1.4 NPK Fertilizer Application to Eroded Knolls

L.E. Cowell and E. de Jong

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INTRODUCTION

The rolling topography of much of Saskatchewan farmland is inherently subject to soil erosion. Agriculture has accelerated the movement of soil from the upper slopes of knolls to lower slopes, with a net imbalance in soil fertility. Upper slopes often have very different fertilizer requirements than mid or lower slope positions. Management of affected fields is difficult, as changes in nutrient status and available soil water may change substantially over short distances.

This field project was established to measure the changing status of nutrients and available soil water over eroded, rolling landscapes, and to measure crop responses to added fertilizer at each slope position.

METHODS

Four sites were selected for this study (Table 1.4.1). Each site covered an eroded knoll, including all slope positions. The slopes were simple, with even drainage towards the lower positions. All of the soils had been subject to erosion. Wind erosion had dominated at the Warman and Pike Lake sites, and occurred on several days of the study year. Water erosion had affected the Alvena sites, and rills formed within the plots after heavy rains. All plots were seeded into cereal stubble, while the adjacent fields were in fallow.

Five fertilizer treatments were used in the study, including (i) 100 kg nitrogen (N)/ha, (ii) 100 kg phosphorus (P_2O_5)/ha, (iii) 100 kg N plus 100 kg P_2O_5/ha, (iv) 100 kg N plus 100 kg P_2O_5 plus 100 kg potassium (K_2O)/ha, and (v) a check strip. Urea (46-0-0), triple superphosphate (0-45-0) and potash (0-0-60) were used as fertilizer sources. The treatments were set out in split plots (3 replicates) to include slope position as a treatment.

Table 1.4.1 Site location and description for eroded knoll study.

Site	Farmer	Soil association (texture)	Slope description		
			%	Length (m)	Aspect
Warman	Haichert	Asquith (sl)	4	130	west
Pike Lake	Kinzi	Alluvium (sl)	7	35	west
Alvena - 1	Kolibab	Blaine Lake (l)	12	110	east
Alvena - 2	Komarnicki	Oxbow (l)	8	65	east

Soil samples were taken to a depth of 120 cm at the upper, mid and lower slope positions within each block before seeding for analysis of available nutrients and gravimetric soil moisture. The plots were seeded with a double disc drill with 18 cm row spacings. The P/K blend and P alone were shallow banded before seeding using the seed drill. N was applied by broadcasting from the drill while seeding by disconnecting the fertilizer spouts from the seed runs.

Barley var. Harrington was seeded at the Warman, Pike Lake and Alvena - 1 sites and var. Bonanza at the Alvena - 2 site. The seeding rate was 75 kg/ha. Weeds were controlled with Hoegrass II (diclofop methyl plus bromoxynil).

The plots were harvested at maturity with a self-propelled clipper, and the samples were air-dried, measured for total grain straw weight, and threshed to measure grain yield. On each plot a 5 m^2 sample was taken at the lower, mid, upper and crest slope positions. After harvest composite soil samples to 120 cm of each treatment were taken at the lower, mid and upper slope harvest positions for measurement of available N, P and K nutrients and gravimetric soil moisture.

Growing season rainfall was recorded by the cooperating farmer to supplement soil water data for crop water use calculations.

RESULTS

Spring Nutrients and Saskatchewan Soil Testing Laboratory Predictions

Soil sampled before seeding was analyzed for available N, P and K, and compared to Saskatchewan Soil Testing Laboratory fertilizer recommendations (Table 1.4.2). At Warman and Pike Lake, the NO_3-N values were high on the upper slopes compared to the mid and lower slopes. In contrast, both Alvena sites had higher NO_3-N levels on the mid and lower slopes.

Available P levels followed a similar trend as NO_3-N. A response to P should be expected at all sites, with the Warman site having the largest apparent P deficiency. No sites showed a deficiency in available K.

Total Plant Weights

Significant differences between slope positions occurred for total straw + grain weight at each site (Table 1.4.3). Yields on crest and upper positions were not different in any case. The lower slope position yield was highest at Pike Lake and Alvena - 2. At Alvena - 1, the mid position was the highest yielding, though not significantly more than the lower position. At Warman, the yield on the mid position was much lower than any other position.

There were significant increases in total weights in response to fertilizer treatments at all sites except Alvena - 2. At the other three sites, the N+P treatment was highest yielding in each case. At the Pike Lake and Warman sites, the P and N+P+K treatments also yielded more than the check, while the N treatment yield was similar to the check yield. P seemed to be the limiting nutrient at these sites.

At Warman the yield response was greatest on the crest, upper and mid positions, with no significant response to fertilizer treatment on the lower slope. The opposite trend showed at Pike Lake, where yield increases were measured on the mid and lower slope

Table 1.4.2 Available spring nutrients and fertilizer recommendations.

Slope	Nutrients (kg/ha)							
	Depth (cm)	NO_3-N	Total NO_3-N (0-60 cm)	Recommended N fertilizer	P	Recommended P fertilizer	K	Recommended K fertilizer
				Warman site				
Upper	0-15	5			9	35	490	0
	15-30	5						
	30-60	66	76	5				
Mid	0-15	4			11	30	160	15
	15-30	3						
	30-60	6	13	70				
Lower	0-15	7			6	35	290	0
	15-30	8						
	30-60	12	27	55				
				Pike Lake site				
Upper	0-15	19			17	25	850	0
	15-30	24						
	30-60	40	83	0				
Mid	0-15	8			24	20	670	0
	15-30	5						
	30-60	14	27	55				
Lower	0-15	8			15	30	850	0
	15-30	5						
	30-60	22	35	50				

Table 1.4.2 Continued.

Slope	Nutrients (kg/ha)							
	Depth (cm)	NO_3-N	Total NO_3-N (0-60 cm)	Recommended N fertilizer	P	Recommended P fertilizer	K	Recommended K fertilizer
				Alvena - 1 site				
Upper	0-15	8			21	20	310	20
	15-30	8						
	30-60	16	32	75				
Mid	0-15	12			16	25	370	25
	15-30	15						
	30-60	26	53	55				
Lower	0-15	15			34	15	910	15
	15-30	21						
	30-60	35	71	40				
				Alvena - 1 site				
Upper	0-15	15			12	30	230	0
	15-30	15						
	30-60	10	39	70				
Mid	0-15	39			17	25	320	0
	15-30	42						
	30-60	56	137	0				
Lower	0-15	45			15	25	330	0
	15-30	49						
	30-60	35	129	5				

Recommended nutrients based on 1989 nutrient requirement guidelines for Saskatchewan field crops.

Table 1.4.3 Total plant weight response to fertilizer and slope position.

Slope position	Treatment total yields (kg/ha)					
	Check	+ N	+ P	+ N + P	+ N + P + K	Mean
Warman site						
Crest	2089	1819	2567	3145	1929	2310 b
Upper	1611	2419	2390	3347	3012	2556 b
Mid	260	861	645	1449	912	825 a
Lower	1888	1929	2089	2720	2453	2216 b
Mean	1462 a	1757 ab	1923 b	2665 c	2077 b	
LSD between slopes = 1063 LSD between treatments = 424 LSD among treatments for same slope = 849						
Pike Lake site						
Crest	667	691	837	945	847	797 a
Upper	1023	999	1120	1279	1317	1148 a
Mid	859	916	1061	1321	1411	1114 a
Lower	2734	2928	3223	3417	2811	2831 c
Mean	1321 a	1384 ab	1560 bc	1741 c	1597 bc	
LSD between slopes = 470 LSD between treatments = 193 LSD among treatments for same slope = 387						
Alvena - 1 site						
Crest	2424	3571	2398	4385	3815	3319 a
Upper	2422	2400	2896	4099	3776	3119 a
Mid	3697	6421	3834	7439	6180	5514 b
Lower	4361	5472	4216	5989	5596	4917 b
Mean	3226 a	4466 b	3336 a	5478 c	4842 b	
LSD between slopes = 1365 LSD between treatments = 439 LSD among treatments for same slope = 878						
Alvena - 2 site						
Crest	1888	1975	1928	2614	2452	2171 a
Upper	2337	2466	2231	2576	3010	2524 a
Mid	2107	2808	2493	3046	2185	2528 a
Lower	4963	5289	5483	5348	5291	5126 b
Mean	2824	3135	3034	3396	3235	
LSD between slopes = 746 LSD between treatments = NS LSD among treatments for same slope = NS						

positions but not on the crest and upper positions. At both sites the fertilizer responses occurred on the highest yielding slope position.

At Alvena - 1 the N+P+K, N+P and N treatments yielded more than the P and check treatments. N was therefore limiting and increased yield at all slope positions, though less so on the lower slope.

The N+P+K treatment often yielded lower than other fertilizer treatments: the high rate of total fertilizer, though not seed placed, may have had a negative effect on seedling germination and emergence.

Grain Weights

The grain weights generally followed the same pattern as total yield over the slope position and fertilizer treatments, though the responses were not as strong (Table 1.4.4). Grain weights were reduced due to two week period of very hot dry weather in mid July. Many heads or parts of heads were aborted due to these conditions. This dampened the response to treatments and slope position.

Grain/Straw Ratio

Low grain/straw ratios (G/S) were a result of the intense heat and drought during anthesis at all sites (Table 1.4.5). No significant difference in G/S occurred between slope positions for the Pike Lake and Warman sites. These sites had sandy soil, so the crop suffered more intensely than at Alvena. At the two Alvena sites, G/S decreased from the crest to the lower positions.

G/S was not strongly affected by fertilizer treatments. Generally the check plots had a lower G/S than the fertilized plots. At the Alvena sites, where N responses predominated, treatments with N fertilizer had the lowest G/S. At the Alvena - 2 site, which showed no fertilizer response for grain or total yields, the check and P treatments

Table 1.4.4 Grain yield as affected by slope position and fertilizer treatment.

Slope position	Treatment yields (bu/acre)					
	Check	+ N	+ P	+ N + P	+ N + P + K	Mean
Warman site						
Crest	16.2	13.0	21.9	22.7	14.5	17.6 a
Upper	13.7	16.5	20.1	24.3	21.9	19.3 a
Mid	2.2	4.6	4.6	8.8	5.7	5.2 b
Lower	14.2	12.5	15.3	13.4	14.5	14.0 a
Mean	11.6 a	11.7 a	15.5 bc	17.3 bc	14.1 ab	
LSD between slopes = 8.8 LSD between treatments = 3.0 LSD among treatments for same slope = 5.9						
Pike Lake site						
Crest	2.9	2.5	3.1	3.9	3.9	3.3 a
Upper	3.7	2.8	5.2	4.9	6.4	4.6 a
Mid	3.1	2.6	3.8	4.8	5.9	4.0 a
Lower	11.5	11.4	12.4	14.4	12.1	12.4 b
Mean	5.3 ab	4.8 a	6.1 ab	7.0 b	7.1 b	
LSD between slopes = 4.7 LSD between treatments = 1.8 LSD among treatments for same slope = NS						
Alvena - 1 site						
Crest	22.7	28.2	23.1	35.5	31.6	28.2 a
Upper	20.9	18.9	26.4	31.5	26.4	24.8 a
Mid	30.1	48.0	34.5	46.0	41.0	40.0 b
Lower	33.3	27.9	31.5	31.7	29.8	30.8 ab
Mean	26.8 a	30.7 ab	28.9 ab	36.2 c	32.2 bc	
LSD between slopes = 10.3 LSD between treatments = 4.0 LSD among treatments for same slope = 8.0						
Alvena - 2 site						
Crest	19.2	19.1	19.3	22.9	22.0	20.5 a
Upper	23.8	22.3	22.0	23.1	25.5	23.3 a
Mid	17.2	19.9	21.4	22.9	18.5	20.0 a
Lower	38.4	35.8	42.6	38.5	35.7	38.2 b
Mean	24.6	24.3	26.3	26.9	25.4	
LSD between slopes = 8.5 LSD between treatments = NS LSD among treatments for same slope = NS						

Table 1.4.6 Water use efficiency of barley in eroded knoll trials.

Slope position	Treatment water use efficiency (kg/ha/cm)					
	Check	+ N	+ P	+ N + P	+ N + P + K	Mean
Warman site						
Crest	39	39	68	69	43	51.6 b
Upper	43	50	62	74	68	59.4 b
Mid	8	15	16	22	21	16.4 a
Lower	42	34	43	37	37	38.6 ab
Mean	33 a	34.5 a	47.3 b	50.5 b	42.3 ab	
LSD between slopes = 26 LSD between treatments = 10 LSD among treatments for same slope = 19						
Pike Lake site						
Crest	9.4	7.9	10.4	12	13	10.5 a
Upper	11.8	8.8	17.8	14.9	21.9	15.0 a
Mid	11.4	8.8	12.6	16.6	19.9	13.9 a
Lower	32.8	32.1	33.9	40.6	32.5	34.4 b
Mean	16.4 ab	14.4 a	18.7 abc	21.0 bc	21.8 bc	
LSD between slopes = 13.4 LSD between treatments = 4.9 LSD among treatments for same slope = 9.8						
Alvena - 1 site						
Crest	46	50	50	76	59	56.2 ab
Upper	42	33	57	67	49	49.6 a
Mid	76	118	95	109	103	100.2 c
Lower	83	66	94	78	66	77.4 bc
Mean	61.8 a	66.8 ab	74 bc	82.5 bc	69.3 ab	
LSD between slopes = 24 LSD between treatments = 10 LSD among treatments for same slope = 20						
Alvena - 2 site						
Crest	39	40	41	48	44	42.4 a
Upper	48	47	47	48	50	48.0 a
Mid	38	44	46	49	32	41.8 a
Lower	79	81	95	83	69	81.4 b
Mean	51.0	53.0	57.3	57.0	48.8	
LSD between slopes = 19 LSD between treatments = NS LSD among treatments for same slope = NS						

Table 1.4.7a Available nutrients in soil sampled after harvest - Warman site.

Slope	Treatment	Depth (cm)	Nutrients (kg/ha) NO_3-N	Total NO_3-N (0-60 cm)	P	K
Upper	Check	0-15	5		10	300
		15-30	2			
		30-60	2	9		
	N	0-15	34		10	290
		15-30	9			
		30-60	6	49		
	P	0-15	6		26	400
		15-30	3			
		30-60	3	12		
	N+P	0-15	30		15	350
		15-30	8			
		30-60	4	42		
	N+P+K	0-15	15		12	380
		15-30	4			
		30-60	3	22		
Mid	Check	0-15	4		10	170
		15-30	4			
		30-60	6	14		
	N	0-15	18		10	230
		15-30	14			
		30-60	9	41		
	P	0-15	5		50	180
		15-30	3			
		30-60	5	13		
	N+P	0-15	20		18	200
		15-30	9			
		30-60	4	33		
	N+P+K	0-15	9		10	160
		15-30	5			
		30-60	5	19		
Lower	Check	0-15	10		14	460
		15-30	4			
		30-60	15	29		
	N	0-15	42		14	340
		15-30	10			
		30-60	15	67		
	P	0-15	19		64	380
		15-30	6			
		30-60	10	35		
	N+P	0-15	28		20	340
		15-30	8			
		30-60	7	43		
	N+P+K	0-15	48		28	460
		15-30	12			
		30-60	10	70		

Table 1.4.7b Available nutrients in soil sampled after harvest - Pike Lake site.

Slope	Treatment	Depth (cm)	Nutrients (kg/ha) NO_3-N	Total NO_3-N (0-60 cm)	P	K
Upper	Check	0-15	18		28	750
		15-30	13			
		30-60	21	52		
	N	0-15	50		16	500
		15-30	12			
		30-60	16	78		
	P	0-15	25		80	700
		15-30	8			
		30-60	16	49		
	N+P	0-15	44		18	500
		15-30	14			
		30-60	12	70		
	N+P+K	0-15	53		17	440
		15-30	12			
		30-60	17	82		
Mid	Check	0-15	12		18	620
		15-30	10			
		30-60	4	26		
	N	0-15	48		15	660
		15-30	42			
		30-60	18	108		
	P	0-15	13		94	700
		15-30	9			
		30-60	13	35		
	N+P	0-15	23		26	570
		15-30	78			
		30-60	20	121		
	N+P+K	0-15	31		17	700
		15-30	17			
		30-60	46	94		
Lower	Check	0-15	21		25	900
		15-30	8			
		30-60	10	39		
	N	0-15	115		25	900
		15-30	17			
		30-60	17	149		
	P	0-15	32		28	900
		15-30	7			
		30-60	8	47		
	N+P	0-15	84		22	900
		15-30	16			
		30-60	13	113		
	N+P+K	0-15	68		37	900
		15-30	26			
		30-60	17	111		

Table 1.4.7c Available nutrients in soil sampled after harvest - Alvena - 1 site.

Slope	Treatment	Depth (cm)	Nutrients (kg/ha) NO_3-N	Total NO_3-N (0-60 cm)	P	K
Upper	Check	0-15	3		10	260
		15-30	2			
		30-60	3	8		
	N	0-15	6.5		8	250
		15-30	10			
		30-60	16	32.5		
	P	0-15	4		40	350
		15-30	1.5			
		30-60	3	8.5		
	N+P	0-15	7		32	300
		15-30	5			
		30-60	32	44		
	N+P+K	0-15	7		12	320
		15-30	13			
		30-60	28	48		
Mid	Check	0-15	6		20	550
		15-30	4			
		30-60	4	14		
	N	0-15	10		20	560
		15-30	18			
		30-60	11	39		
	P	0-15	6		120	560
		15-30	8			
		30-60	5	19		
	N+P	0-15	7		95	500
		15-30	4			
		30-60	6	17		
	N+P+K	0-15	10		40	500
		15-30	12			
		30-60	5	27		
Lower	Check	0-15	18		60	900
		15-30	15			
		30-60	7	40		
	N	0-15	10		40	900
		15-30	6			
		30-60	9	25		
	P	0-15	8		50	900
		15-30	4			
		30-60	5	17		
	N+P	0-15	10		50	900
		15-30	4			
		30-60	12	26		
	N+P+K	0-15	8		42	900
		15-30	5			
		30-60	5	18		

Table 1.4.7d Available nutrients in soil sampled after harvest - Alvena - 2 site.

Slope	Treatment	Depth (cm)	Nutrients (kg/ha) NO_3-N	Total NO_3-N (0-60 cm)	P	K
Upper	Check	0-15	5		14	270
		15-30	4			
		30-60	5	14		
	N	0-15	27		10	220
		15-30	94			
		30-60	38	159		
	P	0-15	5		12	270
		15-30	5			
		30-60	5	15		
	N+P	0-15	7		15	270
		15-30	12			
		30-60	29	48		
	N+P+K	0-15	54		10	250
		15-30	41			
		30-60	14	109		
Mid	Check	0-15	14		14	270
		15-30	20			
		30-60	46	80		
	N	0-15	13		20	380
		15-30	42			
		30-60	56	111		
	P	0-15	11		26	300
		15-30	20			
		30-60	25	56		
	N+P	0-15	21		58	370
		15-30	46			
		30-60	26	93		
	N+P+K	0-15	17		15	320
		15-30	31			
		30-60	62	110		
Lower	Check	0-15	10		15	750
		15-30	7			
		30-60	8	25		
	N	0-15	14		20	740
		15-30	12			
		30-60	17	43		
	P	0-15	13		120	900
		15-30	9			
		30-60	13	35		
	N+P	0-15	23		25	600
		15-30	28			
		30-60	17	68		
	N+P+K	0-15	28		18	900
		15-30	8			
		30-60	20	56		

all sites, whether an actual yield response to P was measured or not. No consistent increase in extractable K was measured where fertilizer K was added.

DISCUSSION

A two week period of intense heat and drought during anthesis had a marked effect on barley grain yield. The grain yield was reduced, and low G/S and WUE values resulted. The total straw plus grain weight therefore gave the strongest response to the slope position and fertilizer treatments.

Slope position strongly affected total weight, and the lower slope was highest yielding at Pike Lake and Alvena - 2. At Warman, the gentle slope and sandy soil provided less water movement to lower slopes, so there was less difference in yield. At this site the mid slope was much lower yielding, possibly indicating significant erosion having occurred here in the past. At Alvena - 1, the very steep slope provided runoff water to the mid slope position, thus increasing yield there.

The N+P treatment consistently provided the highest yield. At the coarse textured Pike Lake and Warman sites, the treatments including P yielded best, and responses were greatest on the highest yielding slope position. At Alvena - 1, N addition increased yield most, with a strong response at all slope positions.

Spring soil samples provided some indication of potential crop response to fertilizer, but the predictions were not consistently accurate. For example, the Alvena - 2 site should have had a large N response on the upper slope, and a P response at all positions. No significant responses to fertilizer were measured at this site. At Alvena - 1, a large N response was expected, especially on the upper slope; this trend was observed. However, a P response did not occur at this site as predicted by the soil test. At both Warman and Pike Lake, a large fertilizer N recommendation was made for the lower slopes, but no significant yield response occurred. P fertilizer was recommended, and a P response did occur at both sites. No K responses were predicted nor measured at any site.

The summer drought probably played a part in the nutrient responses. The crop yields, especially on the coarse textured soils, were quite low. However some refinement is obviously needed in the response predictions. The prediction needs to recognize differences in soil texture, and potential yields; the present use of 'dry', normal' and 'wet' soil in respective soil zones is insufficient. Considering the complex nature of most fields, especially those affected by erosion, the farmer requires a better choice of fertilizer management strategies for his field.

Residual N and P fertilizer was mainly confined to the 0-15 cm soil depth. There was a substantial carryover of fertilizer N. Residual P levels were higher when P was added alone than with N fertilizer. Good growing conditions early in the summer probably induced the crop to rapidly take up fertilizer P where available, and this uptake seemed to be enhanced by fertilizer N. Though not measured, the crop residue from the N+P treatments may contain more P than residue from the P only treatment.

Fertilization can play a role in eroded knoll reclamation. Certainly, the farmer should utilize his knowledge of the knoll productivity, and combine this with soil test data to establish a fertilizer management program. With varied rate application of fertilizer, the producer may be able to increase his return to his fertilizer dollar.