BETTER CROPS WITH PLANT FOOD

2003 Number 2

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Our Cover: To better understand crop nutrient issues, take a closer look.
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INTRODUCTION TO THIS SPECIAL ISSUE

You're a typical North American consumer picking up groceries in the supermarket. Which bread is low-priced, yet nutritious? Do those organically grown fruits and vegetables represent the best choices for your family's health? Are there other wonder foods? Do careful selections really matter? Will any random selections be okay? Does each of those 60 or so cereals on the endless shelves represent a sameness in safety and nutrition?

Food choices are traditionally impacted by concerns for price and nourishment. Most recently, there's a growing focus on food being safe or unsafe. And because of increased awareness of environmental issues, many shoppers have thought about whether or not certain products contain ingredients produced in harmony with nature.

This issue of *Better Crops with Plant Food* addresses topics of concern to the increasingly literate and involved consumers of North America. The Potash & Phosphate Institute (PPI) has joined with The Fertilizer Institute (TFI) to offer a closer look at modern agriculture's food and fiber production. Hopefully, with your help, we'll reach a wider audience than that composed of the publication's regular readers.

The articles featured in this special issue present straightforward information to assist in explaining the topics covered to individuals or groups that may have limited awareness of fertilizers and agriculture in general. These topics should interest all who care about keeping their bodies healthy—and the environment healthy. Our challenge to readers is to use the content of this issue to help others to: ***Take a Closer Look!***

Kraig R. Naasz, President of TFI, observes: "The fertilizer industry is committed to helping farmers use its products with science-based practices in the production of healthy food. We're committed to be good neighbors in our communities, good partners with our customers, and good stewards of the environment in which we all live. This ***Take a Closer Look*** initiative will help the consumers agriculture serves by providing them with a greater appreciation of the critical role of fertilizers in food production."

Dr. David Dibb, President of PPI, comments: "We're pleased to join with TFI in helping the public better understand how plant nutrients enable today's farmers to produce high-yielding, high-quality crops. We invite those who work in our industry and the public we serve to ***Take a Closer Look*** at the vital role of modern production agriculture in providing the food and fiber needed by consumers in North America and other regions of the world."

The articles on the following pages will provide insights into North American food production and the management of organic as well as inorganic nutrients in producing a food supply that is among the safest and most abundant in the world. BC

Nutrients in Soil and Nutrients for Food Production

By Adrian M. Johnston

Have you ever considered the link between human nutrition and soil fertility? While most people are aware of the need to conserve the soil resource, there is growing concern that many are not aware of the role that fertile soils play in producing high quality food. The crop products we are consuming today meet our nutritional needs as a result of nutrients applied to soils as fertilizer, livestock manure, or crop residues.

While the philosophy of farmers may differ on managing soil fertility, they are well aware of the impact that past soil management has on current production, and the implications of soil fertility decline on a sustainable future for agriculture.

Fortunately, plants do not discriminate among nutrient sources in the soil, taking them up as plant-available inorganic forms regardless of their origin. Commercial fertilizers have played a large role in the success of today's farms–directly with those that apply them, and indirectly with the few that don't.

Resource scientists confirm that one of the greatest advantages held by North American farmers in the competitive world of food production is the quality of their soil resource. Native soil fertility in vast regions of North America still allows the production of high crop yields in the absence of nutrient additions. The practice of summer fallowing, or letting the land rest (that is leaving it uncropped) for a period of time when crops normally would be grown allows the soil to replenish stored moisture and build up plant-available nutrients as they are released from the soil's organic matter. Spring wheat grain yield trends from a semiarid research site in western Canada illustrate the inherent productivity of many grassland soils (**Figure 1**). In the absence of phosphorus fertilizer additions, yield averaged about 84% of the fertilized wheat for over 30 years. However, in the mid 1990s the spread between fertilized and unfertilized wheat yield started to increase, reflecting a reduced nutrient supply in the fallowed land in the absence of phosphorus replacement with fertilizer use.

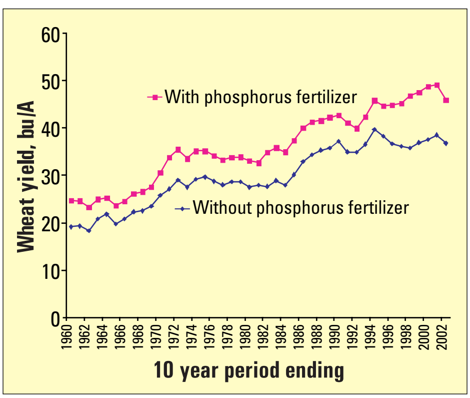

Figure 1. Yield of spring wheat grown on summer fallow with and without fertilizer phosphorus additions.

A small proportion of North American farmers have opted to use organic crop production methods, a practice that removes the use of certain external inputs, in particular most commercial fertilizers and pesticides. Fortunately, past fertilizer use on lands converted to organic production continues to provide residual crop responses for a number of years into the future (**Figure 2**). Additions of phosphorus and potassium to soils improves their inherent fertility for future production. Certain legume crops–such as alfalfa, clovers, and soybeans–can fix their own nitrogen from the air. However, soil reserves of plant-available phosphorus and potassium are finite and annual removals deplete soil supply in the absence of some form of addition.

Sole reliance on nutrients which are generated on-farm limits productivity. A recent survey of organic farms in the northeast Great Plains found crops produced organically yielded only 44 to 75% of those produced conventionally (**Table 1**). An evaluation of soil nutrient status with soil testing was carried out on these same survey farms. Soil nitrogen levels were average to high on most farms, reflecting the use of forage and grain legume crops to restore nitrogen fertility through nitrogen fixation. However, the survey found low levels of phosphorus and sulfur in many of the fields sampled. Deficiencies in phosphorus and sulfur could limit future nitrogen fixation by legumes. However, the imbalance of high nitrogen with low phosphorus and sulfur is more likely to reduce crop yield by inefficient use of soil-available nitrogen. For organic farms to continue to produce good yields per acre, this often means bringing in nutrients from off the farm.

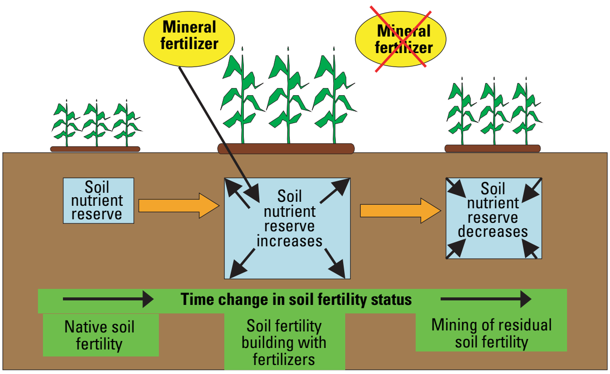

Figure 2. Role of past fertilizer additions in future crop production.

TABLE 1. Yield of selected cereal, oilseed, and pulse crops grown using organic and conventional production practices in Manitoba.

	Organic	Conventional[1]	Organic as % of
	..........Yield, bu/A	....	conventional
Wheat (hard red spring)	25.3	35.2	72
Barley	45.7	60.9	75
Oats	45.9	64.8	71
Flax	11.8	22.0	54
Canola	12.9	29.5	44
Field pea	18.7	34.5	54

[1]Conventional yield source was Manitoba Crop Insurance Corporation data from southwestern Manitoba.

Addressing the net export of nutrients from organic farms will become a major challenge in the future. Some growers obtain organic nutrients from neighboring farms to balance their nutrient needs. Composts, crop residues, and animal manures all contain nutrients derived in part from commercial fertilizer, either directly applied or from past application. And even after many years of transition to organic farming, soils still contain phosphorus and potassium built up by previous fertilizer use (**Figure 2**). So, organic farmers also benefit from North America's long history of applying commercial fertilizers.

A recent survey of organic farms in the northeast Great Plains found crops produced organically yielded only 44 to 75% of those produced conventionally.

Suggested changes in organic certification criteria are making it more difficult to source nutrients and crop production inputs for organic farms. It has been suggested that manures and composts only come from livestock managed on certified organic farms. The same applies to new seed grain cultivars introduced to capture improvements in yield, quality, and pest resistance. These restrictions are bound to increase the interdependence between organic farms and limit the possibilities to manage nutrients and maintain productive soils.

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Why North America Imports Few Food or Fiber Staples

By Harold F. Reetz

Most North Americans are not concerned about their food supply...they don't have to be. Over 97% of the people in the U.S. are free to pursue other jobs and interests, because highly efficient farming systems require only 2 to 3% of the population in production agriculture. We spend a very small portion (about 9%) of our income on food...and the majority of that is for transportation, processing, and packaging. Our ability to help supply the world market for grain and fiber also provides a stable ***domestic*** food and fiber supply. We don't have to depend on foreign sources for our basic food supply. Although we do depend on foreign sources of special fresh foods and other products, our basic needs are met by domestic production. Few nations in the world share the luxury...and security...of a more-than-adequate food and fiber supply.

> Use of commercial fertilizers is responsible for an estimated 40% of food production in the U.S. The contribution of agricultural products to the North American balance of trade is usually taken for granted, but cannot be overlooked. Supplying foreign markets with food and fiber allows us to purchase products from other countries to support our high standard of living.

Agriculture also has the capacity to help substantially reduce our dependence on foreign energy sources. Ethanol from corn and bio-diesel from soybeans can now be efficiently produced to replace fossil fuels and at the same time better protect air quality, especially in concentrated urban areas. Even if subsidies are needed initially to develop the infrastructure for jump-starting the bio-fuel industry, the long-term potential for independence in energy sources and improvements in air quality may be well worth the investment.

Why are we so fortunate? We are blessed with some of the world's largest regions of ideal soils and climate for crop production. But we also have developed a system of research and education through universities and industry that is unequalled in the world. North American farmers and their advisers have access to a wealth of information and technology that keep them on the leading edge of productivity. Scientists in the universities, government agencies, and industry keep the information flowing and the new challenges addressed.

North American farmers and their advisers have unprecedented access to weather and market data, research summaries, and recommendations. The Internet has dramatically changed the flow of information. The latest technology even allows farmers to access the Internet from their tractor cab in the field. The challenge becomes managing and interpreting the information to make better-informed decisions, using the technology to maintain a competitive edge in the global economy.

North American agriculture's success is a product of a unique set of resources:

- vast fertile soil and climate resources ideal for crop production;

- a highly skilled, experienced, and motivated management/workforce rooted in the family farm tradition;
- an unparalleled system of basic research to develop new technology and genetic material;
- a well-developed system of applied research to capture the benefits of new technology into new practices;
- an unmatched Extension education network to get the practices adopted in the field;
- an infrastructure of the input supply, service, and information networks needed to support production;
- an infrastructure to transport raw and processed products to domestic and global markets.

The productivity of modern agriculture in North America helps protect fragile lands in other regions of the world.

The ***combination*** of these systems is probably the most important factor. Nowhere in the world has it been duplicated. Current economic pressures within government, universities, and industry threaten the stability of this system, and with it the food-fiber-energy security we have come to depend upon. All members of the agricultural system are critical to maintaining that security.

Total volume of production is still the key to our overall balance of trade and domestic food and fiber security. While specialty products and associated markets are increasingly important, commodity production is still the mainstay of our agricultural economy and will be for the foreseeable future. Our success and efficiency in commodity production is dependent upon maintaining, and improving, productivity through proper nutrient management. Higher yields supported by proper fertility will sustain the system. Nutrient management planning has drawn considerable attention in recent years with respect to environmental concerns, but it may be even more important from the standpoint of maintaining productivity.

Nutrient levels on many North American farms are being depleted as a result of several trends:

- Farmers share the concern for the environment and have cut back on nutrient applications…beyond sustainable levels in some cases.
- Due to narrowing profit potential, farmers have cut back on nutrient applications over the past 20 years, allowing crops to draw from the soil nutrient "bank account".
- Crop production levels–and thus nutrient removals–have increased, resulting in an "overdraft" in some fields.

We cannot afford to let the current trends of depletion of soil nutrients continue. At least 40% of our food production is possible only due to use of commercial fertilizers. In fact, use of fertilizer makes it possible for us to continue to use large areas of land for forests, parks, and wildlife areas. Maintaining soil test levels in Illinois corn fields helps protect the rainforests of Brazil and the fragile wildlife habitats of sub-Saharan Africa.

Without fertilizer to maintain productivity on North American farms, more of the world's fragile lands would have to be converted to growing food. Fertilizers increase yield potential of farmland, so that other land can be used for other purposes.

Correcting the trends toward lower soil tests will help farmers and our national food security by:

- Maintaining our low-cost food supply through increasing yields and reduced cost per unit of production.
- Increasing potential to produce low-cost feedstuffs for industrial uses.
- Enhancing competitiveness of agriculturally-derived energy products.
- Ensuring continued independence for our most basic food and fiber needs.

Our future food/fiber/energy security depends on responsible attention to nutrient management today...on all fields. Correcting current trends requires better attention to soil testing and fertilizer application to address deficiencies and avoid excesses. Techniques are being refined, such as site-specific nutrient management systems. Scientifically sound, balanced nutrition in farm fields leads to more balanced diets for animal and human consumption, and supports our national independence in food, fiber, and, perhaps someday, energy. BC

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Nutrients in Soil and Nutrients for Food Production

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Commercial fertilizers supply nutrients in the inorganic form–the form that plants actually absorb–to boost the growth of plants. Using these nutrients, plants produce the organic materials critical to building soil structure and to supporting the soil organisms essential to nutrient cycling. Thus, inorganic nutrients play a vital role in the biology and health of the soil ecosystem.

Across North America, crops currently remove 77% of the nitrogen supplied in fertilizers, manures, and by legumes. The figure for phosphorus is 95%. Some losses occur, but growers have made progress over the past two or three decades in reducing them. Soil potassium, however, is currently being depleted. Crops remove 43% more potassium than is supplied in fertilizers and recoverable manure.

Agriculture has, and continues to be, oriented toward producing healthy food for all consumers. Managing the Earth's large reserves of inorganic nutrients is imperative to sustain an agriculture that produces healthy food for all. BC

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AGRICULTURE'S BALANCING ACT

BY T. SCOTT MURRELL

Ever seen a pond or lake that's green and smells bad? Isn't the water supposed to be clear enough to swim in? After all, what's the point in going to the lake if you and your family can't enjoy it? Turns out the problem may be too much of a good thing...nutrients. Phosphorus is essential for plant and animal health. Fish need some phosphorus in their water to survive. But too much phosphorus in the water is bad for fish and other aquatic life. It's like food. Without it, we starve, but if we binge, we bloat. The key is balance. And right now, our lands and waters have unbalanced levels of phosphorus. We've got too much in some places, and not nearly enough in others.

Progress is being made in better managing application of fertilizers and livestock manures for optimum use in crop production, while protecting water quality. While too much phosphorus is not good in rivers, lakes, and other water bodies, soils in many areas are still low in availability of the nutrient.

How did our lands and waters get into this shape? Well, it didn't happen overnight. We all like food that doesn't cost us an arm or a leg, but we want it to be nutritious...except for an occasional candy bar. Combine this with the fact that most of us had kids. So over time, we placed greater and greater demands on the food supply…more, better, cheaper…and agriculture responded with bigger, fewer, more efficient farming operations. It's the economy of scale. Spread costs of production over more bushels or snouts, and each little pig or ear of corn costs less to produce. So agriculture has seen a lot of consolidation.

Now, one thing hasn't changed, and that is if you put food in one end of an animal you'll get something (waste) out at the opposite end. If you've got a lot of these opposite ends in one place, given the economy of scale, pretty soon you find yourself knee-deep in stuff we pay a high price for at the garden store. So, you need to find some way to get rid of all the waste.

Increasing attention to water quality in recent years has resulted in more efforts in crop nutrient management.

Well, these animals aren't going to hold it in until you've got the barn all nice and clean and then give them the green light. You've got to keep up. So you scrape and shovel it out of the barn. That keeps the barn clean, but now you've got a pile right outside the door that you must do something about. Since the garden store only has so much shelf space, you've got to find another option...put it on the land. Great idea. Manure contains nutrients and plants out there on the land need nutrients. A match made in, well, hog heaven.

(continued on next page)

Unfortunately, like most matches, things aren't always as perfect as they first appear. Hauling manure from a pile to the surrounding land is a never-ending job, kind of like taking out the garbage. Plus, you don't want to haul it too far because it takes time and money. So you figure closer is better. Another problem solved.

Except now there's something else wrong. Remember all those nutrients in that manure? Well, plants only need so much. In fact, they need different amounts of each. They took more of the nitrogen, but left a lot of the phosphorus. Now those handy nearby lands have a lot of phosphorus…more than plants need, but the land you farm farther out doesn't. Too much here…too little there. So what are you going to do about the crop nutritional needs of that more distant land?

You already know that if you haul the manure too far, you can't keep up with the pile near the barn, plus it starts getting uneconomical...lots of trips back and forth and you wind up feeding the gas tank more than your kids. Plus, the relative amounts of nutrients in manure aren't well matched to what plants need. If they were, you wouldn't have this problem to begin with. What you want is something economical to haul longer distances plus meet the crop nutrient needs more exactly, to avoid creating a big pile of phosphorus somewhere else. The solution? Commercial fertilizer.

Yes, commercial fertilizer is a modern marvel...little granules of highly concentrated nutrients that can be blended together into just the right mix. You can haul it a long way and still afford to buy candy bars. Great, one more problem solved. Time to go fishing.

As you whistle down the lane, fishing rod in one hand, tackle box in the other, you suddenly remember the problem that started all this...all that green algae in the pond. Now, just having a lot of phosphorus on the land doesn't automatically mean that fish are going to start popping to the surface. For that to happen, phosphorus has to get from the land to the water and there has to be enough phosphorus around to be a problem. So if you've got enriched soil on flat land in a drier area...no real problem. But a gully-washer rain falling on barren land that slopes down to a creek gets the fish worrying about their future.

Livestock manure can provide some needed nutrients for crops, but transportation and balancing nutrient levels correctly are challenges.

Phosphorus enters water in many ways, both natural and through human activity. Agriculture is only one of the ways. But we are striving to fix our part of the problem. So, what are we doing? Right now, agricultural scientists, agencies, and industries are finding ways to work together to educate people about what we already know to be some of the best ways of managing nutrients...integrating manure and commercial fertilizer applications to better distribute nutrients in the environment while meeting plant and animal needs. And of course, there are many things we don't know yet about how all this works. For that, we conduct research to help find some practical approaches.

We have a long way to go, but working together, we are making strides toward cleaning up our part of the water problems. The people in agricultural production want to assure you have access to an inexpensive, reliable, nutritious food supply…even if you sometimes opt for a candy bar.

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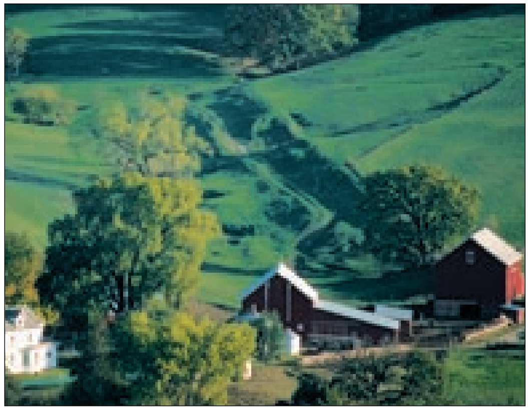
Acknowledgment: Photos on page 9 courtesy of USDA-NRCS.



Farmers, agricultural scientists, government agencies, industry, and others are working together to achieve efficient crop and livestock production while protecting the environment.

Enviro-Briefs Series Offers Information on Web

Take a closer look at the relationship between agriculture and the environment in a series of short articles, called *Enviro-Briefs*, on the PPI website. These topics present important facts and observations on the interaction among crop production, nutrients, and the Earth's air, water, and soil resources. Consumers, students, agronomists, farmers, and others will find this series informative and easy to read.

Titles of *Enviro-Briefs* currently available are:

- Crop Plants Take Up (Absorb) Nutrients in Inorganic Form
- Organic or Inorganic: Which Nutrient Source Is Better for Plants?
- Crop Fertilization Improves Soil Quality
- Nutrient Balance: Critical to Crop Production and Environmental Protection
- Nutrient Balance Can be Achieved Using Both Inorganic and Organic Sources
- Nutrient Use and Beneficial Organisms
- Crop Fertilization and Heavy Metal Accumulation in Soils
- Crop Fertilization and Water Quality

Each of these appears as a web article and is also available as a PDF file to print as a single page. New topics will also be added to the series. Visit the website at: www.ppi-ppic.org/enviro-briefs.

Water Quality in the Gulf... Taking Steps to Protect It

By C.S. Snyder

Seasonal low oxygen levels–less than 2 milligrams per liter or 2 parts per million–in the bottom of shallow (less than 100 ft. deep) coastal waters in the northern Gulf of Mexico are causing a biological concern. This low-oxygen condition is referred to as hypoxia. Hypoxia has probably always been present, but measurements since 1985 indicate it is increasing in size in the Gulf of Mexico (**Figure 1**). And it may be lasting longer into the fall than in the past. Discharge and layering of nutrient-rich, warmer Mississippi River freshwater, over cooler, denser saline water is necessary for the development and persistence of hypoxia conditions. Excess nitrate-nitrogen delivery by the Mississippi and Atchafalaya Rivers, originating from 31 states in the Mississippi River Basin, is believed to be fueling hypoxia conditions in the Gulf of Mexico.

> Rainfall patterns, stream flow, and nutrient management in the 31 states within the Mississippi River Basin (MRB), all affect water quality in the Mississippi River, and ultimately the Gulf of Mexico. There is a false perception that fertilizer nitrogen use is the major factor impacting Gulf water quality. In reality, the volume of water flow from the Mississippi Basin, and the time when runoff-producing rains occur, have been the most significant factors affecting Mississippi River and Gulf of Mexico water quality in the last 20 years.

Fertilizer nitrogen use, primarily in the upper Mississippi River Basin states, has been frequently singled out and blamed as "the cause" of hypoxia, especially in media articles that have sensationalized the hypoxia phenomenon in the Gulf and labeled the area as "The Dead Zone." However, there are a number of nitrogen sources in addition to fertilizer: soil organic matter; manure; lawn, golf course, athletic field, and other urban runoff; municipal waste and industrial discharge; forest and natural area runoff; and atmospheric deposition.

An abundance of nutrients, primarily nitrogen and phosphorus, in water helps stimulate the production of microscopic aquatic plants called phytoplankton, which are a source of food for marine life. When phytoplankton die, they fall through the water column to the bottom mud. As bacteria in the mud use the organic matter as a food source, they consume oxygen from the water and accelerate hypoxia development.

Some marine scientists believe hypoxia is reducing the per-effort-catch of shrimp, crabs, and some fish by bottom-dragging trawlers. Fish that swim in the upper part of the coastal waters still get enough oxygen and are not affected. There has been no measured negative economic impact on Gulf fisheries so far. Still, there is a growing fear that Gulf fisheries resources are threatened and that poor water quality could hurt tourism.

The U.S. Geological Survey (USGS) estimates that the total annual nitrate-nitrogen discharge to the Gulf is equivalent to about 2.6 pounds of nitrogen from each acre in the Mississippi River Basin. Putting that number in perspective, it would be an amount equivalent to about 9% of the fertilizer nitrogen applied annually to major U.S. crops in the Basin.

Historically (1955 to 1999), nitrate-nitrogen delivery to the Gulf has been strongly associated with both total water flow to the Gulf from the Mississippi and Atchafalaya Rivers and a two-year lag in fertilizer nitrogen use in the Mississippi River Basin states (two years prior to current annual water flow).*

There have been many agricultural production changes in recent years which may have altered this historic relationship:

- increased tile drainage in the upper Mississippi Basin,
- land grading and surface drainage improvements in the lower Mississippi Basin,
- increased conservation and no-till production,
- new site-specific fertilizer application technologies, and
- increased crop yields, resulting in greater removal of nutrients in harvested crops.

Nitrogen use statistics show that corn production per pound of nitrogen has increased from about 0.76 bushels per pound of nitrogen in 1980 to about 1.03 bushels per pound of nitrogen in 2000: **a 35% increase in apparent fertilizer use efficiency.**

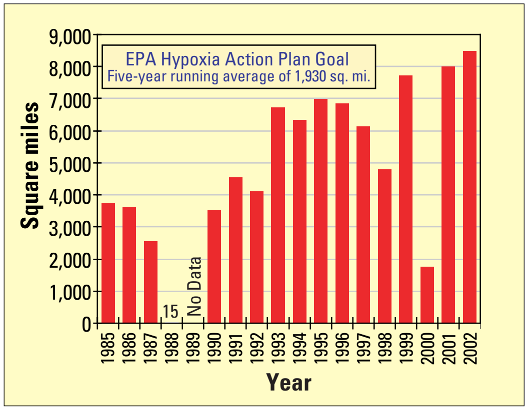


Figure 1. Approximate size of the hypoxia zone in the northern Gulf of Mexico. *Source: N. Rabalais, Louisiana Universities Marine Consortium.*

Best management practices are being used by more farmers to increase soil and water protection and achieve more efficient production.

To evaluate the potential impact of these more recent agricultural changes, the data on water flow to the Gulf of Mexico by the Mississippi and Atchafalaya Rivers, fertilizer nitrogen use in the Mississippi River Basin, and nitrate-nitrogen discharge to the Gulf from 1980 to 1999 were reviewed. This review showed that nitrate-nitrogen delivery since 1980 has been predominantly controlled by the volume of water flow and **not** fertilizer nitrogen use (**Figures 2** and **3**). The flow of fresh water to the Gulf accounted for 79% of the variation in annual nitrate-nitrogen discharge to the Gulf, while fertilizer nitrogen use in the Mississippi River Basin accounted for only 1% of the variation in the annual delivery of nitrate-nitrogen to the Gulf of Mexico from 1980 to 1999.

A recent summary of soil test results in North America shows that 47% of the soil samples test medium or lower in phosphorus and 43% of samples test medium or lower in potassium. Inadequate phosphorus and potassium fertility management reduces crop yields, limits farmer profit, and is probably also limiting nitrogen use efficiency in many crops.

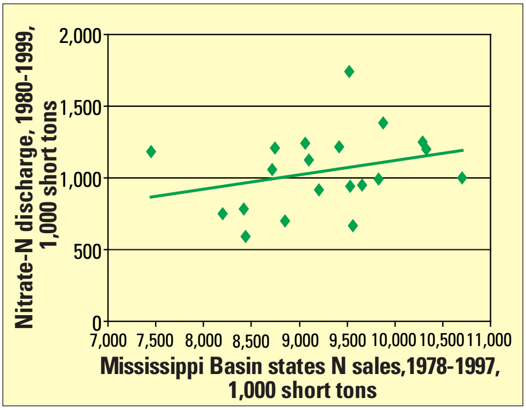


Figure 2. Nitrate-nitrogen discharge to the Gulf of Mexico vs. two year lag in Mississippi River Basin fertilizer nitrogen sales. *Source: U.S. Geological Survey (Don Goolsby) and The Fertilizer Institute.*

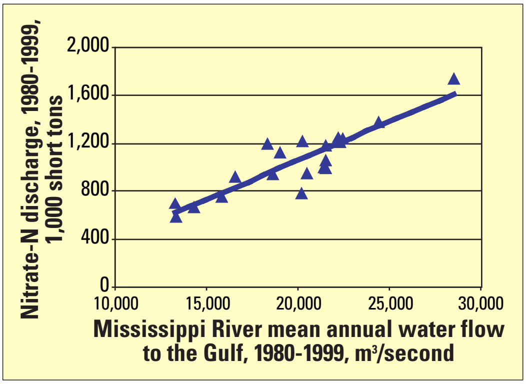


Figure 3. Nitrate-nitrogen discharge to the Gulf of Mexico vs. Mississippi River mean annual water flow. *Source: U.S. Geological Survey (Don Goolsby).*

In spite of these nutrient deficit challenges, there has been progress in the following areas:

- Farmers have been voluntarily implementing best management practices (BMPs) to increase soil and water protection while striving for higher yields and more efficient production.
- Fertilizer industry is partnering with university scientists and educators, Certified Crop Advisers (CCAs), and others to encourage farmers to delay fall nitrogen (typically anhydrous ammonia) applications until soil temperatures at a 4- to 6-in. depth are consistently below about 50 to 55°F in the upper Mississippi River Basin.
- In Basin states where nitrogen sources other than anhydrous ammonia predominate and where justified by agronomic research, timely split applications of nitrogen are being encouraged to improve crop nitrogen use-efficiency.

Members of the agricultural community are striving to improve management. Industry and university-sponsored educational programs, and voluntary stewardship action by farmers, are helping to reduce the potential for loss of nitrogen from fields to local streams, and ultimately to the Gulf of Mexico. All involved in agriculture want to protect and preserve our water resources and are committed to wise resource stewardship through intensive management. BC

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**(Source: USGS Fact Sheet 135-00: http://ks.water.usgs.gov/Kansas/pubs/fact-sheets/fs.135-00.html).*

Fertilizer for Better Bread

By W.M. Stewart

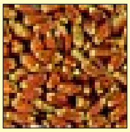
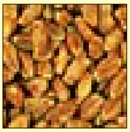
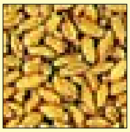
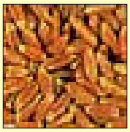
Did you know that wheat provides greater nourishment for people globally than any other food grain? It's easy to see why wheat production is a top priority for farmers and the agricultural industry that feeds the world. Did you know that commercial fertilizer nutrient inputs produce about 30 to 50% of crop yield, including wheat, in North America? The use of fertilizer is clearly important to producing enough wheat to meet global demands. In the year 2000, fertilizer inputs were responsible for the production of an estimated 1.28 billion bushels of wheat in North America… enough to make 90 billion loaves of bread!

> Regardless of region, class of wheat, or specific conditions, fertilizer inputs are responsible for a large portion of the grain produced in North America. Proper fertilization is an important determinant of the quality of bread and other food items made from various kinds of wheat.

The world consumes more wheat than any other food grain. Wheat is used in a wide range of products–bread, tortillas, crackers, bagels, pastries, and pasta. Wheat is also an important source of animal feed and forage in many areas. More land is devoted to wheat production worldwide than any other commercial crop. One reason is that wheat is a highly adaptable crop and can be grown across a wide range of environments. Wheat is clearly important to human nutrition, and anything that affects wheat management and production has the potential for significant worldwide impact.

North America produces about 15% of the world's wheat (based on 1998 to 2000 averages). There are six classes of wheat produced in North America (**Table 1**). Wheat classes are determined by the time of year they are planted and harvested, and by their kernel hardness, color, and shape. Each class of wheat has similar family characteristics, especially as related to milling, baking, and other food use. Where each class of wheat is grown depends largely on rainfall,

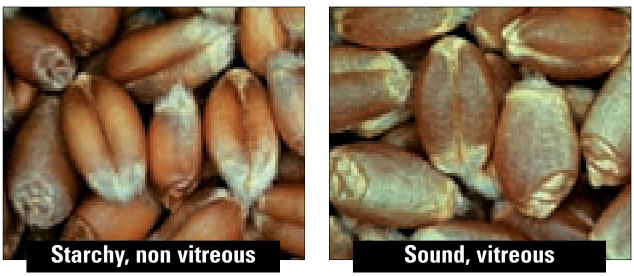
TABLE 1. Classes of wheat produced in North America, their uses, and where they are produced.

						
Wheat class:	Hard red winter (HRW)	Hard red spring (HRS)	Soft red winter (SRW)	Hard white winter (HWW)	Soft white winter (SWW)	Durum
Major uses:	Bread, rolls, bagels	Bread	Crackers, pastries, cakes	Yeast breads, hard rolls, bulgur, tortillas	Crackers, pastries, cakes	Pasta
Regions of production:	U.S. Great Plains	Northeastern Great Plains, Canadian Prairies	Eastern U.S.	CA, ID, KS, MT	Pacific Northwest	Northern Great Plains, AZ, CA

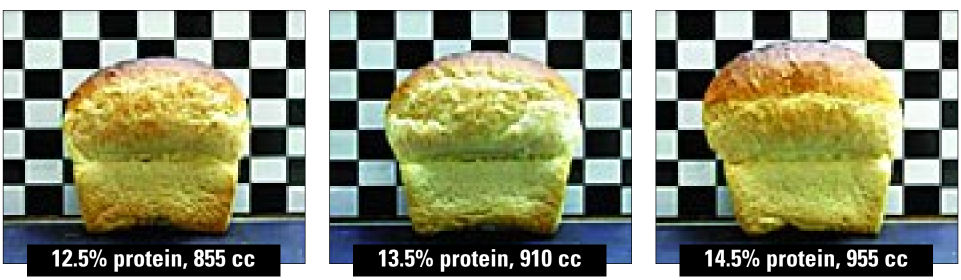
temperature, soil conditions, and tradition.

Nutrient inputs make a substantial contribution to wheat yields. For example, a long-term study at Oklahoma State University demonstrated that fertilizer was responsible for 40% of wheat grain yield over a 71-year period. In another long-term wheat study at the University of Missouri, nutrient inputs contributed 62% of wheat grain yield over a 100-year period. These and other estimates show that a reasonable assumption is that about 40% of wheat production is due to nutrient inputs. In other words, fertilizer inputs are responsible for about four out of every 10 loaves of bread produced from North American wheat.

Lack of nitrogen nutrition has the potential to substantially limit wheat yield. Nitrogen deficiency of wheat can be expressed as a yellowing of foliage during the season, or it can be expressed in the grain at harvest. The photo at left below shows effects of nitrogen deficiency on grain. It takes about 2 to 2.5 pounds of available nitrogen to produce one bushel of hard red winter wheat. Soft wheat requires less nitrogen since its protein content is lower. Assuming that 2 pounds of nitrogen fertilizer are required to produce one bushel of wheat, that other factors are not limiting, and that a bushel of wheat produces 70 loaves of bread, then a 100 pound bag of nitrogen fertilizer will produce about 3,500 loaves of bread...an efficient conversion by any standard.



Without adequate nitrogen, wheat grains may be starchy, faded, and low in protein, as shown in the photo at left. This condition is sometimes called "yellow berry" or "piebald," and results in flour with poor baking quality (such as used in the loaf of bread at left in the photo below). With adequate nitrogen, wheat kernels have more protein and a sound, vitreous appearance, as shown at right above. The higher protein content results in better baking quality, as illustrated by the loaf of bread at right in the photo below.
Source: Grain Biology, Grain Research Laboratory, Canadian Grain Commission.



Higher protein content of wheat fertilized with nitrogen results in better quality bread. The lower protein wheat at left produced a more dense loaf of bread...855 cubic centimeters (cc)...while the higher protein wheat enabled the bread dough to rise more. Loaves shown are from 2001 Canadian western spring wheat harvest. *Source: Ken Preston. Grain Research Laboratory, Canadian Grain Commission, Winnipeg, Manitoba.*

Nutrient inputs can affect wheat quality as well as yield. Nitrogen fertilizer impacts wheat quality by affecting protein content. Wheat contains water insoluble gluten proteins. These proteins enable leavened bread dough to rise by trapping carbon dioxide gas. Thus, as the protein content of wheat used in baking bread increases, the loaf size also tends to increase, as shown in the photos. In other words, nitrogen fertilization is important in producing wheat with optimal protein levels that in turn produces better quality bread.

Wheat response to phosphorus fertilizer is shown at right (no phosphorus fertilizer on the left).

Although nitrogen is important in wheat production from the standpoint of both yield and quality, it is of limited value if other needed nutrients are not in adequate supply. Phosphorus nutrition is an important component of wheat production. Lack of phosphorus is second only to inadequate nitrogen in North America as the nutrient deficiency that most commonly limits wheat growth and development. Phosphorus affects wheat growth throughout the season. It is important in seedling and early season development. Enhanced availability of phosphorus encourages the early season development of roots and early proliferation of shoots, increasing grain and forage yield potential. Winterhardiness is improved with adequate available phosphorus. Also, wheat with adequate phosphorus nutrition matures earlier and more uniformly. The top photo at right compares wheat plots with and without phosphorus.

Chloride deficiency symptoms appear on wheat leaves at right. Wheat leaves at left are from a plot which received chloride fertilization.

In recent years, chloride has been identified as a nutrient often needed in some regions of North America for wheat production. Research conducted across the Great Plains and Canadian Prairies has demonstrated that wheat is sensitive to chloride deficiencies. Chloride plays an important role in suppressing wheat fungal disease infection and in hastening maturity. Lack of sufficient chloride in wheat production can result in substantial yield and economic losses.

Wheat may also be responsive to other fertilizer inputs such as potassium and sulfur. Soil testing is a useful tool, frequently used to determine which specific nutrients are needed in each situation. When wheat and other crops are harvested, they remove nutrients from the soil which must be replaced to maintain productivity. BC

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Acknowledgment: Photos in Table 1 courtesy of Minnesota Association of Wheat Growers.

Fertilizer and Tofu

By T.W. Bruulsema

Tofu is just one of the many kinds of foods made from soybeans. It's an excellent source of protein, and is often included in vegetarian diets. It's an example of the type of food being sought out more and more by people concerned about how diet affects their health. And like nearly all plant products, it benefits from fertilizer.

Science is discovering important health benefits to eating foods such as tofu. Reviewing such science has led the U.S. Food and Drug Administration (FDA) to authorize health claims on foods. The claim "...foods that include 25 grams of soy protein a day may reduce the risk of heart disease" is an example. It applies to tofu and other soy products.

Consumers increasingly search out foods for health benefits. The healthfulness of foods owes a lot to commercial fertilizers. Farmers optimize both yield and quality when they apply fertilizers in accordance with science-based nutrient management. For nutritional quality of food, it does not matter whether the nutrient source for plants is organic or inorganic.

Oilseeds, grains, fruits, and vegetables contain complex compounds made by plants. These compounds–phytochemicals including lycopene, isoflavones, and antioxidants–help prevent many of today's most common health problems, including heart disease and cancer. The compounds are called nutraceuticals, and the foods that contain them are called functional foods—foods that have a specific health function.

Soybeans contain isoflavones as one of their nutraceutical ingredients. They also contain potassium, an ingredient which supports another health claim. Foods that are low in sodium and contain good sources of potassium may contribute to reduced risk of stroke (by lowering blood pressure). **Table 1** shows that tofu and a range of soy foods provide substantial amounts of protein, isoflavones, and potassium. Truly functional foods.

So what's tofu got to do with commercial fertilizers? Recent research has shown that fertilizing soybeans with potassium increases their isoflavone levels. At a site where potassium fertilizer boosted the yield of soybeans by 10%, it increased their isoflavone level by 16%. Soybeans grown on soils of varying fertility showed a link between the levels of potassium and isoflavones in the seed (**Figure 1**). Results varied by year, but the link was positive in both.

TABLE 1. Soy foods and their protein, isoflavone, and potassium content per serving.

Soy foods	Serving size	Protein, g	Isoflavones, mg	Potassium, mg
Tofu, firm	1/2 cup	20	25	300
Tempeh	1/2 cup	17	53	340
Miso	1 tablespoon	2	7	28
Soymilk, plain	1 cup	7	24	345
Soybeans, roasted	1/4 cup	17	55	59

Nutrient Database Laboratory, USDA.

Note: FDA Daily Reference Values (DRVs) are generally 3,500 mg of potassium and 50 g of protein, with adjustments for certain conditions.

Scientists are increasingly interested in the connection between plant mineral nutrition and the nutritive value of foods—nourishing the soil to nourish people. The American Society of Agronomy recently featured the symposium "Fertilizing Crops for Functional Food." It highlighted research on a wide range of crops and nutrient elements.

For example, at the University of Wisconsin, Dr. Irwin Goldman found that fertilizing with sulfur influenced the selenium uptake of onions and cole crops. And conversely, fertilizing with selenium influenced their production of sulfur compounds. He concluded that balance of these two nutrients–and all essential nutrients–was important. Both sulfur and selenium affected health functionality.

The symposium also featured recent research on nitrogen, phosphorus, and potassium fertilizers affecting:

- Apple and tomato functional food ingredients
- Citrus functional components
- Echinacea phytochemicals
- Flaxseed lignans
- Soybean isoflavones
- Watermelon antioxidants

The recent findings agree with what has long been known about the impact of fertilizers on nutritional quality. Generally, supplying the plant with an appropriate balance of nutrients, avoiding excesses and deficiencies, produces good quality. It does not matter whether their source is organic or inorganic. However, it's usually easier to achieve the right balance when commercial fertilizers are part of the mix—they supplement and correct the fixed ratios of nutrients in soils, crop residues, and manures.

Specific effects of each nutrient are not always consistent, but a few are worth remembering. Nitrogen increases protein and carotenes, but can reduce vitamin C if applied in excess. Potassium can boost vitamin C in vegetables, and also carotenes, especially lycopene. Potassium and chloride have both been shown to suppress many plant diseases that reduce food quality.

Health concerns lead many people to buy organic food. They seek food that has been grown as naturally as possible. But there is a limitation. Natural conditions lead to deficiencies in plant nutrients in the soil where crops are grown. The nutrients taken away need to be replenished. **Returning crop residues and animal manures puts back some—but not all—of the nutrients removed. So to grow optimally, and to have the greatest nutritional value, crops need commercial fertilizers.**

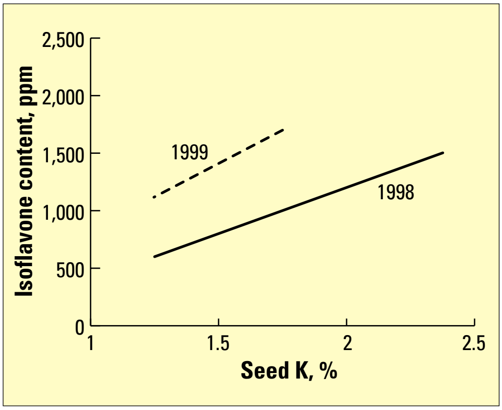

Figure 1. Isoflavone content of Ontario soybeans increases with higher seed potassium, but results vary by year. (ppm=parts per million)

The health benefits of apples, tomatoes, potatoes, citrus, and other foods are receiving more recognition. However, there is no evidence that foods produced with organic methods are healthier or safer than conventional products.

Tofu, is a healthy, high protein food made from soybeans. Research indicates that potassium may benefit isoflavone content of soybeans.

Both organic and conventional farmers use a combination of organic and mineral sources of nutrients. However, regulations for organic farming prohibit or limit the use of soluble inorganic forms of plant nutrients—the very forms that plants take up, and the forms that are most effective in correcting imbalances within the natural mineral and organic sources. **Nutritional scientists have concluded that organic foods are neither healthier nor safer than conventional products.**

Science-based nutrient management includes use of soil testing to determine the fertility of the soil. It includes the use of plant analysis to determine the nutrient status of the plant and the nutritional quality of its product. It includes using the best available technology for precision application and placement of fertilizers, specific to the characteristics of the soil and landscape. And it includes integrating the use of manures and other available nutrient sources with commercial fertilizers for optimum nutrient use efficiency.

Plants are the original source of all organic matter. Their role in capturing sunlight to convert carbon dioxide in the air to carbohydrates is fundamental to the nutrition of all human and animal life on earth. Mineral nutrients are essential to plants in filling this role. When farmers use science-based nutrient management to guide the application of commercial fertilizers, they are optimizing both the yield and the quality of the food that plants produce. BC

Dr. T.W. Bruulsema is Eastern Canada and Northeastern U.S. Director for PPI/PPIC and is located at Guelph, Ontario; e-mail: tbruulsema@ppi-ppic.org.

Acknowledgment: Soybean photo at top of page 18 courtesy of USDA-ARS. Small photo (in circle) at top of page 18 courtesy Indiana Soybean Board. Tofu photo at top left, page 20, courtesy www.outofthefryingpan.com. Tofu photo at top right, page 20, courtesy www.everydayvegan.com.

THE FERTILIZER IN YOUR SALT SHAKER

BY R.L. MIKKELSEN

Fertilizer potassium is sometimes called "potash", a term that comes from an early production technique where potassium was leached from wood ashes and concentrated by evaporating the leachate in large iron pots. Clearly, this practice is no longer practical and is not environmentally sustainable. This potash collection method depended on the tree roots to deplete the soil of potassium, which was recovered from the wood after it was harvested and burned. Large amounts of wood were burned to collect relatively little potash. Potassium removed from the soil in harvested crops must be replaced in order to maintain a sustainable production system.

> Individuals who are advised by their physicians to restrict sodium (Na) intake often use potassium chloride (KCl) to season food rather than common table salt, sodium chloride (NaCl). This is the same potassium chloride used in commercial fertilizer to supply these two nutrients to crops. And, it's the same potassium chloride sometimes added to drinking water through water softeners to reduce hard minerals. So, what's the point? The point is that the "chemicals" in fertilizers are so safe that some are added directly to the food we eat and the water we drink. Let's take a closer look at fertilizer potassium.

The use of finely ground rock minerals has also been attempted as a potassium source for growing plants. However, the agricultural use of ground rock has now been largely discarded, since it frequently takes hundreds or thousands of years for these rocks to geologically weather and release the minerals for the plant—a long period of time even for forestry applications!

Where Does Fertilizer Potassium Come From?

Over 350 million years ago, even before the dinosaurs were on the Earth, the great Devonian Sea was slowly drying up in the area of Central Canada and the northern U.S. As the sun evaporated the water, the ocean salt became increasingly concentrated and minerals were left behind. While the Devonian Sea no longer exists, the process of mineral deposition from drying salt water continues in places such as the Great Salt Lake and the Dead Sea.

Today, these ancient marine salts, especially potassium (the natural potassium rock salt mineral is called sylvite) and common table salt (halite) are recovered and used in a variety of useful ways. The potassium intended for human or for plant use is prepared by washing away the sodium, since neither humans nor plants benefit from excess sodium. After the potassium is separated, it can be used directly as a plant fertilizer or in many other applications (**Figure 1**). Likewise, sodium chloride can be used for various purposes.

While the majority of this separated potassium mineral goes into common fertilizer, its advantages in other uses may be surprising. Potassium chloride is commonly used as a salt substitute for people on a low-sodium diet. It is routinely used to melt ice from roads and walkways, and can be used in water softeners to reduce hard minerals. Whatever the intended use–as a food supplement or a fertilizer, the potassium chloride is exactly the same.

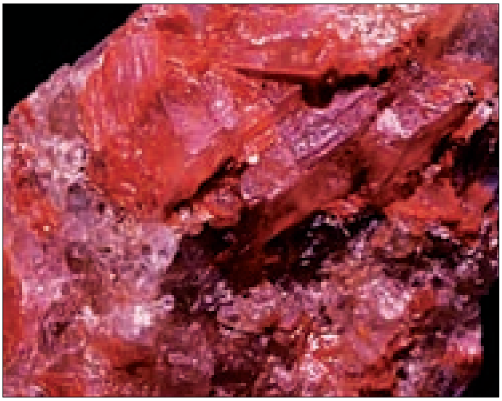

Figure 1. The most common type of potassium ore, called sylvinite, is a mixture of potassium chloride and sodium chloride.

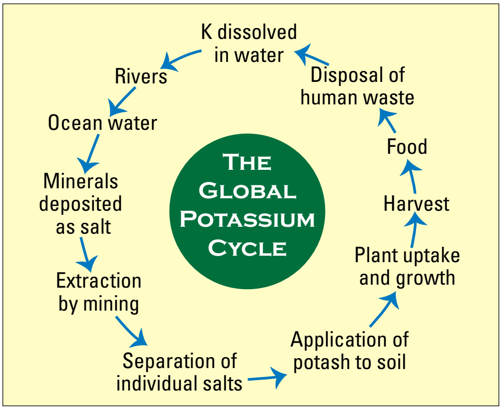

Figure 2. The global potassium (K) cycle.

Natural Material: From the Earth and Back to the Earth

Potassium fertilizer is clearly not an artificial or manufactured chemical—it comes directly from the earth. After potassium is added to the soil as a plant nutrient or directly to our food, it eventually returns to the sea again. Potassium is not consumed or destroyed, but simply recycled through very long-term geologic processes (**Figure 2**).

Potassium is a natural plant food because compounds such as potassium chloride, potassium sulfate, and potassium nitrate are widely found in nature. When these compounds are added to water, they rapidly dissolve into the positively charged potassium cation and the negatively charged anion (such as chloride, or sulfate). The potassium atom used by humans or plants is identical, regardless of the form that it is used. Even potassium found in animal manure is very water soluble, with a minor portion bound to the organic matter. Since potassium in animal manure behaves like mineral sources of potassium, there is no reason to distinguish between these two materials as far as potassium supply is concerned. Whether added to soil as fertilizer or manure, potassium salts are quite soluble and rapidly enter the soil solution.

Potassium fertilizers are safe to use since they pose no harmful environmental or health effects when used at normally recommended rates. However, like any substance, when fertilizer potassium is used in excess quantities, unintended side effects can result. In particular, due to the very high solubility of most potassium sources, large amounts of these materials should not be placed in close proximity to seeds and seedlings. Despite its natural solubility, potassium additions at appropriate levels are not rapidly lost from soils as are other nutrients, such as nitrogen.

Some plants prefer fertilization with sulfate forms of potassium, and this can be easily supplied from minerals that come from naturally occurring deposits of potassium sulfate or deposits containing a mixture of potassium sulfate and magnesium sulfate. The chloride that naturally occurs in some potassium fertilizers, manure, table salt, and rainfall is an essential plant nutrient and must not be confused with chlorine gas, hypochlorite used as a sterilant, or other chlorine forms which do not naturally occur in soils, plants, or fertilizers.

The most important role of fertilizer potassium is to replace the soil potassium removed by crop plants. Without it, not only would the quantity of food produced be markedly reduced, but the quantity of potassium in that food would be reduced as well. Potassium is an important mineral required for human health. Since potassium is not stored in the human body, it is necessary to continually replace this nutrient on a regular basis. The U.S. Food and Drug Administration (FDA) recognizes that "diets containing foods that are good sources of potassium and low in sodium may reduce the risk of high blood pressure and stroke." **Table 1** shows normal potassium levels in major potassium-supplying foods.

TABLE 1. Some examples of food sources of potassium (K).

Food/serving	K content, mg	Food/serving	K content, mg
8 oz. whole milk	371	1 medium potato	610
1 medium banana	467	8 oz. yogurt	531
8 oz. orange juice	473	1 tomato	273
3 oz. sirloin steak	311		

From USDA Nutrient Database:
http://www.nal.usda.gov/fnic/foodcomp/Data/SR15/wtrank/sr15a306.pdf
Note: FDA Daily Reference Values (DRVs) generally indicate 3,500 mg of potassium.

Potassium is a common mineral that has important functions for maintaining the health of both humans and plants. Although several forms of potassium are available, they are all natural, safe, and abundant in nature. These minerals are recycled through natural geological processes to sustain a productive and healthy ecosystem.

Dr. Mikkelsen is PPI Western U.S. Regional Director, located at Davis, CA; e-mail: rmikkelsen@ppi-far.org.

Acknowledgment: Photo at top of page 21 courtesy of Salt Lake Convention and Visitors Bureau.

InfoAg 2003 Set for July 30 to August 1

Certified Crop Advisers (CCAs), field agronomists, Extension representatives, innovative farmers, and other precision agriculture enthusiasts are encouraged to mark their calendars for the sixth Information Agriculture Conference, InfoAg 2003. The event is scheduled for July 30 through August 1, at the Adam's Mark Hotel, Indianapolis Airport.

An optional precision agriculture field day is planned for Monday, July 29, preceding the conference, with visits to the Ag One Co-op facility at Wilkinson, Indiana, and the Davis-Purdue Agricultural Center.

Keynote speaker for InfoAg will be Bruce Vincent, agriculture advocate known for developing positive programs and messages directed to community groups. Program content for InfoAg 2003 will be oriented to practical, real-world application of technology and analysis of data essential in site-specific farming. As in the past, an exhibit area will feature the latest in data collection and management, communications technology, and other tools for precision agriculture.

InfoAg 2003 is organized by the Potash & Phosphate Institute (PPI), Foundation for Agronomic Research (FAR), and CropLife Media Group (*CropLife* and *CyberDealer* magazines). The conference is supported in part by a grant from the USDA-CSREES Initiative for Future Agriculture and Food Systems (IFAFS) program.

More details about program plans, registration and exhibitor fees, and related information will be available at the website: www.ppi-far.org/infoag.

Phosphorus and Potassium: Naturally Good for You

A better title for this commentary might have been–Phosphorus and Potassium: You Can't Live Without Them. The truth is, phosphorus and potassium are absolutely essential to life, for crop plants and humans. I chose the other title, however, because it makes me feel good to know that essential nutrients are provided naturally through the use of mineral fertilizers.

Fertilizer phosphorus and potassium are produced by mining and refining ore deposits that were laid down by nature over long periods of time. Their application to soils to replace nutrients removed by crop growth is a step in the recycling process that has allowed the world as we know it to evolve. Another step occurs when we eat foods produced with proper fertilization.

We need lots of phosphorus. In fact, of all the mineral nutrients contained in our bodies, phosphorus is the second most abundant. It can be found in every cell, but nearly 80% is concentrated in our teeth and bones. It makes sense, then, that in order to have strong teeth and bones we must consume large quantities of the nutrient. How can we be sure we are getting enough? Fortunately, nature supplies us with liberal amounts in our foods–meats, dairy products, fruits, nuts, and vegetables. Eating a balanced diet that includes sufficient phosphorus is our best defense against bad teeth and weak bones as well as other potentially serious health problems.

As one of millions in North America with high blood pressure, I am aware of the need for potassium. One of my medications (a diuretic) tends to deplete my body of potassium as it removes excess water to lower blood pressure. So, I must be careful to include high potassium foods such as bananas in my diet. My wife and I season our food with lite salt, a mixture of potassium chloride and sodium chloride (ordinary table salt), to increase our consumption of potassium and lower our sodium intake. We use potassium chloride in our water conditioner for the same reason.

It is comforting to me to know that such a vital part of my well being can be maintained so easily, simply by following nature's process of recycling…by eating tasty, nutritious foods that contain the phosphorus, potassium, and other nutrients provided by mineral fertilizers. Remember, these nutrients are naturally good for you.

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