Nutrient Requirements

Of

Mixed Forages

(1998/99 Final Report)

Project #96E156

Prepared for:
Potash & Phosphate Institute

April, 1999

Nutrient Requirements of Mixed Forages
1999 Final Report

Background

A gradual decrease in the percent legume in mixed forages has been accepted by many farmers as a normal symptom of an aging sward. Efforts to rejuvenate swards by aerating and sod-seeding have resulted in limited success. Workdown and re-establishment of the sward may not be the best option on soils where topography or soil texture may predispose the soil to erosion or where stoniness greatly increases the cost of tillage. Re-establishment of the sward also interrupts the supply of forage, which must be compensated for by purchases of hay or temporarily reducing cattle inventory. A balanced soil fertility program along with timely harvest management may be instrumental in maintaining the legume component of the sward and hence maintain yield over an extended period of time. With the potential for strength in the cereal and oilseed markets to decrease the land base used for forage production, strategies to increase forage yields must be explored.

Objectives

Component A

- Identify the fertilizer regimes necessary to maximize yield of mixed grass-legume swards.
- Determine the effect of nitrogen and phosphorus applied alone and in combinations on the composition of mixed forage swards.
- Determine the effect of nitrogen and phosphorus on forage quality.

Component B

- compare harvesting methods (fodder and simulated grazing) on yield, composition and quality of the sward at different levels of fertilization

Progress to Date

Trials to assess the nutrient requirements of mixed forages were established in May 1995 near Calmar (NE 20-48-26-4) on an eluviated Black Chernozemic soil and at Lac La Biche (SW 29-67-12-4) on an Orthic Gray Luvisol. At Calmar, the trial was established on a two-year-old stand of alfalfa (Medicago Sativa) and orchardgrass (Dactylis glomerata) while the stand at Lac La Biche was a three-year-old mixture of alfalfa (Medicago sativa cv. Grimm) and timothy (Phleum pratense cv. Climax).

Component A

Fertilizer was broadcast during the last week of April each year. Urea (46-0-0) and Triple Super Phosphate (0-45-0) were used as the sources of nitrogen and phosphate respectively. Potassium Sulphate (0-0-50-17) was used to supply 88 kg ha $^{-1}$ and 30 kg ha $^{-1}$ of potash and sulphur respectively. Nitrogen and phosphate were applied in a factorial design to assess the effect of all combinations on yield and percent composition of the sward. A list of treatments is displayed in Table 1. Plots were harvested when the sward was at approximately 10 to 20 percent bloom.

Table 1. List of Treatments

Treatment #	Nitrogen (kg/ha)	Phosphorus (kg/ha)
1	0	0
2	0	10
3	0	20
4	0	30
5	0	40
6	20	0
7	20	10
8	20	20
9	20	30
10	20	40
11	40	0
12	40	10
13	40	20
14	40	30
15	40	40
16	60	0
17	60	10
18	60	20
19	60	30
20	60	40
21	80	0
22	80	10
23	80	20
24	80	30
25	80	40

Results

The probability (P) values for the effect of N, P_2O_5 and their interaction on yield and quality of forage grown in Component A at Calmar are presented in appendices 1 to 4 and for Lac La Biche in appendices 5 to 8 for 1995 through 1998 respectively. The effect of treatment on yield at Calmar is presented in appendices 9 to 12 and for Lac La Biche in appendices 13 to 16 for 1995 through 1998 respectively.

A. Yield

At Calmar, nitrogen significantly increased yield of the first cut in all years except 1996 (Table 2). A small application of nitrogen (20 kg ha^{-1}) may be economic sound particularly when forage is produced for high value markets such as dairy rations and the de-hy industry or in years when low soil temperatures limit the nitrogen fixation process. Research conducted by Wendell Rice at Agriculture and Agri-Food Canada research station at Beaverlodge has shown the nitrogen fixation process is temperature dependent and a minimum soil temperature of 9 - 10°C is required for fixation to occur. Relatively cool temperatures in 1995-97 may explain a response from nitrogen in the first cut however a response in 1998 when very mild weather conditions prevailed was not anticipated. At Lac La Biche nitrogen increased yield of the first cut in all years except 1997 (Table 3). At both locations in all years there was no effect of nitrogen on yield of the second cut except at Lac La Biche in 1998. These results suggest nitrogen fixation supplied the nitrogen requirements of the crop or that nitrogen applied in spring was removed by growth harvested in the first cut.

Table 2. Effect of Nitrogen on Yield (kg/ha) of Mixed Forage Calmar, 1995-1998 (Component A)

	1995		
	Cut 1	Cut 2	Total
0N	3736 a	2788 a	6524 a
20N	3972 b	2851 a	6823 a
40N	4064 b	2834 a	6899 a
60N	4169 b	2817 a	6986 a
80N	4194 b	2908 a	7103 a

	1996		
	Cut 1	Cut 2	Total
0N	3935 a	2572 a	6507 a
20N	3895 a	2673 a	6568 a
40N	4209 a	2778 a	6987 a
60N	4286 a	2750 a	7036 a
80N	4226 a	2791 a	7017 a

	1997			
	Cut 1	Cut 2	Cut 3	Total
0N	3919 a	1995 a	1337 a	7251 a
20N	4032 a	2065 a	1253 a	7350 a
40N	4130 ab	2061 a	1312 a	7503 a
60N	4149 ab	2187 a	1464 a	7800 a
80N	4363 b	2087 a	1297 a	7747 a

	1998		
	Cut 1	Cut 2	Total
0N	2788 a	3711 a	6498 a
20N	3487 b	3503 a	6990 a
40N	3782 b	3370 a	7152 a
60N	4191 c	3856 a	8046 b
80N	4385 c	4083 a	8468 b

Table 3. Effect of Nitrogen on Yield (kg/ha) of Mixed Forage Lac La Biche, 1995-1998 (Component A)

	1995		
	Cut 1	Cut 2	Total
0N	3211 a	2388 a	5599 a
20N	3816 b	2452 a	6268 ab
40N	4090 b	2470 a	6560 b
60N	4353 b	2648 a	7001 b
80N	4068 b	2528 a	6595 b

	1996		
	Cut 1	Cut 2	Total
0N	3649 a	3149 a	6798 a
20N	4105 b	3351 a	7456 b
40N	4705 c	3200 a	7905 c
60N	4772 c	3002 a	7774 bc
80N	4857 c	3061 a	7917 c

	1997		
	Cut 1	Cut 2	Total
0N	3785 a	2703 a	6489 a
20N	3993 a	2826 a	6819 a
40N	3662 a	2975 a	6637 a
60N	3669 a	3002 a	6671 a
80N	3622 a	2870 a	6492 a

	1998		
	Cut 1	Cut 2	Total
0N	2977 a	2602 a	5580 a
20N	3727 b	2764 ab	6491 b
40N	4072 bc	2560 a	6632 b
60N	4353 c	2934 bc	7288 c
80N	4158 c	3141 c	7299 c

The effect of nitrogen at Calmar and Lac La Biche averaged over four years is presented in Figures 1 and 2 respectively. These results clearly show the effect of nitrogen is greatest in the first cut. There is less effect in the second cut presumably because of nitrogen depletion by growth removed in the first cut.

Figure 1. Effect of Nitrogen on Yield of First and Second Cut Mixed Forage, Calmar Component A (Average of 4 Years)

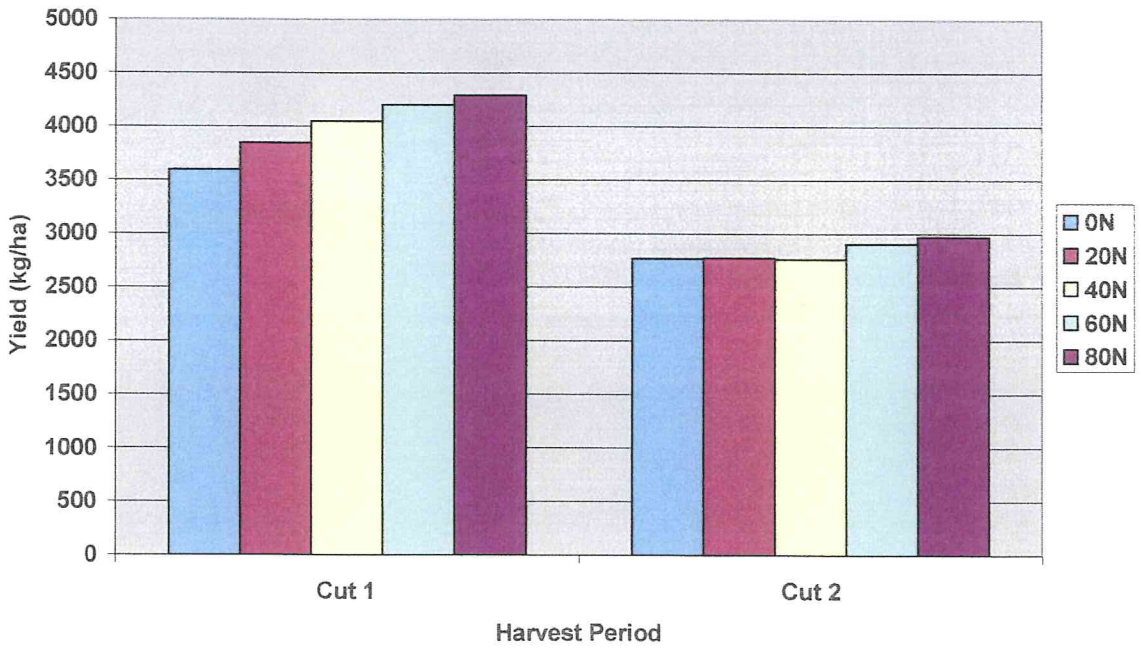
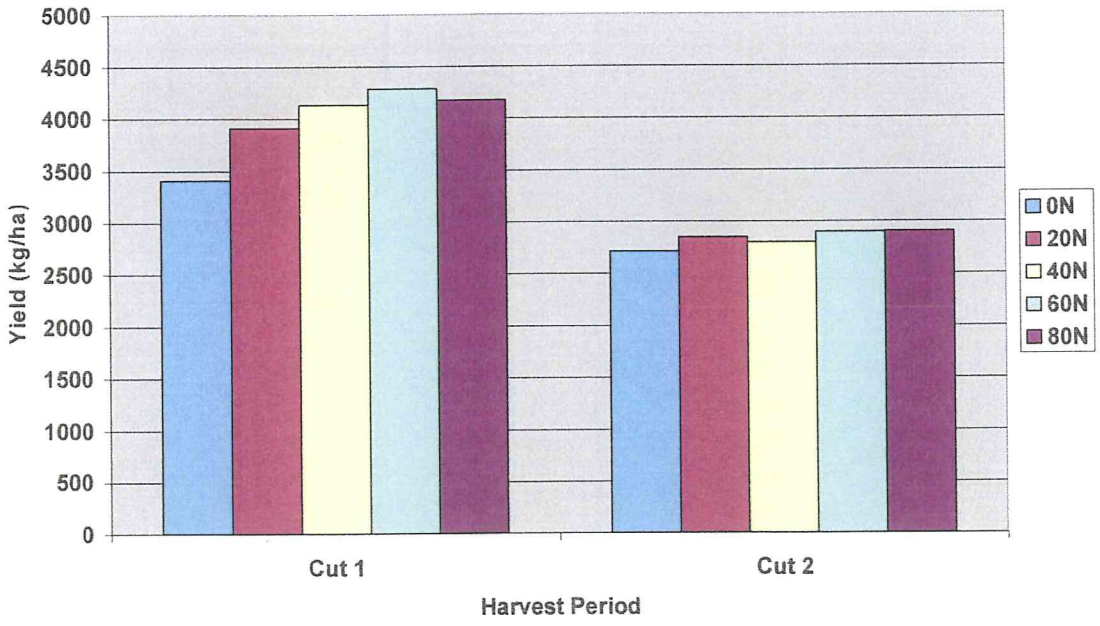
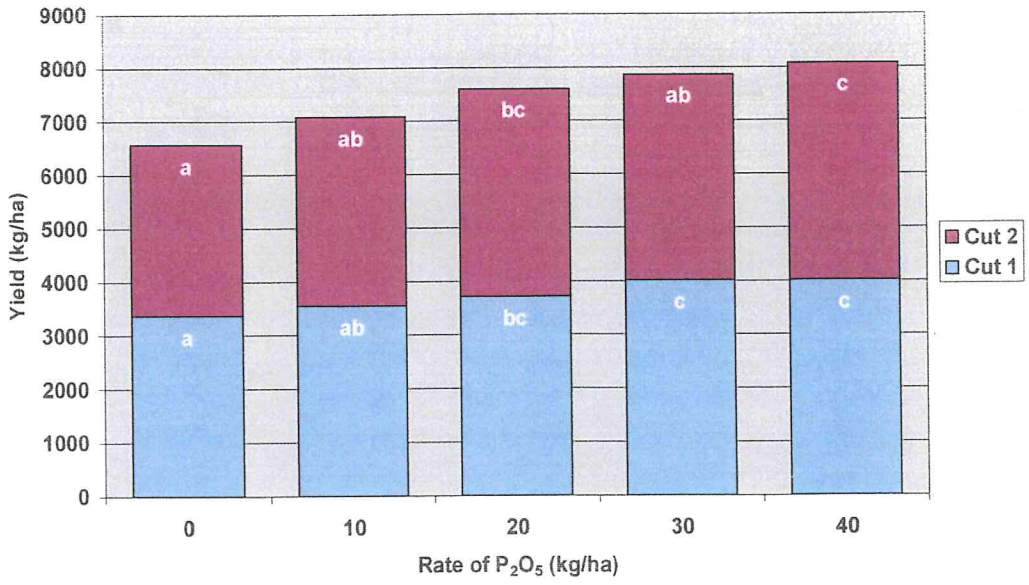


Figure 2. Effect of Nitrogen on Yield of First and Second Cut Mixed Forage, Lac La Biche Component A (Average of 4 years)



Phosphorus had no effect on yield at Calmar except in 1998. The effect of phosphorus on yield in both cuts as well as total yield is presented in Figure 3. Total yield increased from 6555 kg ha $^{-1}$ at 0 P_2O_5 to 8071 kg ha $^{-1}$ at 40 P_2O_5. Regrowth following the second cut also showed a very dramatic effect from applied phosphate however yield assessments were not made since growth was insufficient to harvested (refer to photograph). There was no effect of phosphate on the yield at Lac La Biche.

Figure 3. Effect of Phosphorus on Yield of Mixed Forage (Calmar A, 1998)



Research has shown the response to phosphorus is highly variable. Residual phosphorus applied to annual crops grown in rotation with forages may supply the phosphorus requirement of the forage crops. It is reasonable to assume that the potential to demonstrate increase in yield to phosphorus would be greater in older stands where residual phosphorus may have been removed by previous growth. Phosphorus deficiency may in part be responsible for gradual reduction in the legume component on mixed forage swards. This observation has lead many farmers and researchers to conclude this was a normal symptom of an aging sward. Other research near Mayerthorpe has shown in a sward that has been established over thirty years ago, tame species were a minor contributor to stand composition however these species became dominant after only two annual applications of fertilizer containing phosphorus, potash and sulphur. This clearly demonstrates that proper fertilization can be an effective method of rejuvenating degraded forage swards.

B. Composition

The effect of nitrogen on percent alfalfa in 1995-98 is presented in Table 4. Nitrogen significantly reduced percent alfalfa in the first cut in all years at Calmar and in 1996 and 1998 at Lac La Biche. Nitrogen increased the vigour and hence yield of the grass component of the swards thereby reducing the percent alfalfa in the sward. Growing season conditions in 1995 and 1997 at Lac La Biche were characterized by extreme drought that limited crop growth early in the growing season and this may have influenced experimental results. Nitrogen reduced percent alfalfa in the second cut at both locations and in all years with the exception of 1997 and 1998 at Calmar however the effect was not as great as in the first cut. This result was unexpected since the rate of nitrogen applied is small in comparison to the nitrogen requirement of forage crops and it would be anticipated fertilizer nitrogen would be consumed by growth harvested in the first cut as is shown by the yield data. It is possible that unusual climatic conditions during the experimental period may have influenced experimental results.

Phosphorus had no effect on percent alfalfa at either location with the exception of a small increase in the second cut at Lac La Biche in 1996.

Table 4. Effect of Nitrogen on Percent Alfalfa in Mixed Forage Swards, 1995 - 1998 (Component A)

	1995			
	Percent Alfalfa			
	Calmar		Lac La Biche	
N Applied	Cut 1	Cut 2	Cut 1	Cut 2
0	61 a	77 a	69 a	89 a
20	56 ab	75 ab	58 a	87 ab
40	54 bc	72 bc	56 a	86 b
60	49 cd	70 cd	53 a	85 b
80	46 d	67 d	54 a	85 b

	1996			
	Percent Alfalfa			
	Calmar		Lac La Biche	
N Applied	Cut 1	Cut 2	Cut 1	Cut 2
0	78 a	84 a	72 a	84 ab
20	70 b	81 ab	64 b	87 a
40	63 c	78 bc	55 c	80 bc
60	59 cd	76 c	49 d	78 c
80	55 d	74 c	51 cd	80 bc

	1997			
	Percent Alfalfa			
	Calmar		Lac La Biche	
N Applied	Cut 1	Cut 2	Cut 1	Cut 2
0	63 a	86 a	61 a	73 a
20	62 a	84 a	57 a	69 ab
40	57 ab	82 a	52 a	62 bc
60	57 ab	81 a	53 a	60 c
80	52 b	79 a	59 a	65 bc

	1998			
	Percent Alfalfa			
	Calmar		Lac La Biche	
N Applied	Cut 1	Cut 2	Cut 1	Cut 2
0	46 a	59 a	45 a	64 a
20	32 bc	55 a	35 b	63 a
40	33 b	51 a	28 c	57 b
60	28 bc	55 a	30 bc	53 bc
80	25 c	48 a	28 c	48 c

Component B

Trials were established adjacent to Component A at both locations to determine the effect of method of harvesting on yield and composition of the sward. Fertilizer was applied at the same time as in Component A. Plots were harvested by simulated grazing (clipping) when the alfalfa was 20 cm (8 in). Other elements of the experimental design were identical to those of Component. A list of treatments is displayed in table 5.

Table 5. List of Treatments

Treatment #	Nitrogen (kg/ha)	Phosphorus (kg/ha)
1	0	10
2	0	30
3	20	10
4	20	30
5	40	10
6	40	30
7	80	10
8	80	30

Results and Discussion

The probability (P) values for the effect of N, P_2O_5 and their interaction on yield at Calmar and Lac La Biche are shown in Appendices 17 and 18 respectively.

1. Effect of nitrogen

A. Yield

The effect of nitrogen on total yield of mixed forage grown under simulated grazing at Calmar and Lac La Biche in 1995 - 1998 is shown in Table 6 and Table 7 respectively. At Calmar, four cuts were taken in 1995 and three cuts were taken in the remaining years. Nitrogen significantly increased yield of the first cut in all years except 1997 when drought limited early season growth. Nitrogen significantly increased yield in the second and fourth cuts in 1995 and the third cut in 1996. Highest yields were generally obtained at the 80 N rate. A rigorous harvesting regime when combined with nitrogen fertilization encouraging growth of the grass component has resulted in reduced vigour of the alfalfa. At both locations white clover has become a significant species in the sward. White clover is well adapted to grazing and is the dominant legume species on many pasture fields where a continuous grazing system is used. At Calmar there is no clover in the forage surrounding the plot site which has been harvested in a two cut hay system or in component A.

Table 6. The Effect of Nitrogen on Yield (kg/ha) of Mixed Forage Calmar 1995-1998 (Component B)

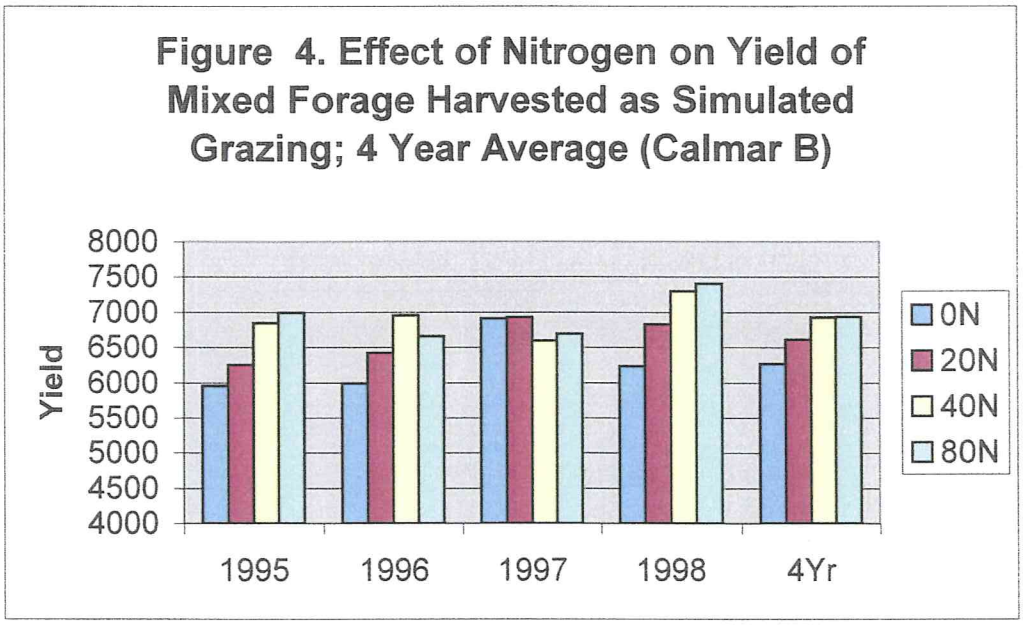
		FIRST CUT	SECOND CUT	THIRD CUT	FOURTH CUT	TOTAL
1995	0N	2782 b	837 c	1000 a	1334 c	5953 b
	20N	3005 ab	950 bc	959 a	1337 bc	6251 b
	40N	3273 a	1029 ab	1079 a	1466 ab	6847 a
	80N	3309 a	1142 a	1052 a	1482 a	6985 a
1996	0N	2367 c	2469 a	1151 a		5988 c
	20N	2962 b	2330 a	1125 a		6418 b
	40N	3472 a	2410 a	1073 a		6954 a
	80N	3472 a	2306 a	873 b		6651 ab
1997	0N	3157 a	2136 a	1611 a		6905 a
	20N	3290 a	2062 a	1577 a		6929 a
	40N	3206 a	1975 a	1412 a		6592 a
	80N	3361 a	1984 a	1342 a		6687 a
1998	0N	2361 a	3287 a	881 a		6528 a
	20N	2908 b	3517 a	924 a		7349 b
	40N	2992 b	3346 a	878 a		7215 b
	80N	3117 b	3452 a	774 a		7342 b

Table 7. The Effect of Nitrogen on Yield (kg/ha) of Mixed Forage Lac La Biche 1995-1998 (Component B)

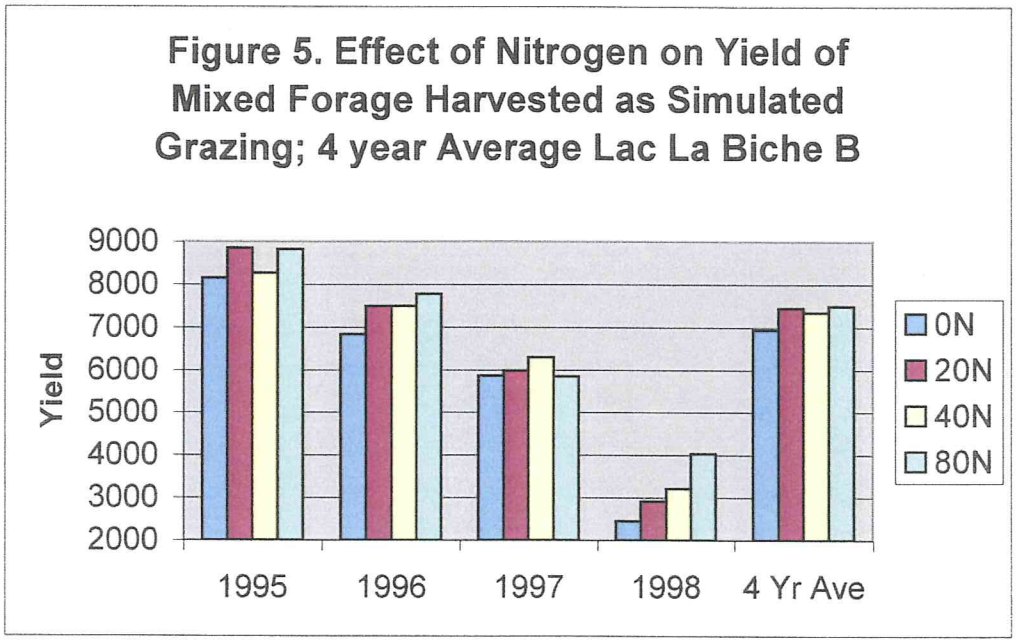
		FIRST CUT	SECOND CUT	THIRD CUT	TOTAL
1995	0N	2695	5445		8140
	20N	3139	5716		8856
	40N	3234	5026		8260
	80N	3576	5245		8822
1996	0N	2043 d	1538 a	3245 a	6827 a
	20N	2557 c	1495 a	3430 a	7482 a
	40N	2953 b	1279 a	3254 a	7486 a
	80N	3409 a	1178 a	3193 a	7780 a
1997	0N	3376 a	1305 ab	1178 a	5859 a
	20N	3664 a	1209 a	1108 a	5981 a
	40N	3746 a	1463 bc	1079 a	6288 a
	80N	3216 a	1633 c	1001 a	5849 a
1998	0N	622 d	1820 b		2442 a
	20N	1132 c	1778 b		2910 b
	40N	1348 b	1871 ab		3219 c
	80N	1929 a	2098 a		4027 d

At Lac La Biche, two cuts were taken in 1995 and 1998 when drought delayed growth of the sward in 1995 and limited regrowth following the second cut in 1998. In 1996 and 1997, three cuts were taken. Nitrogen significantly increased yield of the first cut in 1996 and 1998. Nitrogen promoted growth of the grass component and hence yield of the first cut showed a straight-line function with rate of nitrogen applied. Nitrogen increased yield of the second cut in 1997 and 1998 however the increases were small and hence would not be economic.

The effect of nitrogen on total yield of mixed forage in 1995 through 1998 at Calmar and Lac La Biche is shown in Figures 4 and 5 respectively. At both locations there is a strong trend for nitrogen to increase total yield. As previously referred to the greatest increase in yield occurred in the first cut.



Phosphorus had no discernible effect on yield at either site with an exception of a small increase in the second cut in 1997 at Calmar and in the first cut in 1998 at Lac La Biche (Data not shown).



B. Composition

The effect of nitrogen on composition of mixed forage grown at Calmar and Lac La Biche is shown in Table 8. At both locations there is a strong trend for nitrogen to decrease the percent alfalfa in the stand particularly in the first cut. With successive harvest events this effect becomes less apparent and in the last harvest period, nitrogen had no effect at either location. There is also a trend for the percent alfalfa in the first cut to decrease over the trial period at both locations but particularly at Calmar. This may be due to a combination of harvest regime and nitrogen fertilization. It is more likely this effect is due to harvest regime since percent legume in the second cuts in Component A tend to increase when compared to the first cut. A three cut harvest schedule does not provide the legume with adequate time to replenish carbohydrate reserves in the root system and hence reducing the hardiness of the alfalfa component. By 1997, a change in composition of the legume component became apparent. White clover, which is well adapted to grazing, became a dominant species in the legume component. At Lac La Biche, percent white clover was 24% at 0N; 27% at 20N; 30% at 40N and 14% at 80N in 1998.

Table 8. Effect of Nitrogen on Percent Alfalfa in Mixed Forage Swards (Component B)

1995	Calmar				Lac La Biche	
N Applied	Cut 1	Cut 2	Cut 3	Cut 4	Cut 1	Cut2
0	66 a	73 a	69 a	34 a	58 a	77 a
20	54 b	65 a	66 ab	30 a	48 b	72 a
40	54 b	62 a	60 b	32 a	36 c	73 a
80	53 b	59 a	57 b	28 a	38 c	70 a

1996	Calmar			Lac La Biche		
N Applied	Cut 1	Cut 2	Cut3	Cut 1	Cut 2	Cut3
0	57 a	65 a	72 a	66 a	82 a	67 a
20	39 b	55 b	74 a	55 ab	83 a	70 a
40	36 b	49 b	64 a	47 bc	85 a	70 a
80	24 c	50 b	70 a	38 c	72 b	69 a

1997	Calmar		Lac La Biche	
N Applied	Cut 1	Cut 2	Cut 1	Cut 2
0	42 a	54 a	47 a	82 a
20	36 ab	59 a	32 b	77 ab
40	34 b	46 a	39 ab	72 bc
80	30 b	49 a	33 b	63 c

1998	Calmar			Lac La Biche	
N Applied	Cut 1	Cut 2	Cut 3	Cut 1	Cut 2
0	53 a	84 a	95 a	13 a	34 a
20	47 ab	85 a	93 a	11 a	40 a
40	35 c	77 ab	92 a	9 a	21 a
80	39 bc	68 b	82 a	8 a	31 a

2. Effect of phosphorus

The effect of phosphorus on yield at Calmar and Lac La Biche is shown in Tables 9 and 10 respectively. Phosphorus had a significant effect on yield in the second cut at Calmar in 1997 and in the first cut at Lac La Biche in 1998. As previously mentioned, residual phosphorus may provide the phosphorus requirement of forage crops and long-term monitoring is required understand the dynamics of phosphorus fertilization in forage crops.

Table 9. The Effect of Phosphorus on Yield (kg/ha) of Mixed Forage Calmar 1995-1998 (Component B)

		FIRST CUT	SECOND CUT	THIRD CUT	FOURTH CUT	TOTAL
1995	10P	3148	987	1037	1372	6543
	30P	3037	993	1008	1438	6475
1996	10P	3071	2317	1074		6462
	30P	3065	2441	1037		6544
1997	10P	3242	1954 b	1416		6612
	30P	3265	2125 a	1555		6945
1998	10P	2772	3290	849		6912
	30P	2917	3510	879		7306

Table 10. The Effect of Phosphorus on Yield of Mixed Forage Lac La Biche 1995-1998 (Component B)

		FIRST CUT	SECOND CUT	THIRD CUT	TOTAL
1995	10P	3179	5408		8587
	30P	3143	5308		8451
1996	10P	2733	1369	3432	7535
	30P	2749	1376	3129	7253
1997	10P	3415	1345	1084	5844
	30P	3586	1459	1099	6145
1998	10P	1184 b	1913	1084	4181
	30P	1332 a	1871	1099	4302

Conclusions

1. Nitrogen may significantly increase yield of mixed forage swards particularly in years when cool spring and early summer temperatures may limit the nitrogen fixation process in legumes. Under these conditions growth of both the legume and grass components of a sward may be limited by nitrogen deficiency.

2. Phosphorus had a significant effect on yield at Calmar in Component A 1998 but not in previous years. This suggests residual fertilizer may be an effective source of phosphorus for forage crops immediately following cereal and oilseed crops. As phosphorus is depleted, addition of fertilizer phosphorus may increase longevity and yield in succeeding years.

3. Proper fertilization with special attention to phosphorus, potash and sulphur may be important components of a management system that ensures long-lived and productive forage swards.

4. Nitrogen enhanced growth of the grass component of the sward and consequently decreased percent alfalfa in the sward at both locations and in both cuts in Component A.

5. In the simulated grazing trial (Component B), a small application of nitrogen increased yield at both locations.

6. White clover, which is well-adapted grazing conditions and may become a dominant species under grazing situations.

Acknowledgements

The author acknowledges financial support provided by the Alberta Milk Producers, Potash and Phosphate Institute and Agrium Inc. Laboratory analysis was provided by the Soil and Crop Diagnostic Centre and field activity was coordinated by Roy Panasiuk. Roy Panasiuk performed statistical analysis. Stephen Dusek assisted with the graphics and preparation of this report.

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A productive mixed forage sward

Harvesting mixed forage

Separations to determine composition

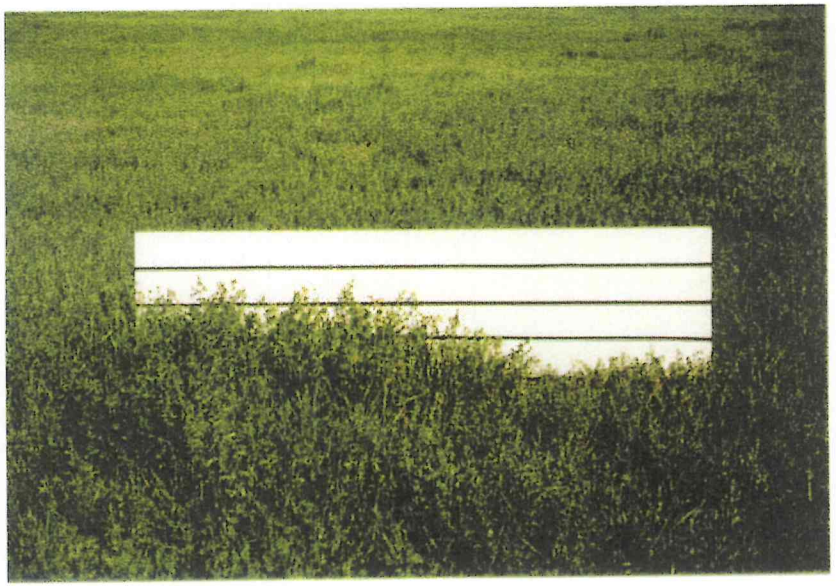
Fertilizing Component A at Calmar

Overview of Calmar site

A degraded mixed sward

A productive mixed sward

Regrowth following second cut at Calmar



A deteriorating sward

Appendix 1. Analysis of Variance Probability Table (Calmar, Component A, 1995)

	Source	First Cut (P)	Second Cut (P)	Total (P)
Yield	REP (A)	0.5727	0.0495	0.1019
	N (B)	0.0009	0.6861	0.0070
	P (C)	0.1966	0.0188	0.0532
	B*C	0.1989	0.3907	0.1649
Protein	REP (A)	0.0993	0.2216	
	N (B)	0.0000	0.2764	
	P (C)	0.3448	0.1707	
	B*C	0.8790	0.3419	
ADF	REP (A)	0.1771	0.2470	
	N (B)	0.1920	0.1686	
	P (C)	0.5069	0.0901	
	B*C	0.8890	0.5248	
NDF	REP (A)	0.2129	0.6944	
	N (B)	0.0002	0.0000	
	P (C)	0.6806	0.0798	
	B*C	0.8746	0.7276	

Appendix 2. Analysis of Variance Probability Table (Calmar, Component A, 1996)

	Source	First Cut (P)	Second Cut (P)	Total (P)
Yield	N	0.2487	0.1761	0.1183
	P	0.2520	0.0787	0.0566
	NXP	0.4049	0.3915	0.8491
Protein	N	0.0079	0.0016	
	P	0.3244	0.9212	
	NXP	0.2019	0.2948	
ADF	N	0.2099	0.0368	
	P	0.6758	0.7623	
	NXP	0.0561	0.4452	
NDF	N	0.0000	0.0011	
	P	0.3451	0.8993	
	NXP	0.0962	0.1652	
% Legume	N	0.0000	0.0004	
	P	0.6442	0.7626	
	NXP	0.1250	0.4294	
Alfalfa Yield	N	0.0008	0.1986	0.0011
	P	0.3648	0.1399	0.1994
	NXP	0.1004	0.3527	0.4288

Appendix 3. Analysis of Variance Probability Table (Calmar, Component A, 1997)

	Source	First Cut (P)	Second Cut (P)	Third Cut (P)	Total (P)
Yield	N	0.0099*	0.3864	0.4189	0.1594
	P	0.4267	0.4089	0.6229	0.2461
	NXP	0.2821	0.8727	0.4278	0.6078
% Legume	N	0.0479*	0.0817		
	P	0.8954	0.7783		
	NXP	0.4517	0.6753		
Alfalfa Yield	N	0.5809	0.8023		0.5017
	P	0.8557	0.9148		0.9524
	NXP	0.3157	0.9518		0.5406

Appendix 4. Analysis of Variance Probability Table (Calmar, Component A, 1998)

	Source	First Cut (P)	Second Cut (P)	Total (P)
Yield	N	0.0000*	0.0543	0.0000*
	P	0.0002*	0.0099*	0.0006*
	NXP	0.8012	0.4019	0.8621
% Legume	N	0.0000*	0.0569	
	P	0.6847	0.6336	
	NXP	0.5108	0.8424	
Alfalfa Yield	N	0.6650	0.2516	0.5497
	P	0.4917	0.0931	0.1390
	NXP	0.6622	0.5302	0.8433

Appendix 5. Analysis of Variance Probability Table (Lac La Biche, Component A, 1995)

	Source	First Cut (P)	Second Cut (P)	Total (P)
Yield	REP (A)	0.0122	0.0000	0.0003
	N (B)	0.0040	0.5067	0.0084
	P (C)	0.0685	0.3015	0.0615
	B*C	0.3167	0.9654	0.4978
Protein	REP (A)	0.3225	0.0430	
	N (B)	0.2301	0.0120	
	P (C)	0.5133	0.7136	
	B*C	0.6904	0.9913	
ADF	REP (A)	0.1808	0.0043	
	N (B)	0.0368	0.0120	
	P (C)	0.4867	0.7136	
	B*C	0.2977	0.9913	
NDF	REP (A)	0.4836	0.0039	
	N (B)	0.0038	0.0651	
	P (C)	0.8155	0.6549	
	B*C	0.7409	0.9465	

Appendix 6. Analysis of Variance Probability Table (Lac La Biche, Component A, 1996)

	Source	First Cut (P)	Second Cut (P)	Total (P)
Yield	N	0.0000	0.2129	0.0000
	P	0.9412	0.5769	0.6263
	NXP	0.6262	0.1388	0.2535
Protein	N	0.0063	0.0001	
	P	0.2435	0.0287	
	NXP	0.3564	0.7829	
ADF	N	0.0003	0.1394	
	P	0.3796	0.0174	
	NXP	0.0771	0.6421	
NDF	N	0.0000	0.0001	
	P	0.3110	0.1358	
	NXP	0.1107	0.5630	
% Legume	N	0.0000	0.0244	
	P	0.0917	0.0036	
	NXP	0.2593	0.8735	
Alfalfa Yield	N	0.2290	0.0119	0.0110
	P	0.2102	0.2443	0.0814
	NXP	0.1492	0.4464	0.2807

Appendix 7. Analysis of Variance Probability Table (Lac La Biche, Component A, 1997)

	Source	First Cut (P)	Second Cut (P)	Total (P)
Yield	N	0.3500	0.1572	0.7061
	P	0.3555	0.6741	0.3086
	NXP	0.8143	0.5515	0.4374
% Legume	N	0.1274	0.0065*	
	P	0.0128*	0.1005	
	NXP	0.1293	0.2176	
Alfalfa Yield	N	0.1355	0.7857	0.2047
	P	0.0190*	0.3226	0.0557
	NXP	0.0973	0.3067	0.0928

Appendix 8 Analysis of Variance Probability Table (Lac La Biche, Component A, 1998)

	Source	First Cut (P)	Second Cut (P)	Total (P)
Yield	N	0.0000*	0.0004*	0.0000*
	P	0.6319	0.1038	0.4431
	NXP	0.3294	0.8207	0.8145
% Legume	N	0.0000*	0.0000*	
	P	0.8442	0.2590	
	NXP	0.0427*	0.4241	
Alfalfa Yield	N	0.4346	0.0809	0.1523
	P	0.1233	0.1000	0.0880
	NXP	0.0619	0.8914	0.2229

Appendix 9. Average Treatment Yields (kg/ha) for Calmar Mixed Forage Plot (Component A, 1995)

TREATMENT	FIRST CUT	SECOND CUT	TOTAL	FERTILIZER RATE (kg/ha)
1	3546	2574	6121	0-0-88-30
2	3960	2933	6894	0-10-88-30
3	3726	2792	6518	0-20-88-30
4	3736	2795	6531	0-30-88-30
5	3714	2843	6558	0-40-88-30
6	4024	2781	6805	20-0-88-30
7	4073	2716	6789	20-10-88-30
8	3869	2720	6590	20-20-88-30
9	4350	3199	7549	20-30-88-30
10	3544	2839	6383	20-40-88-30
11	3867	2525	6392	40-0-88-30
12	4333	2783	7116	40-10-88-30
13	4202	3111	7313	40-20-88-30
14	3952	2833	6784	40-30-88-30
15	3969	2919	6888	40-40-88-30
16	3890	2654	6544	60-0-88-30
17	4403	2722	7125	60-10-88-30
18	4115	3002	7116	60-20-88-30
19	4131	2934	7065	60-30-88-30
20	4305	2773	7078	60-40-88-30
21	4272	2819	7091	80-0-88-30
22	4044	2951	6995	80-10-88-30
23	3942	2880	6822	80-20-88-30
24	4324	2896	7220	80-30-88-30
25	4389	2997	7386	80-40-88-30

Appendix 10. Average Treatment Yields (kg/ha) for Calmar Mixed Forage Plot (Component A, 1996)

TREATMENT	FIRST CUT	SECOND CUT	TOTAL	FERTILIZER RATE (kg/ha)
1	3625	2444	6069	0-0-88-30
2	3818	2406	6224	0-10-88-30
3	4357	2687	7044	0-20-88-30
4	3459	2786	6245	0-30-88-30
5	4414	2537	6951	0-40-88-30
6	3756	2581	6336	20-0-88-30
7	3849	2543	6392	20-10-88-30
8	3696	2743	6439	20-20-88-30
9	4288	2666	6954	20-30-88-30
10	3885	2833	6717	20-40-88-30
11	3897	2592	6489	40-0-88-30
12	4088	2470	6558	40-10-88-30
13	4848	2703	7551	40-20-88-30
14	4138	3079	7217	40-30-88-30
15	4074	3045	7119	40-40-88-30
16	3574	2764	6338	60-0-88-30
17	4527	2944	7471	60-10-88-30
18	4462	2372	6833	60-20-88-30
19	4773	2669	7441	60-30-88-30
20	4098	3001	7098	60-40-88-30
21	4210	2611	6821	80-0-88-30
22	4091	2697	6788	80-10-88-30
23	3931	2991	6921	80-20-88-30
24	4220	3001	7222	80-30-88-30
25	4678	2653	7331	80-40-88-30

Appendix 11. Average Treatment Yields (kg/ha) for Calmar Mixed Forage Plot (Component A, 1997)

TREATMENT	FIRST CUT	SECOND CUT	THIRD CUT	TOTAL	FERTILIZER RATE (kg/ha)
1	3737	2047	1053	6837	0-0-88-30
2	3936	1862	1161	6959	0-10-88-30
3	4238	2034	1511	7783	0-20-88-30
4	3778	2005	1666	7449	0-30-88-30
5	3904	2028	1294	7227	0-40-88-30
6	3937	1966	1223	7125	20-0-88-30
7	4156	1992	1085	7232	20-10-88-30
8	3731	2095	1169	6995	20-20-88-30
9	4229	2200	1304	7734	20-30-88-30
10	4108	2070	1485	7663	20-40-88-30
11	3988	2069	1344	7401	40-0-88-30
12	4166	1884	1602	7653	40-10-88-30
13	4121	2005	1044	7171	40-20-88-30
14	4139	2095	1253	7486	40-30-88-30
15	4235	2253	1317	7805	40-40-88-30
16	3943	2005	1476	7424	60-0-88-30
17	4362	2365	1385	8112	60-10-88-30
18	4031	2014	1496	7541	60-20-88-30
19	4367	2197	1591	8156	60-30-88-30
20	4041	2356	1372	7769	60-40-88-30
21	4415	1873	1103	7392	80-0-88-30
22	3871	2106	1344	7322	80-10-88-30
23	4315	2221	1376	7912	80-20-88-30
24	4611	2095	1208	7914	80-30-88-30
25	4605	2138	1453	8197	80-40-88-30

Appendix 12. Average Treatment Yields (kg/ha) for Calmar Mixed Forage Plot (Component A, 1998)

TREATMENT	FIRST CUT	SECOND CUT	TOTAL	FERTILIZER RATE (kg/ha)
1	2292	3840	6132	0-0-88-30
2	2597	2990	5587	0-10-88-30
3	2725	3962	6687	0-20-88-30
4	3216	3846	7062	0-30-88-30
5	3108	3915	7024	0-40-88-30
6	3578	2710	6288	20-0-88-30
7	3188	3055	6244	20-10-88-30
8	3395	3790	7185	20-20-88-30
9	3507	3901	7408	20-30-88-30
10	3768	4060	7828	20-40-88-30
11	3402	3243	6645	40-0-88-30
12	3804	3058	6862	40-10-88-30
13	3672	3702	7373	40-20-88-30
14	4007	3042	7048	40-30-88-30
15	4024	3807	7831	40-40-88-30
16	3919	2954	6874	60-0-88-30
17	3757	3793	7550	60-10-88-30
18	4269	3802	8071	60-20-88-30
19	4544	4400	8944	60-30-88-30
20	4464	4329	8793	60-40-88-30
21	3616	3220	6836	80-0-88-30
22	4357	4776	9133	80-10-88-30
23	4502	4172	8674	80-20-88-30
24	4774	4046	8821	80-30-88-30
25	4677	4202	8879	80-40-88-30

Appendix 13. Average Treatment Yields (kg/ha) for Lac La Biche Mixed Forage Plot (Component A, 1995)

TREATMENT	FIRST CUT	SECOND CUT	TOTAL	FERTILIZER RATE (kg/ha)
1	3466	2282	5748	0-0-88-30
2	3052	2214	5265	0-10-88-30
3	3297	2222	5519	0-20-88-30
4	3888	2552	6440	0-30-88-30
5	3997	2670	6667	0-40-88-30
6	3321	2131	5452	20-0-88-30
7	3771	2366	6137	20-10-88-30
8	3486	2537	6023	20-20-88-30
9	4285	2550	6835	20-30-88-30
10	4662	2674	7336	20-40-88-30
11	5284	2608	7891	40-0-88-30
12	3423	2587	6010	40-10-88-30
13	3653	2228	5881	40-20-88-30
14	4598	2539	7138	40-30-88-30
15	4511	2388	6898	40-40-88-30
16	4310	2516	6826	60-0-88-30
17	4210	2605	6815	60-10-88-30
18	3958	2492	6450	60-20-88-30
19	4430	2782	7212	60-30-88-30
20	4757	2847	7604	60-40-88-30
21	4266	2406	6673	80-0-88-30
22	4000	2688	6689	80-10-88-30
23	4078	2426	6504	80-20-88-30
24	3563	2365	5929	80-30-88-30
25	3825	2753	6578	80-40-88-30

Appendix 14. Average Treatment Yields (kg/ha) for Lac La Biche Mixed Forage Plot (Component A, 1996)

TREATMENT	FIRST CUT	SECOND CUT	TOTAL	FERTILIZER RATE (kg/ha)
1	3386	2877	6263	0-0-88-30
2	3783	3336	7120	0-10-88-30
3	3682	2938	6620	0-20-88-30
4	3811	3270	7081	0-30-88-30
5	3585	3322	6907	0-40-88-30
6	4219	3289	7508	20-0-88-30
7	3939	2946	6885	20-10-88-30
8	3944	3461	7405	20-20-88-30
9	3893	3926	7819	20-30-88-30
10	4533	3131	7663	20-40-88-30
11	4703	3149	7852	40-0-88-30
12	4884	3181	8066	40-10-88-30
13	4454	2758	7211	40-20-88-30
14	4888	3439	8327	40-30-88-30
15	4598	3472	8070	40-40-88-30
16	4619	2597	7216	60-0-88-30
17	4595	3260	7855	60-10-88-30
18	4826	3227	8053	60-20-88-30
19	5014	2920	7934	60-30-88-30
20	4804	3006	7811	60-40-88-30
21	4876	3438	8314	80-0-88-30
22	5166	3140	8307	80-10-88-30
23	4988	2882	7870	80-20-88-30
24	4455	2870	7326	80-30-88-30
25	4797	2973	7770	80-40-88-30

Appendix 15. Average Treatment Yields (kg/ha) for Lac La Biche Mixed Forage Plot (Component A, 1997)

TREATMENT	FIRST CUT	SECOND CUT	TOTAL	FERTILIZER RATE (kg/ha)
1	3457	2524	5981	0-0-88-30
2	4227	2735	6962	0-10-88-30
3	3822	2721	6543	0-20-88-30
4	3480	2709	6190	0-30-88-30
5	3940	2827	6767	0-40-88-30
6	3763	2870	6634	20-0-88-30
7	3970	2656	6626	20-10-88-30
8	3623	2478	6101	20-20-88-30
9	4236	3135	7371	20-30-88-30
10	4373	2988	7361	20-40-88-30
11	3618	3191	6810	40-0-88-30
12	3591	2978	6569	40-10-88-30
13	3741	3077	6817	40-20-88-30
14	3538	2771	6309	40-30-88-30
15	3822	2859	6681	40-40-88-30
16	3269	2679	5947	60-0-88-30
17	3902	3058	6960	60-10-88-30
18	3799	3003	6802	60-20-88-30
19	4064	3294	7358	60-30-88-30
20	3312	2974	6286	60-40-88-30
21	3420	2760	6181	80-0-88-30
22	3617	2905	6522	80-10-88-30
23	3586	2763	6349	80-20-88-30
24	3552	2790	6342	80-30-88-30
25	3934	3130	7065	80-40-88-30

Appendix 16. Average Treatment Yields (kg/ha) for Lac La Biche Mixed Forage Plot (Component A, 1998)

TREATMENT	FIRST CUT	SECOND CUT	TOTAL	FERTILIZER RATE (kg/ha)
1	3270	2477	5747	0-0-88-30
2	2761	2902	5663	0-10-88-30
3	2765	2589	5354	0-20-88-30
4	3236	2354	5589	0-30-88-30
5	2855	2689	5544	0-40-88-30
6	3512	2825	6337	20-0-88-30
7	3886	2980	6865	20-10-88-30
8	3722	2728	6451	20-20-88-30
9	3561	2899	6460	20-30-88-30
10	3953	2390	6343	20-40-88-30
11	4275	2233	6508	40-0-88-30
12	4284	2740	7024	40-10-88-30
13	3710	2951	6660	40-20-88-30
14	4311	2502	6813	40-30-88-30
15	3780	2375	6155	40-40-88-30
16	4086	2681	6766	60-0-88-30
17	4143	2957	7100	60-10-88-30
18	4635	3175	7809	60-20-88-30
19	4322	2912	7234	60-30-88-30
20	4582	2946	7528	60-40-88-30
21	3618	3073	6691	80-0-88-30
22	4528	3355	7883	80-10-88-30
23	3859	3064	6924	80-20-88-30
24	4182	3094	7276	80-30-88-30
25	4603	3119	7722	80-40-88-30

Appendix 17a. Analysis of Variance Probability Table (Calmar, Component B, 1995)

	Source	First Cut (P)	Second Cut (P)	Third Cut (P)	Fourth Cut (P)	Total (P)
Yield	REP (A)	0.0210	0.3968	0.8689	0.4956	0.0692
	N (B)	0.0070	0.0011	0.2445	0.0410	0.0004
	P (C)	0.3119	0.8970	0.5133	0.1522	0.6727
	B*C	0.5225	0.6365	0.5834	0.5688	0.5824

Appendix 17b. Analysis of Variance Probability Table (Calmar, Component B, 1996)

	Source	First Cut (P)	Second Cut (P)	Third Cut (P)	Total (P)
Yield	N	0.0000	0.8373	0.0161	0.0021
	P	0.9407	0.3855	0.5929	0.4023
	NXP	0.7699	0.9671	0.6041	0.9087
% Legume	N	0.0000	0.0065	0.4057	
	P	0.0424	0.5597	0.5856	
	NXP	0.8110	0.0579	0.3427	
Alfalfa Yield	N	0.0114	0.0240	0.0365	0.0005
	P	0.0620	0.7966	0.9969	0.2553
	NXP	0.8670	0.2496	0.3925	0.1389

Appendix 17c. Analysis of Variance Probability Table (Calmar, Component B, 1997)

	Source	First Cut (P)	Second Cut (P)	Third Cut (P)	Total (P)
Yield	N	0.3239	0.4349	0.0538	0.3312
	P	0.7793	0.0383*	0.0767	0.0374*
	NXP	0.2385	0.7178	0.3055	0.2710
%Legume	N	0.0417*	0.4151		
	P	0.7001	0.6336		
	NXP	0.2124	0.1054		
Alfalfa Yield	N	0.1929	0.2573		0.1867
	P	0.7552	0.3147		0.6332
	NXP	0.1179	0.0893		0.0585

Appendix 17d. Analysis of Variance Probability Table (Calmar, Component B, 1998)

	Source	First Cut (P)	Second Cut (P)	Third Cut (P)	Total (P)
Yield	N	0.0000*	0.6155	0.8711	0.0422*
	P	0.1132	0.1117	0.8234	0.0621
	NXP	0.6477	0.6602	0.6230	0.3698
%Legume	N	0.0218*	0.0430*	0.1894	
	P	0.2956	0.5320	0.3676	
	NXP	0.1779	0.5052	0.6242	
Alfalfa Yield	N	0.0092*	0.0793	0.7861	0.0751
	P	0.1437	0.1423	0.8079	0.7304
	NXP	0.3663	0.3015	0.6565	0.6872

Appendix 18a. Analysis of Variance Probability Table (Lac La Biche , Component B, 1996)

	Source	First Cut (P)	Second Cut (P)	Third Cut (P)	Total (P)
Yield	N	0.0001	0.1496	0.9063	0.1333
	P	0.7742	0.9590	0.2223	0.3251
	NXP	0.5563	0.7743	0.2711	0.2350
% Legume	N	0.0012	0.0002	0.9031	
	P	0.2453	0.0374	0.6951	
	NXP	0.4638	0.4409	0.0596	
Alfalfa Yield	N	0.9693	0.0228	0.8567	0.3624
	P	0.3267	0.5367	0.1948	0.8856
	NXP	0.4622	0.5867	0.2730	0.1838

Appendix 18b. Analysis of Variance Probability Table (Lac La Biche , Component B, 1997)

	Source	First Cut (P)	Second Cut (P)	Third Cut (P)	Total (P)
Yield	N	0.0866	0.0052*	0.2538	0.4507
	P	0.2842	0.1583	0.7968	0.1740
	NXP	0.6899	0.6922	0.2840	0.6899
% Legume	N	0.0040*	0.0036*		
	P	0.0521	0.1254		
	NXP	0.9948	0.4409		
Alfalfa Yield	N	0.0009*	0.6756		0.0222*
	P	0.0052*	0.1048		0.0084*
	NXP	0.7159	0.7675		0.7717

Appendix 18c. Analysis of Variance Probability Table (Lac La Biche , Component B, 1998)

	Source	First Cut (P)	Second Cut (P)	Third Cut (P)	Total (P)
Yield	N	0.0000*	0.0465*		0.0000*
	P	0.0262*	0.6074		0.2324
	NXP	0.0539	0.8721		0.1754
% Legume	N	0.3364	0.1000		
	P	0.4281	0.9791		
	NXP	0.7674	0.2026		
Alfalfa Yield	N	0.1087	0.1862		0.1473
	P	0.0808	0.9792		0.6720
	NXP	0.3231	0.1549		0.1071