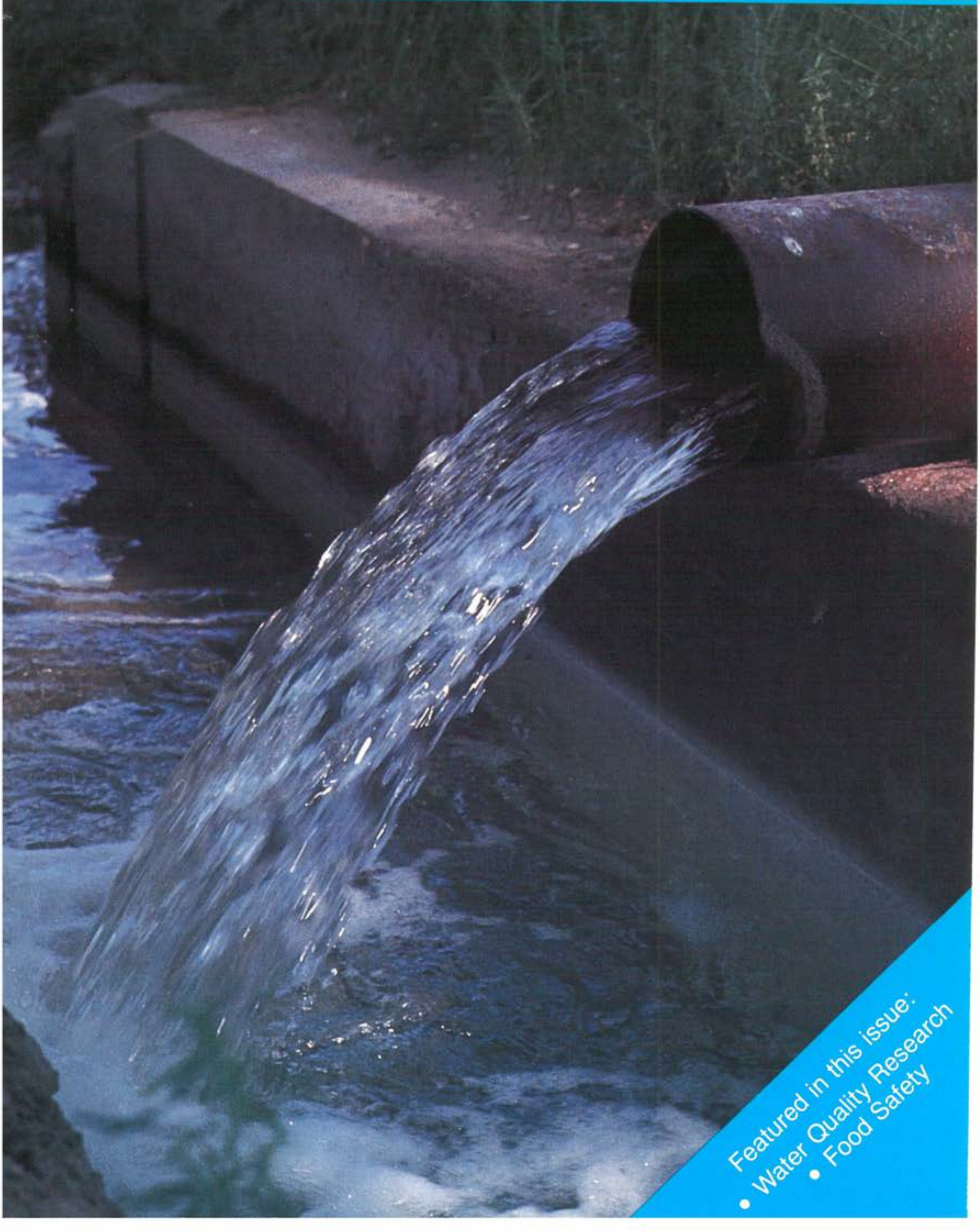
BETTER CROPS
WITH PLANT FOOD

Spring 1991



Featured in this issue:
- Water Quality Research
- Food Safety

BETTER CROPS With Plant Food

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Contents

Our Cover: Clear water flows from a farm pump near Coolidge, Kansas. Photo by Dr. Larry S. Murphy.

America's Farmers and Ranchers: Partners with the Environment

By Ernest Shea

IN RECENT YEARS, America's farmers and ranchers and the conservation professionals who work directly with them have come under attack for failing to adequately protect and conserve the nation's soil and water resource base. While such a charge may accurately reflect the attitudes and actions of a few, it is hardly representative of mainstream U.S. agriculture.

If we have failed at anything, it has been our inability to effectively communicate the nature and magnitude of the problems we work to address, the gaps in technology that impede our progress and the accomplishments that we have achieved along the way.

Expanding Responsibilities

For the past 50 years, America's soil and water conservation districts, along with their federal and state agency partners, have been helping farmers and ranchers solve complex natural resource problems. Born in the Dust Bowl days with an original mandate to address cropland erosion concerns, districts have worked successfully to incorporate erosion control practices into most farming operations.

While erosion control work is an ongoing program objective, district workloads have expanded dramatically in recent years to address a broad spectrum of natural resource concerns. A quick examination of almost any district's plan of work reveals that it is also delivering water quality protection, forest and rangeland management, wetlands conservation, wildlife habitat enhancement, recreation, stormwater management, and urban erosion and sediment control assistance directly to local land managers.

Cooperation or Regulation?

In advancing the conservation, wise use and orderly development of the land, water and related natural resources of the United States, districts work cooperatively with land managers using educational, technical and financial assistance tools to achieve program objectives. Although this approach runs contrary to those who advocate the use of command and control regulatory programs to achieve natural resource goals, we believe it is still a sound and practical strategy for addressing today's environmental agenda.

Stewardship

As conservation professionals, we understand and appreciate the stewardship ethic that most farmers and ranchers have towards their land and water. To be sure, there are many problems that still need to be addressed, but farmer commitment to resource protection is not chief among them.

Opportunities

As we move through this decade of the environment, it is incumbent on all of us who are closely associated with production agriculture to seek out opportunities to tell the American public about the positive commitment that farmers and ranchers have towards conservation. Let's go on the offensive and talk about our successes. Agriculture and the environment can coexist and, in fact, are inseparable. By advancing economically viable and environmentally sound agricultural production systems, we can achieve sustainability. In doing so, we will be providing an invaluable service not only to the producers of food and fiber, but to the American public and the environment as well. ■

Mr. Shea is Executive Vice President of the National Association of Conservation Districts, Washington, D.C.

Point Sources vs. Nonpoint Sources of Groundwater Contamination

By Richard S. Fawcett

Preventing contamination of wells by pesticides and nitrate requires an understanding of how contaminants reach the well, so that appropriate corrective actions can be taken. Misidentifying the cause or route of contamination can lead to the adoption of inappropriate and ineffective protection practices, costing money and causing hardships for farmers, without correcting the problem. Recent research and monitoring results have helped to improve our understanding of groundwater and well contamination and to direct efforts at effective solutions.

Nitrate in Groundwater

WHEN pesticides and nitrate are detected in wells, often the first source to be blamed is leaching of materials from treated farm fields. This type of nonpoint contamination can occur with nitrate and with certain pesticides under the right conditions. However, it is becoming increasingly clear that many cases of groundwater contamination by pesticides and nitrate are related to activities very near the well and may be due in part to construction of the well itself.

Determining the source of nitrate in wells can be difficult because nitrate occurs naturally and originates from many sources. Consistently high nitrate concentrations in shallow groundwater in some areas such as the Platte River Valley of Nebraska are apparently due primarily to nonpoint sources. However, in many cases, wells with nitrate concentrations exceeding the drinking water standard have been affected by their location near point sources of contamination such as livestock feedlots, septic systems or fertilizer handling sites. Evidence is increasing that well location and well construction can explain some high nitrate concentrations.

Pesticides in Groundwater

Pesticides vary tremendously in their physical and biological properties. Some pesticides break down quickly or are strongly bound by soil particles resulting in a very low risk of leaching to groundwater. Compounds which are more persistent and/or are weakly held by soil particles have a greater leaching potential. Certain products have specific label restrictions against use in highly permeable soils where the groundwater is shallow. Natural sinkholes in karst topographies or unplugged, abandoned wells permit direct entrance of any pesticide to groundwater, either attached to eroded soil particles or dissolved in runoff water.

Iowa. While nonpoint leaching of detectable amounts of certain pesticides is possible, recent studies have implicated point sources at pesticide storage, mixing and disposal sites as causes of many cases of well contamination.

In 1987, all public well systems in Iowa were tested for the presence of pesticides. Eight percent showed some pesticide content. All detects were of a few specific herbicides, except for one case of an insecticide. Levels detected were generally well below health standards, with the exception of three wells which exceeded a Lifetime Health Advisory or MCL (maximum contaminant level).

Many of the Iowa wells with pesticides had subpart per billion concentrations of atrazine, a herbicide found more frequently in groundwater due to its greater persistence and moderate mobility. Some

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of these wells apparently contained atrazine from nonpoint sources, either small amounts leached from fields or more likely through surface runoff and erosion into rivers, followed by interaction of the surface water with shallow, alluvial aquifers. But for all other pesticides detected, a totally different pattern emerged. Over 80 percent of all public wells with pesticides other than atrazine had a pesticide mixing-loading site near the well, often a few hundred feet away.

Illinois. Illinois monitoring has traced all cases of public well detection of pesticides to point sources. These data led the Illinois EPA to conclude in a December 1989 report: "There is no indication from the sampling carried out to date that the field application of pesticides is affecting Illinois' community well systems."

Handling and Loading Sites

Soil will normally adsorb and degrade most pesticides and prevent measurable leaching. But if extreme concentrations are added to the soil, the system can be overloaded and leaching can occur. Unfortunately, there are many places where extreme concentrations of herbicides have been added to the soil. This occurs where herbicides have been mixed and sprayers rinsed over the years. Repeated small spills or occasional large spills contribute to soil overloading. Mixing and handling of large quantities of herbicides and fertilizer at sites close to a municipal well could lead to contamination.

Although farmers do not handle the quantities of chemicals processed by commercial chemical supply businesses, they have unfortunately often handled and loaded chemicals in the worst of possible places in the past—immediately adjacent to the farm well. Because of convenience and lack of an understanding that this kind of practice threatens well contamination, this activity has frequently gone on for many years. Handling chemicals near wells is especially risky if the well is shallow, is not properly constructed or maintained and if contaminated surface water can directly enter the well.

Confining all pesticide mixing activities to water-tight pads, where all spills and rinsate are contained for proper disposal, is one solution to this problem. In fact, states are beginning to require commercial pesticide storage and handling sites to install such secondary containment systems. This technique will work on farms as well, but simply moving the activity from the well site by conducting all mixing and rinsing activities in the field may be the most practical solution. That way, one site is not continually exposed to spills and the chemical ends up in the intended field. Moving pesticide activities away from the well also avoids any chance of backsiphoning when filling sprayers.

Results of a systematic survey of Iowa rural wells have thrown considerable light on the extent and causes of well contamination by nitrate and pesticides. Six-hundred-eighty-six rural wells were monitored. Eighteen percent of wells exceeded the nitrate drinking water standard, and one percent exceeded a standard for a herbicide. Thirteen percent of the wells showed some pesticide content, almost entirely comprised of a few herbicides. **The most striking result was the fact that 45 percent of the rural wells had unsafe levels of coliform bacteria. The presence of coliform bacteria is often evidence of contaminated surface water entering the well system due to well construction.** If bacteria can enter the system with surface water, herbicide molecules certainly can enter due to their much smaller size.

The fact that many rural wells are not properly sealed against surface contamination makes it all the more important that farmers change practices to move chemical handling from the well site. **But ultimately solving the bacterial and nitrate problems will often require improvements in the well itself.**

A recent study of rural wells in Kansas by Kansas State University illustrated the strong correlation of well site and construction to detection of nitrate and pesticides. Nitrate concentration averaged less when the well site was closer to production fields and farther from the

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Fertilizer Nitrates Not Causing Problems in North Carolina Groundwater

By J.W. Gilliam

Analyses of water samples over a 20-year period indicate few problems with agricultural contamination of groundwater in North Carolina. Proper management practices in crop production and other activities can help prevent risk of contamination.

CONCERNS about agricultural sources of nitrates in drinking water first appeared in the late 1960s. Research on the subject has been underway at North Carolina State since that time. Conclusions from that research are summarized in this article.

What is the potential for nitrate contamination of groundwater from nitrogen (N) fertilizer? The annual N application to North Carolina soils has averaged about 200,000 tons. If all of this fertilizer N were dissolved uniformly in the approximately 13.5 inches of annual drainage water (difference between rainfall and evapotranspiration), the concentration of N in the water would be 4 parts per million (ppm). If we assume crops utilized 50 percent of the N and all remaining N went to drainage waters, the concentration would be only 2 ppm. Obviously, the high percentage of land which does not receive N (forests, 66 percent) offers markedly reduced potential for groundwater contamination with fertilizer N.

What is the potential problem in localized areas? Corn is potentially the greatest problem crop because it receives the large majority of the N applied in North Carolina. The state average corn yield in North Carolina is about 95 bu/A. Corn receives about 150 lb/A N. If none of the applied N were lost as a gas through denitrification, we would expect the drainage water to contain about 17 ppm of nitrate-N. It is not uncommon to observe concentrations of 15-20 ppm of nitrate-N in shallow groundwater below corn fields, although we have never measured concentrations of this magnitude below a depth of approximately 13 feet.

The lower Coastal Plain region has the largest agricultural fields and receives the most N fertilizer per unit area. Extensive research has been conducted on these poorly drained, high organic matter, high water table soils, on both the surface and subsurface water quality. We have verified what is most likely: There is sufficient organic matter in the shallow groundwater to provide an energy source for microorganisms so that reducing conditions are usually present and nitrate-N concentrations are minimal. We have never seen nitrate concentrations higher than 1 ppm below 10 feet in any poorly drained, high organic matter soils (**Figure 1**).

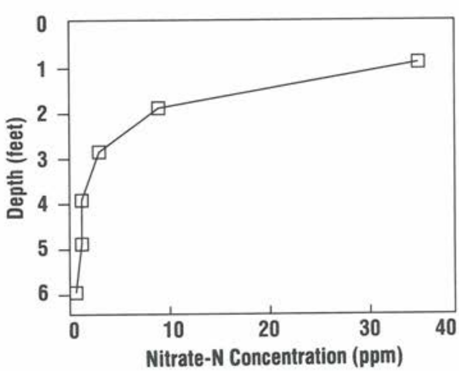

Figure 1. Typical nitrate-N profile in soil water in a cultivated, poorly drained, high water table Coastal Plain soil (North Carolina).

Dr. Gilliam is Professor, Soil Science, North Carolina State University.

Many Coastal Plain regions have moderately well to well drained soils with low organic matter content where little denitrification occurs. It is in these areas where a problem with nitrate contamination of groundwater is the most probable. We have monitored groundwater where these conditions exist. Typical data are shown in **Figure 2.**

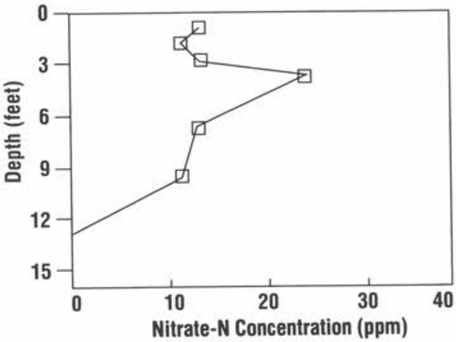

Figure 2. Typical nitrate-N profile in soil water in a cultivated, moderately well-drained, Coastal Plain soil with aquatard between 10 and 13 feet.

The nitrate concentrations observed are consistent with those expected where little denitrification occurs. No nitrate was observed below 13 feet because of an impermeable horizon between 10 and 13 feet. This is very typical of these Coastal Plain soils. Water reaching these layers flows laterally to a lower elevation where it frequently enters into a stream.

There is convincing evidence that much of the nitrate flowing laterally to an outlet is either utilized by plants along the way or is lost through denitrification. Similar results have been reported by researchers in Georgia and Maryland. This indicates that nature has a very effective way of removing much of the nitrate before it can cause problems.

We have also monitored cultivated fields in the Upper Coastal Plains without those restrictive horizons below the surface and fields in the Piedmont which have been in cultivation for long periods. No nitrate problems have been observed in these areas (**Figure 3**).

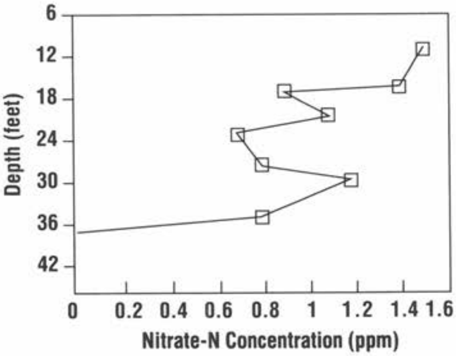

Figure 3. Soil nitrate-N profile of a cultivated Piedmont soil.

All the data collected and analyzed over the past 20 years by the Soil Science Department at North Carolina State University indicate that no nitrate problems exist in groundwater below cultivated fields which have been fertilized in a manner consistent with normal crop production. This does not preclude a problem where higher than recommended rates of N are applied in an effort to dispose of animal wastes, sewage sludge, and other wastes. The potential for problems in these situations where very high rates of N have been soil applied are indicated in **Figure 4.**

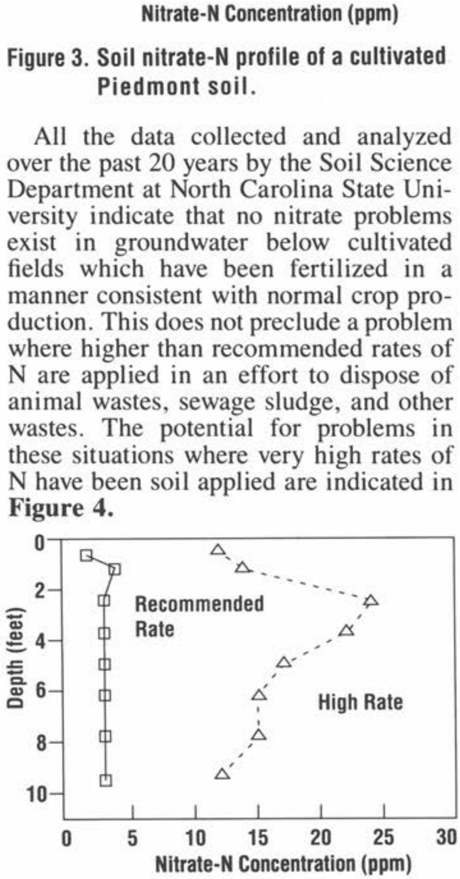

Figure 4. Soil nitrate-N profile of an area of Coastal bermudagrass on a Coastal Plain soil receiving different rates of N.

Summary

Based on the analyses of thousands of samples over a 20-year period from the

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farmstead. Similarly, pesticide detections were least likely when the well was closest to a crop production field and most likely if the well was close to the farmstead. **The problem of pesticide detection and elevated nitrate concentrations wasn't related to crop production, but to activities at the farmstead . . . pesticide mixing and disposal, livestock feedlots, and septic systems.**

Point sources aren't the only cause of well contamination by pesticides, but they are often the biggest one. Nonpoint sources, which vary greatly depending on product and site, need to be addressed. Increasingly, farmers will need to consider groundwater vulnerability of each field before making pesticide use decisions. **Because crops must be supplied with nitrogen (N), because nitrate can easily leach, and because all N sources are eventually converted to nitrate, improvements in use efficiency of all N sources, along with other management changes, will be necessary to reduce nitrate leaching potentials. But concentrating on nonpoint sources to the exclusion of point sources, as has happened in some states, will ignore the most important cause of well and groundwater contamination by pesticides.** ■

Fertilizer Nitrates . . . from page 7

most intensively cultivated areas of North Carolina, few problems of agricultural contamination of groundwater with nitrate exist. There are several factors preventing problems at this time. These are:

- North Carolina has a lower percentage of land in cultivated crops receiving N than some other regions.
- Higher annual rainfall in North Carolina than some other regions.
- Much denitrification occurs in shallow groundwater of poorly drained soils.
- Restrictive horizons below much of the Coastal Plain result in lateral movement of shallow groundwater containing nitrate to poorly drained areas where significant amounts of the nitrate is denitrified.

Nitrate problems in groundwater can occur if N application rates in excess of those recommended for crop production are used. Also, tests have shown nitrate contamination of a small number of shallow home wells. It is suspected that many of the wells were contaminated by surface water because of poor construction. ■

Organically Grown Foods Are Not Without Risks

DON'T ASSUME that organically grown produce is worry-free, cautions Dr. Curtis Melton, a food technologist with the Agricultural Extension Service at the University of Tennessee.

"Without insecticides or rodenticides, organically grown fruits and vegetables may be vulnerable to bugs or rodents that carry diseases," he explains.

A study conducted by the Institute of Food Technologists reported that the responsible use of pesticides will help protect organically grown crops against disease-causing micro-organisms, molds and worms.

"Organic farming methods—particularly those using untreated animal wastes—may not safeguard against these disease-causing culprits. And, indeed these practices may spread them. If you want to pay the extra price, fine. But, you're really buying more hype than benefit," the food technologist says.

Shoppers need to check sources when buying organically grown foods. Quality can vary from store to store. Some organic farmers use substandard techniques, Dr. Melton adds.

"For example," he notes, "some organic farmers use untreated animal manures and compost, such as grass clippings and vegetable waste. Such fertilizers could contaminate both crops and surface water and cause human illness." ■

Production Agriculture Featured in New Video from PPI/FAR

"PRODUCTION AGRICULTURE: Feeding People, Protecting The Environment" is the title of a new video just released by the Potash & Phosphate Institute (PPI) and Foundation for Agronomic Research (FAR).

"This program presents a modern, fast-paced, science-based view of production agriculture and its benefits to consumers. It emphasizes the abundance of safe, economical, high quality food we enjoy today," explains Dr. B.C. Darst, Vice President for Communications at PPI and President of FAR.

The video points out the importance of science and research for continuing advances in production agriculture. Soil testing and other best management practices (BMPs) are highlighted. Agriculture's concern for the environment is also featured.

"We appreciate the support of PPI member companies, FAR contributors, and many other groups and individuals who made this program a reality," says Dr. David W. Dibb, President of PPI.

NARRATOR Melanie Ramsay is shown here in a scene from the new PPI/FAR video. Much of the program was taped at field locations and in settings from the farm to the grocery store.

While the message is directed primarily to non-farm audiences, many in agriculture will also be interested in the content.

The 15-minute video is available in VHS format. For details on cost and how to order, turn to page 31. ■

Intermountain Meadow Symposium Scheduled July 1-3 in Colorado

COLORADO State University and the University of Wyoming are sponsoring the Third Intermountain Meadow Symposium at the Sheraton Steamboat Resort and Conference Center at Steamboat Springs, CO, on July 1, 2, and 3, 1991. The purposes of the symposium are 1) to promote improved meadow management, 2) to publish new research findings, 3) to share management information, and 4) to provide a forum for discussing mountain meadow concerns.

On July 1 and 2, there will be 27 (invited) verbal and poster presentations on these meadow-related topics: national concerns, the legislative process, forage management in diverse environments, water issues and water management, soil management, soil fertility, plant species for meadows, forage utilization, weed control, grazing hazards and riparian area management.

On the morning of July 3, there will be a 110-mile tour of forage production and utilization in Routt County, Colorado.

A printed proceedings, containing all reports, will be distributed at the symposium.

For further information, contact Dr. Gene Siemer (P.O. Box 598, Gunnison, CO, 81230, telephone 303-641-2515) or Co-Chairman, Dr. Dave Koch (Plant Science Division, University of Wyoming, P.O. Box 3354, Laramie, WY, 82071, telephone 307-766-3242). ■

Changes in Nutrient Content of Kentucky Streams

By G.W. Thomas, K.L. Wells, and G.R. Haszler

Concern about the effect of commercial fertilizers on water quality has greatly increased during the past several years. This article describes what was found in assessing whether increased use of commercial fertilizers during the past 20 years has affected the nitrate and phosphate content of streamflow from several watersheds in Kentucky.

THE WATERSHEDS we studied represent some of the more important agricultural land use systems in Kentucky. They were located for study in 1970, and nitrate and phosphate content of water flowing from them was documented. Use of commercial nitrogen (N) fertilizers increased from just over 100,000 tons N in 1970 to more than 180,000 tons in 1989. Use of phosphate fertilizers increased from 90,000 tons of phosphate to just over 100,000 tons.

Streamflows from seven watersheds were sampled during the high flow winter months in 1972 and again during the high flow winter months in 1990 to see if the general increase in fertilizer N and phosphate across the state had influenced nitrate and phosphate content.

The size and land use characteristics of the seven watersheds are shown in **Table 1.** The watersheds selected are all agricultural and only one changed markedly between 1972 and 1990. In the Perry Creek watershed, a subdivision of 15 large houses has been built near the creek. The sewage from these houses is treated in a small plant near the creek and the effluent enters the creek at the point where samples were taken in 1972. Because of this radical change, Perry Creek was sampled both above and below the sewage plant in 1990. These samples are referred to as Perry (a) and Perry (b), respectively.

The levels of phosphorus (P) in the streams in 1990 tended to be lower than those of 1972 but not significantly so. The mean values for both years are shown in **Table 2.** One stream which was consistently high in P was Cave Creek, which drains a watershed which is 98 percent in pasture and stocked lightly with horses. The rock underlying the soil in the Cave Creek watershed is a high-phosphate

Table 1. Characteristics of watersheds drained by creeks sampled in the study.

Name	Size (acres)	Land Use
Cave Creek	1,618	Pasture, 2% tobacco
Flat Creek	3,604	Pasture, 54% wooded
McGills Creek	1,368	75% wooded, 25% pasture, corn
Perry Creek	1,101	Corn, soybeans, hay
Plum Creek	20,350	Pasture, corn, tobacco
Rose Creek	1,344	Corn, soybeans, hay, 5% wooded
West Bays Fork	4,779	20% wooded, 80% pasture, corn, tobacco

Table 2. Mean phosphate-phosphorus levels in seven Kentucky streams in 1972 and in 1990.

Stream	1972	1990
	ppm PO_4-P	
Cave Creek	0.28	0.17
Flat Creek	0.28	<0.005
McGills Creek	0.01	<0.005
Perry Creek (a)	0.04	0.03
Perry Creek (b)	—	1.79
Plum Creek	0.10	<0.005
Rose Creek	0.03	<0.005
West Bays Fork	0.006	<0.005

G.W. Thomas and K.L. Wells are Professors, G.R. Haszler is Senior Research Analyst, Department of Agronomy, University of Kentucky.

limestone. Other studies, as long ago as 1921 and as recent as 1990, show that water in contact with this limestone is always quite high in phosphate.

Perry Creek, below the sewage outlet, was even higher in phosphate; above the sewage effluent it was very low. **The results indicate that geology and human activities (sewage) influence phosphate in stream water and that agricultural activities do not have a measurable effect.**

Mean nitrate-N contents of streams for the years 1972 and 1990 are shown in **Table 3.** There were no significant differences in nitrate-N between 1972 and 1990 in any stream but there was a tendency towards slightly lower values in some streams in 1990.

Table 3. Mean nitrate-nitrogen levels in seven Kentucky streams in 1972 and in 1990.

Stream	1972	1990
	ppm nitrate-N	
Cave Creek	4.48	4.12
Flat Creek	0.49	0.17
McGills Creek	0.48	0.54
Perry Creek (a)	0.93	1.12
Perry Creek (b)	—	3.78
Plum Creek	1.08	0.63
Rose Creek	2.74	1.20
West Bays Fork	0.64	0.82

As with the phosphate, high nitrate-N was restricted to Cave Creek (a watershed in pasture with very low N fertilizer use) and to Perry Creek below the sewage outlet. The levels of Cave Creek in 1972 and 1990 were approximately 4 parts per million (ppm) of nitrate-N. These figures agree closely with streams in other parts of the Inner Bluegrass, underlain by the same limestone. It appears that the high level of P in these soils encourages legume growth and that a portion of the biologically fixed N added to the soil by legume residues turns up in the water. At the very least, the nitrate-N cannot be very well associated with N fertilizer because almost none is used on the pastures.

In the case of the high nitrate-N below the sewage outlet in Perry Creek, this represents the output of 15 houses, whereas the value for Perry Creek (a) represents 1,100 acres of farmland, much of which is in row crops. These 15 houses account for much more nitrate-N and phosphate than the rest of the 1,100 acres of farms.

The assumption that farming and fertilizers are responsible for the nitrate-N and phosphate in streams is not supported by this study. Instead, geology and human waste seem to be the more important factors. ■

Conventional Nitrogen Rates for High-Yielding Corn Not Likely to Affect Groundwater Quality

USING CONVENTIONAL RATES of nitrogen (N) on high yielding no-till corn likely won't cause significant groundwater contamination, according to a research report from the University of Kentucky College of Agriculture.

"The amount of fertilizer N applied at 160 lb/A on high yielding corn did not lead to the potential for high rates entering into the groundwater supplies," reports Ken Wells, Extension agronomist.

In a three-year study, Dr. Wells and colleagues Harold Rice and Bill Thom applied ammonium nitrate at rates of 80 and 160 lb N/A to high yielding corn on Pope silt loam soil located at the University of Kentucky's Robinson Substation.

The N was applied either all broadcast at planting or broadcast four to five weeks after planting, when the corn was about 18 inches high.

"We found a significant yield response to the higher rates of N tested. We also found that about 70 percent of the applied N was used by the plant and therefore was not available to enter the groundwater supplies," Dr. Wells said.

Much of the other 30 percent of the N was likely immobilized in the soil by soil bacteria, making it unavailable for groundwater contamination. ■

Sustainable Soil and Nutrient Management

By P.E. Fixen

Much debate on the characteristics of sustainable agriculture and sustainable soil and nutrient management require some definition as well as discussion. This paper focuses on how modern nutrient management improves nutrient use efficiency, improves yield, and provides simultaneous environmental protection.

ONE DEFINITION offered by the dictionary for the verb sustain is: "to keep going." Therefore, if an industry or a system is sustainable it must be capable of continuing far into the future. The implication is that the integrity of the basic resources involved in the industry must be maintained. Resource degrading processes such as soil erosion, loss of soil organic matter, decline of nutrient supplies, salinization, and contamination of surface and groundwater must be minimized. At the same time the industry must produce in sufficient quantity, quality, and price to meet the demands of society while providing an acceptable return to management.

Food Quantity. According to Orville Freeman, former U.S. Secretary of Agriculture, global annual food production doubled over the last 20 years while food reserves remained constant. As we look to the future we see staggering estimates of food demand. Freeman estimated that the next 2 to 4 generations of agriculturalists will need to produce as much food as has ever been produced in the entire 12,000 year history of agriculture. The challenge is great.

Food Quality. This is a real problem in many parts of the world due to spoilage and protein-deficient diets. In North America, most of the recent attention given this topic centers on a fear that our food is laced with pesticide and drug residues. The scientific community has clearly indicated that our food supply is among the safest in the world and that microbiological and natural toxicants are a much greater risk than residues of applied chemicals. The major challenge is to correct the misconception of the consumer that "organically grown" food is healthier . . . to educate the public.

Food Price. On the average, U.S. and Canadian consumers spend only 11 percent of their income on food. Still, 30 percent of families in both countries spend over 50 percent of their income on food. As long as we hold the fundamental humanitarian belief that food is a right and not a privilege, it is hard to imagine acceptance of a system that significantly increases food prices or decreases our ability to compete in global markets or participate in humanitarian efforts.

Soil

No resource is more basic to agriculture or society than the soil. Considerable historical evidence links soil quality or productivity to the survival of civilizations. Dr. B.A. Stewart of the USDA stated that soil erosion and organic matter decline are likely the dominant processes contributing to soil degradation. These processes must be controlled or balanced to sustain soil productivity.

Intensive tillage, fallowing, and erosion resulted in loss of 15 to 30 percent of the original soil organic nitrogen (N) in soils of the Corn Belt and Great Plains during the first 20 years of cultivation.

Dr. Fixen is Northcentral Director, Potash & Phosphate Institute (PPI), P.O. Box 682, Brookings, SD 57006. This article is adapted from a paper presented at the 13th Annual Manitoba-North Dakota Zero-Tillage Workshop, Brandon, Manitoba, January, 1991.

Another 6 to 10 percent was lost during the next 20 years. Reductions in soil aeration, water holding capacity, and permeability likely accompanied the organic matter decline.

Several recent studies clearly demonstrate that these declines are reversible. Kansas research has shown that soil organic matter levels increase as crop residue production increases and tillage decreases. Long-term experiments in Missouri have demonstrated that improved crop management, including the use of adequate fertilizer for wheat and corn, tends to reverse the long-term decline in soil organic matter levels. Ongoing studies in eastern Colorado are showing that no-till crop rotations that include less fallowing are increasing soil organic carbon and profitability just 4 years after establishment. Long-term experiments conducted at several locations in the Canadian prairies have shown that appropriate fertilization and crop rotation can reverse the decline in soil organic matter.

These and many other studies indicate that with proper management, intensive and profitable crop production in the Great Plains can occur while the soil resource is actually being improved for future generations. Successful systems in these studies were not defined by quantity of inputs, but were based on use of site specific best management practices (BMPs).

Nutrient

This term is vitally important. Efficient nutrient management in the Great Plains starts with the realization that all nutrient sources must be managed, not just commercially produced fertilizers. This includes N resulting from organic matter mineralization, N fixed by legumes, and N from manure. Fertilizer N is by far the easiest of these sources to manage and nearly always becomes the source that balances nutrient supply and crop demand.

The role of fertilizers in agricultural systems is shown in **Figure 1.** In a "natural" system, nutrient inputs or deposition and nutrient losses are balanced without the involvement of fertilizers. This is possible because nothing is harvested from the system. However, in an agricultural system the objective is to harvest and, except in subsistence agriculture, export the harvest from the farm. Along with the exported harvest of grain, meat, eggs, milk, fiber, and in some cases even manure, goes essential plant nutrients.

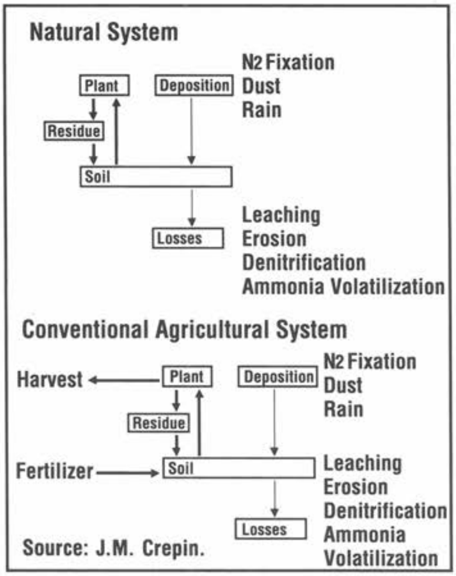

Figure 1. Simplified nutrient cycles.

The fertilizer industry developed to balance nutrients exported to the city or to other farms. In our civilization, there is a definite long-term link between urbanization and fertilization. Also, the high yields produced by well managed systems using optimum levels of fertilizer nutrients provide the flexibility to remove from production the soils most vulnerable to erosion.

Nitrogen. Nitrogen is the nutrient receiving greatest attention in discussions on sustainability due to the amount required in crop production as well as concern about nitrate in ground water. The role of fertilizer N in wheat production has increased markedly in importance over the last 20 years. For example, N use per bushel in North Dakota has gone from an insignificant amount in

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(Sustainable from page 13)
the early 1960s to over 1.2 lb/bu in recent years. That means that on the average, about 80 percent of the N removed in the grain is being replaced by fertilizer in North Dakota (**Figure 2**).

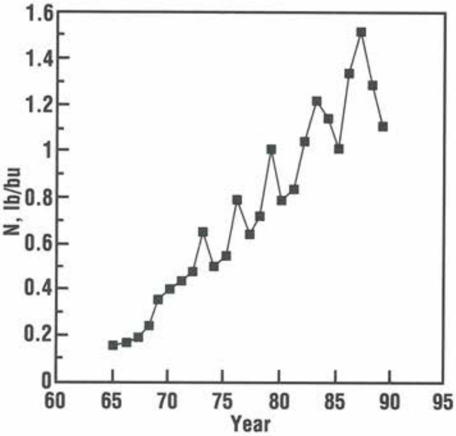

Figure 2. Fertilizer N use per trend bushel of wheat in North Dakota.

The major cause of this increased dependency on fertilizer N is the soil organic matter mentioned earlier. Before the 1960s, crops were being nourished through the mining of soil organic matter. During the first years the prairies were tilled, N was likely mineralized at rates at least twice that required for the crops being grown. Soil samples collected from a field in eastern North Dakota 10 years after it was plowed out of native prairie showed the soil profile to a depth of 10 feet contained over 600 lb/A nitrate-N. Since no fertilizer had ever been applied, the N had to have resulted from organic matter mineralization in excess of what the wheat crops could utilize.

After 1960, soil organic matter levels likely began to stabilize and N released from organic matter was approaching that which was being returned as crop residues. Since then a progressively greater proportion of N taken up by crops has been coming from fertilizers.

Remember the old expression, "There's no such thing as a free lunch." At some point somebody pays. As we adopt cropping systems that use less or no tillage, soil organic matter begins to increase. Since that organic matter contains N, extra N inputs will be needed and the N mined by the farmers that settled the Plains will need to be replaced. Their "free lunch" is now being paid for.

Legumes can potentially be used in the rotation to provide some of the N requirement for non-legume crops. This offers no environmental advantage over appropriate N fertilization and may be a disadvantage due to inability to control the amount and timing of N produced by the legumes. The major agronomic challenge involves the water consumed by the legume. In some years this will not be a problem, but in others the N fixed could be extremely expensive in terms of lost yield potential. Research is under way to find legume species that maximize N produced per inch of water consumed. In addition to the water use problem, other risk factors such as stand establishment make this practice especially challenging in the Great Plains.

In many cases, the perception is that fertilizer applied to cropland is the primary source of potential groundwater contamination. The media frequently refer to "fertilizer in water supplies" rather than nitrate. Clearly, in those areas with vulnerable groundwater, the entire N cycle must be managed to minimize potential contamination. Excessive fallowing and the resulting accumulation of nitrate in water have been identified as the most probable cause of nitrate leaching below the root zone in much of the Great Plains.

Colorado studies serve as an excellent example of how to improve management of N by using no-till and more intensive crop rotations (**Table 1**). Even though more fertilizer N was used in the more intensive rotations, residual nitrate after cropping was lower, water use efficiency was doubled, and gross as well as net income was increased substantially. Such systems appear to meet all the criteria for sustainability even though fertilizer and herbicide use is higher than for a conventional wheat-fallow system.

Phosphorus (P). Generally, environmental problems associated with P are caused either by P deficiencies which

Table 1. Fertilizer N applied, residual nitrate, water use efficiency, and gross income for three no-till rotations in Colorado.

Rotation[1]	After 4 years Fertilizer N applied	Residual Nitrate-N	Grain per inch of precipitation	Annual gross income[2]
	lb/A	lb/A-6ft.	lb/inch	$/A
WF	60	134	65	60
WCF	135	100	133	104
WCMF	112	44	138	131

Westfall and Peterson, Colorado State University

[1]W,C,M,F = wheat, corn, millet, fallow respectively.
[2]Projected over 4 years.

decrease N use efficiency or are related to accelerated eutrophication of surface water. The latter is really an erosion problem and is solved by the same practices that sustain soil productivity.

The majority of soils in the northern Great Plains appear to be below economic optimum soil test levels. Using soil test calibration data summarized by Halvorson, the long-term economic optimum Olsen P test level would be near 30 lb/A for most farmers. Factors such as land tenure, interest rates, yield potential, soil P fixing potential, and fertilizer and wheat prices will cause the optimum level to vary from approximately 20 to over 40 lb/A. As an example, only 12 percent of North Dakota soils tested above 30 lb/A in 1988.

Such data suggest that productivity of many if not most Great Plains farming systems could be increased by adequate P fertilizer use. Decreasing P inputs would appear to be moving away from sustainability rather than towards it. Tillage reduction and subsurface banding of fertilizer P will likely increase P efficiency and cause soil test levels to increase more rapidly.

Management

Management puts theory into practice. Collectively, the use of best management practices (BMPs) is the means by which science and common sense are organized into sustainable systems. Following are examples of soil and nutrient BMPs for the Great Plains.

- Optimization of fallow frequency. In some cases this means elimination of fallowing using water conserving cultural practices.
- Use of tillage systems that leave residue in vertical orientation.
- Use of intensive crop rotations. Diversity helps.
- Annual soil testing to at least a 2-foot depth for fields to be planted to non-legumes.
- Increasing soil test levels over time to the optimum range defined by appropriate calibration data and maintaining them in that range.
- Setting realistic yield goals based on historical yields and refined for seasonal moisture status. Some studies indicate that the economic optimum yield goal is the highest yield attained in the last 5 or 6 years.
- Giving N credit for previous legume crop.
- Banding of P on low P testing soils.
- Subsurface banding or injection of N in high residue systems.
- Timing N applications for maximum efficiency.
- Management of specific soils rather than fields to the greatest extent possible.

Summary

The dominant emphasis of sustainable agriculture has been reduction of off-farm inputs. It is ironic that the factual sustainability problems of the Great Plains have been caused by an agriculture that took far more from the land than it replaced. Optimization of inputs within a system of BMPs has the greatest potential for obtaining maximum economic yields in the long term and in sustaining agriculture in the Great Plains. ■

Food Safety—
The Issue in the Future

By Philip T. Tybor

Public concern has shifted away from worry about adequate food supply and now tends to focus on food safety. While absolute safety is impossible, advancements continue toward improving quality and reducing potential risks.

FOOD SAFETY is a historical issue. Since the dawn of man, food consumption has been known to have an element of risk. Early man discovered that certain plants and animals were poisonous or a potential source of sickness if improperly cooked or preserved. In the not so distant past, during the settlement of North America, food safety was an issue overshadowed by an even greater problem—the food supply. Oftentimes, the source of food for the next meal was an unknown. Therefore, food safety took a back seat to the food supply.

Today

Today, there is a new ''American Revolution'' where food safety overshadows concerns for food supply. Domestic foods from both plant and animal sources have become an abundant resource. The shift from general public concern over supply to safety has occurred as a result of a number of factors, i.e. new technologies in agriculture and food processing, rapid transportation systems and global communications. This renewed concern for food safety is a composite of numerous sub-issues such as microbiological pathogens, pesticides, antibiotics, naturally occurring toxicants, hormones, food additives, irradiation, plus many others.

As each special issue rises to the point of widespread public awareness, the confidence of the consumer is eroded. This type of erosion leads to confusion and an uncertainty. Public opinion surveys continue to demonstrate that pesticides are the top ranked issue perceived to be the highest risk by the consuming public. At the same time, surveys of experts have identified the number one potential food safety hazard as microbiological pathogens. The reason for this difference is that public views are often based upon perceptions, while expert opinion is based upon scientific data derived from the documentation of actual cases of foodborne illness.

The 1990 annual survey by the Food Marketing Institute (**Table 1**) exemplifies public opinion relating to pesticide residues in foods. When respondents were asked for a comparison rating of potential hazards, pesticides, antibiotics/hormones, irradiated foods, nitrites, additives/preservatives and artificial coloring, the highest rated potential risk was pesticide residues.

In the same 1990 Food Marketing Institute survey, when respondents were allowed to volunteer answers, spoilage and germs were identified as the number one potential threat to the safety of the food supply. Pesticides were rated as the second most important threat.

A comparison of 1989 versus 1990 data (**Table 2**) shows some change in perception for these two potential hazards.

In 1990, fewer respondents identified spoilage and germs as a threat, while more respondents identified pesticide residues as the threat to safety.

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Table 1. Consumer concern about selected food attributes: 1984-1990.

Serious Hazard		Jan. 1984	Jan. 1985	Jan. 1986	Jan. 1987	Jan. 1988	Jan. 1989	Jan. 1990
Residues, such as pesticides and herbicides	%	77	73	75	76	75	82	80
Antibiotics and hormones in poultry and livestock	%				61	61	61	56
Irradiated foods	%			37	43	36	42	42
Nitrites in food	%				38	44	44	37
Additives and preservatives	%	32	36	33	36	29	30	26
Artificial coloring	%	26	28	26	24	21	28	21

Source: Food Marketing Institute, 1990.

Table 2. Perceived threats to food safety.

		Jan. 1989 Total	Jan. 1990 Total
Base		772	1,005
Spoilage/germs	%	36	29
Pesticides/residues/insecticides/herbicides	%	16	19
Improper packaging/canning	%	17	16
Chemicals	%	11	16
Tampering	%	20	14
Unsanitary handling by supermarket employees	%	10	11
Preservatives	%	7	8
Additives (non-specific)	%	7	6
Unsanitary handling by supermarket shoppers	%	6	4
Pollution/environmental pollution	%	3	4
Processing/preparation of foods	%	4	3
Bugs/pests/rats	%	3	3
Artificial coloring	%	2	3
Antibiotics	%	1	2
Radiation	%	1	1
Other	%	6	10
None	%	2	6
Not sure	%	11	12

Source: Food Marketing Institute, 1990.

The Facts

Although pesticides are a potential risk to our food supply, the number one risk is the bacterial pathogen. A 1990 report from the Centers for Disease Control clearly demonstrates that the bacterial pathogen is the number one "public enemy" of food safety. Over the years 1973 through 1987, there were 237,000 cases of foodborne illness reported within the U.S. In 87 percent of the cases, the bacterial pathogen was the causative agent. Over the same time frame, chemical food poisoning occurred only 4 percent of the time. The major chemical source within these food poisoning cases was not pesticides, but, rather, other naturally occurring toxicants, as in the case of mushroom poisoning or heavy metals.

The U.S. food supply is subjected to numerous tests to assure the safety for our consuming public. The testing is conducted by federal agencies such as the Food and Drug Administration (FDA), state regulatory agencies, food processors and by the agricultural producers. In pesticide residue testing, the results demonstrate one of three things - first, no residue is found; second, a residue is found but it is not violative of current regulations; or thirdly, a residue is found and is violative. FDA data published in 1989 on pesticide residues for various food commodities did demonstrate that some violative residues were found within our food supply (**Figure 1**).

This presence of a violative residue simply means that the product was illegal rather than a food safety risk. A clear understanding of the difference between violative/illegal versus safe is critical to the public's understanding and their perceptions on the safety of our food supply. Public confidence in the U.S. food supply can be enhanced through clear, concise and factual information.The agricultural producer and agribusiness have a major role to play in the dissemination of this

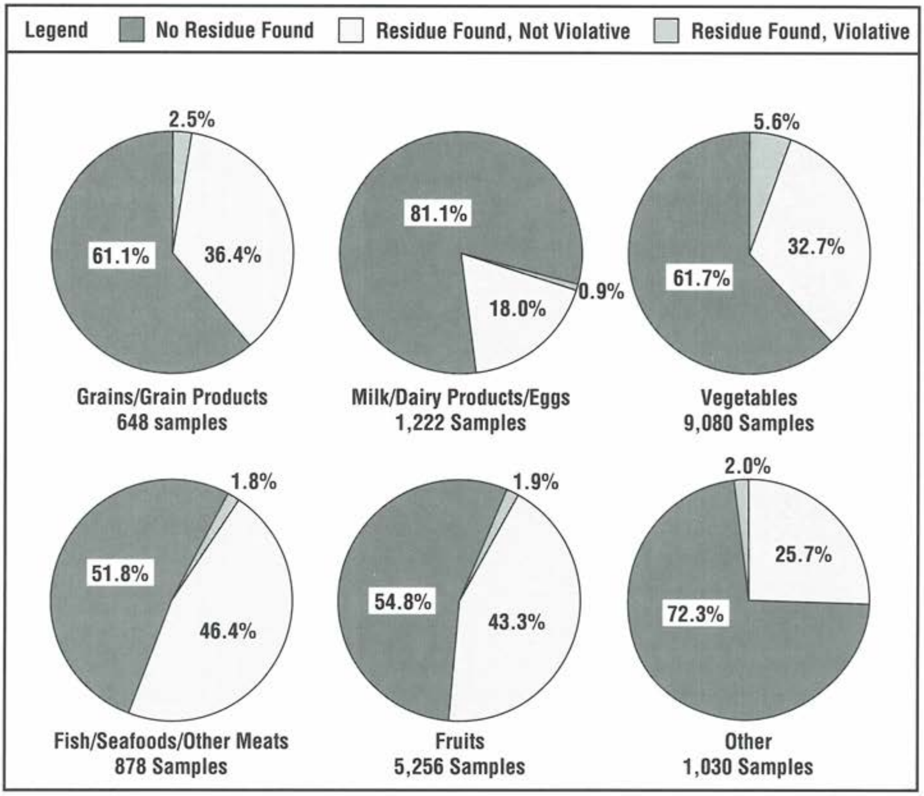

Figure 1. Summary of results (domestic and import) of 1988 sample analysis for pesticide residues by commodity groups.
Source: FDA, "Residues in Food-- 1988"

information. The task will be challenging. **Here are key points in relation to the future of food safety issues:**

- **Concern over food safety will not go away**. Food safety will continue to be a strategic issue during the decade of the '90s and into the 21st century.

- **There will be periodic emergence of specific issues** which will sway public opinion and perceptions and adversely impact upon agriculture and the food delivery system.

- **New technology and biotechnology will be challenged** using food safety as the lever to create public doubt and sway opinion. New opportunities and integrated pest management with a biotechnology base could be the hardest hit. The net result will be that new technologies will be unnecessarily delayed in their practical implementation.

- **There will be further advancement** of new methodologies and sensitivities of existing technologies and methodologies for the detection of residues. The advancement and analytical capabilities will confound the philosophy of zero tolerance and, therefore, contribute to even greater confusion relative to absolute safety.

- **The general public will become more aware and knowledgeable** on food safety. However, the advancement of science will continue to stockpile more information than the public can ever be expected to learn and know.

- **Public policy will take a greater microscopic approach** to the food safety issue resolution through the legislative process, as was the case in the 1990 Farm Bill. Public policy will continue to change through more laws and regulations. The creation of more stringent standards will put pressures on both the agricultural producer and the processor. Regulations targeting the food processor can filter back to the farmer through more stringent standards or specifications for agricultural commodities.

- **Greater demands will be placed upon the agricultural producer for improved record keeping**, a mechanism of on-farm quality control and the potential application of management systems such as Hazard Analysis and Critical Control Points. Simultaneously, abundant and low cost food commodities will continue to be expected by the consuming public.

- **The mass communication system** of print, audio and visual media as an information resource will continue with a journalistic style that is sometimes biased, inaccurate, incomplete or overly scientific. The food safety educational process will, therefore, continue to be difficult and require reactive measures in public communication.

- **The specific issues** of pesticides, antibiotics and hormone residues in food will continue to obscure public recognition of the major food safety hazard—the bacterial pathogen.

- **Human error** and the failure to use good common sense will continue to fuel the food safety issue.

Overall, absolute food safety is an impossibility. The advancement of systems to better assure safety is a probability. The aggressive approach to the food safety issue is one of doing things correctly and doing the correct things. ■

Application of Potassium to Tart Cherries through Drip Irrigation

By Nancy W. Callan and Mal Westcott

Fertilization of fruit trees through drip irrigation can make efficient and effective use of fertilizer materials and labor while delivering nutrients directly to the root zone. While injection of nitrogen (N) through drip irrigation is most common, potassium (K) has also been applied successfully in this manner.

DRIP IRRIGATION using emitters may restrict root activity and nutrient uptake to the wetted area, especially in arid climates. Interactions between applied and native mineral nutrients may be accentuated because of the limited nutrient absorption zone. Applied K frequently inhibits uptake of calcium (Ca) and magnesium (Mg) by fruit trees. The optimum K application rate for a particular soil would be one that results in the most efficient fertilizer use while minimizing interaction with other essential nutrients.

The form of applied K is an important consideration. Available K sources include potassium chloride (KCl), potassium nitrate (KNO_3), potassium sulphate (K_2SO_4), and potassium-magnesium sulphate ($K_2SO_4 \bullet 2MgSO_4$). Crop plants differ considerably in their sensitivity to chloride (Cl). For example, wheat will tolerate nearly 10 times as much Cl in the soil than will stone fruits. Research has shown that Cl can impair the growth of several species of fruit trees, including cherry. Because of this, fertilizers containing Cl have not been recommended for stone fruits.

Current Research

This study was designed to evaluate the consequences of K application to tart cherries through drip irrigation over a 3-year period. Treatments were chosen to reflect recommended soil-applied K rates and available fertilizer sources.

The experiment was conducted in a block of 5-year old 'Montmorency' tart cherries on Mahaleb rootstock at the Western Agricultural Research Center of Montana State University at Corvallis. The orchard, situated on a Burnt Fork sandy loam of pH 7.4, was irrigated with two 1-gallon-per-hour (gph) emitters per tree. The Bitterroot Valley is an arid area, with annual precipitation of about 13 inches, distributed fairly uniformly throughout the year.

Potassium was injected in 4 biweekly applications beginning 2 weeks post-bloom. Potassium chloride, KNO_3, and K_2SO_4 were applied at 0.75, 1.5, and 3.0 lb K_2O per tree. Nitrogen as UAN was injected concurrently with K. To obtain uniform N application among treatments, the 3.0 lb K_2O rate of KNO_3 consisted of 1.5 lb K_2O from KNO_3 and 1.5 lb K_2O from KCl. Six replications were used. Data collected included yield, fruit set, fruit size, soluble solids, fruit removal force, and mid-August mid-shoot leaf analysis.

Results

The experimental orchard was deficient in K at the beginning of the experiment (below 1.0 percent foliar K), and decreased to 0.76 percent K in control

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trees during the course of the experiment. No foliar symptoms were evident during the study.

Potassium. Foliar K was increased to within the sufficiency range of 1.3 to 2.0 percent for cherries (Oregon State University) by all rates of all K sources in the first year of the study (**Figure 1**.) Increased K application rate resulted in higher foliar K levels. But while KNO_3 and K_2SO_4 application continued to elevate leaf K in the second and third years of the study, KCl did not. The inhibitory effect of Cl on K uptake was first documented when it was found that K in cherry, peach and apple leaves decreased as Cl was increased in nutrient culture. The combination of KCl and KNO_3 apparently moderated this effect, as the K level resulting from this treatment was similar to that from K_2SO_4.

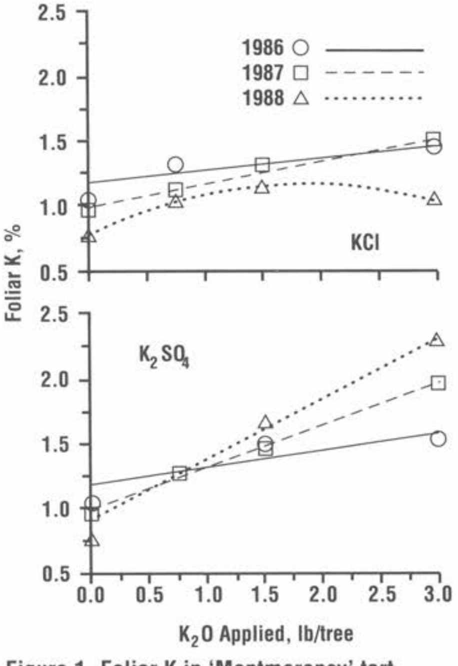

Figure 1. Foliar K in 'Montmorency' tart cherry as influenced by application of KCl and K_2SO_4 through drip irrigation. Potassium levels resulting from KNO_3 application were similar to those from K_2SO_4.

POTASSIUM applied through drip irrigation can increase yield of tart cherries. Careful management is essential.

Calcium and magnesium. Calcium and Mg in the control trees increased in subsequent yearly foliar samples as K levels decreased. These two nutrients behaved similarly in their response to K fertilization. With KNO_3 and K_2SO_4, a suppression of Ca and Mg uptake was evident the first year of application and became more pronounced in the second and third years, although deficiency levels were never approached. Application of KCl did not affect Ca and Mg uptake. Magnesium uptake was reduced to a greater extent by K than was Ca, which agreed with earlier research.

Chloride. Chloride was concentrated in the leaves with the use of KCl when applied either alone or in combination with KNO_3 (**Figure 2**). Continued application increased concentrations. Chloride leaf injury has been reported to occur at 3,000 to 5,000 parts per million (ppm) in Cl-sensitive crops. Although no Cl toxicity symptoms were observed, leaf concentrations of more than 3,000 ppm Cl were reached with the 3.0 lb K_2O rate as KCl during the third year of the experiment.

Yield. No fruit was produced in 1986 because of spring frost, but trees yielded moderately in 1987 and heavily in 1988. In 1987, there was a significant relationship among yield, K_2O rate and foliar K concentrations. Yield increased with increase in foliar K up to 1.5 percent and then decreased slightly. The greatest yields were obtained with low to moderate rates of K_2O.

(continued on next page)

In 1988, with all K sources, fruit yield was highest with the lowest rate of K_2O applied. While the association of yield with applied K_2O or foliar K level was not as strong as in 1987, maximum yield again occurred at about 1.5 percent K. Fruit quality and maturity characteristics such as size and soluble solids were more dependent on individual tree crop load or Cl level than on K treatment.

None of the treatments reduced Ca or Mg below the normal level (1.0 and 0.25 percent, respectively) so classical nutrient deficiencies were not induced. More subtle effects involving the balance between K and Ca, Mg, or other nutrients were probably occurring at higher K application rates.

Summary

Foliar K levels and tart cherry yields were increased by application of K through drip irrigation. In the first year of the experiment, application of all three K sources at 0.75 lb K_2O per tree increased foliar K levels from the deficiency range to above 1.3 percent K, which is considered normal for cherries. Use of KCl for more than one year is not recommended, as Cl levels accumulate rapidly and may have a negative impact on tree health. In addition, KCl was less effective in supplying K in subsequent years than the other two sources. Soil pH should be considered when selecting an appropriate K source.

Annual applications of either KNO_3 or K_2SO_4 at 0.75 lb K_2O per tree for up to 3 years maintained leaf K levels above 1.3 percent. Suppression of Ca and Mg uptake by K was minimized with lower K_2O rates. Response to drip-applied K may vary with soil characteristics and climate. Because response to K is often limited in acid soils with low buffering capacity, a soil pH and lime requirement test should be conducted to determine whether soils should be limed prior to application of K-containing materials. Foliar nutrients should be monitored so that fertilizer applications may be adjusted to maintain a level of 1.3 to 1.5 percent K.

This research demonstrates the usefulness of K application to tart cherries through drip irrigation on a neutral soil, but also points out that the grower must be aware of K source and rate effects. When nutrients are applied to a restricted root zone such as may be created with drip irrigation, unexpected or greatly magnified plant responses may result. Nutrient interactions occurring in this restricted root zone may have more dramatic effects than in conventionally-irrigated orchards. ■

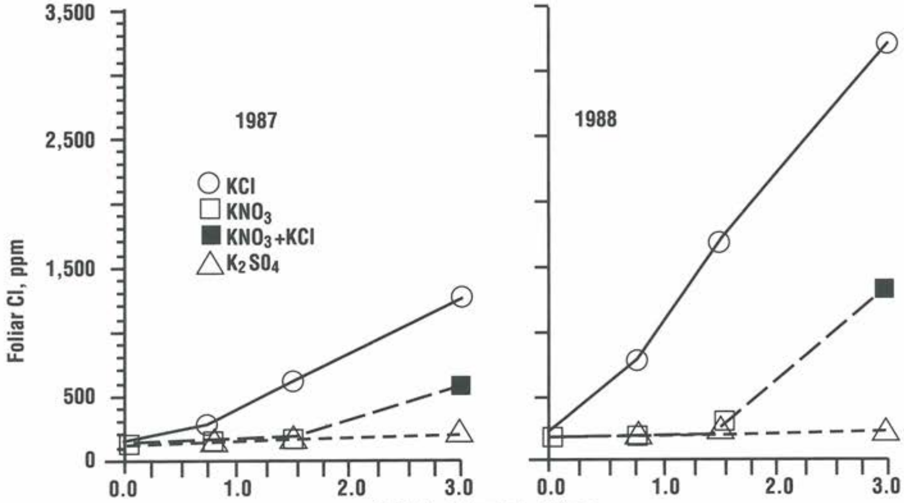

Figure 2. Foliar Cl in 'Montmorency' tart cherry following application of KCl, KNO_3, and K_2SO_4. The 3.0 lb K_2O rate of KNO_3, which also contained KCl, is represented by solid sqaure.

Louisiana

Potassium Fertilization Increases Nitrogen Utilization by Coastal Bermudagrass

COASTAL and other hybrid bermudagrasses require high levels of available nitrogen (N) and moisture to achieve their exceptionally high yield potentials. In producing high yields they also require large quantities of potassium (K). Research at the Louisiana Agricultural Experiment Station shows that K applications to Coastal bermudagrass can increase N uptake by the grass and increase the recovery rate of applied N, as well as increase forage yields.

In this study, K applications to Coastal bermudagrass produced modest, but consistent yield increases. Average yields increased from 7.4 tons/A where no K was applied to 8.7 tons/A at the 320 lb/A rate of K_2O. These yields were 84 and 99 percent of the yield at 640 lb/A of K_2O. As K application rates and forage yields increased, N removal in the forage also increased even though N concentrations slightly decreased. In this study, N was applied uniformly at 640 lb/A/yr. The greater quantities of N removed in the forage resulted in higher N recovery rates, with values increasing from 53 percent where no K was applied to 62 percent at the 320 lb/A K_2O rate. Larger yield responses would be expected to increase N recovery rates even further. Higher N recovery rates indicate that less N remains in the soil profile at the end of the growing season, lowering the potential for N losses from the soil. ■

Source: Donald L. Robinson, Agronomy Department, Louisiana Agricultural Experiment Station, LSU Agricultural Center, Baton Rouge. Published in Commun. in Soil Sci. Plant Anal. 21:753-769 (1990).

Colorado

Evaluating the Need for Spring Nitrogen Fertilization on Hard Red Winter Wheat

RESEARCHERS found that plant nitrogen (N) measurements made at early tiller (Feekes 3) had limited diagnostic value in identifying N sufficiency or deficiency. Late tillering (Feekes 6) and early jointing (Feekes 7) were the best growth stages to sample.

Total N in the whole plant was a better indicator than was NO_3-N in stems or whole plant.

In a related study, it was found that, to insure reliable spring N fertilizer recommendations, soil samples taken in the spring should be analyzed for soil nitrate plus ammonium-N. Testing for nitrate-N only was not reliable. Also, sampling to depths greater than 2 feet did not improve predictability of available N. ■

Source: B. Vaughan, Department of Crop and Soil Sciences, Michigan State University, East Lansing,MI 48824; D.G. Westfall and K.A. Barbarick, Department of Agronomy and P.L. Chapman, Statistical Department, Colorado State University, Ft. Collins, CO 80523. Published in Agron. J. 82:561-565 and 82:565-571 (1990).

Soil Sampling: Guidelines for Band-Applied Phosphorus

By D.G. Westfall, N.R. Kitchen, and J.L. Havlin

Soil testing is one of the most important steps in developing a sound fertilization program. Several procedures have been recommended for soil sampling where fertilizers have been broadcast and incorporated into the soil. However, soil sampling procedures have not been investigated under no-till or reduced-till systems where fertilizers have been band-applied and the bands not distributed by cultivation. This article reports results of some recent research in the Great Plains.

WITH TIME, banded fertilizer is either absorbed by succeeding crops or converted to less soluble phosphorus (P) minerals. The question is: "How much influence do these residual bands have on soil test levels?" The P concentration at any time in a fertilizer band is dependent upon many soil characteristics. Soil test P is likely to remain higher in the band than in the surrounding soil for some time after application, possibly years. Undoubtedly, this can result in large variations in soil test levels, depending upon the amount of soil sample that was collected from the area influenced by the band as contrasted to outside the band.

Colorado-Kansas Studies

In an attempt to resolve the question of "proper soil sampling," a cooperative research program between Colorado State University and Kansas State University was undertaken to develop guidelines for the best soil sampling procedure for no-till or reduced-till systems where P fertilizer has been band applied.

Experiments were conducted on Keith, Woodsen, and Harney soils in eastern Colorado and western Kansas. Liquid P fertilizers, either dilute phosphoric acid or ammonium polyphosphate, were band applied 1 inch below the seed at planting. The P_2O_5 rates ranged from zero to as high as 80 lb/A (**Table 1**).

Crops were either dryland summer fallowed grain sorghum in 30- or 24-inch row spacings or wheat in 12-inch row spacings. Soil samples, 6 inches deep, were collected during the fallow period at various distances moving away from the residual P fertilizer bands 12, 15, and 23 months after initial fertilization on the Keith, Woodsen, and Harney soils, respectively.

The soils were analyzed using sodium bicarbonate (Olsen) and acid-fluoride

Table 1. Characteristics of the field sites.

Soil Series	Organic Matter	$CaCO_3$	Initial Extractable P[1]	P Rates	Rotation	Initial Crop (for P rates)	Fertilizer Band Spacing
	----%----		--ppm--	-lb P_2O_5/A-			inches
Keith loam	1.4	0.3	4.7	0,20,40,80	wheat-sorghum-fallow	sorghum	30
Woodsen silt loam	5.1	0	8.1	0,15,30,45	wheat-sorghum-fallow	sorghum	24
Harney silt loam	2.0	4.0	7.2	0,15,45,75	wheat-fallow	wheat	12

[1]$NaHCO_3$-P with Keith and Harney soils and Bray P-1 for Woodsen soil.

The authors are Professor, Department of Agronomy, Colorado State University, Fort Collins, CO; former Graduate Student, CSU, currently Assistant Professor and Project Manager, Missouri MESA Project, Columbia, MO, University of Missouri; and Associate Professor, Department of Agronomy, Kansas State University, Manhattan, KS, respectively.

THE EFFECTS of residual P bands on wheat. Phosphorus (45 lb P_2O_5/A) was banded on 24-inch centers for grain sorghum approximately 16 months before wheat was seeded in 12-inch rows. The wheat row in the center was planted directly over the P band. Soil test P was low.

(Bray P-1) extractants. Only the result of the sodium bicarbonate extraction and the Keith and Harney soils will be discussed because similar trends with both P extracting procedures and the Woodsen soil were observed.

The P-concentration in-the-band was highly dependent upon the P fertility rate, band spacing, and time since fertilization (**Figure 1**). The wider the band spacing, the higher the application rate in-the-band, and subsequently, the higher residual

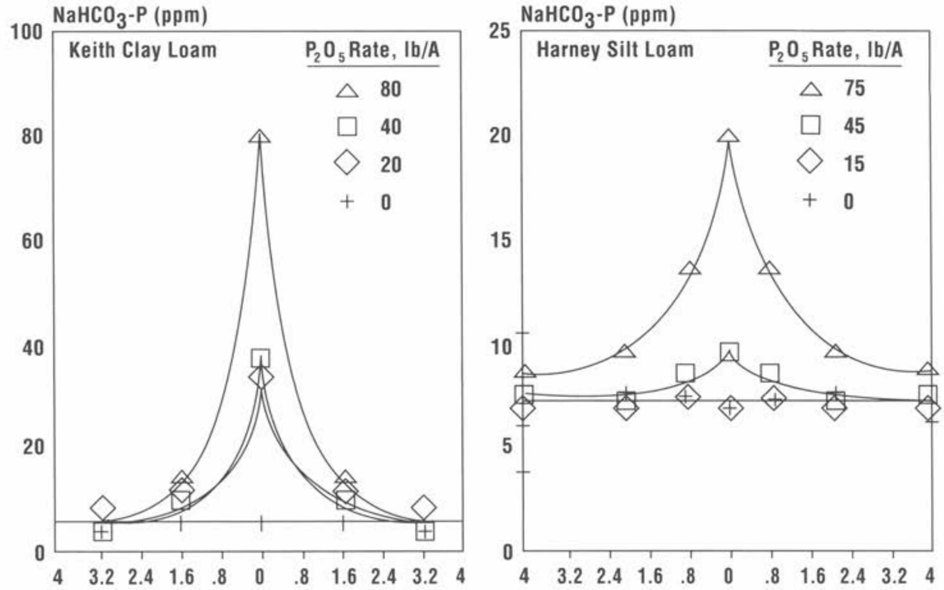

Figure 1. The P soil test level of fertilizer bands as influenced by P rate and band spacing (Keith and Harney soils, 30- and 12-inch band spacing, respectively).

P levels. The P fixing capacity of a soil will have a great influence upon the actual soil test level within the band.

Once the characteristics of the fertilizer bands were identified by intensive soil sampling, a computer analysis was used to determine the most accurate soil sampling procedure that would best estimate the average soil test level of the field. Two cases are evident when considering sampling fields where P fertilizer has been band applied: **Case I,** the location of the residual P band is known, and **Case II,** the location of the residual P band is unknown.

Case I: Location of the Residual P Band Is Known

When the location of the residual P band can be identified from undisturbed crop residue rows, sampling to include or exclude the band can be controlled. A soil test value was obtained by averaging the soil test levels from in-the-band and between-the-band samples and comparing those values to the "true P soil test" mean. The "true P soil test" mean was obtained by integrating the area under the curves in **Figure 1.** This number represents the average P soil test for the entire soil volume (field).

Table 2. Soil test P levels with various ratios of in-the-band soil to between-the-band soil cores.

Ratio of in-the-band to between-the-band soil cores	Band spacing (in.)			
	30		12	
	Keith		Harney	
	-Rate (lb P_2O_5/A)-			
	40	80	45	75
	-soil test P (ppm)-			
1:1	21	42	8	14
1:3	13	23	8	11
1:5	10	17	8	10
1:8	8	13	8	10
1:12	7	10	7	9
1:16	7	9	7	9
1:20	6	8	7	9
1:24	6	7	7	9
"True P soil test" Mean	6	8	8	10

The various soil test levels that were obtained were highly influenced by the ratio of soil cores collected between-the-band to in-the-band cores (**Table 2**). It is evident that the proportion of the soil cores collected between-the-band as contrasted to in-the-band results in a wide range of soil test values. The "true P soil test" mean is shown at the bottom of **Table 2,** ranging between 6 and 10 parts per million (ppm) sodium bicarbonate-P.

Proper Soil Sampling Procedure

Information in **Table 1** shows that the "true P soil test" mean can be accurately determined if the following formula is used in determining the number of soil cores to be collected between-the-bands for every one in-the-band.

$$S = 8\,\frac{\text{Band spacing (inches)}}{12}$$

where: S = the number of soil cores to be taken between-the-bands for every soil core taken in-the-band. For example, if the P fertilizer bands were in a 24-inch spacing in the field, 16 soil cores should be collected outside the influence of the band for every one collected from the band.

Improper Sampling Results in High P Soil Tests

The relationship of the ratios between-the-band to in-the-band cores in **Table 1** and the resulting P soil test levels indicates that there is a higher probability of getting a P soil test above the true mean as contrasted to a P soil test below the true mean. A ratio of 1:1 sampling versus 1:12 sampling in the Keith soil on the 30-inch spacings at 80 lb P_2O_5/A changed the P soil test from 42 to 10 ppm P while going from 1:12 to 1:24 only changes from 10 to 7 ppm. Therefore, taking a small number of cores, even if only one is taken from the old residual P band, will result in a high P-soil test level, resulting in a lower fertilizer P recommendation.

P Rate and Band Spacing Are Important Considerations

A very important parameter affecting the final P soil test value is the P rate applied and the band spacing. As band spacing increases from 12 inches to 24 inches with a constant P application rate, the P concentration in the band doubles. The concentration of P applied in-the-band has a dramatic effect on the longevity of P availability in-the-band (**Figure 1**). When 80 lb/A P_2O_5 was banded on 30-inch spacing on the Keith soil (12 months after application and after grain sorghum harvest) the P soil test in-the-band was 80 ppm, considered extremely high. With 20 or 40 lb/A P_2O_5, the P soil test level in-the-band was only half this value (40 ppm P).

Similar trends can be seen in the Harney soil data. However, at the Harney soil site, P was applied on 12-inch band spacings and the samples were collected 23 months after fertilization. Note that after 23 months, the 45 lb P_2O_5/A rate band concentration had dropped to essentially the same level as the surrounding soil. Therefore, if "lower" rates of P are band applied on narrow spacings, high extractable P concentrations in the fertilizer do not persist. That means when band spacings are wider and band applied P rates are higher, the concentration of extractable P will remain high. This makes the use of proper soil sampling procedures essential in order to accurately evaluate the "true P soil test" mean of the field.

Case II: Location of the Residual P Band Is Unknown

When the location of the residual P band is unknown, random sampling or some modification is the only choice. Two scenarios were tested: a) complete random sampling, and b) paired sampling: the first core taken completely random and the second core 50 percent of the band spacing from the first, perpendicular to the band direction (CR + 50 percent). The results of these two scenarios are shown in **Table 3.**

Standard deviations (SD) of 100 samples were used as criteria to determine the sampling procedure that would give the least amount of sample variability. The smaller the standard deviation, the more accurate the soil test would be in representing the "true P soil test" mean of the field. A standard deviation less than 1.0 ppm-P was classified as "acceptable."

Table 3. The standard deviations (SD) for two soil sampling procedures, based on 100 means.

Soil sampling procedures	Number of cores in composite	Band spacing (in.) 30 Keith		12 Harney
		---(lb P_2O_5/A)---		
		80	40	75
		SD	SD	SD
		-soil test P (ppm)-		
Completely Random	6	4.1	2.0	1.2
	10	3.8	1.5	0.9
	20	2.2	1.1	0.6
	30	2.0	0.9	0.5
	40	1.6	0.8	0.4
	60	1.3	0.7	0.4
	80	1.2	0.6	0.3
CR + 50%[1]	6	4.1	1.9	0.7
	10	2.9	1.4	0.6
	20	2.2	0.9	0.4
	30	2.1	0.7	0.3
	40	1.5	0.7	0.3
	60	1.4	0.6	0.2
	80	1.2	0.5	0.2

[1]Paired-sampling: first core completely random; second core 50% of the band spacing distance from the first core, perpendicular to the band direction.

Generally, the CR + 50 sampling required a smaller number of cores to be collected to most accurately determine the "true P soil test" mean of the field. Therefore, based upon our results, if the location of the band is not known, paired sampling (the first core taken completely random and the second core 50 percent of the band spacing from the first, perpendicular to the band direction) will result in minimal variability and the most accurate determination of the true soil test level.

The variability that occurred within the soil test values became greater with increased P rate, increased band spacing, and fewer numbers of cores taken. The reason is the same as described in **Case I.** The numbers of cores required to get a true estimate of the "true P soil test" mean vary greatly, dependent upon the P rate and band spacing.

(continued on page 30)

Legumes in Cereal-Based Rotations: Influence on Profitability and Soil Quality

By C.A. Campbell, R.P. Zentner and G.P. Lafond

Rotation studies in Saskatchewan show that the quantity and quality of soil organic matter can be increased as effectively by fertilizing continuous wheat as by inclusion of legumes or hay crops in cereal rotations. Both legumes and fertilization were shown to improve economics and profitability.

AN ONGOING CROP ROTATION STUDY has been carried out on a moderately fertile, medium textured, thin Black Chernozem at Indian Head, Saskatchewan, for over 30 years. The project has provided a unique opportunity to compare the relative benefits of legumes and fertilizers used in cereal-based cropping systems. The rotations included fallow-wheat (F-W), continuous wheat, green manure (sweet clover)-wheat-wheat (GM-W-W) and a 6-year rotation of fallow-wheat-wheat-hay-(brome-alfalfa)-hay-hay (F-W-W-H-H-H). The legume-containing systems received no fertilizers, but the monoculture systems each had fertilized and unfertilized treatments.

Results

Early in the study, fallow wheat yields in the 6-year rotation averaged 9 to 16 percent higher than in the moderately fertilized F-W or the fallow-wheat-wheat (F-W-W) rotations, and 22 to 30 percent higher than in the two unfertilized monoculture wheat rotations. However, since 1978, when higher rates of N were applied to the monoculture wheat systems based on soil tests, the yields of wheat after wheat in the 6-year rotation averaged about 20 percent less than wheat grown on stubble in the fertilized F-W-W and continuous wheat systems.

Economic analysis showed that fertilized F-W-W, fertilized continuous wheat, and the two legume-containing systems resulted in good economic performance under most economic situations (**Table 1**). Fertilization generally increased net returns, especially for the longer rotations. Straw baling did not decrease net returns. Risk analysis showed that rota-

Table 1. Annual net incomes[1] for rotations during two fertility periods.[2]

Rotation Sequence	N & P Fertilized	1960-77 Mean	1960-77 Min	1960-77 Max	1978-84 Mean	1978-84 Min	1978-84 Max
		$/A					
F-W	No	4	-40	49	-.5	-32	41
F-W	Yes	7	-44	49	1	-32	49
F-W-W	No	-2	-51	62	-10	-46	34
F-W-W	Yes	6	-51	62	7	-29	57
F-W-W (straw baled)	Yes	9	-57	66	12	-16	58
GM-W-W	No	17	-54	72	9	-18	39
F-W-W-H-H-H	No	9	-44	61	13	-18	41
Continuous wheat	No	-23	-64	70	-40	-99	30
Continuous wheat	Yes	-4	-71	97	7	-96	93

[1]Base assumptions: Wheat = \$4/bu; hay = \$61/ton; fertilizer N = 26¢/lb; P_2O_5 = 27¢/lb; labor = \$10/hr; interest = 11 percent.
[2]Fertilized according to general recommendations for the region in period 1960-77, but according to soil tests in 1978-84; the latter period required much higher rates of N.

The authors are research scientists with Agriculture Canada; Dr. Campbell and Dr. Zentner are located at Swift Current Research Station, Saskatchewan and Dr. Lafond is located at Indian Head Research Station, Saskatchewan, Canada.

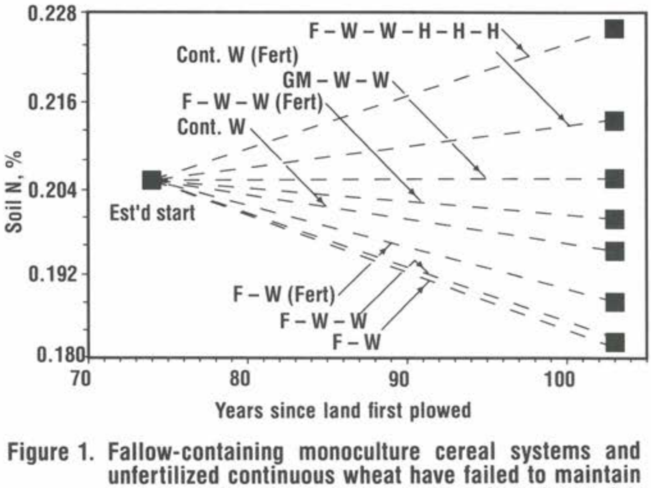

Figure 1. Fallow-containing monoculture cereal systems and unfertilized continuous wheat have failed to maintain soil organic matter of the 0 to 6 inch layer, but legumes in rotation and fertilized continuous wheat have increased it.

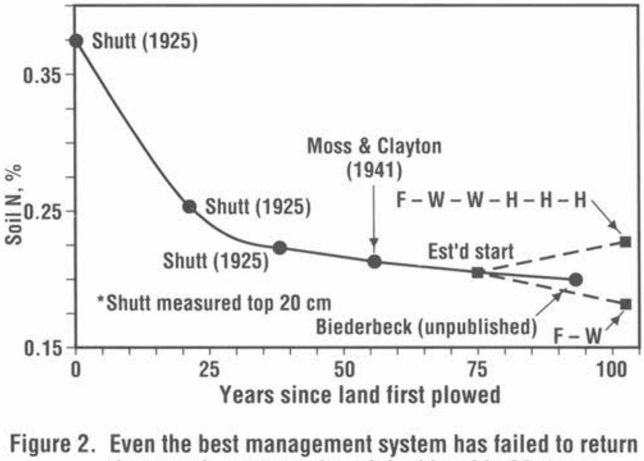

Figure 2. Even the best management system has failed to return the organic matter to its original level in 30 years. (F = fallow; W = spring wheat; GM = sweetclover green manure; H = brome-alfalfa hay).

tions containing high proportions of fallow or legumes had the lowest frequency and risk of financial loss.

Assessment of the effect of these rotations on soil organic matter quantity (**Figures 1 and 2**) and quality (**Figure 3**) confirmed the benefits of legumes in improving soil quality. It also showed that fertilization of continuous wheat at soil-recommended rates can be as effective as legumes in improving soil organic matter quality. Surprisingly, straw-baling had little influence on soil organic matter.

This information demonstrates that achievement of sustainable agricultural production is not predicated solely on the use of organic sources for maintaining or enhancing soil fertility. Properly fertilized monoculture cropping can provide economically viable systems that improve soil quality. These results, though valid for a soil of medium fertility located in a region of generally reliable

(continued on next page)

Legumes . . . from page 29
precipitation, may not be applicable to soils in drier regions where moisture limits the use of the hay-containing and clover GM systems with cereals. In the more fertile (10 percent organic matter) thick Black Chernozem areas where moisture is not limiting, inclusion of legume green manure or hay crops may only serve to maintain soil organic matter and help suppress diseases and pests. The results at Indian Head should be applicable to the Dark Gray and Gray Luvisols areas of the Prairie Provinces.

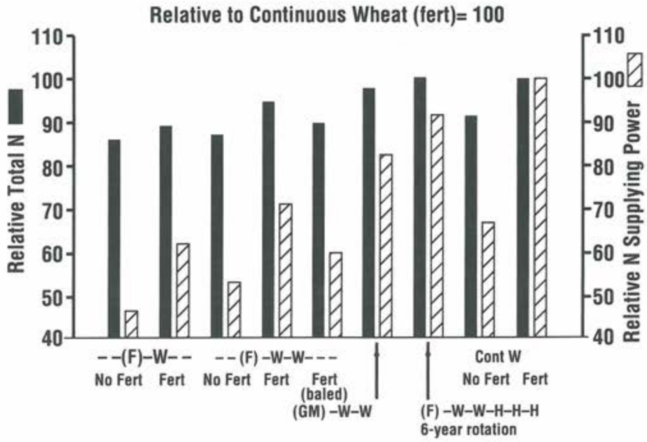

Figure 3. Benefits from fertilizers, increased cropping frequency, maintaining straw, including legume green manure or grass–legume hay crops in rotation with cereals, are shown by the N supplying power more dramatically than by the total N.

Conclusions

Where moisture is not limiting and soil fertility is not already high, legume green manure or hay crops grown in rotation with cereals will enhance soil quality and economics, but so can the judicious use of fertilizers with annual cropping to wheat. ■

Soil Sampling . . . from page 27

Banding High P Rates on Wide Spacings Results in Large Soil Test Variability

If high rates of P are applied in wide band spacing, it is almost impossible to collect enough soil cores to accurately determine the "true P soil test" mean for the field. If 1 ppm is an acceptable deviation in your P soil test, over 80 cores would have to be collected (see **Table 3,** Keith soil-80 lb P_2O_5/A). If you accepted 2 ppm deviation, 30 cores would be required. However, if 40 lb P_2O_5/A was applied, about 20 cores result in 1 ppm deviation. This means that the application of high P rates in bands will make soil testing and accurate recommendations difficult. This is particularly true when wider band spacings are used.

Conclusions

In fields where P fertilizer has been band applied and the location of the band is known, the following formula can be used to determine the proper sampling procedure:

$$S = 8 \frac{\text{Band spacing (inches)}}{12}$$

where: S = the number of soil cores to be taken between-the-bands for every soil core taken in-the-band. Where the location of the band cannot be identified, the first soil core should be taken at random and the second core 50 percent of the band spacing from the first, perpendicular to the band direction. If high rates of P fertilizers are band applied, it is economically and logistically impossible to take enough soil cores from a field to get an accurate soil test. This problem is magnified as the band spacing becomes wider. Regardless, representative soil sampling is the key to accurate fertilizer recommendations. Taking too few cores from fields where P has been band applied has a high probability of resulting in a high soil test level, resulting in low P fertilizer recommendations, as contrasted to a low soil test and a high P fertilizer recommendation. ■

Information Materials from PPI

Listed here are several recent releases from the Potash & Phosphate Institute (PPI).

	Quantity	Cost
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A Concerned Industry

It is far more impressive when others discover your good qualities without your help.

The agrichemical industry is being scolded by some environmentalists who are unaware of industry's efforts to avoid harm to the environment.

Many in the industry are taking the initiative in building containment facilities, in doing soil and plant analysis, and in monitoring fields to avoid excessive use of pesticides. Educational meetings are being held to teach and promote safe pesticides. The industry is very much concerned about protecting and improving the environment. After all, their future depends on the continued success of their customers. Industry has provided the capital investment to acquire equipment necessary to accurately place or apply the products purchased by customers . . . efficiency has been improved.

Industry realizes that the best customers are the "good" farmers who avoid environmental risks, who follow recommendations, and work with Extension. The farmer who doesn't pay his bill is the one who doesn't take advantage of technology, and hasn't been exposed to educational programs.

This latter group is the one we should try to educate. Industry is encouraging reduction of inputs where reduction is in accordance with research-established facts. But it has been established that **excessive** reduction of inputs is a poor management practice and must be avoided. Such a practice could actually lead to greater harm to the environment.

Industry's rule—careful attention to recommendations **proven through research**—will give the greatest environmental protection. Let's continue to be positive about protection.

—J. Fielding Reed

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