#### CHAPTER 5

# Potassium

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## **ABSTRACT**

Potassium (K) deficient soils occupy approximately 1.01, 0.41, and 0.41 million hectares in Alberta, Saskatchewan, and Manitoba, respectively. Generally, soils with severe deficiencies exist in the coarse textured Black, Dark Gray, Gray Luvisolic and Organic soils. The Brown and Dark Brown soils contain by far the largest amount of exchangeable or available K. The NaHCO<sub>3</sub> extractable K level of Gray Luvisolic soils is typically 400 kg K ha<sup>-1</sup>, while that of a Brown Chernozem is over 1000 kg K ha<sup>-1</sup>.

Over the past 30 years, a large number of field experiments to investigate K fertilizer management have been conducted across the prairies. These experiments have provided extensive data for soil test correlations. Plant available K, primarily in the form of exchangeable K, can be precisely measured using dilute NH<sub>4</sub>OAc and/or NaHCO<sub>3</sub> as extractants.

Soil test benchmarks and the extraction procedures currently in use provide an adequate basis for separating fertilizer K responsive soils from non-responsive soils. The large majority of soils across the prairies contain adequate amounts of available K, and would not be expected to respond to fertilizer K applications. Slightly deficient and moderately deficient soils containing from 50 to 200 kg K ha<sup>-1</sup> often respond to K fertilizer in spotty and irregular patterns, while soils containing less than 50 kg K ha<sup>-1</sup> respond strongly and consistently, with yields frequently being more than doubled.

Generally, barley, wheat, oats, corn, and potatoes respond more strongly to fertilizer K than oilseeds, such as canola or flax. Among the cereal grains it appears that barley may respond more consistently and strongly to K.

Fertilizer K placement studies have shown that while grain and oilseed crops more frequently benefit from seed-placed KCl, broadcast applications are also an effective means of overcoming K deficiencies in soil; furthermore, broadcasting results in longer-lasting benefits because larger amounts of K can be applied.

Significant yield responses to applications of fertilizer K have been recorded in all provinces on soils high in exchangeable K. The random responses, which occur at a sufficiently low frequency to be graded uneconomic, have been related to factors such as disease suppression rather than K nutrition *per se*.

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The prime sources of fertilizer K are KCl (0-0-60), K<sub>2</sub>SO<sub>4</sub> (0-0-50) and KNO<sub>3</sub> (13-0-44). KCL is the superior source; the Cl component enhances disease control. Sulphate does not enhance the availability of the K in K<sub>2</sub>SO<sub>4</sub>, and there appears to be little justification to use this source of K except for chlorine (Cl) sensitive crops. There is fairly strong evidence suggesting that mixing KCl and monoammonium phosphate will inhibit the uptake of fertilizer P applied in a band with the cereal seeds.

In view of the very large amount of field research that has been conducted on K fertilizer management practices, future work involving K fertilizer should be restricted to solving specific problems or answering difficult questions such as the role of KCl in disease suppression or the significance of K fertilizers in the maintenance of crop quality.

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#### INTRODUCTION

To date, the needs for K fertilizer for the cropping systems of most prairie soils have been extensively investigated, in spite of the fact that it has been generally shown that most prairie soils have large reserves of available K, and that crops are generally well nourished with this element (Beaton, 1976). The purpose of this chapter is to provide a summary of the findings from the major K research projects that have been conducted in the prairie provinces, and to address areas of K deficiencies on the prairies. An excellent general treatise of K as it relates to all aspects of crop production is provided in a bulletin by the Potash and Phosphate Institute (1987).

## POTASSIUM DEFICIENCY IS COMPLEX

Even though soils may, on the basis of soil test K, appear to contain abundant quantities of this nutrient, there is no assurance that crops will necessarily be able to fully utilize such supplies (Beaton, 1980b). Some factors that may interfere with crop uptake of available soil K are: free lime in the rooting zone, low soil pH, poor drainage, cool temperatures, soil compaction, and a shallow root zone (Beaton, 1980a).

One set of conditions which interferes with crop uptake of available soil K is cool, wet soil in the spring; consequently, crops such as winter wheat, fall rye, alfalfa, grasses, early spring seeded corn and small grain crops are often negatively affected by restricted K uptake early in the growing season. The addition of fertilizer K will likely help such crops through stress periods (Beaton, 1980a).

The presence of high concentrations of Ca and/or Mg in the rooting zone of crops may also interfere with K uptake from prairie soils (Spratt, 1979; Grant et al., 1988). Both of these nutrients compete with soil K for entry into plant roots and may consequently restrict the availability of soil K to plants. Competition among Ca, Mg, and K ions has been observed in several studies (Halstead et al., 1958; Carter et al., 1979; Grant and Racz,

1987). As a result, consistent economic responses in wheat and barley have been reported in Manitoba from K fertilization of wheat grown on high Mg soils (Beaton, 1980a).

#### POTASSIUM DEFICIENT AREAS

Potassium deficient soils (< 200 kg K ha<sup>-1</sup>) have been estimated to occupy about 1.01 million hectares of cultivated land in Alberta and 0.41 million hectares in each of Saskatchewan and Manitoba (Halstead et al., 1970). Low soil K levels may be found in soils that are coarse textured, low in organic matter, or which contain large amounts of lime in the rooting zone (Beaton, 1980a). Sandy soils and soils located in high precipitation areas are particularly susceptible to K deficiency. The severest K deficiency problems in the prairies exist mainly on coarse-textured Black, Dark Gray and Gray Luvisolic, and Organic soils (Beaton, 1980a).

Some excellent reviews of crop response to K fertilization are readily available. Beaton and Sekhon (1985) provide a detailed review of the K nutrition of small grains, including the biochemical functions of K for improving drought tolerance and lodging resistance. Similarly, Bailey and Soper (1985) provide a complete review of the K nutrition of rapeseed, flax, sunflower, and safflower crops. For information on the trends in available K in the prairies, the reader is referred to Chapter 2. A brief summary of the extent of K deficient soils and their response to K follows.

Alberta: The major region of K deficient soils straddles the zone bordering the Black Chernozemics and Gray Luvisolics of central Alberta. Smaller pockets of K deficiency occur in the Peace River district. New areas of low K soils were identified in the mid-1970s in the Ponoka, Wetaskiwin, and Leduc areas (Beaton, 1980a).

In Alberta, exchangeable soil K levels are closely related to soil zone, with levels being highest in the Brown soil zone and lowest in the more humid Gray soil zones (Cameron and Toogood, 1970).

Manitoba: Most of the coarse-textured soils in Manitoba are low in K. To the east of Winnipeg, there is an area running south from Lake Winnipeg to the U.S.A. boundary where the soils do not contain sufficient available K for most crops. There is also a broad belt of soils lying between lakes Winnipegosis and Manitoba and the Manitoba escarpment where K fertilization is recommended for crops with high K requirements (e.g., corn, potatoes). Other low K soils are found in areas Northwest, West, and Southwest of Brandon (Beaton, 1980a).

The number of Manitoba fields with low soil test K levels has been variable over the last 25 years. On average, 5.8% of the fields submitted to the Manitoba soil testing facility were considered K deficient (i.e., NH<sub>4</sub>OAc extractable K < 200 kg ha<sup>-1</sup> in top 15 cm). Soil K levels have not changed over the past 25 years in Manitoba (*see Chapter 8*).

Saskatchewan: Approximately 405 000 ha of Saskatchewan soils are estimated to be deficient in K (Button, 1978). The largest percentage of, and most severely K deficient soils in Saskatchewan, occur in the Northeast, mainly in the Carrot River district. Isolated areas of soils in other parts of Northern Saskatchewan may also be low in K (Button, 1978; Beaton, 1980a).

In 1969, summaries of NH<sub>4</sub>OAc extractable K levels for approximately 30 000 fields revealed slight differences between soils on stubble and fallow land, and there was a gradual decrease in extractable soil K as one moved from the arid to more humid regions of the province (*see Chapter 8*). The highest average levels of NH<sub>4</sub>OAc extractable K occur in the Brown soil zone (≈ 1100 kg ha<sup>-1</sup>) and decrease to an average of 450 kg ha<sup>-1</sup> in the Gray Luvisolic soils (Halstead et al., 1970).

#### POTASSIUM FERTILIZATION

Potassium is almost exclusively applied as KCl, i.e., muriate of potash (0-0-60). Two less commonly used sources of K are K<sub>2</sub>SO<sub>4</sub> (0-0-50) and KNO<sub>3</sub> (13-0-44). These

two sources are most often used on crops such as potatoes which are sensitive to Cl (Zirk, 1965).

The method of fertilizer K placement depends on soil clay content and the nature of the crop grown. For soils with a large clay content, broadcast K application may be inefficient because K is easily fixed by expanding lattice clays. On such soils, the best results are obtained if the K is seed-placed or applied as a band near the seed to minimize fixation. Broadcast application of fertilizer K has merit on soils with high K levels, or where high rates of K are required, or for small-seeded crops where seed placement may restrict germination (Spratt, 1986).

# Crop Responses

Alberta: Numerous field experiments have been conducted on various soil types in Alberta to measure cereal response to K-fertilizer. The results generally show that small yield responses (e.g., 250 to 400 kg grain ha<sup>-1</sup>) can sometimes be expected when large crop yields are produced on soils in the northern half of the province. Except for a few soils, K fertilizer rarely produces large yield responses (Halstead et al., 1970).

A summary of ninety field experiments conducted from 1957 to 1965 in the Black and Thin Black soil zones of central Alberta revealed that K fertilization increased grain yields by an average of 5% over control treatments. Similar experiments in the Dark Brown and Brown soils of southern Alberta during the same period showed that K fertilization decreased yields by 1% relative to control in 43 trials (Halstead et al., 1970).

Results from a series of studies conducted in central Alberta in the 1960s showed that few soils were deficient in K (yield increase were seldom significant) and that most K responsive soils were high in free carbonates. The results also showed that a low rate of drilled K (e.g., 22 kg ha<sup>-1</sup>), was as effective as much higher rates of broadcast K addition (Halstead et al., 1970).

Anderson and Kusch (1968) found no response of rapeseed to seed-placed K on two Gleysolic soils and one Dark Gray Luvisolic soil in northern Alberta. Some benefit to K addition was observed when it was combined with P and S fertilization.

At Beaverlodge, 23 trials were conducted on Gray Luvisolic stubble soils from 1965 to 1968 to examine the response of barley and oats to K. In most cases, fertilizer K was seed-placed as KCl or K<sub>2</sub>SO<sub>4</sub> at rates of 28 to 39 kg ha<sup>-1</sup>. The average yield of the 'NPS' treatment was 2680 kg ha<sup>-1</sup>, and that of the 'NPSK' treatment was 2740 kg ha<sup>-1</sup> (Halstead et al., 1970). A series of similar experiments were established between 1966 and 1968. The results of the 3-year study suggested that yield responses to K could be expected only on heavily fertilized Gray Luvisolic soils producing high crop yields (Halstead et al., 1970).

Tests with barley on fallow land in 1969 at 26 locations, in an area extending from northwest of Edmonton to Lloydminster, showed only two significant responses to K, one on a Dark Brown soil and the other on a Meadow soil (Halstead et al., 1970).

In general, results in Alberta show poor correlation between soil test K (NH<sub>4</sub>OAc extractable) and crop response to K fertilization. Most crop responses to K were obtained on soils which have low soil test levels of K. In most cases, crop response to K fertilization is generally so small that establishing good correlations to soil tests has been difficult. For example, on a series of field experiments carried out in Lacombe and Peace River, 10 of 13 field experiments showed a significant yield response to K fertilization, when the soil test K level was less than 340 kg ha<sup>-1</sup>. Two yield responses were also observed on Gray Luvisolic soils of the Peace River district with very high extractable soil K levels (924 and 709 kg ha<sup>-1</sup>) (Halstead et al., 1970).

Research involving potatoes on coarse-textured soils in the Peace River and Edmonton areas has shown only small to moderate responses to K. Two field trials in the Peace River region on an irrigated sandy loam soil showed that the application of 90 kg  $K_2O$  ha<sup>-1</sup> increased yields by over 20%. Trials in the Edmonton area conducted over two

years on soils ranging from sandy loam, loam, to silty clay loam textures, have all shown a yield response in at least one of the test years. Yield increases ranged from 2.2 to 6.7 t ha<sup>-1</sup> or 7 to 25% increase above control (Halstead et al., 1970).

In southern Alberta, more than 20 field tests were conducted between 1961 to 1967 to measure K response of vegetable crops on irrigated soils. The test crops included: potatoes, sugar beets, peas, and beans. Only one test (with field peas) showed a significant yield response to applied K (Halstead et al., 1970).

Grain and oilseed crops frequently benefit from seed-placed KCl, particularly in low K soils and when low rates of fertilizer are used (Table 1). Seed-placed and broadcast applications of KCl have shown good yield increases for Klondike barley at ten sites in northern Alberta (Table 2). Although the largest yield increase was noted for the broadcast application of KCl, banding smaller amounts near the seed produced greater economic yield benefits (Robertson, 1980).

Dubetz and Dudas (1981) measured the soil K levels of an irrigated southern Alberta soil which had provided high crop yields for 66 years without fertilizer K. By the end of this study, the NH<sub>4</sub>OAc extractable K level of the soil (0-15 cm) had decreased by approximately 28%. In spite of this decrease, the total K status of the soil remained relatively unaffected. Forty experiments established from 1982 to 1986 throughout the irrigated areas of southern Alberta, clearly revealed that K fertilization was not necessary for the production of wheat, barley, canola or flax. In addition, KCl had no effect in reducing lodging or increasing disease resistance. However, responses to K were not expected in the experiments because the majority of the soils had high K levels (McKenzie et al., 1987).

Manitoba: Soils and crop specialists in Manitoba have conducted extensive research involving the response of various crops to K fertilization. A partial account of the results of some of this research from 1963 to the present, for crops ranging from wheat to potatoes, is presented Table 3. Generally, the largest yield increases from K fertilization

Table 1. Comparison of potassium placement methods for barley in central Alberta (Walker, 1978).

K <sub>2</sub> O rate	Placement	Yield	increase
		1974 (6 trails)	1976 (13 trials)
(kg ha <sup>-1</sup> )		(kg	ha-1) ———
17	broadcast	453	
	banded	673	326
	seed-placed	989	563
34	broadcast	895	
	banded	989	421
	seed-placed	1105	642

Table 2. Average yield response of barley to banded and broadcast KCl fertilizer from ten research sites in northern Alberta (Robertson, 1980).

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K <sub>2</sub> O rate	Placement	Average yield	Yield increase	
(kg ha <sup>-1</sup> )		(kg ha <sup>-1</sup> )	(%)	
0		1194		
6	banded	1326	11	
12	11 11	1323	11	
24		1427	20	
121	broadcast	1532	28	

Table 3. A summary of the yield response of various crops to K-fertilization on several Manitoba soils since 1963.

Mean soil-K	Crop	K <sub>2</sub> O Rate	Control Y	ield Fertilized	Reference
(kg ha <sup>-1</sup> )		(kg ha-1)	—— (kg	ha <sup>-1</sup> ) ——	
600	Flax Oats Rapeseed Com (grain)	67	628 2427 1116 4344	471 2360 1104 4860	Soper and Racz, 1963
897	Rapeseed	67	855	1012	Soper, 1964
37	Barley	33 100 225	1854	2472 2526 2700	Soper, 1965
490	Barley	34	3026	3105	Hedlin and Soper, 1965
	Sunflowers Corn (silage)	101 101	1281 7980	1308 9891	Bonnefoy, 1965 Bonnefoy, 1965
317	Sugar beets	40	4087	4254	Rank, 1965
	Potatoes	33 67 101	20850	23200 25000 23150	Zirk, 1965
<del></del>	Wheat	17 34 67 135	1840	1320 1633 1737 1337	Bell, 1966
230	Barley	17 34 50 167 225	2410	2490 2260 2810 3190 3450	Bailey, 1967
	Flax	112	1080	1060	Racz, 1969 <sup>b</sup>
	Fall Rye	56 112	1946	2366 1939	Gorby, 1969
530	Corn (grain)	44 89	4145	4075 3976	Racz, 1969 <sup>a</sup>
595	Peas	17 34 100	888	984 864 982	Racz, 1970
237	Soybeans	34 67 135 270	775	237 1799 2311 2766	Bailey, 1977
942	Lentils	112	1003	1042	Hnatowich et al., 1982

Basal applications of N and P provided at each site.

occurred on coarse-textured soils with low soil test K values. The results of these studies were variable, but generally K fertilization was seldom effective in increasing crop production in Manitoba. (The reader is referred to the 1963-77 Manitoba Soil Science Society Proceedings for a more detailed account of these projects.)

Field experiments in Manitoba, conducted during the 1960s, revealed that the addition of K to soils with low available K resulted in increased barley yields. These trials also showed that broadcasting large amounts of K resulted in greater yield increases than placing small amounts of K with the seed (Table 4). However, the application of 17 to 34 kg K<sub>2</sub>O ha<sup>-1</sup> with the seed provided notable yield increases relative to the control (Halstead et al., 1970). These early experiments confirmed that soils with less than 200 kg ha<sup>-1</sup> of NH<sub>4</sub>OAc extractable K were deficient for cereal crop production in Manitoba.

Soper (1971) reported one of the first studies conducted in Manitoba to determine the relationship between yield response of rapeseed to K and extractable soil K levels. This study established that rapeseed was most likely to positively respond to K additions when it was grown on soils with NH4OAc-extractable K levels less than  $100 \mu g g^{-1}$ . Of the five trials with soil test levels  $\leq 100 \mu g g^{-1}$ , only two trials with very low soil K levels (25 and  $32 \mu g g^{-1}$ ) showed a significant yield response to K fertilization.

In 1968, an experiment was established to measure the response of barley, wheat, and oats to K fertilization on a soil with a very low level of available K. All three crops showed large responses to K addition (Table 5). Yield results for barley suggest that seed placement of K is superior to broadcast application, even at rates as high as 112 kg ha<sup>-1</sup>. Yield results also indicated that small amounts of K applied with the seed may result in large yield increases. Broadcast application of higher rates of K was also an effective treatment (Halstead et al., 1970).

Potatoes have shown good yield responses to K fertilization under field conditions. Yield increases were consistent when grown on coarse-textured soils with low levels of extractable K. Generally, soils with less than 450 kg ha<sup>-1</sup> of NH<sub>4</sub>OAc-extractable K ha<sup>-1</sup>

Table 4. Yield response of barley to potassium fertilizer on seven Manitoba soils (Halstead et al., 1970).

Soil	Extractable-K			Rate of K2	O	
texture	(NH4OAc)	0	17 <sup>†</sup>	34†	202 <sup>†</sup>	225 <sup>‡</sup>
			(kg ha	-1)		
SiCL	620	2947		2579		
SiC	616	2895		3211		
LFS	225	2579		2789		
VFSL	762	3684		3842		
LFS	63	2000	2842	2789	3053	3158
LS	70	1789	2105	2421	2105	2316
FSL	169	1737	2368	2211	2421	2632

<sup>†</sup> Seed-placed K, ‡ Broadcast K

Table 5. Effect of fertilizer K on the yields of barley, wheat, and oats on a K deficient Manitoba soil (Halstead et al., 1970).

Treatment		Crop yield	
K	Barley	Wheat	Oats
(kg ha <sup>-1</sup> )		(kg ha <sup>-1</sup> )	
0	126	333	858
17†	2305	2247	2015
34 <sup>†</sup>	2995	2713	2888
67 <sup>††</sup>	3047		
112 <sup>††</sup>	3116	2960	3242

<sup>†</sup> Seed-placed K, †† Broadcast K

are regarded as K deficient for potato production (Halstead et al., 1970). Menzies (1966) showed that K applied as KCl or K<sub>2</sub>SO<sub>4</sub> had no effect on potato yield at three Manitoba locations. However, when yield data from each location and the K source were analyzed together, the highest rate (225 kg ha<sup>-1</sup>) produced significantly higher yields than the control. Similar results were reported by Zirk (1965) for KCl, K<sub>2</sub>SO<sub>4</sub>, and KNO<sub>3</sub> fertilization of potatoes.

Some research has addressed the response of grain corn to K fertilization. Yield increases of 500 to 750 kg ha<sup>-1</sup> have been obtained as a result of K applications of 67 to 89 kg K<sub>2</sub>O ha<sup>-1</sup> (Halstead et al., 1970).

Saskatchewan: In Saskatchewan, researchers have studied K fertilization in field experiments throughout the province since 1949. In some of the earliest experiments which were continued for 22 years at the Indian Head Experimental Farm, 22 kg ha<sup>-1</sup> of KCl was applied with 45 kg ha<sup>-1</sup> of 11-48-0 to spring wheat annually. No yield response to K was obtained. Similar negative results were obtained at off-station test sites near Alameda, Arcola, Fleming, Strasbourg, Wawota, and Yorkton (Halstead, 1969). During the same period, similar experiments were conducted in northeastern Saskatchewan on 121 soils (Black, Grey Black and Grey Luvisols) by the Melfort Research station. These trials, carried out over a 5 year period showed that with the exception of two Dark Grey soils, all others (including a coarse-textured Grey Luvisol) appeared to be well supplied with soil K (Halstead, 1969).

Similarly, in northwestern Saskatchewan, experiments conducted by the Agriculture Canada experimental farm at Scott from 1949 to 1955 on Loon River, Dorintosh, Waitville, Glenbush, and Bodmin soils, resulted in little if any yield benefit from the inclusion of potash at 22 kg K<sub>2</sub>O ha<sup>-1</sup> (Halstead, 1969).

From 1960 to 1963, the Department of Soil Science, University of Saskatchewan, carried out 165 field experiments investigating K response. The majority of the tests included 0-0-60 blended with 11-48-0 (6-26-26) applied to supply 22 kg K<sub>2</sub>O ha<sup>-1</sup>. The

field sites were carefully selected to include K deficient soils, (i.e., either light-textured Gray-Black or Gray Luvisolic soils, or soils which contained free lime to the surface) (Rennie and McKercher, 1965). On Black Chernozems, 6-26-26 did not perform as well as 11-48-0 when applied at the same rate of  $P_2O_5$  (Table 6). This result was surprising because, before these experiments, it was generally accepted that K deficiencies were likely to occur on soils containing free lime carbonate (such as the Yorkton and Canora soils). Similar results were obtained (although many differences were not significant) for light textured Gray-Black soils not withstanding their relatively low exchangeable K status (Rennie and McKercher, 1965). In contrast, substantial yield increases were obtained on the Carrot River and Weirdale soils with soil test levels  $\leq 500 \text{ kg ha}^{-1}$  (Table 7). Both the Weirdale and Carrot River soils contained a proportion of shallow peaty areas which were very responsive to K fertilization. However, on average, no yield response was obtained from K addition in the peat soils.

Evidence of possible adverse effects of seed-placed KCl was illustrated in results from the 1967 trials (Table 8). Barley responded well to K additions on soils with low soil test levels of K. On the average, seed-placed 11-48-0 plus broadcast 0-0-60 was superior to the blended fertilizer (10-30-10) placed with the seed. The yield responses to K fertilized barley were similar at both stubble and fallow sites. In similar barley experiments, carried out on Whitefox, Carrot River, and Shellbrook soils, average yield increases of 380 and 1040 kg ha<sup>-1</sup>, respectively, for 11-48-0 and 11-48-0 + 67 kg ha<sup>-1</sup> K<sub>2</sub>O broadcast were obtained (Rennie et al., 1967).

Yield results from the 1968 experiments (Table 9) showed excellent responses to broadcast K on selected K deficient soils. Barley showed better yield response to K fertilization than wheat. The best response was observed for barley on a Carrot River soil (extractable K level of 75 kg ha<sup>-1</sup>) (Henry, 1968). For barley, in some cases yield increases were recorded for each additional increment of potash added, while in others the initial rate of K produced sharp increases but higher additions of K resulted in yield decline.

Table 6. Wheat response to 11-48-0 and 6-26-26 applied at 22 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> on Black Chernozemic soils (Rennie and McKercher, 1965).

Year	Soil	Number of plots	Check yield	Yield 11-48-0	increase 6-26-26	L.S.D.	ext-K <sup>†</sup>
•					—(kg ha <sup>-1</sup> )—		
1960	Canora	75	1940	360	347	NS	905
1961	Canora	30	1633	473	507	NS	753
1962	Canora	40	2327	487	247	213	933
1962	Yorkton	20	1667	287	100	147	674
Mean			1893	400	300	NS	816

<sup>† 1</sup> M NH<sub>4</sub>OAc extractable soil-K

Table 7. Yield response of wheat to 11-48-0 and 6-26-26 applied at 22 kg P<sub>2</sub>O<sub>5</sub> per ha<sup>-1</sup> on selected Gray Wooded soils (Rennie and McKercher, 1965).

Year	Soil	Number of plots	Check yield	Yield: 11-48-0	increase 6-26-26	L.S.D.	ext-K <sup>†</sup>
					—(kg ha <sup>-1</sup> )—		
1960	Peat	15	1380	-13	-40	NS	573
1961	Weirdale	20	1187	293	287	NS	1158
1962	Weirdale	20	2633	307	673	213	506
1961	Carrot River	10	733	167	347	107	257
1962	Carrot River	20	1107	573	1107	273	
Mean			1407	267	473	93	

<sup>† 1</sup> M NH4OAc extractable soil K

Table 8. Yield response of barley to seed-placed and broadcast applications of K-1967 data (Rennie et al., 1967).

Soil	Check	,	Yield Increas	set	Ext-K <sup>‡</sup>	Rotation
	Yield	11-48-0¥	10-30-10¥	11-48-0 + 0-0-60 <sup>¥¥</sup>		
			—(kg ha <sup>-1</sup> )—			
Glenbush	1490	-42	758	532	54	Fallow
Carrot River	2540	1190	1320	1160	89	Fallow
Carrot River	2230	684	442	842	84	Fallow
Carrot River	1520	805	368	1160	51	Stubble
Carrot River	1330	195	279	347	64	Stubble
Carrot River	1520	-95	589	542	40	Fallow
Mean	1770	458	626	763	64	

<sup>†</sup> N and P<sub>2</sub>O<sub>5</sub> applied according to soil test recommendations

Table 9. Yield responses of barley, wheat, and rapeseed to potash fertilization on low NaHCO<sub>3</sub> soil-K levels—1968 data (Henry, 1968).

Soil	Crop		Mean cr	op yield <sup>‡</sup>		Soil K
	. <del>-</del>	Control	112	225	450	level <sup>†</sup>
				—(kg ha <sup>-1</sup> )—		
Carrot River	Barley	574	1995	2553	3037	75
Carrot River	Barley	1268	2047	2668	2731	69
Carrot River	Barley	2353	3332	3064	3832	100
Carrot River	Barley	2074	2221	2569	3116	162
Whitefox	Barley	2363	3289	2642	2631	193
Carrot River	Wheat	360	993	1213	1360	80
Carrot River	Wheat	2387	2894	2887	2547	117
Weirdale	Wheat	3033	3033	2966	3173	268
Carrot River	Rapeseed	1456	1473	1617	1950	114

<sup>†</sup> N and P<sub>2</sub>O<sub>5</sub> applied according to soil test recommendations † 0.5 M NaHCO<sub>3</sub> extractable soil K

<sup>‡ 1</sup> M NH4OAc extractable soil K

<sup>¥</sup> Seed-placed

<sup>¥¥</sup> Broadcast

Field experiments were expanded in 1970 to determine barley and rapeseed response to K fertilization on soils testing in the medium and high ranges of available K (Schappert, 1970). Barley responded well to K applications for each of the three trials buthigh rates of K reduced the yield increases in some instances (Table 10). At the Shellbrook site, the last increment of K resulted in the largest yield increase, indicating that the maximum yield of barley may not have been reached with 270 kg K<sub>2</sub>O ha<sup>-1</sup>. Rapeseed showed only slight yield responses to K, even though the soils were deficient in available soil K (Tables 9 and 10).

High rates of broadcast K may lead to residual responses of yield in future crops. An exploratory experiment was established in 1968 on a Carrot River soil which received K fertilization at: 0, 112, 225, and 450 kg of 0-0-60 ha<sup>-1</sup>; spring wheat was the test crop. In the autumn of 1969, fall rye was established on this site with no K fertilization so as to measure possible residual effects of K applied the previous year. During the summer of 1970, the rye showed a visual response to residual K. A yield increase of 567 kg ha<sup>-1</sup> (8.5 bu ac<sup>-1</sup>) was obtained on a strip which previously received 450 kg 0-0-60 ha<sup>-1</sup> (Schappert, 1970).

In 1971, experiments were established on two low K soils in the Carrot River area to determine the relative efficiency of various placements of K fertilizers; Conquest barley and Echo rapeseed were the test crops (Henry and Schappert, 1971). Rapeseed showed as no serious reduction in plant population at seed-placed K<sub>2</sub>O rates below 67 kg ha<sup>-1</sup>, while barley showed no reduction in plant population at any K rate (Table 11). Yield increases were obtained for all rates of K applied with the seed at the South Carrot River site. The reduction in plant density noted at high rates of seed-placed K did not reduce canola yield. Side-banding was almost as effective as seed-placed K; broadcast application was only effective at the highest rate (data not shown) (Henry and Schappert, 1971). Rapeseed oil and protein concentrations were unaffected by the treatments. Two major conclusions were drawn from this study: i) barley is more sensitive to K deficiency than wheat or rapeseed,

Table 10. Yield response (yield increase relative to check) of barley and rapeseed to K fertilization on soils with medium and low NaHCO3 extractable soil K levels— 1970 data (Schappert, 1970).

Soil	Crop	Control			K <sub>2</sub> O		Soil K
	•	yield <sup>‡</sup>	34	67	135	270	level <sup>†</sup>
				(kg	ha-1)		
Carrot River	Barley	1553	95	316	216	189	283
Sylvania	Barley	2395	226	642	379	279	350
Shellbrook	Barley	1716	105	163	426	611	153
Carrot River	Rapeseed	1256	-83	6	44	100	81

<sup>‡</sup> N and P<sub>2</sub>O<sub>5</sub> applied according to soil test recommendations † 0.5 M NaHCO<sub>3</sub> extractable soil K (0-15 cm)

Table 11. The effect of seed-placed potash on the germination of Echo rapeseed and Conquest barley on two Carrot River soils (Henry and Schappert, 1971).

Soil	Crop	——K <sub>2</sub> O applied with the seed (kg ha <sup>-1</sup> )———						
		0	17	34	67	135		
			——Plant co	ount <sup>†</sup> per 2.4	4 meter row			
South-Cr	Rapeseed	63	69	58	58	30	-	
·	Barley	85	104	106	106	109		
North-Cr	Rapeseed	100	74	95	73	64		
	Barley	71	99	85	89	79		

<sup>†</sup> Plant counts taken 22 days after seeding

and ii) placing K fertilizer with the seed or in a side-band is more effective than broadcast applications (McGill, 1972; Hamm and Henry, 1973).

As cropland is managed more intensively through irrigation and application of heavier rates of N, P, and S rates of K depletion will accelerate and the likelihood of a crop response to K will increase accordingly (Beaton and Sekhon, 1985).

Notwithstanding the very infrequent responses to fertilizer K, except on very K deficient soil (i.e., soils containing less than 50 kg K ha<sup>-1</sup>), extensive field research programs were continued in Saskatchewan throughout the 1980s. Some of these trials involved widely spread experiments to examine the response of various crops to increasing rates of K fertilization (Table 12). Once again, yield increases were rare and appeared to occur at random; apparent yield decreases were almost as common as yield increases and were not readily related to available soil K. These results suggest that the chances of obtaining profitable yield increases are quite low.

Research carried out comparing KCl to K<sub>2</sub>SO<sub>4</sub> on a limited number of presumably K deficient soils during 1982 and 1983 showed that, for wheat, barley, and canola, there was no yield advantage when the sulphate source was applied as compared to the Cl (Table 13). When lentil was the test crop at a site near Saskatoon, the response appeared to be largely due to the added S as there was no change in yield where KCl was applied. A further series of 23 seed-placed KCl experiments in the 1980s (Henry, 1984, 1985, 1986) using barley, wheat, and canola as the test crops confirmed that yield responses to K applications at 20 kg K<sub>2</sub>O ha<sup>-1</sup> were negative or zero. Similar results were obtained in the Innovative Acres (1985) project at the University of Saskatchewan which involved the establishment of 32 strip trials measuring the response of various crops to seed-placed KCl at 25 kg K<sub>2</sub>O ha<sup>-1</sup> on various soils (Table 14). Although the results were variable, they clearly reconfirmed the random and occasional response obtained in earlier tests.

Table 12. Crop yield response to broadcast KCl fertilization on various soils of Saskatchewan in the 1980s (Henry, 1981, 1982, 1983, 1984).

Soil	Crop	Rate of K fertilization (kg K2O ha-1)						Soil K <sup>†</sup>
Assn	•	0	25	50	100	200	400	(0-15 cm)
	(kg ha <sup>-1</sup> )							
1980 Weirdale B	arley	4346	4683	4461	4722	4800	5056	255
	arley	4116	3676	3427	3702	3863	3381	299
	arley	2077	2099	2073	2087	2123	2138	788
	/heat	3354	2836	3399	3095	3103	3144	795
	/heat	3777	3781	3981	4102	3939	3968	153
	/heat	1959	1876	1889	1779	2022	1995	683
1981						2052	2500	1.47
•	arley	2463	2431	2441	2448	2352	2508	147
	arley	4311	4415	4350	4490	4484	4222	247
	arley	5275	5569	5516	5296	5386	5527	227
Waitville W	/heat	3102	3034	3105	3642	3528	3564	500
1982 Weirdale Ba	arley	3012	2317	3308	3279	3730	3213	168
	arley	2564	2353	2514	2699	2424	2647	
	arley	1324	1426	1493	1494	1255	1409	72
•	ats (forage)	3668	3638	3523	4146	3979	4220	190
	/heat	1670	1471	1356	1580	1549	1295	185
Carrot River Ba	arley	1557	_	2585	2520	3073	_	71
Sylvania Ba	arley	2165	, <u> </u>	2307	2474	2526	· <u> </u>	135
Carrot River Ba	arley	1618	_	1682	1426	1678	_	128
Carrot River Ba	arley	1457	_	1575	1631	1449	- -	169
Carrot River W	/heat	1140	_	1265	1499	1673	-	137
Carrot River Ca	anola	853		945	843	1008	-	122
1983		2700	2042	2660	2442	2405	2561	225
_	ats	2788	3042	2660	2443	3405	2561	225
Shellbrook Ba	arley	2809	3019	3104	3125	3064	3443	110

<sup>†</sup> NaHCO<sub>3</sub> extractable soil K fraction, ¥ KCl applied the previous year (1981), § Peat soil near Shellbrook

Table 13. Yield response of crops to K applied as KCl and K<sub>2</sub>SO<sub>4</sub> at equal rates of K on four Saskatchewan soils over two years (Henry, 1983, 1984).

Soil	Crop	Rate of K fertilization (kg K2O ha-1)						Soil K <sup>†</sup>	
Assn	-	0	25	50	100	200	400	(0-15 cm)	
		(kg ha <sup>-1</sup> )							
1982									
Nipawin	Wheat 'with S' 'no S'	2972 2945	2820 2934	3065 3044	2904 3011	3084 3096	2926 3010	370	
Waitville	Barley 'with S' 'no S'	2692 2890	2745 2830	2630 3086	3156 2904	2832 2979	2999 3174	278	
Bradwell	Lentils 'with S' 'no S'	2126 2154	2289 2003	2126 2274	1975 2192	2365 1652	2340 2202	302	
1983 Sylvania	Canola 'with S' 'no S'	1494 1661	1369 1426	1369 1447	1529 1373	1535 1666	1377 1633	375	

S applied at rates of: 4.3, 8.5, 17, 34, and 68 kg ha<sup>-1</sup> for 25, 50, 100, 200, and 400 kg K<sub>2</sub>O ha<sup>-1</sup> rates

Table 14. Summary table of the response of barley, wheat, canola, and peas to seedplaced KCl at 25 kg K<sub>2</sub>O ha<sup>-1</sup> on various soils (Innovative Acres, 1985).

No. of	Crop	Average	Averag	Yield	
trials		ext. soil-K <sup>†</sup>	Control	Fertilized	increase
			— (kg ha <sup>-1</sup> ) —		<u> </u>
8	Barley	326	3224	3337	3.5
16	Spring Wheat	353	1932	2126	10.0
1	Durum Wheat	535	1520	1413	-7.0
4	Winter Wheat	405	1967	2384	21.2
2	Canola	433	1720	1687	-1.9
1	Peas	490	2231	2606	16.8

# Grain Quality

Besides yield responses, improved grain quality may result from K additions. Although increased grain weight and quality are commonly credited to K fertilization, research results have been inconsistent. Vasey and Soper (1966) reported that K increased both the yield and kernel plumpness of malting barley in soils high in available K.

## Disease Control

When evidence of disease suppression has been obtained in experiments involving KCl, scientists have attributed this to the Cl<sup>-</sup> ion. Other materials containing Cl have also been shown to decrease the incidence of plant disease, i.e., Beaton (1980a) reports that additions of NH<sub>4</sub>Cl (and KCl) lowered infection by net blotch (*Pyreophora teres* Drechs.) in barley in Alberta. Further, Stewart and Karamanos (1986) reported that KCl was more effective in reducing disease incidence than additions of K<sub>2</sub>SO<sub>4</sub>.

Plant pathologists have established that potash often suppresses various plant diseases including rusts, powdery mildew, bunt, stalk smuts, net blotch, take-all, common root rot, and yellow dwarf virus. The Cl component of KCl and other materials supplying Cl ions has been shown to inhibit take-all, stripe rust, glume blotch, halo spot, net blotch, and common root rot. Excellent general reviews of the interaction between K and plant diseases are provided by Beaton and Sekhon (1985), Huber and Arny (1985) and Wang (1987). Articles are also available addressing Cl fertilization as a means of suppressing plant disease on prairie soils (Fixen et al., 1986; Fixen, 1987; Goos, 1987; Goos et al., 1987ab, 1989; Mohr and Flaten, 1990).

To adequately assess the effect of K addition on plant disease, each interaction between the host, pathogen, and environment must be considered. In many studies nutrient status often obscures the results reported for K fertility and disease. For example, there is very little quantitative information available on the concentration of K<sup>+</sup> in soil or in the plant tissues that result in the observed effect on disease expression.

In North Dakota malting barley research has shown evidence of yield and quality responses to small additions of KCl fertilizer on soils with ample supplies of exchangeable K. Five field experiments on soils with exchangeable K levels over 800 kg ha<sup>-1</sup> were established by Timm et al. (1986) to determine if a Cl-induced repression of common root rot (induced by *Cochliobulus sativus*) could explain a previously noted response to KCl. Fertilization with KCl significantly decreased root rot incidence by the boot stage at two of the five sites and significantly decreased disease severity by the dough stage at three of the five sites. Fertilization with K<sub>2</sub>SO<sub>4</sub> significantly increased disease severity at two sites, otherwise there was no effect on disease incidence, severity, or grain yield.

In Alberta, Piening (1982) found that seed-placed additions of 28 kg K<sub>2</sub>O ha<sup>-1</sup> (as KCl) suppressed common root rot infection in five barley varieties grown on a soil very low in available K. Root rot decreased from 91% without K to 40% with K supplied as KCl.

Thirty-six field strip trials were conducted on a variety of Saskatchewan soils in 1985 to evaluate the effect of K and Cl on root rot infection. Overall, KCl had little effect on the mean K levels of plant tissues, but did increase the Cl plant tissue concentrations in most of the trials (Wand, 1987) (Table 15). A reduction of root rot disease was noted for KCl-fertilized spring wheat; however, increased disease ratings for winter wheat and barley were noted at most sites.

A more detailed study was conducted in 1986 on six sites in Saskatchewan. The results showed no significant differences in root rot disease, K, and Cl concentration in tissue, or yield. None of the soils was deficient in K or Cl (Innovative Acres, 1986; Wang, 1987).

More recently, a series of strip trials measuring crop response to KCl fertilization in eastern Saskatchewan was conducted by Central Canada Potash Inc. Although the results of these trials were variable, they showed a slight crop response to KCl fertilization, particularly in terms of disease resistance (Doyle et al., 1992).

Table 15. Effect of Cl on plant tissue analysis, root rot disease rating, root infection and grain yield of various cereal crops (Innovative Acres, 1985; Wang, 1987).

	Tissue		Root rot	Root i	Grain				
Rate	K+	Cl-	resistance	H. sativum	Fusarium spp.	yield			
(kg K <sub>2</sub> O ha <sup>-1</sup> )			(%)-			(kg ha <sup>-1</sup> )			
Spring Wheat (18 trials)									
Check	2.08	0.49	16.9	53.6	33.9	2052			
24 <sup>†</sup>	2.09	0.62	14.5	48.4	36.9	2244			
Winter Wheat (6 trials)									
Check	2.13	0.48	5.0	43.1	58.4	2103			
175 <sup>††</sup>	2.07	0.95	6.2	47.2	49.0	2445			
Durum Wheat (3 trials)									
Check	1.97	0.62	14.5	46.0	48.2	1125			
24 †	2.03	0.69	7.2	40.2	50.6	1107			
Barley (9 trials)									
Check	2.44	0.60	15.5	44.9	40.5	3449			
24 <sup>†</sup>	2.50	0.85	16.9	46.5	43.6	3577			

<sup>†</sup> Seed-placed †† Broadcast applications

## CONCLUSIONS

Over the last 30 years, considerable research on K has been conducted on prairie soils. At present, K is the fourth most frequently encountered nutrient limiting crop production on the prairies. Soil testing benchmarks and the NaHCO<sub>3</sub> extraction procedure provide an adequate basis for predicting a yield response of most crops to K fertilization. The majority of prairie soils are well supplied with plant available soil K and rarely respond to fertilizer K. In addition, K deficiencies will continue to be rare as long as the yields of small grains are low. However, as cropland becomes managed more intensively and crop yields escalate, the likelihood of K deficiencies on prairie soils is a possibility.

The impact of K and Cl ions on disease suppression has been extensively researched and the results have been inconsistent.

In view of the large amounts of research already conducted, any future work involving K fertility should be limited to studies involving grain quality and disease suppression rather than to grain production. It is well established that cereals are more likely to respond to K addition than are oilseeds. In fact, recommendations for additions of fertilizer K are generally low for canola, even when grown on soils with very low extractable K levels.

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