SOURCES OF POTASSIUM

by

R. Kunkel, N. M. Holstad, W. H. Gardner

Functions of Potassium

Potassium is essential for plant growth. This has been known for many years. The various functions of potassium in the plant are, nevertheless, not well understood because it is not known to be chemically combined in any plant compound. Potassium appears to be necessary for (1) synthesis of simple sugars and starch, (2) translocation of carbohydrates, (3) reduction of nitrates, (4) synthesis of proteins particularly in meristems, (5) normal cell division, (6) opening and closing of the stomata, (7) maintenance of permeability of cytoplasmic membranes, and (8) hydration of protoplasm.

The bulk of the potassium is normally absorbed by a plant during the earlier stages of growth. It remains in an inorganic form and is readily transported from one part to another throughout the life of the plant. Older leaves and organs frequently lose potassium to growing regions. Potassium is generally the most abundant univalent cation in plant cells. In the absence of potassium in some plants, cells tend to elongate but do not divide. Potassium is absorbed from the soil in quantities far in excess of the amounts believed necessary for physiological processes. The tendency to absorb such excessive quantities of potassium has perplexed many plant physiologists. Although much of the role of potassium has been discussed in the literature, its importance to water relations within plants in high temperature, low humidity areas like Washington's Columbia Basin, has not been adequately stressed.

Since potassium is not chemically combined to any extent into any organic compounds within the plant, it remains in ionic form in the vacuole of the cell and is therefore osmotically active. This activity enables the plant roots to extract water from the soil and to resist dessication of the leaves. The symptoms of potassium deficiency, commonly observed in the Columbia Basin, are those also commonly associated with water deficits such as shown in table 1.

Table 1. Similarities between potassium and water deficits within a potato plant.

Potassium	Water
Low turgor pressure	Low turgor pressure
Cell division	Cell division
Stomate opening	Stomate opening
Dark green foliage	Dark green foliage
Tissue necrosis	Tissue necrosis
Leaf margin scorch	Leaf margin scorch
Shedding lower leaves	Shedding lower leaves
Reduced yield	Reduced yield
High dry matter tubers	High dry matter tubers
Blackspot tubers	Blackspot tubers

Without adequate water, cell turgor is lacking, and without cell turgor there is no cell division. Potassium is known to be associated with the opening and closing of the stomata, which is also turgor pressure related. Hence, it is not unreasonable to conclude that potassium functions as a nutrient and also as a water regulator.

Potassium may play a greater role in hot, dry areas where, even with adequate water in the rooting zone, temporary stress conditions could exist in parts of a plant. Cells in growing tissues are bathed in a water solution in the cell wall and intercellular space. Their turgor depends upon the osomotic pressure of the cell contents with respect to that of the outside solution. For growth and proper functioning of the cell, a positive pressure or turgor pressure must exist within the cell. Increase in the osmotic pressure outside of the cell by, say, rapid water loss through transpiration, would create an osmotic gradient across the cell wall. Water would move out of the cell and turgor would be reduced. Restoration of water surrounding the cell would lead to return water flow across the cell membrane and restoration of turgor within the cell. A high concentration of potassium (K^+ and an accompanying anion) within the cell could, by virtue of an associated high osmotic pressure, prevent or delay water flow out of the cell and loss of turgor. High osmotic pressures in all plant solutions, inside or outside of cells, would retard water loss from the plant for similar reasons. Thus, high levels of potassium within a plant would have a buffering effect against water loss and loss of turgor. Doubling the amount of K in a cell roughly doubles the osmotic pressure with significant improvement in the water retention of the tissue.

The magnitude of osmotic pressure increase which could result from the presence of high levels of potassium may be computed. Osmotic pressures may be measured in bars (a unit of pressure approximately equal to the pressure of the atmosphere, 1 bar = 1 atmos). The osmotic pressure of the cell sap of leaf tissue with little or no potassium present might be taken as about 4 bars. Increasing the potassium content of leaf tissues would increase the osmotic pressure to as much as 8 bars, a reasonable figure based upon field measurements of potassium in the leaf system. Such a 4-bar difference would be sufficient to support a column of water about 40 meters high (ca 130 ft). Such an osmotic pressure in plant tissues would exert a measureable effect upon maintaining turgor necessary for maximum plant growth and tuber quality.

Sources of Potassium

There are four common sources of potassium: potassium chloride, also known as muriate of potash; potassium nitrate; potassium sulfate, also known as sulfate of potash; and sulfate of potash-magnesia. Some of the new, highly water soluble potassium polyphosphates are good sources of potassium but are not generally available in the Columbia Basin. Each of these sources has some advantages and disadvantages. The four common sources with their K content and salt index are listed in table 2.

Table 2. Sources of potassium, percentage compositions and their salt indices.

		Salt Index	
Material	% K	Per equal[1] weights	Per 20 lbs.
Potassium chloride	49.8	116.3	1.936
Potassium nitrate	38.7	73.6	1.219
Potassium sulfate	44.8	46.1	0.853
Sulfate of potash-magnesia	18.2	43.2	1.971

[1]basis is $NaNO_3$ = 100

Potassium chloride contains the highest percentage of potassium and the highest salt index. The higher salt index, however, would not normally be considered serious unless water becomes limiting and the amount of potassium chloride applied was large.

All three potassium sources are the salts of strong bases and strong acids. Therefore, the reactions in the soil are similar. The positively charged K^+ ions are adsorbed onto the surfaces of the negatively charged soil colloids, and under ordinary circumstances they do not leach or move to any great extent in the soil. The Cl^-, NO_3^-, and $SO_4^=$ ions are negatively charged and are repelled by the negatively charged colloids. They, therefore, move readily through the soil in the direction of the moving water. The sources, the formulas, and the solubilities of potassium are shown in Table 3.

Table 3. Sources of potassium, their formulas and their solubilities.

Material	Formula	Parts in 100 parts of water*
Potassium chloride	KCl	28
Potassium nitrate	KNO_3	13
Potassium sulfate	K_2SO_4	8

*Solubilities of some potassium fertilizer chemicals in pure water at 32°F.

All the negatively charged ions are essential for growth. The Cl^- ion being required in the least amounts and the NO_3^- ion in the greatest amount. There is some evidence that excessive amounts of $SO_4^=$ ions in the plant may reduce yields. Potassium chloride is the most soluble. Therefore the Cl^- ion would have the greatest tendency to produce a "salt effect" and would also be the most likely to leach from the soil, whereas the $SO_4^=$ ion combines with the Ca^+ ion from limestone to form a sparingly soluble calcium sulfate.

Plant Response

Potato growth studies conducted over a period of years comparing potassium chloride, sulfate, and nitrate as potassium sources have failed to show a consistent difference in yield and quality factors, or nutrient intake among the three sources (table 4). In these studies, as in the source of nitrogen studies, the nitrate nitrogen content in the petioles was slightly higher where potassium sulfate was used. The total nitrogen content, however, was about the same or perhaps slightly less than when potassium chloride was used. This suggested that the nitrates were higher when potassium sulfate was used because the nitrates were not being converted to other forms of nitrogen. When nitrogen is available and growth is restricted, regardless of the cause, nitrates begin to accumulate. This explanation for the higher nitrates in the petioles of the potassium sulfate fertilized plants agrees with the negative correlations found among sulfate-sulfur and yield.

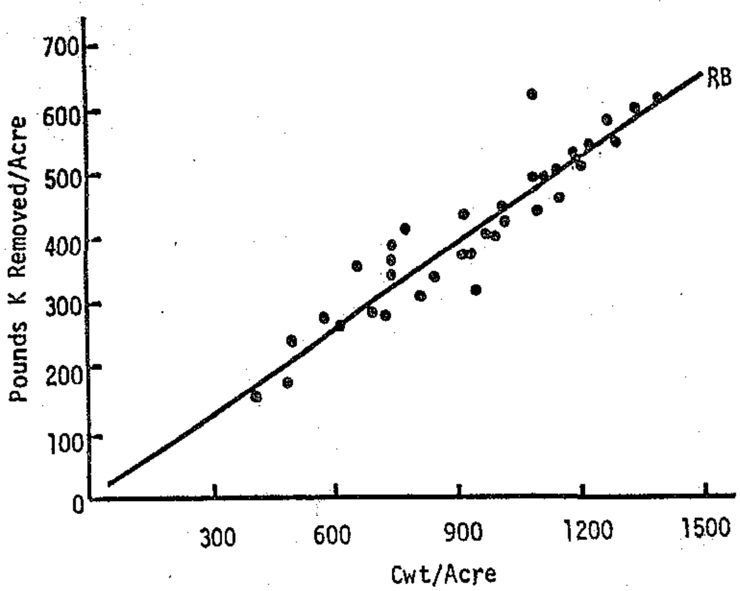
Translocation and Amount of Potassium

The amount of potassium needed is closely related to the size of the crop produced (Fig. 1). This, in turn, is closely correlated with the length of the growing season. The concentration of potassium in the tubers, expressed as a percentage of the dry matter, is relatively constant, regardless of the amount applied in the fertilizer. Large tuber yields remove large quantities of potassium from the soil, (about .44 lbs. of potassium per hundredweight of tubers). The relationship between the pounds of potassium in the vines and pounds in the tubers has not been discussed previously by me.

Table 4. Effects of sources of potassium on some important factors in the Russet Burbank potato variety.

			KCl	K_2SO_4	KNO_3
Total yield cwt/a			554	550	598
Percent no. 1's			70	71	68
Specific gravity			1.084	1.084	1.088
Blackspot index			69	68	65
Chip color			26	25	24
Percent petiole nitrates			4.48	6.10	5.78
"	"	Total N	3.15	3.03	3.07
"	"	" P	.33	.31	.28
"	"	" K	9.20	8.60	8.70
"	"	" Ca	2.87	2.63	2.82
"	"	" Mg	1.34	1.30	1.37

Figure 1. Relationship between yield of tubers and pounds of potassium in the tubers.



On each of four harvest dates, plants and tubers in 10 consecutive potato hills were harvested from each of eight replications. This was done for plants fertilized with 166 lbs/a of potassium (200 lbs./a of K_2O) and for plants fertilized with 416 lbs/a of potassium (500 lbs/a of K_2O). Both the tubers and vines from the 10 hills were preserved for chemical analyses. Data for potassium content as a function of harvest dates are shown in Figure 2. The curves for potassium are similar to those for nitrogen and similar conclusions are justified:

1.) The amount of potassium in the tubers is roughly equal to the amount of potassium translocated out of the vines. Therefore,

2.) the roots did not absorb potassium rapidly enough to meet the needs of the tubers and maintain the level in the vines.

3.) If adequate potassium is not present in the vines relatively early in the growing season, there will probably not be enough to meet the needs of the tubers.

Figure 2. Relationship between pounds of potassium in the tubers and vines (exclusive of the roots) of Russet Burbank potatoes when fertilized with 166 lbs/a of potassium.

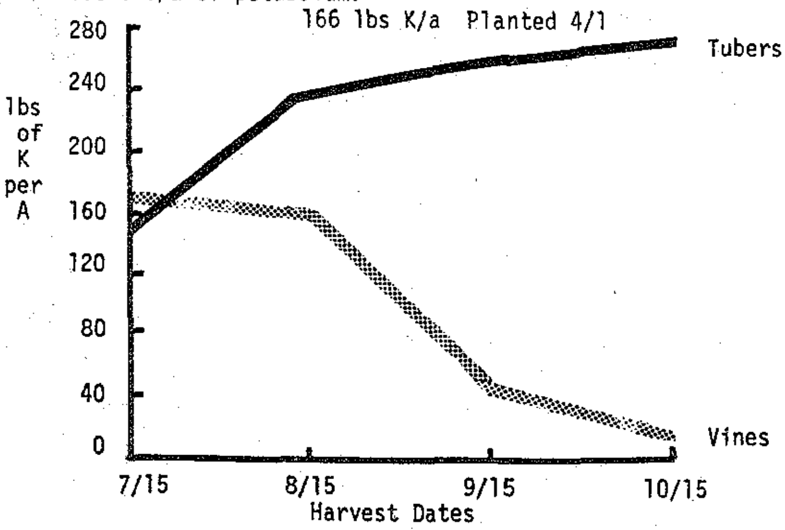


Table 5. Pounds of potassium in the tubers and vines (exclusive of roots) of Russet Burbank potatoes when fertilized with 166 lbs/a of potassium.

Sampled	Tubers	Vines	Total K
July 15	150	163	313
Aug. 15	238	157	395
Sept. 15	260	47	307
Oct. 15	273	13	286

The total yield of tubers for the 166 lbs/a of potassium application was 617 cwt/a. The amount of potassium in the vines and tubers was greater than the amount in the fertilizer and a sizable amount had to come from the soil (Table 5). In the same experiment, the amount of potassium in the tubers and vines was determined when 416 lbs/a of potassium was applied. These data are shown in Figure 3. The yield of tubers in this case was 732 cwt/a. The pounds of potassium in the vines increased slightly between July 15 and August 15, but after August 15 a rapid decrease occurred in the vines, not all of which went into the tubers. This may reflect a loss of leaves from the vines. Again, the data suggest that if the amount of potassium in the vines is not sufficient to meet tuber potassium demands, such demands cannot be met by the roots once rapid tuber enlargement begins. The amount of potassium in the total plant, except for the roots, is given in Table 6.

Figure 3. Relationship between pounds of potassium in the tubers and vines (exclusive of roots) of Russet Burbank potatoes when fertilized with 416 lbs/a of potassium.

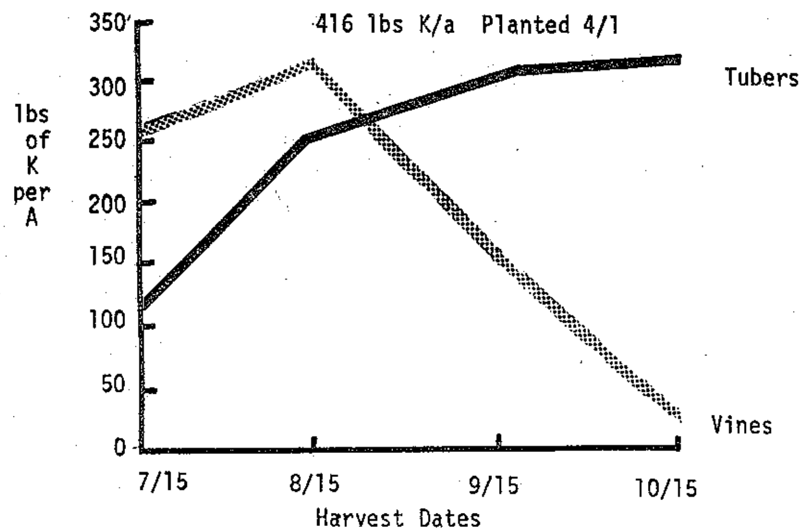


Table 6. Pounds of potassium in the tubers and vines (exclusive of roots) of Russet Burbank potatoes when fertilized with 416 lbs/a of potassium.

Sampled	Tubers	Vines	Total K
July 15	119	260	379
Aug. 15	260	314	574
Sept. 15	304	158	462
Oct. 15	321	28	349

Since there was considerably more potassium in the vines and tubers on August 15 than was applied in the fertilizer, the soil must have been an important source. However, this is not easily determined by means of standard soil sampling procedures. The 166 lbs/a rate of potassium fertilization was not sufficient to maintain the potassium level in the soil. The deficit was about 100 pounds. The 416 lbs/a rate of application provided an excess of about 100 pounds so that in time the potassium level in the soil would increase which would be good on soils with a low residual potassium content.

High levels of potassium in the soil are not only needed for top production but there are some beneficial secondary effects as well. Since there were no important differences among the list of factors evaluated due to anions, the effects observed must be due to potassium per se.

The effects of potassium in reducing tuber blackspot has been known for many years. Its relationship to the water content of the tubers as measured by specific gravity is also well known. The effect of soil moisture in reducing blackspot is most effective if the plant contains adequate amounts of potassium. If potassium is deficient, soil moisture will not control blackspot even though the susceptibility can be reversed in the laboratory by hydration.

Of the essential elements that must be applied in the Columbia Basin, potassium is by far the cheapest and a deficit can have some very deleterious effects on yield and quality.