

# MANAGING POTASSIUM FOR ORGANIC CROP PRODUCTION

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## ABSTRACT

An adequate potassium (K) supply is essential for both organic and conventional crop production. Various organic certification agencies have different regulations governing allowable sources of K. The release of K from soil minerals is discussed along with the behavior of various allowed K sources for organic crop production.

Potassium is an essential nutrient for plant growth, but it generally receives less attention than N and P. All of the Western U.S. states remove more K from the soil in crop harvests than are returned to the soil in fertilizer and manure (Fig 1). This net export of soil nutrients ultimately results in a depletion of nutrients and increasing occurrences of deficiency.

Potassium is the soil cation required in the largest amounts by plants, regardless of nutrient management philosophy. Large amounts of K are required to maintain plant health and vigor. Some specific roles of K in the plant include osmo-regulation, internal cation/anion balance, enzyme activation, and proper water relations. Potassium plays a vital role in photosynthate translocation, especially to grains, tubers, and fruit. Protein synthesis is facilitated with an adequate supply of K. Tolerance of external stress, such as frost, drought, heat, and high light intensity is enhanced with proper K nutrition. Stresses from disease and insect damage are also reduced with an adequate supply of K. Although there are no harmful effects of K to the environment or to human health, the consequences of inadequate K can be severe for crop health and efficient utilization of other nutrients, such as N and P. Maintenance of adequate K is essential for both organic and conventional crop production.

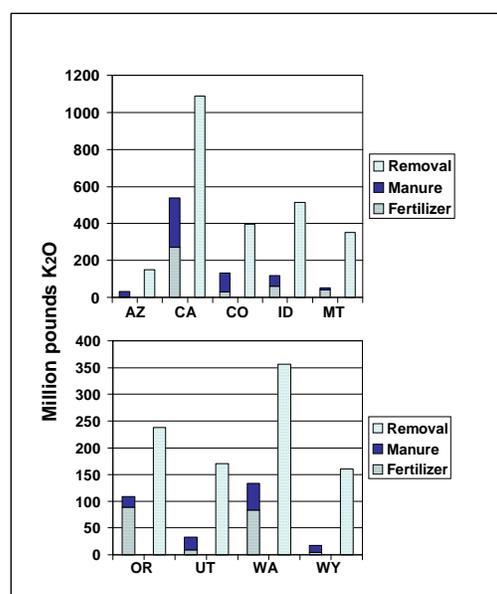


Figure 1. Balance of K inputs in fertilizer and recoverable manure compared with K removal in harvested crops in western U.S. states (PPI, 2002).

## ORGANIC CROP PRODUCTION

The basic principles of plant nutrition are the same, whatever the production system used. Both organic and conventional production systems have many common objectives and generally work with the same basic global resources. While specific nutrient management techniques and options may vary between the two systems, the fundamental processes supporting soil fertility

and plant nutrition do not change.

In general, the objectives of organic plant nutrition are to:

- Work within natural systems and cycles
- Maintain or increase long-term soil fertility
- Use renewable resources as much as possible
- Produce food that is safe, wholesome and nutritious

For some nutrients, such as K and P, there are not many differences between management of conventional and organic production, except for some of the allowable nutrient sources. Organic regulations require growers to rely on the use of untreated products for supplying K, where conventional producers have a wider range of materials to maintain soil fertility and meet crop nutrient demands. The greatest differences between the two systems likely occur with nitrogen management.

### **WHICH ORGANIC STANDARDS TO FOLLOW?**

The use of approved nutrient sources is governed by a variety of oversight organizations. In the USA, the USDA National Organic Program is responsible for setting and maintaining standards. In Canada, the Canadian General Standards Board oversees the organic production systems program. In Europe, the major organizations include IFOAM (International Federation of Organic Agriculture Movements) and Codex Alimentarius (a joint FAO/WHO organization). Each of these organizations maintains somewhat different standards and allows different materials to be allowed in their organic production systems. As a result, a grower seeking advice on certified organic materials should first know where the agricultural produce will be sold in order to meet the requirements of that market.

In general, regulations for mined K sources specify that they must not be processed, purified, or altered from their original form. However, there is disagreement between different certifying bodies over what specific materials can be used. Unfortunately, some of these restrictions on certain nutrient materials do not have scientific justification and their inclusion or exclusion on various lists should not be viewed as one material being more or less “safe” than another fertilizer material.

### **A VARIETY OF ORGANIC PRODUCTION SYSTEMS**

There many variations possible for successful K management for organic production. The largest differences occur on farms that produce both livestock and crops compared with farms that strictly produce crops for off-farm sale. In the mixed livestock/crop systems, the nutrition of the animals generally takes first priority and the residual manure is returned to surrounding cropland. In these cases, imported K in feed and bedding frequently exceeds the output in milk and meat products, sometimes leading to an accumulation of K in the surrounding fields. Large losses of K sometimes occur on these farms during manure storage and composting. Since excreted K mostly goes into urine, if this fraction is not effectively recovered it will not be returned to the field with the solid portion of the manure. In this paper, the discussion will be confined to farms that are using organic techniques for crop production alone.

Crop rotations are a central part of organic production systems. While this practice can be helpful for supplying N when legume crops are included, it does not supply any additional K to the farm. Subsoil K reserves may be important for some cropping systems, however the removal of any plant material from the field continually depletes the soil nutrient supply and ultimately reduces the long-term productivity.

Plant-available K is usually measured in the topsoil, but some deep-rooted plant species can take up considerable amounts of K from the subsoil (Kuhlman, 1990). The contribution of subsoil K to the plant K requirement depends on the amount of plant-available K in the top and subsoil, potential root-limiting factors (such as compaction, salinity, or acidity), and the root distribution pattern of the specific crop.

It is important to define the “sustainability” of using soil K resources as a long-term nutrient source. Does sustainable K management mean not depleting the exchangeable K to a point where mineral K begins to supply the plant with K? Is the removal of exchangeable K acceptable as long as it is replaced with K from less available pools?

## POTASSIUM BALANCE

Since sales of farm produce will always lead to a loss of K and some additional loss of K through leaching and runoff is inevitable, the potential of the system to resupply the K reserve is important. The use of farm budgets may be most useful for describing the nutrient flow within a farming system and to assist with nutrient planning for rotations and mixed farming systems. Depending on a variety of factors, the on-farm budgets of N, P, and K on organic farms has been shown to range from a surplus to a deficit.

For example, a survey of four long-term organic farms in England showed that soil K concentrations were continually dropping, as the harvested crops extracted the reserves of K and P that were built up during the previous years when the farms were operated with conventional management. (Gosling and Shepherd, 2005). While some excellent nutrient budgets have been developed for European organic farms, relatively little of this work has been done in North America.

The demand for K by various crops has been well established by measuring the K concentration in the harvested portion of the crop (Table 1). However, much less attention has been paid to the rate at which K must be supplied to the plant. Both the total amount required (quantity) and the rate of supply (intensity) are equally important. This concept is important for all crop growth, but requires special attention when using low-solubility nutrient sources that may provide an adequate amount of total K, but not at a rate sufficiently rapid to meet peak-demand periods of plant growth.

Table 1. Average removal of K<sub>2</sub>O equivalent in the harvested portion of some common western crops.

Alfalfa	60 lb K <sub>2</sub> O/ton	Potatoes	0.56 lb K <sub>2</sub> O/cwt
Almond	55 lb K <sub>2</sub> O/ton	Rice	0.40 lb K <sub>2</sub> O/cwt
Corn grain	0.29 lb K <sub>2</sub> O/bu	Sugar beets	8.3 lb K <sub>2</sub> O/ton
Corn silage	8 lb K <sub>2</sub> O/ton	Tomatoes	7.2 lb K <sub>2</sub> O/ton
Cotton	14 lb K <sub>2</sub> O/bale	Wheat	0.57 lb K <sub>2</sub> O/cwt

## POTASSIUM RELEASE FROM SOIL MINERALS

The most common sources of K in soils are feldspars and micas; soil minerals remaining from the primary parent material. Weathering of these primary minerals produces a range of secondary minerals that may also serve as a source of K in soil. These minerals include micaceous clays such as illite and vermiculite.

The release of K from micas proceeds by two processes (Sparks, 1987):

1. K-bearing micas transform to expandable 2:1 layer silicates following the replacement of K with hydrated cations. This occurs through clay-edge weathering or clay-layer weathering.
2. Weathering of the mica (releasing K) and the subsequent formation of secondary weathering products

Soils with high clay content are sometimes associated with high reserves of K, but this is not universally true. For example, soils with montmorillonite, vermiculite, chlorite, and kaolinite clays do not have the same K-supplying capacity as illite clays (Rao and Khera, 1994). The dynamics of K release from these mineral fractions has not been well established for our major production soils and is not routinely measured in soil tests.

Some soil minerals may also act as a sink for removing K from solution. When K is adsorbed in the interlayer sites of illite, vermiculite and other smectite clays, the clay layers collapse and trap the K within the mineral lattice. This fixation process is relatively fast, while the release of this interlayer K is very slow.

The capacity of clays to maintain a given concentration of K is referred to as the K buffer capacity (KBC). A soil with a high KBC suggests good K availability and a low KBC suggests a greater need for frequent K addition. Clearly the type of clay will be important for determining the need for K fertilization, regardless of the type of crop management.

The soil cation exchange capacity is determined by the amount of clay present and its mineralogy, as well as the behavior of the organic matter fraction. Where the CEC is increased with regular organic matter additions, the capacity of soil to retain cations, such as K, will also be increased.

## **POTASSIUM SOURCES FOR ORGANIC PRODUCTION**

Regular applications of soluble K, regardless of the source, will increase the concentration of soluble K and the proportion of K on the cation exchange sites. All of the commonly used K sources (including manures, composts, and green manures) contain this nutrient in the simple cationic  $K^+$  form. Most soluble inorganic fertilizers and organic manures are virtually interchangeable as sources of K for plant nutrition. When using rapidly available forms of K, the overall goal of replacing the harvested K is likely more important than minor differences in the behavior of the K source. Any differences in plant performance are usually due to the accompanying anions (such as Cl or  $SO_4$ ) or organic matter that may accompany the K.

There is no general evidence that  $K_2SO_4$  is more effective than KCl as a source of plant-available K, however both S and Cl are essential plant nutrients that are required for plant health. Chloride is sometimes disparaged as being harmful to soil, but there is no evidence for this claim at typical rates of application. It has an important role in improving plant health and prevention of a variety of plant diseases. Chloride-derived salinity was the same as sulfate-based salinity on its effect on common soil microbes (e.g. Li et al., 2006).

Crushed rocks and minerals have been evaluated as K sources in several field and greenhouse experiments. In general, plants are able to gain a very limited amount of K from minerals applied as biotite, phlogopite, muscovite, and nepheline. Feldspar K is not plant available without additional treatment or weathering. The rate of K release from minerals is influenced by factors such as soil pH, temperature, moisture, microbial activity, the reactive surface area, and the type of vegetation. Therefore, a mineral that is somewhat effective as a K source in one condition, may be ineffective in another environment.

Organic producers are encouraged to take a long term perspective on soil fertility. Crops require the essential mineral nutrients for growth. High yields of crops, regardless of the production philosophy, place a large drain on the soil reserves of K. This deficit must ultimately be replenished at some point.

### **APPROVED AND RESTRICTED POTASSIUM SOURCES**

see: USDA-National Organic Program (NOP) [http://www.omri.org/crops\\_generic.pdf](http://www.omri.org/crops_generic.pdf) and Canadian General Standards Board (CGSB) [http://www.pwgsc.gc.ca/cgsb/on\\_the\\_net/organic/032\\_0311\\_2006-e.pdf](http://www.pwgsc.gc.ca/cgsb/on_the_net/organic/032_0311_2006-e.pdf)

#### Potassium sulfate

$K_2SO_4$  is allowed if it is produced from natural sources. Much of the current production of organically approved  $K_2SO_4$  comes from the Great Salt Lake. It may not undergo further processing or purification after mining or evaporation- other than crushing and sieving. This product is not allowed in some European countries without special permission from the inspection agency.

#### Potassium Chloride

KCl is restricted in the USDA standards unless it is from a mined source (such as sylvinite) and undergoes no further processing to remove Na salts. It must be applied in a manner that minimizes chloride accumulation in the soil. Generally KCl should only be used after consultation with the inspection agency. The Canadian General Standards Board (CGSB) has included KCl on the "Permitted Substances List" for organic food production systems.

#### Greensand

Greensand is the name commonly applied to a sandy rock or sediment containing a high percentage of the green mineral glauconite. Because of its K content (up to 6%  $K_2O$ ), greensand has been marketed for over 100 years as a natural fertilizer and soil conditioner. The very slow K release rate of plant is touted to minimize the possibility of plant damage by fertilizer "burn" while the mineral's moisture retention may aid soil conditioning. However, the K release rate is too slow to provide any significant nutritional benefit to plants at realistic application rates (Heckman and Tedrow, 2004). Soluble K is <0.1% of the total K present.

#### Seaweed

Since sea water contains an average of 0.4 g K/kg, seaweed may accumulate K up to several percent of its biomass. When harvested, processed seaweed biomass can be used directly as a K source or the soluble K may be extracted. These K sources are readily soluble and typically contain less than 2%  $K_2O$ .

#### Wood Ash

Ash from hardwood trees served as one of the earliest sources of K for building soil fertility. This highly variable material is composed of whatever elements were present in the wood when it was burned. Ash is an alkaline material with a pH ranging from 9 to 13 and has a liming effect of between 8 and 90% of the total neutralizing power of lime. In terms of commercial fertilizer, average wood ash would have an analysis of approximately 0-2-5. The use of ash derived from manures, coal, and some substances is prohibited.

### Rock Powders

Mined rocks, including ballast, biotite, mica, feldspars, granite and greensand are allowed without restriction. Tremendous variability exists in the K release rate from these mineral sources. Some of them are not suitable K sources for plant nutrition.

### Manure and Compost

Since these materials are extremely variable (based on their raw materials and their handling), they also contain variable K content. Composts are allowed as a nutrient source as needed. Raw manures may have restrictions on their use, but the exact details depend on the inspection agency. The K in these materials is largely available for plant uptake.

### Langbeinite (Potassium-magnesium sulfate)

This material is allowed as a nutrient source if it is used in the raw, crushed form without any further refinement or purification. Several excellent sources of this organically approved product are available.

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