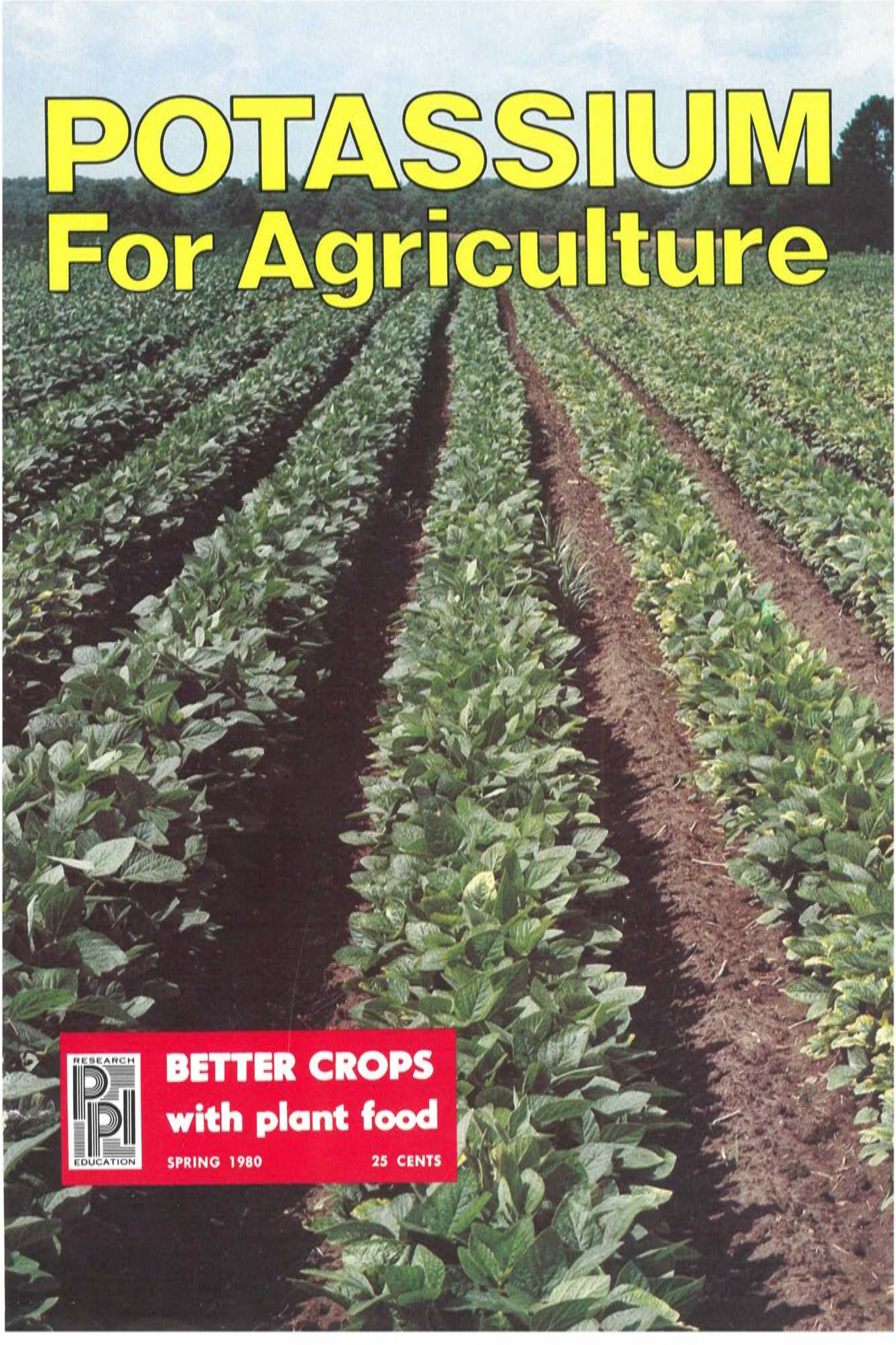
POTASSIUM For Agriculture



RESEARCH PPI EDUCATION

BETTER CROPS with plant food

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BETTER CROPS with plant food

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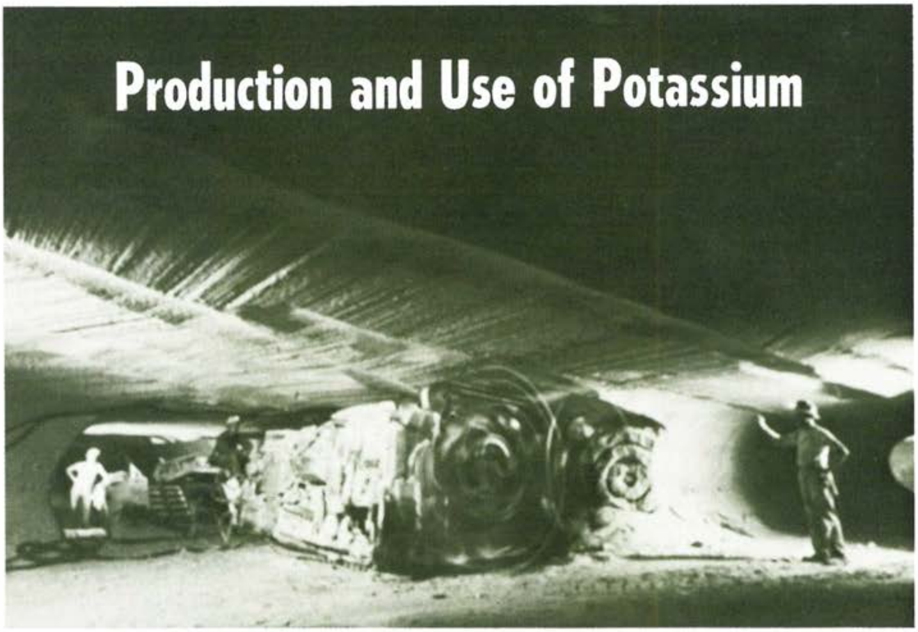
COVER:
Two years before the soybeans on the left were grown without potash, corn got 120 pounds K_2O/A each year. On the right, corn got 120 pounds K_2O/A two years ago, but 2 soybean crops that followed got none. Soybeans respond to potash, too! Photo by Dr. G. E. Richards, Smith-Douglass.

Production and Use of Potassium



More than a half-mile underground, a powerful continuous mining machine bites off a new bite of potash ore . . . to be sent up to the refinery.

POTASSIUM IS ESSENTIAL to all forms of plant and animal life. It is a chemically active metal. And because of its highly active characteristics, it is never found in its pure state in nature. It is always combined with one or more other elements.

Potassium is found widely distributed throughout the earth's crust. It is the seventh most abundant element in the world. It is not only found in every living plant and animal, but is also found in rocks, minerals, soils, lakes, rivers and oceans.

Agricultural soils may contain from 2 to 30 tons of potassium in an acre furrow slice. Unfortunately, most of it is chemically bound in insoluble mineral forms and is only slowly available for plant growth. This is especially true on many soils that have been depleted by decades or even centuries of continuous farming with crop removals.

For example, in 1979 alone the U.S. corn and soybean crops removed 2.2 million tons of potassium from the fields in which they were grown.

Potassium is added as a fertilizer in the form of potassium chloride, potassium sulphate, or potassium magnesium sulphate or some other forms which will be discussed later. Any and all of these forms are spoken of as potash.

The term "potash" comes from "pot ashes" which, in colonial days in America, were the primary source of potassium for fertilizers and for soap, glass, gunpowder and other industrial uses.

Potash is sold on the basis of its oxide or K_2O equivalent content. For example, chemically pure potassium chloride or muriate of potash (KCl) contains 52.44% potassium (K) or 63.17% K_2O equivalent. Most muriate of potash sold as fertilizer contains 60 to 62% K_2O.

It is frequently necessary to convert from K to K_2O or from K_2O to K. $K \times 1.2 = K_2O$. $K_2O \times 0.83 = K$.

POTASH FERTILIZER MATERIALS. In North America, muriate of potash (KCl) accounts for approximately 95% of all potash fertilizers. Potassium sulphate and potassium magnesium sulphate are also widely used forms, but they account for less than five percent of the total. Other forms such as potassium nitrate, potassium carbonate, potassium metaphosphate, potassium calcium pyrophosphates, and potassium orthophosphates are used only to a very limited extent.

The composition of several potash fertilizers is as follows:

	Percent K_2O	Percent K
Muriate of Potash	60-62.5	49.8-51.9
Sulphate of Potash	50-52	41.5-43.2
Sulphate of Potash—Magnesia	22	18.3
Potassium Nitrate	44	36.5
Sodium Nitrate & Potassium Nitrate	14	11.6
Manure salts	22-27	18.3-22.4
Potassium Hydroxide	83	68.9
Potassium Carbonate	68 or less	56.4
Potassium Metaphosphate	38	31.5
Potassium Calcium Pyrophosphate	25-26	20.7-21.6
Potassium Orthophosphates	30-50	24.9-41.5

OTHER POTASH MATERIALS. Some industrial wastes offer a source of potash. Tobacco stems, wool waste, sugar beet factory waste, flue-dust, and similar wastes from many industries can be used to a limited extent.

MIXED FERTILIZERS. While nearly all the potash fertilizer used comes in one of the forms described above, much of it is applied to the soil as part of a fertilizer which contains one or more other nutrients in addition to potash.

Thus in a 5-20-20 fertilizer, there is 5% nitrogen, 20% phosphoric acid (P_2O_5), and 20% potash (K_2O) by weight.

The analyses are always stated in the same order. Blended fertilizers, a physical mixture of such materials as KC1 and diammonium phosphate, are widely used. Fluid fertilizers contain relatively small amounts of K_2O in clear solutions but relatively high amounts in suspensions.

MINING OF POTASH. Most potash fertilizers are mined from **underground bedded deposits.**

In the Carlsbad, New Mexico area these deposits are located between 700 and 1800 feet underground.

In Saskatchewan, Canada, most deposits are more than 3,000 feet below the surface while in New Brunswick the deposits are approximately 2500 feet below the surface. The Canadian deposits are, however, of high grade, thick, and relatively easy to mine once a shaft is sunk to the level of the bed.

Solution mining is another method of extracting potash from underground deposits.

In this method, water is injected into the deposit through a well to dissolve the salts and a solution containing the potassium and sodium chlorides is withdrawn through another nearby well. This method has advantages when the deposit is irregular in shape or when the depth is too great for conventional mining.

A third method for mining potash is the **evaporation of water from salt lakes and subsurface brines.**

This technique is used in the U.S. at the Great Salt Lake and Bonneville salt flats in Utah, in Searles Lake in California, and in Israel at the Dead Sea.

The water which is already near the saturation point in potassium, sodium and magnesium salts is further evaporated in shallow ponds and the different salts are separated.

POTASH PRODUCTION AND CONSUMPTION. Total world production increased from 4.22 million tons K_2O in 1950 to 16.9 in 1969 and 28.3 in 1979.

In 1978 the Soviet Union produced 32 percent of the world total. Thirty-two percent was produced in North America, 19 percent in Western Europe, 13 percent in Eastern Europe, 4 percent in Asia and less than one percent in Africa.

In 1979, 76 percent or 7.4 million tons of the production in North America came from Canada and the remaining 2.3 million tons came from the United States.

Production in North America has shifted from the United States to Canada. The U.S. decline is due largely to the exhaustion of high grade ore in the Carlsbad, New Mexico, mining area. Canadian production began in 1962 and has increased steadily ever since.

The use of potash fertilizer in the U.S. has shown phenomenal growth.

In 1900, there were only 90,000 tons K_2O used. By 1914 this figure had grown to 250,000 tons and by 1935 to 400,000 tons. In 1950 1.4 million tons were used. In 1960 the figure was 2.1 and in 1979, 6.2 million tons.

Canadian consumption has shown a similar increase. In 1979, 322,000 tons were used.

Potash Consumption in N. America
5 Year Averages
(1,000 short tons K_2O)

	1960-64	1965-69	1970-74	1975-79
U.S.	2,365	3,477	4,465	5,448
Canada	106	167	220	269
	2,471	3,644	4,685	5,717

RESERVES AND RESOURCES. Potash reserves are those that can be mined at a profit under existing market conditions. Resources are those in such a form or location that mining is or may become feasible in the future.

Total reserves in the U.S. amount to 200 million short tons of K_2O recoverable at 1976 prices. This includes about 100 million tons in bedded deposits in New Mexico and 100 million tons in brines.

Total U.S. resources are estimated at 6 billion tons, most of which is found between 5,000 and 10,000 feet below the surface in Utah, North Dakota and Michigan.

Canadian reserves have been estimated at 10 billion tons of K_2O in Saskatchewan alone and total resources are estimated at 74 billion tons.

World reserves are estimated at 13 billion tons and world resources 138 billion tons of K_2O. **The End**

The potash ore is brought up to a refinery to be processed for market.

Functions of Potassium in Plants

POTASSIUM INCREASES crop yields because it is needed for several yield-forming processes in plants.

1. ENZYME ACTIVATION. Enzymes are catalysts that bring other molecules together to react chemically.

An example is starch synthetase which attaches sugar molecules together to form starch. Potassium activates starch synthetase and at least 60 other enzymes by changing the shape of the enzyme and exposing its chemically active site.

Plants use the rate of K movement into cells as a "valve" to control the speed of chemical reactions.

Enzyme activation then is K's most important function because so many vital reactions in plants are controlled by K activated enzymes.

2. WATER USE. Potassium provides much of the osmotic "pull" that draws water into plant roots. Thus, K-deficient plants are less able to withstand water stress.

Plants use K to open and close stomata, the pores in leaves that allow the entrance of carbon dioxide and the exit of water and oxygen. When K moves into the guard cells surrounding the pore, the pore opens. Proper functioning of stomata is important for water conservation and photosynthesis. See **Figure 1.**

PLANTS LOSE LESS MOISTURE WITH ADEQUATE K

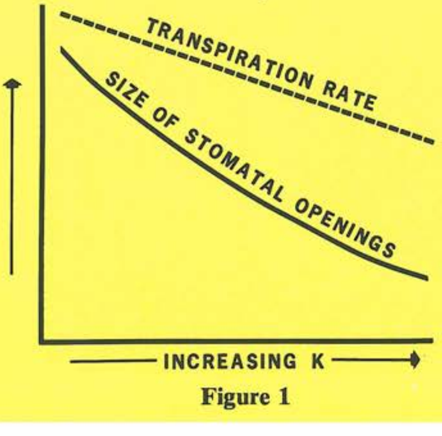


Figure 1

3. PHOTOSYNTHESIS. The most important reaction in nature is photosynthesis which stores sun's energy by combining carbon dioxide and water into sugars.

The role of K is to maintain the balance of electric charges at the site of ATP production—the initial high-energy product of photosynthesis.

The rate of photosynthesis drops sharply when plants are K deficient. ATP is used as the energy source for many yield-forming reactions in plants.

4. TRANSPORT OF SUGARS. The sugars produced in the leaves by photosynthesis must be transported to other parts of the plant for growth or storage in the fruit or roots.

Loading sugars into the plant's transportation ducts consumes energy in the form of ATP.

5. PROTEIN SYNTHESIS. K is required for N uptake and synthesis of protein. Potassium is involved through its role in ATP production. For each amino acid (the building blocks of protein) joined to a protein molecule there is at least one ATP consumed.

	Protein in spring wheat grain
Low N low K	13.3%
high K	15.3%
High N low K	16.7%
high K	17.6%

6. STARCH SYNTHESIS. Starch is the principal stored form of energy in many grains such as corn and wheat, and in root crops such as potatoes. Sugars are joined together by starch synthetase—a K activated enzyme—to form the long chain molecules of starch.

Potassium is the only univalent cation that is generally indispensable for all living organisms.

Yield decreases usually occur in the "Hidden Hunger" stage before visual symptoms of K deficiency appear. Plant processes such as photosynthesis, translocation, and enzyme activity slow down during this stage. **The End**

K Availability and Uptake

POTASSIUM AVAILABILITY and uptake is a complicated subject. In brief, three factors affect K availability and uptake. They are soil factors, plant factors, and fertilizer and management factors.

SOIL FACTORS . . .

1. The soil itself. This includes the material from which the soil was formed, the amount and type of clay minerals in it, the vegetation under which it was formed, the topography and drainage, the climate under which it was formed and the length of time it has been forming.

2. The cation exchange capacity or CEC of the soil. This reflects the soil's ability to hold K and other cations and store them in the soil for crop uptake.

Clay minerals and soil organic matter are the two parts of soil that contribute to CEC. In general, the higher the CEC of the soil, the greater the level of exchangeable K availability.

3. The quantity of exchangeable K in the soil. This is the value the K soil test measures. It usually reflects the soil's readily available K and it includes the water soluble K. As the level of soil test K decreases, the crop response to applied potash increases, shown in **Figure 1.**

4. The nonexchangeable or slowly available K. This is the K that is in equilibrium with the exchangeable K and renews the soil's supply of exchangeable K. For most soils, the more crops depend on nonexchangeable K, the lower the yields.

5. The K fixation capacity of the soil. Some soils have a high capacity to retain K that is added, in fairly large amounts, reducing the immediate availability to the crop and the increase in the soil test or exchangeable K. The nonexchangeable K is increased.

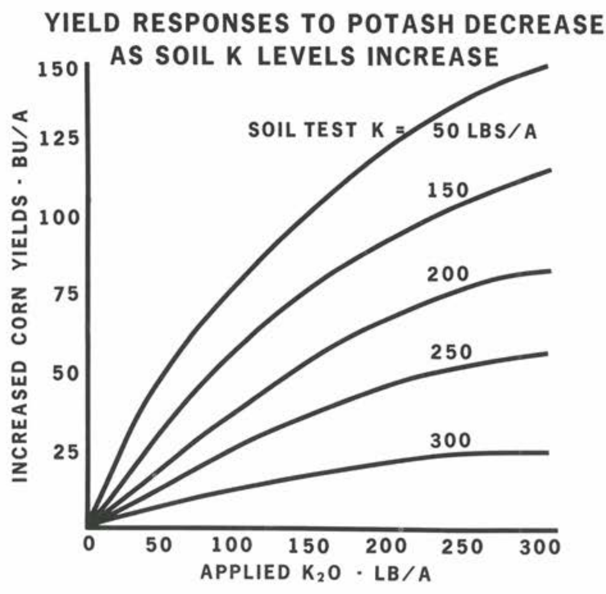


Figure 1. Yield responses to potash are greater on lower K soils, but yields are highest with adequate K.

Table 1. More K is needed by higher yielding crops.

Corn yield	K uptake	K uptake per bushel
bu/A	lb/A	lb K/bu
110	117	1.06
154	151	0.98
202	223	1.10
231	259	1.12
255*	304*	1.19*

*From a different experiment at a widely different location.

6. The amount of K in the subsoil and the density or consistency of subsoil layers. Some subsoils are high in K available to roots. Others, such as those formed under grass in the central Corn Belt have low K availability.

If dense layers develop in the subsoil, root penetration and rooting volumes are decreased, reducing the availability of the K and nutrients that are there.

7. Soil temperature. Low soil temperatures reduce K availability and uptake rate by crops. The optimum soil temperature for K uptake for a crop like corn is about 85°F.

Effects of low temperature can be offset some by increasing soil K levels. Row K can be important with lower soil temperatures, especially for early planted and minimum till crops.

8. Soil moisture. Moisture is needed for K to move to plant roots for uptake.

Moisture is needed for root growth through the soil to "new" supplies of K. It is needed for mass-flow movement of K to the plant roots with water and for the diffusion of K to the roots to resupply that taken up by the roots.

Drought stress or excess moisture reduces K availability and uptake by crops. Increasing soil K levels can help overcome the adverse effects.

9. Soil tilth. This is related to the friability and ability to get air into the soil. Air is needed for root respiration for K uptake. Tillage when soils are too wet leads to compaction.

PLANT FACTORS . . .

1. The crop. Crops differ in their ability to take up K from a given soil. This is associated with the type of root system and surface area of the roots. Grasses, for example, have a much greater capacity to take up K from the plow layer than alfalfa does. Grasses have many more fibrous, branching roots increasing the K absorbing surface.

2. The variety or hybrid. Crop genetics comes into play with the differences among varieties or hybrids of a given crop.

Differences are developed through plant breeding. They usually relate back to the type of root system, root density and metabolic activity that affect K uptake and, hence, availability of K for a given K test.

Potassium as a nutrient has a very positive effect on root branching and density.

The other factor is that new varieties often have higher yield potentials which increase the demands placed on soil K. Additional potash will be needed under higher yields.

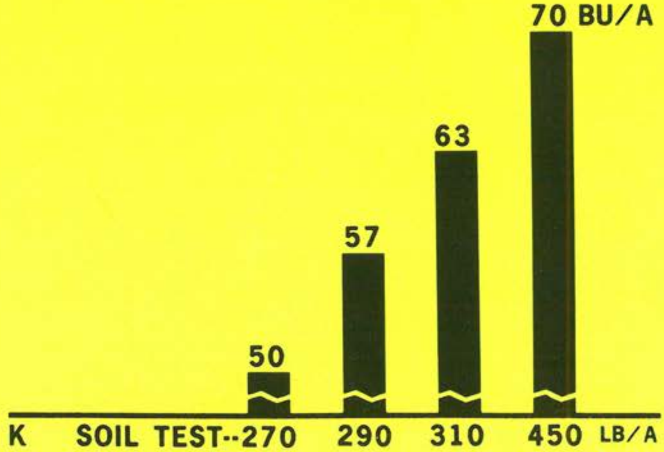


Figure 2. Higher K soil tests can increase soybean yields.

3. Plant populations. As plant populations increase yields are greater and demands on soil K are increased.

Yields often will not increase with higher populations unless adequate levels of K are in the soil, from native or fertilizer sources.

4. The crop yield level. As crop yield levels increase, K total uptake increases. **Table 1.** But the uptake per unit of crop yield, such as pounds of K per bushel or ton, may be nearly constant at optimum yield levels.

FERTILIZER AND MANAGEMENT PRACTICES . . .

1. Increased use of N, P and other limiting nutrients. When adequate K is available, additions of N and/or P greatly increase K uptake, as yields are increased. Usually, the uptake of K by crops closely parallels N uptake, often being greater. So, as limiting nutrients are added, the demands on soil K increase.

2. Applications of K in fertilizers, manures or crop residues. The major way to increase K availability is to apply adequate amounts. K is readily available from all these sources, provided they are mixed deeply enough into the soil where roots can absorb the K, **Figure 2.**

3. Placement of K. Broadcast plowdown applications of K are more available than surface applied disked-in K. Row K at moderate lower rates is usually twice as available as similar amounts broadcast.

Deep placement or drip irrigation help move K down. Gypsum applied with potash also helps move K down in very fine textured soils.

4. Minimum or reduced tillage limits availability of surface applied K. Soil K levels should be built to high levels before shifting to minimum or conservation tillage. This improves K distribution within the plowlayer. In many fine textured soils, surface applied K does not move into the soil and has low availability, particularly under dryland conditions.

5. Drainage increases K availability. Draining soils of excess moisture helps many soils warm up earlier and improves the aeration of the soil. This improves the availability of soil K.

6. Weed and insect control. Controlling weeds and insects reduces competition for moisture and nutrients, so that the crop being produced has relatively more K available. **The End**

Yield and Economic Responses to Potassium

GROWERS ARE FACED with spiralling costs in all phases of their farming operations. In order to stay in business, today's farmers should be aware of the importance of each input in their farm enterprises.

The following observations from a comprehensive review of fertilizer experiments conducted on a wide range of soils and cropping conditions in the U.S. and Canada show what growers can expect from the use of K.

ON CORN (40 experiments in 12 states and provinces)

- Responses varied between 4 and 98 bu/acre with increases of 25 bu/acre or more in 50% of trials.
- Net value of K responses varied from \$3 to \$192/acre.
- Returns on K investment exceeded 250% in more than 50% of studies.
- Rates of K_2O were under 150 lb/acre in 70% of experiments.

ON SOYBEANS (30 experiments in 14 states and provinces)

- Responses of 10 bu/acre or greater in just over 40 percent of the experiments.
- Net value of the responses to K ranged between \$9 and \$240/acre.
- 66% of the time returns on K investment were over 250%.
- Rates of K_2O were usually less than 150 lb/acre.

ON BARLEY (14 experiments in 5 states and provinces)

- Yield increases of from 3 to 63 bu/acre, with many of the responses falling between 8 and 20 bu/acre.
- Returns on K investment varied between 20 and 572%. In slightly more than 50% of the experiments, returns were greater than 250%.
- Applications of K_2O were normally less than 60 lb/acre.

ON WHEAT (18 experiments in 6 states and provinces)

- Responses fluctuated between 3 and 39 bu/acre with increases of 4 to 10 bu/acre most common.
- Investment returns were 200% or higher approximately 60% of the time.
- Rates of K_2O were usually less than 60 lb/acre.

ON OATS (3 experiments in 2 states and provinces)

- Yield increases of between 8 and 62 bu/acre were obtained with K_2O rates ranging from 25 to 100 lb/acre.
- Returns on K investment varied from 63 to 309%.

ON SORGHUM (5 experiments in 1 state)

- Responses of 7 to 31 bu/acre were obtained.
- Returns on the K_2O investments were 49 to 226%.

Net value of K responses on the various small grains started at a low of \$3 and rose to more than \$130/acre. Profits from K fertilization were greatest on soils low in available K but substantial benefits also occurred on soils with higher available K status.

ON COTTON (21 experiments in 7 states)

- Lint yields were raised by 38 to 886 lb/acre.
- Net value of the increased lint production varied from a low of about \$12/acre to a high of over \$422/acre.
- Earnings on K investments ranged from 104 to 382%.
- Rates of 40 to 80 lb/acre of K_2O were typical.

ON POTATOES (20 experiments in 7 states and provinces)

- Yield increases of 0.3 to 13 tons/acre were obtained with 50% of the responses greater than 2 tons.

Table 1. K helps profits in corn production

K_2O lb/A	Yield bu/A	Prod. cost $/A	Net return $/A	Cost of crop $/bu
0	112	$285	–$5	$2.54
50	142	297	58	2.09
100	147	303	65	2.06
150	145	308	55	2.12
200	148	314	56	2.12

Corn $2.50/bu, K_2O 11¢/lb applied, harvest 20¢/bu, medium K soil, Ohio.

- Net value of the K responses varied from $36/acre to over $800/acre. Netbacks of $100/acre or more were common.
- In 50% of the experiments return on K investment was over 250%.
- Rates of K_2O were usually less than 400 lb/acre.

ON TOMATOES (4 experiments in 2 states)

- Responses of 8 to 15 tons/acre were seen with net values of $500 to $1000/acre.
- Earnings on K investments were between 186 and 274%.
- Rates of 200 to 720 lb of K_2O/acre were used.

ON FORAGES (38 experiments in 17 states and provinces)

- Responses of up to 3 tons/acre were noted.
- Net value of increased forage yields based on selling hay ranged from $1/acre to $142/acre. About 40% of the responses resulted in net returns exceeding $20/acre.
- Returns on K investment varied from 5 to 289% with 100% or more being realized about 26% of the time.

LOWER PRODUCTION COSTS per unit of crop. The principle of lowering production costs per unit of crop is functioning when K fertilization results in higher yields. As seen in **Table 1**, lower unit production costs translate into higher returns per acre.

On this soil testing medium in K, 100 lb K_2O per acre gave the **highest net return/A** and the **lowest cost/bu.**

One of the most certain ways growers can survive in these times of rapidly escalating production costs is to produce more per acre lowering the production cost per unit of crop and increasing profit. The grower must aim for maximum economic yield.

CROP QUALITY. Credit should be given to improved crop quality when considering the economics of K fertilization. In the review of fertilizer experiments referred to earlier, the beneficial effects of K on crop quality factors produced returns of $15 to $600/acre. These sums represented from 14 to 52% of total net income.

ENERGY EFFICIENCY. One obvious way of cushioning the impact of rapidly rising fuel costs is to increase energy efficiency by increasing the amount of crop produced per unit of energy consumed. High yields resulting from K fertilization will lower the amount of energy consumed per unit of crop produced.

It costs just as much to plow a field yielding 100 bu of corn per acre as a field yielding 150 bu/A. **The End**

PICTORIAL CONCEPTS

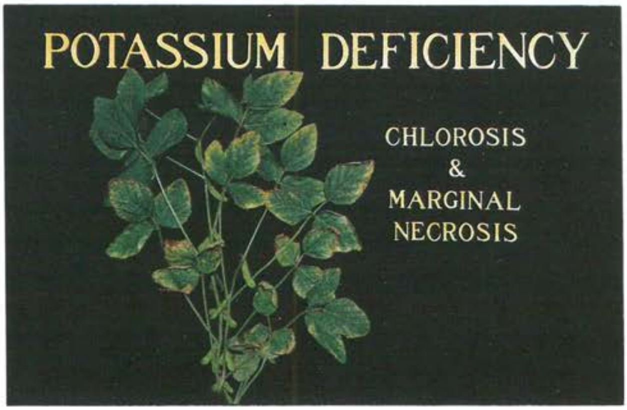
When corn lodges, the crop may have run short on potassium. Research has shown K reducing down corn as much as 75%, while adding more bushels through better standing corn.

Low-K corn ages too fast . . . cells die . . . tissues deteriorate . . . inviting stalk rot. Potassium builds strong stalks and more brace roots . . . helps prevent decaying stalks.

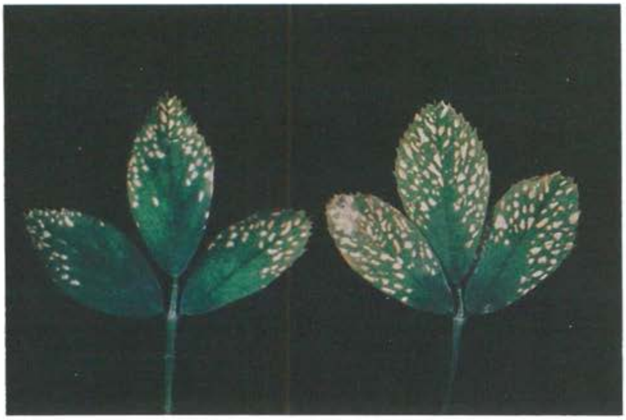
Cotton "rust" is potassium starvation. First sign is yellowish white mottling in leaf, most evident between veins. Leaf turns yellowish green. Brown specks show at tip around margin and between veins.

PICTORIAL CONCEPTS

Potassium hunger in soybeans begins as firing or scorching on outer edge of leaf. When leaf tissue dies, leaf edges become broken or ragged, with delayed maturity and slow defoliation.



This is potassium hunger on alfalfa leaves. The first signs show up as small white or yellowish dots around the outer edges of the leaves. As deficiency increases, these edges turn yellow, become brown, and die.



Tobacco demands high potassium concentration in leaves for both yield and quality. This shows tobacco leaves with and without potassium hunger. Note the marginal burning.

Effects of K on Drouth and Cool Temperature Resistance

DROUTH REDUCES a crop's K uptake. Potassium moves to the plant root by diffusing through the water films around the soil particles. In a drouth, these water films become very thin, reducing K movement to the root.

Higher K levels help maintain K uptake during drouth. Increasing K concentration in the soil, and thus in the soil solution, speeds K delivery to the root through thin water films.

Figure 1 shows how a higher K level (as shown by rubidium, an element which behaves like K) helps maintain uptake by corn seedlings, with decreased soil moisture.

When high stress reduced K uptake by Iowa corn on a low K soil, added K increased K content 0.5% (below). Potassium deficiency symptoms are more likely to appear in dry years.

	No stress	Stress
	% K in corn leaves	
0 K_2O	1.1%	0.7%
160 lb K_2O/A	1.6%	1.2%

Crop response to K is greater under low rainfall. Netherlands reported this for wheat and potatoes, Indiana and Ohio for corn, and Indiana for soybeans.

Figure 2 shows an 18-year experiment in Indiana. The soybeans showed a greater percentage yield increase from K with lower amounts of rainfall for the 12-week period following planting.

In Ohio, in an optimum rainfall year, corn yield response to K was 3 bu/A on a medium K soil. The next year, a dry one, the response was 43 bu on the same plots.

Potassium is of special help under wet conditions. In dry, optimum, and wet years on a low K soil in Indiana, added K increased corn yields 39, 8 and 48 bushels, respectively.

In Maine, a poorly drained soil low in K produced about 0.8 ton/A less alfalfa-timothy than a well drained soil. **With high K, yields were increased and there was no difference in yield between the two soils.**

An important effect of K is to reduce transpiration (loss of water from the

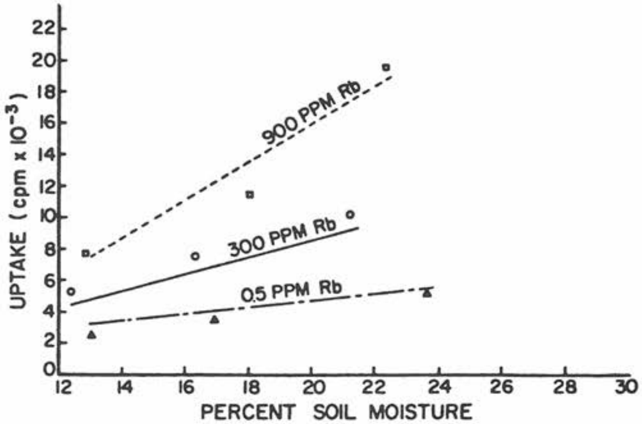


Figure 1—Low soil moisture decreases uptake by corn but higher levels of potassium (an element similar to Rb) help to overcome the problem.

plant) under stress conditions. The openings in the leaves (stomates) from which water is lost are sluggish with low K. In Montana, barley with adequate K had a reduced transpiration rate 5 minutes after exposure to hot, windy conditions. With severe K deficiency, about 45 minutes was required for transpiration to be reduced.

TEMPERATURE. Cool temperature reduces a crop's K uptake. The K in the soil is less available, root growth is less and the plant is less active in K absorption. Over a 6-day period, soil solution K was double and root length of corn seedlings was 8 times greater at 86°F than at 59°F. The content of K in the shoot was 8.1% at 86°F and 3.7% at 59°F.

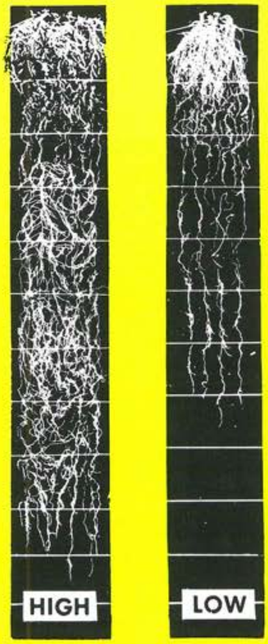
Figure 3 shows the uptake of K by sorghum is much greater at 90°F than at 60°F, with or without K.

In cooler climate areas, a higher K soil test level or rate of applied K is necessary to equal K content of crops in warmer areas. For example, to obtain 2% K in alfalfa plants, a 50% higher level of exchangeable soil K is required in northern Wisconsin than in southern Wisconsin.

Earlier planting puts more stress on young plants. In Indiana on a low K soil, extra K increased corn yield 26 bu/A planted April 26, only 12 bu planted June 2.

No-till increases K needs in cooler,

Potassium helps crops use moisture more effectively. Three positive effects of adequate fertility are:



FERTILITY

- **Increased root growth depth.** K helps plant roots penetrate deeper for another inch or two of water.

- **Faster closing of crop canopy.** This soil cover (1) reduces water evaporation and (2) allows more rainfall to enter the soil.

- **Speeds maturity.** K may help plants get through pollination earlier—before drouth.

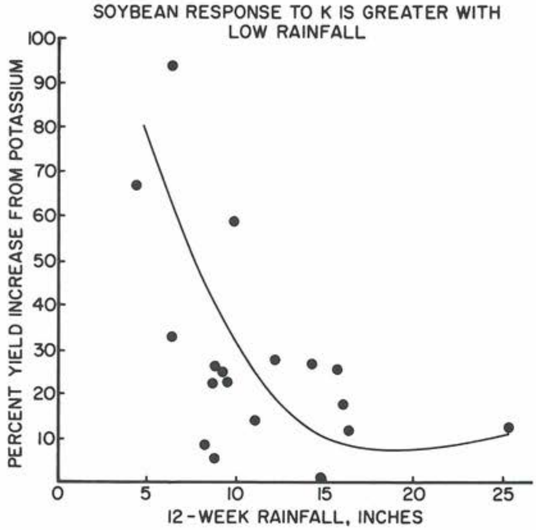


Figure 2—The less the rainfall for the 12-week period after planting the greater the percent yield response of soybeans to K on a low K soil.

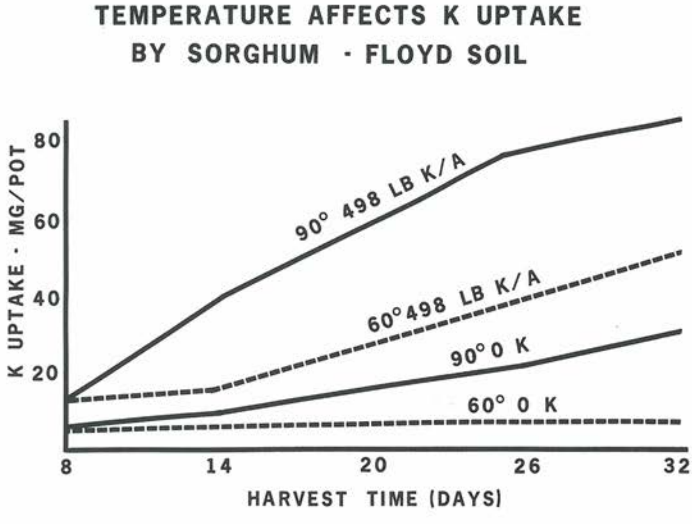


Figure 3—K uptake by sorghum is much greater at 90° than at 60°F with zero or with added K.

drier areas as less K gets into the plant.

Winterhardiness and survival of alfalfa is improved by K. On a low K soil in New Jersey, the stand after 5 years was only 3% on the no K plots as compared to 93% on plots receiving 330 lb K_2O/A annually.

Higher K levels clearly help get crops through periods of drouth and/or cool temperature stress. Many observations show the need to plan a strong K soil fertility program to make crops more certain in an uncertain environment. **The End**

Potassium Placement

POTASSIUM IS available to plants as a monovalent cation (K+). Because of this positive charge and its attraction to the predominantly negatively charged sites in the soil (described as CEC), K is described as an immobile nutrient in the soil.

In practice, this means that the K available to the growing plant is that which is in very close proximity to the root.

PLACEMENT: This characteristic of immobility suggests placement of K in a specific location to the growing root system may be advantageous and has led researchers to explore potassium placement. These explorations have included many variations of placement including:

(1) **Surface broadcast.** (2) **Disced.** (3) **Plowdown.** (4) **Seed placed.** (5) **Banding —including all combinations of distances below and to the side of the seed.** (6) **Plow-sole placed.** (7) **Deep placement.** (8) **Layering.** (9) **Strip placement, etc. as well as many combinations of the various separate methods.**

All of these placement methods may be considered a variation or combination of the two extremes of **banding** or **broadcast and mixed within the plowlayer.**

RESULTS. Response to K placement varies with the crop being grown and the specific environmental condition that exists during the growth period.

CORN. Corn may respond differently depending on specific soil characteristics.

In Illinois, **three soils responded differently to band vs broadcast K.** In one case, the broadcast yield never reached the banded K yield at the K rates used.

In Iowa, with higher broadcast rates, the banding advantage disappeared, **Figure 1.**

In Indiana, a five-year study showed an advantage for an intermediate placement method in getting the applied K into the plant on a low medium K soil, **Figure 2.** The strips were applied on the surface 28 inches apart and plowed down.

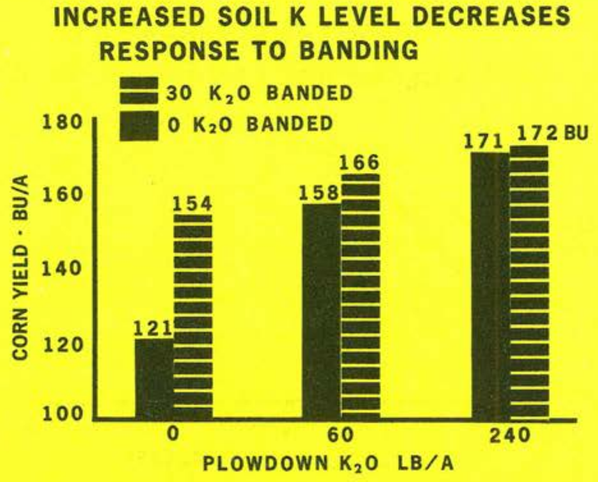


Figure 1

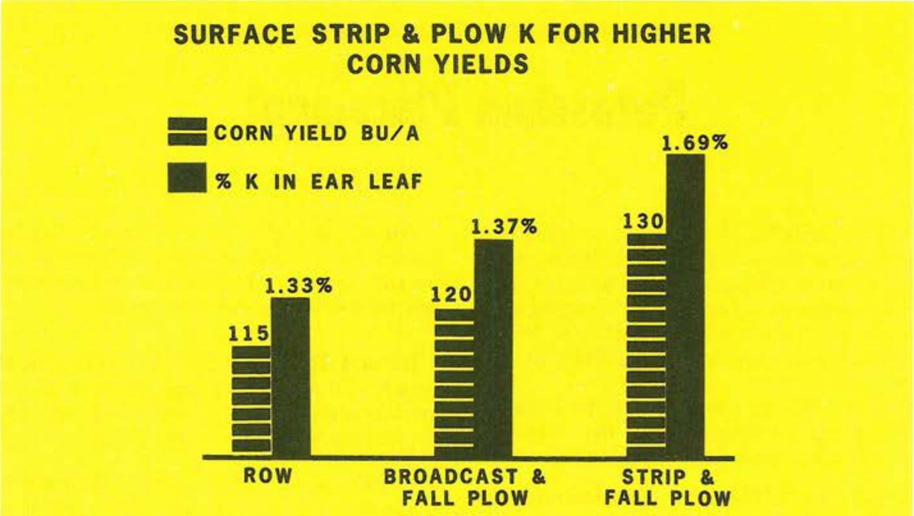


Figure 2

No-till or minimum till corn presents another problem. The yield disadvantage of unplowed corn land as compared to plowed land was found to be related to K distribution in the profile and lower K uptake. This disadvantage was decreased in a Wisconsin study by increasing K applications, shown here.

Table 1. Yield loss due to reduced tillage is decreased by K additions.

K_2O	K in corn leaves at silking Plowed	Not-plowed	Yield loss from not plowing
lb/A	% K		bu/A
0	0.73	0.59	36
80	1.40	1.04	22
160	1.71	1.42	7

Medium K soil.

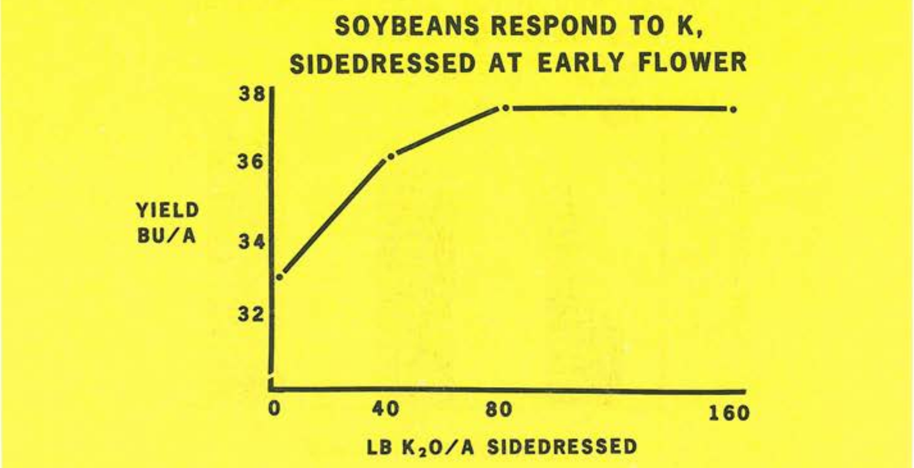


Figure 3

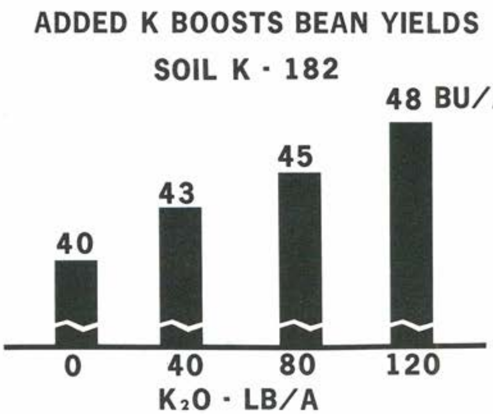


Figure 4

These data emphasize building up soil K levels before entering a minimum till program—perhaps even higher than under a conventional till program and then plowing every 3 to 4 years to redistribute applied P and K. Under minimum-till, K is an important part of a row fertilizer program.

In summary, corn requires high soil test K levels for maximum production. While that soil test level is being built up, some form of more specific placement may be an advantage for some of the K applied.

On some soils, after the high test has been achieved, it still may be advantageous to band place the maintenance rates.

SOYBEANS. They require high K. Most studies have indicated good response to added K on deficient soils, whether banded or broadcast. In an interesting experiment with a rescue type treatment in Alabama, soybeans responded well to sidedressed K when applied at early flower, **Figure 3.**

Ohio showed added K boosting bean yields, **Figure 4.** The program should be to get the K on before planting, but a precisely placed rescue treatment does provide an opportunity to regain some lost yield.

ALFALFA. High yielding alfalfa has one of the highest K needs of any crop, many times exceeding 60 to 70 lb K_2O/ton of hay. Topdressing alfalfa with K is an adequate way of maintaining yield.

For increased yield potential of the life of the stand, Illinois has shown that building up fertility before seeding and then topdressing for maintenance is the best approach.

COTTON. The limited data for cotton shows that broadcast K is adequate for high yields on soils that test medium or high.

SMALL GRAINS. Small grains present an interesting case. Limited root systems, shorter growing seasons, and cooler temperatures enhance the yield advantage of seed-placed over broadcast K.

But, because of the potential salt damage of K sources on seedling emergence when more than about 20 lb of K/A are applied with the seed, broadcasting most of the K for buildup may be the best alternative.

With barley in Canada there was a consistent advantage of seed K placement at low K rates, **Table 2.**

Table 2. Seed-placed K increased barley yield over band or broadcast on K deficient soils.

Treatment		Yield increase bu/A 6 tests	13 tests
15 lb K_2O/A	Broadcast	8.6	
	Banded	12.8	6.2
	With seed	18.8	10.7
30 lb K_2O/A	Broadcast	17.0	
	Banded	18.8	8.0
	With seed	21.0	12.2

In contrast to barley, rapeseed responded the same regardless of placement. **The End.**

Potassium Interactions with Other Nutrients

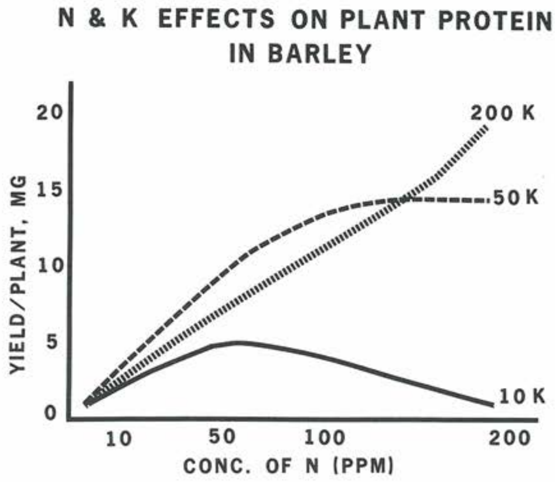


FIGURE 1

POTASSIUM UPTAKE and utilization is closely related to availability and uptake of other nutrients.

NITROGEN-POTASSIUM INTERACTIONS. Potassium affects nitrate absorption and reduction. Rapid nitrate uptake depends on adequate K in the soil solution. Activity of the enzyme, glutamine synthetase, in wheat is lower when K is deficient.

Potassium stimulates leaf protein synthesis. Note the effect on barley in **Figure 1.**

Putting it all together, better N uptake and utilization with adequate K means improved N use and higher yields. Crops need more K with higher N rates to take advantage of the extra N. Illinois corn data showed a higher optimum N rate as K applications increased, **Figure 2.**

Potassium uptake. Nitrogen form can affect K absorption. Tomatoes grown in nutrient solution with nitrate-N have shown a higher relative growth rate than plants supplied with ammonium-N. After 4 days, the total K content decreased in ammonium-grown tomato plants and remained constant in ones supplied with nitrate, **Table 1.**

Higher forage yields and improved forage quality are the goals of any fertiliza-

Table 1. K content of nitrate- and ammonia-grown tomato plants.

Days to harvest	mgm K/gm dry weight Nitrate-grown	Ammonia-grown
0	59.2	59.2
4	59.0	56.7
10	41.8	32.9
21	41.4	25.3
24	41.3	28.1

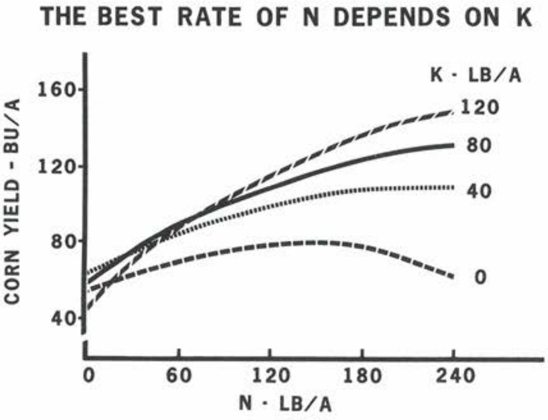


FIGURE 2

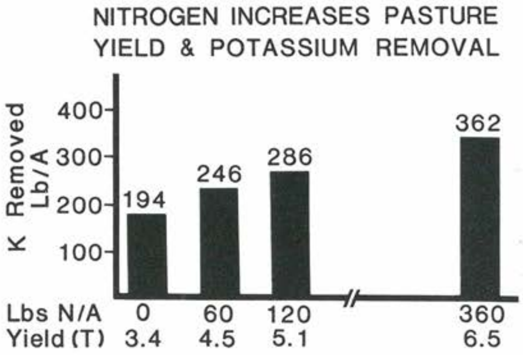


FIGURE 3

tion program. In Washington, higher N applications boosted yields 91 percent and increased K removal, **Figure 3.** Timothy yields were limited by both N and K in a New Brunswick study, but teamwork of N and K doubled first cutting yields.

Turf quality requires close attention to N-K interactions. Potassium is important in Kentucky bluegrass and creeping bentgrass fertilization. Quality response of creeping bentgrass to N improved with higher levels of K. More K was required than N for best growth and quality.

Plant diseases and K interactions. More severe stalk rot in corn with higher N rates can be offset by higher K rates.

Wisconsin research showed both a corn yield increase and a lower incidence of lodging when a balanced fertilizer program including needed K was used, shown in **Figure 4.**

Nitrogen without needed K increases lodging and stalk rot symptoms in grain sorghum, particularly following moisture stress. Potassium applications, even with high N, decreased stalk rot, reduced lodging, and increased yields in Kansas.

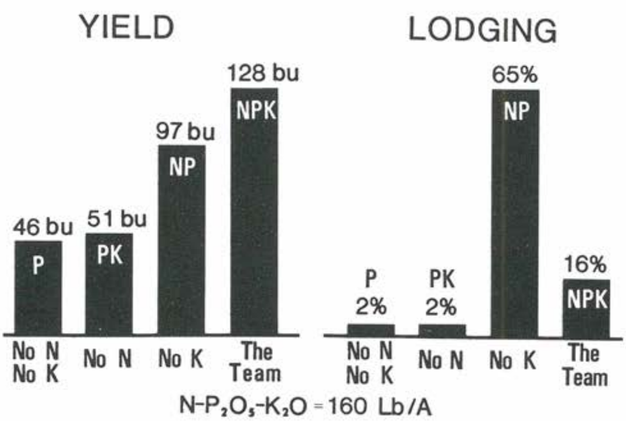


FIGURE 4

Table 2. Economics of a P x K Interaction on Soybeans.

P_2O_5	K_2O	Yield	Gross return	Prod. cost	Net return	Cost/bu
——lb/A——		bu/A	——$/A——			$/bu
0	0	25	150	200	−50	8.00
120	0	26	156	232	−76	8.92
0	120	47	282	220	62	4.68
120	120	55	330	252	78	4.58

Soybeans $6/bu, P_2O_5 26¢/lb, K_2O 12¢/lb, 24¢/bu for extra yield harvested.

POTASSIUM-PHOSPHORUS INTERACTIONS. Even in soils testing high in exchangeable K, added K sometimes affects uptake of other elements, particularly under cold, wet soil conditions following planting.

Corn received 20 lbs of K_2O banded to the side and below the seed on a high K soil in Kansas. Planting was followed by cool, wet weather. Plant P concentrations were increased from 0.25 to 0.43 percent by the small amount of added K.

A Virginia soybean study, **Table 2,** shows the influence of P and K on net returns and production costs per bushel. Higher yields spread production costs over more bushels, lowered production costs per bushel, increased yields and profits.

POTASSIUM-MAGNESIUM INTERACTIONS. Low magnesium in forages can affect animals producing low blood serum magnesium (grass tetany).

Incidence of tetany tends to be lower if forage Mg exceeds 0.2 percent. High plant K can have an antagonistic effect on Mg concentrations, particularly when Mg is low in soils.

Seasonal changes in forage composition may be associated with factors such as levels and forms of N absorbed by plants. Absorption of ammonium-N may result in greatly reduced uptake of Ca and Mg while having lesser effects on K.

Large amounts of ammonium-N in the soil would have the same effect on a forage as that of K, causing depressed uptake of Ca and Mg.

Sudden rises in temperature tend to be associated with wider K/(Ca + Mg) ratios, which correspond with a higher grass tetany potential. Higher temperatures tend to increase the K uptake faster than that of Ca and Mg.

POTASSIUM-MICRONUTRIENT INTERACTIONS. (1) **Potassium-zinc** Large amounts of available P in a Zn deficient or border-line Zn deficient soil result in more severe Zn deficiencies.

Nebraska data show that K tended to offset the severity of the P-Zn interaction in corn as the available K content of the soil increased.

(2) **Potassium-boron.** Missouri research has shown a significant decline in B concentration in soybeans when the soil K saturation of the clay was increased from 0.5 percent to 8.0 percent. Boron enhanced plant growth.

(3) **Potassium-molybdenum.** Potassium-molybdenum (Mo) relationships are not common. Increasing applications of K tended to depress the Mo concentration in corn leaves. **The End**

A Chemical Traffic Policeman

WITHOUT POTASSIUM, there would be no life—no human, animal, or plant life. It is basic to life processes. Under normal conditions, plants can absorb K easily.

Potassium is very mobile inside the plant, moving readily from older tissues to the growing points. But unlike nitrogen, phosphorus, and most vital nutrients, it does not become part of the chemical structure of the plant.

A big part of K exists in the cell sap in soluble form. From there it influences crops in many ways.

Because it does, potassium has been called many things: A chemical traffic policeman . . . a root booster . . . a stalk strengthener . . . a food former . . . an enzyme activator . . . a breathing regulator . . . a water stretcher . . . a sugar and starch transporter . . . a protein builder . . . a wilt reducer . . . a disease retarder.

Some get carried away and say it puts muscle into plants. Research has shown crops that get enough of it can face stress better.

But potassium is nothing without its companion nutrients, such as nitrogen, phosphorus, magnesium, and sulphur. The elements work TOGETHER to build crop yields and quality . . . because success is in the balance.

Potassium's influence on growth is seldom obvious to the eye. It doesn't usually cause plant life to show quick spurts of rich-green growth, but it can quietly push the plant toward early maturity . . . and do many other things to win yields and influence quality.

This booklet shows why plenty of potassium is essential in a well-balanced fertilizer program.

Effects of Potassium on Nitrogen Fixation

Table 1. Effects of K on soybean yield, nodulation and protein production.

K_2O Rate	Yield	Nodule Number	Nodule Weight	Seed Protein Production
lb/A	bu/A	/plant	g/cu. ft.	lb/A
0	26.4	59	9.6	662
120	54.8	114	25.7	1,289

IT IS GENERALLY AGREED that factors favoring nitrogen fixation are similar to those necessary for good growth, vigor, and dry matter production of the host plant.

The two nutrients high-yielding legumes need the most are nitrogen and potassium. Six to ten times more N and K are taken up by legumes than P, Mg, or S. Numerous experiments have shown that K has a favorable effect on legume dry matter production, seed yield, nodule number, nodule size and nitrogen production. **Table 1.**

Despite the favorable K relationships with N-fixation, there are doubts about the involvement of K in the N-fixation process because it is often noted that K depresses the percent N in forage and seed legumes.

Invariably, the depressive effect K has on the percent N is associated with greater dry matter production and greater total N uptake.

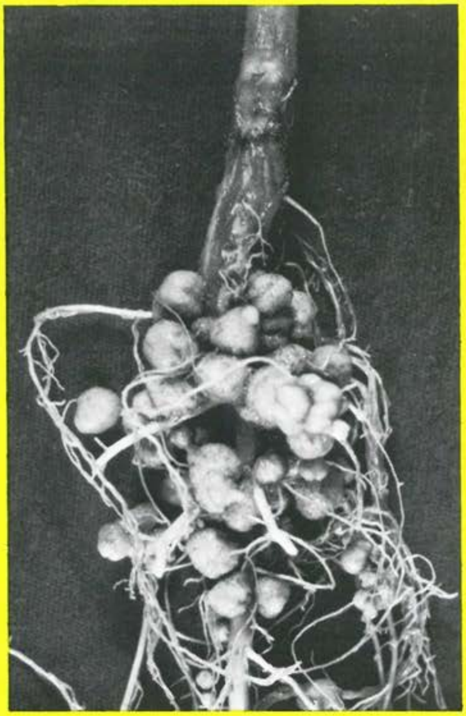
Estimates have been made that 10^8 tons of N are fixed annually in the world. In the United States, N-fixation is estimated at 11.9 million tons per year. The amount fixed in the U.S. surpasses the fertilizer N used in the 1978-79 fertilizer year.

Yet, when one considers the N-fixing capacity of high-yielding legumes through the adoption of approved management practices, the tonnage of N fixed annually in the United States is a small percent of the potential.

The yield response of alfalfa, soybeans, and other legumes to K is well known. The use of adequate potassium, in conjunction with other proven management practices, is the single most important factor in determining the total N fixation.

POTASSIUM HAS SPECIFIC roles to play in nitrogen fixation. Research has shown that an efficient and effective nitrogen fixation process:

1. **Requires a great amount of energy in the form of ATP.**
2. **Needs good supply of carbohydrates to be combined with the reduced nitrogen to form the various N-compounds necessary for legume growth and development.**



"A MANY-SPLENDORED THING." That's what O. N. Allen calls the relationship of the root nodule bacteria with a leguminous plant, in the third edition of **Forages,** issued by the Iowa State University Press.

The plant benefits. Rhizobia grow and prosper. And nitrogen is converted into available forms for all living things to use.

Different legumes fix different amounts of nitrogen. The estimated ranges for 4 important legumes vary widely with yield level.

HOST	NITROGEN FIXED
Peas, Vetch	30-140 lb/A
Alfalfa	80-400
Clovers	50-250
Soybeans	60-240

Potassium Increases Nitrogen Fixation in Legumes

3. **Depends on the translocation of the carbohydrates from the host plant to the nodules and the return of the N-compounds from the nodule to the host plant.**

4. **Improves with good root growth and nodule development.**

Potassium has a favorable influence on each of the above factors. Some of these favorable K-effects had a major influence on soybean yields in Virginia, **Table 1.** Soybean yield, nodule number, nodule weight, and total protein production were all increased on this medium-K Davidson silt loam soil.

Alfalfa with sufficient K begins N fixation sooner after cutting than low-K plants and has higher N fixation rates during rapid growth.

The determination of a direct role for K in N-fixation is primarily of scientific interest. The real value to production agriculture is in the **combined effects** of essential nutrients on the process.

Nitrogen fixation is no different than all other plant functions where an optimum level of all essential nutrients in conjunction with top crop management is needed for optimum activity. **The End**

Effects of K On Crop Maturity

POTASSIUM FUNCTIONS as a "free agent" or "chemical policeman" in the plant.

Although its exact functions are not well understood, its primary role seems to be tied to plant metabolism. Unlike N and P, K does not form organic compounds in the plant.

Potassium is necessary to keep the plant alive and growing toward its normal maturity. What is the effect of K on plant maturity? Its influence can be exhibited in many ways.

POTASSIUM HASTENS SILKING. In a Kentucky study, K reduced the days from emergence to silk, but delayed maturity by as many as five days. The net effect was an increase of seven days in number of days of grain development and higher yields.

Other studies have shown that K hastens silking and most show that it does not shorten the total production cycle. In other words, **there is a longer grain filling period.**

In an Illinois study on a medium K soil, K had a tendency to increase grain moisture at harvest, another measure of maturity effects, **Table 2.**

Table 2. Potassium Increases Corn Yield and Grain Moisture

K_2O Lb/A	Moisture in Grain, %	Yield, Bu/A
0	26.5	148
60	27.1	160
120	27.7	164
240	27.4	164

Soil test K = 226 Lb/A

The tendency for added K to increase moisture content may have an indirect effect on physiological maturity.

Low K causes early death of corn plant tissue, allowing stalk rot to kill the plant prematurely. Potassium reduces the percentage of senescent (aging) corn stalks on a low-medium K soil, **Table 3.**

Table 3. Potassium Reduces Percentage of Senescent Corn Stalks

	K Rate, Lb/A			
Year	0	50	100	200
	— % Senescent Stalks —			
First	92	74	60	57
Second	76	59	50	50
Third	72	60	58	54

DELAYED MATURITY from K starvation is shown on soybeans. With low K, plants are usually stunted. Leaves show yellowish margins. Both leaves and stems remain green after normal plants have matured and dropped their leaves.

Apparently the real physiological cause is that there are fewer seed pods and the seeds do not form normally. So the plant tries to stay alive until more seeds form. The same effect of bean plants remaining green longer can be caused by pulling off the seed pods before maturity.

TABLE 1. POTASSIUM INCREASES GRAIN DEVELOPMENT DAYS

K_2O Rate, Lb/A	Days from Emergence to Silk	Days from Emergence to Maturity	Days of Grain Development	Yield, Bu/A
0	83	138	55	142
60	81	142	61	155
240	80	142	62	170

THE OVERALL INFLUENCE OF K on cotton maturity ranges from speeding it up to no effect to a delay.

In Louisiana on a low K acid soil, K had no effect on first harvest yields on an acid soil without lime. But when dolomitic lime was applied, K increased both first harvest and total yields, **Table 4.** In Arkansas, K did not affect first harvest yield, but it did delay maturity in Alabama.

Table 4. Potassium and Lime Increase First Harvest and Total Yields of Seedcotton

Lb/A K_2O	First Harvest Yield, Lb/A	Total Yield, Lb/A
No Lime		
0	684	1,008
64	685	1,194
Dol. Lime		
0	1,057	1,283
64	1,400	1,920

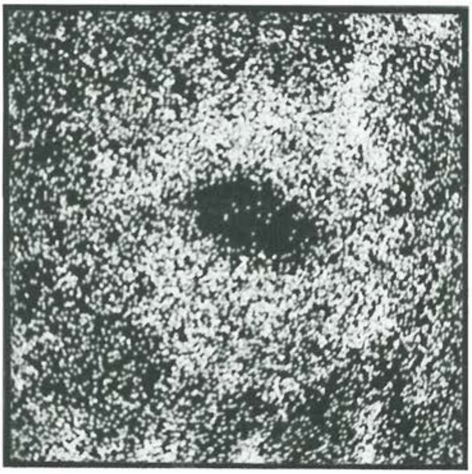
The effects of K on maturity of fruit and vegetable crops vary.

In one study, K increased early harvest and total yields of tomatoes, but had no effect in another study. Adequate K has been shown to reduce premature drop of tomatoes and citrus fruits. There may be a slight early season advantage from K on cauliflower. But high K rates have delayed maturity of broccoli. In a North Carolina study, K increased yields and hastened the maturity of blueberries **(Table 5).**

Table 5. Potassium Increases Yield and Hastens Maturity of Blueberries

K Rate, Lb/A	Yield, Lb/Bush	Weeks to Harvest from Fruit Set
0	5.14	8.4
43	5.49	8.3
85	5.31	7.7

Early maturity of fruit and vegetables almost always offers the advantage of higher prices in the market place. **The End**



K Adequate **Potassium helps plants retard disease entry through proper stomata activity.** **K Deficient**

Effects of Potassium on Plant Diseases

NEARLY 80 YEARS ago scientists were aware that potassium aided plants in resisting disease. Since that time, more than 1200 research studies have been reported on plant disease-potassium relationships. While much is known, there is much yet to learn.

POTASSIUM'S ROLE in disease resistance. Plant resistance or susceptibility to a disease depends upon two factors . . . ease of entry into the plant . . . and ease of development within the plant. Potassium plays several roles in reducing plant susceptibility to disease:

- **Increases efficiency of stomatal movement**
- **Strengthens cell walls (high lignin content)**
- **Increases silica content of cells**
- **Regulates nitrogen transformation**
- **Improves cellular nutrition**
- **Prevents premature parenchyma breakdown**

HIGH NITROGEN NEEDS ADEQUATE POTASSIUM. High nitrogen rates without adequate potassium are often associated with higher incidence of plant disease. As farmers strive for high yields, the need for disease prevention will grow. The benefits of potassium in disease resistance will come into sharper focus.

An Illinois study using 300 lbs of N per acre illustrates the benefits of potassium at high yield levels on a soil testing high in K. Potassium provided not only an average annual yield increase of 21 bu/A, but also reduced lodging in 3 of the 4 years, **Table 1.**

Potassium with high N decreases lodging and stalk rot of sorghum and increases yields, **Table 2.**

The need for balanced fertility is vital not only for row crops but for turf grass such as "Merion" Kentucky Bluegrass. The fungus disease **(Ustilago striiformis)** is a problem with high rates of N. Grass

Lower Internodes of Corn Stalks

Healthiest stalks with 160-70-133 (Sept. 20).

Aug. 16 Sept. 20 Oct. 3

Rapid corn stalk tissue breakdown with 160-70-0.

Table 1. Potassium increased corn yields and reduced lodging.

Year	Yield		Stalk Lodging	
	Control	120 lb/A K_2O	Control	120 lb/A K_2O
	bu/A		%	
1st	148	164	56	60
2nd	148	164	30	25
3rd	151	187	30	16
4th	104	120	52	27

Table 2. Added K lowered stalk rot and increased grain sorghum yields.

K_2O rate	Stalk rot	Grain yield
lb/A	percent	bu/A
0	22	52
40	20	61
80	26	72
160	16	76
320	4	83

N—150 lb/A
Low K soil test
Kansas

receiving high rates of NPK fertilizer was less diseased than that receiving high nitrogen alone or nitrogen plus P or K, **Table 3.**

Table 3. High rates of NPK fertilizer reduced disease severity in bluegrass.

	12-2-4	24-4-8	48-8-16
	(% smutted tillers)		
N	8	13	40
NP	1	5	30
NK	1	6	26
NPK	2	2	11

Table 4. Soybeans respond to P-K fertilization.

Fertilizer* P_2O_5	K_2O	Soybean Yield	Shriveled & Diseased Seed	Dockage
lb/A		bu/A	%	$/bu
0	0	35	20.8	1.18
400	0	29	12.5	.54
0	400	38	1.8	none
400	400	52	1.3	none

*Applied only in first of the five-year study.

BUILD SOIL FERTILITY TO IMPROVE DISEASE RESISTANCE. Low fertility soils often respond to fertilizer use and top production practices in three ways . . . higher yields . . . improved crop quality . . . and lower disease susceptibility. Potassium plays a key role.

Soybeans show that building low fertility soils pays in several ways. Results from a 5-year study show improved yield, on a soil medium in P and low in K improved seed quality and lower dockage at the elevator. Again, the potassium plus phosphorus team generated the best net return, **Table 4.**

POTASSIUM IMPROVES CROP DISEASE RESISTANCE. Potassium deficient soils are a major factor leading to poor corn standability at harvest. Team potassium with other nutrients and high yield production practices. There are several reasons why.

Potassium helps maintain firm, healthy stalks until natural maturity.

K also helps plants develop strong cell walls for added disease resistance, **Table 5.**

Table 5. Potassium helps develop strong cell walls.

K_2O lb/A	Rind Thickness cm/10^3	Stalk Crushing Strength kg
0	91	254
60	97	349
120	100	374

Many soybean varieties are highly susceptible to pod and stem blight caused by the fungus **diaporthe sojae L.** The gray moldy seed resulting from the fungus infection means not only lower yield, but also lower seed quality. The top pods of the plant often have the highest incidence of invasion by the fungus. These same pods are first to reflect low K nutrition. Potassium as either potassium chloride or potassium sulphate has been shown to decrease the percent of diseased seed, **Table 6.**

ADVERSE WEATHER LOWERS DISEASE RESISTANCE. Adverse climatic conditions often lead to crop disease problems.

In an extremely dry season, potassium boosted soybean yields by 9 bushels per acre and reduced shriveled and diseased seed from 37 percent down to negligible levels. Soybean seed value was lowered $2.50 per bushel simply due to heavy seed disease attack, **Table 7.**

Table 7. Potassium helps maintain quality of seed.

Potassium	Seed Yield	Shriveled Seed	Elevator Dockage
0 lb/A	4.2 bu/A	37%	$2.50/bu
120	13.1	1	—

Table 6. Potassium fertilization reduces percent of diseased seed.

KCl or K_2SO_4 (g/cylinder)	Seeds/Plant	Diseased Seed (%)*
Control	254	87
2	262	65
10	275	21
30 + 10 sidedress	264	13

*% gray, moldy seed (**D. sojae L.** infected)

These eight points generally summarize research results.

1. Potassium improved plant health in 65% of the studies and was deleterious 23% of the time.

2. Potassium reduced bacterial and fungal diseases 70% of the time, insects and mites 60% of the time, and nematodes and virus influences in a majority of the cases.

3. Fungal disease infestation was reduced an average of 48% where soils tested low in potassium and 14% where soil test levels were unknown. Where the soils tested low, 88% of the studies showed crop response to applied potassium. Crops responded 60% of the time where soil test levels were undefined.

4. Potassium's influence upon crop yield varied according to the parasite group. The average increase in yield or growth was 48% for fungal diseases, 99% for viruses, 115% for nematodes, 14% for insects and mites, and 70% for bacteria.

Crop yield and growth increases were greatest for nematodes and viruses even though these pathogens were often increased by potassium.

5. The mode of action is through plant metabolism and morphology, primarily. Accumulating nitrogen compounds, sugars, etc., are frequently accompanied by improved conditions for parasite development. Tissue hardening, stomatal opening patterns, etc., are closely related to infestation intensity.

6. Crop response was not consistently different for potassium sources.

7. Nitrogen balanced with potassium is significant to disease resistance by plants.

8. Benefits were noted more frequently in the field than in laboratory and greenhouse experiments. The End

Potassium & Crop Quality

CROP QUALITY is a neglected but important aspect of crop production.

For the producers, good quality can mean many things: More protein, higher feed value, improved persistence, reduced drying costs, less dockage for diseased or shriveled grains, greater consumer acceptance and higher prices.

For the consumers, many quality factors affect the quantity purchased and price paid: Size, shape, color, freedom from internal and external blemishes, retention of quality in storage or on the shelf, flavor and texture.

Food processors are conscious that they must provide products of uniformly high quality.

Let's look at a few specific effects of potash on crop quality.

ON CORN: Although N is usually considered to be the most important nutrient in crop production, it must be balanced with adequate K for both quantity and quality. Numerous experiments have shown that K reduces stalk aging and lodging, increases rind thickness, improves brace root development, and decreases internal disintegration of the stalk at maturity.

Good stalk strength means lower grain losses during harvest. In Ohio, yield losses resulting from delayed harvest were reduced by half with high K.

ON CORN SILAGE: N is the most important nutrient determining protein production per acre, but adequate K is needed to convert the soluble N compounds in the corn plant to true protein. In Wisconsin studies, K increased the carotene content of corn silage and reduced fermentation losses.

ON SOYBEANS: In a Virginia study, K fertilization increased the number and weight of soybean nodules. These are essential for N fixation by legume crops such as soybeans. Nodules per plant increased from 27 without fertilizer to 63 with balanced PK fertilization.

In the same studies, the percentage of sound seed was increased by P and/or K. The percentage of purple stain was reduced by P and K, especially in the top third of the plant, shown in **Table 1.**

Table 1. Effect of P and K on purple stain in soybeans.

		Purple seed stain	
P_2O_5	K_2O	Top	Bottom
lb/A		%	
0	0	27	8
400	0	22	12
0	400	17	8
400	400	11	6

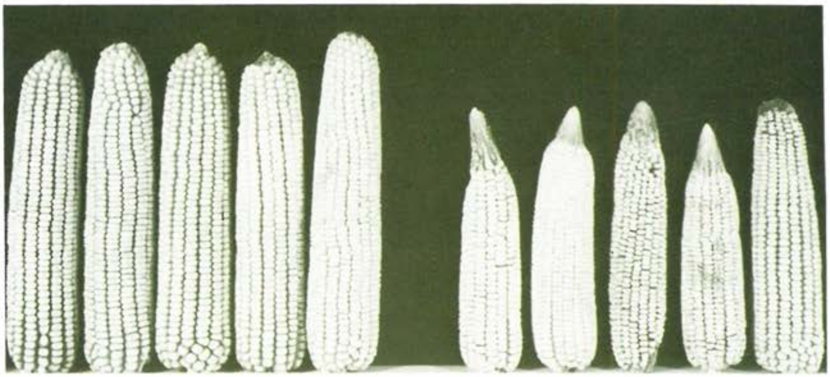
Top—one-third of plant, bottom two-thirds of plant. Va.

Potash can reduce the number of moldy, shriveled seeds, meaning less dockage for diseased beans. In one study, K reduced the proportion of moldy and shriveled seed from 12.5 to 1.8 percent. In another experiment, 75 percent of the seeds were diseased with low K, compared to only 13 percent with high K.

ON SMALL GRAINS: Adequate K increases stem strength and decreases lodging caused by high N. On high K soils in Montana, K increased the diameter of wheat stems by 10 percent and relative breaking force of upper stems by 18 percent.

Many experiments have shown K can influence the conversion of nitrogen compounds into protein. European workers found high K increased wheat yield, single grain weight, and grain protein content.

In North Dakota and Manitoba, the application of 30 lb K_2O/A on soils testing high in K gave small but profitable increases in barley yields. It also increased the percentage of plump kernels, a desirable quality factor for malting purposes.



+ K = higher yield
+ better quality

— K = chaffy ears and
lodged stalks

ON FORAGE CROPS: The effects of K in improving the quality of forage crops are especially important. The proportion of legumes and grasses, persistence, rate of regrowth, leaf to stem rates, chemical composition, and total feeding value of forages have all been positively influenced by adequate K.

In one long-term experiment, alfalfa made up only 17 percent of the stand without K after three years production compared to 66 percent when 400 lb K_2O/A was applied annually. Potash increases the size and extent of root systems and the reserves of carbohydrates in roots which are essential for persistence.

Virginia studies showed a close relationship between K fertilization rate and K content of alfalfa, rate of regrowth, and leaf area index. Applying 400 lb K_2O/A increased the 18-day regrowth by 75 percent. This can permit one extra cut per year and increase total feed value. In Michigan, the combination of high K, plus one extra cut, increased alfalfa yields by 63 percent and feed value by 92 percent.

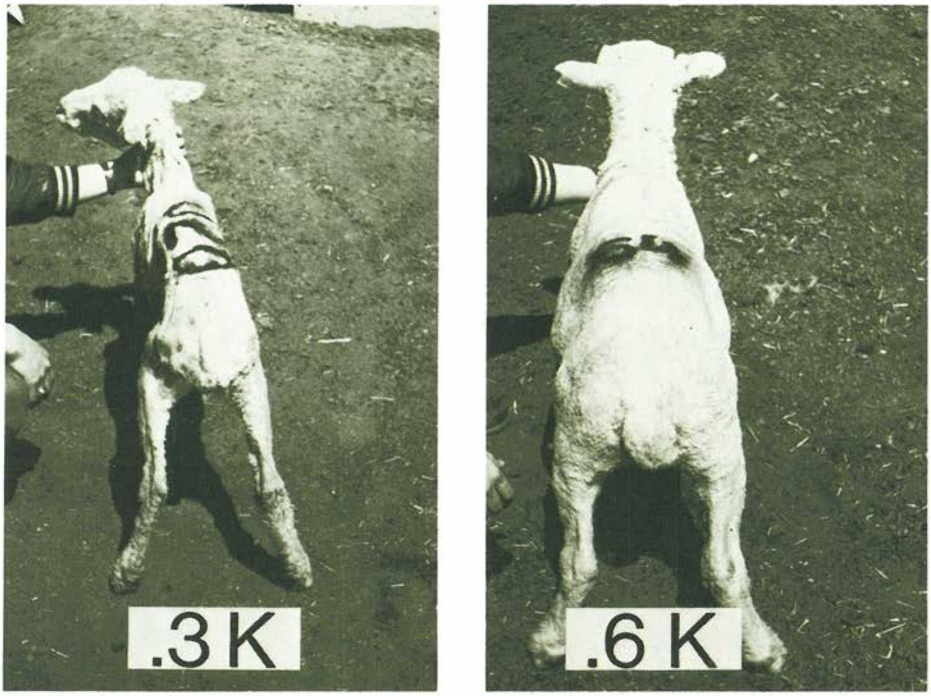
ON HORTICULTURAL CROPS: Numerous studies with vegetable and fruit crops have shown that unbalanced fertilization programs lead to many undesirable quality characteristics. For example, in experiments with potatoes and tomatoes, high K gave as much as a three-fold reduction in the proportion of "culls."

Size, shape, color, and other quality factors are influenced by nutrient balance. With apples, high N rates will give maximum yields. But best color, flavor, texture, and storage quality is obtained with lower N and high K.

ON COTTON: In modern cotton culture, greater emphasis is being placed on the length, strength, and fineness of the fiber. In Missouri, the combination of K applied initially, plus annual K applications, increased seed yield, micronaire index and percent lint. With low K, micronaire values were below the desirable range leading to substantial price discounts for inferior quality.

The quality of many other crops such as rice, sugar beets, sugarcane, citrus and turf is very closely related to K levels in the soil and the quantities of applied K. High quality means extra dollars for the producer and greater acceptance by the processor and consumer.

It is "the quantity of quality" that pays off in crop production. See many examples on pages 36 and 37. **The End**



WITH SHEEP . . . researchers have gotten their best rate of gain, feed intake, dressing percent, carcass gain and grade from 0.62% K in the ration, the highest they tried. Carcass weight rose more than 5 lbs from 0.30% K to 0.62% K in the ration.

Potassium in Animal Nutrition

POTASSIUM HAS been recognized as an essential nutrient in animal nutrition since the importance of K was pointed out by Sidney Ringer in 1883. Potassium is absolutely essential for life. Young animals will fail to grow and will die within a few days when the diet is quite deficient in K.

Potassium is the third most abundant mineral element in the animal body, surpassed only by Ca and P. Potassium concentrations in cells exceed the concentration of Na by 20 to 30 times. Outside the cell the reverse is true. Potassium composes about 5% of the total mineral content of the body.

Muscle contains more than 55% of the total K in the body of animals, **Table 1.**

Table 1. Concentration and distribution of K in animal body

Tissue or organ	K, meq/kg	K, %
Muscle	110.0	56.0
Skin	58.6	11.1
Digestive tract	96.6	5.6
Liver	95.0	5.3
Red blood cells	106.0	4.2
Blood plasma	4.2	2.2
Brain	98.6	1.4
Kidney	77.6	0.9
Lung	79.3	0.5
Spleen	130.0	0.4
Heart	77.8	0.4
Bones and other	—	12.6

Potassium is contained almost entirely within the cells and is the most plentiful ion of the intracellular fluids. Potassium is found in every cell. It is present in tissues and cells only as the K ion.

Concentrations of electrolytes differ markedly between the intra- and extracellular spaces. Sodium and Cl are mostly extracellular, whereas most of the K, P, and S are intracellular. This remarkable segregation of Na and K in body fluids is one of the real "mysteries of life".

FUNCTIONS OF POTASSIUM. Potassium is absolutely essential for life. It functions in the intracellular fluids the same as Na does in the extracellular fluids.

The major functions of K in the human and animal body are:

1. **Helps maintain water balance;**
2. **Helps maintain osmotic pressure;**
3. **Helps maintain acid-base equilibrium;**
4. **Activates several enzymes of metabolic functions;**
5. **Functions in carbohydrate and protein metabolism and protein synthesis;**
6. **Functions in irritability of muscles. Important with Ca in regulation of neuromuscular activity. K helps regulate heartbeat.**

POTASSIUM DEFICIENCY. There are several causes of K deficiency: **Inadequate amounts of K in diet, K losses in digestive secretions caused by vomiting and diarrhea, high intake of Na, increased urination, and stress conditions.**

Potassium deficiency may commonly be manifested by depressed growth, muscular weakness, stiffness, decreased feed intake, intracellular acidosis, and nervous disorders.

The first sign of K deficiency is reduced feed intake. Many of the other signs stem from reduced feed intake.

K must be supplied in the daily ration because it is a mobile nutrient and there are not any appreciable reserves.

K UPTAKE AND CONTROL. Potassium is absorbed in the small intestine. Potassium availability in the digestion is nearly 100%. Most K is lost or excreted in urine. There is a small amount lost in perspiration. Kidneys play the most important role in maintenance and control of K. Under stress conditions the kidneys tend to excrete more K and conserve Na.

POTASSIUM IN HUMAN NUTRITION. The usual American diet normally contains adequate K. The recommended daily allowance is 2500 mg. The usual intake is 2000 to 4000 mg per day.

Problems with K intake can occur. Diets low in carbohydrates lower blood K and can cause an irregular heartbeat. Potassium deficiency can become serious due to K depletion in cases of cirrhosis of liver, diarrhea, vomiting, diabetic acidosis, body burns, and severe protein-calorie malnutrition.

Potassium plays important functions in good cardiac health. Blood pressure is influenced by K. It helps overcome the adverse effect of Na on blood pressure. Sodium can be balanced with K to maintain normal blood pressure. The desirable Na to K ratio is 1:1.

POTASSIUM IN ANIMAL NUTRITION. Potassium is especially important in diets of poultry and turkeys during the first 8 weeks. The recommended daily allowance (RDA) for starting chicks is 0.2% of ration. The RDA for laying hens is 0.1%. Heat stress can increase the needed levels to 0.4% or 0.6% to insure against imbalance at elevated temperatures.

Adequate K in the ration of laying hens assures good egg production, egg weight, and shell thickness. In starter chicks and turkey poults adequate K increases weight gain, feed efficiency and reduces mortality in the first 4 weeks.

Swine RDA is higher for young pigs than older ones. It ranges from 0.27% to 0.30% in ration for pigs weighing 1 to 4 kg to 0.2% in rations of pigs up to 20 to 35 kg.

In ruminants the RDA is about 0.5% of the ration. Ruminants are able to metabolize large amounts of K from the ration. Potassium is also essential for rumen microorganisms.

The single most consistent effect of suboptimal K in the ration of ruminants is decreased feed intake.

Dairy cattle have a RDA of 0.8% K of dry ration, **Table 2.** High K in ration is especially needed during early to mid lactation of high producing dairy cows. Other dairy classes have a similar requirement.

Table 2. Effects of ration K on dairy cows, early lactation

	Ration K, %		
	0.51	0.75	0.99
Adjusted feed intake, kg/day	17.8	19.9	20.7
Adjusted milk production, kg/day	28.5	29.9	29.2
Body weight change, kg	−55.7	−35.1	−46.8

The RDA of beef cattle is about 0.6% to 0.8% of dry ration, **Table 3.** Several studies have been reported with weight gains by steers on rations containing optimum levels of K.

In Texas and Tennessee, adequate K in the ration helped reduce the shock of shipping.

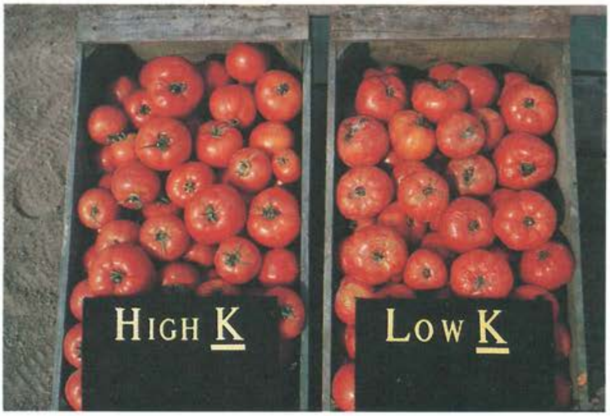
Calves on winter native range in Nebraska that were fed supplemental K did not have a depression in weight gains. Dry cows were also helped by supplemental K.

Table 3. Recommended K level, % in dry ration

Animal	Recommended level[1]
Beef cattle	0.6 to 0.8
Sheep	0.5
Dairy cattle	0.8
Swine	0.2 to 0.3
Poultry	
chickens	
starting chicks	0.2
laying or breeding hens	0.1
turkeys	0.4

[1]National Research Council of National Academy of Science

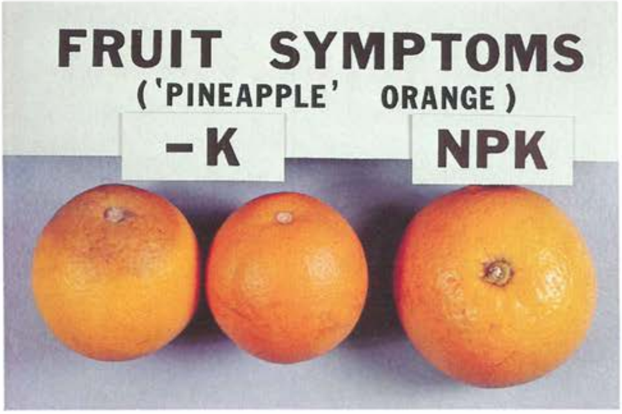
Hypomagnesia grass tetany is a pathological situation in ruminants related to high K intake, and the relationships are not clear. Hypomagnesia grass tetany in ruminants results from either a deficiency or poor utilization of Mg. The involvement of K is inconclusive. **The End**



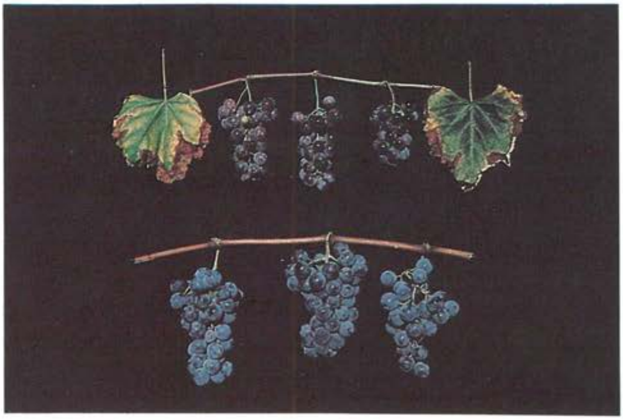
PICTORIAL CONCEPTS

To produce No. 1 grade vegetables, it pays to keep the K built up . . . because potassium builds profit-making quality. Potassium made the difference in these tomatoes. High K tomato on left . . . low K tomato on right. Potassium improved color, stem ends, size, etc. Both direct and indirect effects of K hunger caused 26% culls at third and fourth pickings.

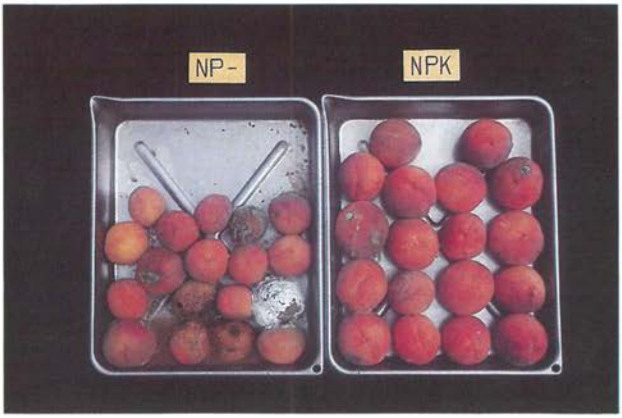
PICTORIAL CONCEPTS



When oranges don't get enough potassium, look for creasing on the rind and extremely thin rind. Also early deterioration on the stem end of the rind, low acid-sugar ratio, small fruit, heavy fruit fall, and low yield.



This is potassium hunger in grape leaves and fruit, compared with normal leaves and fruit. Note the similarity between these leaf symptoms and those of many other plants. The fruit is small, poorly formed, and low quality.



Potassium builds healthier crops to fight invading organisms during growth and even in storage—like these peaches. Note what K meant to storage life after 14 days (right). Low K peaches (left) broke down faster.

PLANT FOOD UTILIZATION

(At various yield levels)

LB/A	CORN			SOYBEANS			WHEAT		
	125	200	250 bu	40	60	80 bu	40	80	100 bu
N	155	266	350	216	324	432	67	134	168
P_2O_5	58	114	150	43	64	85	27	54	68
K_2O	165	266	350	95	142	189	81	162	203
Mg	41	65	81	18	27	36	12	24	30
S	21	33	41	17	25	33	10	20	25

	COTTON (LINT)			GRAIN SORGHUM			POTATOES		
	750	1125	1500 lb	6,000	8,000	10,000 lb	200	350	500 cwt
N	105	143	180	188	250	313	108	188	269
P_2O_5	45	54	63	68	90	113	36	63	90
K_2O	65	96	126	150	200	250	218	382	546
Mg	17	26	35	33	44	55	20	35	50
S	15	23	30	29	38	47	9	15	22

	ALFALFA			CLOVER-GRASS			CTL. BERMUDAGRASS		
	4	8	10 tons	3	6	7 tons	6	10	12 tons
N	225	450	600	150	300	350	300	500	600
P_2O_5	40	80	120	45	90	105	84	140	168
K_2O	200	480	600	180	360	420	252	420	504
Mg	20	40	53	15	30	35	27	45	54
S	20	40	51	15	30	35	27	45	54

RESEARCH PPI EDUCATION

Figures are total nutrients taken up by the crop in harvested and unharvested portions.

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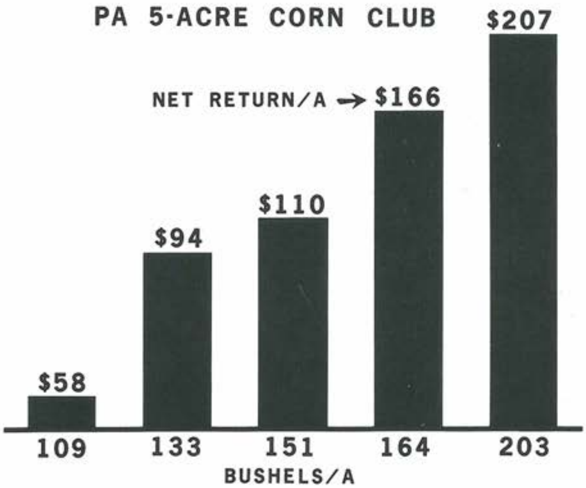
Good yields increase profit potential.
Set optimum yield goals for each soil type.
Fertilize so plant nutrients are not limiting.
Multiple cropping increases annual plant food use.

POTASSIUM HUNGER SIGNS IN SOME CROPS

CORN	• Firing or scorching on outer edge of leaf, while midrib remains green. May be some yellow striping on lower leaves. (Sorghum and most grasses also react this way.) Poor root development, defective nodal tissues, unfilled-chaffy ears, stalk lodging.
SOYBEANS	• Firing or scorching begins on outer edge of leaf. When leaf tissue dies, leaf edges become broken and ragged . . . delayed maturity and slow defoliation . . . shriveled, much less uniform beans, many worthless.
COTTON	• Cotton "rust" . . . first a yellowish white mottling in the leaf, clearest between veins. Leaf turns yellowish green, brown specks at tip around margin and between veins. As breakdown progresses, whole leaf becomes reddish brown, dies, sheds prematurely. Short plants with fewer, smaller bolls of short, weak fibers.
WHEAT	• No outstanding hunger signs on leaf itself (no discoloration, scorching, or mottling), but sharp difference in plant size and number, length, and condition of roots. Lodging tendency. Smaller kernels.
ALFALFA	• First signs small white or yellowish dots around outer edges of leaves . . . then edges turn yellow and tissue dies and becomes brown and dry.
CLOVERS	• First signs white spots size of small pinheads near the border of leaves . . . later toward center . . . while border turns yellow, curls up, and dies. The spots appear first on the older leaves. Slower regrowth.
FRUIT TREE CROPS	• Yellowish green leaves curl upward along entire leaf . . . scorched areas develop along edges that become ragged. Undersized fruit dropping prematurely. Poor storage, shipping, and canning qualities in fruit.
POTATOES	• Upper leaves usually smaller, crinkled, and darker green than normal . . . middle to lower leaves marginal scorch and yellowing. Early indicator: dark green, crinkled leaves, though varieties differ in normal leaf color-texture.
TOMATOES	• Stunted plants, slow growth, older leaves ashen gray green with yellowish brown margins . . . small fruit, darkened stem ends from poor attachments to the plant, cracking of flesh around stems, poor uneven color externally and internally.

HIGHER CORN YIELDS TRIPLE NET RETURNS



INDIVIDUAL FARMERS such as Gerald Schmit in Nebraska have taken up the challenge of maximum economic corn yields. He averaged 190 bu/A on 1,145 acres with a net profit of $262/A, 285 bu on 40 acres ($389) and 311 bu on one acre with a net profit of $446/A.

He and others like him are searching for ways to go still higher in order to better control their unit costs. Best help can come from maximum yield research. Meaningful soil testing is also a key.

How are potash levels of U.S. soils? Soil test summaries show that in most states east of the Great Plains 50 to 75% of the soils test medium or less in K. Some agronomists think these figures are conservative. Why? (1) More samples from better farmers. (2) Calibrations are often too low for today's high-yield goals.

Unless soils test very high, adding K to some high-K soils can pay. How? (1) Avoids depletion. (2) You are ready for super seasons. Also, there is always the possibility that the average K-test of a **composite** soil sample may not reveal those areas in the field that are lower in K.

Better Crops
WITH PLANT FOOD

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