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Forage Yield and Quality of Temperate Perennial Grasses as Influenced by Stubble Height

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Abstract

Timing of spring grass harvest is critical to obtaining optimum forage quality, and the harvest window is narrow. We studied the feasibility of harvesting grass at higher stubble heights to improve forage quality. 'Okay' orchardgrass, 'Rival' reed canarygrass, and 'Select' tall fescue were fertilized with N fertilizer at 0, 100 and 200 lb/acre at spring greenup and sampled in late May or early June in 2001, 2002, and 2003 after optimum forage quality was reached. Four replicates at each of two sites were sampled: a fertile site in Ithaca, NY and a high-elevation site with low-productivity soil in Dryden, NY. Samples were cut at a 4-inch stubble height and sectioned into 2-inch increments using a paper cutter. Samples were dried, ground, and analyzed for forage quality parameters. As expected, species, level of N fertilization, and location affected the nutritive value characteristics crude protein (CP), neutral detergent fiber (NDF), in vitro true digestibility (IVTD), and digestible NDF, as well as Milk2000 estimates (milk per ton, milk per acre, and relative forage quality). Change in nutritive value per inch of increased stubble height on a percentage basis was small, resulting in small increases in milk per ton (0.83 ± 0.42%) and relative forage quality (1.7 ± 0.84%) estimates. The decline in yield compared to the increase in quality with increased stubble height resulted in a -5.39 ± 1.30% change in milk per acre/inch. The small increase in forage quality with increased stubble height does not offset the significant loss of DM yield.

Introduction

Perennial grass can be an excellent forage source for both lactating and dry dairy cows if managed correctly (5). Grass-based diets have been shown to produce as much milk as alfalfa-based diets (2). Perennial grasses on dairy farms can also help to alleviate nutrient management problems (16). Timing of spring grass harvest is critical to obtaining optimum forage quality (3).

Recent studies with corn (*Zea mays*) harvested for silage suggest that increasing the stubble height will improve the nutritive value of corn silage (6,9) and directly affects the grain-to-stover ratio in grain crops. Research has shown that raising the cutting height, which will leave more low nutritive value stem in the field, will improve nutritive value (10), but it is not clear if grass slightly past the optimum harvest window can be salvaged for lactating dairy feed by using a higher stubble height. The objective of this study was to study the feasibility of harvesting perennial grass forages at higher stubble heights to improve the quality of the forage for use in dairy rations. A range of N fertilization levels commonly used on grasses was also tested.

Studies on Effect of Stubble Height on Yield and Quality

One-year-old seedings of 'Rival' reed canarygrass (*Phalaris arundinacea* L.), 'Okay' orchardgrass (*Dactylis glomerata* L.) and 'Select' tall fescue (*Festuca arundinaceae* Schreb.) at two sites: a Niagara silt loam (fine-silty, mixed, active, mesic Aeric Epiqualfs) soil with 0 to 2% slope in Ithaca, NY and a second site on a Volusia silt loam soil (fine loamy, mixed, active, mesic Aeric Fragiaquepts) soil with 0 to 6% slope in Dryden, NY. Four field replicates were established at each site. Sites were split into blocks that received N at 0, 100, or 200 lb/acre. Both sites were fertilized with P and K according to soil test recommendations. Broadleaf weeds were controlled by annual applications of either 2,4-D amine (2,4-dichlorophenoxy acetic acid dimethylamine) at 0.12 lb/acre in the spring or Banvel (0.28 lb/gal dicamba) at 0.10 lb/acre in the fall.

Fig. 1. Stubble height sections separated with paper cutter.

Sites were harvested in late May or early June in 2001, 2002, and 2003 at about 55 to 60% neutral detergent fiber (NDF). Three-×-20-ft harvest strips at a 4-inch stubble height were taken for yield with a Carter Harvester (Carter Mfg. Co., Inc., Brookston, IN). This stubble height is standard in many parts of the Northeast, where stoney fields preclude setting the cutting bar any lower. Samples (1.3 to 1.8 lbs) were then collected along the cut edge of the plot for quality using a hand-clipper and a 4-inch high metal frame in the early afternoon. Samples were all in the late-boot stage of vegetation. Samples were then chopped into three fractions of 2-inch segments plus remaining canopy height using a standard paper cutter (Fig. 1). Fractions were from 4 to 6 inches, from 6 to 8 inches, from 8 to 10 inches, and 10 inches and above. Data means were calculated using weighted averages from the three segments plus remaining canopy height. Change per inch of increase in stubble height for measured variables were fit to a regression line. Only data from segments below 10 inches were used, as segments above 10 inches contained different amounts of material for different samples. Separate equations were generated for each year × species × nitrogen fertilization rate × replication combination.

Forage fractions were oven dried at 60°C for dry matter (DM) determination and ground to pass a 1-mm screen. Nitrogen concentration of samples was determined using a Leco N analyzer (LECO Corp., St. Joseph, MI) with Dumas combustion (12,17). Samples (0.5 g) were analyzed for NDF using the procedure described by Van Soest et al. (15), 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 (8) using the ANKOM incubator (4). Digested residues were subject to NDF analysis to determine in vitro true digestibility (IVTD). Digestibility of NDF (NDFD) was calculated as the proportion of the NDF digested after 48 h incubation.

Milk2000 (11) was used to estimate milk per acre, milk per ton, and relative forage quality (RFQ). In Milk2000, forage energy intake is calculated for a 1350 lb milking cow consuming a 30% NDF diet and then energy for maintenance of this cow is subtracted. The remainder is an estimate of the energy available for conversion to milk. Milk produced per ton of forage multiplied by DM yield provides milk per acre and combines yield and quality into a single term.

Statistical design was a split-plot with a factorial arrangement of treatments, two locations and four replications per site for three years. A split-plot analysis of variance with repeated measures was used to test for statistical significance of treatment effects and interactions using PROC MIXED (7) in SAS, version 7.0 software (SAS Institute, Cary, NC). Location, species, and fertilization rates were considered fixed effects, while year and replication were considered random effects.

Influence of Species, N fertilization, and Location on Forage Yield and Quality Means

Two- and three-way interactions, with the exception of location × species, among fertilization rates, locations, and species were generally not significant for quality (CP, NDF, IVTD, and NDFD) and Milk2000 estimates (milk per ton, milk per acre, and RFQ), and general trends were very consistent (Tables 1 and

2). Therefore, main effects will be discussed, with interactions discussed where significant. Ithaca produced higher quality forage compared to Dryden (Table 1). Dryden was higher yielding than Ithaca (Table 2). Plants at Dryden were slightly more advanced physiologically than those at Ithaca; advanced maturity generally results in increased fiber and lower digestibility and CP (14). Reed canarygrass had higher CP than the other grass species (Table 1). Crude protein increased linearly with increased N fertilization (Table 1), as reported previously (1,18). Nitrogen fertilization affected NDF and digestibility quadratically, as reported previously (1). Species were not significantly different in IVTD or NDFD (Table 1). Forage NDF was generally above 55%, with the exception of reed canarygrass at Ithaca. The NDF of forage used as the sole roughage source in a ration should be no more than 55% to facilitate ration balancing (L. E. Chase, personal communication as cited by Cherney [3]).

Table 1. Quality means of total forage clipped at a 4-inch stubble height as influenced by location, species, and nitrogen fertilization rate.

	CP[v] (%)	**NDF** (%)	**IVTD** (%)	**NDFD** (%)
Species				
Orchardgrass	14.9a[w]	59.5c	84.1a	73.3b
Reed canarygrass	18.2b	56.1a	83.6a	71.3a
Tall fescue	15.0a	57.3b	83.4a	71.4a
SED[x]	0.27	0.60	0.56	1.05
N rate (lb/acre)[y]				
0	12.5a	57.4a	85.3b	74.5b
100	16.0b	58.8b	82.5a	70.5a
200	19.6c	56.6a	83.3a	70.9a
SED	0.27	0.59	0.70	1.02
Location				
Ithaca, NY	16.0a	56.4a	86.0b	75.4b
Dryden, NY	16.1a	58.8b	81.4a	68.5a
SED	0.22	0.49	0.68	0.85
	P <[z]			
Location	0.51	0.01	0.01	0.01
Species	0.01	0.01	0.57	0.08
N rate	0.01	0.01	0.01	0.01
Location × species	0.04	0.01	0.01	0.01
Location × N rate	0.16	0.18	0.81	0.69
Species × N rate	0.12	0.81	0.37	0.33
Location × species × N rate	0.29	0.94	0.74	0.79

[v] CP = crude protein; NDF = neutral detergent fiber; IVTD = in vitro true digestibility; NDFD = digestible NDF.

[w] Means followed by a different letter within a column differ ($P < 0.05$).

[x] Standard error of the difference.

[y] N rate = N fertilization rate.

[z] Probability level.

Table 2. Yield and Milk 2000 means of total forage clipped at a 4-inch stubble height as influenced by location, species, and nitrogen fertilization rate.

	Height (inches)	**Yield** (lb/acre)	**Milk**[v] (lb/ton)	**Milk** (lb/acre)	**RFQ**
Species					
Orchardgrass	29.7c[w]	3190b	3504b	6949b	152a
Reed canarygrass	25.0a	2813a	3288a	5831a	146a
Tall fescue	27.0b	3158b	3399ab	7120b	150a
SED[x]	0.82	116.5	77.2	272.2	4.0
N rate (lb/acre)[y]					
0	22.1a	1699a	3564b	4166a	159b
100	29.1b	3625b	3309a	7594b	141a
200	30.5c	3836b	3319a	8140c	148a
SED	0.80	119.9	75.0	264.6	3.9
Location					
Ithaca, NY	25.4a	2641a	3545b	6225a	162b
Dryden, NY	29.1b	3466b	3250a	7042b	137a
SED	0.66	96.4	62.1	218.9	3.2
	P<[z]				
Location	0.01	0.01	0.01	0.01	0.01
Species	0.01	0.01	0.03	0.01	0.28
N rate	0.01	0.01	0.01	0.01	0.01
Location × species	0.07	0.01	0.04	0.04	0.01
Location × N rate	0.99	0.01	0.71	0.06	0.97
Species × N rate	0.02	0.05	0.18	0.54	0.41
Location × species × N rate	0.60	0.07	0.75	0.45	0.94

[v] Milk per ton, Milk per acre, and relative forage quality (RFQ) were estimated using Milk2000 (11). RFQ is based on the concept of digestible dry matter intake relative to a standard forage (13).

[w] Means followed by a different letter within a column differ ($P < 0.05$).

[x] Standard error of the difference.

[y] N rate = N fertilization rate.

[z] Probability level.

Canopy height and yield increased with increasing fertilization (Table 2). Interactions between location and species and species and N rate were due to magnitude of response rather than direction of response. For Milk2000 estimates, only location × species interactions were significant, and these were reflective of magnitude of response rather than direction of response. There was a slight tendency for milk per ton and RFQ to decrease with N fertilization, but only reed canarygrass had significantly lower ($P < 0.05$) milk per ton and RFQ with increased N fertilization. Milk per acre increased with increased N fertilization, mirroring the increase in yield.

Change per Inch of Increase in Stubble Height

Correlation coefficients for regression equations for change with increased stubble height averaged 0.98. Changes in parameters per inch of increase in stubble height (Tables 3 and 4) also had consistent trends, with few significant interactions. Nitrogen fertilization rate did not have a major effect on changes in quality parameters associated with stubble height other than tall fescue NDF. Applying N fertilization resulted in lower NDF per inch of increased stubble height. The change in reed canarygrass quality was affected more by stubble height than the other species, in part due to unfertilized reed canarygrass being significantly shorter than the other species. Forage CP increased 0.55 percentage units per inch of increased stubble height for reed canarygrass, compared to 0.35 for the other species. Forage NDF decreased 0.57 percentage units per inch of increased stubble height for reed canarygrass, compared to 0.28 for the other species. Tall fescue and orchardgrass had smaller decreases in NDF with increasing stubble height at Dryden than Ithaca, while reed canarygrass rates were not different ($P > 0.05$) between the two sites. Reed canarygrass also had higher rates of increasing IVTD and NDFD than orchardgrass and tall fescue.

Table 3. Change in nutritive value per inch of increase in stubble height from 4 to 10 inches as influenced by location, species, and nitrogen fertilization rate.

	CP[v] (%)	**NDF** (%)	**IVTD** (%)	**NDFD** (%)
Species				
Orchardgrass	0.34a[w]	-0.26a	0.26a	0.23a
Reed canarygrass	0.55b	-0.57b	0.69c	0.72c
Tall fescue	0.35a	-0.30a	0.48b	0.47b
SED[x]	0.015	0.034	0.065	0.079
N rate (lb/acre)[y]				
0	0.42a	-0.27a	0.44a	0.48a
100	0.42a	-0.43b	0.55a	0.52a
200	0.40a	-0.43b	0.45a	0.41a
SED	0.018	0.033	0.063	0.077
Location				
Ithaca, NY	0.46b	-0.47b	0.47a	0.45a
Dryden, NY	0.37a	-0.28a	0.49a	0.49a
SED	0.18	0.027	0.052	0.063
	$P<$[z]			
Location	0.01	0.01	0.61	0.03
Species	0.01	0.01	0.01	0.01
N rate	0.27	0.01	0.18	0.31
Location × species	0.26	0.01	0.01	0.55
Location × N rate	0.45	0.10	0.83	0.87
Species × N rate	0.73	0.01	0.50	0.23
Location × species × N rate	0.38	0.34	0.38	0.29

[v] CP = crude protein; NDF = neutral detergent fiber; IVTD = in vitro true digestibility; NDFD = digestible NDF.

[w] Means followed by a different letter within a column differ ($P < 0.05$).

[x] Standard error of the difference.

[y] N rate = N fertilization rate.

[z] Probability level.

Table 4. Changes in yield and Milk2000 estimates per inch of increase in stubble height from 4 to 10 inches as influenced by location, species, and nitrogen fertilization rate.

	Yield (lb/acre)	**Milk**[v] (per ton)	**Milk** (lb/acre)	**RFQ** (units)
Species				
Orchardgrass	-189a[w]	14.2a	-318b	1.3a
Reed canarygrass	-182a	97.2b	-274a	3.7c
Tall fescue	-250b	26.3a	-405c	2.0b
SED[x]	6.8	52.95	15.4	0.27
N rate (lb/acre)[y]				
0	-159a	23.4a	-274a	2.1a
100	-232b	28.9a	-355b	2.5a
200	-231b	85.4a	-368b	2.4a
SED	6.6	52.00	15.0	0.28
Location				
Ithaca, NY	-201a	67.3a	-344a	2.6b
Dryden, NY	-213b	24.5a	-321a	2.1a
SED	5.5	42.4	12.4	0.22
	$P<$[z]			
Location	0.04	0.70	0.08	0.03
Species	0.01	0.01	0.01	0.01
N rate	0.01	0.20	0.01	0.31
Location × species	0.03	0.02	0.02	0.55
Location × N rate	0.05	0.83	0.53	0.87
Species × N rate	0.04	0.54	0.04	0.23
Location × species × N rate	0.44	0.37	0.86	0.29

[v] Milk per ton, Milk per acre, and relative forage quality (RFQ) were estimated using Milk2000 (11). RFQ is based on the concept of digestible dry matter intake relative to a standard forage (13).

[w] Means followed by a different letter within a column differ ($P < 0.05$).

[x] Standard error of the difference.

[y] N rate = N fertilization rate.

[z] Probability level.

Yield accumulated more per inch at Dryden than Ithaca, and applying N fertilization had a greater effect on yield accumulation at Dryden than Ithaca (Table 4). There was a N rate × species interaction, with orchardgrass yield accumulation per inch responding less to N fertilization than either reed canarygrass or tall fescue. Reed canarygrass tended to have a greater and tall fescue a lower rate of milk per ton increase at Dryden than Ithaca. Rate of milk per ton increase was higher for reed canarygrass than orchardgrass at Ithaca and higher than orchardgrass and tall fescue at Dryden. Milk per ton is an estimate of quality (11), which tended to be higher in reed canarygrass forage. Increases in RFQ per inch of increased stubble height was greater at Ithaca than Dryden, consistent with the higher forage quality at Ithaca. As with nutritive value characteristics, RFQ of reed canarygrass increased more per inch of increase in stubble height than orchardgrass and tall fescue.

As expected, forage species, level of N fertilization, and location affected forage quality parameters and Milk2000 estimates and rates of increase or decrease of these parameters and estimates. On a percentage basis, change per inch of increased stubble height, expressed as change per inch divided by mean at 4 inch stubble height × 100, was small for most nutritive value characteristics, and resulted in small changes per inch on a percentage basis for milk per ton (0.8 ± 0.42%) and milk per acre (1.7 ± 0.84%) estimates. Rate of reduction in yield per inch increase in stubble height on a percentage basis (-5.7 ± 1.23%) was comparatively greater than the change for nutritive value estimates. The greater reduction in percent yield than increased percent quality resulted in a -5.39 ± 1.30% change in milk per acre, a term that combines both quality and quantity. Based on these results, it would not be advisable to use increased stubble height as a management tool to offset harvesting perennial grasses 5 to 10% past optimum quality (55% NDF) for dairy rations.

Summary and Conclusions

Once first-cutting perennial grasses have passed the harvest window for optimum forage quality, raising the cutter bar at harvest will not improve quality enough to offset yield losses. Cutting high enough to increase forage CP by one percentage unit, or to reduce NDF by one percentage unit, would reduce overall DM yield by 12%. Thus, this is not an economical management tool for orchardgrass, tall fescue, and reed canarygrass, regardless of the level of N fertilization.

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