sorghum sudanense* Piper) hybrids (SxS) as a replacement for silage corn (*Zea mays* L.) in north-eastern USA. Recent studies suggest it is suitable for both rotational grazing and as a hay crop and could compete with corn silage dry matter yields in years when wet spring conditions prevent the timely planting of corn. Studies by Kilcer et al. (2005) showed that for optimum yield and quality BMR SxS grown in the north-eastern USA should be managed using a two-cut system with harvest taking place when stand heights are about 125 cm or less. However, little is known about its suitability as a forage for non-lactating cows.

Our objective was to evaluate the impact of K fertilizer management under optimum N management on yield, quality and K concentrations of BMR SxS over a 2-year period. The site, representative of a third of New York State's agricultural land, was classified as high in plant-available K and medium K-supplying capacity at the onset of the trial. Soil test K levels were monitored over the 2-year cycle to examine the effect of K fertilizer management on plant-available K.

Materials and Methods

Location

Studies were conducted on a Volusia soil (fine loamy, mixed, active, mesic Aeric Fragiaquepts) at the Mt Pleasant Research Farm in Tompkins County, NY, USA. This soil is representative of a large portion of Southern Tier New York soils (Cline and Marshall 1977), classified as having a medium K supplying power based on soil texture, illitic clay mineralogy and depth of profile. The pH of the soil (0–20 cm depth) was 6.2 at the onset of the trial and the soil organic matter content was 32 g kg^{-1}. Based on the Morgan (1941) soil test extraction, and interpretations for New York (Cornell Cooperative Extension 2004), the site was classified as medium in available phosphorus (2.5 mg P kg^{-1} soil), medium in zinc (0.27 mg Zn kg^{-1} soil) and high in K (70 mg K kg^{-1} soil), calcium (1178 mg Ca kg^{-1} soil) and magnesium (188 mg Mg kg^{-1} soil).

Experimental design and treatments

In 2002, a split-plot design was used to establish the N × K trial with N application rate as the main treatment (complete randomized block design) and K application as subplots. The trial was conducted in four replicates and repeated on the same location in 2003. Potassium was applied in the form of muriate of potash (60 % K_2O) at three levels: 0, 112 or 224 kg K_2O ha^{-1} cut^{-1}. Nitrogen applications were in the form of ammonium sulphate (21 % N) and applied at 2 levels: 112 and 168 kg N ha^{-1} cut^{-1}. The latter rates were chosen as other work (unpublished data) had shown optimum economic N rates to vary between 112 and 168 kg N ha^{-1} cut^{-1}. Plots were 1.80 m wide and 4.5 m long with a sampling and harvest area of 0.9 m × 4.0 m. All plots received the equivalent of 50 kg P_2O_5 ha^{-1} at planting based on the medium soil test classification.

Planting occurred on 14 June 2002 and 9 June 2003, using a John Deere grain drill and 67 kg of seed ha^{-1}. In 2002, first and second harvest took place on 30 July and 25 September respectively. Both times, cutting height was 7.5–9.0 cm and harvest was initiated when the plots had reached a height of 90–115 cm. In 2003, the first harvest occurred on 31 July (90 cm stand height) and the second cut on 26 September (stand height of 115 cm). Height was measured as canopy height (from the surface of the soil to the horizontal curve of the tallest leaf). Fresh weights were determined and subsamples were taken to measure moisture content and analyse for forage quality.

Forage analyses

Forage N and K concentrations, ash, NDF, and 30 h *in vitro* true digestibility (IVTD) were determined at the DairyOne Forage Testing Laboratory, Ithaca, NY. For potassium determination, samples were dry ashed for 4 h at 500 °C, cooled, and then dried again on a 100–120 °C hot plate after addition of 3 ml of 6 N HCl. Ashed samples were extracted in dilute acid (1.5 N HNO_3 and 0.5 N HCl), and plant K concentrations were determined by analysing dissolved minerals using a Thermo Jarrel Ash IRIS Advantage Inductively Coupled Plasma Radial Spectrometer (Jarrell Ash, Franklin, MA) (Greweling 1976). Nitrogen was determined by combustion (Leco Instruments, Inc., St Joseph, MI) (AOAC 1990b) and multiplied by 6.25 to obtain CP, assuming that the BMR SxS feed protein contains 16 % N. Ash was determined by dry combustion (AOAC 1990a). IVTD was determined according to ANKOM Application Note 11/00 using the Daisy $II^{200/220}$ *in vitro* incubator and the $ANKOM^{200/220}$ fiber analyzer (both from ANKOM Technology, Fairport, NY). NDF was analysed according to Van Soest et al. (1991) using the ANKOM system. The 30-h NDF digestibility (dNDF) was calculated as (NDF − IVTD residue at 30 h)/NDF × 100. The 30-h dNDF was multiplied by 1.16 to obtain an estimate of the dNDF at 48 h (J.H. Cherney, unpublished data). The latter is an input for the alfalfa-grass spreadsheet of Milk2000 version 7.4 which was used to estimate milk yields. This software tool was developed by Shaver et al. (2001) to estimate milk per ton of forage dry matter as an index of forage quality. Standard values were used for ether extract (3.6 % on a dry matter basis) and neutral detergent insoluble crude protein (NDICP; 2.4 % on a dry matter basis) as reported for SxS silage in the 2001 Nutrient Requirements for Dairy Cattle (National Research Council 2001).

Soil analyses

Soil samples (0–20 cm) were taken at planting and immediately after the first and second harvests in both years and the trials were conducted on the same plots so a 2-year soil test history could be obtained. Soil samples were dried at 55 °C, ground and passed through a 2-mm sieve prior to analyses. Soil pH was measured in a 1 : 1 (w/v) water extract. Morgan-extractable K was obtained by shaking samples in a 1 : 5 (v/v) ratio for 15 min and filtering the extract through a Whatman No. 2 equivalent filter paper. Potassium in the extracts was determined using a JY70 Type II Inductively Coupled Plasma Atomic Emission Spectrometer (ICP-AES) (Jobin Yvon, Edison, NJ). The Morgan soil extraction solution consists of 1 N sodium acetate buffered at pH 4.8 (Morgan 1941). This extraction solution and method forms the basis for fertility recommendations in New York State, Massachusetts, and Rhode Island while the Modified Morgan extraction solution consisting of ammonium acetate buffered at pH 4.8 (McIntosh 1969) is used for fertilizer recommendations in Vermont, Maine and Connecticut. The Morgan test is also the basis for fertilizer recommendations in Ireland (Daly and Casey 2003).

Statistical analyses

The forage quality and soil fertility data were analysed as a split-plot design using PROC MIXED of SAS Institute Inc. (1999) for each year and cut (forage) or sampling date (soil fertility) separately with N application rates as the main treatment and K application as the subplots, and for the two cuts and 2 years combined (total season harvest and K removal). Mean differences were considered significant if $P \leq 0.05$.

Results and Discussion

In neither year were there N × K interactions for any of the yield or quality response parameters. Hence, main K effects (i.e. averaged over the two N treatments) are reported for all response parameters. Yields were higher in 2003 due to the record drought that occurred in 2002. However, application of potassium fertilizer did not significantly increase dry matter yields in either of the 2 years (Table 1). Averaged over 2 years, NDF significantly increased with K addition with similar but non-significant (at $P \leq 0.05$) trends observed in each of the years individually. Digestibility of NDF was unaffected by K fertilizer treatments. CP concentrations showed a significant decrease with K application in 2002 and similar trends were observed in 2003, although differences were not significant at $P \leq 0.05$. The linear relationship between yield and estimated milk production in Mg of milk ha^{-1} (Fig. 1) indicates that the changes in NDF and CP did not significantly impact forage quality expressed as estimated milk production per megagram of silage.

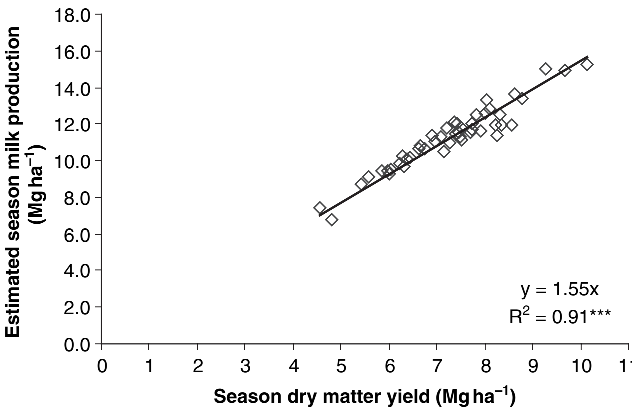

Fig. 1: Dry matter yield (first and second cut combined for each year) and estimated milk production in Mg milk ha^{-1} for brown midrib sorghum sudangrass grown in 2002 and 2003 on a fine loamy, mixed, active, mesic Aeric Fragiaquepts at the Mt Pleasant Research Farm in Tompkins County, NY, USA

Table 1: Yield, predicted milk production, crude protein (CP), neutral detergent fibre (NDF), digestibility of NDF (dNDF) as affected by K application rate in a two-cut brown midrib sorghum sudangrass trial on a fine loamy, mixed, active, mesic Aeric Fragiaquepts at Mt Pleasant, New York, USA, in 2002 and 2003

K_2O applied per cut (kg ha^{-1})	Yield (kg ha^{-1})	Estimated milk production[1] (kg Mg^{-1})	Estimated milk production[1] (kg ha^{-1})	CP (% of dm)	NDF (% of dm)	dNDF (% of NDF)
First and second cut combined, 2002 growing season						
0	6474 a	1600 a	10354 a	13.9 a	62.8 a	80.3 a
100	6596 a	1580 a	10416 a	13.6 ab	63.2 a	80.8 a
200	6245 a	1566 a	9803 a	13.3 b	63.8 a	80.9 a
First and second cut combined, 2002 growing season						
0	7843 a	1553 a	12162 a	12.6 a	59.8 a	74.2 a
100	8663 a	1532 a	13286 a	12.2 a	60.4 a	75.1 a
200	7961 a	1481 a	11783 a	12.1 a	60.5 a	73.7 a
Average annual season harvest, 2002 and 2003 combined						
0	7158 a	1577 a	11258 ab	13.2 a	61.3 b	77.2 a
100	7629 a	1556 a	11851 a	12.8 a	61.8 ab	78.0 a
200	7103 a	1524 a	10793 b	12.7 a	62.1 a	77.3 a

[1] Milk yields were predicted using Milk2000 (http://www.uwex.edu/ces/forage/pubs/milk2000.xls, last accessed: November 11, 2004).

Table 2: Effects of K application rate on K, Mg and Ca concentrations in brown midrib sorghum sudangrass and K, Mg and Ca uptake on a fine loamy, mixed, active, mesic Aeric Fragiaquepts at Mt Pleasant, NY

K_2O applied (kg ha^{-1} cut^{-1})	First cut 2002	Second cut 2002	First cut 2003	Second cut 2003
K concentration in the forage (g kg^{-1} of dry matter)				
0	23 c	20 b	21 c	15 b
112	26 b	23 b	28 b	21 ab
224	30 a	26 a	34 a	23 a
Mg concentration in the forage (g kg^{-1} of dry matter)				
0	4.3 a	5.1 a	4.4 c	4.3 a
112	3.9 b	4.9 ab	3.9 b	3.6 b
224	3.5 c	4.4 b	3.5 b	3.4 b
Ca concentration in the forage (g kg^{-1} of dry matter)				
0	5.3 a	5.3 a	6.2 a	5.7 a
112	5.0 b	4.8 ab	5.5 b	4.6 b
224	4.7 c	4.5 b	5.1 b	4.5 b
K uptake (kg K_2O ha^{-1})				
0	89 a	80 a	82 c	82 b
112	98 a	94 a	115 b	134 a
224	105 a	101 a	143 a	121 a
Mg uptake (kg Mg ha^{-1})				
0	13.7 a	17.3 a	14.7 a	19.3 b
112	12.4 ab	17.2 a	13.5 ab	18.7 ab
224	10.4 b	14.7 a	12.4 b	15.1 a
Ca uptake (kg Ca ha^{-1})				
0	16.7 a	17.6 a	20.7 a	25.7 a
112	15.6 a	16.6 a	19.2 ab	24.2 ab
224	13.8 a	15.0 a	18.0 b	19.9 b

Yields are reported in Table 1.

As expected, the K concentrations in the forage were greatly affected by K application rate (Table 2). Potassium application increased forage K concentrations up to 34 mg K kg^{-1} dry matter (in the first cut in 2003) when compared with 21 mg K kg^{-1} dry matter when no K had been applied. Forage Ca and Mg concentrations decreased with K addition except for the first cut in 2002 where differences between the 112 and 224 kg K_2O ha^{-1} treatments were not significant. Calcium and Mg concentrations in forage grasses typically decrease with increased K fertilization (Cherney et al. 1998). Without K fertilizer application during the 2-year period, forage K concentrations decreased from 23 mg kg^{-1} for the first cut in 2002 to 15 mg kg^{-1} for the second cut in 2003. The K concentrations for first cuttings were consistently higher than those for second cuttings, as has been found in perennial grasses (Cherney et al. 1998). These results support the observation that K fertilization often alters elemental concentrations in forage, but generally does not have a significant impact on forage quality parameters (Cherney et al. 2003).

Low K forage was obtained for all second-cut forage unless 224 kg K_2O ha^{-1} cut^{-1} had been added. First-cut forage was suitable only when no additional K had been applied. Thus, low K SxS forage was harvested from this initially high K soil as long as no additional K fertilizer was added.

Potassium removal with harvest varied from 167 kg ha^{-1} year^{-1} without K addition to 235 kg K_2O ha^{-1} year^{-1} with the addition of 224 kg K_2O ha^{-1} cut^{-1}. Without the addition of K, the soil went from a classification of high in available K in the 2002 growing season to low after the first cut in 2003 and remained low at the end of the second season (Table 3). This is not surprising given the average annual K removal rate of 167 kg K_2O ha^{-1} year^{-1}. This K was in its entirety supplied by the soil. Where 112 kg K_2O ha^{-1} cut^{-1} were applied, crop removal amounted to 224 kg K_2O ha^{-1}. Under this management scenario, soil test K levels declined to medium levels after the first growing season. Thus, soil test K values decreased

Table 3: Effects of potassium application rate on plant available K (agronomic soil test K). Extractable K was determined using 1 N sodium acetate buffered at pH 4.8 according to Morgan (1941). Yields are reported in Table 1

K_2O applied (kg ha^{-1} cut^{-1})	Soil test K Cornell Morgan Extraction[1] (mg K kg^{-1} soil)					
	2002 growing season			2003 growing season		
	At planting	After first cut	After second cut	At planting	After first cut	After second cut
0	70 a	64 a	67 b	54 b	37 c	37 b
112	66 a	66 a	80 b	68 b	52 b	53 b
224	70 a	78 a	111 a	97 a	72 a	80 a

[1] For this soil, a soil test of 23–39 mg K kg^{-1} soil is classified as low in K, 40–59 mg K kg^{-1} soil is medium, 60–99 mg K kg^{-1} soil is high and ≥100 mg K kg^{-1} soil is classified as very high in K (Cornell Cooperative Extension 2004).

with K application rates equal to crop removal, although the fertilizer uptake efficiency was very low (25 %). Upon the addition of 224 kg K_2O ha^{-1} cut^{-1}, soil test K levels remained high. Potassium fertilizer use efficiency was very low (16 %). Although the 2002 data suggest an increase in soil test K, this trend was not continued in 2003. Soil test levels under this treatment were too variable over time to conclude whether continued application of K at this rate will maintain or increase soil test K levels. As BMR SxS is not likely to be grown for more than two seasons consecutively, this is an academic rather than a practical question. The lack of yield response to K fertilizer implies that the critical soil test level for BMR SxS may be less than the 60 mg K kg^{-1} commonly applied for field crops (Cornell Cooperative Extension 2004).

Potassium addition decreased forage Ca and Mg concentrations (Table 2). Magnesium removal varied from 26.3 kg Mg ha^{-1} $year^{-1}$ with the application of 224 kg K_2O ha^{-1} $year^{-1}$ to 32.5 kg Mg ha^{-1} $year^{-1}$ without the addition of K. Calcium removal for the same treatments ranged from 33.4 to 40.4 kg Ca ha^{-1} $year^{-1}$. Phosphorus concentrations were unaffected by K treatment (data not shown). The average P concentration was 2.9 mg P kg^{-1} dry matter resulting in an average annual removal rate of 21.5 kg P ha^{-1} $year^{-1}$ (49.5 kg P_2O_5 P ha^{-1} $year^{-1}$).

Conclusions

Forage feed quality of BMR SxS was not affected by K fertilization with the exception of a slight increase in NDF and decrease in CP upon addition of K fertilizer. Potassium fertilizer addition did increase K concentrations and lower Mg and Ca concentrations of the forage as shown previously for perennial grasses. Soil test K levels decreased over the 2 years with K applications of 112 kg K_2O ha^{-1} $year^{-1}$ cut^{-1} or less. Potassium fertilization may be needed to obtain higher yields on soils testing low for available K or when soil test K needs to be maintained at high levels. Low K forage necessary for dry cows to reduce the possibility of metabolic disorders after calving was obtained without K fertilization. Second cuttings had lower K concentrations than first cuttings.

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References

AOAC, 1990a: Official Methods of Analysis of the Association of Official analytical Chemists. 15th edn, p. 70. AOAC, Arlington, VA.

AOAC, 1990b: Official Methods of Analysis of the Association of Official Analytical Chemists, 15th edn, p. 72. AOAC, Arlington, VA.

Beede, D. K., 1996: Cation–anion differences in dairy rations: dealing with high potassium content of alfalfa. In: Proc. 26th Nat. Alfalfa Symp., East Lansing, MI. 5–6 Mar. 1996, pp. 30–37. Alfalfa Seed Council, Inc., Davis, CA.

Cherney, J. H., D. J. R. Cherney, and T. W. Bruulsema, 1998: Potassium management. In: J. H. Cherney, and D. J. R. Cherney (eds), Grass for Dairy Cattle, pp. 147–148. CAB International, Wallingford, UK.

Cherney, J. H., D. J. R. Cherney, and M. D. Casler, 2003: Low intensity harvest management of reed canarygrass. Agron. J. **95,** 627—634.

Cline, M. G., and R. L. Marshall, 1977: Soil of New York Landscapes. Media and Technology Services, Cornell University, Ithaca, NY.

Cornell Cooperative Extension, 2004: Cornell Guide for Integrated Field Crop Management. Media and Technology Services, Cornell University, Ithaca, NY.

Daly, K. and A. Casey, 2003: Eutrophication From Agricultural Sources. Environmental Soil Phosphorus Test (2000-LS-2.1.6-M2). Final Report Prepared for the Environmental Protection Agency. Teagasc, Johnstown Castle, Wexford, Ireland.

Goff, J. P., and R. L. Horst, 1997: Effects of the addition of potassium or sodium, but not calcium, to prepartum rations on milk fever in dairy cows. J. Dairy Sci **80,** 176—186.

Greweling, T., 1976: Chemical analysis of plant tissue. Cornell Univ. Agric. Exp. Stn. Search Agriculture, Agronomy **6**(8), 1—35.

Kilcer, T. F., Q. M. Ketterings, J. H. Cherney, P. Cerosaletti, and P. Barney, 2005: Optimum stand height for forage brown midrib sorghum × sudangrass in northeastern USA. J. Agron. Crop Sci. **191,** 35—40.

McIntosh, J. L., 1969: Bray and Morgan soil test extractants modified for testing acid soils from different parent materials. Agron. J. **61,** 259—265.

Morgan, M. F., 1941: Chemical soil diagnosis by the universal soil testing system. Conn. Agric. Exp. Stn. Bull. **450**.

National Research Council, 2001: Nutrient Requirements of Dairy Cattle, 7th edn, 408 pp. National Academy Press, Washington, DC.

SAS Institute Inc., 1999: SAS/STAT User's Guide. Release 8.00. SAS Institute Inc., Cary, NC, USA.

Shaver, R., D. Undersander, E. Schwab, P. Hoffman, J. Lauer, D. Combs, and J. Coors, 2001: Milk2000: combining yield and quality into a single term. Available at: http://corn.agronomy.wisc.edu/ComputerDSS/Milk2000.doc. (last accessed: November 11, 2004).

Van Soest, P. J., J. B. Robertson, and B. A. Lewis, 1991: Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. J. Dairy Sci. **74,** 3583—3597.