Managing Potassium for Organic Crop Production

By Robert Mikkelsen

An adequate K supply is essential for both organic and conventional crop production. Potassium is involved in many plant physiological reactions, including osmoregulation, protein synthesis, enzyme activation, and photosynthate translocation. The K balance on many farms is negative, where more K is removed in harvested crops than is returned again to the soil. An overview of commonly used K fertilizers for organic production is provided.

Potassium is an essential nutrient for plant growth, but it often receives less attention than N and P in many crop production systems. Many regions of the U.S.A. and all of the Canadian provinces remove more K during harvest than is returned to the soil in fertilizer and manure (**Figure 1**). In the U.S.A., an average of only 3 units of K is replaced as fertilizer and manure for every 4 units of K removed in crops, resulting in a depletion of nutrients from the soil and increasing occurrences of deficiency in many places.

Potassium is the soil cation required in the largest amount by plants, regardless of nutrient management philosophy.

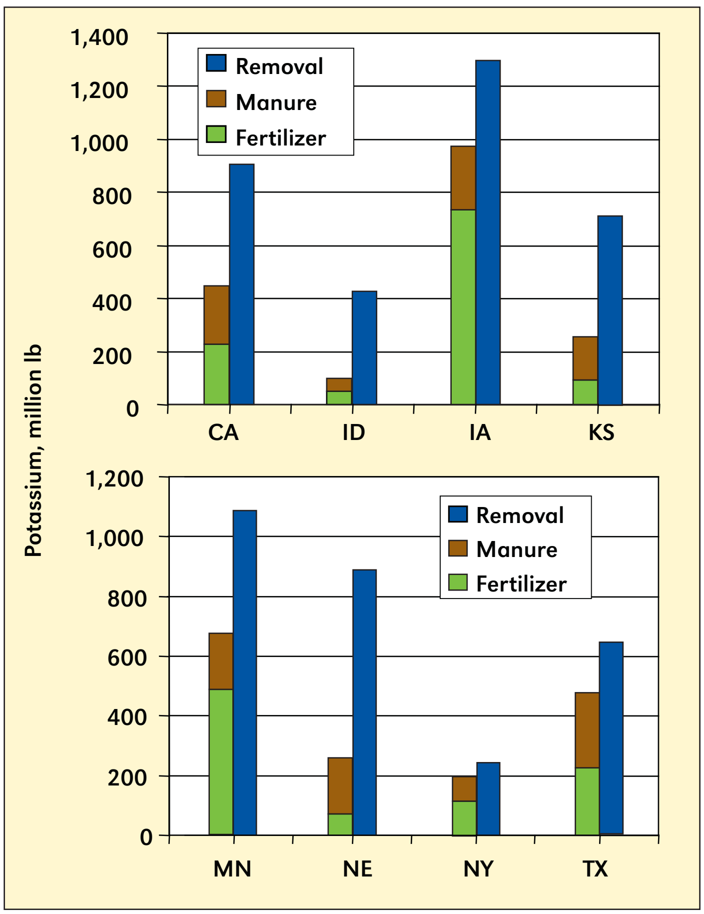

Figure 1. Annual balance of K inputs in fertilizer and recoverable manure compared with K removal in harvested crops in eight selected states: California (CA); Idaho (ID); Iowa (IA); Kansas (KS); Minnesota (MN); Nebraska (NE); New York (NY); Texas (TX).

Abbreviations and notes for this article: K = potassium; N = nitrogen; P = phosphorus; Mg = magnesium; S = sulfur.

Hay and forage crops can remove hundreds of pounds of K from the soil each year, placing a heavy demand on soil resources.

Large amounts of K are required to maintain plant health and vigor. Some specific roles of K in the plant include osmoregulation, internal cation/anion balance, enzyme activation, proper water relations, photosynthate translocation, and protein synthesis. 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 known harmful effects of K to the environment or to human health, the consequences of inadequate K can be severe for crop growth and efficient utilization of other nutrients, such as N and P. Maintenance of adequate K is essential for both organic and conventional crop production. More information and an extensive list of references are available at the website: **>www.ipni.net/organic/kreference<**.

Supplemental K is sometimes called "potash", a term that comes from an early production technique where K was leached from wood ashes and concentrated by evaporating the leachate in large iron pots. Clearly this practice is no longer practical and is not environmentally sustainable. This potash collection method depended on the tree roots to acquire soil K, which was then recovered after the wood was harvested and burned. Most K fertilizer, whether used in organic or conventional agriculture, comes from ancient marine salts, deposited as inland seas evaporated. This natural geological process is still visible in places such as the Great Salt Lake and the Dead Sea.

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 (i) work within natural systems and cycles, (ii) maintain or increase long-term soil fertility, (iii) use renewable resources as much as possible, and (iv) produce food that is safe, wholesome, and nutritious.

Which Organic Standards to Follow?

The use of approved nutrient sources is governed by a variety of regional, national, and international oversight organizations. Each organization maintains somewhat different standards and allows different materials to be used in their organic production systems as they individually interpret the intent of organic agricultural principles. As a result, a grower seeking advice on permissible 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 solid 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.

Using On-Farm Resources

There are many variations possible for successful K management in organic production systems. 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 that receive manure. Large losses of K may 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.

Crop rotations are a central part of organic production systems. While this practice can be helpful for supplying N when legume crops are included and may also reduce K leaching losses, rotations alone do not supply any additional K to the farm. Plant roots have been shown to enhance soil mineral weathering by depleting rhizosphere K and causing a shift in the K equilibrium. This shift can speed natural processes and enhance the rate of clay transformations. Subsoil K reserves may be important for some crop rotation systems where deep-rooted plants can extract K which may be subsequently used by shallow-rooted crops. While rotational crops may influence the availability of existing soil K, the removal of any plant material from the field continually depletes the soil nutrient supply and ultimately reduces 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. 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, and the root distribution pattern of the specific crop. Soil testing done near the soil surface will not account for this subsoil contribution to the K supply.

Table 1. Average K removal in the harvested portion of some common agronomic and horticultural crops (International Plant Nutrition Institute, 2007; Natural Resources Conservation Service, 2007).

Crop	Scientific name	K removal, lb K/ton
Alfalfa	*Medicago sativa*	45
Almond	*Prunus dulcis*	100
Corn grain	*Zea mays*	8
Corn silage	*Zea mays*	7
Potatoes	*Solanum tuberosum*	10
Spinach	*Spinacia oleracea*	11
Squash	*Cucurbita pepo*	10
Rice	*Oryza sativa*	8
Tomatoes	*Lycopersicon esculentum*	6
Wheat	*Triticum aestivum*	10

Moisture is based on marketing conventions.

Potassium Balance

Since off-farm sales will always lead to a removal of K and additional loss of K through leaching and runoff is inevitable, the potential of a cropping management system to replenish the K reserve is important. The use of farm budgets is useful for describing the nutrient flow within a farming system and to assist with nutrient planning for long-term rotations and mixed farming systems. Depending on a variety of factors, the on-farm budgets of N, P, and K on organic farms have been shown to range from a surplus to a deficit.

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 growing

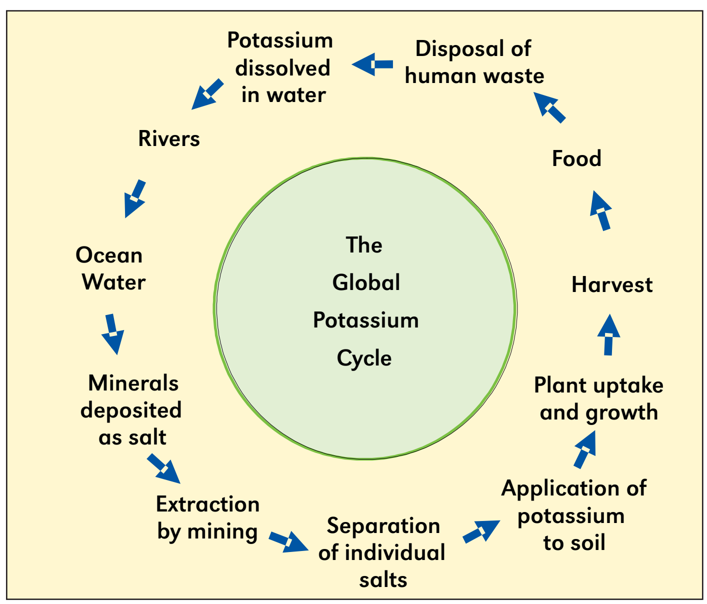

Figure 2. The global K cycle.

plants. 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.

Potassium Release from Soil Minerals

The most common mineral 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.

Crushed rocks and minerals have been evaluated as K sources in many 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.

Some soil minerals may 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. Non-exchangeable K should not be confused with mineral K, since non-exchangeable K is held between adjacent tetrahedral layers of clay, instead of being covalently bonded in mineral crystal structures.

Potassium Sources for Organic Production

Regular applications of soluble K, regardless of the source, will increase the concentration of K in the soil solution and the proportion of K on the cation exchange sites. All of the commonly used soluble 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 readily available forms of K, the overall goal of replacing the harvested K is generally 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 chloride (Cl^-) or sulfate (SO_4^{2-}) or the organic matter that may accompany the added K.

There is no general evidence that potassium sulfate (K_2SO_4) is more effective than potassium chloride (KCl) as a source of plant-available K, and both SO_4^{2-} and Cl^- provide essential 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 a well-documented 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) and the addition of K decreased the harmful effects of salinity on soil microbial activity (Okur et al., 2002).

Organic production frequently occurs on smaller-sized farms where the use of organically approved K sources is feasible for maintaining soil fertility.

Approved and Restricted Potassium Sources

The National Organic Program in the U.S. and the Canadian General Standards Board classifies products as either allowed, restricted, or prohibited for use in organic production. Allowed products are permitted for organic production when applied as directed on the label. Restricted materials can only be applied for certain uses and under specific conditions. Prohibited products may never be used for organic production. The properties and value of these materials as sources of plant nutrients vary considerably. The following K sources are used sometimes for organic production.

Greensand has a very slow K release rate, which limits its nutritional benefit.

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 5% K), greensand has been marketed for over 100 years as a natural fertilizer and soil conditioner. The very slow K release rate of greensand 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. Soluble K is generally <0.1% of the total K present. Deposits of greensand are found in several states (including Arkansas and Texas), but the only active greensand mine in North America is located in New Jersey.

Langbeinite (Potassium-magnesium sulfate) This material ($K_2SO_4 \cdot MgSO_4$) 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 approved product are available for use with organic crop production. Langbeinite typically contains 18% K, 11% Mg, and 22% S in forms readily available for plant uptake. The major source of langbeinite in North America is from underground deposits in New Mexico.

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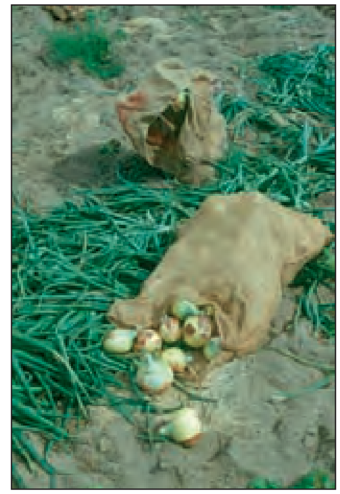
Manure and Compost Since these organic materials are extremely variable (based on their raw materials and their handling), they also contain highly variable K concentrations. Composted organic matter is generally allowed as a nutrient source. Raw manures have restrictions on the timing of their use, but the details depend on the certifying agency. The K in these organic materials is largely available for plant uptake, similar to approved inorganic sources. Repeated applications of large amounts of manure can result in K accumulation in the soil, which may lead to luxury consumption of K by the plant. A chemical analysis of the manure or compost composition is necessary in order to use these resources for maximum benefit. It may be helpful to consider where the compost or manure K is coming from, since neither composting nor animal digestion produces any nutrients.

Potassium Sulfate When K_2SO_4 is derived from natural sources, it is allowed for organic crop production. Much of the current production of organically approved K_2SO_4 in North America comes from the Great Salt Lake in Utah. 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 certifying agency. It generally contains approximately 40% K and 17% S.

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 wholly unsuitable as K sources for plant nutrition due to their limited solubility and their heavy and bulky nature, while others may have value over long periods of time. In general, a smaller particle size translates to a greater surface area, reactivity, and weathering rate. Obtain information for specific rock materials before using.

Seaweed Since sea water contains an average of 0.4 g K/L, seaweed may accumulate up to several percent K. When harvested, 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 that 2% K. While seaweed-derived products are excellent K sources, their low K content and high transportation costs can make it problematic for field-scale use, especially far from the harvesting area.

Sylvinite (Potassium Chloride) KCl is restricted in the USDA standards unless it is from a mined source (such as sylvinite) and undergoes no further processing. It must be applied in a manner that minimizes Cl accumulation in the soil. Generally, KCl should only be used after consultation with the certifying agency. The Canadian GSB has included KCl on the "Permitted Substances List" for organic food production systems. Unprocessed sylvinite often contains approximately 17% K.



Production of high quality crops is sustained with attention to proper soil nutrition.

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 the elements initially present in the wood which were not volatilized when burned. Wood 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 value of commercial limestone. In terms of commercial fertilizer, average wood ash would have an analysis of approximately 0% N, 1% P, and 4% K. The use of ash derived from manures, biosolids, coal, and some substances is prohibited for organic production. Check with the certifying organization prior to applying ash to soil.

Conclusions

Growers using organic production practices, like all growers, have need for an adequate supply of soil K to sustain healthy and high-yielding crops. There are many excellent sources of K that are available for replacing the nutrients removed from the soil in harvested crops. Failure to maintain adequate K in the rootzone will result in poor water use efficiency, greater pest problems, decreased harvest quality, and reduced yields. Regular soil testing for K is the key for establishing the requirement for fertilization. If a need for supplemental K exists, organic producers generally should first consider locally available K resources and supplement with mineral sources. The expense of transporting and applying low nutrient content amendments must also be considered. BC

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For more information and a list of references, visit the website at **>www.ipni.net/organic/kreferences<**.

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