1.1 Alfalfa Forage Response to Residual P and K Fertilizer

L.E. Cowell

(Project funded by Agriculture Development Fund through Innovative Acres)

INTRODUCTION

Alfalfa grown for hay is a major crop in Saskatchewan. If properly inoculated, alfalfa will fix its nitrogen (N) requirement from the atmosphere. However, alfalfa has a high phosphorus (P) and potassium (K) requirement which must be taken from soil reserves or added fertilizers. When alfalfa is cut for hay large amounts of nutrients are removed. Fertilization of alfalfa is therefore often essential, but there is a lack of information on the residual availability of fertilizer P and K to alfalfa. Interest from farmers in the Innovative Acres Program initiated a project to measure the long term availability of fertilizer P and K for alfalfa as measured by hay yield and protein content.

METHODS

In 1987 three plots were set out in Innovative Acres cooperator alfalfa fields. Three diverse sites were selected at Porcupine Plain (Gray Luvisol, Whitewood loam association), Melville (Black Chernozem, Oxbow loam association) and at Marcelin (Black Chernozem, Meota loamy sand association). At Porcupine Plain the plot was placed on a one year old alfalfa stand. At Melville and Marcelin the plots were laid out before the farmer seeded the field. Unfortunately a severe spring frost killed the alfalfa at Marcelin. Seed placed P had been applied with the barley nurse crop at Porcupine Plain. No nurse crop nor seed placed fertilizer was used at Melville. At each site, 0-0-60 and 11-51-0 fertilizers were broadcast in a split plot design (4 blocks) to provide rates of 0, 30, 60 and 120 kg K_2O/ha and 0, 25, 50 and 100 kg P_2O_5/ha. The fertilizer was broadcast in May 1987 using a small fertilizer spreader. Harvest samples of hay were cut in the early bloom stage. The plots were sampled once per year, though the farmers cut and removed hay

twice each year (including the plot areas). Yields and protein contents were measured for the second (fall) cut at Porcupine Plain in 1987, and for the first spring cut at both sites in 1988 and 1989. Soil samples were taken before fertilizer application in 1987. At harvest in the spring of 1988 and 1989 composite samples were taken from the P0K0, P0K30, P0K60, P0K120, K0P25, K0P50 and K0P100 plots.

RESULTS

Soil Analyses and Yield Increase Predictions

Analysis of soil sampled prior to fertilizer application indicated a deficiency in P and K at Porcupine Plain, but only a slight P deficiency and no need for K at Melville (Tables 1.1.1 and 1.1.2). Available N levels did not change with treatment and remained low due to the high and constant requirement of N by alfalfa. Recommendations for fertilizer N were not made, assuming proper inoculation of the seed and subsequent fixation of atmospheric N_2 by the plants.

The initial available soil P levels were very low at Porcupine Plain but nearly adequate at Melville. Fertilizer P recommendations for the sites were 75 and 25 kg/ha, respectively. In the following years the soil test level of P reflected the amount of fertilizer P originally applied. As a consequence fertilizer recommendations were reduced because of the earlier fertilizer applications. At both sites the level of soil test P was much lower in the third year of the trial than in the second year. Crop uptake reduced the level of available P to the point that large P recommendations would have been made even in the second year at Porcupine Plain and by the third year at Melville.

Extracted soil K levels were initially low at Porcupine Plain and remained low in following years despite fertilizer K application. Soil K levels were initially sufficient at Melville, but by the third year were reduced to the point that fertilizer recommendations were made for the plots that received no fertilizer K. Soil test levels did not reflect additions of K fertilizer at either site.

Table 1.1.1 Soil nutrient analyses and fertilizer recommendations for Porcupine Plain before fertilizer application, and at harvest in 1988 and 1989.

Treatment	Nutrients (kg/ha)					
	N (0-60 cm)	Recommended† N	P (0-15 cm)	Recommended† P_2O_5	K (0-15 cm)	Recommended† K_2O
1987 (before fertilizer application)						
Composite of site	20	0	8	75	100	110
1988 (spring harvest)						
P0K0	11	0	10	75	180	60
P0K30	10	0	10	50	150	90
P0K60	11	0	12	50	160	60
P0K120	10	0	11	50	170	60
P25K0	12	0	14	50	140	90
P50K0	15	0	15	50	140	90
P100K0	14	0	20	25	160	60
1989 (spring harvest)						
P0K0	24	0	8	75	110	110
P0K30	19	0	7	75	100	110
P0K60	16	0	9	75	100	110
P0K120	49	0	13	50	100	110
P25K0	22	0	9	75	110	110
P50K0	28	0	9	75	110	110
P100K0	31	0	17	25	120	110

† Recommended fertilizer application rates based on the Saskatchewan Soil Testing Laboratory guidelines

Table 1.1.2 Soil nutrient analyses and fertilizer recommendations for Melville site before fertilizer application, and at harvest in 1988 and 1989.

Treatment	Nutrients (kg/ha)					
	N (0-60 cm)	Recommended† N	P (0-15 cm)	Recommended† P_2O_5	K (0-15 cm)	Recommended† K_2O
1987 (before fertilizer application)						
Composite of site	56	0	20	25	290	0
1988 (spring harvest)						
P0K0	15	0	22	0	230	0
P0K30	21	0	23	0	380	0
P0K60	19	0	20	25	310	0
P0K120	25	0	18	25	330	0
P25K0	20	0	16	25	200	15
P50K0	22	0	24	0	240	0
P100K0	18	0	25	0	220	0
1989 (spring harvest)						
P0K0	15	0	9	75	160	60
P0K30	14	0	9	75	250	0
P0K60	17	0	8	75	260	0
P0K120	17	0	11	50	230	0
P25K0	13	0	10	75	160	60
P50K0	25	0	14	50	180	60
P100K0	15	0	11	50	180	60

† Recommended fertilizer application rates based on the Saskatchewan Soil Testing Laboratory guidelines

Hay Yield and Protein Response to P Fertilizer

As predicted by soil testing, hay yield increased with P fertilizer addition at Porcupine Plain (Table 1.1.3). The alfalfa was able to utilize residual P fertilizer. For example, total yield was increased by 33%, 60% and 50% in 1987, 1988 and 1989 with the 100 kg P_2O_5/ha treatment in 1987. Yield was increased in both dry years (1988) and when moisture was adequate (1989). No P x K interaction was measured for the Porcupine Plain yield, nor in any other parameter in this study. P fertilizer also significantly increased hay protein content in 1988 and 1989, and protein yield in each year.

At Melville original soil tests indicated an adequate level of soil P, and there was no yield response to fertilizer P in 1988 (Table 1.1.4). In 1989 the soil P test levels were low, and a corresponding hay yield increase occurred (Table 1.1.4). Protein yield was increased in 1988 with P addition. A similar trend occurred in 1989, though the response was not significant.

Hay Yield and Protein Response to K Fertilizer

At Porcupine Plain extracted soil K levels were low each year and large fertilizer K recommendations were made. Although a yield response did occur in 1987 and 1988, the response was small and inconsistent and did not occur in 1989 (Table 1.1.3). Protein content of the hay was not increased in any year.

No K fertilizer was initially recommended at Melville. In 1989 soil test levels for K were low and a yield increase was measured for K fertilizer addition. Alfalfa uptake and removal of soil K was high enough to induce a K deficiency in the final year. Hay protein content was increased in 1988, perhaps as an early indication of the yield response that would occur the next year.

Table 1.1.3 Hay yields and protein contents after P and K fertilizer application at Porcupine Plain site.

Treatment	Hay yield (kg/ha)	Protein (%)	Protein yield (kg/ha)
	1987		
K0	1919	17.8	344
K30	1682	18.8	316
K60	1761	17.3	305
K120	1999	19.3	385
LSD (0.05)	207	NS	82
P0	1580	17.9	281
P25	1770	18.0	321
P50	1904	17.8	340
P100	2107	19.5	410
LSD (0.05)	153	NS	51
	1988		
K0	2030	18.1	365
K30	1620	18.3	302
K60	1930	17.9	350
K120	1950	17.9	350
LSD (0.05)	314	NS	NS
P0	1420	17.6	252
P25	1750	17.4	305
P50	2040	17.7	360
P100	2320	19.5	452
LSD (0.05)	185	1.49	49
	1989		
K0	2855	18.4	528
K30	2735	18.3	503
K60	3065	17.1	528
K120	2725	17.9	490
LSD (0.05)	NS	NS	NS
P0	2327	17.8	411
P25	2489	17.2	429
P50	3145	17.9	565
P100	3420	18.9	642
LSD (0.05)	453	0.86	89

Table 1.1.4 Hay yields and protein contents after P and K fertilizer application at Melville site.

Treatment	Hay yield (kg/ha)	Protein (%)	Protein yield (kg/ha)
		1988	
K0	3795	14.9	560
K30	3645	16.3	600
K60	3980	17.3	685
K120	3775	15.6	590
LSD (0.05)	NS	0.9	69
P0	3665	15.3	570
P25	3765	15.7	590
P50	3935	16.7	660
P100	3835	16.4	625
LSD (0.05)	NS	NS	63
		1989	
K0	2458	15.4	377
K30	2925	15.4	440
K60	2911	16.3	476
K120	2737	15.0	407
LSD (0.05)	319	NS	80
P0	2474	15.8	390
P25	2654	14.7	390
P50	2803	16.4	446
P100	3101	15.2	474
LSD (0.05)	166	NS	NS

Economic Returns to Applied P and K Fertilizers

The economic return to applied fertilizer is of primary concern to the farmer. Costs of fertilizers were approximately \$0.70/kg for P_2O_5 and \$0.18/kg for K_2O. Hay prices fluctuated with each year, but an average of \$60/tonne could have been achieved over the three years. The plots were sampled only once per year, but two cuts were actually taken by the farmers (including the plot area). Second cut yields were similar to first cut yields according to farmer information. Total yield increase was therefore assumed

to twice that measured in the single plot harvest. Net return and marginal returns were then calculated for P fertilizer applications (Table 1.1.5). Within three years a large return was realized for the fertilizer dollar at Porcupine Plain. Net returns increased to the P100 level and marginal returns were high for all fertilizer rates. At Melville, where a yield increase occurred only in the second of two years, net and marginal returns were lower. Returns were still adequate to provide a reasonable marginal return to at least the P50 level. With added harvest years this return could improve. Response to the added P had not shown signs of reduction after three years at either site.

The inconsistent yield response to fertilizer K made any economic evaluation difficult and probably invalid. The investment into K fertilizer would have been of questionable value at either site.

Table 1.1.5 Economic return to P fertilizer applications.

Site	Treatment	Yield increase[1] (kg/ha)	Net return[2] ($/ha)	Marginal return[3]
Porcupine Plain	P25	1364	64	4.5
	P50	3524	175	5.9
	P100	5040	230	4.2
Melville	P25	560	15	1.9
	P50	1198	36	2.0
	P100	1374	10	1.1

[1] Total yield increase for 3 years at Porcupine Plain and 2 years at Melville: assumes two harvests per year.

[2] Value of hay yield increase less fertilizer cost.

[3] Marginal return = Value of increased yield/cost of fertilizer input.

CONCLUSIONS AND RECOMMENDATIONS

This project has provided several points to consider in P and K fertilization of forage alfalfa. P and K fertilizers obviously have residual value beyond the year of application and can be broadcast at high rates for long term nutrient management of alfalfa.

Soil P analysis was able to accurately predict P deficiencies and fertilizer requirements for alfalfa. Residual fertilizer was detected by soil analysis and fertilizer recommendations reflected the differences. Alfalfa has a high requirement for P and K, and long rotations may develop P and K deficiencies over time, as at Melville.

Extracted soil K did not consistently nor accurately predict K requirements. An exception to this was the detection of a K deficiency at Melville in the final year, and an associated yield increase. A yield response to K fertilizer was not initially expected at Melville since this site had a chernozemic Oxbow loam soil, which is not typically K deficient. Residual fertilizer K was not detected by the soil analysis.

Economic responses to added P were large and persisted throughout the length of the trial. Fertilizer K would have been a poor investment in this trial, despite predictions of a large K deficiency at Porcupine Plain.

Further refinement of the K analysis and for the recommendation ranges for P and K are needed. However, soil testing in each year of an alfalfa rotation would be a valuable tool in detecting nutrient deficiencies.