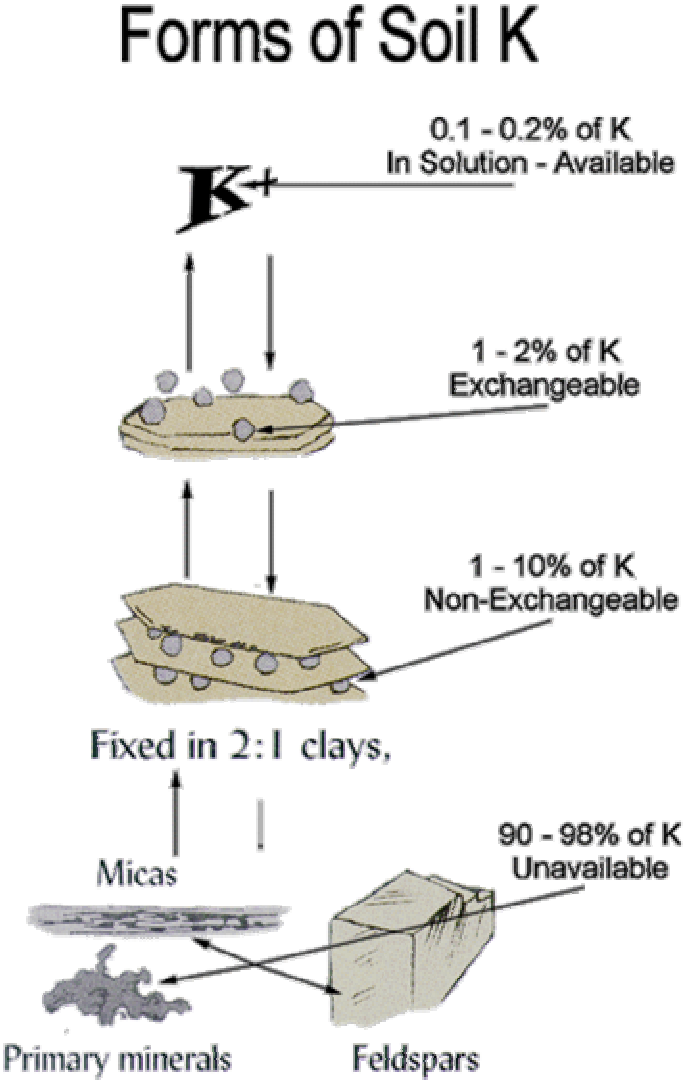
Potassium in Soils

Except in pure quartz sands, natural potassium levels are highest of all the macronutrients. Most soils contain from 31,000 to 45,000 pounds per acre of total potassium. However, the quantity of available K is often low as illustrated.

From 90 – 98% of the potassium in soils is found in a "rock" form of micas, primary minerals and feldspars. This K is very slowly available only through natural weathering.

Some crops, especially those with large fibrous root systems (grasses) are effective in acquiring K from non-exchangeable sites. By-products of microbes (organic acids) are also capable of increasing availability of K from non-exchangeable and unavailable sites.

Soils that contain a high amount of 2:1 clays (smectite, vermiculite & illite) can have up to 10% of the K tied up in a non-exchangeable form, "sandwiched" in between the clay sheets.



Only 1 - 2% of the total soil potassium is in a readily available form. Of this small percentage, 90% is weakly absorbed to colloidal surfaces on the outside of 2:1 clays, 1:1 clays and humus. Only a very small amount of this readily available K is found in the soil solution as free K ions (K^+).

As the arrows in the diagram indicate, the flow of K is in both directions. Under growing conditions, plants take up free K^+, which is replaced by K from the exchangeable sites. When a large amount of fertilizer (free K+) is added, the reverse occurs; K is tied up on exchangeable sites and even fixed in non-exchangeable sites such as 2:1 clays. This is an important concept to understand for potassium fertilization of various soils.

Monitoring K Availability

Only in extremely sandy soils is the problem of potassium fertility a question of total supply. In most soils it is more of an issue of the RATE of availability then the supply of potassium. There are come important concepts to use in planning K fertilization.

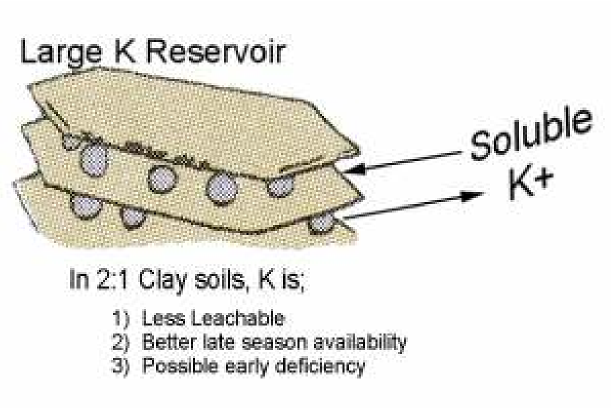
Rotation

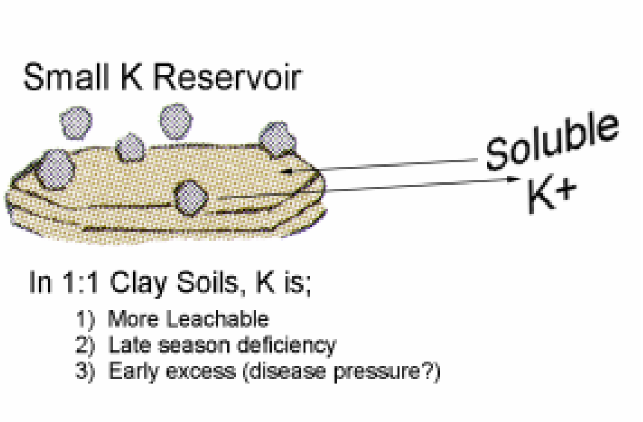
As stated, some crops are very capable of acquiring K from non-exchangeable forms. Grasses and alfalfa are two of these. In the case of alfalfa, the problem is made worse by the fact that alfalfa requires a lot of K, is capable of luxury consumption and all of the K is harvested and removed from the field. When alfalfa is followed by a crop that requires large amounts of K (i.e. potatoes or tomatoes), but is not as aggressive in feeding from non-exchangeable sources, the deficiency becomes even more severe.

Types of Colloids

For soils high in 2:1 clays, added potassium could be indefinitely tied up in the clay particle. This has desirable and undesirable effects as illustrated below. Large applications of potassium can be tied up and less available early in the growing season but released later. However, with 1:1 clays, there are few non-exchangeable sites to store potassium so it is much more susceptible to leaching and deficiency later in the growing season.

In this scenario, higher applications of K on 2:1 clay based soils is good in that little is leached, more is available in late season (most fruits require bulk of K late) and excess K is not available early in the season. For 1:1 clay based soils, or sandy soils, K fertilization is better latter in the season, when needed. This will result in less leaching, more availability when needed and avoidance of early excess in plant tissue.





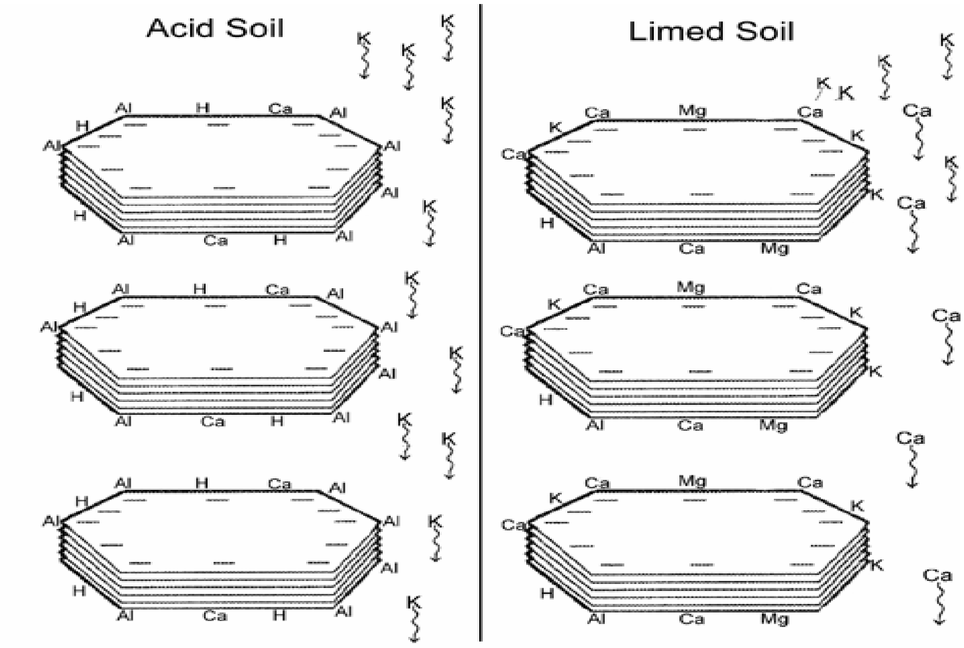
Although K plays an important role in a plants natural defense against disease, applying excess amounts of K in low calcium soil can cause an increase in disease pressure. Potassium is an "antagonist" to calcium. This means that a high amount of available K as water-soluble ions (K fertilizer) can suppress the uptake of calcium. This problem can become worse when cooler and wetter conditions predominate. Under these conditions calcium availability is lower than normal; therefore, disease pressure on young tissues can be much higher.

The following table gives some relevant data comparing the total K, exchangeable K and soluble K in soils of different clay types:

	Dominant Clay Types in Soils		
	Kaolinite (26 soils)	Mixed (53 soils)	Smectite (23 soils)
		mg K/kg Soil	
Total Potassium	3,340	8,920	15,780
Exchangeable Potassium	45 (1.35%)	224 (2.51%)	183 (1.16%)
Water-soluble Potassium	2 (0.06%)	5 (0.056%)	4 (0.025%)

Influence of pH

Soil pH plays an important role in potassium management. In acid soils (especially 1:1 clays) the hydrogen ion (H^+) and aluminum (Al^{+++}) is more tightly held on the colloidal surface and K^+ is not easily held in an exchangeable form and is subject to leaching. As the diagram illustrates, raising the pH and adding calcium makes the potassium more fixable on the colloidal surface.

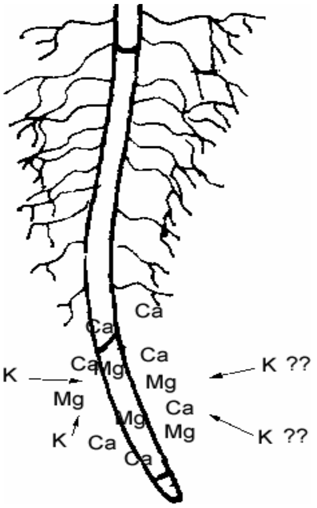


Excess Calcium & Magnesium

Calcium and magnesium are both extremely competitive at the root/soil interface with K. Therefore, even with high levels of K in the total CEC, K can be deficient in calcareous soils. Add to this factor an abundance of 2:1 clay and K levels can be up to 5% of CEC and still be deficient during peak demands.

In these cases it is advisable to divide total K by the square root of Ca + Mg. This is an accepted formula for calculated K release potential in these soils.

In low CEC soils, high K applications can cause magnesium and calcium deficiencies. High applications of magnesium or calcium and can cause K uptake problems. When applying high amounts of K, always consider the affect on Ca:Mg:K ratios and total CEC.



K Movement in Soils

Eighty-five percent (85%) of K movement in the soil is by diffusion. This concept is important to understand when growing crops that require high amounts of K during a certain cycle of growth. (Cotton, tomatoes, potatoes & fruits.) The process of "diffusion" is rather slow; therefore, rapid plant growth & uptake may deplete K around root surfaces even when high amounts are available.

Moisture levels and soil temperature effect K movement in the soil. Under dry or cool soil conditions, K diffusion will be hampered. Oxygen levels also negatively affect K uptake. When soils are waterlogged, low % of Ca on clay, or compacted, K deficiencies can cause loss of crop potential.

3 Ways of Nutrient uptake by roots:

Root Interception - Plant root "hits" the nutrient.

Mass Flow - Plant takes water, nutrients flow in the water towards root.

Diffusion - Root depletes area of nutrient; higher concentration from distant area fills depleted area.

K Uptake Timing

Most crops require as much, or more, K than nitrogen. Many crops will require from 200 to 400 lbs/acre per year. Plants require the peak amounts of K during flower and fruit development. At this time, especially fruit bulking, some crops can remove from 3-4 lbs/acre/day! Plants usually absorb most of their K during the first 1/2 of their growth cycle, or at full canopy. In high "sugar" crops (potatoes - starch/grapes - sugar), late season K deficiency is very common.

K Translocation in Plants

Most cellular membranes are characterized by a high permeability to K, which explains the extreme mobility of K throughout the plant. Potassium is very mobile in plants; therefore signs of deficiency will occur in the OLD growth long before NEW growth. Petiole K testing of new plant growth is not a good indicator of potential K deficiencies.

Interactions with other Elements

Nitrogen

- N = Soft, rapid tissue development (increased disease pressure)
- K = Promotion of firmer plant tissues (increased disease resistance)
- Nitrate N (NO_3) tends to increase K uptake because it is a negative charge, whereas ammonia N (NH_4) is positive & can suppress K uptake. (Increasing calcium levels tends to decrease the negative effect of NH_4 on K uptake.)
- K can reduce NH4 toxicity to plants
- Optimum ratio of NH4:K should be less than 1:4

Ca & Mg

- High soil K suppresses Ca & Mg uptake.
- High Mg suppresses K uptake more than Ca
- Optimum ratios of K:Mg in most plant tissues is 10:1. A ration of 14:1 will cause serious growth restriction in corn even if Mg levels are sufficient.

Na

- K & Na (sodium) ions are similar in ionic size and other chemical properties (solubility). Na can replace K in some essential roles.
- Na may "hide" K deficiency, but plants will still be weak in growth.
- KCl (potassium chloride) can reduce uptake of Na if soil sulfates are high & chlorides are low.