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Potassium Fertilizer Application in Crop Production

Potassium (K) is required by all plant and animal life. While potassium is not a commonly limiting soil nutrient in crop production in Alberta, about 15 per cent of Alberta soils used for annual crop production are estimated to have slight to moderate potassium deficiency.

Adequate potassium results in superior quality of the whole plant due to the improved efficiency of photosynthesis, increased resistance to some diseases and greater water use efficiency. Potassium helps maintain a normal balance between carbohydrates and proteins.

Sufficient potassium results in stronger straw of cereal crops and assists in seed filling. Potassium deficiency in cereal crops results in reduced growth, delayed maturity, lodging caused by weaker straw and lower bushel weight.

Potassium deficiencies are most common on well drained, coarse-textured soils. These deficiencies can be corrected with potassium (potash) fertilizer (K_20).

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Soil potassium

The majority of soils in Alberta contain sufficient plant-available potassium to satisfy crop growth. The total amount of potassium in soil often exceeds 40,000 kg/ha (36,000 lb/ac) in the top 15 cm (6 in) of soil. However, only 1 to 2 per cent of the total K in soil is in a form available to plants.

The parent geologic material on which Alberta soils developed generally contains considerable potassium-bearing clay minerals. Potassium becomes available to crops through weathering of these soil minerals.

There are three forms or pools of potassium in soil:

1. **Unavailable K:** About 90 to 95 per cent of the total soil potassium is contained in clay minerals. This pool of soil K is locked within the structure of the layered clay sheets and is not available to plants.
2. **Slowly available K:** About 5 to 10 per cent of the total soil potassium is slowly becoming available to plants. Weathering of the clay minerals occurs on the surface of the minerals and results in a very slow release of K from the unavailable K pool locked within the clay minerals. The weathering of clay minerals gradually releases K from the minerals to recharge the K removed from the available soil K pool.
3. **Available and exchangeable K:** The K in soil available to plants is dissolved in soil water while exchangeable K is loosely held on the exchange sites on the surface of clay particles. Typically, this K pool or fraction represents about 1 to 2 per cent of the total soil K. A portion of this pool is plant-available K dissolved in the soil water. The exchangeable K, which is positively charged (K+), is loosely held on the negatively charged exchange sites on the surface of clay minerals and is referred to as exchangeable K. As the available K dissolved in the soil water is taken up by plant roots, exchangeable K is released into the soil solution to maintain an equilibrium between the two forms. Soil tests attempt to measure the available and exchangeable K in soil to determine the K-supplying power for the soil K for crop production. Available and exchangeable levels of K generally range between 300 and 1,000 kg/ha (270 - 900 lb/ac) in Alberta soils in the top 15 cm (6 in) of soil. A very small percentage of Alberta soils have as little as 100 kg/ha (90 lb/ac) of available potassium. A minimum of 200 kg K/ha (180 lb/ac) in the top 15 cm (6 in.) of soil is generally required for adequate growth of most crops grown in Alberta.

Potassium only occurs in soils in inorganic form and does not make up part of the soil organic matter. Potassium in soil solution and in exchangeable form occurs as a positively charged ion, K+.

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Soil colloids and the surface of soil clay minerals are negatively charged. Therefore, K will tend to be adsorbed onto the surface of negatively charged soil particles. As a result, soil K tends to be fairly immobile in soil and is not subject to leaching or downward movement in soil.

Soils that have the greatest potential for potassium deficiencies are the coarse (sandy) and medium (loam) textured soils in the Black, Gray-Black and Gray soil zones as well as the organic soils in Alberta. Irrigated coarse textured soils that have intensive crop rotations that include potatoes, sugar beets and/or alfalfa in the rotation may require potassium. A soil test is often very useful to determine whether potassium fertilizer application is warranted.

It is important to note that plants take up potassium in ionic form as K^+. Potassium fertilizer is sold as K_20. The most commonly sold K fertilizer in Alberta is potassium chloride (KCl) (0-0-60), which contains 60 per cent K_20.

To convert from lb of K_20 to lb of K, divide by 1.6. Soil tests normally report available and exchangeable potassium as K and provide potassium fertilizer recommendations in lb of K_20.

Potassium deficiency

Potassium deficiency symptoms on cereal grains appear as a burning or scorching of the older, lower leaves. The burning begins at the leaf tip and continues down the leaf margin. Lower leaves are affected first because potassium in these older leaves is translocated to the new upper leaves to meet growth requirements.

In alfalfa, potassium deficiency appears as white or yellow spots on the lower leaves. Many other factors can affect the appearance of lower leaves, so a diagnosis based on visual deficiency symptoms must be confirmed with soil tests.

Potassium deficiency in Alberta is less common than nitrogen, phosphorus or sulphur deficiency for several reasons. First, the parent geologic material on which the soils developed generally contains considerable potassium-bearing clay minerals. Second, Alberta soils are young and have undergone minimal weathering and leaching. Third, crop removal has been relatively minor where cereal, oilseed and pulse crops have been the dominant crops, especially where straw was left on the field or manure returned. About 80 per cent of the potassium taken up by crops remains in the straw and is returned to the soil.

There are an estimated **3 million acres of potassium-deficient soils in Alberta** (see Figure 1). Of this total, about 2.5 million are moderately deficient and **0.5 million very deficient**. Potassium-deficient soils tend to be sandy (light to medium textured), alkaline, carbonated and/or imperfectly to poorly drained in their natural state. Organic soils are also frequently deficient in potassium.

Forage crops, silage crops, potatoes and sugar beets have a high K requirement and take up and remove relatively large amounts of K from soils. When these crops are included in an intensive crop rotation on sandy soils, there is an increased risk of potassium deficiency.

Potassium is a relatively inexpensive nutrient, and deficiencies can often be corrected with moderate rates of application. Correcting a potassium deficiency can result in excellent economic returns. Potassium chloride (KCl) (0-0-60), also called **muriate of potash**, is the most commonly used potassium fertilizer, which contains 60 per cent K_20.

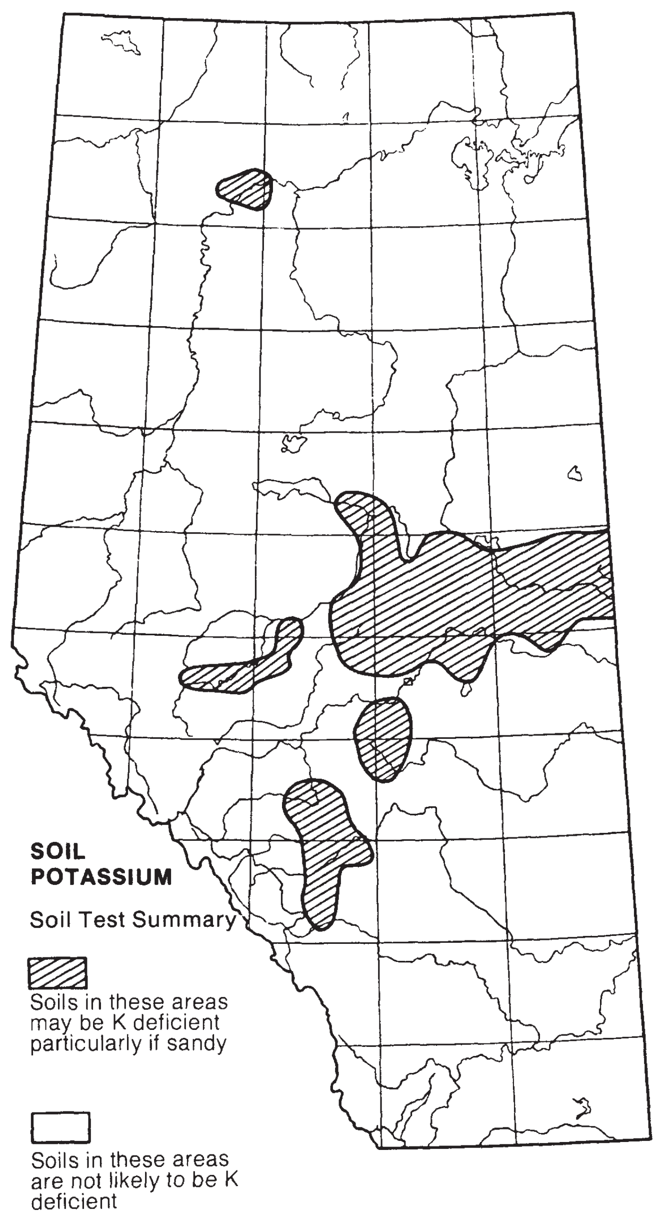

Figure 1. Soil areas of Alberta more prone to having potassium-deficient soils.

Table 1. Approximate nutrient uptake of crops for specific yields									
	Yield			N		P_2O_5		K_2O	
		grain	straw	grain	straw	grain	straw	grain	straw
	(bu/ac)	(kg/ha)		(lb/ac)					
Wheat	40	2,400	3,600	60	25	25	6	15	70
Barley	80	3,400	3,500	70	30	35	10	25	90
Canola	35	2,000	3,000	65	40	35	15	20	70
Flax	25	1,500	2,300	50	20	20	6	15	45
				Tubers					
Potatoes	50,000 (20 t/ac)			140		65		300	
				Hay					
Alfalfa	11,000 (5 t/ac)			280		65		300	
Grass	7,000 (3 t/ac)			100		30		130	

Crop potassium requirements

The K content of the above ground portion of commonly grown crops is shown in Table 1. Note the distribution of potassium between grain and straw as compared to nitrogen and phosphorus. Potassium removal from the soil is relatively low when only the grain of cereals is removed from the field. Potassium removal is much higher when forage, silage crops or potatoes are grown. If the forage is fed to livestock on the farm, the manure can be used to return much of the potassium removed by the forage crops.

While an awareness of the amount of K removed by various crops is useful, it is not in itself a basis for determining fertilizer requirements. The majority of soils in the prairie region contain high levels of plant-available K and can supply adequate amounts, even for high-use crops, for many years. On soils marginal to deficient in potassium, high-use crops will require higher rates of potassium fertilizer to maintain adequate nutrition.

Determining potassium fertilization need

The easiest way to determine the need for potassium fertilization is through a soil test. In Alberta, response to potassium fertilizer has been related to the amount of potassium extracted from the soil with ammonium acetate.

The most common soil test method used in Alberta to extract K from the soil is the modified Kelowna method. Results of potassium fertilizer research with barley in central Alberta are shown in Table 2.

In studies, large increases in barley yield were usually obtained when potassium fertilizer was applied to soils with less than 151 lb/ac of extractable potassium. Sites with a soil test K level of less than 150 lb/ac all responded to added K fertilizer. On soils with 200 to 250 lb/ac of extractable potassium, moderate fertilization of 15 to 30 lb/ac of K_2O may result in a profitable response.

The probability of response above a soil test level of 250 lb/ac was low (Table 2). However, at soil test K levels between 250 and 300 lb/ac, producers should consider a maintenance application of 15 to 20 lb K_2O/ac to help replace K taken up by crops. This application could also potentially improve crop yield in areas of a field that may have slightly deficient soil K levels.

Table 2. Yield response of barley to potassium fertilizer at different soil extractable K levels

Soil extractable-K (lb/ac in the 0-6 in. depth)	No. of sites	No. of responsive sites (per cent)
< 101	17	75
101 - 150	21	66
151 - 200	18	24
201 - 250	8	18
> 250	34	3

(Agriculture and Agri-Food Canada, Lacombe Research Station, and Alberta Agriculture and Rural Development data.)

A response to potassium fertilization is sometimes obtained on soils not considered deficient in potassium. Research, principally in Oregon, Washington and South Dakota, has shown that the presence of chloride in potassium chloride fertilizer can result in increased yield through the suppression of plant diseases such as take-all and common root rot in wheat and barley. Such responses have not been observed in Alberta research with wheat and barley; therefore, the use of potassium chloride on non-potassium- deficient soil for the suppression of disease must be on a trial basis.

Research in Montana has indicated that potassium deficiency may occasionally occur on soil with high soil test potassium because of slow potassium diffusion in cold, dense soils. These results have been used to promote the need for potassium fertilization for early seeding of cereal crops in central and northern Alberta.

Research in Alberta on potassium-deficient soils has shown equal response of barley to potassium with early and later seeding. If soil potassium was less available at lower soil temperatures, greater response to potassium should have been obtained with early versus later seeding. The results do not support a higher potassium requirement for early seeded cereal crops.

Choosing application rates

The soil test benchmarks and recommendations for various crops in Alberta are shown in the following tables:

- Table 3 for cereal crops
- Table 4 for oilseed crops
- Table 5 for pulse crops
- Table 6 for alfalfa
- Table 7 for grass
- Table 8 for root crops

The rates of application are based on the soil test level and the responsiveness of the crop. On soils marginal to deficient in potassium, crop removal (Table 1) should also be taken into account when planning an on-going potassium fertilization program.

Table 3. Soil test potassium and corresponding recommended rate of potassium application for cereal crops for the various soil zones in Alberta

Soil test K (lb/ac in 0-6 in. depth)		Brown soil	Dark Brown soil	Thin Black soil	Black soil	Dark Gray and Gray soil	Irrigated soils
		(lb K_2O/ac)					
0 - 50	Very deficient	80-100	90-110	90-110	95-115	95-115	100-120
50 - 100		60-80	65-90	65-90	70-95	70-95	80-100
100 - 150		40-60	45-65	45-65	50-70	50-70	60-80
150 - 200	Moderately deficient	20-40	25-45	25-45	30-50	30-50	40-60
200 - 250		15-20	15-25	15-25	15-30	15-30	20-40
250 - 300	marginal	0-15	0-15	0-15	0-15	0-15	0-15
>300	adequate	0	0	0	0	0	0

* Rates above 30 lb K_2O/ac for cereals crops should be banded or broadcast to avoid seedling injury. At low rates of application, placement with the seed is more effective than banding, and banding is more effective than broadcast (see Methods of Application section).

Table 4. Soil test potassium and corresponding recommended rate of potassium application for oilseed crops including canola, mustard and flax for the various soil zones in Alberta

Soil test K (lb/ac in 0-6 in. depth)		Brown soil	Dark Brown soil	Thin Black soil	Black soil	Dark Gray and Gray soil	Irrigated soils
		(lb K_2O/ac)					
0 - 50	Very deficient	85-105	90-110	90-110	95-115	95-115	100-120
50 - 100		60-85	65-90	65-90	70-95	70-95	80-100
100 - 150		40-60	45-65	45-65	50-70	50-70	60-80
150 - 200	Moderately deficient	20-40	25-45	25-45	30-50	30-50	40-60
200 - 250		15-20	15-25	15-25	15-30	15-30	20-40
250 - 300	Marginal	0-15	0-15	0-15	0-15	0-15	0-15
>300	Adequate	0	0	0	0	0	0

* Rates above 15 lb K_2O/ac for small seeded crops should be banded or broadcast to avoid seedling injury. At low rates of application, placement with the seed is more effective than banding, and banding is more effective than broadcast (see Methods of Application section).

Table 5. Soil test potassium and corresponding recommended rate of potassium application for pulse crops including pea and lentil for the various soil zones in Alberta

Soil test K (lb/ac in 0-6 in. depth)		Brown soil	Dark Brown soil	Thin Black soil	Black soil	Dark Gray and Gray soil	Irrigated soils
		($lb\ K_2O/ac$)					
0 - 50	Very deficient	120-145	125-150	125-150	130-155	130-155	135-160
50 - 100		95-120	100-125	100-125	105-130	105-130	115-135
100 - 150		75-95	80-100	80-100	95-105	95-105	90-115
150 - 200	Moderately deficient	50-75	55-90	55-90	70-95	70-95	65-90
200 - 250		25-50	30-55	30-55	50-70	50-70	45-65
250 - 300	Marginal	15-25	15-30	15-30	15-35	15-35	15-45
>300	Adequate	0	0	0	0	0	0

* Rates above 20-25 lb K_2O/ac for pulse crops should be banded or broadcast to avoid seedling injury. At low rates of application, placement with the seed is more effective than banding, and banding is more effective than broadcast (see Methods of Application section).

Table 6. Soil test potassium and corresponding recommended rate of potassium application for alfalfa for the various soil zones in Alberta

Soil test K (lb/ac in 0-6 in. depth)		Brown soil	Dark Brown soil	Thin Black soil	Black soil	Dark Gray and Gray soil	Irrigated soils
		($lb\ K_2O/ac$)					
0 - 50	Very deficient	110-145	115-150	115-150	120-155	120-155	125-160
50 - 100		75-110	80-115	80-115	85-120	85-120	90-125
100 - 150	Moderately deficient	40-75	45-80	45-80	50-85	50-85	55-90
150 - 200	Marginal	20-40	20-45	20-45	20-50	20-50	20-55
200 - 250		0-20	0-20	0-20	0-20	0-20	0-20
250 - 300	Adequate	0	0	0	0	0	0
>300		0	0	0	0	0	0

Table 7. Soil test potassium and corresponding recommended rate of potassium application for grass crops for the various soil zones in Alberta

Soil test K (lb/ac in 0-6 in. depth)		Brown soil	Dark Brown soil	Thin Black soil	Black soil	Dark Gray and Gray soil	Irrigated soils
		($lb\ K_2O/ac$)					
0 - 50	Very deficient	75-105	80-110	80-110	85-115	85-115	90-120
50 - 100		45-75	50-80	50-80	55-85	55-85	60-90
100 - 150	Moderately deficient	20-45	20-50	20-50	25-55	25-55	30-60
150 - 200	Marginal	0-20	0-20	0-20	0-25	0-25	0-30
200 - 250	Adequate	0	0	0	0	0	0
250 - 300		0	0	0	0	0	0
>300		0	0	0	0	0	0

Table 8. Soil test potassium and corresponding recommended rate of potassium application for root crops including potatoes for the various soil zones in Alberta, and potatoes and sugar beets under irrigation					
Soil test K (lb/ac in 0-6 in. depth)		**Thin Black soil**	**Black soil**	**Dark Gray and Gray soil**	**Irrigated soils**
		(lb K_20/ac)			
0 - 50	Very deficient	125-145	130-155	130-155	135-160
50 - 100		100-125	105-130	105-130	115-135
100 - 150		80-100	85-105	85-105	90-115
150 - 200	Moderately deficient	55-80	60-85	60-85	65-90
200 - 250		30-55	35-60	35-60	45-65
250 - 300	Marginal	20-30	20-35	20-35	20-45
>300	Adequate	0	0	0	0

The majority of potassium-deficient soils in Alberta are only slightly to moderately deficient. Maximum response to potassium on these soils is usually obtained with an application of 15 to 30 lb/ac of K_20 to cereal crops. On soils that are very deficient in potassium (soil test potassium less than 150 lb/ac), high rates of potassium fertilization are usually required to achieve maximum productivity. On very potassium-deficient soils, soil potassium can be built-up with an initial application of 200 to 300 lb/ac of K_20 (broadcast and incorporated), followed in subsequent years with annual applications of about 30 lb/ac. Similar results could be achieved by banding 50 to 80 lb/ac for a few years to build up soil K levels.

Research in Alberta indicates that soil tests do not always adequately reflect residual fertilizer potassium where high rates have been applied to very potassium-deficient soils. Following the application of up to 810 lb/ac of K_20 on very potassium-deficient soils, soil test potassium was still in the deficient range, but subsequent crops showed little or no response to additional potassium fertilizer. These heavily fertilized soils contained residual, crop-available potassium that was not reflected in the soil test. Therefore, when high rates of potassium fertilizer are applied to very potassium-deficient soils, the subsequent need for additional fertilizer should be determined on the basis of crop response, rather than solely on the basis of a soil test.

Potassium fertilizers

The most common form of potassium fertilizer used in Alberta is potassium chloride (KCl), which has the analysis 0-0-60 or 0-0-62 (Table 9). It is mined and refined in Saskatchewan. Potassium chloride can be safely blended with nitrogen and phosphate fertilizers to produce various blends to achieve optimum N-P_20_5-K_20 application.

Table 9. Potassium fertilizers available in Alberta					
	Nutrients – % by weight				
Name	**N**	**P_20_5**	**K_20**	**S**	**Remarks**
Potassium chloride	0	0	60	0	Are the most commonly available K fertilizers and least expensive
	0	0	62	0	
Potassium sulphate	0	0	50	18	Contains sulfur as well as potassium
Potassium nitrate	13	0	37	0	Used mainly for horticultural application

Although not extensively utilized to date, potassium sulphate (K_2SO_4) could be an important fertilizer source in areas where both potassium and sulfur are required nutrients. In the past, potassium sulphate produced in the United States has not been competitively priced with potassium chloride (KCl) from Saskatchewan.

Methods of application

Annual crops

Since soil potassium is not mobile in soil, placement of potassium fertilizers with or near the seed is usually the most effective and efficient method of application provided the rate of application is not greater than the seed can tolerate. Potassium chloride (KCl) is a salt. If too much potassium or a combination of other fertilizers that have a high salt index are placed with the seed, a “salt effect” can delay or reduce seed germination and emergence. The salt effect of fertilizer will interfere with the moisture uptake by the seed and may result in the death of a germinating seed.

The safe level of potassium that can be applied with the seed depends on the crop. In general, smaller seeded crops such as canola have a lower tolerance than cereal crops. The clay and organic matter content of the soil and the soil moisture content will also have an effect on possible germination problems. Soils with a higher clay content or higher organic matter content can hold more water. This situation can slightly reduce the salt effect when soil moisture levels are good by diluting the amount of potassium salt dissolved in the soil water.

With average soil moisture conditions and medium-textured soils, the total amount of seed-placed fertilizer materials should not exceed 175 lb/ac, and the total amount of N plus K_20 should not exceed 40 lb/ac at a seed-bed utilization (SBU) of 10 per cent. For less tolerant crops such as canola, flax and peas, the application of potassium with the seed should not exceed 15 lb K_20/ac, provided other fertilizers are not seed placed.

These recommendations are based on the use of a seed drill with a 10 per cent SBU, which places the seed and fertilizer in a very narrow band. If the opener spreads the seed over a wider band, higher rates of fertilizer can be safely placed with the seed.

Side-band placement is an efficient means of applying potassium and much safer than seed placement, particularly when higher rates of K must be applied. Ideally, with this placement, the fertilizer is in a band approximately 2.5 cm (1 inch) to the side and possibly 2.5 cm (1 inch) beneath the seed. This separation of fertilizer and seed reduces the possible detrimental effects on germination when high rates are applied. There are a number of different openers that have slightly different placement positions.

Banding, also referred to as deep banding, places the potassium into the soil in a concentrated band prior to seeding. It is believed that this placement method should provide similar results to side-banding K.

Broadcasting potassium before seeding is less efficient than applying potassium in a band with or near the seed. The major role for broadcast applications of potassium fertilizer will be in building up soils extremely deficient in potassium or for use with forage crops.

Perennial crops

For perennial forage crops, potassium is best applied by broadcasting and incorporating at higher rates of 100 lb K_20/ac before seeding. Higher rates should be used on K-deficient irrigated land. This approach will overcome the problem of limited movement of potassium into the soil when applications are made after stand establishment.

Where established stands require potassium fertilizer, broadcast applications are the only option, and relatively high rates may be required on severely potassium-deficient soils. Fall or spring applications could be made, but fall applications would likely be preferred in dry areas because of the additional winter moisture available to move the potassium into the root zone. For potassium-deficient soils, potassium fertilizer application in early fall may help reduce alfalfa winterkill and help maintain the proportion of alfalfa in mixed forage stands.

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