THE ECONOMICS OF NITROGEN FERTILIZATION OF BROMEGRASS

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INTRODUCTION

Bromegrass is widely grown in western Canada as a source of hay and pasture for beef cattle. Traditionally, producers make decisions each fall or spring on the nitrogen (N) needs of the forthcoming grass crop. In deciding the economic optimum rates of N fertilizer to apply, cost and price information must be combined with expected yield response, forage quality data, and other management factors. It has been hypothesized that many producers in this region are under-fertilizing their grass crops because of an apparent lack of knowledge regarding some of the underlying agronomic and economic considerations (Malhi et al. 1987; Ukrainetz et al. 1988).

The objective of this study was to determine economic optimum N fertilizer management strategies in regard to rate, source, and method of application for established stands of bromegrass grown in the Dark Brown and Gray Luvisolic soil zones of Saskatchewan.

MATERIALS AND METHODS

Experimental Data

Both experiments were started in 1977; the 5-yr study at Scott was initiated on a 12-yr old stand of bromegrass (Ukrainetz and Campbell 1988), and the 9-yr study at Loon Lake on an 8-yr old stand (Ukrainetz et al. 1988). Urea (46-0-0) or ammonium nitrate (34-0-0) were broadcast in spring at several rates either once at the start of the experiment or annually. Single application rates were 100, 200, 400, and 800 kg N ha^{-1}; for ammonium nitrate applications of 600 and 1000 kg ha^{-1} were also included. The N rates for annual applications were 50, 100, and 200 kg ha^{-1}. All plots, including the check (zero N treatment), received blanket applications of phosphorus, potassium, and sulfur (S) which was broadcasted in the fall of 1976 with follow up applications in the spring of every second year thereafter. At Scott, the rates of application of these nutrients were 100 kg P_2O_5 ha^{-1} (0-45-0), 100 kg K_2O ha^{-1} (0-0-60), and 50 kg S ha^{-1} as granular gypsum; at Loon Lake the rates were 224 kg P_2O_5 ha^{-1}, 112 kg K_2O ha^{-1}, and 45 kg S ha^{-1}. All fertilizer treatments were replicated 4 times.

Each plot was cut at the flowering stage of growth with a similar second cut taken on regrowth in 1978 at Scott and in 1979 at both locations. Yields were converted to a dry weight basis using moisture content determinations made on sub-samples taken from each plot. The dried forage was analyzed for Kjeldahl N and P. When there were two cuts were made, total yield was taken as the sum, %N and %P in the forage were calculated as the weighted average of the two cuts. Precipitation was recorded at each site.

Economic Analysis

The economic analysis for each location was conducted in two steps. First, direct comparisons were made of the discounted revenues and costs (Doll and Orazem 1978) for the fertilizer treatments. This involved computing the net present value (NPV) of the yield increase over the check plot for each N rate, source, and method of application. The comparisons were made over the respective 5-yr and 9-yr study periods, as well as after the first 4 yr at both locations, and after the first 8 yr at Loon Lake. The 4-yr and 8-yr periods allowed for comparison of treatments receiving equal amounts of N by both methods of application. For example, treatments with 200 kg N ha^{-1} applied annually received the same total applied N after 4 yr as the single application treatment of 800 kg N ha^{-1}. The NPV formulas for the single (1) and annual (2) fertilizer application methods were as follows:

$$NPV_{ijk} = \sum_{t=0}^{T-1} [(V.\Delta Y_{ijkt}) (\frac{1}{1+r})^{t}] - C_{ijk} \qquad (1)$$

$$NPV_{ijk} = \sum_{t=0}^{T-1} [(V.\Delta Y_{ijkt} - C_{ijkt}) (\frac{1}{1+r})^{t}] \qquad (2)$$

where, ΔY = dry matter forage yield increase over the check (kg ha^{-1}) for fertilizer rate i, N source j, replicate k, and year t,
V = value of harvested forage (\$ kg^{-1}),
C = cost of fertilizer plus application cost (\$ ha^{-1}),
r = discount rate (%), and
T = length of study period (years).

The analyses were made for 4 levels of forage price and 3 levels each of N fertilizer cost and discount rate (Table 1). Two methods were used to assign market values to the harvested forage: i) a fixed forage price regardless of forage quality, which is a method typical of that used by many producers who sell hay; and ii) an empirical relationship developed by the Saskatchewan Feed Testing Laboratory for establishing forage values based on its nutritional composition for beef cattle (Campbell et al. 1986). In the analysis, no allowance was made for residual N fertilizer effects beyond the end of the respective study periods.

The second step in the economic analysis involved determining the optimum annual rates of N fertilizer that maximized expected profit for various ratios of fertilizer cost to forage price (Anderson et al. 1977). Regression analysis was used to establish continuous functions relating forage dry matter yields to N rate, forage stand age, and precipitation for each fertilizer N source. The regression models used the level of precipitation received in the March-April period at Scott and in the April-May period at Loon Lake (Loon Lake is north of Scott and the growing season commences several weeks later). The optimum N rates were found by computing the costs and revenues resulting from all possible precipitation values and for each level of applied N fertilizer, and then choosing that N rate which maximized expected profit (Doll and Orazem 1978). Expected profits were calculated using probability density functions for the precipitation variables which were developed from historical weather records (1951-86) at each site. The economic optimum rates of N fertilizer were also calculated for highly risk averse producers assuming a marginal return of $1.50 per $1.00 invested in N fertilizer and for selected moisture levels representing dry (1.5 standard deviations lower than the mean), and wet (1.5 standard deviations higher than the mean) conditions at each site.

Table 1. Summary of economic parameters

Price/cost	Base Value	Low-High	Units
Bromegrass hay+	0.07	0.05-0.09	$ kg^{-1} DM‡
Fertilizer N - Urea	0.45	0.30-0.60	$ kg^{-1}
- Ammonium Nitrate	0.50	0.33-0.67	$ kg^{-1}
Fertilizer Application - Variable Cost	4.25		$ t^{-1}
- Fixed Cost	3.60		$ ha^{-1}
Discount Rate	5	0-10	%

+ Prices reflecting differences in forage nutrient composition are not shown.

‡ DM = dry matter.

RESULTS AND DISCUSSION

Effect of N Source and Rate on Net Returns

i) At Scott the 5-yr NPV for both methods of N application were significantly influenced ($P<0.05$) by rate and source of N for all forage price and fertilizer cost scenarios (Table 2). In general, N fertilization of bromegrass was highly profitable for most economic situations, except at the higher rates of N application when forage prices were low and fertilizer costs high. Further, NPV was generally higher when N was applied as ammonium nitrate as opposed to urea, reflecting the greater loss of urea-N by volatilization (Ukrainetz and Campbell 1988). Changes in the interest rate used to discount the revenues and costs influenced the magnitude of NPV, but had little effect on the relative profitability of the fertilizer treatments (data not shown).

When N was applied annually, NPV was highest for the 100 or 200 kg ha^{-1} N rates at most constant forage price and fertilizer cost situations. When price was adjusted for the nutrient composition of the forage, NPV was generally highest at the 200 kg ha^{-1} N rate reflecting the positive influence of N fertilizer on forage N and P concentrations. The economic advantage of ammonium nitrate over urea-N (averaged over N rates for the base fertilizer costs) was 53 $ ha^{-1} at a forage price of 0.05 $ kg^{-1}, 117 $

Table 2. Net present value of returns from N fertilization at Scott (1977-81)[†]

Forage Price ($ kg^{-1})	N Source[‡]	N Cost ($ kg^{-1})	Annual N Applications 50	100	200	Single N Applications 100	200	400	600	800	1000
			($ ha^{-1})								
1. Constant Forage Price											
0.05	UR	0.45	151	265	132	94	130	134	-	82	-
	AN	0.50	219	315	173	91	190	189	146	105	1
	UR	0.60	116	197	-4	79	100	74	-	-38	-
	AN	0.67	185	247	36	76	160	129	56	-15	-150
		$S_{\bar{x}}$[§] Source = 18.6; Rate = 22.8				$S_{\bar{x}}$ Source = 8.7; Rate = 15.0					
0.07	UR	0.45	259	460	356	151	220	262	-	382	-
	AN	0.50	359	539	432	149	308	347	328	416	203
	UR	0.60	225	392	220	136	190	202	-	142	-
	AN	0.67	325	471	295	134	278	287	238	176	53
		$S_{\bar{x}}$ Source = 26.1; Rate = 31.9				$S_{\bar{x}}$ Source = 12.1; Rate = 21.1					
0.09	UR	0.45	367	656	581	208	310	389	-	442	-
	AN	0.50	499	764	691	207	426	505	509	497	406
	UR	0.60	333	587	445	193	280	329	-	322	-
	AN	0.67	465	695	554	192	396	445	419	377	256
		$S_{\bar{x}}$ Source = 33.5; Rate = 41.1				$S_{\bar{x}}$ Source = 15.6; Rate = 27.1					
2. Quality Adjusted Forage Price											
	UR	0.45	295	428	586	164	318	312	-	345	-
	AN	0.50	340	602	746	196	365	553	433	356	291
	UR	0.60	261	360	449	149	288	252	-	225	-
	AN	0.67	306	534	609	181	335	493	343	236	141
		$S_{\bar{x}}$[¶] Source = 20.3; Rate = 24.8				$S_{\bar{x}}$ Source = 19.3; Rate = 33.5;					

[†] In this and subsequent tables, the discount rate = 5%.

[‡] UR = urea; AN = ammonium nitrate.

[§] Standard errors for each method of N application are applicable to all fertilizer N costs within a forage price level.

[¶] Standard errors based on only 2 replicates.

ha^{-1} at a price of 0.09 \$ kg^{-1}, and 126 \$ ha^{-1} when prices were adjusted for forage nutrient composition. Proportional changes in the cost of the two N sources had little effect on the economic advantage of ammonium nitrate over urea.

When N was applied as a single application at the start of the experiment, NPV peaked at the 800 or 1000 kg ha^{-1} N rates, except at low forage prices and high fertilizer costs where there was often little difference in profitability over N rates of 200 to 800 kg ha^{-1} (Table 2). This implies that the discounted revenues obtained from additional units of N were about equal to the added fertilizer costs, thus providing a similar NPV. Similar to annual N applications, forage nutrient composition generally increased the relative profitability of the higher N rate treatments. However, at these higher N rates potentially toxic levels of NO_3-N may accumulate in the forage (Ukrainetz and Campbell 1988), thus reducing their desirability, particularly for pasture situations. For single applications, the economic advantage of ammonium nitrate over urea averaged 34 \$ ha^{-1} at a forage price of 0.05 \$ kg^{-1}, 72 \$ ha^{-1} at a price of 0.09 \$ kg^{-1}, and 83 \$ ha^{-1} when price was adjusted for forage quality.

ii) At Loon Lake the effects of rate and source of N on the 9-yr NPV were generally similar to those at Scott (Table 3). For annual N application treatments, NPV decreased with N rates greater than 100 kg ha^{-1} at low or medium forage prices, but NPV increased in a linear fashion with N rates to 200 kg ha^{-1} at high forage prices or when forage nutrient composition was considered. As at Scott, ammonium nitrate-N provided greater NPV than urea-N, and this was little affected by proportional changes in cost of the two N sources. The economic advantage of ammonium nitrate over urea averaged 48 and 121 \$ ha^{-1} at forage prices of 0.05 and 0.09 \$ kg^{-1}, respectively, and 145 \$ ha^{-1} when forage nutrient composition was considered.

For single N application treatments, NPV increased with N rates of 400 to 600 kg ha^{-1} or even higher, except for the situation of low forage price and high fertilizer costs when NPV increased with N rates but only to about 200 kg ha^{-1} (Table 3). The greater yield and economic response to single applications at Loon Lake when compared to Scott is likely due to the increased precipitation and lower soil quality of the Loon Lake region, (Ukrainetz et al. 1988). Again, ammonium nitrate provided greater ($P<0.05$) NPV than urea when averaged over N rates, although there was a tendency for urea to provide similar NPV as ammonium nitrate at N rates below 200 kg ha^{-1}.

Effect of Method of N Application on Net Returns

i) At Scott the NPV calculated after the first 4 yr was significantly higher ($P<0.05$) for annual than single applications at the 400 and 800 kg ha^{-1} N rates; at the 200 kg ha^{-1} N rate NPV was similar for both methods of application (Table 4). The additional economic benefit from annual compared to single N applications at the two higher N rates averaged 111 and 196 \$ ha^{-1} at forage prices of 0.05 and 0.09 \$ kg^{-1}, respectively, and 79 \$ ha^{-1} when price was adjusted for forage nutrient composition.

ii) At Loon Lake the effect of method of N application on NPV for the first 4 yr was generally similar to that at Scott, except at the 400 kg

Table 3. Net present value of returns from N fertilization at Loon Lake (1977-85)

Forage Price ($ kg^{-1})	N Source	N Cost ($ kg^{-1})	Annual N Applications 50	100	200	Single N Applications 100	200	400	600	800	1000
			($ ha^{-1})								
1. Constant Forage Price											
0.05	UR	0.45	165	211	153	52	123	78	-	71	-
	AN	0.50	220	245	207	-18	87	172	148	181	186
	UR	0.60	109	99	-71	37	93	18	-	-49	-
	AN	0.67	164	133	-17	-33	57	112	58	61	36
			$S\bar{x}$ Source = 21.4; Rate = 25.8			$S\bar{x}$ Source = 16.1; Rate = 27.8					
0.07	UR	0.45	310	442	496	92	210	184	-	247	-
	AN	0.50	394	505	601	-3	163	323	330	416	463
	UR	0.60	254	330	272	77	180	124	-	127	-
	AN	0.67	338	393	377	-18	133	263	240	296	313
			$S\bar{x}$ Source = 29.9; Rate = 36.7			$S\bar{x}$ Source = 22.5; Rate = 38.9					
0.09	UR	0.45	454	672	839	132	297	289	-	422	-
	AN	0.50	568	764	996	12	240	473	511	652	740
	UR	0.60	398	560	615	117	267	229	-	302	-
	AN	0.67	512	652	772	-3	210	413	421	532	590
			$S\bar{x}$ Source = 38.5; Rate = 47.2			$S\bar{x}$ Source = 28.9; Rate = 50.1					
2. Quality Adjusted Forage Price											
	UR	0.45	423	619	780	87	258	269	-	469	-
	AN	0.50	517	719	1020	-42	222	447	497	735	801
	UR	0.60	367	507	556	72	228	329	-	349	-
	AN	0.67	461	607	796	-57	192	387	407	615	651
			$S\bar{x}$ Source = 38.9; Rate = 47.6			$S\bar{x}$ Source = 30.3; Rate = 52.4					

Table 4. Effect of method of N application on net present value after first four years at Scott (1977-80)

Forage Price ($ kg^{-1})	N Source‡	Annual N Applications{ 200	400	800	Single N Applications 200	400	800
		($ ha^{-1})					
1. Constant Forage Price							
0.05	UR	137	228	120	127	118	28
	AN	203	275	148	183	143	39
	$S\bar{x}$ Source = Method = 10.6; Rate = 13.0; Rate x Method = 18.3						
0.07	UR	231	392	309	216	240	185
	AN	327	465	363	298	283	203
	$S\bar{x}$ Source = Method = 14.9; Rate = 18.2; Rate x Method = 25.7						
0.09	UR	325	556	498	304	361	343
	AN	451	656	578	413	422	377
	$S\bar{x}$ Source = Method = 19.1; Rate = 23.4; Rate x Method = 33.1						
2. Quality Adjusted Forage Price							
	UR	255	354	438	316	297	378
	AN	307	493	592	357	493	392
	$S\bar{x}$ Source = Method = 16.1; Rate = 19.6; Rate x Method = 27.8						

‡ In this table and in Table 5 urea cost = 0.45 $ kg^{-1}, ammonium nitrate cost = 0.50 $ kg^{-1}.

{ Application rates correspond to 50, 100, and 200 kg ha^{-1} N applied annually in each of the first 4 years (e.g., 50 kg ha^{-1} x 4 yr = 200 kg ha^{-1}).

ha^{-1} N rate where single applications of ammonium nitrate was significantly more profitable ($P<0.05$) than the other treatments (Table 5a). When forage nutrient composition was considered, method of N application had little effect ($P>0.05$) on NPV.

Based on the first 8 yr, NPV was similar for the 400 and 800 kg ha^{-1} N rates when forage prices were low, but at high forage prices or when forage nutrient composition was considered NPV was highest at 800 kg N ha^{-1} (Table 5b). Furthermore, at all constant forage prices NPV tended to be higher for ammonium nitrate than for urea and higher for annual than single N applications.

Yield Response Functions and Optimum N Rates for Annually Applied N Fertilizer

Results of the regression analysis showed that dry matter forage yields for each N source were significantly related to N rate, available

Table 5. Effect of method of N application on net present value after first four years (1977-80) and first eight years (1977-85) at Loon Lake

Forage Price ($ kg^{-1})	N Source	Annual N Applications[1] 200	400	800	Single N Applications 200	400	800
		($ ha^{-1})					
A. First Four-Year Period							
1. Constant Forage Price							
0.05	UR	70	108	125	123	88	66
	AN	124	116	176	91	177	111
	S$\bar{x}$ Source = 13.9; Rate = 17.1; Source x Rate x Method = 24.1						
0.07	UR	138	224	315	210	198	239
	AN	217	243	402	169	330	318
	S$\bar{x}$ Source = 19.5; Rate = 23.9; Source x Rate x Method = 33.8						
0.09	UR	205	341	506	296	307	412
	AN	309	370	629	247	482	525
	S$\bar{x}$ Source = 25.1; Rate = 30.7; Source x Rate x Method = 43.4						
2. Quality Adjusted Forage Price							
	UR	173	273	407	255	225	458
	AN	241	281	586	227	461	598
	S$\bar{x}$ Source = 35.0; Rate = 42.8						
B. First Eight-Year Period							
1. Constant Forage Price							
0.05	UR	-	163	203	-	115	71
	AN	-	224	229	-	172	179
	S$\bar{x}$ Source = Rate = Method = 16.2; Source x Method = Rate x Method = 22.9						
0.07	UR	-	299	418	-	234	247
	AN	-	392	468	-	323	414
	S$\bar{x}$ Source = Rate = Method = 22.7; Source x Method = Rate x Method = 32.1						
0.09	UR	-	436	632	-	355	422
	AN	-	560	706	-	474	648
	S$\bar{x}$ Source = Rate = Method = 29.2; Source x Method = Rate x Method = 41.3						
2. Quality Adjusted Forage Price							
	UR	-	405	582	-	210	468
	AN	-	509	656	-	448	730
	S$\bar{x}$ Source = Rate = 48.1						

[1] Annual N applications for first 4-yr period correspond to 50, 100, and 200 kg ha^{-1} applied each year, while application rates for first 8-yr period correspond to 50 and 100 kg ha^{-1} applied each year.

moisture, and age of stand (Table 6). All estimated coefficients were highly significant ($P<0.001$) and had signs that were in general agreement with other studies (Malhi et al. 1987). Yields increased at decreasing rates in response to N fertilizer and precipitation, and declined linearly with stand age. The positive interactions of N fertilizer with precipitation indicates that the marginal yield responses to N fertilizer (shown by the first derivatives) vary directly with the level of precipitation.

Table 6. Regression coefficients for total dry matter yields of bromegrass

	Scott‡		Loon Lake‡	
Independent Variable+	Urea	Amm. Nitrate	Urea	Amm. Nitrate
Intercept	10018 (1041){	11030 (1199)	2802 (452)	2927 (479)
N	18.1 (3.6)	23.2 (4.2)	15.6 (3.6)	18.5 (3.8)
N^2	-0.085 (0.02)	-0.104 (0.02)	-0.044 (0.02)	-0.050 (0.02)
M	173.8 (31.5)	193.8 (36.3)	27.8 (5.5)	30.3 (5.9)
M^2	-1.511 (0.34)	-1.723 (0.39)	-0.084 (0.03)	-0.099 (0.03)
N * M	0.258 (0.04)	0.264 (0.05)	0.056 (0.02)	0.055 (0.02)
Age	-950 (107)	-1047 (123)	-259 (27)	-275 (29)
R^2	90	89	75	75

+ N = rate of N fertilizer applied (kg ha^{-1}); M = March plus April rainfall (mm) at Scott, and April plus May rainfall (mm) at Loon Lake; Age = years since forage establishment.

‡ All coefficients are significant at $P < 0.001$.

{ Number in brackets refers to the standard error of the coefficients.

Based on the long-term probability distributions for precipitation at the two sites (data not shown), the rates of urea and ammonium nitrate that maximized expected profit for risk neutral and risk averse producers were inversely related to the ratio of fertilizer N cost to forage price (Table 7). At Scott, the optimum N rates for urea and ammonium nitrate tended to be similar at low relative costs for fertilizer; but, at high relative costs the optimum urea-N rates averaged 7-14 kg ha^{-1} lower than those for

Table 7. Optimal rates of annually applied N fertilizer for bromegrass hay

Fertilizer N cost/ forage price ratio	To Achieve Max. Expected Profit[+] Urea	Amm. Nitrate	Low Moisture[‡] Urea	Amm. Nitrate	High Moisture[‡] Urea	Amm. Nitrate
	(kg N ha^{-1})					
Scott Location						
i) Risk Neutral						
4	150	148	101	107	198	189
6	138	138	90	98	187	179
8	126	129	78	88	175	169
10	115	119	66	79	163	160
12	103	110	54	69	151	150
ii) High Risk Aversion[{]						
4	138	138	90	98	187	179
6	120	124	72	83	169	165
8	103	110	54	69	151	150
10	85	95	37	55	134	136
12	67	81	19	40	116	121
Loon Lake Location						
i) Risk Neutral						
4	170	178	140	152	201	204
6	147	158	117	132	178	184
8	125	138	94	112	155	164
10	102	118	71	92	132	144
12	79	98	49	72	110	124
ii) High Risk Aversion						
4	147	158	117	132	178	184
6	113	128	83	102	144	154
8	79	98	49	72	110	124
10	45	68	15	42	76	94
12	11	38	0	12	42	64

[+] Refers to the N rate that maximizes expected profit based on the historical probability density functions for precipitation.

[‡] Low and high moisture refer to March plus April precipitation of 12 and 76 mm at Scott, respectively, and April plus May precipitation of 12 and 108 mm at Loon Lake.

[{] Assumes a marginal rate of return of $1.50 per $1.00 invested in fertilizer N.

ammonium nitrate-N. At Loon Lake, the optimum urea-N rates averaged 8-27 kg ha^{-1} lower than for ammonium nitrate-N, with the largest differences occurring at high relative fertilizer costs. These results reflect the greater losses that occur with urea compared to ammonium nitrate when N is broadcasted. At low relative N costs, the optimum N rates were generally greater at Loon Lake than at Scott, while the opposite was true at high relative N costs. The optimum N rates for risk neutral producers at Loon Lake averaged 10-20 kg ha^{-1} lower (for similar N cost/forage price ratios) than those computed by Malhi et al. (1987) for the Gray Luvisols in Alberta. In Saskatchewan, the current recommended N rate for grasses grown under average moisture is 35-80 kg ha^{-1} in the Dark Brown soil zone and 35-100 kg ha^{-1} in the Gray Luvisolic soil zone (Saskatchewan Agriculture 1987). This suggests that producers in these areas, especially those with lower risk aversion, should use more N fertilizer to maximize expected economic returns.

The optimum rates of N application computed for dry (mean - 1.5 standard deviations), and wet (mean + 1.5 standard deviations) conditions illustrates the great dependency of fertilizer response to moisture and how the optimum rates of N may be adjusted to reflect expectations on moisture. At low moisture, the optimum N rates were 40-50 kg ha^{-1} lower at Scott and 25-30 kg ha^{-1} lower at Loon Lake than when the average expected moisture occurs. At high moisture, the optimum N rates were greater by similar amounts relative to the average expected moisture situation.

CONCLUSIONS

Results of a 5-yr study in the Dark Brown soil zone and a 9-yr study in the Gray Luvisolic soil zone of Saskatchewan show that substantial economic benefit can be obtained from proper N fertilization of bromegrass. For best results the N should be broadcast in smaller doses annually instead of large single applications. There are cost savings associated with single or one-time fertilizer applications but these were generally off-set by forgone revenues because of the greater losses of N by volatilization, immobilization, and leaching. Large single applications of N have some economic merit when fertilizer costs are low and forage prices are high, or when producers desire forage with high N and P concentrations during the first few years after application; however, this method of N application also runs the risk of NO_3 N poisoning of livestock, which is a particularly difficult problem to deal with in pasture situations.

Application of N in the ammonium nitrate (34-0-0) form was more profitable than in the urea (46-0-0) form, despite its higher unit cost. This reflects the lower N losses by volatilization when ammonium nitrate is broadcast on the soil surface as compared to urea. The economic advantage of ammonium nitrate over urea was also shown to increase at higher forage prices or when the nutrient composition of the forage is an important consideration in its utilization.

The economic optimum rates of N fertilizer calculated for annual applications were generally higher than the currently recommended rates for these regions of Saskatchewan which lends support to the notion that producers are under-fertilizing their grass crops for maximum economic return. Further, information is presented which should facilitate extension personnel in making adjustments to these recommendations, including the consideration of expected moisture conditions.

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