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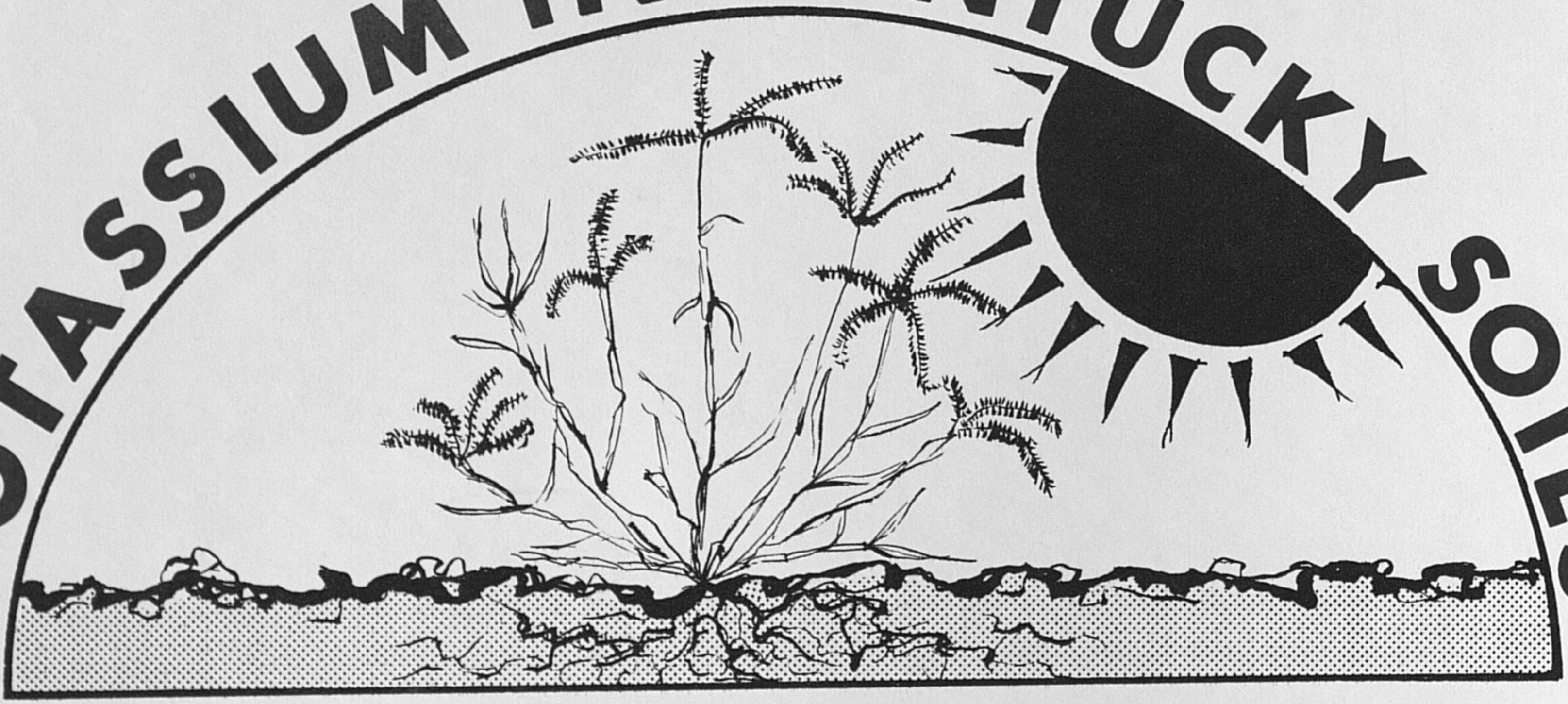

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UNIVERSITY OF KENTUCKY*COOPERATIVE EXTENSION SERVICE*AGRICULTURE AND HOME ECONOMICS

# POTASSIUM IN KENTUCKY SOILS

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Potassium is one of the 16 or more plant food elements that are essential for crop growth. An adequate supply of available potassium in the soil helps to insure the health of plants and improves the quality of the crop. It insures greater efficiency in photosynthesis, assists in the functioning of chlorophyll and aids in the formation and translocation of sugars, starches and oils. It increases the plumpness of cereal grains and stiffness of straw. Potassium tends to offset the effects of excessive nitrogen.

## POTASSIUM CONTENT OF KENTUCKY SOILS

Unlike nitrogen and phosphorus, the quantity of total potassium found in Kentucky soils is relatively high. Table 1 shows the potassium content of the plow layer (the surface 7 inches) of a few Kentucky soils.

The potassium in Kentucky soil can be attributed to two sources —native and fertilizer potassium.

### Native potassium

This is the potassium that was in the parent materials—rocks containing feldspars and micas—from which the soil was formed.

**Table 1.—Total Potassium Content of the Surface 7 Inches of Soils on Experiment Fields in Kentucky***

| Soil Class | Location of Experiment Field | Total Potassium Content (lbs/A) |
|---|---|---|
| Maury silt loam | Lexington | 29,000 |
| Crider silt loam | Princeton (limestone | 32,600 |
| Tilsit silt loam | Princeton (sandstone) | 30,000 |
| Monongahela silt loam | Berea | 19,000 |
| Welston silt loam | Fariston (Laurel Co.) | 24,400 |
| Bedford and Dickson silt loam | Campbellsville | 13,000 |
| Tilsit catena silt loam | Greenville | 24,600 |
| Grenada silt loam | Mayfield | 29,700 |

*Kentucky Agricultural Experiment Station Bulletin 397, "Soil Management Experiments." (Out of print; copies available only at libraries.)

**Table 2.—Potassium Uptake by Millet Grown on Six Kentucky Soils***

| Soil Type | Parent Percent Material | Exchangeable (Potassium lb/A) Soil Test Level | | Potassium Removed in 4 Millet Crops (lb/A) |
|---|---|---|---|---|
| | | Before Cropping | After 4 Crops | |
| Eden | Calcareous Shale, Siltstone and Limestone | 300 | 193 | 1100 |
| Pembroke | Limestone | 173 | 74 | 275 |
| Maury | Phosphatic Limestone | 114 | 73 | 125 |
| Bedford | Limestone | 91 | 49 | 125 |
| Grenada | Loess | 78 | 54 | 75 |
| Tilsit | Sandstone and Shale | 54 | 45 | 50 |

*Data from paper by Paul Sutton and W. A. Seay (1958), "Relationship Between Potassium Removed by Millet and Red Clover and the Potassium Extracted by Four Chemical Methods from Six Kentucky Soils."
SSSAP22:110

The feldspars and micas are relatively high in potassium content and thus soils derived from parent materials containing these minerals are apt to have a high native potassium content. On the other hand, some parent materials, sandstone for example, are low in potassium content and soils derived from these are apt to release potassium to the available form slowly. An illustration of this is shown in Table 2. On an Eden soil having 300 pounds of exchangeable potassium per acre, four millet crops removed 1100 pounds of potassium, while on a Tilsit soil with 54 pounds of exchangeable potassium per acre, the four millet crops removed only 50 pounds of potassium.

Alluvial (water transported) soil materials may have been carried great distances from their area of origin. However, they may have varying levels of potassium, depending on the mineralogical composition of the parent material in the area of their origin.

## Fertilizer potassium

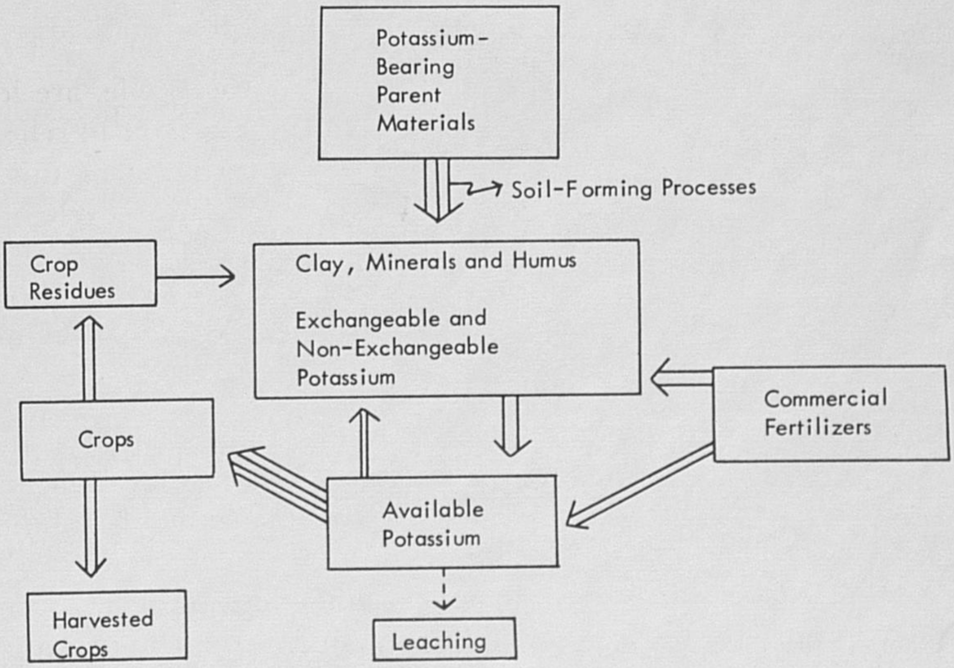
Potassium contained in commercial fertilizers has been applied, sometimes in large amounts, to many Kentucky soils. This may have increased the potassium content, particularly in and just below the plow layer, to levels greater than that of the parent materials. Much Kentucky tobacco land is a good example of this. On the other hand, where potassium removal by crops has been greater than the potassium applications, the potassium content may have been decreased below the original level.

Fig. 1 illustrates the potassium cycle in the soil. During weathering, physical, chemical, and biological forces act on the parent materials and break them into finer fractions, largely sand, silt. and clay particle sizes. Such breakdown is accompanied by the release of chemical elements, including potassium, as well as by the formation of clay minerals.

Most native potassium that is released during the soil-forming processes will be in the exchangeable and non-exchangeable forms, and some fertilizer potassium will revert to these forms. Note in Fig. 1 that both exchangeable and non-exchangeable potassium are sources of readily available potassium and that the process is reversible. The process is discussed on pages 7-9.

## POTASSIUM FIXATION AND RELEASE

The relative amounts of sand, silt and clay fractions found in a soil depend on the kind of parent material (sandstone, limestone, shale or mica) from which the soil was derived. The relative



WIDTH OF ARROW INDICATES THE VALUE OF POTASSIUM MOVEMENT

**Fig. 1.—Potassium Cycle in the Soil.**

This schematic drawing shows the sources of soil potassium, potassium fixation, and how the levels of available potassium are depleted and replenished. There is little or no leaching of potassium except in sandy soils.

amounts of these fractions and the kind of clay minerals in a soil determine its ability to fix or release potassium.

## Sand and silt fractions

The sand and silt fractions of most soils are made up largely of quartz, which is resistant to decomposition by weathering. The other minerals in these fractions may contain potassium and other nutrient elements but, since the particle size is relatively large, the rate of potassium release is low. Also, because of the physical and chemical nature of sand and silt, their ability to fix potassium is low.

## Clay minerals

On the other hand, the clay minerals (the dominant materials in the clay or colloidal fraction) of a soil are relatively active in fixing and releasing potassium.

Generally there are four kinds of clay minerals in Kentucky soils. Listed in the order of their abundance, they are kaolinite, soil mica or illite, vermiculite, and montmorillonite. No soil is composed of only one of these and more often a soil may contain as many as three or four. Each clay mineral has its own characteristics with respect to potassium fixation and release. In addition, each clay mineral contains different amounts of native potassium, which is bonded between the clay layers.

Because of this crystal structure and the location of the negative charges within the crystals, the illite and vermiculite clays are capable of absorbing potassium from the soil solution and entrapping it between neighboring clay particles. These "fixed" potassium cations can be entrapped in this way because of the relationship of their size of the "hexagonal" cavities in the silica sheets of two adjoining mica or vermiculite layers (see Fig. 2). Fixed potassium is not as available to plants as is exchangeable potassium, but may be gradually released as levels of exchangeable and soil solution potassium become low.

A knowledge of the types of clay minerals in a soil is important in interpreting soil test results and in planning potassium fertilization programs. Response to potassium fertilization of crops grown on soils that contain different kinds of clay minerals may go in seevral interesting directions. Crops grown on soils containing predominantly kaolin-type minerals generally respond to potash fertilization when a soil test indicates a need for additional potassium. Crops grown on soils with a high content of illite or vermiculite clay minerals may show little or no response even though a soil test indicates a need for potassium. Such behavior is thought to be due to the release of enough potassium from the crystal structure or from previously fixed potassium to meet the requirements of the crop.

Few Kentucky soils, except the Purchase area and slack water bottoms, contain appreciable quantities of montmorillonite clay. The potassium reactions with this clay are complex, since potassium may or may not be fixed, depending upon the pattern of soil acidity to which the clay mineral has been exposed.

Since Kentucky soils contain mixtures of the various types of clay minerals, plant behavior following a given treatment will usually fall somewhat between the extremes mentioned above.

Soils derived from calcareous shales can release potassium that usually is not reflected in a soil test. These soils contain some illite and vermiculite in their fine silt and clay fractions as well as some weatherable potassium-bearing feldspars.

Kentucky soils derived from limestone are medium in their ability to release potassium. This suggests that they are composed

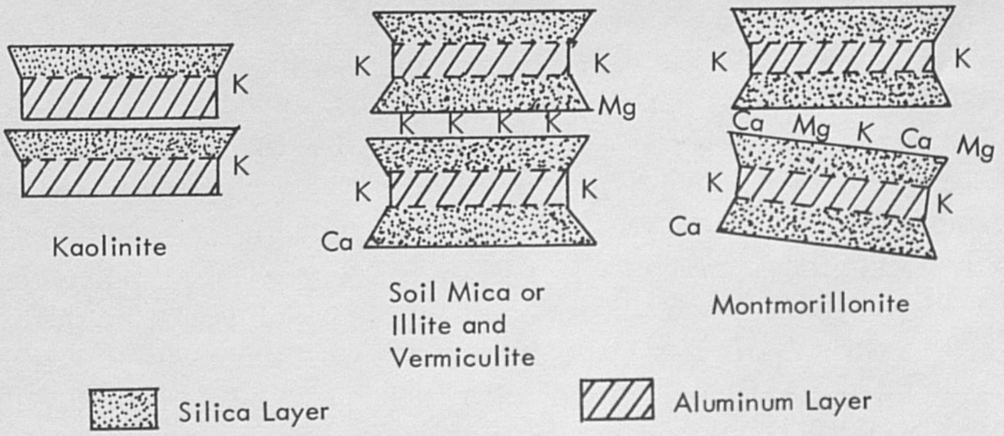


**Fig. 2.—The Structure of Four Types of Clay Minerals Found in Kentucky Soils.**

The potassium held by the kaolin-type clay is adsorbed on the jagged edges of the plates and is exchangeable or available for plant use. It will be reflected in a soil test.

The potassium held by the illite and vermiculite types is adsorbed on the surfaces of and between the clay crystals or layers. The potassium held between the layers is largely non-exchangeable, while that held on the surface is exchangeable. Soil tests may not reflect all the potassium that becomes available for plant use during a growing season.

The potassium held by the montmorillonite is also held on the surface and between the layers. Most of this potassium is exchangeable and most of it will be reflected in a soil test.

of a mixture of the clay minerals, with kaolinite predominating but with vermiculite and illite present.

The parent materials from which loessal soils are derived are unknown. However, they are composed of montmorillonite and illite clays, and are medium in their ability to release potassium.

Soils derived from sandstone and acid shales are low in their ability to release potassium. The major factor is that the percentage of clay minerals is low in these soils and that kaolinite is the principal mineral present.

### Organic material

Growing plants obtain potassium from the soil for their nutrient supply. When plant residues are returned to the soil, this potassium will be readily released to a new crop and to exchange sites in the soil (see Fig. 1). Highly decomposed organic matter is called humus. Because of the negative charges on the humus particles, they may adsorb potassium cations in much the same way as the clay minerals and hold potassium in an exchangeable form for rapid release to plant roots.

## CATION EXCHANGE

The interaction of potassium and other cations, such as calcium and magnesium, with the soil colloids is referred to as "cation exchange." The ability of a soil to retain or hold applied potassium depends to a large degree on its cation exchange capacity (CEC). The CEC, usually expressed in milliequivalents (meq.), is defined as the sum of the exchangeable cations per unit weight (100 grams) of soil.

Although the fine silt fractions of a soil can contribute some exchange sites, the clay and organic fractions (humus) are primarily responsible for the CEC of a soil. The contribution of humus to the CEC of a soil depends to a large extent on the amount present in the soil, while the contribution of the clay minerals depends on both the kind and amount in the soil.

Clays of the kaolin group have the lowest CEC ($<$ 10 meq./100 grams). The CEC of illite minerals is intermediate (35 – 50 meq./100 grams), while the montmorillonite and vermiculite clay minerals are relatively high (80 – 120 meq./100 grame). The CEC of humus is about 140 meq./100 grams. The above values are for pure clay minerals or humus. When they are mixed with each other and with sand and silt, the CEC of the soil body will be the sum of the CEC's of the various fractions that comprise the soil. Thus, if the humus content and the kind and amount of clay minerals in a soil are known, a rather close approximation of its CEC can be made.

Cation exchange in soils is a reversible chemical reaction in which one cation adsorbed on the surface of a soil colloid is replaced by another cation. These cations are rather loosely held on the edges of the clay minerals or humus particles or between the layers of clay minerals. They occupy exchange sites because they are balancing the negative charges of the clay minerals or humus.

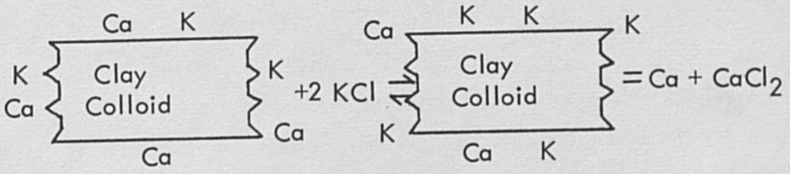


**Fig. 3.—Cation Exchange.**

Note that when potassium chloride is added as fertilizer, the potassium replaces calcium on the clay colloid, allowing the calcium to combine with the chloride in the soil solution. The process is reversible.

The importance of cation exchange capacity is that it prevents or reduces leaching of fertilizer components, such as potassium, ammonium, magnesium and calcium. Cation exchange is a means by which the soil can store potassium and other cations that may be released later to plants.

## AVAILABLE POTASSIUM

Terms commonly used by soil scientists to describe the different categories of potassium in the soil are "non-exchangeable" or "fixed," "exchangeable" or "available," and "readily available" (see Fig. 4).

Like nitrogen and phosphorus, potassium must be in an available form to be used by plants. Even though the total potassium content of most Kentucky soils is well above the amounts required or removed by crops, many of these soils need potassium applications to obtain highest crop yields. This is because only a very small amount of the total potassium is in the readily available forms during a cropping season.

Exchange reactions of the soil are such that a balance is maintained between the three categories of potassium (Fig. 4). As growing crops remove readily available potassium from the soil solution, exchangeable potassium will move into solution. Also some of the non-exchangeable or fixed potassium will move into an exchangeable form. However, the rate at which non-exchangeable potassium moves to an exchangeable form is slower than the rate at which the exchangeable potassium moves to the readily available form. This process is reversible if there is an excess of readily available potassium over exchangeable potassium (see Fig. 4).

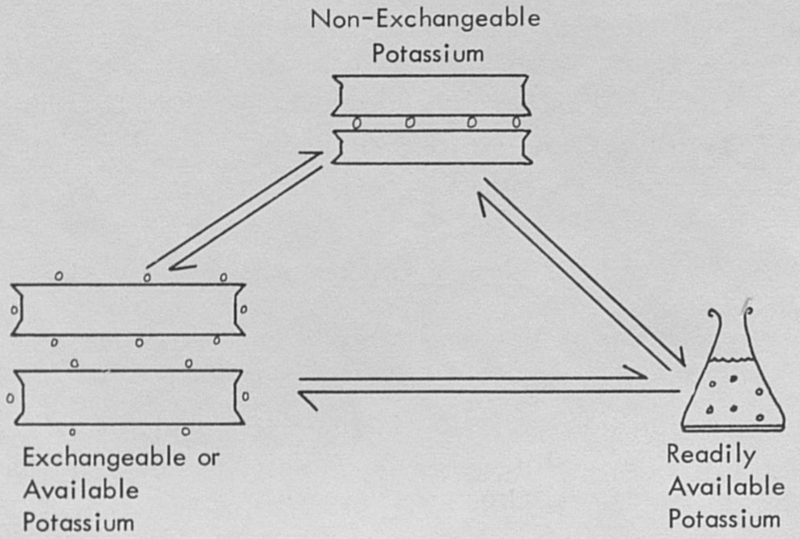


**Fig. 4.—Potassium Forms and Reactions in the Soil. Note that the reactions are reversible.**

The black dots represent potassium cations. Most of the non-exchangeable potassium is trapped between the layers of illite and collapsed vermiculite clay minerals. The exchangeable or available potassium is largely the cations that are adsorbed on the surface and edges of kaolinite and montmorillonite clay minerals and between the layers of expanded vermiculite.

Readily available potassium is the cations that are in the soil solution (soil water) and are not attached to the clay minerals.

Soil tests reflect the amounts of exchangeable and readily available potassium present when the sample is tested. They do not reflect the non-exchangeable or fixed potassium that can move into the exchangeable form over a long period. This explains why some soils may have a low test but yet supply enough potassium for relatively high crop yields. It also illustrates the need for a knowledge of the clay mineralogy of a particular soil, recent potassium applications, and past crop growth, as well as the soil test results, when planning potassium fertilizer programs.

Available potassium is only a part of the total potassium in a soil that is potentially available to a crop during a growing season. Available potassium includes the potassium in the soil solution plus some of the potassium that is adsorbed on the soil colloids. Some of the adsorbed (exchangeable) potassium is obtained by plant roots if they grow close to it. Plant roots also possess negative charges and may attract potassium ions from the clay mineral surfaces or edges.

Potassium in commercial fertilizers is guaranteed to be soluble in a standardized extracting solution. When applied to the soil, it dissolves and enters the soil solution for a short period and is readily available. However, in the presence of the soil colloids, much of it will revert to the exchangeable form and some may revert to the non-exchangeable or fixed form.

## HOW TO MAKE POTASSIUM MORE AVAILABLE

Potassium fixation is not necessarily bad. It can work to the farmer's advantage, since fixed potassium as well as that held in the exchangeable form almost never leaches below the plow layer except perhaps in sandy soils. More potassium can be made available by good soil management practices.

### Lime acid soils

As soil pH is adjusted to near neutral (pH 6.0–7.2) certain plant nutrients, particularly phosphorus, are made move available and the supplies of calcium and magnesium are obviously increased. Since crops need a balance of all the nutrients, they will use potassium more efficiently when the soil pH is adjusted so that the other nutrients are available in abundant supply.

Calcium or lime added to soils composed of different clay minerals may react differently with respect to the release of potassium. The addition of calcium to acid soils with large amounts of kaolinite and/or montmorillonite clay minerals may increase the availability of potassium to plants, whereas adding calcium to vermiculite and/or illite soils may have little or no effect on the availability of potassium. Liming acid soils may increase root growth and thus the amount of available potassium that plants can get.

## Avoid over-liming

When soils are over-limed (to near pH 8.0), a high concentration of calcium around the plant roots may reduce the amount of potassium cations in solution or in close proximity to the plant roots. This may inhibit the uptake of potassium. Furthermore, there is a limit to the total amount of cations (calcium, potassium, magnesium, sodium, etc.) that a plant will absorb. Plants need a proper balance of these cations to make maximum growth. If there is an excessive amount of calcium around the roots, the plant may absorb a disproportionate amount of calcium at the expense of the needed potassium. (See Kentucky Extension Circular 602, "Controlling Soil Acidity" for phosphorus fixation at high pH levels.)

## Apply heavy rates of potassium fertilizers

In soils that are low in potassium content, some of the applied potassium will revert to the non-exchangeable form and some to the exchangeable or available form. Heavy rates of application will build up the level of potassium in the soil to a point where less will revert to the non-exchangeable or fixed form. Then smaller applications of potassium fertilizers will be needed to supply crop needs.

## Return crop residues

A 100-bushel corn crop (stover and cobs included) contains, at maturity, about 100 pounds of elemental potassium. Only about 22 pounds of this will be in the grain. Hence about 78 pounds of potassium will be returned to the soil if the stover and cobs are returned. Likewise, 40 bushels of wheat contain about 12.5 pounds of potassium, whereas the straw alone contains about 30 pounds. These examples illustrate the importance of returning crop residues to the soil.

When the whole crop is harvested, as in the case of corn silage or hay, larger amounts of potassium are removed. Take this fact into consideration when planning potassium fertilization programs.

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