1.3 Fertilizer Application to Eroded Knolls

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INTRODUCTION

The variability of soil nutrients over rolling landscapes continues to be a barrier to efficient use of fertilizers by crops. Technology is now becoming available to farmers for changing application rates while applying fertilizer. To date, very little research has measured how soil nutrients and crop response changes over a rolling field. The goal of this project, started in 1989, was to measure the potential yield increase due to nitrogen (N) and phosphorus (P) fertilizer applied to eroded knolls near Alvena, Saskatchewan.

METHODS AND MATERIALS

Two sites were chosen within the same field on the Komarnicki farm near Alvena. Triticale was grown the previous year, with an average field yield of 4000 kg/ha. Both sites covered the south aspect of similar knolls and included all slope positions. The slope on each site approached 10% gradient and 50 m length. The soil is mapped as a rolling Blaine Lake/Oxbow complex.

The sites will be referred to as "North" and "South" in this paper in reference to their relative position in the field. There were few topographical differences between the slopes. The lower position of the South site was subject to temporary water ponding in spring.

On each site, four fertilizer treatments were applied in three blocks. The treatments were: (i) 80 kg/ha N as urea (46-0-0); (ii) 80 kg/ha P_2O_5 as monoammonium phosphate (11-55-0); (iii) 80 kg/ha N plus 80 kg/ha P_2O_5; and (iv) a check strip.

Before seeding, soil was sampled to 90 cm on each slope position. The plots were seeded with a double disc drill with 22 cm row spacing. The fertilizer was side banded in every second row space. Barley (var. Bonanza) was seeded at 90 kg/ha.

At harvest, 2 m^2 samples were taken on each slope for total and grain yield measurement. Two mid slope positions were sampled since the area covered by the mid position was larger than the other slope positions. After harvest, composite soil samples to 90 cm were taken from each treatment at the same position as the harvest samples.

The plot design did not allow measurement of N x P interaction. The size of the knolls limits the size of treatments so only single fertilizer rates could be used. Data was analyzed in ANOVA tables and the appropriate LSDs were calculated for significant F values.

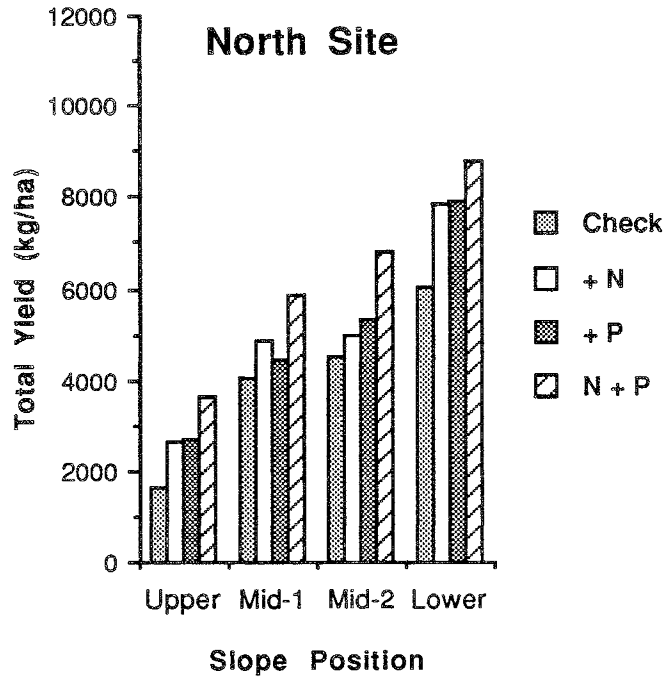
RESULTS AND DISCUSSION

Crop Response to Fertilizer

Fertilizer application increased crop total and grain yields on both sites, though the response varied with slope position.

The combined application of N and P fertilizer significantly increased total yield on both sites and all slope positions (Fig. 1.3.1 and Table 1.3.1). Nitrogen or P fertilizer applied alone did not consistently increase yield. Yield increase due to N and P fertilizer appears additive.

Grain yield was also significantly increased by fertilizer application, generally in the same pattern as total yield (Fig. 1.3.2 and Table 1.3.2). However, fertilizer application increased grain yield by a much smaller amount than total yield, a pattern often noted in yield studies. In a few cases, a significant total yield increase did result into a significant grain yield increase.



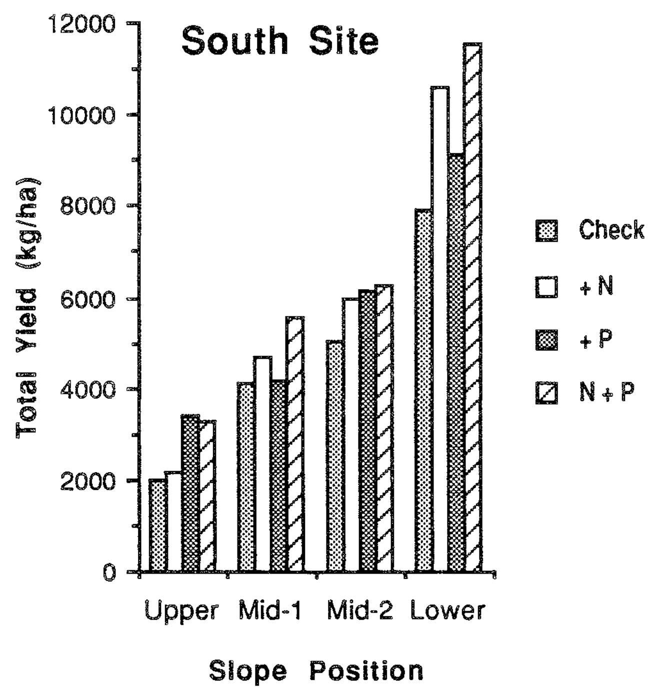


Figure 1.3.1 Total yield of each treatment and slope position for the two sites. The LSD between treatments on the same slope for the North site is 1070 kg/ha (P >0.10, F = 10.7, d.f. = 24) and for the South site is 960 kg/ha (P >0.10, F = 11.8, d.f. = 24)

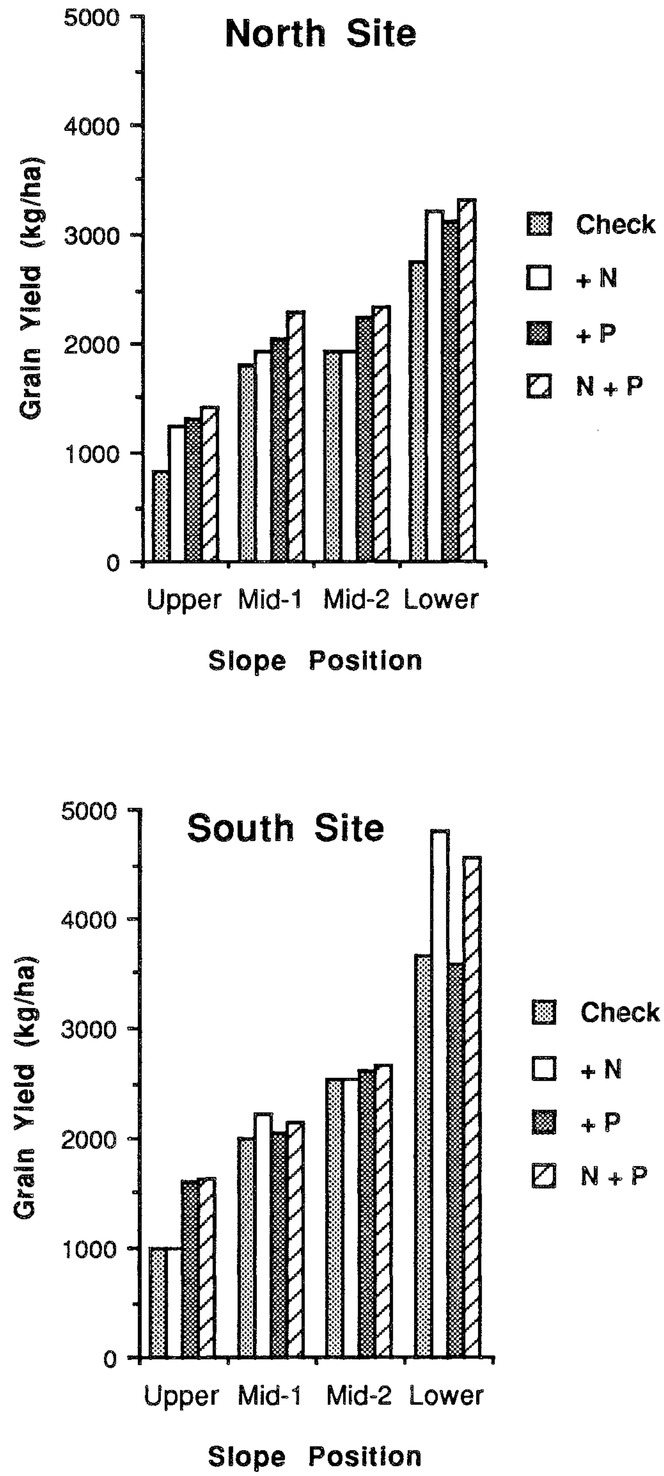


Figure 1.3.2 Grain yield of each treatment and slope position for the two sites. The LSD between treatments on the same slope for the North site is 362 kg/ha (P >0.10, F = 9.9, d.f. = 24) and for the South site is 537 kg/ha (P >0.10, F = 3.1, d.f. = 24)

Table 1.3.1 Total and percent total yield increase due to fertilizer treatment as compared to check yields

Site	Slope	Total yield increase due to fertilizer treatment in kg/ha (%)*		
		N	P	N + P
North	Upper	1077 (66)	1077 (68)	2032 (126)
	Mid-1	NS	NS	1787 (44)
	Mid-2	NS	NS	2310 (51)
	Lower	1845 (31)	1910 (32)	2747 (46)
South	Upper	NS	1430 (72)	1323 (67)
	Mid-1	NS	NS	1455 (36)
	Mid-2	NS	1107 (22)	1235 (25)
	Lower	2712 (34)	1225 (16)	3617 (46)

* Yield increase is the total or percent difference between the treated plot and check plot, reported if significant at P <0.10 according to the F value of the ANOVA.

Table 1.3.2 Total and percent grain yield increase due to fertilizer treatment as compared to check yields

Site	Slope	Grain yield increase due to fertilizer treatment in kg/ha (%)*		
		N	P	N + P
North	Upper	420 (51)	494 (60)	602 (73)
	Mid-1	NS	NS	495 (27)
	Mid-2	NS	364 (17)	429 (22)
	Lower	465 (17)	376 (14)	561 (20)
South	Upper	NS	612 (62)	632 (63)
	Mid-1	NS	NS	NS
	Mid-2	NS	NS	NS
	Lower	1135 (31)	NS	892 (24)

* Yield increase is the total or percent difference between the treated plot and check plot, reported if significant at P <0.10 according to the F value of the ANOVA.

On the eroded upper slope positions, yields were sharply increased by both N and P on the North site but only by P on the South site. Midslope positions showed little response to fertilizer. On the lower slopes, yield was increased by both N and P on the North site but only by N on the South site. The requirement for N but not P is typical for spring flooded lower slopes as on the South site.

The combined application of N and P was the most effective fertilizer treatment. Nitrogen or P fertilizer applied alone would not be used as efficiently by the crop. Nutrient requirements were generally largest on the upper and lower extremes of the slope. The lower slopes responded most to N fertilizer and the eroded upper slopes were more P deficient.

Yield Predictions and Nutrient Recommendations

Soil nutrients measured in spring can be compared to standard fertilizer recommendations and actual yield increases.

Soil nitrates (NO_3) and ammonium (NH_4) were measured in spring (Table 1.3.3). Between 60 and 75% of the measured available N was in the NH_4 form. This is contrary to the belief that nitrates dominate in our prairie soils. There is no obvious reason for the soil to have a high ammonium content. The soil was sampled in late spring (May 31st) and the slope aspect was south, so the soil was warm and fairly dry. Each slope position and soil depth contained substantial ammonium levels. The previous triticale crop yield was 4000 kg/ha. This yield is not inordinately large and would be much lower on the upper slopes.

A comparison of soil test recommendations and actual yield increases lend support to the measured ammonium levels (Table 1.3.4). A soil test based on nitrates alone would recommend over 70 kg/ha of N fertilizer with an expected yield increase of 1200 to 2000 kg/ha. If both nitrates and ammonium are considered the recommended N fertilizer and expected yield increase are much lower and are comparable to the actual yield increase measured in the plots. In the 1989 trials, it was noted that soil tests provided a poor

Table 1.3.3 Available soil nitrate (NO_3) and ammonium (NH_4) nitrogen measured before seeding (May 31)

Slope position	Depth (cm)	NO_3-N (kg/ha)	NH_4-N (kg/ha)	$NO_3 + NH_4$ (kg/ha)
		North Site		
Upper	0-15	2	12	14
	15-30	4	11	15
	30-60	8	17	25
	60-90	6	18	24
	Total	20	58	78
Mid	0-15	5	13	18
	15-30	4	12	16
	30-60	13	16	29
	60-90	8	16	24
	Total	30	57	87
Lower	0-15	7	15	22
	15-30	6	14	20
	30-60	12	26	38
	60-90	10	24	34
	Total	35	79	114
		South Site		
Upper	0-15	2	9	11
	15-30	2	9	11
	30-60	8	16	24
	60-90	4	16	20
	Total	16	50	66
Mid	0-15	5	12	17
	15-30	2	12	14
	30-60	10	21	31
	60-90	9	24	33
	Total	26	69	95
Lower	0-15	10	16	26
	15-30	8	12	20
	30-60	18	22	40
	60-90	11	22	33
	Total	47	72	119

Table 1.3.4 Recommended N fertilizer and expected yield increase based on soil NO_3 or soil $NO_3 + NH_4$, and compared to actual yield increase

Slope position	Recommended N fertilizer* Based on NO_3	Recommended N fertilizer* Based on $NO_3 + NH_4$	Expected yield increase Based on NO_3	Expected yield increase Based on $NO_3 + NH_4$	Actual yield increase**
	kg/ha				
			North Site		
Upper	95	35	1904	448	235
Mid	85	30	1736	392	263
Lower	85	15	1736	168	202
			South Site		
Upper	95	45	2072	672	22
Mid	80	20	1624	224	84
Lower	70	5	1288	56	1019

* Recommended fertilizer requirement according to SSTL 1990 guidelines for 'normal' soil moisture.
** Data is based on a comparison of the N + P treatment to the P treatment.

estimate of N fertilizer requirements for a similar soil. Soil ammonium N was not measured in 1989 but may have played a role in crop nutrition.

Phosphorus fertilizer was recommended for each slope position but a yield response was not consistent (Table 1.3.5). When combined with 1989 data, the ratio of fertilized yield to check yield appears to be much larger than 1.0 only when the available P in the 0-15 cm soil depth is less than 20 kg/ha (Fig. 1.3.3). There is insufficient data to verify this observation. The present guidelines recommend P fertilizer until available soil P in the top 15 cm of soil exceeds 60 kg/ha.

Table 1.3.5 Recommended P fertilizer requirement and actual yield response

Slope	Spring available P (0-15 cm, kg/ha)	Recommended P_2O_5 fertilizer* (kg/ha)	Grain yield increase** (kg/ha)
		North Site	
Upper	9	35	412
Mid	13	30	NS
Lower	15	30	360
		South Site	
Upper	10	35	617
Mid	15	30	NS
Lower	60	15	NS

* SSTL recommended fertilizer based on measured soil P.
** Yield of N + P treated to N treated plots.

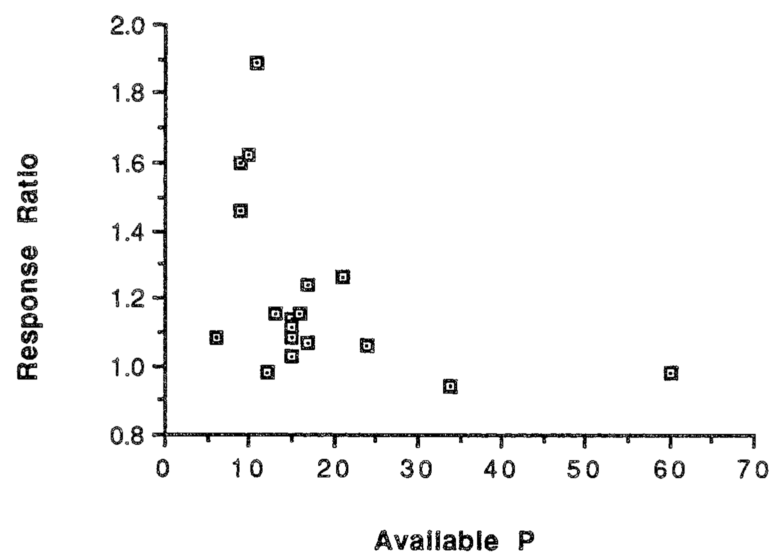


Figure 1.3.3 The ratio of grain yield in P fertilized plots to grain yield in check plots compared to available soil P; 1989 and 1990 data

Field Fertilization

Variable soil nutrients and crop growth combine to make fertilization of rolling fields very difficult. This data cannot suggest specific rates of fertilizer requirement, but the potential yield response to proper fertilization can be estimated. If it is assumed the mid, upper and lower slope positions cover 66, 17 and 17% of the field, the overall yield increase is:

$$\Delta \text{ Yield} = \Delta \text{ Yield, upper} + 2\,(\Delta \text{ Yield, mid-1} + \Delta \text{ Yield, mid-2}) + \Delta \text{ Yield, lower}$$

For the average site data, this equation would predict yield increases of 298 kg/ha for N fertilizer, 383 kg/ha for P fertilizer and 572 kg/ha for N + P fertilizer. Again, N and P responses appear to be additive. To achieve this yield increase without an excessive blanket fertilizer application, separate soil samples of each slope position are required. The farmer must also have a simple means of separately adjusting N and P fertilizer application rates.

Crop Water Use

Soil moisture was measured before seeding and after harvest. Added to the growing season precipitation of 23 cm, these measurements were used to calculate water use efficiency (Tables 1.3.6 and 1.3.7). The soil moisture measurements were single

Table 1.3.6 Gravimetric soil moisture measured to 90 cm before crop seeding. Each value was of a composite sample from each block.

	Total soil water (cm)
North plot	
Upper	15.4
Mid	14.4
Lower	17.8
South plot	
Upper	12.3
Mid	14.7
Lower	18.5

Table 1.3.7 Soil water use and water use efficiency for each treatment.

	Treatment	Soil water use* (cm)	Water use efficiency** (kg/ha/cm)
		North plot	
Upper	Check	4.6	31
	+ N	4.0	49
	+ P	5.7	49
	N + P	5.3	54
Mid	Check	4.0	73
	+ N	5.4	73
	+ P	4.7	80
	N + P	4.0	92
Lower	Check	5.5	104
	+ N	8.5	109
	+ P	7.5	106
	N + P	6.4	121
		South plot	
Upper	Check	5.1	38
	+ N	5.7	38
	+ P	5.8	60
	N + P	7.4	57
Mid	Check	7.3	71
	+ N	7.6	78
	+ P	6.7	74
	N + P	6.2	78
Lower	Check	8.9	122
	+ N	8.6	162
	+ P	10.9	113
	N + P	9.7	148

* Soil water use = Spring soil water - Fall soil water
** Water use efficiency = Grain yield / (Soil water use + Growing season precipitation)

values for each slope position, so statistical significance cannot be assigned. However, there is an obvious trend to increased water use efficiency with fertilization.

CONCLUSIONS

Crop response to N and P fertilizers varies with slope position. The upper and lower slopes had the largest yield increases, with a trend for larger responses to P fertilizer on eroded upper slopes and to N fertilizer on moist lower slopes. Nitrogen and P fertilizer added together consistently gave much larger yield increases than either fertilizer added alone.

Ammonium may be an important source of plant available N. Further efforts should be made to determine why and when soil ammonium predominates as the available soil N form.