3 Potassium

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Potassium (K) is an essential plant nutrient. Next to nitrogen (N), crops absorb potassium in greater amounts than any other nutrient.

Most major soils are mineral soils and this is true for soils in Nebraska. Mineral soils are formed from minerals such as feldspar, mica and hornblendes as well as secondary minerals and clays. The potassium content of different minerals and clays is variable because soils were not all formed from the same minerals or parent materials. Total potassium varies widely in soil, and therefore, soil test values also vary greatly as shown in Table 3-1.

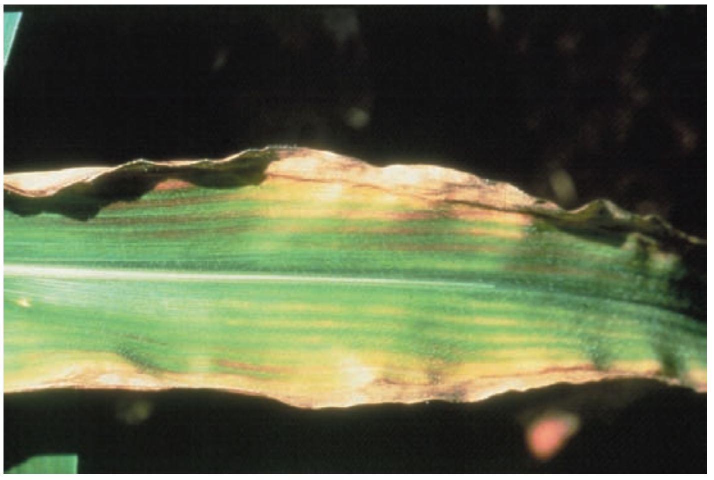


Figure 3-1

Potassium deficiency in corn. Photograph courtesy of the Potash Phosphate Institute.

Form and Availability of Potassium

Potassium, unlike nitrogen and phosphorus (P), is not associated to any great extent with organic matter, but it is more dependent on the type and content of minerals and clay in different soil series. Total potassium in soil varies from 0.3% to more than 2.5%. While total potassium content is important, it has little value in determining how well a given soil can supply potassium to growing plants. The general terminology used to describe the potassium reaction in soil is shown in Figure 3-2.

■ *Relatively unavailable forms (pools)*

Depending on soil type, from 90% to 98% (Figure 3-2) of soil potassium is in relatively unavailable forms. Feldspar and mica minerals contain the most potassium. While these minerals are the source of soil potassium, in these crystalline-insoluble forms, potassium is not available to plants. Over time, these minerals weather and release potassium very slowly to more available forms where potassium is then removed by crops or leaching.

Slowly available (nonexchangeable) forms

Potassium in the slowly available form is part of the internal structure of clay minerals forming the soil colloidal fraction. Slowly available potassium cannot be replaced by ordinary cation exchange processes, making it nonexchangeable. As shown in Figure 3-2, nonexchangeable potassium is in equilibrium with available forms and it acts as an important reservoir of potassium.

An equilibrium exists between nonexchangeable, exchangeable and soil solution potassium as shown by the arrows in Figure 3-2. Because of this equilibrium, some potassium applied as fertilizer can be temporarily converted to the nonexchangeable form. This reaction is important because it helps reduce leaching of potassium from applied fertilizer, especially in sandy soils.

Readily available forms (exchangeable and soil solution potassium)

Readily available potassium includes exchangeable and soil solution potassium. Exchangeable potassium is absorbed on the soil colloid surfaces and is available to plants; however, plants obtain most of their potassium from the soil solution.

As shown in Figure 3-2, these three forms of soil potassium are in dynamic equilibrium where an interchange between the different forms occurs. Therefore, the amount of potassium in the different forms ranges from 1% to 2% for readily available, 1% to 10% for slowly available and from 90% to 98% in unavailable forms.

Exchangeable potassium values vary considerably with location and soil type as shown in Table 3-1.

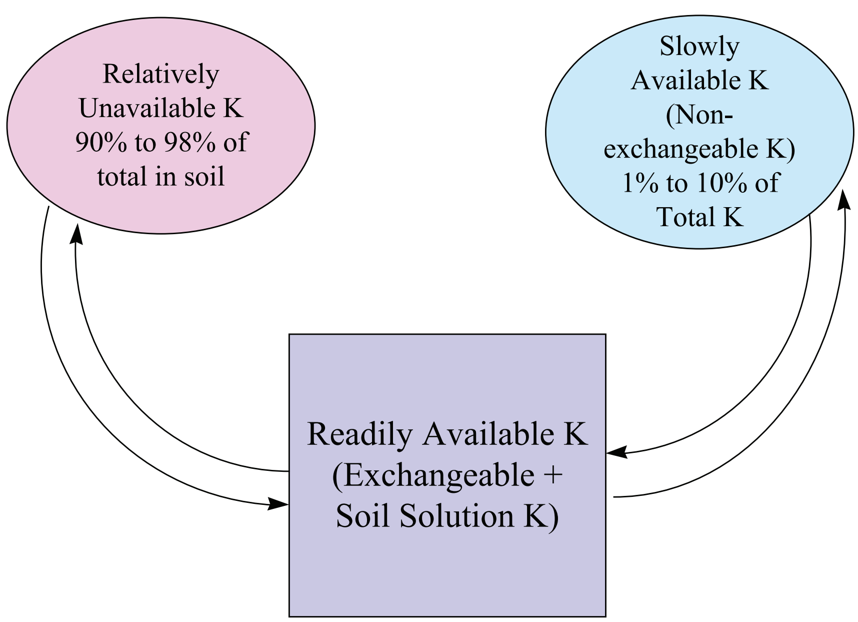


FIGURE 3-2

Relationship among the three types of soil potassium.

TABLE 3-1

Exchangeable potassium for crop-producing soils.

Soil Depth	Clarion silt Story, IA[1]	Hall silt loam, Dawson, NE	Thurman loamy sand, Merrick, NE	Milaca fine sandy loam, Benton, MN
	Soil Series and Location (County and State)			
	Exchangeable K (Field-moist Samples)			
inches	*ppm*			
0-6	72	744	124	34
6-12	49	496	78	16
12-18	31	363	44	15
18-24	17	356	36	12
24-30	15	510	35	15
30-36	17	679	45	16

Source:
[1]North Central Regional Potassium Studies, Research Bulletin 494, Iowa State University, Ames, Iowa, July 1961.

Estimating the Ability of Soils to Provide Potassium to Crops

The purpose of developing a soil test for potassium is to estimate the ability of soil to supply potassium from the readily available potassium pool to different crops during the growing season.

A chemical soil test procedure for potassium *does not measure total potassium* in the soil. The value from the chemical analysis is an *index* of the soil's ability to supply potassium to different crops.

Data for the Thurman loamy sand (ls) in Table 3-1 provides an example of the relationship between potassium forms shown in Figure 3-2 in terms of pounds of potassium (shown in Table 3-2) and why the soil test for potassium is an index and not a measure of total potassium. For this example, the following assumptions are:

- Thurman soils weighs 4,000,000 pounds per acre foot,
- readily available potassium equals exchangeable plus soil solution potassium, which equals 2% of the total potassium (e.g., 124 pounds of potassium per 1,000,000 pounds of soil x 2,000,000 pounds of soil per acre-six inches = 248 pounds of potassium per acre-six inches),
- slowly available potassium equals 10% of total potassium,
- corn plants will draw potassium from the top three feet of soil,
- a 150-bushel corn crop will require about 200 pounds of potassium during the growing season.

Table 3-1 shows 722 pounds of exchangeable potassium in the top three feet of the Thurman loamy sand soil (361x2). From Figure 3-2, 10% of this is in the soil solution (0.1 x 722 = 72 pounds). Therefore, at any given time only about 35% of the total potassium requirement is available for the 150-bushel corn crop (72/200x100).

TABLE 3-2

Pounds of potassium in the top six inches of the Thurman loamy sand soil of Table 3-1 present in the various forms of Figure 3-2.

Type of Potassium		**Pounds of K per Acre at a 6" Soil Depth for the Thurman Loamy Sand Soil in Table 3-1**
Soil solution K + exchangeable K	=	248 lbs/A = Readily available K=2%
Total K	=	Readily available K/2% = 12,400 lbs/A
Slowly available K	=	10% of total K = 1,240 lbs/A
Relatively unavailable K	=	90% of total K = 11,160 lbs/A

The most commonly used chemical extracting agent to estimate exchangeable and solution potassium is 1.0 molar ammonium acetate at pH 7. Field research is required to correlate the soil test index values into ranges where different crops respond to applied potassium. The numerical value of the index with a corresponding rating varies across states as shown in Table 3-3. Once the index ranges are established, numerous field studies with rates of potassium are required to calibrate the soil test for different soils and for individual crops.

Potassium

Table 3-3 shows that for a given soil test potassium index value, the potassium recommendation can change for different crops. Also as shown in Table 3-3, for a given potassium index level, the potassium recommendation will vary across states for the same crops. Wisconsin recommendations are more complex than they appear in Table 3-3 because potassium recommendations in that state will vary for the same crop depending on the soil type.

■ *Why potassium recommendations vary*

Potassium recommendations vary because conditions change. A primary influence on a specific soil's ability to provide potassium to plants is the type of potassium minerals found in the soil. Additional factors influencing potassium availability and uptake are soil moisture, soil aeration and oxygen (O) level, soil temperature, soil cation exchange capacity (CEC) and rooting depth, and subsoil potassium levels.

TABLE 3-3

Potassium recommendations (pounds per acre) for selected crops by state according to soil test index values. The index values given are in parts per million (ppm) using 1 M ammonium acetate as the extracting agent.

NEBRASKA	**(No specific expected yield)**				
	0 - 40	41 - 74	75 - 124	125 - 150	>150
Index (ppm)	Very low	Low	Medium	High	Very high
	K_2O (pounds per acre)				
Corn	120 + 20 row	80 + 10 row	40 or 10 row	0	0
Edible Beans	60	40	20	0	0
Soybeans	60	40	20	0	0
Sorghum	80	60	40	0	0

MINNESOTA					
	0 - 40	41 - 74	75 - 124	125 - 150	>150
Index (ppm)	Very low	Low	Medium	High	Very high
	K_2O (pounds per acre)				
Corn 190 Bu/Acre	185 or 90 row	135 or 70 row	80 or 50 row	25 or 10-15 row	0 or 10-15 row
Edible Beans 2,401-2,900 Lb/Acre	80	60	35	15	0
Soybeans	100	60	20	0	0

WISCONSIN[2]					
	0 - 59	60 - 80	81 - 100	101 - 140	>140
Index-Corn (ppm)	Very low	Low	Optimum	High	Excessively high[1]
	K_2O (pounds per acre)				
Corn 190 Bu/Acre	75	65	45	20	0

	0 - 49	50 - 80	81 - 100	101 - 120	121 - 140	>140
Index-Soybeans (ppm)	Very low	Low	Optimum	High	Very high	Excessively high
	K_2O (pounds per acre)					
Soybeans 50 Bu/Acre	80	70	50	25	10	0

[1]Wisconsin doesn't show a very high category for corn. The "medium" range for other states is called "optimum" in Wisconsin.
[2]The index values are for corn grown on soils with "medium" potassium in the subsoil.

Soil moisture

Factors such as potassium diffusion rate, soil oxygen content, root growth, and potassium release and fixation from soil colloids are influenced by soil moisture. Because factors governing potassium uptake by plants are interdependent, there is no universal agreement among researchers on the influence of soil moisture on potassium uptake by plants. Generally, potassium uptake increases as soil moisture increases. Soil moisture content influences the ratio of potassium to calcium (Ca) plus magnesium (Mg). Research has shown that as soil moisture decreases, the K: Ca+Mg ratio decreases in the soil solution as well as in the plant. Also, potassium diffusion coefficients increase as soil moisture increases, resulting in increased potassium uptake by plants.

FIGURE 3-3

Spreading fertilizer on alfalfa.

Soil aeration and oxygen levels

Oxygen is necessary for root respiration and potassium uptake. Therefore, factors such as soil compaction and excess moisture that reduce oxygen levels in the root zone decrease potassium uptake. Researchers agree that the oxygen percentage required for adequate potassium uptake is not the same for all plants. For example, tobacco plants show a decrease in potassium uptake at 10% oxygen, while barley shows no deficiency in potassium uptake until the oxygen level reaches 5%.

Soil temperature

In general, the optimum soil temperature for potassium uptake by plants is between 60° F and 80° F.; however, potassium uptake is also influenced by the way temperature affects different crops. Soil temperature influences potassium uptake by plants in two ways. First, as temperature increases, release of potassium from the nonexchangeable to the exchangeable form increases. Second, as temperature increases, plant root metabolic activity increases, resulting in more potassium uptake until the point where roots become damaged by heat.

Cation exchange capacity (CEC)

According to recent research in Ohio, higher levels of exchangeable potassium are required for maximum yields on soils with higher cation exchange capacity (CEC) levels; however, according to numerous research trials in Nebraska CEC is not a factor in potassium availability to plants. This is undoubtedly due to the large amount of potassium feldspar and trioctahedral mica, its derivatives, and other potassium silicate minerals in Nebraska soils. These relatively unweathered soils release potassium from nonexchangeable forms almost as rapidly as plants utilize potassium. Predominant soils in the eastern and southeastern United States, and parts of Minnesota and Wisconsin do not have this ability to quickly release potassium to rapidly growing plants.

Some crop consultants recommend balancing potassium applications with other nutrients. This balance approach is based on the theory that the relationship between potassium, calcium and magnesium influences the ability of a soil to supply potassium to plants. Research in numerous states has shown that the K:Ca:Mg ratio approach has little basis for making potassium, calcium or magnesium recommendations (Schulte and Kelling, 1985).

Rooting depth and subsoil potassium levels

Subsoil potassium can be an important potassium source for plants especially where rooting depths are not limited by physical factors such as compaction or by chemical factors such as extremely acid subsoils. Exchangeable potassium varies with depth depending on soil type (Table 3-1). In Nebraska, subsoil potassium is not a factor in potassium recommendations, but it is in Wisconsin and other states. Considering that the Clarion soil in Table 3-1 is representative of a large area of highly productive soils in northern Iowa and southern Minnesota, it is understandable why potassium recommendations for crops grown on soils in those areas would be different than even the Thurman sands of Nebraska.

Losses of Soil Potassium and Sources of Supplemental Potassium

Losses of potassium from soil are caused primarily by crop removal, fixation by clay minerals, and leaching. Under Nebraska conditions, leaching may be a minor factor in very sandy soils. Fixation is not a problem with Nebraska soils.

Crop removal accounts for the largest loss of potassium from soil. As shown in Table 3-4, grain crops remove less potassium than alfalfa or crops harvested for silage.

Several sources of supplemental potassium are available. Table 3-5 contains general fertilizer sources. Potassium chloride (KCl) is the source producers use most often. However, in soils needing magnesium and sulfur (S), potassium magnesium sulfate is a possible choice.

Manure is an excellent source of potassium. The potassium content of manure varies depending on the source of manure and the way the manure is handled. For example, liquid pumped from lagoons can be high in potassium. Continued pumping of lagoon effluent on the same area of land can lead to excessive potassium buildup relative to other cations. The high K:Ca ratio can alter the physical and chemical properties of the soil. Similarly, manure application to satisfy nitrogen needs will cause exchangeable potassium accumulation in the soil.

Irrigation water is another source of potassium. Potassium content of Nebraska irrigation water is relatively stable, but varies with location. Usually, a chemical analysis every 10 years is sufficient to determine irrigation water potassium concentration.

TABLE 3-4

Average removal of potassium by crop production.

Crop	Yield	K_2O Removed
		pounds per acre
Corn stover	150 bu/A	42
	9000 lb/A	144
Wheat straw	60 bu/A	23
	3600 bu/A	53
Soybeans	50 bu/A	66
Alfalfa	6 ton/A	270

Source:
Franzen, D., and J. Gerwing. 1977. Effectiveness of Using Low Rates of Plant Nutrients. North Central Regional Research Publication 341. University of Nebraska, Lincoln, NE.

TABLE 3-5

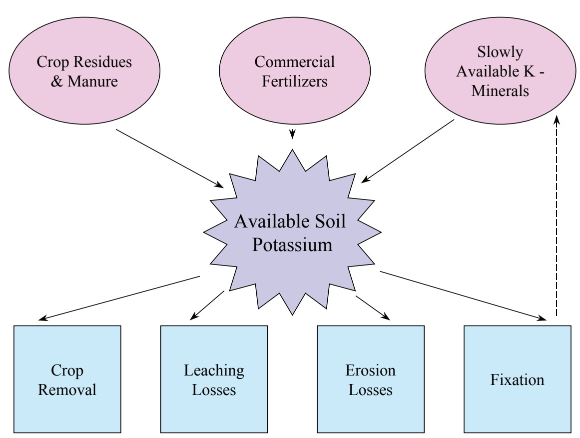
Principle potassium fertilizer sources.

Material	K_2O
	percent
Potassium chloride (KCl)	60 - 62
Potassium sulfate (K_2SO_4)	50 - 52
Potassium magnesium sulfate ($K_2SO_4 \cdot MgSO_4$)	22
Potassium nitrate (KNO_3)	44

Figure 3-4 summarizes the nature of soil potassium. Available soil potassium is associated with the clay complex and soil solution. It is in equilibrium with slowly available minerals which are constantly supplying available potassium. Fertilizers and crop residues add potassium to the soil. Fertilizer potassium may be fixed and become slowly available or it can be lost by crop removal, leaching or erosion.

FIGURE 3-4

Available potassium in relation to additions and losses.



Potassium Deficiency Symptoms

Potassium is a mobile nutrient in plants, and can be translocated from older to younger tissue. Consequently, deficiency symptoms will normally show up on older, lower leaves first, and then progress up the plant. In corn and sorghum, potassium deficiency will first be visible as yellowing or necrosis of leaf margins of lower leaves. Potassium deficient plants also may be prone to lodging late in the season, and may exhibit poorly filled ear tips. For wheat and small grains, chlorosis due to potassium deficiency will initially be uniform on lower leaves, and then become streaked with yellow or bronze, or leaves will become necrotic at the edges.

For soybean and alfalfa, potassium deficiency is noted initially as irregular yellow mottling around the leaf margins of older leaves. Further deficiency results in necrosis of chlorotic areas and downward cupping of leaf margins.

FIGURES 3-5 AND 3-6

Potassium deficiency in alfalfa (left) and soybean (right). Photographs courtesy of the Potash Phosphate Institute.

Resources

1. Frank, K., and D. Knudsen. 1974. Understand Your Soil Test: Phosphorus and Potassium. NebGuide G74-127. University of Nebraska, Cooperative Extension, Lincoln, NE.
2. Kelling, K., E. Schulte, L. Bundy, S. Combs, and J. Peters. 1991. Soil Test Recommendations for Field, Vegetable and Fruit Crops. University of Wisconsin Soil and Plant Analysis Laboratory, Madison, WI.
3. Kilmer, V.J., S.E. Younts, and N.C. Bradley (eds.). 1968. The Role of Potassium in Agriculture. ASA, CSSA, SSSA, Madison, WI.
4. Potassium for Corn Production. *In* National Corn Handbook, NCH-32. Purdue University Cooperative Extension, West Lafayette, IN.
5. Rehm, G., M. Schmidt, and R. Munter. 1993. Fertilizer Recommendations for Agronomic Crops in Minnesota. Bu-6240-E, Minnesota Extension, University of Minnesota, St. Paul, MN.
6. Schulte, E.E., and K. Kelling. 1985. Soil calcium to magnesium ratios—should you be concerned? University of Wisconsin, Extension Bulletin No. G2986, Madison, WI.