Low Intensity Harvest Management of Reed Canarygrass

J. H. Cherney,* D. J. R. Cherney, and M. D. Casler

ABSTRACT

High K grass forage increases risk of animal metabolic disorders, and forage management of perennial grass grown under K-limiting soil conditions needs further study. Our objective was to evaluate forage nutritive value, yield, and stand persistence of reed canarygrass (*Phalaris arundinaceae* L.) under two-harvest management and low availability of soil K. Three N and three K fertilizer treatments were applied to reed canarygrass for 5 yr at two sites in central New York state with Niagara silt loam (fine-silty, mixed, active, mesic Aeric Epiqualfs) and Williamson silt loam (coarse-silty, mixed, active, mesic Typic Fragiudepts) soil types. Reed canarygrass persisted under all treatments throughout the experiment, although K deficiency symptoms appeared in the high N, low K fertilizer combination. At the high N fertilizer rate, dry matter (DM) yield increased linearly ($P < 0.05$) with increased K fertilizer rate, while K fertilizer did not influence yield in the absence of N fertilizer. Recovery of K fertilizer was low and increased linearly ($P < 0.05$) with increased N fertilizer rate from 6 to 42%. Soil test K increased to 59.9 mg kg^{-1} with no N fertilization and decreased to 34.9 mg kg^{-1} with 224 kg N ha^{-1}. Under high N fertilization with no K fertilization, grass forage K concentration averaged <12 g kg^{-1} in the spring and <8 g kg^{-1} in the fall. Sufficient yields of grass forage with reasonable quality and low concentrations of K were possible through high N, low K fertility management in a two-harvest system.

Perennial grasses will absorb K in excess of plant requirements, depending on the quantity of available soil K and the availability of other elements, particularly N. Regions of the world, such as Europe, that rely heavily on grazing appear to have few concerns regarding plant K, and K often is not discussed in their literature concerning grass management (Beever et al., 2000). In contrast, in the USA, where stored forage is the primary dairy forage source, concerns regarding K content of dairy cattle diets are high (Horst et al., 1997). Incidence of milk fever in dairy cows fed a low calcium (Ca) diet was 0% for a diet containing 11 g K kg^{-1} dry matter (DM), 36% for a diet containing 21 g K kg^{-1} DM, and 80% for a diet containing 31 g K kg^{-1} DM (Goff and Horst, 1997). High concentrations of soil-test K in perennial grass fields are common on many dairy farms in the northern USA owing to preferential application of animal manure on these fields.

On prairie soil with low available soil K concentration, no yield increase resulted from K fertilization of smooth bromegrass (*Bromus inermis* Leyss.) (George et al., 1979). Timothy (*Phleum pratense* L.) yield was significantly reduced under a 2-cut management when forage K concentration was <12 g kg^{-1} (Brown et al., 1969). Timothy stands should persist over time with a concentration of 15 to 18 g K kg^{-1} in headed spring growth and 12 to 16 g K kg^{-1} in regrowth, according to Grant and MacLean (1966). Nitrogen fertilization of grasses initially increases forage K concentration if there is sufficient available soil K, but prolonged N fertilization of a grass stand will quickly deplete soil K and result in decreased forage K concentration (Cherney et al., 1998).

Management systems that result in low forage K concentration are a prerequisite for grass forage fed to nonlactating dairy cows (Cherney et al., 1998). Based on results of Goff and Horst (1997), animal scientists generally suggest that forage for nonlactating dairy cows contain less than 25 g K kg^{-1} DM to reduce the risk of high dietary K on animal health. High dietary K can predispose pregnant cows to a number of disorders, including ketosis, metritis, retained placenta, and displaced abomasums (Beede, 1996). Our objective was to evaluate the effects of extensive harvest management and low availability of soil K on reed canarygrass forage yield, nutritive value, and stand persistence.

MATERIALS AND METHODS

Reed canarygrass was established in 1992 on a Niagara silt loam (fine-silty, mixed, active, mesic Aeric Epiqualfs) soil with 0 to 2% slope in Ithaca, NY (Site 1). A second site was established in 1993 on a Williamson silt loam (coarse-silty, mixed, active, mesic Typic Fragiudepts) soil with 0 to 6% slope in Ithaca, NY (Site 2). Both soils are classified as having medium K supplying power, based primarily on their clay content.

Site 1 was fertilized with three rates of N fertilizer: 0, 168, or 336 kg N ha^{-1}, split applied before each of three harvests in 1993 and 1994. Site 2 received the same fertilization/harvest regime in 1994 and 1995. Both sites were fertilized with P and K during the first 2 yr following the establishment year according to soil test recommendations.

In 1995 previous N fertilized plots were split into three subplots (2.13 by 6.08 m), with 0, 56 and 112 kg K ha^{-1} applied annually from 1995 to 2000. Previous N-fertilized plots received 0, 112 or 224 kg N ha^{-1} annually from 1995 to 2000, split applied at spring greenup and immediately after first harvest. The same management sequence was applied to Site 2, starting 1 yr later than Site 1. Potassium fertilizer was applied as one annual early spring application from 1995 through 1997, and then applied to both sites as one annual application following spring harvest in 1998 through 2000.

Broadleaf weeds were controlled by annual applications of either 2,4-D [(2,4-dichlorophenoxy) acetic acid] at 0.14 kg a.i. ha^{-1} in the spring or dicamba [(3,5-dichloro-2-methoxy) benzoic acid] at 0.11 kg a.i. ha^{-1} in the fall. From 1995 to 2000 for Site 1 and from 1996 to 2000 for Site 2, plots were harvested

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Abbreviations: Ca, calcium; CP, crude protein; DM, dry matter; IVTD, in vitro true digestibility; K, potassium; N, nitrogen; NDF, neutral detergent fiber; OM, organic matter.

Table 1. Spring N fertilization and harvest dates in Ithaca, NY.

	Fertilizer application dates		Harvest dates			
	Site 1	Site 2	Site 1		Site 2	
Year	Spring N†	Spring N	Spring harvest	Fall harvest	Spring harvest	Fall harvest
1996	7 May	9 May	10 June	6 Sept.	17 June	11 Sept.
1997	29 Apr.	29 Apr.	19 June	18 Sept.	20 June	19 Sept.
1998	1 May	29 Apr.	9 June	1 Sept.	10 June	1 Sept.
1999	17 Apr.	17 Apr.	3 June	10 Sept.	3 June	13 Sept.
2000	25 Apr.	25 Apr.	8 June	5 Sept.	8 June	5 Sept.

† Date of initial N fertilizer application following spring green-up.

twice a season, in early to mid-June (Spring) and again in early to mid-September (Fall) (Table 1). A 1 m by 6.1 m strip of each plot was harvested from each of four replicates for yield determination with a flail harvester at a 10-cm stubble height. Harvested forage was sampled and oven-dried at 60°C for DM determination. Samples of approximately 800 g were collected for nutritive value analysis from the edge of the harvest strip at a 10-cm stubble height, dried at 60°C, and ground to pass a 1-mm screen.

The N concentration of samples was determined using Kjeldahl methods (1996–1997) with a copper catalyst (Assoc. of Official Analytical Chemists, 1990) or using a Leco N analyzer (1998–2000) (LECO Corp., St. Joseph, MI) with Dumas combustion (Tate, 1994; Wiles et al., 1998). Yield and recovery of N and K were calculated (Jokela, 1992). Yield of N or K was calculated as the product of forage dry matter yield and N or K concentration. Recovery of N or K applied was calculated as the quantity of N or K in the harvested forage minus the quantity in the 0 treatment, divided by the amount of N or K applied. Samples (0.5 g) were analyzed for neutral detergent fiber (NDF) using the procedure described by Van Soest et al. (1991), except that the ANKOM fiber analyzer with filter bags was used. In vitro digestibility was determined by incubating ground samples in buffered rumen fluid with urea for 48 h (Marten and Barnes, 1980) using the ANKOM incubator (Cherney et al., 1997). Urea was added to the in vitro medium because dairy cattle rations are typically supplemented with N and also to reduce analytical error associated with variations in rumen inoculum (Alexander and McGowan, 1966). Digested residues were subject to NDF analysis to determine in vitro "true" digestibility. Digestibility of NDF was calculated as the proportion of the NDF digested after 48 h incubation. Plant elemental concentrations were determined by dry ashing samples, extracting in dilute HCl and analyzing dissolved minerals using an inductively coupled emission plasma spectrophotometer (Greweling, 1976).

Soil samples were collected following fall harvest in 1997, 1999, and 2000 to a 152-mm depth, air-dried, and manually crushed. Soil pH was measured from a 1:1 soil/water suspension (McLean, 1982). Soil organic matter was determined by loss on ignition at 500°C. Soil exchangeable K was extracted with 1 *M* ammonium acetate at pH 7.0 using a Zero-Max E2 vacuum extractor (Zero Max, Minneapolis, MN) and analyzed by inductively coupled argon emission plasma, JY70 Type II (Instruments S.A., Edison, NJ). Soil samples also were collected and composited from the high N fertilized plots in late fall of 1994 for Site 1 and late fall of 1995 for Site 2, before initiating K fertilization regimes and two-cut harvest management. Reed canarygrass tillers were counted on 10 May 2000 and 15 May 2001 in a random 0.1 m^2 area in all plots.

Experimental design was a repeated measures split plot design. Data were analyzed using the mixed model program of SAS (PROC MIXED) with repeated measures analysis (SAS Inst., 1997). Years were the repeated measures variable, and a heterogenous first-order autoregressive [ARH(1)] covariance structure was selected as the one that best fit the experimental data. Replicates and interactions including replicates were assumed to be random effects. As years were sequential with potentially cumulative effects on soil and plant parameters, years were considered fixed effects. Data from 1995 were excluded from the analysis, resulting in a balanced set of data across locations. Nitrogen fertilizer was the main plot and K fertilizer was the subplot. Multiple comparisons of all pairwise differences of least-squares means of fixed effects were adjusted using the Tukey-Kramer procedure in PROC MIXED. Standard errors for least-squares means calculated by PROC MIXED were adjusted for covariance parameter estimates (Littell et al., 1996). With heterogeneous covariance structures such as ARH(1) for repeated measures, standard error of the difference (SED) for years are different for each different pairs of years. The SED values in data tables for years were obtained by pooling SED for different pairs of years, weighting them by their degrees of freedom. Where fertilizer rate means were significant, single degree of freedom linear/quadratic contrasts were used to evaluate trends.

RESULTS AND DISCUSSION

Relatively large error degrees of freedom resulted in significant differences being detected in numerous interaction terms. Many of these significant interactions, particularly N rate × Year and K rate × Year interactions, were due to differences in magnitude of response and these interactions are not discussed. There was little or no year effect when N or K fertilizer was not applied. When N or K was applied, however, there were enhanced responses to the environment, resulting in significant interactions due to magnitude of response, but not changes in the direction of the response.

Growing Conditions and Stand Persistence

Seasonal rainfall patterns deviated considerably from normal in 3 out of 5 yr, with rainfall significantly below normal in 1997 and 1999, and above normal in 1996 (Table 2). Both sites were fertilized with recommended levels of K fertilizer during the 2 yr following the seeding

Table 2. Actual and normal rainfall during the growing season in Ithaca, NY.

Year	April	May	June	July	August	September	October	Seasonal total
	mm							
1996	130	145	96	71	119	112	102	775
1997	36	71	99	73	55	82	32	448
1998	106	79	130	64	51	59	77	566
1999	56	21	52	31	73	176	43	452
2000	117	143	123	74	43	85	84	669
Avg.†	74	84	96	88	87	90	83	602

† Thirty-year average precipitation.

year that preceded the initiation of K fertilizer treatments and two-harvest management. Stand persistence, as used here, does not address individual plant persistence but refers to the perenniality of a stand (Volenec and Nelson, 1995), and was evaluated based on botanical composition of the stand (Belanger et al., 1989). Reed canarygrass stands persisted throughout the study for both sites under all treatments, including treatments receiving no N or K fertilization. Reed canarygrass stands in May 2001 were relatively free of weeds, except for annual bluegrass (*Poa annua* L.) and wild carrot (*Daucus carota* L.) in the low N fertilizer plots at Site 1 and wild carrot in the low N fertilizer plots at Site 2. Herbicide applications prevented establishment of broadleaf species, particularly volunteer red clover (*Trifolium pratense* L.) and white clover (*Trifolium repens* L.) in treatments receiving no fertilizer N. Clovers will commonly become established in perennial grass stands in the northeast USA under low N fertilization (Collins and Allinson, 1995). Reed canarygrass stands persisted for the duration of the experiment even though K deficiency symptoms appeared when plant K concentration dropped below approximately 8 g kg^{-1} DM. Deficiency symptoms included yellowing and browning of leaf tips and margins, similar in appearance to drought damage or normal senescence (Brown et al., 1969).

Number of reed canarygrass tillers was influenced by N and K fertilization, with significant ($P < 0.01$) linear increases in tiller number with both increasing N and K fertilizer rates. Averaged over 2000 and 2001, grass tiller density was 8223, 9758, and 11 567 tillers m^{-2} for 0, 112, and 224 kg N ha^{-1} rates, respectively. Grass tiller density was 8692, 10 092, and 10 765 tillers m^{-2} for 0, 56, and 112 kg K ha^{-1} rates, respectively. The N × K fertilizer rate interaction was not significant ($P > 0.05$) for tiller count. Reed canarygrass stands were visibly thinner at Site 1, with 7665 tillers m^{-2} compared with 12 033 tillers m^{-2} at Site 2.

Yield

Averaged over sites and years, DM yield had an expected significant ($P < 0.05$) linear and quadratic response to applied fertilizer N (Table 3). Although DM yield also responded with a linear increase to applied K fertilizer, the N × K fertilizer rate interaction was significant (Fig. 1). Yield of DM did not increase with increased K fertilization when no N fertilizer was applied, but DM yield increased with increased K fertilization when N fertilizer was applied. The proportion of the total DM yield in the spring harvest increased linearly with increased N fertilizer rate (Table 3). The N rate × K rate interaction for proportion of yield in the spring was significant because this proportion increased with K fertilization rate when no N fertilizer was applied, and decreased with K fertilization rate at both 112 and 224 kg N ha^{-1} rates. Annual DM yield was lower in years with below average rainfall (Table 3), as was expected.

Uptake of K followed a similar pattern as DM yield, with a significant N × K interaction (Fig. 1). Uptake of N responded linearly to increased N fertilizer rate, but was not affected by K fertilizer rate (Table 3). Apparent N recovery did not differ between the two rates of N fertilizer, and was not affected by K fertilization (Table 3). Apparent N recovery averaged 0.595, within the normal range of 0.55 to 0.70 for perennial grasses (Whitehead, 1970). Apparent K recovery was not influenced by rate of K fertilization, but increased linearly from 0.06 to 0.42 with increased N fertilization rate. Uptake of K was relatively high when no fertilizer K was applied; therefore, apparent recovery of fertilizer K was relatively low.

Table 3. Yield of DM, N, and K, and apparent recovery of N and K fertilizer.†

Treatment	DM yield	Proportion of yield in spring	Annual uptake		Apparent recovery‡	
			N	K	N	K
Year	kg ha^{-1}		—— kg DM ha^{-1} ——			
1996	7748b§	0.491ab	112.0b	123.0a	0.674b	0.228bc
1997	6519c	0.509a	101.2c	77.6c	0.567c	0.161bc
1998	8336a	0.495ab	131.3a	87.1b	0.787a	0.247b
1999	4102d	0.488b	73.2e	47.8d	0.436e	0.162c
2000	6766c	0.439c	97.8d	84.8b	0.512d	0.342a
SED	155	0.010	4.4	2.6	0.030	0.035
N rate						
0¶	3074	0.440	42.6	45.8	–	0.056
112	7388	0.479	100.0	96.0	0.582	0.209
224	9621	0.534	163.1	110.3	0.608	0.419
Response#	LQ	L	L	LQ	NS	L
SED	185	0.008	3.6	3.3	0.026	0.054
K rate						
0††	6399	0.492	99.7	73.6	0.570	–
56	6643	0.480	100.6	82.0	0.601	0.228
112	7041	0.481	100.6	96.6	0.614	0.227
Response	L	NS	NS	L	NS	NS
SED	98	0.005	2.5	2.2	0.026	0.031

† Least-squares means of fixed effects computed using PROC MIXED of SAS.
‡ Expressed as proportion of fertilizer applied.
§ Means followed by different letters within a column are significantly different at $P < 0.05$.
¶ kg N fertilizer ha^{-1} applied annually.
# Linear (L) and quadratic (Q) responses significant at $P < 0.05$.
†† kg K fertilizer ha^{-1} applied annually.

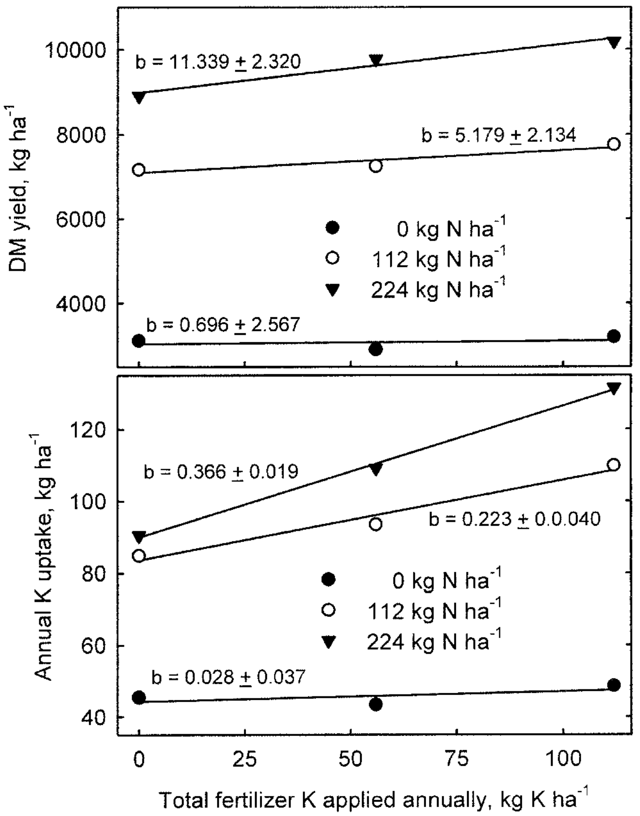

Fig. 1. Annual yield of DM and K uptake of reed canarygrass as influenced by N and K fertilization rate. A linear regression slope (*b*) ± SE is provided for each N fertilization rate. Data are means across 10 site–year combinations and four replicates.

Soil Analyses

Soil test P was maintained in the medium range at both sites throughout the duration of the experiment. Soil test K decreased linearly with increased N fertilization rate and increased linearly with increased K fertilization rate (Table 4). The N rate × K rate interaction was significant ($P < 0.01$) due to soil accumulation of applied K fertilizer when no N fertilizer was applied (Fig. 2). The three-way interaction of N × K × Year also was significant for soil test K (Fig. 3). When K fertilizer was applied with no N fertilization, soil test K increased up to 82.1 mg kg^{-1} from 1997 to 2000. With no N fertilization dry matter yield as well as K uptake of perennial grasses is low (Cherney et al., 1998). When K fertilizer was applied along with N fertilizer, however, soil test K decreased from 1997 to 2000. Allinson et al. (1992) reported a similar pattern on a fine sandy loam soil. Other studies have demonstrated that soil test K could be significantly decreased in one growing season if K fertilizer was not applied (Crill et al., 1998; Robinson et al., 1990; Webb et al., 1990).

Table 4. Soil test values as influenced by N and K fertilizer.†

Treatment	K	OM‡	pH
Year	mg kg^{-1}	g kg^{-1}	
1997	48.39a§	24.2b	5.97b
1999	45.49a	24.9a	6.01b
2000	39.38b	24.1b	6.08a
SED	1.71	0.022	0.221
N rate			
0¶	59.85	23.6	6.14
112	38.49	24.6	6.07
224	34.88	25.0	5.86
Response#	LQ	L	L
SED	1.40	0.051	0.066
K rate			
0††	34.61	24.0	6.03
56	41.83	24.3	6.05
112	56.78	24.8	5.98
Response	L	L	LQ
SED	1.35	0.023	0.026

† Least-squares means of fixed effects computed using PROC MIXED of SAS.
‡ Soil organic matter.
§ Means followed by different letters within a column are significantly different at $P < 0.05$.
¶ kg N fertilizer ha^{-1} applied annually.
# Linear (L) and quadratic (Q) responses significant at $P < 0.05$.
†† kg K fertilizer ha^{-1} applied annually.

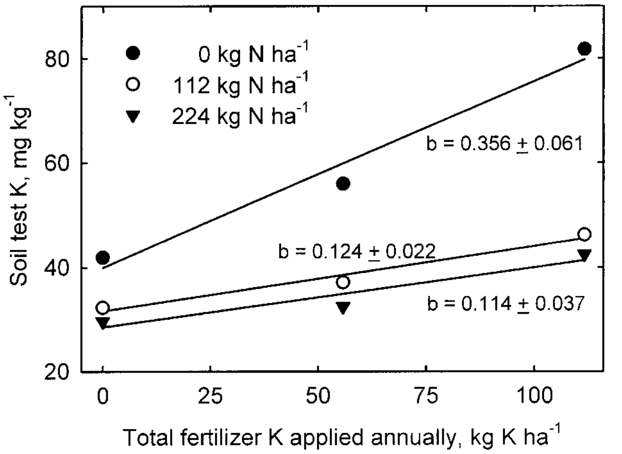

Fig. 2. Soil test K following fall harvest, as influenced by N and K fertilization rate. A linear regression slope (*b*) ± SE is provided for each N fertilization rate. Data are means across six site–year combinations and four replicates.

Organic matter content of soil increased linearly with increased N and K fertilization rate (Table 4), although changes in OM content were relatively small. Soil pH decreased linearly with increased N fertilization rate (Table 4), as often occurs in N-fertilized grasslands (Hopkins, 2000). Soil Ca content was not influenced by either N or K fertilization (data not shown), but was significantly lower in 1999 (2286 kg ha^{-1}) compared with 1997 (2486 kg ha^{-1}), and also was significantly lower in 2000 (2189 kg ha^{-1}) compared with 1999. Calcium is removed from soil by leaching and in harvested forage.

Forage Nutritive Value

In general, nutritive value differences in spring forage over years reflected differences in spring harvest date (Table 1). Crude protein concentration significantly increased with increased N fertilization for the spring harvest (Table 5). Although there was a significant linear and quadratic response of CP concentration to N fertilization in the fall, the CP concentration actually declined from 0 N fertilization to 112 kg N fertilizer ha^{-1} applied annually. Fertilization of grass with a moderate level of N after spring harvest apparently increased DM yield sufficiently to dilute uptake of N per unit DM accumulated. Fertilization with K had no effect on CP concen-

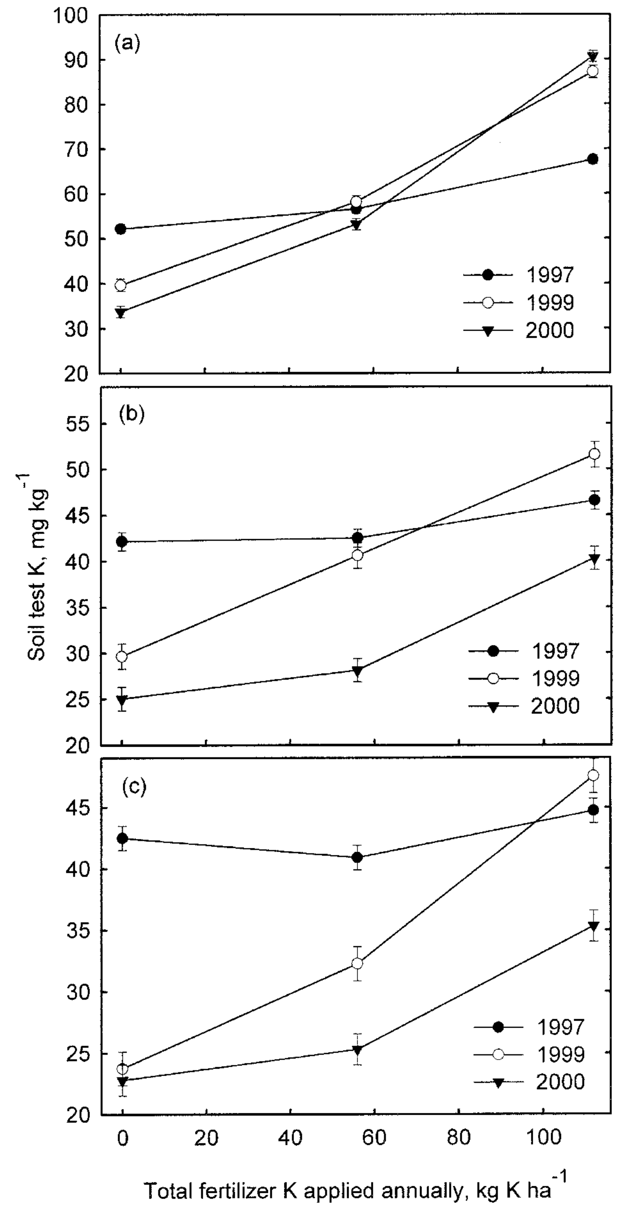

Fig. 3. Soil test K following fall harvest, as influenced by N and K fertilization rate and year. (*a*) 0 kg N ha^{-1}, (*b*) 112 kg N ha^{-1}, and (*c*) 224 kg N ha^{-1}. Error bars are standard errors of two sites and four replicates.

tration. Neutral detergent fiber concentration increased slightly, but significantly, with increased N fertilization at both harvests, and with increased K fertilization at spring harvest (Table 5). Concentration of NDF in spring-harvested forage exceeded 600 g kg^{-1}, which is considered high for lactating dairy cattle on high forage diets (Mertens, 1994), but acceptable for nonlactating cows, which require considerably more fiber in their diet. Fall harvested cool-season grass is typically lower in NDF concentration than grass forage harvested in June, possibly due in part to a greater stem/leaf ratio in spring growth.

In vitro true digestibility (IVTD) of spring-harvested forage varied significantly from year to year (Table 5), caused in part by different June harvest dates over years (Table 1). Increased N fertilization significantly decreased IVTD, while K fertilization had no effect on IVTD. Digestibility of NDF also decreased with increased N fertilization (Table 5). Fall-harvested forage was lower in NDF concentration compared with that of spring forage, but NDF digestibility of fall-harvested forage was lower than observed for spring forage. Although lignin was not measured, the long growth period between spring and fall harvests should result in increased lignification and decreased NDF digestibility. Spring forage was harvested when NDF concentration was reaching a plateau, but lignification and the resulting decrease in NDF digestibility had not yet reached a plateau. Overall, NDF digestibility was closely correlated with in vitro true digestibility, with Pearson correlation coefficients of 0.980 (n = 360) for spring forage and 0.958 (n = 360) for fall forage.

Elemental Composition

Forage K concentration varied from year to year owing in part to the quantity of soil-fixed K released in any given year, and in part to the date of harvest. Potassium concentration decreased with increased N fertilization rate (Table 6). Although K concentration will increase with increased N fertilization when adequate soil K is available, the opposite response occurs under conditions of low soil K availability (Cherney et al., 1998). All spring and fall harvested forage during this study had K concentration below the critical 25 g kg^{-1} level desired for nonlactating dairy cow forage. Concentration of K increased linearly with increased K fertilization rate; however, the N × K interaction was significant for both spring and fall harvest (Fig. 4). As with DM yield, there was a much greater response to K fertilization with the addition of N fertilizer. Fall harvested forage at the highest N fertilizer rate with no K fertilization averaged 7.4 g K kg^{-1} DM. All fall harvested forage that received N fertilizer contained K concentrations below that considered necessary for optimum yield (Cherney et al., 1998).

Concentration of P in forage declined significantly with increased N fertilization (Table 6). Total P uptake (data not shown) increased due to the large yield increase associated with N fertilization. Fertilization with N has been shown to increase total P uptake (Fageria, 2001). Fertilization with K did not greatly impact P concentration. Concentration of Ca and Mg increased linearly with increased N fertilizer rate, except for Ca in fall-harvested forage (Table 6). Response of Ca and Mg concentrations to N fertilization was similar to that found previously in other grasses (Cherney et al., 1998). Fertilization with K had the opposite effect, resulting in decreased Ca and Mg concentrations, except for Mg at fall harvest. Fertilization with K has been shown to increase K concentration in grass forage at the expense of Mg and Ca concentrations (Grunes et al., 1992). The N × K fertilizer interaction was significant for Mg and Ca at spring harvest, but both were caused by changes in the magnitude of response, with a much larger response to K fertilizer at higher rates of N fertilization.

Table 5. Forage quality of reed canarygrass under two-harvest management as influenced by N and K fertilization.†

	CP		NDF		IVTD		NDF digestibility	
Treatment	**Spring‡**	**Fall**	**Spring**	**Fall**	**Spring**	**Fall**	**Spring**	**Fall**
Year	g kg^{-1} DM						g kg^{-1} NDF	
1996	105.0b§	93.6c	655b	596a	707d	668c	555d	444c
1997	109.4b	98.9b	679a	586b	709d	698b	572d	484b
1998	109.8b	104.1ab	622d	544d	745c	722a	591c	489b
1999	129.2a	106.4a	634c	577c	793a	727a	674a	528a
2000	108.4b	78.7d	633c	576c	761b	665c	625b	420d
SED	3.3	2.7	3/3	4.1	6.0	4.2	8.2	7.7
N rate								
0¶	98.3	98.3	625	568	792	732	670	528
112	106.5	85.7	653	575	731	685	590	454
224	132.2	105.1	656	584	705	671	550	438
Response#	LQ	LQ	LQ	L	LQ	LQ	LQ	LQ
SED	2.7	1.9	3.4	2.9	4.7	4.0	6.2	6.1
K rate								
0††	114.3	97.7	639	578	744	693	602	469
56	111.9	96.2	643	575	746	701	607	481
112	110.8	95.1	651	575	739	695	601	470
Response	NS	NS	L	NS	NS	NS	NS	NS
SED	2.3	1.7	2.3	2.1	4.2	3.6	6.0	5.8

† Least-squares means of fixed effects computed using PROC MIXED of SAS.

‡ Spring or fall harvest.

§ Means followed by different letters within a column are significantly different at $P < 0.05$.

¶ kg N fertilizer ha^{-1} applied annually.

Linear (L) and quadratic (Q) responses significant at $P < 0.05$.

†† kg K fertilizer ha^{-1} applied annually.

Table 6. Elemental composition of reed canarygrass under two-harvest management as influenced by N and K fertilization.†

	K		P		Ca		Mg	
Treatment	**Spring‡**	**Fall**	**Spring**	**Fall**	**Spring**	**Fall**	**Spring**	**Fall**
Year	g kg^{-1} DM							
1996	20.6a§	12.3a	2.94b	3.72a	3.32a	5.79b	2.12a	8.39a
1997	14.3c	9.7c	2.84c	2.91d	2.69c	5.28c	1.88b	8.03a
1998	11.4d	10.0c	2.79c	3.34bc	2.91b	4.97d	1.88b	6.54b
1999	14.1c	8.8d	3.04a	3.51b	3.30a	6.55a	1.73c	6.36b
2000	15.6b	10.9b	3.04a	3.36c	2.86b	4.37e	1.85b	6.31b
SED	0.23	0.19	0.03	0.06	0.05	0.11	0.03	0.22
N rate								
0¶	17.0	12.5	3.20	4.49	2.86	5.56	1.53	6.24
112	15.5	9.7	2.84	2.93	2.95	4.94	1.89	7.38
224	13.0	8.8	2.76	2.68	3.24	5.67	2.26	7.76
Response#	L	LQ	LQ	LQ	L	Q	L	LQ
SED	0.3	0.2	0.07	0.09	0.07	0.10	0.04	0.12
K rate								
0††	14.0	9.6	2.93	3.49	3.15	5.84	1.99	7.24
56	15.1	10.3	2.94	3.41	3.03	5.37	1.89	7.06
112	16.5	11.2	2.92	3.21	2.87	4.95	1.79	7.08
Response	L	L	NS	L	L	L	L	NS
SED	0.2	0.1	0.04	0.06	0.05	0.10	0.03	0.12

† Least-squares means of fixed effects computed using PROC MIXED of SAS.

‡ Spring or fall harvest.

‡ Means followed by different letters within a column are significantly different at $P < 0.05$.

¶ kg N fertilizer ha^{-1} applied annually.

Linear (L) and quadratic (Q) responses significant at $P < 0.05$.

†† kg K fertilizer ha^{-1} applied annually.

SUMMARY AND CONCLUSIONS

High yield of low forage K reed canarygrass was possible by managing N and K fertilization. Nitrogen fertilization decreased forage K concentration, but significantly increased total K uptake. Potassium fertilization had essentially no effect on forage K concentration, total DM yield, or total K uptake in the absence of N fertilizer. Potassium fertilization with constant N fertilization resulted in increased forage K concentration, yield of DM, and annual K uptake. Year-to-year differences in yield and forage nutritive value reflected differences in seasonal rainfall and different maturity at harvest.

Nitrogen-fertilized reed canarygrass under a two-harvest management with no K fertilization produced adequate yield (90% of high K fertilization yield) of forage with sufficiently high IVTD and NDF digestibility for nonlactating dairy cows. Although some CP supplementation in the diet may be required, forage produced under a two-harvest system generally was adequate in nutritive value for nonlactating dairy cows.

Managing K concentration in perennial grass forage is very site-specific, owing to the tremendous variation in available K among soil types. Prolonged N fertilization of perennial grass under extensive harvest manage-

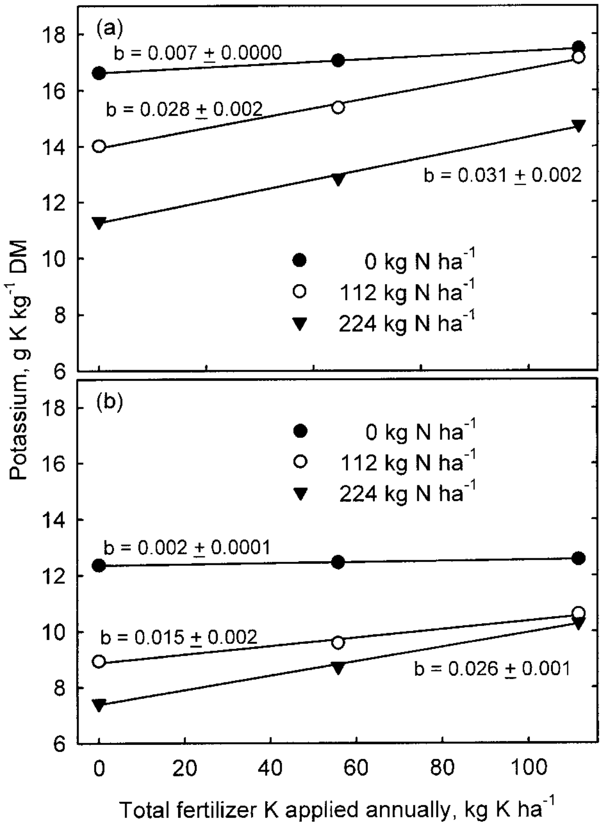

Fig. 4. Potassium concentration of reed canarygrass forage at (*a*) spring and (*b*) fall harvests, as influenced by N and K fertilization rate. A linear regression slope (*b*) ± SE is provided for each N fertilization rate. Data are means across 10 site–year combinations and four replicates.

ment should eventually result in low forage K concentration on most soil types, provided there is no or minimal K fertilization practiced. It appears likely that soils with high or very high K supplying power would not require any K fertilization to maintain optimum grass yield. Although reed canarygrass stand persistence in this study was not affected by prolonged K deficiency, it is prudent to maintain harvested grass forage K concentration above 12 g kg^{-1} DM to minimize risk to stand persistence.

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