Looking at . . .

POTASH DEFICIENCY AND CARBOHYDRATE METABOLISM

Scientists conclude . . .

1. *Tests for accumulated sugars in plants can be related to visual symptoms of potash deficiency if comparisons are made between deficient and normal plants.*

2. *Accumulation of sugars over extended periods together with necrosis of plant tissues resulting from potash starvation probably enable leaf disease organisms to invade and develop rapidly in deficient corn plants.*

3. *More research in the future will be directed toward interrelationships between mineral nutrition, organic synthesis, and disease incidence of crops.*

THE importance of potassium in crop production can be emphasized in many ways.

For instance, by examining the weak stalks, diseased roots, and poorly filled ears of potassium-deficient corn plants, attention is focused on the basic requirement of potassium in plant nutrition. Poorly developed roots and tubers, frenching of tobacco leaves, cotton rust, reduced citrus size, and marginal scorch on leafy vegetables are all symptoms which may be attributed to a need for additional potassium.

Some Functions of Potassium

The functions of potassium within the plant are many. Indeed, the external effects of an acute shortage may be evident in several parts of a plant—leaf, stalk or petiole, root, or fruit—at the same time. Sometimes symptoms appear one after another. The disturbance of one or more vital processes logically results in varied visual symptoms of disorder. Unfortunately, it is difficult to assign definite roles within closely related physiological processes.

To emphasize the fact that not a great deal is known about the specific functions of potassium as a mobile constituent in plant tissue, one may ask a number of questions.

For example, why is marginal yellowing or bronzing of the leaf structure so characteristic of potassium-starved crops? About the only lead has come from studies by Steinberg, who found frenching of tobacco plants seemed related to abnormal protein metabolism and an excessive accumulation of free amino acids.

Is potassium essential for photosynthesis? A number of physiologists have suggested that potassium deficiency results in reduced rates of carbon dioxide assimilation. However, this point is difficult to prove since fertilization with potash increases the leaf surface areas of many plants on potash-deficient soils.

What is the role of potassium in enzyme systems? This is an interesting question, but we are still groping for the answer. Schweigart has shown potassium is essential for a number of enzyme systems. It can be regarded as an integrating part of several enzyme systems, as well as an integrating or faculative activator in other enzyme systems, with functions not yet known. At least one worker has assumed that absence of the potassium ion may activate such enzymes as amylase, sacchrase, and B-glucosidase, which catalyze the transformation of carbohydrates. In this case, the glucose-starch ratio would rise as the supply of available potassium decreased.

By
K. Lawton & L. Shepherd

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Michigan
Agricultural Experiment Station

Dr. Kirk Lawton, Minnesota native, is a member of the soils staff at Michigan State University, specializing in soil chemistry and plant nutrition. He earned his B. S. from the University of Minnesota, his Ph.D. in soil science from Michigan State. Coming from the Iowa State College staff, he joined Michigan State in 1946.

Decreased Carbohydrate Accumulation

How does potassium affect the synthesis of simple sugars and starch in plants? Ample evidence shows the potassium level has a marked influence on carbohydrate accumulation. Just why this element is essential for this activity in living cells is not clearly understood.

Generally speaking, a decrease in carbohydrates has been associated with severe potassium deficiency, although a few workers have reported initial accumulation in the early stages of starvation. Reduced Photosynthetic activity or green leaf surface may be partly responsible, but in addition several workers have also pointed out that respiration in plants is highly accelerated by potassium deficiency. This condition would tend to lower the overall level of carbohydrates.

Susceptible to Disease

Anyone who has seen the shriveled, immature seed of small grains of corn or the small, nubby tubers of potato plants starving for potassium, can realize its importance in starch accumulation. An inadequate supply may also be responsible for the susceptibility of root tissues to certain types of disease organisms.

As early as 1930 Hoffer found a lack of available soil potassium resulted in accumulation of iron compounds in the nodal tissue of corn plants, disrupting translocation from leaves to roots. As food supply was reduced, root tissues were weakened and became more susceptible to fungal attack.

Certain Sugars May Accumulate

We might then ask ourselves—are potassium deficient plants lower in sugars than normal plants?

This query can be answered in several ways:

(1) The total production of sugars is undoubtedly lower in plants where potassium stress is apparent.

(2) The level of sugars, especially reducing sugars, may at times be higher in potassium deficient tissues. Evidence for the latter statement comes from investigators who found a higher proportion of reducing sugars to total carbohydrates in plants inadequately supplied with potash.

This point regarding accumulation of sugars in potassium deficient plants was brought to our attention in the late summer of 1955 by Mr. Herb Garrard, field agronomist for the American Potash Institute. He believed that plant sap from the stalks of some potash-starved corn plants tasted sweeter than that of nearby healthy plants.

At his suggestion some preliminary tests for sugars were made from stalks collected in early September. Using the α-naphthol reagent (Molisch test), tissue extracts of non-deficient plants seemed to contain as much or more sugar than ones showing marked need for potassuim. However, it was believed that the sampling date was too late since ear formation was essentially complete. At this stage sugars would tend to accumulate in all plants. Plans were made to continue the study at an earlier period the next year.

About the third week in August, 1956, corn stalk samples, 3 to 6 inches above the corn ear, and sugar beet petioles were collected at mid-day from plots receiving 1000 pounds per acre of 5-20-0 and

5-10-40 fertilizer at the Michigan State Experimental Muck Farm.

Again the Molisch test indicated no difference—abundant sugars being present in plants from both high and low potash treatments. Considering that, perhaps, the early morning would be a better time for sampling, *it was found by the same test that potassium deficient plants were distinctly higher in sugars.* Apparently *during the night* a large proportion of sugars in normal plants had been translocated out of the stalks of petioles to storage organs.

This was not the case for the potash-starved crops. In the following table are listed the yield and leaf potassium content of corn and sugar beets from plots with and without potash. Relative values are also given for the α-naphthol sugar test.

Table 1.—Yield, potassium content, and sugar test of normal and potash deficient corn and sugar beet plants.

	Corn		Sugar beets	
	5-20-0	5-10-40	5-20-0	5-10-40
	(bushels)		(tons)	
Yield	27.2	86.8	2.2	12.2
Leaf K	0.19%	2.37%	0.67%	5.01%
Sugar test*	High	Low	High	Low

*Sampled August 27, 1956 at 7 A. M.

Testing for Sugar

In testing for sugars, the following procedure was used:

(1) Ten grams of freshly chopped tissue was processed with 200 milliliters of distilled water in a Waring Blendor for one minute.

(2) The extract was then filtered and 50 milliliters of the filtrate diluted with water.

(3) Then 5 milliliters of diluted extract were placed in a test tube and after adding 5 drops of a 10% α-naphthol solution (made up in 95% ethyl alcohol), the tube was thoroughly shaken.

(4) Five milliliters of concentrated sulfuric acid were then slowly added down the side of the tube to form two layers. A violet ring formed at the junction of the layers when sugars were present. Upon shaking the tube the entire contents turned a blue-violet.

Standards can be made with sucrose solution and the reagent is sensitive to as little as 0.001% sucrose. In the course of this study it was found that faint colors tend to fade. In addition, some tissue extracts contain considerable pigments and probably certain polysaccharides which are decomposed by sulfuric acid and give off-shade colors. However, this problem usually can be minimized by diluting the extract. Usually, dilutions in the range of 10 to 50 times are sufficient to distinguish differences between deficient and non-deficient plants.

Summary

The authors feel that tests for accumulated sugars in plants can be related to visual symptoms of potash deficiency provided comparisons are made between deficient and normal plants. More information is needed on different crops and environmental conditions at the time plant samples are collected.

Accumulation of sugars over extended periods together with necrosis of plant tissues as a result of potash starvation probably enable leaf disease organisms to invade and develop rapidly in deficient corn plants.

Undoubtedly more research in the future will be directed toward interrelationships between mineral nutrition, organic synthesis, and disease incidence of crops.

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