Nitrogen Value and Protein Degradation Kinetics for Crabgrass Harvested on Seven Dates in Northern Arkansas

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Story in Brief

Common crabgrass [*Digitaria ciliaris* (Retz.) Koel.] is undesirable in fields of bermudagrass [*Cynodon dactylon* (L.) Pers.] hay fields because it dries more slowly than bermudagrass, which raises concerns about potential spontaneous heating and molding in hay. However, visual observations indicate that grazing livestock prefer crabgrass to many other summer forages. Our objectives were to assess the concentrations of various N fractions within leaf, stem, and whole-plant tissue in crabgrass forage, harvested on seven dates during 2001. In addition we evaluated ruminal in-situ disappearance kinetics of N and neutral detergent insoluble N (NDIN) and compared them with alfalfa (*Medicago sativa* L.), bermudagrass, and orchardgrass (*Dactylis glomerata* L.) hays. Crabgrass was harvested weekly beginning on July 11 and ending on August 22, 2001. Whole-plant concentrations of N declined linearly ($P = 0.001$) from 3.36 to 2.55% over this time period. Forage samples were evaluated for in-situ disappearance of N and NDIN in five (843 ± 50 lb) ruminally cannulated steers. Crabgrass had a more rapid N disappearance rate than bermudagrass ($P < 0.0001$), while alfalfa ($P < 0.0001$) had a faster rate than crabgrass. There was no difference between the disappearance rate for crabgrass and orchardgrass ($P = 0.15$). The effective ruminal degradability of N was greater ($P < 0.0001$) for crabgrass than for alfalfa, bermudagrass, or orchardgrass hays. The disappearance rate for NDIN was faster for crabgrass than bermudagrass ($P < 0.0001$) and orchardgrass ($P = 0.01$), but the disappearance rate for alfalfa hay was faster ($P < 0.0001$) than crabgrass. The effective ruminal degradability of NDIN was greater for crabgrass than for bermudagrass or alfalfa hays ($P < 0.0001$); but no difference ($P = 0.87$) was observed between crabgrass and orchardgrass.

Introduction

Crabgrass is a warm-season annual grass. Although crabgrass is not a perennial, it is a very prolific reseeder that is difficult to control. It is undesirable in bermudagrass hay fields because it dries more slowly than bermudagrass, creating concerns about the potential for spontaneous heating and molding in hay (Dalrymple, 1999). However, both visual observation and circumstantial evidence indicate that grazing livestock prefer crabgrass to many other summer forages, and cattle often exhibit good summer performance when consuming this forage.

The recent creation of new feeding models (Sniffen et al., 1992; NRC, 1996) has resulted in a need for in-depth knowledge of forage proteins. Nitrogen from forage is utilized more efficiently when these systems are used properly. Knowing the distribution of N within the fiber and cell-soluble fractions of the plant, and understanding the ruminal disappearance kinetics of forage N is important in order to acquire the greatest benefit from these feeding models.

Because crabgrass can be an alternative to other important forage species, we need to know more about its nutritive value and degradation properties in the rumen. Our objectives in this study were to: 1) determine the concentration of N fractions in leaf, stem, and whole-plant tissue; and 2) evaluate the ruminal in-situ disappearance kinetics of N and NDIN for common crabgrass harvested at weekly intervals during the summer.

Experimental Procedures

Collection of Experimental Forages and Laboratory Analysis. Crabgrass forages and control hays were collected, processed, and analyzed as described in a companion report (Ogden et al., 2004). Concentrations of N, neutral detergent soluble nitrogen (NDSN) and NDIN were determined by rapid combustion (1574°F; LECO Model FP-428; LECO Corp., St. Joseph, Mich.). Concentration of acid detergent insoluble N (ADIN) was determined by identical procedures following digestion of forage samples in acid detergent. Identical methodology for quantification of N was used to determine residual N and NDIN following ruminal incubation in-situ. Procedures for digestion of in-situ residues in neutral detergent prior to quantifying NDIN have been described previously (Ogden et al., 2004).

In-situ Procedures in Confinement. Procedures for determination of N and NDIN disappearance kinetics, determination of rate of passage, and statistical analysis are identical to those reported in a companion report evaluating disappearance kinetics of NDF (Ogden et al., 2004). Briefly, dacron bags were filled with 5-g of each experimental forage (4 x 8 in; 50 ± 10-µm pore size; ANKOM Technology, Corp., Fairport, N.Y.) and heat sealed with an impulse sealer (Type TISH-200; TEWI International Co., Ltd., Taipei, Taiwan). Samples were pre-incubated in tepid (102°F) water, incubated in the rumen for 3, 6, 9, 12, 24, 36, 48, 72, or 96 h, rinsed in a top load washing machine, and dried under forced air at 122°F. A separate set of bags was pre-incubated and then rinsed in the washing machine without ruminal incubation (0 h).

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Data for ruminal disappearance of N and NDIN were fitted to the nonlinear regression model of Mertens and Loften (1980) by PROC NLIN of SAS (SAS Inst., Inc., Cary, N.C.). Nitrogen and NDIN were partitioned into three fractions based on relative susceptibility to ruminal disappearance as described by Coblentz et al. (1998). The A fraction was defined as the immediately soluble portion; the B fraction represented that portion of N or NDIN that disappeared at a measurable rate; and fraction C was defined as the portion of N or NDIN that was undegradable in the rumen. Fractions B and C, disappearance rate (k_d), and the discrete lag time were determined directly by the nonlinear regression model. For each forage, fraction A was calculated as 100 – (B + C); similarly, the potential extent of disappearance was calculated as 100 – C. For all forages, the degradability of N or NDIN was calculated as A + B x $[k_d/(k_d + k_p)]$, where k_p = passage rate (0.025 ± 0.005/h). Prior to making these calculations, a cross-section of in-situ residues (n = 50) representing all steers, forages, and incubation periods were analyzed for purines to assess microbial contamination by the method of Zinn and Owens (1986). Purine concentrations were found to be negligible and no corrections for microbial contaminant N were applied to the determination of kinetic parameters.

Statistics. Characteristics of nutritive value for the experimental crabgrass forages were analyzed as a randomized complete block design with field blocks (n = 4) as replications and seven harvest dates as the treatment term. Harvest dates were evaluated by single degree-of-freedom orthogonal contrasts for linear, quadratic, cubic, and quartic effects of time. Disappearance kinetics of N and NDIN for crabgrass harvested on seven dates and for the alfalfa, orchardgrass, and bermudagrass hay controls were evaluated as a randomized complete block design with the five steers as blocks. Single degree-of-freedom contrasts were utilized to evaluate the effects of harvest date on the disappearance kinetics of crabgrass, and to compare crabgrass with the control hays.

Results and Discussion

Nutritive Value of Crabgrass. In general, the concentration of N within leaf tissue (Table 1) declined linearly (P < 0.0001) throughout the harvest period. On August 1, concentrations of N exhibited a numerical increase from 3.40 to 3.68%; this increase can probably be explained on the basis of new tiller development following a total of 1.3 in of rainfall that fell between July 25 and 30. Concentrations of N in stem tissue declined linearly (P = 0.002) across harvest dates, ranging from 3.31 to 2.42%. Whole-plant concentrations of N declined linearly (P = 0.001) from 3.36 to 2.55% over sampling dates. Whole-plant concentrations of NDSN declined linearly (P < 0.0001) and cubically (P = 0.006), while concentrations of NDIN increased with the same polynomial effects (Table 1).

Disappearance Kinetics of N. Fraction A for crabgrass forages declined with linear (P = 0.037), quadratic (P < 0.0001), cubic (P < 0.0001), and quartic (P < 0.0001) effects over harvest dates (Table 2). Fraction B fluctuated over harvest dates in quadratic, cubic, and quartic (P < 0.0001) trends. In contrast, fraction C increased from 5.2 to 7.3% over harvest dates in a linear (P < 0.0001) pattern. Crabgrass had a larger fraction A (P < 0.0001), smaller fraction B (P < 0.0001), and smaller fraction C (P < 0.0001) than the alfalfa hay control.

To our knowledge, disappearance rates of N for crabgrass have not been determined previously. There was a linear (P = 0.019) decline for N disappearance rate (overall mean = 0.092/h) across sampling dates for crabgrass. In this study, crabgrass had more rapid disappearance rate than bermudagrass hay (P < 0.0001), but N from crabgrass disappeared at a slower (P < 0.0001) rate than observed for the alfalfa hay controls. There was no difference (P = 0.153) between the rate of N disappearance for orchardgrass hay and crabgrass. The potential extent of ruminal disappearance was greater for crabgrass (P < 0.0001) than for alfalfa and orchardgrass hays, but lower for crabgrass than bermudagrass hay (P < 0.0001). The effective ruminal degradability of N was greater for crabgrass (P < 0.0001) than for the alfalfa, bermudagrass, or orchardgrass hays.

Disappearance Kinetics of NDIN. Fraction B decreased from 89.9 to 87.9% in linear, quadratic and quartic (P ≤ 0.024) pattern over harvest dates (Table 3). The C fraction increased over harvest dates in linear (P < 0.0001), quadratic (P = 0.004), and quartic (P < 0.0001) patterns. Crabgrass had a greater fraction B (P < 0.0001) and smaller C fraction (P < 0.0001) than alfalfa, but it exhibited a smaller fraction B (P < 0.0001) and greater fraction C (P < 0.0001) than bermudagrass. The disappearance rate for NDIN in crabgrass declined in a linear (P = 0.001) pattern over harvest dates. The rate of NDIN disappearance was faster for crabgrass than bermudagrass (P < 0.0001) and orchardgrass (P = 0.010) hays; in contrast, alfalfa hay exhibited a more rapid (P < 0.0001) NDIN disappearance rate than crabgrass. The effective ruminal degradability of NDIN for crabgrass declined in a linear (P < 0.0001) and quartic (P = 0.002) pattern over harvest dates from 73.4 to 70.8%. Crabgrass had a greater (P < 0.0001) effective ruminal degradability of NDIN than the alfalfa or bermudagrass hays.

Implications

The mean effective rumen degradability for crabgrass N (85.3%) and NDIN (72.0%) was 2.0 and 21.5 percentage units greater, respectively, than that of alfalfa hay utilized in this study. These results indicate that crabgrass N exhibits high ruminal availability, but disappearance rates are slower than observed for alfalfa hay, which may improve the efficiency of protein use in ruminants.

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Table 1. Nitrogen characteristics of leaf, stem, and whole-plant fractions for crabgrass forages harvested during 2001 near Prairie Grove, Ark.

Harvest date	N	NDSN[1]	NDIN	ADIN
	% of DM		% of N	
Leaf				
July 11	3.80	70.4	29.6	3.89
July 18	3.62	67.2	32.8	4.14
July 25	3.40	65.9	34.1	3.88
August 1	3.68	67.8	32.2	3.69
August 8	3.36	56.7	43.3	4.31
August 15	3.21	56.3	43.7	4.85
August 22	3.13	55.0	45.0	5.93
SEM[2]	0.110	1.56	1.56	0.349
Effect[3]	L < 0.0001	L < 0.0001 Qu = 0.049	L < 0.0001 Qu = 0.049	L = 0.0004 Q = 0.007
Stem				
July 11	3.31	79.8	20.2	4.05
July 18	2.98	78.1	21.9	3.87
July 25	2.61	76.5	23.5	6.09
August 1	3.10	79.1	20.9	4.14
August 8	2.81	73.4	26.6	5.46
August 15	2.53	72.1	27.9	5.81
August 22	2.42	69.2	30.8	6.73
SEM[2]	0.173	1.63	1.63	0.658
Effect[3]	L = 0.002	L < 0.0001	L < 0.0001	L = 0.005
Whole plant				
July 11	3.36	76.3	23.7	4.84
July 18	3.07	72.2	27.8	6.13
July 25	2.74	69.5	30.5	6.12
August 1	3.05	71.1	28.9	5.21
August 8	2.85	69.2	30.8	5.59
August 15	2.68	68.8	31.2	7.58
August 22	2.55	61.1	38.9	6.64
SEM[2]	0.148	1.51	1.51	0.696
Effect[3]	L = 0.001	L < 0.0001 C = 0.006	L < 0.0001 C = 0.006	L = 0.049 Qu = 0.046

[1] Abbreviations: NDSN, neutral detergent soluble N; NDIN, neutral detergent insoluble N; ADIN, acid detergent insoluble N.

[2] Standard error of the mean.

[3] L, linear effect; Q, quadratic effect; C, cubic effect; Qu, quartic effect.

Table 2. In situ degradation kinetics of N for common crabgrass harvested on weekly intervals near Prairie Grove, Ark., and compared with alfalfa, bermudagrass, and orchardgrass hay controls.

Forage/harvest date	Fraction A[1]	Fraction B	Fraction C	Potential extent	Lag time	k_d	Degradability[2]
	% of N	% of N	% of N	% of N	h	/h	% of N
Crabgrass (CRAB)							
July 11	57.4	37.4	5.2	94.8	0.98	0.096	87.1
July 18	51.0	43.5	5.5	94.5	1.04	0.105	86.1
July 25	51.8	41.4	6.8	93.2	1.05	0.102	85.1
August 1	59.8	34.1	6.1	93.9	1.33	0.084	86.2
August 8	57.0	36.2	6.8	93.2	1.26	0.088	85.3
August 15	55.5	37.5	7.1	92.9	1.68	0.083	84.3
August 22	49.9	42.8	7.3	92.7	0.97	0.086	83.1
Alfalfa Hay (ALF)	43.4	44.8	11.8	88.2	0.94	0.223	83.3
Bermudagrass Hay (BER)	31.6	62.8	5.6	94.4	2.33	0.046	72.3
Orchardgrass Hay (OG)	27.1	64.1	8.7	91.3	4.86	0.081	76.0
SEM[3]	0.75	0.76	0.18	0.18	0.29	0.007	0.44
Contrasts	P > F						
CRAB Linear[4]	0.037	0.795	<0.0001	<0.0001	0.342	0.019	<0.0001
CRAB Quadratic	<0.0001	<0.0001	0.136	0.136	0.357	0.947	0.232
CRAB Cubic	<0.0001	<0.0001	0.131	0.131	0.227	0.141	0.031
CRAB Quartic	<0.0001	<0.0001	0.786	0.786	0.415	0.382	0.362
CRAB vs. ALF	<0.0001	<0.0001	<0.0001	<0.0001	0.428	<0.0001	<0.0001
CRAB vs. BER	<0.0001	<0.0001	<0.0001	<0.0001	0.0004	<0.0001	<0.0001
CRAB vs. OG	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.153	<0.0001
ALF vs. BER	<0.0001	<0.0001	<0.0001	<0.0001	0.001	<0.0001	<0.0001
OG vs. BER	<0.0001	0.211	<0.0001	<0.0001	<0.0001	0.001	<0.0001

[1]Abbreviations: A = immediately soluble fraction, B = fraction disappearing at a measurable rate, C = undegraded fraction, and k_d= disappearance rate.

[2]Calculated as $A + B[(k_d/(k_d + \text{passage rate})]$, where k_d = disappearance rate and the passage rate = 0.025 ± 0.005/h.

[3] Standard error of the mean.

[4] Linear, quadratic, cubic, and quartic effects of harvest date on each response variable.

Table 3. In situ degradation kinetics of NDIN for common crabgrass harvested on weekly intervals near Prairie Grove, Ark., and compared with alfalfa, bermudagrass, and orchardgrass hay controls.

	Fraction						
Forage/harvest date	A[1]	B	C	Potential extent	Lag time	k_d	Degradability[2]
	% of NDIN				h	/h	% of N
Crabgrass (CRAB)							
July 11	0.62	88.4	10.9	89.1	0.71	0.118	73.4
July 18	0.66	89.9	9.5	90.5	0.35	0.113	74.2
July 25	0.66	87.3	12.0	88.0	0.73	0.115	72.4
August 1	0.26	86.6	13.1	86.9	1.30	0.107	70.3
August 8	0.88	86.7	12.4	87.6	0.73	0.111	71.8
August 15	0.48	87.6	11.9	88.1	0.85	0.102	71.0
August 22	0.10	87.9	12.0	88.0	0.79	0.102	70.8
Alfalfa Hay (ALF)	0.00	59.0	41.0	59.0	3.00	0.15	50.5
Bermudagrass Hay (BER)	0.22	93.4	6.4	93.6	1.42	0.072	69.0
Orchardgrass Hay (OG)	2.73	88.0	9.3	90.7	4.07	0.098	72.1
SEM[3]	0.27	0.55	0.40	0.40	0.165	0.004	0.45
Contrasts	P > F						
CRAB Linear[4]	0.226	0.024	<0.0001	<0.0001	0.157	0.001	<0.0001
CRAB Quadratic	0.406	0.011	0.004	0.004	0.170	0.947	0.073
CRAB Cubic	0.389	0.094	0.083	0.083	0.307	0.936	0.286
CRAB Quartic	0.421	0.006	<0.0001	<0.0001	0.010	0.653	0.002
CRAB vs. ALF	0.071	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
CRAB vs. BER	0.287	<0.0001	<0.0001	<0.0001	0.0005	<0.0001	<0.0001
CRAB vs. OG	<0.0001	0.707	<0.0001	<0.0001	<0.0001	0.010	0.865
ALF vs. BER	0.569	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
OG vs. BER	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

[1] Abbreviations: A = immediately soluble fraction, B = fraction disappearing at a measurable rate, C = undegraded fraction, and k_d = disappearance rate.

[2] Calculated as $A + B[(k_d/(k_d + \text{passage rate})]$, where k_d = disappearance rate and the passage rate = 0.025 ± 0.005/h.

[3] Standard error of the mean.

[4] Linear, quadratic, cubic, and quartic effects of harvest date on each response variable.