

# Potassium a Nutrient Essential for Life



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ISBN 978-3-905887-11-2  
DOI 10.3235/978-3-905887-11-2

# Potassium a Nutrient Essential for Life



ALCHEMICAL SYMBOL OF **POTASSIUM**

19
<b>K</b>
POTASSIUM
39.0983

NAME: **POTASSIUM**  
SYMBOL: **K**  
ATOMIC NUMBER: **19**  
ATOMIC WEIGHT: **39**  
GROUP NAME: **ALKALI METALS**

Discovered in 1807 by Sir Humphry Davy in England. From the English word *potash* (pot ashes) and the Arabic word *qali* meaning alkali. The origin of the symbol K comes from the Latin word *kalium*.

# Potassium a Nutrient Essential for Life



## **POTASSIUM** - A NUTRIENT ESSENTIAL FOR LIFE

Potassium is one of the key elements for life on earth. It is required in large quantities by all plants and animals and is obtained by plants from the soil in which they grow. Animals obtain their potassium from plants, either directly or by eating other animals (and animal products) which have fed on plants.

The harvesting of plant materials, such as grains, fruits or foliage, removes from the field the potassium they have taken up from the soil. As the global population and food production has grown, so the total amount of potassium removed from farmland has also increased, and this has to be replaced to maintain the fertility and productive capacity of the soil. This replenishment plays a vital role in supporting sustainable global food security.

A proportion of this replacement potassium is provided by recycled manures and crop residues on farm. However the greater part of the potassium in the human food produced on farm is not returned, but is effectively lost to the ocean from the sewerage systems of the world's towns and cities. This non-recycled potassium is replaced by the use of potassium fertilizers on the fields which originally produced the food.

### Origins of production and measurement

Before the beginning of the 20<sup>th</sup> century potassium was mostly derived from the ashes of trees leached in metal pots, giving rise to the term *potash*, although much of this leached potassium salt was used in the manufacture of soap, needed particularly for washing wool fleeces. This word *potash* is now almost universally used when referring to potassium fertilizers.

The requirement for potassium by plants was discovered through the mineral analyses of the ash of plants, and from the early days the potassium content of fertilizers was measured in terms of the oxide of potassium,  $K_2O$ . This often causes confusion, because in fact this oxide is rarely if ever present in fertilizers. This leaflet is primarily discussing potassium in the context of fertilizers, so for consistency  $K_2O$  is generally used throughout to describe quantities, rather than the alternative K, which is used only occasionally<sup>1</sup>.

<sup>1</sup> To convert  $K_2O$  values to K, multiply by 0.83. To convert K values to  $K_2O$  divide by 0.83.

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## HOW MUCH POTASSIUM IS NEEDED BY HUMANS?

The average quantity of potassium in the human body is about 140 grams of K, which is equivalent to a total of about 1 Mt  $K_2O$  (Mt = million tonnes) in the total global population of 7 billion people. However the body requires a daily supply of potassium with recommended amounts equivalent to an intake of about 2 kg  $K_2O$  per person per year, and a similar quantity is voided. Thus the total recommended annual intake for the global population is about 14 Mt  $K_2O$ . Considering the tendency for increased consumption of potassium-rich fruit and vegetables and the inefficiencies in the food chain, the quantity of potash leaving the world's farms could be at least double this figure. Such an estimate is supported by a calculation of the quantities of potash involved in the annual transfer from farm to consumer. Table 1 shows an estimate of the potash contained in the annual global production of some major crops and foodstuffs.

*Table 1. Estimated annual removal of potash ( $K_2O$ ) in the harvest of the 10 agricultural products (crops and milk) with the greatest output, excluding grass, forage/fodder crops and meat.*

Commodity	FAO global production estimate	Estimated quantity of $K_2O$ in products
	Mt	Mt
Soybeans	261.6	5.0
Sugarcane	1,685.4	4.7
Maize, grain	844.4	4.2
Vegetables, fresh	1,036.3	4.0
Wheat, grain	650.9	3.6
Rice, paddy, grain	672.0	2.2
Potatoes	324.2	1.9
Fruit	602.9	1.5
Cow milk, whole, fresh	599.4	1.1
Barley, grain	123.5	0.7
<b>TOTAL</b>		<b>28.9</b>

Table 1, which excludes the potash in grass, forage/fodder crops and meat products, indicates an annual flux of potassium in harvested crops of about 29 Mt  $K_2O$ . If meat products were to be included, the total flux could be well in excess of 35 Mt  $K_2O$  per annum.

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## HOW MUCH POTASSIUM IS NEEDED BY PLANTS?

Despite the very large quantities of potassium which are contained in harvested crops (Table 1), the amount required by the crops when they are growing is even larger. In almost every case, the quantity of potassium in a crop is far greater than any other nutrient, including nitrogen.

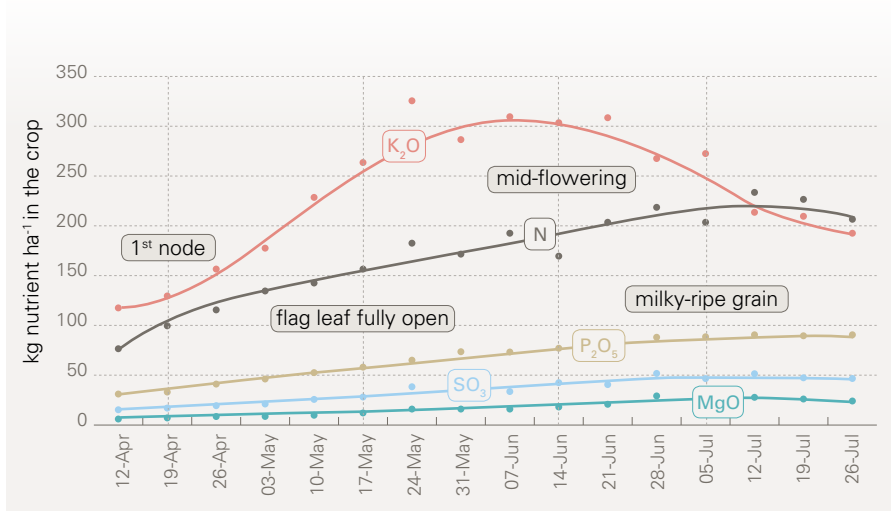
Potassium plays a major role in the ability of plants to tolerate externally induced stress, such as drought, frost, high light levels and attack from pests and disease. Crops which are potassium deficient are more likely to suffer from the effects of these stresses, whereas yields of well-fertilized crops will be much less affected. Potassium is also essential for many of the major plant functions, including enzyme activation, protein production and photosynthesis and is found throughout the plant.

By far the largest proportion of the potassium in plants is in the cell sap, where it ensures that the cells of the plant are rigid and under pressure from the water absorbed into the cell by osmosis. In effect, this *water* contained in plant cells is



a potassium solution, with a general concentration of up to about 7.8 g K liter<sup>-1</sup> of water. This concentration would be equivalent to about 9.5 kg K<sub>2</sub>O per tonne of tissue water; a high biomass crop may often contain more than 60 tonnes per hectare of tissue water.

Even at lower concentrations of potassium, it is evident that the growing crop can contain very large quantities, frequently in excess of 300 kg K<sub>2</sub>O ha<sup>-1</sup> (see Fig. 1). This quantity is considerably more than the recommended fertilizer dressing for most crops, except those harvested at maximum biomass such as green vegetables and grass for silage, because much of this potassium in the tissue water is returned to the soil as the plant senesces and dries out or it is retained in the straw. Relatively little is removed at harvest in cereal grain; this actual removal determines the standard fertilizer recommendation. Plants have a high demand for potassium while they are growing and this must be available from the reserves in the soil.



**Fig. 1.** Accumulation of nutrients per hectare in a wheat crop, showing the high requirement for potassium (N = nitrogen, P<sub>2</sub>O<sub>5</sub> = phosphate, K<sub>2</sub>O = potash, MgO = magnesium, SO<sub>3</sub> = sulphur). Source: PDA (2012; from SCPA & MAP data, France); [www.pda.org.uk/news/nf76.php](http://www.pda.org.uk/news/nf76.php).

## Potassium a Nutrient Essential for Life

An adequate supply of potassium is indispensable to the quality of the harvested crop. Potassium is key to many transport and other processes within the plant and a deficiency during growth will reduce the efficiency of these, and adversely affect crop performance and output quality. A reduction in the transport of assimilates to the grain, with its negative effect on both yield and quality, is an example of the effects of potassium deficiency, as indicated in Fig. 2.



*Plate 1. Effect of potassium on wheat. Experiment at farmers' fields. IPI project in Bhondsi, Haryana, India. Source: IPI Coordination India. 2001.*



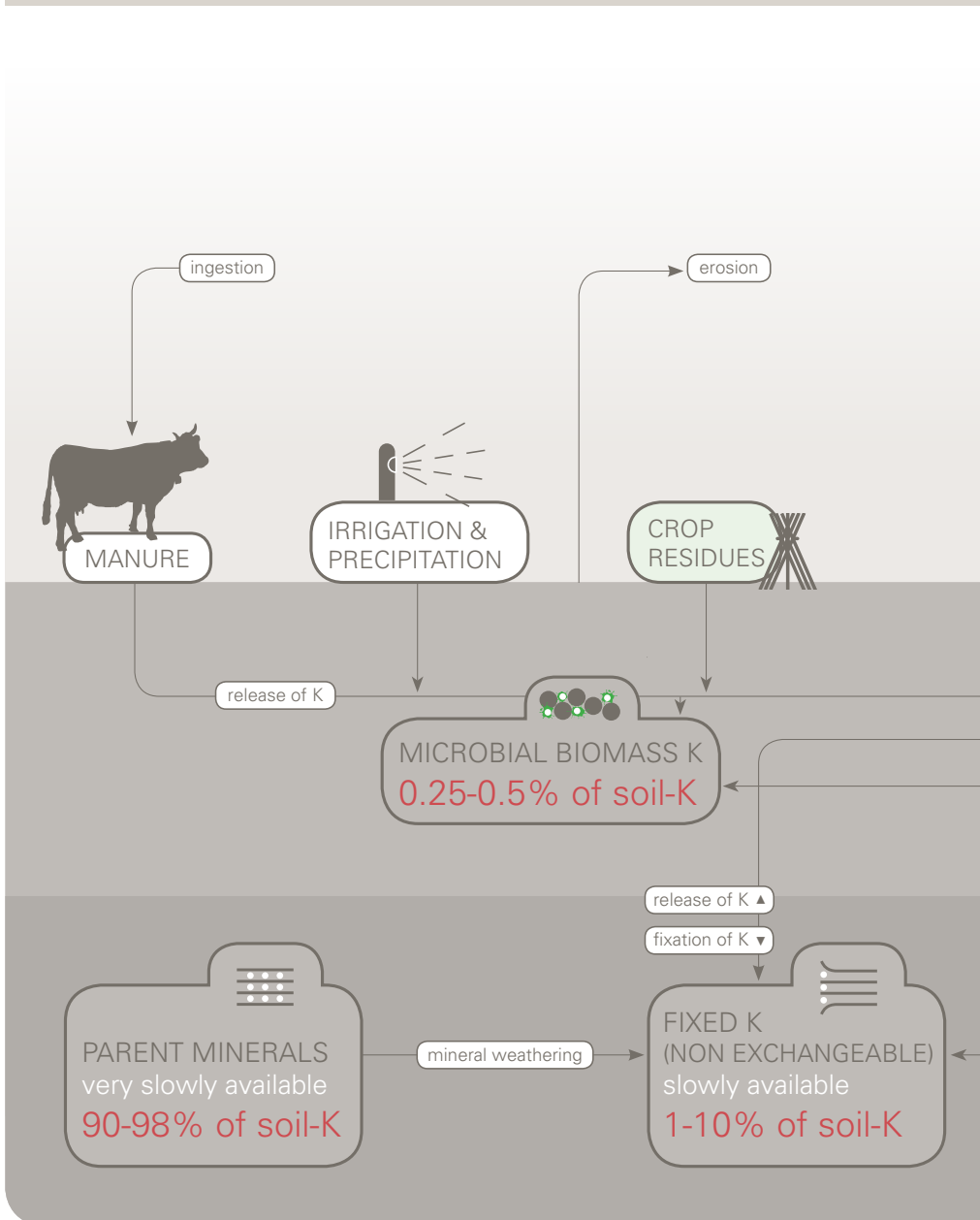
*Plate 2. Typical potassium deficiency symptoms in groundnut. Courtesy of Ch. Srinivasa Rao, CRIDA, Hyderabad, India.*

## **POTASSIUM DEFICIENCY AND ITS SYMPTOMS**

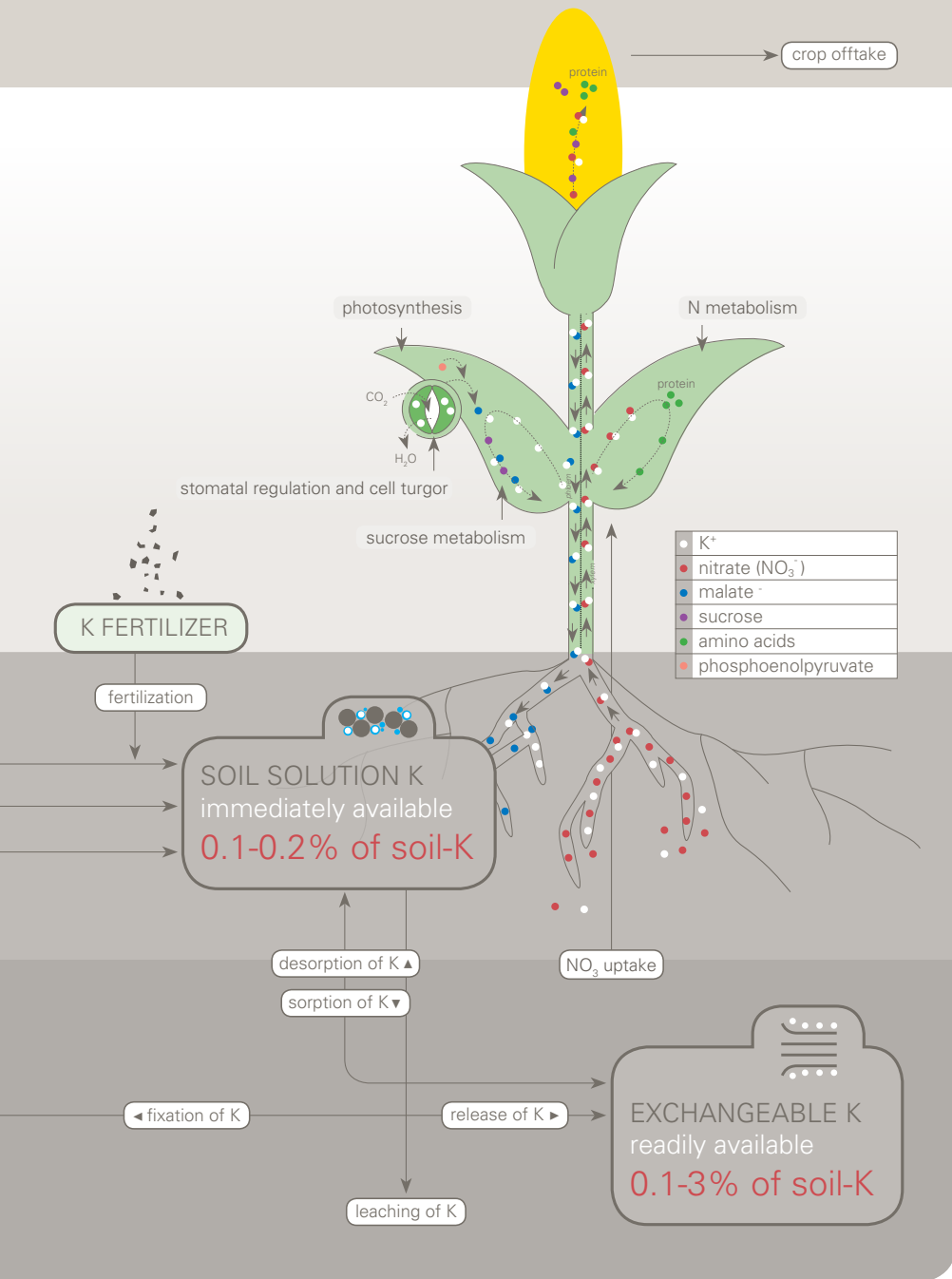
Potassium deficiency symptoms are often seen as necrosis of the leaf tips or margins, as illustrated above in groundnuts (Plate 2). However crops can be deficient in potassium without there being any visible symptoms; this effect is commonly referred to as *hidden hunger* (see Fig. 3). If visible symptoms of potassium deficiency are seen, there will be significant effects on the crop yield and quality; these effects could perhaps be reduced by the immediate application of potash fertilizer to the crop but they cannot be fully corrected.

The symptoms of stress caused by potassium deficiency can often be seen, even though the plant does not itself appear deficient. Plate 3 shows maize leaves from non-deficient (+K) and deficient (-K) plants, with the deficient leaf showing the classic *rolling* associated with drought stress, exacerbated by potash deficiency.

FIG 2. SCHEMATIC OF **POTASSIUM IN SOIL AND PLANT SYSTEMS**



Sources: Marschner et al., 1996 (based on)



Benzioni et al., 1971 and Kirkby and Knight, 1977); Syers, 1998; Krauss, 2003; Pettigrew, 2008; Römheld and Kirkby, 2010.

# Potassium a Nutrient Essential for Life

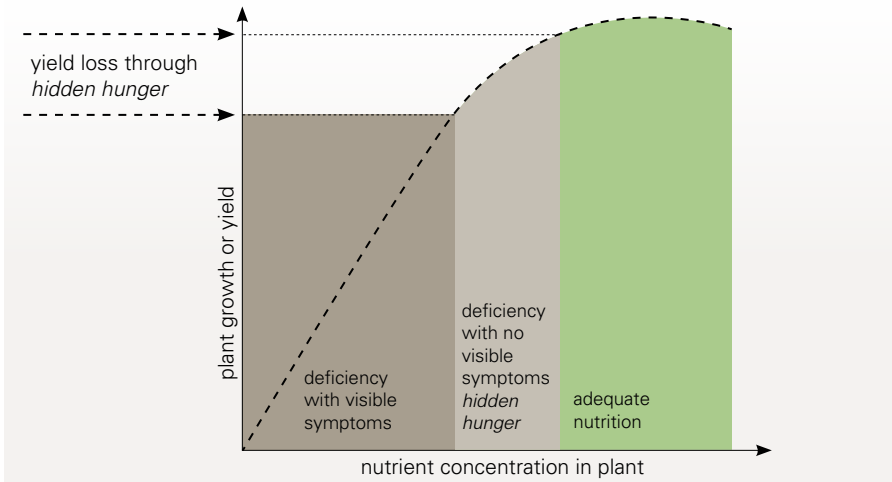


Fig. 3. Illustration of the effect on yield or growth of a potassium deficiency, with and without visible symptoms.

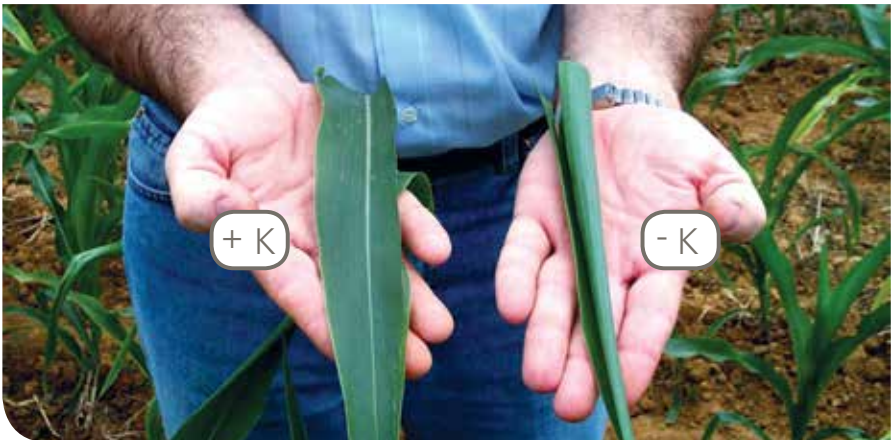


Plate 3. Drought stress in maize leaves is not visible when K is applied to the crop.



## POTASSIUM IN THE SOIL

Soils have to be *fertile* to be productive, whether that means producing forest, grassland or agricultural crops. Fertile soil has the ability to hold reserves of many available essential plant nutrients, including potassium. This nutrient retention depends on the clay and organic matter in soil; potassium does not leach except to some extent from very sandy soils. The reserve of potassium provides a secure store which is available to the crop as it grows.

However, the harvesting and removal of crops from the field will also remove the nutrients they contain, so depleting the soil reserve (also called *soil mining*). An adequate reserve of potassium in the soil is necessary because of the large quantities required by the growing crop, and the function of potash fertilizers is to replenish this soil reserve (Fig. 2).

The quantity of potassium which is available in a soil can be determined by laboratory analysis of the soil. This is a standard procedure in good farming practice, and helps to inform the farmer of the quantity of potash fertilizer or manure which is required to ensure that his crops will not be deficient.

# Potassium a Nutrient Essential for Life

## POTASSIUM PRODUCTION AND RESERVES

It is clear that the scale of production and usage of potash fertilizers is both large and necessary. An annual global estimate of production and reserves is produced by the US Geological Survey (USGS) as shown in Table 2.

*Table 2. Potash ( $K_2O$ ) production and reserves in current sources by producing country. Source: USGS 2012; <http://minerals.usgs.gov/minerals/pubs/commodity/potash/mcs-2011-potas.pdf>.*

	Production in 2010	Production in 2011	Reserves
	kt $K_2O$		
Canada	9,788	11,200	4,400,000
Russia	6,280	7,400	3,300,000
Belarus	5,250	5,500	750,000
Brazil	453	400	300,000
China	3,200	3,200	210,000
Germany	3,000	3,300	150,000
United States	930	1,100	130,000
Chile	800	800	130,000
Israel	1,960	2,000	40,000
Jordan	1,200	1,400	40,000
United Kingdom	427	430	22,000
Spain	415	420	20,000
Other countries	-	-	50,000
<b>World total (rounded)</b>	<b>33,700</b>	<b>37,000</b>	<b>9,500,000</b>

The reserves indicated in Table 2 are those which are known to exist in the sources which are currently operational. At the current rate of extraction these are likely to continue to produce for about 250 years. However, in part because the cost of production would not be economical at today's prices, there are many potash resources which are not currently in production. It is estimated that these could contain about 250 billion tonnes; this quantity could provide a supply for about 5,000 years. In addition, the potassium content of seawater is significant at about



400 ppm, meaning that about 2,000 tonnes of seawater would yield about 1 tonne of  $K_2O$ . As desalination plants producing drinking water become more widespread, it is likely that the minerals in seawater, including potassium, could become a by-product of the process. It is clear that there is no global shortage of potassium, but it is still appropriate that the potassium in the harvested produce and livestock which leaves the world's farms should be recycled back to the land where feasible.



*Plate 4. Potash storage and handling before shipping.*





## POTASSIUM AND THE ENVIRONMENT

The earth's crust and its soils contain on average about  $2,000 \text{ mg kg}^{-1}$  of potassium (equivalent to approximately  $2,400 \text{ mg K}_2\text{O kg}^{-1}$ ). While perhaps about 5% of this may be available for uptake by plants at any time, very little is in solution in the soil, and even less is liable to be leached through the soil by rainfall. Relatively high levels of potassium in soils do not have any deleterious effect on soil quality and biodiversity, and the level in rivers rarely approaches  $10 \text{ mg K liter}^{-1}$ . Potassium is essential for plant and animal health, and there are no known adverse effects on human health or the environment from levels very much higher than those commonly found in rivers and farm soils. However a negative environmental effect associated with potassium can arise where a shortage of this major nutrient in the soil leads to the inefficient use of nitrogen due to an imbalanced nutrient supply.

The maintenance of a sufficient reserve of available potassium in the soil is not just to avoid the direct negative effects of a shortage of potassium in the crop, but is also essential to ensure efficient recovery and utilization of other nutrients. This is particularly the case for the nutrient nitrogen, even if the correct recommended rate of nitrogen is applied. If the soil, and therefore the crop, is potassium deficient, the efficient recovery and utilization of the nitrogen will be severely impaired. This will have a negative effect on the profitability of the crop, and also will mean that unused nitrogen remains in the soil and becomes liable to loss through leaching or other pathways.

# Potassium a Nutrient Essential for Life

## POTASH FERTILIZERS

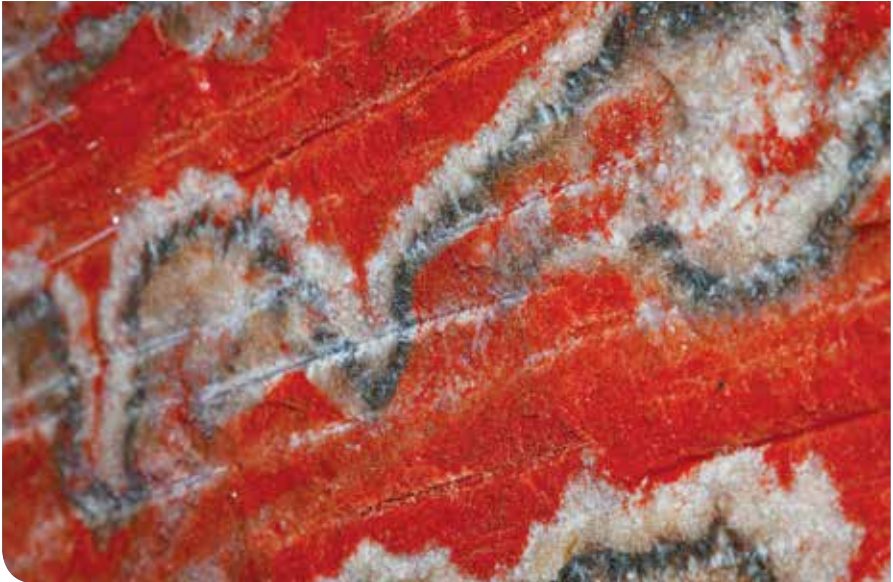
While potassium-containing farm manures and crop residues are applied to fields where available, they are not an actual *source* of potassium, but rather are the system for recycling existing potassium on the farm. As harvested crops are sold off the farm, so the potassium they contain has to be replaced, as was observed by Justus von Liebig in 1840. This replacement is effected in part by recycling back to the farm potash-containing wastes such as composts and anaerobic digestate, and by potassium in irrigation water, but principally replacement is by the use of potash fertilizers.

### Muriate of potash (MOP), potassium chloride, KCl

The majority of potash fertilizer used by farmers is in the form of potassium chloride (muriate of potash). The reserves of potash being mined are the deep residues of dried-out pre-historic seas. As with seas which are currently drying and where the brine is being used as a source of potash – such as the Dead Sea in Israel and the Qinghai Salt Lake in China – the potassium chloride is in association with sodium chloride. Most of the sodium chloride found in brines can be precipitated, and in mined ores crushing and physical separation using flotation techniques are used to remove almost all the sodium chloride. In both processes, the fine crystals of potassium chloride are often compacted and re-crushed to provide a granular fertilizer which can be spread accurately by farmers. The fine crystal product is used in the manufacture of complex fertilizers, and is also further purified to produce a product suitable for use in solution fertilizers, for industry and for use in low-sodium table salt.

### Sulphate of potash (SOP), potassium sulphate, $K_2SO_4$

In areas with low rainfall, the chloride in the standard fertilizer product can accumulate and give rise to some salinization of the soil; in these situations sulphate of potash is the preferred fertilizer. This source of potash does not occur widely in nature and the majority is manufactured from potassium chloride in a process which uses sulphuric acid – the Mannheim Process. Potassium sulphate contains less potassium than potassium chloride, with the former containing an equivalent 50%  $K_2O$ , compared with the 60%  $K_2O$  equivalent in fertilizer grade potassium chloride.



*Plate 5. Ore containing K in deep layers of a potash mine in Russia.*

### Other potash-containing minerals

There are many other naturally occurring potash-containing minerals, including kainite, schoenite and polyhalite, as well as the sylvinitic ore from which most muriate of potash is extracted, and some natural sources of potassium sulphate. Many of these ores contain other plant nutrients such as magnesium and sulphur, as well as sodium chloride. Most of these minerals have approval for use in organic farming, where a need for them has been determined.

### Nitrate of potash (NOP), potassium nitrate, $\text{KNO}_3$ ; Mono-potassium phosphate (MKP), $\text{KH}_2\text{PO}_4$

These fertilizer materials are usually manufactured from potassium chloride and nitric or phosphoric acids, and are speciality sources of nutrients. They are commonly used where these nutrients are supplied in irrigation water (fertigation), for example in horticulture.

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## REFERENCES

- Benzioni, A., Y. Vaadia, and H.S. Lips. 1971. Nitrate Uptake by Roots as Regulated by Nitrate Reduction Products of the Shoot. *Physiol. Plant* 24:288-290.
- Kirkby, E.A., and A.H. Knight. 1977. Influence of the Level of Nitrate Nutrition on Ion Uptake and Assimilation, Organic Acid Accumulation, and Cation-Anion Balance in Whole Tomato Plants. *Plant Physiol.* 60(3):349-353.
- Krauss, A. 2003. Assessing Soil Potassium in View of Contemporary Crop Production. Regional IPI-LIA-LUA Workshop on Balanced Fertilization in Contemporary Plant Production, Kaunas-Marijampol, Lithuania, 30 September – 1 October 2003.
- Marschner, H., E.A. Kirkby, and I. Cakmak. 1996. Effect of Mineral Nutritional Status on Shoot-Root Partitioning of Photoassimilates and Cycling of Mineral Nutrients. *J. Exp. Bot.* 47:1255-1263.
- Pettigrew, W.T. 2008. Potassium Influences on Yield and Quality Production for Maize, Wheat, Soybean and Cotton. *Physiol. Plant.* 133(4):670-681.
- Römheld, V., and E.A. Kirkby. 2010. Research on Potassium in Agriculture: Needs and Prospects. *Plant and Soil* 335(1-2):155-180.
- Syers, J.K. 1998. Soil and Plant Potassium in Agriculture. Proceedings No. 411. International Fertiliser Society, York, UK. 32 p.
- The Potash Development Association. 2011. Potassium Uptake Requirements of Some Crops. [www.pda.org.uk/news/nf76.php](http://www.pda.org.uk/news/nf76.php).
- U.S. Geological Survey. Mineral Commodity Summaries. 2011. <http://minerals.usgs.gov/minerals/pubs/commodity/potash/mcs-2011-potas.pdf>.



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