RESEARCH PPI EDUCATION

BETTER CROPS

WITH PLANT FOOD

Spring 1990

BETTER CROPS With Plant Food

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Our Cover: Canola is a colorful plant with growing importance as an oilseed crop. Proceedings of the recent International Canola Conference will be available from the Potash & Phosphate Institute (PPI). See page 31.

Photo source: Dr. Julian Smith

Sustainable Agriculture: Vision or Division?

By C.A. Gracey

This article condenses a discussion paper Mr. Gracey presented at the Agriculture Canada National Agri-Food Policy Conference, Ottawa, in December 1989. More than 1600 Canadian farmers, associations, industry, university and government people participated in the forum to help set the direction of Canada's agricultural policy. This frank, no-nonsense approach to "sustainable agriculture" takes a critical look at conventional farming practices, defends its value and recommends embodying the concept of sustainabililty into conventional agriculture.

— Dr. Mark D. Stauffer, PPI/PPIC Director
Eastern Canada, Michigan and New York

MODERN AGRICULTURE can neither surrender its modern technology nor employ it recklessly. The former is a prescription for starvation, the latter for catastrophe. Rather, we must choose the course we are now on. That is, to use technology wisely, much as we use fire . . . ensuring that it warms but does not burn.

The last four or five generations of North Americans, in general, have not known hunger. We live one decade longer, grow six inches taller and at the half century point in our lives, we chew with our own teeth. These should be obvious reminders that the health we enjoy relates to good nutrition. Our abundance of food is the result of recent and progressive waves of science and technology applied to farming. Electrification, mechanization, capitalization, and most recently, chemical technolization have, each in turn, doubled and redoubled our capacity to produce more food with fewer farmers. Today, Canadian agriculture grows enough food for two nations the size of Canada, with only a few percent of its population.

Each wave of technology brought significant and major benefits to the farmer and society at relatively small costs. Undoubtedly, concern about the environment was largely ignored, particularly in the sense and perspective that agricultural consumption was minor compared to total usage. The issue of sustainable agriculture has much to do with the increased use of chemicals and pharmaceutical products; but not that alone. Agriculture has not explained to society what it does and why it is doing it. Hence, there are misconceptions and misunderstanding.

A sustainable agriculture is committed to maintain and preserve the agricultural base of soil, water, and atmosphere, ensuring future generations the capacity to feed themselves with an adequate supply of safe and wholesome food.

Mainstream agriculture has, and must display, its commitment to sustainable agriculture by (1) explaining the benefits of modern farming practices, and (2) identifying the unsustainable components. In general, this is not much different than what we do now. However, subtle shifts in attitude may be required for us to see the middle ground. All agree on the goal. We differ on the means to achieve it. However, to prevent "sustainable agriculture" from becoming a code phrase for the radical fringes, mainstream agriculture must seize it as a working goal and an attainable objective.

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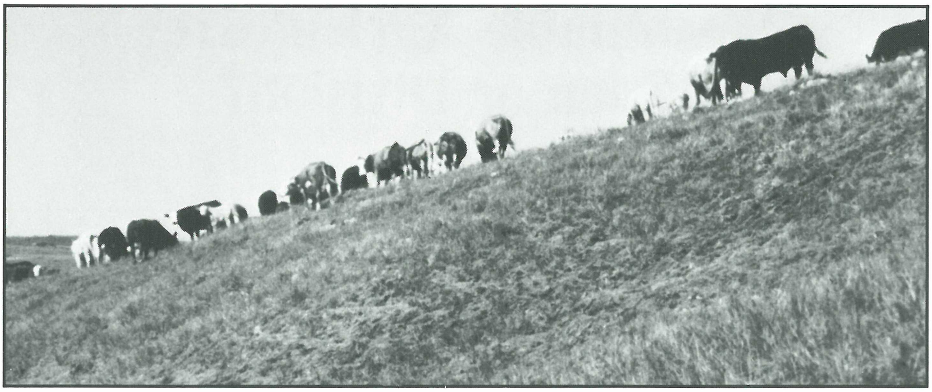
Mr. Gracey was Executive Vice President, Canadian Cattlemen's Association, Toronto. He is now Member of the Canadian International Trade Tribunal, Ottawa.



WHILE it may be an uphill climb, the future of farming can include the concept of sustainability in conventional agriculture.

Agriculture must recognize and concede that we threaten the physical resource base in many ways. For example, productive land is lost to non-agricultural uses, productivity is reduced by excessive aquifer or subsoil moisture drawdown, through soil compaction and organic matter loss. Contamination of our soil and water with chemicals or excessive runoff from fields, feedlots and barnyards could compromise the safety of our food and water.

All these unpleasant things can, and to varying degrees, do happen. It's folly to pretend otherwise. That is why the concept of a "sustainable agriculture" is an idea whose time has arrived. We must adopt it as our own.

Sustainable Agriculture— The Time Is Right

The phrase "sustainable agriculture" has just emerged, but what about the activities? Although it's been forced onto our agenda, that shouldn't preclude mainstream agriculture from embracing it and defining it themselves. Consider that our university departments of animal, crop and soil **science** evolved from departments of **husbandry.** Is it not appropriate, then, for us to emphasize science within the concept of husbandry? That is, the understanding and practice of thrifty management and preservation of our productive resources. The issue of technology and sustainability is not an "either/or" proposition. Modern technology can be combined with good husbandry practices. And it is.

The problem we face in defining and practicing sustainable agriculture is the broadening belief that "sustainable" means "low-input" — an agriculture more or less bereft of modern scientific technology. As mainstream agriculture embraces the concept of sustainable agriculture, it must do so carefully and deliberately, avoiding too zealous and uncritical acceptance of proposed practices.

We already know that many low-input practices are unsustainable. Dr. Don Rennie, Dean-emeritus, College of Agriculture, University of Saskatchewan and an authoritative soil scientist stated: "Low-input agriculture, and one which perhaps for the first 60-75 years fell within the category of organic farming, has been tried and found wanting in the prairies. We practiced that kind of agriculture for the first 50-75 years and during that time extensive (soil) degradation has occurred." Evidence of the superiority of modern cropping practices is found in the fact that prairie grain yields in 1988 and 1989 were much higher than in the 1930s, despite the more severe moisture shortage in the 1980s.

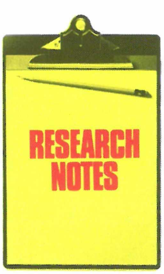
Future generations may well recall our wisdom in harnessing the team of advanced technology and the concept of sustainable agriculture to our benefit and theirs. That our interest in sustainable agriculture was awakened and our position sharpened by those voicing extreme viewpoints is perhaps fortunate. For example, it took extravagant claims about "natural beef" to prompt explanations of how safe and nutritious the regular product is. Further, the lowly cow had to be condemned as a polluter of the atmosphere, a walking methane generator and wasteful converter of grain to meat before we explained the role of the ruminant in nature and in our food system.

It is unfortunate that those who pretend to respect nature fail to detect the complexity of natural interrelationships. While some see livestock as competing with the world's hungry for food, others understand that livestock more often complement and supplement the human food supply. Yet, these accusations forced us to start talking and begin explaining in earnest, the benefits, safety and security of modern agricultural methods to society.

Modern scientific technology will work its own salvation. Indeed, it already is working. No longer can harmful chemical residues go undetected because of our scientific capability and analytical technology. Society has no reason to feel threatened by the legitimate use of modern farm chemicals. The science-derived technology which many consider to be the villain provides hope and opportunity for the future. Explanation of modern food production methods has begun. Demonstration of mainstream agriculture's commitment to a sustainable production agriculture must follow and be apparent.

Sustainable agriculture must not become a cult. For agriculture to survive, it must both use and conserve its resources to sustain the environment's integrity, as well as generate economic capacity. We will do a great disservice to farmers if, through the mechanism of myth and perception, we create a demand for "organic" or "natural" products that cannot be produced economically. We are doubly foolish if we eschew proven and safe production technologies in the process.

The approach to sustainable agriculture must be deliberate and objective. This is no place for zealots and missionaries, but rather thoughtful agriculturalists and sensible farmers. ■



A Review

Phosphorus Fertilization through Drip Irrigation

ALTHOUGH phosphorus (P) fertilization through drip irrigation systems has not been widely recommended, a review of currently available literature indicates this fertilizer application technique can offer many advantages when performed properly. Using drip irrigation to apply P fertilizer allows nutrient placement directly into the plant root zone during critical periods of nutrient demand.

Less P fertilizer is generally required to achieve sufficient tissue P concentrations and equivalent yields when it is drip-applied than with other application methods. The distribution of drip-applied P in soil depends on soil properties, the source of P fertilizer, the rate of application, and the amount of applied water. When irrigation water contains elevated concentrations of Ca^{2+} or Mg^{2+}, acidic P fertilizers are effective in drip systems for preventing precipitation of insoluble P salts. A variety of other soluble P fertilizers has been successfully used where the dissolved salt concentration of the irrigation water is low.

A fertilizer compatibility test with the irrigation water should be conducted before injecting any soluble P fertilizer into a drip irrigation system. ■

Source: R.L. Mikkelsen, Tennessee Valley Authority, Muscle Shoals, AL. Published in J. Prod. Agric. 2:279-286 (1989).

Sustainable Innovations — A Part of, *Not Apart from* Conventional Agriculture

Many definitions are being cast about regarding "sustainable agriculture." But regardless of which you choose, the fact remains that a crop management system must be profitable to be sustainable in the long term.

THE DEVELOPMENT of conventional agriculture systems is a continuous process. New technology, new problems to solve, and changes in the physical, economic and political environment of agriculture drive this evolution.

The fertilizer industry was established in response to a need for nutrients beyond those readily available on the farm. The chemical pesticide industry developed in response to a need to control the pests which reduce potential yield and quality of crops produced by farmers. These industries have grown, changed, and adapted in a continuing effort to meet the needs of farmers and, ultimately, consumers. As potential threats to the environment from these products have been identified, industry and the dealers and farmers who use the products have changed their practices to reduce the potential for contamination of the environment.

Does "sustainable" agriculture differ from "conventional"?

Sustainable agriculture has been defined in many different ways. In the final analysis, the system that is *sustainable* will be the system that is *profitable* and *environmentally sound. Sustainable and conventional agriculture can be one and the same.*

Conventional agriculture is composed of modern, site specific, progressive, science-based production systems in which available and applicable technologies and inputs are used effectively and efficiently. Conventional agriculture shows concern for the environment as well as profitability.

Production systems have developed over time because they are more efficient and profitable. Today's conventional systems are the result of extensive research and education programs on the development, adaptation, and implementation of technology and production practices in a competitive system. Any inefficient, resource-wasting practices are constantly being eliminated and replaced with more efficient, best management practices (BMPs).

This article was prepared by agronomists of the Potash & Phosphate Institute (PPI). For details, contact Dr. Harold F. Reetz, Jr., PPI Westcentral Director, R.R.2, Box 13, Monticello, IL 61856; phone (217) 762-2074.

Practices and inputs determined through scientific study to be unsafe have been eliminated.

Conservation Tillage

Concerns over the loss of valuable topsoil and the potential contamination of surface water supplies from soil erosion, along with the need to more efficiently utilize water resources, have prompted farmers to adopt conservation tillage systems. Reduced tillage and no-till systems have been in place on many farms for over 20 years in an effort to control erosion. University researchers and Extension specialists, in cooperation with the chemical and farm machinery industry, have worked closely with farmers to develop and refine management systems to make reduced tillage work. These practices have become the conventional systems in many erosion-prone areas.

Making this adjustment has required a systematic approach, beginning with farmer experimentation with new ideas, university and industry research into developing equipment and management systems for reduced tillage, and Extension programs to spread the adoption of the practices. Maintaining residue cover throughout the sensitive parts of the year

. . . "And he gave it for his opinion that whoever could make two ears of corn or two blades of grass to grow upon the spot of ground where only one grew before, would deserve better of mankind and do more essential service to his country than the whole race of politicians put together."

— Jonathan Swift
18th Century English writer

is a major part of the conservation tillage system. Increased residue production as a result of increased yields has been a major part of the conservation tillage system. Improved fertility management in conjunction with conservation tillage has contributed to these higher yields.

Ridge-till systems have evolved into workable management packages in recent years as the proper combinations of equipment, chemicals, and fertilizer placement have been developed. Residue and moisture management, along with the proper complements of herbicides and cultivation, is a key component.

Improvements in weed control systems, particularly through the use of selective herbicides, have been critical to the success of conservation tillage systems.

Conservation tillage may mean different things to different people, ranging from elimination of one or more tillage operations to complete no-till systems. In general it involves a reduction of the amount of tillage that is used to control weeds and prepare the soil for the following crop. According to the 1989 National Survey of Conservation Tillage Practices, 71 million acres of U.S. cropland were farmed with conservation tillage practices in 1989. Illinois led the nation with 8.2 million acres of conservation tillage, and also had the highest no-till acreage at 1.96 million acres.

Crop Rotations

Crop rotations have always been a part of conventional cropping systems, wherever possible. The Morrow Plots at the University of Illinois have demonstrated

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the value of crop rotations since their establishment in 1876. Research as well as farmer experience has consistently-shown the value of rotations. A common example in the Midwest is the corn/soybean rotation, which has been shown to have many advantages over monoculture systems. Weed control is improved, usually with reduced use of herbicides. Reduced tillage is often used, with many farmers now using no-till corn planting systems in the soybean residue. Small grain/canola rotations in the Prairie Provinces, wheat/soybean rotations in the East and South, and wheat/sorghum rotations in the Plains are other examples.

Rotations may allow farmers to reduce nitrogen (N) fertilizer use by taking advantage of the N produced by legumes in the rotation. Herbicide options may be increased to provide adequate weed control with less total chemical applied in the system. The requirement for insecticides can also be substantially reduced or eliminated for some crops. All of these factors are integral parts of conventional agriculture.

Extensive data available from land grant universities document a 10 to 15 percent yield advantage for both crops when rotated in a corn/soybean system. Another advantage is that the machinery requirement is similar for both crops. Also, planting and harvest dates are not usually competitive.

Soil Testing/Fertilizer Application Systems

Increased use of soil testing is a BMP that has helped reduce production costs per unit and make more efficient use of the fertilizer applied. While not a perfect system, soil testing is a scientific input into the process of determining fertilizer application needs. Plant analysis provides another tool for determining nutrient use efficiency and for diagnosing crop needs for future nutrient applications. Both are widely used in conventional agriculture and have been for many years.

Soil testing, calibrated with good field research response data, provides a means of determining the potential advantage of

fertilizer applications. Farmers are using more detailed sampling grids to gain a better understanding of the variation of fertility levels within their fields, and to adjust application of fertilizers according to specific needs.

With changes in tillage systems and in crop rotations have come innovations in fertilizer application techniques. These include deep placement, strip and band application, point injection, and fertigation. Each system is designed to place nutrients in a location and at a time closer to the actual needs of the crop. These application innovations are being used to stimulate growth, to increase nutrient uptake efficiency, to reduce soil fixation of the nutrients, and to minimize nutrient losses via runoff, erosion, volatilization and leaching.

Improved plant nutrition through soil testing and appropriate fertilizer applica-

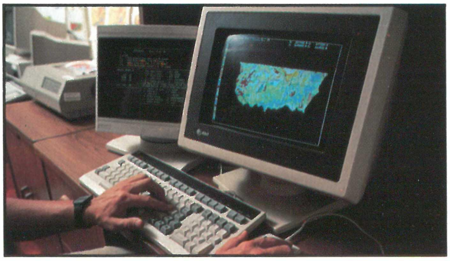
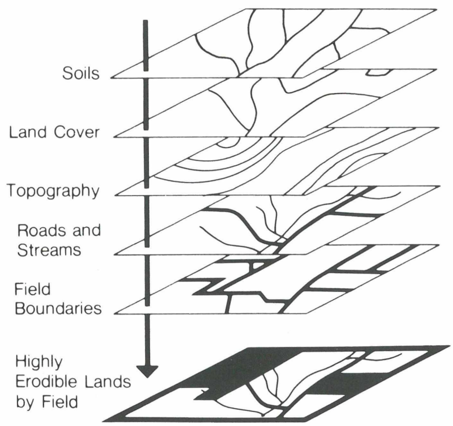


Photo source: USDA Soil Conservation Service



tion helps crops withstand moisture stress, improves water use efficiency, and may reduce the incidence of some diseases and pests, lessening their impact on crop yield. High potash (K) levels, for example, have been shown to substantially reduce the impact of soybean cyst nematode on soybean yields and to lower the incidence of stalk rot in corn.

Nitrification inhibitors or N "extenders" provide a means of improving the efficiency of N utilization by the crop and may reduce the risk of nitrate leaching into water resources.

Newer-technology fertilizer application systems use computers on-board the fertilizer applicator to adjust fertilizer blends and application rates as the machine moves across the field. The computer is programmed with a detailed soil test map showing areas where different rates and nutrient combinations are needed.

This system helps the farmer provide nutrients at a uniform, optimum level. Higher nutrient rates can be applied to areas of the field where needed and lower rates can be used where soil tests indicate less need. Higher yields, lower production costs per bushel, and higher net profits have been shown to result from this redistribution of inputs.

Computerized Records and Applications

Computerized soil test maps are now being used in conventional agriculture as a part of a computerized record system that includes crop history, chemical and fertilizer use, crop yields, tillage systems, weather information, etc., along with concurrent economic information. Maps of these data can be "stacked" in the computer and overlaid on one another to draw correlations between physical characteristics, yield responses, management problems, etc.

This data base can be used for economic analysis of the farming system and projections of effects of management changes. Such systems will become more common in the next few years as more farmers, their suppliers, and their consultants are equipped with computer systems and software to collect and utilize the data bases. Joint efforts of universities, industry, and farmers are being focused on development of improved record keeping and interpretation systems that are an integral part of the management decision process.

Planting Equipment

Innovations in planting equipment in the past 10 to 15 years have made it much easier to achieve a uniform planting depth and spacing of seed in the row, leading to more uniform plant populations, more uniform emergence and early growth of the crop and, ultimately, increased yield potential. Specialized planting systems for different crops and different tillage practices have been important improvements. Examples include no-till planters

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and drills, ridge planters, and better depth control and seed placement systems on conventional planters. Here, too, electronic monitoring and control systems are beginning to assist in developing site-specific adjustments of rates and depths.

Varietal/Hybrid Improvements

Plant breeders suggest that 30 to 50 percent of the improvement in crop yields over the past 50 years has been the direct result of improved varieties and hybrids. Experiments comparing older genetic lines with modern lines have proven these estimates to be accurate. Some of the major increases have been due to improved disease and insect resistance, but improvements in root development, water use efficiency, and physiological activity have also been made. More recent improvements such as resistance to specific herbicides promise to impact the overall management system by opening up new weed control possibilities. These are some of the first real benefits to be derived from genetic engineering and biotechnology research.

Other variety improvements relate to crop quality or to specialty uses for the crop. Often farmers contract for a substantial premium from processors who want a specific variety or type of grain.

Integrated Pest Management (IPM) and Integrated Crop Management (ICM)

Conventional management systems for many years have been a part of the development of integrated systems for pest control and general crop management. Cooperative efforts of university researchers, Extension specialists, crop consultants, and growers have pulled together components of the complete management system to make best use of the resources available to the farm, and to work toward the goal of maximum profitability and minimum impact on the environment.

IPM has helped improve pest management programs by determining exactly when pesticide applications are necessary. Regular scouting of fields for developing problems helps avoid pest induced disasters, while at the same time protecting the yield potential and quality of the crops produced.

Photo source: Purdue Pest Management Program

The most advanced farming operations are carrying the concept further by adopting ICM, which includes pest management, but also fertility management, crop rotations, production record analysis, and variety selection. Both IPM and ICM represent the growing trend toward a systems approach to crop management. Paying attention to all the details and attempting to optimize inputs relative to yield, profitability, and environmental impact represent the thrust of conventional agriculture.

Pesticides of the future—including many now available—will be more concentrated, more specific in activity, and of much less environmental concern. Biodegradable pesticides in biodegradable packaging will become the standard.

Farmers are using more types of pesticides in more ways for specific pests and at specific times, and more are directly involved in site-specific, pest-specific decisions.

Maximum Economic Yield (MEY)

A well-developed type of ICM system is known as MEY. It utilizes a system of BMPs to achieve the most profitable and environmentally sound yield level. MEY will be somewhat lower than the maximum potential yield for the given soil-crop-climate system. Production inputs are evaluated and applied in the combination which research has determined maximizes profitability while protecting the environment.

MEY systems require a high level of management. The appropriate BMPs to be used have been identified through research projects, coupled with appropriate on-farm demonstrations and Extension/consulting programs for site specific management planning. These BMPs may change as economics change and/or as new technology becomes available.

Education/Communication

Programs for continuing education and communications for farmers have helped enhance the sustainability of conventional systems. Computer applications, videotapes, popular and scientific journals, newspapers, and magazines, help to keep farmers up-to-date on latest management systems and technology developments. Leading farmers are now utilizing computer information networks for such services as market and weather information and pest advisories.

These programs are expanding and are used to provide direct communications between the farmer and the various advisors upon whom he depends for information in making management decisions. Some may include short education programs on specific topics to help keep the farmer informed on current recommendations of university and industry specialists, or to provide training in the use of new technology.

" . . . the great cities rest upon our broad (plains) and prairies. Burn down your cities and leave our farms, and your cities will spring up again as if by magic. But destroy our farms and the grass will grow in the streets of every city in the country."

— William Jennings Bryan, 1896

Involvement of the non-farming public in policy-making in the 1990s will increase the need for communication among farmers and agribusiness and consumers regarding the scientific and economic basis for farming practices and inputs and open evaluation of the cost/benefit relationships. This type of communication is beginning to take place, but much more will be needed in the future.

Future

The sustainability of agriculture to meet current and future food, fiber, and energy needs of society will depend ultimately upon profitability. Improved efficiency, lower inputs-per-unit-of-output, higher yield potential, and reduced erosion all need to be parts of the package. Solid research and Extension programs, coupled with programs of industry and commodity organizations to test and promote new technology, are all important components of a truly sustainable agriculture.

But it is not enough for agriculture to be **economically** and **technically** sustainable. It must be **socially** and **politically** sustainable as well. Consumers and elected officials must be better informed about agriculture, so that decisions relative to agricultural policy and attitudes relative to agricultural technology can be based on scientific facts, rather than emotion.

Conventional crop production systems, evolving with constantly improving technology based on sound research and education programs, remain the best means of insuring a dependable, sustainable supply of high quality food, fiber, and energy for our domestic needs and for international markets. ■

Prescription Farming

Varying Fertilizer Applications within a Field

By Daryl D. Buchholz and Nyle C. Wollenhaupt

Missouri researchers have found major benefits from managing fertilizer applications for specific areas within fields. These benefits include improved production, increased profit and fertilizer use efficiency, as well as environmental protection. Systems for managing fertilizer applications within a field can be termed prescription farming, farming by soil type, farming by the grid, and the list goes on. The approach of these practices is to sample small areas within a field for pH, nutrients, and other properties. Each area can then be grouped with other areas of similar soil test levels to give the farmer the opportunity to use different fertility rates within the same field.

MOST FARMERS AND DEALERS recognize that there is some variation in soil texture, color, and/or productivity within field boundaries. Yet, composited soil tests for a field are treated as though constant across the field, resulting in one rate of fertilizer being applied to the entire field.

Soil test levels, however, do vary within a field, and for very good reasons. Previous manure applications probably never covered the entire field or were concentrated in specific areas. The shape of the field, including terraces and uncrossable waterways, influences fertilizer spreading. Soil type variations also affect crop productivity and the amount of nutrient removed from each area of the field, as well as the inherent differences in soil fertility.

Soil testing and fertilizer application technologies have taken us from nutrient needs on a county or statewide basis to the point of managing whole fields. Today, technology allows us to manage just about any size tract of land we wish and treat units within the same field separately. The number of management units within a field is limited by the intensity and cost of soil sampling, the management of additional soil test data, and the capacities of variable rate application equipment.

Is fertilizing the field at varying rates worthwhile? We will draw on a southeast Missouri farmer's experience to address whether varying fertilizer rates is practical. The demonstration area was an irrigated 80-acre field which had been farmed for the previous 35 years by one producer. Although the county soil survey showed the field as one soil type, the farmer had experienced non-uniform crop yields.

The field was segmented into four-acre squares (grids). Samples were taken from each grid and soil tested for phosphorus (P), potassium (K), pH, and organic matter. Phosphorus, measured by the Bray & Kurtz #1 method, varied from 8 to 75 parts per million (ppm) . . . low to very high . . . among grids. Potassium and pH were uniform across the field. Nitrogen (N) rates are typically based on yield potential and goal.

The P fertility pattern was striking. The P-deficient grids were found to be the same areas previously indicated by the farmer as top producing. The farmer also observed that the yields on the "good" ground had once been higher. The soils in the "good"

Daryl D. Buchholz and Nyle C. Wollenhaupt are State Extension Agronomists, University of Missouri-Columbia.

areas were silt loam to silty clay loam, the remainder of the field having a sandy texture. The sandy soils had very high P test levels. The silt loam and heavier textured soils were P-deficient.

In the past, the farmer had followed the single recommended corn fertilization rate which had been based on soil tests. The N-P_2O_5-K_2O rate was 185-23-60 lb/A. Averaging all the grid soil samples would have resulted in an almost identical recommendation of 185-20-85. ''By the book'' fertilization, however, had produced low yields on certain areas of the field. The grid sampling practice showed that generalized soil sampling and recommendations had resulted in mining the fertility on the productive soils within the field, resulting in lower yields.

Based on our grid sampling technique, we recommended three different fertilizer blends for application to specific areas within the field. These three blends contained either 0, 70, or 92 lb/A of P_2O_5 in contrast to the former blanket application of 23 lb/A of P_2O_5 **(Figure 1).**

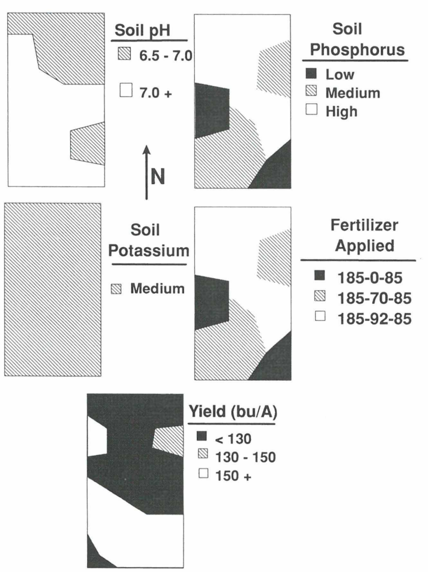


Figure 1. Southeast Missouri 80-acre corn field. Soil fertility determined from a 0 to 6 inch soil sample. Yields determined from hand harvested check strips.

Table 1. Field fertilization plan, Southeast Missouri site.

lb/A	Nutrient	Cost/lb	Acres	Field Cost
	Field Average Recommendation			
185	N	$.17	80	$2,516
20	P_2O_5	.21	80	336
60	K_2O	.11	80	528
		Total		$3,380
	Prescription Management Recommendation			
185	N	$.17	80	$2,516
92	P_2O_5	.21	13	251
70	P_2O_5	.21	21	309
0	P_2O_5	.21	46	0
85	K_2O	.11	80	748
		Total		$3,824

Nitrogen was split-applied, one-half as anhydrous ammonia at planting and one-half as N solution sidedress.

Our prescription recommendations increased the farmer's cost for fertilizer on the 80 acres **(Table 1).** But, through prescription fertilization, the farmer's corn yield on this field increased from its previous 90 or 100 bu/A to 136 bu/A . . . an increase of 36 to 46 bu/A. That represents about a $7,000 increase in gross income from the 80-acre field. Cost of soil sampling, mapping, and spreading over and above our current methods would be estimated at about $12.50 per acre, or $1,000 for the 80 acres. **The investment of $1,350 in soil sampling and additional fertilizer returned $7,000!**

The advantage of detailed soil fertility mapping is apparent through this project. With the development of a yield potential map, N rates could also be varied within the field. Managing variation within fields should not be limited only to fertilizer application. Varying seeding and pesticide rates should also be considered.

Prescription farming technology is presently only in the early stages of introduction into U.S. agriculture. However, managing fields by the acre will be adopted because it matches with all the criteria for sustainability and best management practices (BMPs). Prescription farming for the 1990s provides for resource conservation, sound environmental practices, social acceptance, and commercial competitiveness. ■

Some Facts on Potash

Potassium (K) fertilizer is often referred to as "potash," a term coined by early American settlers who produced potassium carbonate by evaporating water filtered through wood ashes. The ash-like crystalline residue remaining in the large iron pots was called "pot ash," and was used in making soap. This process of making potash is registered as U.S. Patent No. 1.

THE SOURCE of most of the K used for plant food today is potassium chloride (KCl), which is also called *muriate of potash* or *potash*. Most of the world reserves of K were deposited as sea water from ancient inland oceans evaporated, and the K salts crystallized into beds of potash ore being mined today. The deposits are a naturally-occurring mixture of potassium chloride (KCl) and sodium chloride (NaCl), better known as common table salt. Over time, as the surface of the earth changed, these deposits were covered by thousands of feet of soil.

Thus, most potash mines today are deep shaft mines as much as 3,300 feet underground. In above-ground processing plants, the KCl is separated from the mixture to produce a high analysis natural K fertilizer. Other naturally occurring K salts can be separated by various procedures, resulting in potassium sulphate and potassium-magnesium sulphate.

Nearly 95 percent of the KCl produced is used in agriculture. The remaining 5 percent is used for industrial and home uses.

About three-fourths of the potash used in U.S. crop production comes from vast, high quality potash deposits in western Canada. Commercial production of potash in the U.S. has largely been centered around ore deposits near Carlsbad, New Mexico, and at Moab, Utah. Potash is also produced by evaporation of brines . . . such as those from the Great Salt Lake . . . in Utah and California.

Fertilizer potash is applied to supply the K needs of growing crops. Some important functions of K in plants are:

- Increases root growth
- Improves drought resistance
- Helps retard crop diseases
- Maintains cell turgor
- Reduces water loss and wilting
- Increases protein content of plants
- Aids in photosynthesis
- Regulates production of high energy plant growth compounds
- Activates more than 60 enzyme systems
- Produces grain rich in starch
- Builds cellulose
- Reduces lodging due to weak stalks

Potassium Sources

Potassium as a nutrient for plants is available from several sources. Following are some facts on various forms.

Potassium chloride (KCl) or muriate of potash has analyses ranging from 0-0-60 to 0-0-63. It is a crystalline, water-soluble material containing 50 to 52 percent K (60 to 63 percent K_2O) and 46 to 47 percent chlorine (as the chloride ion). It is found in white or red colors, depending upon presence of trace amounts of other minerals such as iron. The K from either white or red forms has the same agronomic value. Potassium chloride has higher water solubility than other K sources.

This article was prepared by agronomists of the Potash & Phosphate Institute (PPI). For more information, contact Dr. Harold F. Reetz, Jr., PPI Westcentral Director, R.R. 2, Box 13, Monticello, IL 61856; phone (217) 762-2074.

The **chloride** (Cl) portion of KCl is also an essential plant nutrient, although there is usually enough available in most soils that it is not limiting to crop yields. Research and farmer experience in the Great Plains and Far West have shown positive benefits from the chloride portion of KCl. The chloride reduces the incidence of some crop diseases in small grains, corn, and many other crops. In these situations, KCl is sometimes recommended even though there may not be a need for K.

It is important to distinguish the *chloride* in potash (KCl) from the *chlorine* used as a disinfectant. While both are derived from the same element, their chemical characteristics and biological activities are dramatically different:

> *Chlorine* is a greenish yellow gas with a sharp, disagreeable odor, but has many important uses. It is most commonly known as a *highly toxic* chemical used as a bleaching agent and disinfectant. When a chemical such as calcium hypochlorite is mixed with water, hypochlorous acid is formed—a powerful oxidizing agent. Many other chlorine compounds are used in industrial and home applications for everything from solvents (carbon tetrachloride) to synthetic materials such as polyvinyl chloride (PVC).
>
> *Chloride* (Cl^-), the negatively-charged ionic form found in potash, is relatively non-reactive in the soil, and is *not toxic* to soil organisms or to higher plants. (Some vegetable and fruit crops are sensitive to excessive chloride in the soil as seedlings.) **Corn, soybeans, wheat, alfalfa, cotton, and most other major crops are not particularly sensitive to chloride, even under high potash fertilizer application rates.** (Chloride can accumulate, along with other salts, to toxic levels in soils with severely limited internal drainage. These *saline soils* are found mostly in isolated spots in semi-arid regions.)
>
> Animals, including humans, require cloride in their diets. Usually it is supplied by table salt (NaCl). But for patients who must restrict their intake of sodium, doctors recommend "lite salt" (KCl), which is the same *potash* used as fertilizer.
>
> Since it carries a negative charge, chloride is not held tightly in the soil, and readily moves downward in drainage water, so it does not accumulate in the root zone in most soils, even under high fertility systems.

Misunderstanding of the differences in chemical and biological activity of chloride and chlorine have led to misguided concerns that using potash fertilizer will lead to the production of toxic chlorine in the soil. *This does not happen*. The chloride in the soil water does not in any way damage the environment.

Potassium sulphate (K_2SO_4) has analysis of 0-0-50. It is a white crystalline salt containing 42 to 44 percent K (50 to 53 percent K_2O), 18 percent sulphur (S), and less than 2.5 percent chloride. It is produced primarily for use on certain crops that require a lower chloride content (such as tobacco, chipping potatoes), or where K and S are deficient in crop production.

Potassium-magnesium sulphate ($K_2SO_4 \cdot 2MgSO_4$) has analysis of 0-0-22. It contains 18 percent K (22 percent K_2O), 11 percent magnesium (Mg), and 22 percent S. It is useful where K, Mg and S are needed because it provides a readily soluble source of all three nutrients.

Potassium nitrate (KNO_3) has analysis of 13-0-44. It contains 37 percent K (44 percent K_2O) and 13 percent nitrogen (N). Originally obtained from Chile as a by-product of the production of nitrate of soda, potassium nitrate is now produced chemically by reacting potassium salts with nitric acid.

Potassium hydroxide (KOH) has analysis of 0-0-75. It contains 62 percent K (75 percent K_2O), and is a highly caustic, highly soluble source of K. However, its high cost makes it useful only for special needs, such as specialty liquid fertilizers, where high analysis of K is desired. ■

Soil Test Summaries: Phosphorus, Potassium and pH

ANALYSIS of available soil test summaries for the U.S. and Canada indicate that many soils are medium or lower in available phosphorus (P) and/or potassium (K) and a significant percentage of soils have pH values of 6.0 or less. These data show that supplemental P and K applications and liming are needed for optimum crop yields and profitability.

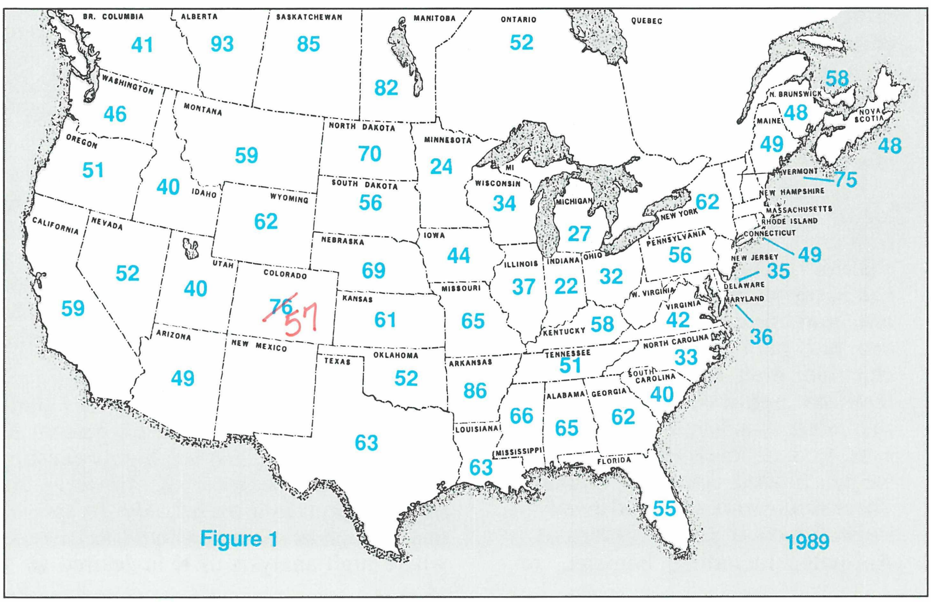
High soil test values for P and K help provide plants with the nutrients needed to take advantage of optimum growing conditions, and benefit from other best management practices (BMPs) and production inputs. They help plants cope with stress conditions. High soil test values provide greater flexibility in fertilizer placement, time of application, future fertilizer application rates and frequency of soil sampling.

Lowering soil acidity through liming is recognized as the "foundation of crop production". Liming provides a means of improving nitrogen (N) fixation by legumes, improving availability of other nutrients such as P, lowering the toxicity of aluminum (Al) and manganese (Mn), providing adequate amounts of the essential elements calcium (Ca) and magnesium (Mg) and improving the effectiveness of several classes of herbicides. The pH value of 6.0 was selected as a break point for this summary. Although the optimum pH varies with different crops, a pH above 6.0 is desirable for most cropping systems.

This information was prepared by agronomists of the Potash & Phosphate Institute (PPI), Suite 401, 2801 Buford Hwy., NE, Atlanta, GA 30329.

Phosphorus Soil Test Summary

Percent Testing Medium or Less



Soil pH values tend to be lower (more acid) where rainfall is higher and where large amounts of vegetation have provided organic acids which help to acidify the soil. However, it's important to recognize that just because soil acidity problems have historically been associated with areas east of the Mississippi River in the U.S. and in the eastern Canadian provinces, they are not limited to those areas. Continued cropping and the addition of N to the soil as commercial fertilizer, legume residues, or manure tend to produce soil acidity. Inattention to soil acidity can lead to significant drops in crop yields and profitability. Farmers in the central Great Plains, where soils are normally high in pH, have seen yield-limiting soil acidity develop after many years of cropping and N fertilization, particularly on coarse textured soils.

Increased use of conservation tillage systems means that more attention must be paid to soil acidity and to the distribution of nutrients in the soil profile. Minimal incorporation of nutrients, especially N, can result in spectacular drops in soil pH near the soil surface. Special sampling to a depth of 2 to 4 inches just for pH determination helps monitor these changes and alerts the farmer as to when and where lime is needed.

From extensive studies across North America, we know that adequate P and K have important, positive roles in improving use efficiency of water and of other nutrients such as N. Providing adequate P and K improves plants' abilities to develop root systems which are more efficient in exploring the soil and absorbing water and nutrients. That is an important factor when water is a limiting factor and has a positive role in the environment by diminishing nitrate carryover and any potential for nitrate leaching toward groundwater.

Regional variations in the percentages of soils fitting into various soil test categories reflect differences in soil parent material, climate and cropping practices. The data help identify the opportunities that still exist for market development in

(continued on next page)

Potassium Soil Test Summary
Percent Testing Medium or Less

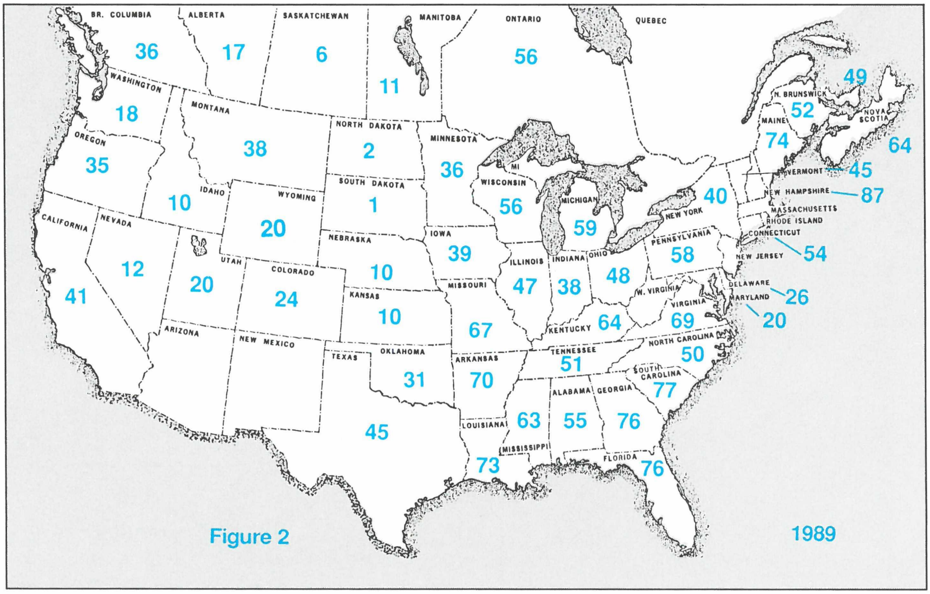


Figure 2

North America, market development that helps crop producers continue to increase yield and profitability for societal and economic sustainability.

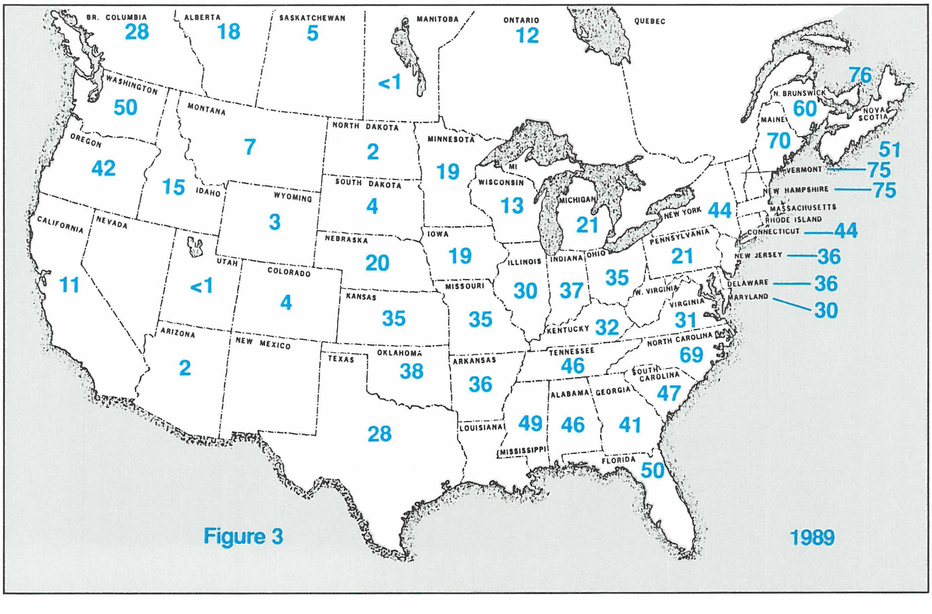
What these soil test summaries don't point out, however, is the variation in nutrient levels and nutrient needs that can exist over small areas, even within fields. Soil sampling and analysis is an important BMP which is extremely site-specific. More sophisticated soil sampling and mapping are beginning to allow growers to target nutrient needs, increasing rates of nutrient application in some areas, decreasing them in others through on-the-go changes in rates as the fertilizer applicator crosses the field. The results are a win-win situation for everyone; higher yields, better control of production costs, improved environmental control (higher N use efficiency), and higher profits.

These summaries also do not show the problems that exist in some areas with low subsoil availability of nutrients which can severely limit crop production. As an example, surface accumulations of K have been documented in many cotton producing areas. Those soils would normally be classified as high or adequate in K. However, high-yielding cotton varieites have shown repeated K deficiencies under university test and producer field conditions due to strong plant demand for K during boll development late in the season. Similarly, high test values for P may reflect surface accumulations due to limited incorporation under reduced tillage conditions, but crop yields may be reduced due to low P levels deeper in the soil. Proper crop management may require nutrient applications even when test levels are high.

Summing Up

In the final analysis, soil testing and application of soil tests to individual crop management systems boil down to a very site specific application of management. Soil testing is one of the important tools in a system of BMPs that continues to provide profitable crop production with positive environmental impacts. ■

pH Soil Test Summary
Percent Testing 6.0 or Less



Potash Improves Drought Tolerance and Water Use Efficiency of Coastal Bermudagrass

By Marcus M. Eichhorn, Jr. and Billy B. Greene

Research in Louisiana shows that potassium (K) nutrition plays a vital role in Coastal bermudagrass performance, with or without adequate moisture availability. Also, fertilization increases forage production per inch of rainfall.

CATTLE PRODUDCERS throughout the Coastal Plain of the southern United States have become acutely aware of the effects of prolonged drought on Coastal and other improved bermudagrasses for hay production. Even though these grasses are the most drought-tolerant of forages grown for hay, limited rainfall during the growing season reduces hay yield to levels that are insufficient to meet the requirements of many livestock producers.

Coastal bermudagrass is the primary forage crop for hay on upland sandy Coastal Plain soils. The soils are inherently low in native fertility, especially K. Moreover, periods of drought are likely to occur annually during the April to September growing season. This article provides a summary of information from a field experiment relative to the effects of K nutrition on Coastal bermudagrass production where rainfall was highly divergent during the growing seasons and the soil was K-deficient.

The experimental site was a Mahan fine sandy loam soil cropped for 10 years with Coastal bermudagrass for hay. The stand exhibited K deficiency, and soil exchangeable K level was very low.

Fertilizer was applied annually for five years, 1980-84, at these rates: nitrogen (N), 400 lb/A (100 lb/A each harvest); phosphate (P_2O_5), 150 lb/A; and sulphur (S), 90 lb/A. Rates of K_2O were applied annually at zero to 600 lb/A. Forage was harvested four times annually in early seedhead development, except in 1983, when persistent drought restricted growth to three harvests.

Rainfall recorded from April 1 to the first harvest, May 19, was adequate for forage production (range 4.51 to 11.29 inches). During the remainder of the growing seasons, rainfall per harvest varied widely as did forage yield, K concentration in forage, and K uptake by forage **(Table 1).**

Table 1. Five-year mean rainfall per harvest, forage yield, K concentration, and K uptake of Coastal bermudagrass over all applied K rates.

	Over 14 harvests (May 20 to Sept. 25)			Corr. Coef. r	
	Range				
Criterion	Min.	Max.	Mean	Rain	Yield
Rainfall, inches	1.65	9.55	4.75	1.00	
Forage					
Yield, lb/A	1,024	5,474	3,514	.26*	1.00
K conc., %	0.50	2.72	1.53	.03	.38*
K uptake, lb/A	5.8	119.0	56.1	.16	.83*

* $P<.01$.

(continued on page 21)

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Balanced Fertility Leads to Profitable Fescue Production

By Richard Mattas

Fescue can be a profitable crop with proper soil fertility management. Many producers, however, apply only enough nitrogen (N) for average yields. Missouri data show that balanced fertility is the key to increasing both yields and profits.

FESCUE is a major forage and hay crop in Missouri and other states. About 36 million acres of fescue are produced in the central U.S., with about 6 million acres in Missouri alone. Producers who have traditionally applied only enough N for average yields have watched yields drop and profits dwindle.

An imbalanced fertilizer program without adequate phosphorus (P) produced low yields, even though N and potassium (K) were adequate. When P_2O_5 rates were increased to 25 and 50 lb/A, yields were increased by 89 and 103 percent, respectively. See **Table 1.**

Table 1. Phosphorus increases fescue yields.

Fertilizer Treatment	Year 1	2	3	Avg.
N-P_2O_5-K_2O, lb/A	-----Yields, tons/A-----			
150-0-200	0.91	1.22	2.35	1.49
150-25-200	1.38	2.92	4.16	2.82
150-50-200	1.54	3.23	4.28	3.02

Table 2 illustrates the relationship of increasing fescue yields, return per dollar invested in P_2O_5 and net returns. The data show that profit from increased fescue yields far outweighs the input cost of additional P_2O_5 needed to achieve these results.

As expected, the first 25 lb increment of P_2O_5 resulted in the highest return per dollar invested, as well as the highest net return per acre.

Missouri data have demonstrated that producers should use soil testing to keep their fertility programs adequate for profitable forage production. In some cases, the "save money" attitude has led producers to a point of low production and low net returns. **Now, many individuals will have to make a substantial investment in fertilizer to regain their former production level and profitability.** ■

Table 2. Relationship between fescue yields and returns to phosphorus.

Fertilizer Treatment	Avg. Yield	Cost of Additional P_2O_5	Avg. Value of Additional Hay	Returns per $ Invested	Net Return per Acre
N-P_2O_5-K_2O, lb/A	tons/A	$	$	$	$
150-0-200	1.49	—	—	—	7.01
150-25-200	2.82	6.25	79.80	12.78	69.53
150-50-200	3.02	6.25	12.00	1.92	69.48

N, 20¢/lb; P_2O_5, 25¢/lb; K_2O, 12¢/lb; custom swathing and raking, $12/A; baling, $11/ton; hay value, $60/ton.

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THESE PHOTOS show the dramatic response of fescue when P_2O_5 was applied in Missouri research. Both plots received N at 100 lb/A and K_2O at 100 lb/A. The plot at left received no P_2O_5, while the plot at right received 50 lb/A.

Coastal Bermudagrass . . . from page 19

Association between rainfall and forage yield was highly significant, while K concentration and K uptake by forage were not significantly associated with rainfall. Forage yield was significantly associated with K concentration and K uptake of forage. Data revealed that K was indeed a growth-limiting factor because both K concentration in forage and K uptake by forage affected forage yield which increased as rainfall increased.

Forage yield, K concentration, and K uptake of Coastal bermudagrass per inch of rainfall/harvest were all highly dependent on the rate of annually applied K_2O. As shown in **Table 2,** forage yield per inch of rainfall maximized when 400 lb/A of K_2O was applied annually, while K concentration and K uptake of forage each maximized when 600 lb/A of K_2O was applied annually. In absence of applied K_2O, forage yield per inch of rainfall was 55 percent of the highest yield; K concentration and K uptake were 63 percent and 76 percent lower.

Data revealed that K nutrition plays a vital role in Coastal bermudagrass performance, irrespective of moisture availability. In this experiment, average rainfall per harvest was 4.75 inches. The K requirement, from both soil and fertilizer, which produced the top yield of 4,232 lb/A (2.38 tons/A of hay) per harvest was 111 lb/A of K_2O per harvest; N was applied at 100 lb/A per harvest and P_2O_5 and S were applied annually in the spring at 150 and 90 lb/A, respectively.

The data also emphasize the importance of adequate K in water use efficiency. Forage produced per inch of rainfall increased an average of 54 percent as K rates were increased to 400 lb K_2O/A/year. This is especially important in maintaining yields under stress conditions due to inadequate moisture. ■

Table 2. Effects of K fertilization on yield, K concentration, and K uptake of Coastal bermudagrass per inch of rainfall per harvest.

Per inch of rainfall per harvest (y)	K_2O rate, lb/A (x)				
	0	100	200	400	600
Yield, lb/A[a]	576	702	796	891	861
K conc., %[b]	0.17	0.26	0.34	0.46	0.54
K uptake, lb/A[c]	4.6	8.6	12.9	19.4	22.0

[a]/$Y = 576.4 + 1.41x - .00156x^2$ ($R^2 = .70$).
[b]/$Y = .17 + .0095x - .00000054x^2$ ($R^2 = .70$).
[c]/$Y = 4.2 + .0524x - .0000537x^2$ ($R^2 .99$).

What Is the Source of Nitrogen in Runoff Water?

By Daryl D. Buchholz

There are some popular misconceptions about the sources of nitrogen (N) in runoff water from fields, and about the effect of fertilizer N rates. Recent studies show that controlling erosion is still the best means of decreasing nutrient losses from cropland.

WHAT percent of the N fertilizer applied to corn or cotton eventually leaves the field with runoff water?

A common sense answer might say: "As N fertilizer rate per acre increases, N fertilizer in runoff waters will also increase, right?" Wrong.

Many people also believe that any N that leaves the field in runoff has to be "fertilizer N." Wrong again.

Research in Missouri evaluated nutrient loss from a Mexico silt loam (3 percent slope) farmed in conventional tillage compared to no-tillage. Continuous corn was grown with three rates of N. **Table 1** shows that water runoff and sediment loss (erosion) were both reduced with adequate N application (150 to 175 lb/A rate).

A yield level of 120 bu/A in dryland production of continuous corn on the Mexico soil would generally require 150 to 175 lb/A. As yield potential changes with management of this soil, so would N requirement.

Both sediment and solution N losses were measured in the research. Nitrogen losses (sum of runoff and sediment) were unaffected when 150 to 175 lb/A rates of N were applied, compared to a check with 10 to 15 lb/A rates of N, applied annually. With very high N application (300-325 lb/A) compared to yield potential, N loss did increase in the runoff water.

Table 1. Water runoff, soil loss and N loss from continuous corn at varying N fertilizer application rates (five-year averages).

Production System	—N Rate Applied, lb/A— 10-15	150-175	300-325
No-till			
Runoff (in.)	10.0	7.2	6.8
Soil Loss (tons/A)	0.54	0.30	0.21
N in runoff (lb/A)	6.5	11.7	25.3
N in Sediment (lb/A)	3.1	1.7	1.2
Conventional tillage			
Runoff (in.)	7.4	5.4	8.1
Soil Loss (tons/A)	2.26	1.99	2.05
N in runoff (lb/A)	6.3	10.8	28.8
N in sediment (lb/A)	13.8	11.4	12.3

Source: Smith et al., 1979

Is the N loss fertilizer N? No, nearly all the N loss in solution runoff can be attributed to the breakdown of plant residues and organic matter. Unfortunately, organic matter breakdown and release of nitrate and ammonium N do not always coincide with crop growth and demand for N. Therefore, N in crop residues could be more susceptible to losses than fertilizer N which can be applied at times when crop demand and uptake efficiencies are high.

As N fertilizer rate increased to an appropriate level, N loss in runoff increased by only 4.8 lb/A annually, but N loss from sediment decreased by 1.9 lb/A when averaged across tillage systems. At the high rate of N fertilizer for the soil's

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yield potential, N loss in runoff increased again, but sediment N loss remained unchanged. Over time with good N fertilization, corn residues will have higher N content. With breakdown, that soluble N from those residues may be transported in runoff water.

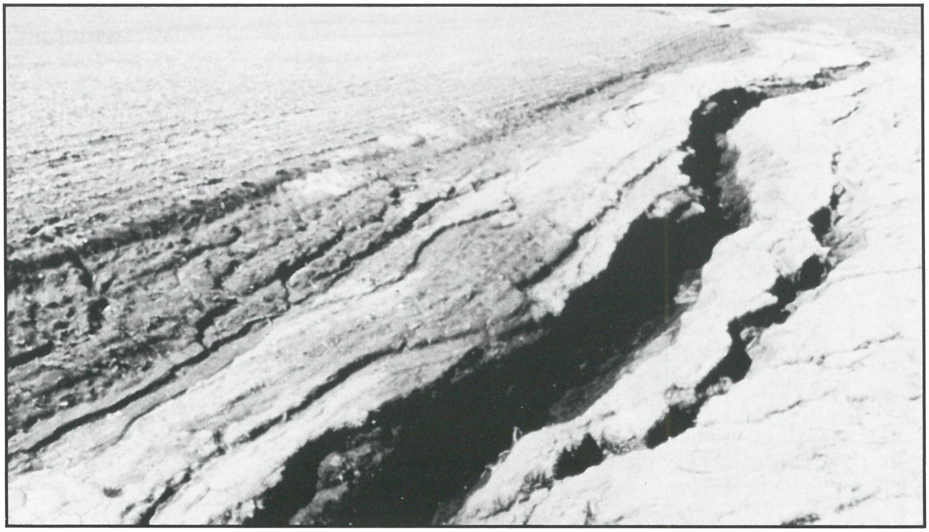
Soybean cropping without fertilizer showed similar N loss in runoff water to corn fertilized with 150 to 175 lb/A N rates. Conventional tilled soybeans lost 7.8 lb/A in runoff waters, no-tilled corn lost 9.0 lb/A. No-tilled corn cut for silage lost only 3.8 lb/A . . . more evidence that residues and breakdown of those residues contribute to the N loss, not the fertilizer N.

Implications of residue breakdown contributing to N in runoff waters could be far-reaching. Manure decay, legume decay, and cover crop decay all contribute N to runoff waters in amounts equal or possibly greater than the use of fertilizer N. Building soil organic N through legumes and manure may actually increase N in runoff waters. However, those are great practices for improving productivity and should be recommended as best management practices (BMPs) right along with the use of appropriate recommended rates of N fertilizer.

The N loss in runoff waters from a field is not fertilizer N, it is N released in the breakdown of plant residues and organic matter.

The next question is: "How much N do we normally receive in rainfall?" Remember all the farmers that say if we get good snowfall there will be more N for the crops next spring? Research from Minnesota would suggest this to be true. In that research, less N was lost from the cropland in runoff waters than fell annually in rainfall. The conclusion was that the soil and residues were actually acting as a sink for some of that ammonium and nitrate-N in precipitation. The fertilizer N applied in that corn rotation system was not contributing to runoff problems. The Minnesota precipitation data showed an average of 6.7 lb/A N contributed annually from rainfall.

To summarize, N in runoff waters from adequately fertilized corn fields will likely be no greater than the N coming off legume fields with no fertilizer N applied. That amount of N may also be no greater than that received annually from precipitation. **Controlling erosion is still the best means of decreasing nutrient losses from all types of cropland fields.** ■



SEDIMENT losses from the land, as soil erosion, contribute the major significant portion of nutrient load in runoff. Controlling erosion will conserve soil nutrients and enhance surface water quality.

Louisiana Research

Fertilization and Liming Practices for Cool-season Clovers

By Donald L. Robinson and Hubert J. Savoy, Jr.

Proper attention to nutrient needs and soil pH is important to maintaining forage yields and quality. Many soils used to grow legumes such as subterranean and white clovers are too acid and low in both phosphorus (P) and potassium (K) fertility. Adequate lime, fertility buildup and nutrient maintenance programs are a necessary part of overall management required to produce most efficient yields.

WINTER PASTURES are a vital part of many livestock operations in Louisiana and other states. But these pastures are produced at considerable expense.

Annual ryegrass is widely grown as winter forage, but cool-season legumes offer an attractive alternative or supplement. Their forage quality may exceed that of ryegrass and they require no nitrogen (N) fertilization. Unfortunately, cool-season legumes generally yield less forage than does ryegrass and they are less dependable than ryegrass because of more frequent stand failures. Studies at the Louisiana Agricultural Experiment Station are determining phosphorus (P), potassium (K) and lime requirements for sustained production of cool-season clovers on highly acid, low fertility soils.

Field experiments with Mt. Barker subterranean clover and La S-1 white clover were conducted on a Providence silt loam at the Idlewild Louisiana Experiment Station near Clinton. White clover was planted the first and third years of the study. Subclover was seeded only the first year but produced adequate seed for good stands in all subsequent years. All seeds were inoculated with the proper *Rhizobium* strain just before planting. White clover was harvested from two to four times and subclover was harvested one to three times each year.

Phosphorus Fertilization

Subclover yields increased as P applications increased to 80 lb P_2O_5/A, although yields were not significantly higher at the 80 than at 40 lb/A rate **(Table 1).** Where no P was applied, yields

Table 1. Three-year average forage yields of subterranean clover and white clover, plant P concentrations and subsequent soil test P levels.

Annual P_2O_5 applied	Mt. Barker subclover Yield	% of Max. Yield	Plant P	Soil[1] Test P	La S-1 white clover Yield	% of Max. Yield	Plant P	Soil[1] Test P
lb/A	tons/A		%	ppm	tons/A		%	ppm
0	0.40	27	0.22	16	0.77	38	0.21	16
20	1.01	68	0.25	17	1.18	58	0.25	19
40	1.26	85	0.30	22	1.48	73	0.27	21
80	1.48	99	0.34	38	1.67	82	0.30	29
160	1.49	100	0.38	91	1.82	90	0.34	54
320	—	—	—	—	2.03	100	0.34	135

[1] Soil tests levels after three years; parts per million (ppm). Providence silt loam.

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averaged only 0.4 tons/A during the three years. At the highest rates of P_2O_5, yields averaged nearly 1.5 tons/A. Yields at 0, 20 and 40 lb/A of P_2O_5 averaged 27, 68 and 85 percent of the yield at the highest P rate. The data indicate that 90 percent of maximum yield, the commonly recommended yield goal, would have been attained at about 50 lb/A of P_2O_5.

Soil test P levels increased with increasing rates of P application over a three-year period. Soil test P levels were low at the 0, 20, and 40 lb/A P_2O_5 rates, but increased to medium and high levels at the 80 and 160 lb/A rates, respectively. These results indicate that the 80 lb/A P_2O_5 rate would exceed long-term P requirements for subclover and soil test P values at that rate would eventually increase into the high category. It appears that about 50 lb/A of P_2O_5 would then maintain adequate soil P to meet subclover P requirements.

Forage yields of La S-1 white clover were increased from 0.77 tons/A where no P was applied to slightly over 2 tons/A where P was applied at the highest rate of 320 lb/A of P_2O_5. About 90 percent of the maximum yield was obtained at the 160 lb/A rate of P_2O_5.

Soil test P values also increased with each higher level of P application, reaching medium and high levels at the 160 and 320 lb/A P_2O_5 rates. The values remained in the low range at all lower application rates. The 80 lb/A rate of P_2O_5 increased soil P to nearly the medium level. The data indicate that near maximum forage yields of white clover were obtained with 80 to 160 lb/A of P_2O_5 on the Providence silt loam soil. At the upper end of this range, soil test P levels increased substantially and would exceed the long-term P requirements of the crop. At the lower end of the range, soil P levels increased slowly and should eventually provide sufficient P for maximum yields.

Potassium Fertilization

Applying 90 lb/A of K_2O to subclover increased three-year average yields by 0.4 tons/A, although the increase was not statistically significant. Declining soil test K levels where no K was applied would indicate that a significant response to K would eventually occur. Where K was applied at the 90 lb/A K_2O rate along with adequate P, soil test K values increased only slightly from the initial level of 70 ppm.

Potassium applications increased white clover yields slightly over the three-year period. At the 40 lb/A rate of K_2O, 91 percent of the maximum yield was obtained; at 80 lb/A K_2O, 96 percent of maximum was reached. But, soil test K levels declined from the original value of 70 ppm to about 50 ppm at rates less than 80 lb/A of K_2O. The soil test K level remained stable at 80 lb/A K_2O, but increased substantially at higher rates of K application. These results indicate that 80 lb/A K_2O was sufficient to maintain soil K levels while producing approximately 2 tons/A of forage containing 2.3 percent K.

Liming

Three rates of lime for subclover increased soil pH from 4.9 to 6.5 but increased yields only about 0.2 tons/A. Those results emphasize that subclover is a relatively acid-tolerant legume. Lime rate studies in the greenhouse showed that Mt. Barker subclover, La S-1 white and Osceola white clovers had very similar acid-tolerance but are much less acid-tolerant than ryegrass. In contrast, Bigbee berseem and Dixie and Chief crimson clovers were relatively intolerant of soil acidity. Until more information is available about the proper pH for specific clovers on specific soils, when soil pH drops below 5.8 sufficient lime should be applied to raise the soil pH to about 6.2.

Summary

Many soils used for winter pasture production are highly acid, low in P and K, and require application of 80 to 160 lb/A of P_2O_5 for two or three years to assure near maximum clover yields and to raise soil P to adequate levels. Subsequent annual applications of 50 lb/A of P_2O_5 appear adequate to maintain yields and soil P levels. Annual applications of 80 lb/A of K_2O provide maximum yields and maintain stable soil K levels. Cool-season clovers are much less acid-tolerant than ryegrass and generally make maximum yields at soil pH 5.8 to 6.2, although subterranean clover and white clovers yield much better at lower soil pH than do berseem or crimson clovers. ■

Increasing Yield and Reducing Disease on Wheat with P and K Fertilization

By G.V. Granade, D.W. Sweeney, W.G. Willis,
M.G. Eversmeyer, D.A. Whitney and L.C. Bonczkowski

Wheat diseases often destroy 10 to 25 percent of yields and can severely lower the quality of grain. Research has shown that fertilization can reduce the incidence of diseases such as take-all, while improving yields. This southeastern Kansas study measured yield and the effects of phosphorus (P) and potassium (K) fertilization on diseases common to the area. Several varieties and P and K rates were evaluated on a soil ranging from very low to high in P and low to medium in K.

YIELDS were significantly increased in the two-year study by application of both P and K. Varietal interaction with each of the nutrients was significant. Averaged across varieties, 30 lb P_2O_5/A increased yield and heads per square yard 44 percent **(Table 1).** Increasing the P_2O_5 rate to 60 lb/A increased yields another 4 percent. Even though yield of all varieties was increased by P, the amount of in-

Table 1. Effects of P fertilization on yield, yield components, grain protein, and disease rating of six wheat varieties.

Wheat Cultivar	P_2O_5 Rate, lb/A	Yield, bu/A	Kernel Weight, mg	Kernels per Head	Heads per Sq. Yard	Protein Content	Disease Rating
						---------- %	----------
Thunderbird	0	49.5	34.0	30.1	372	13.1	8
	30	79.4	32.5	30.3	619	11.4	6
	60	81.9	31.9	29.2	641	11.3	6
Bounty 205	0	52.6	33.4	31.8	393	13.4	19
	30	75.9	31.7	34.8	548	11.7	13
	60	77.8	31.1	35.0	586	11.4	12
Caldwell	0	60.5	27.5	40.7	428	10.8	10
	30	81.2	25.7	37.9	588	10.2	12
	60	83.5	25.4	35.4	656	10.0	9
Karl	0	54.0	33.1	26.9	451	13.5	21
	30	79.6	31.6	28.9	618	11.7	21
	60	83.1	30.2	27.5	706	11.4	18
Newton	0	51.6	30.3	33.2	392	11.7	53
	30	70.3	29.2	32.9	593	10.7	52
	60	72.6	28.7	32.4	612	10.6	47
TAM 107	0	53.7	34.6	27.3	446	11.5	46
	30	76.1	33.2	28.1	608	10.7	47
	60	80.8	32.6	27.3	654	10.5	44
Average P Effects							
	0	53.7	32.1	31.7	414	12.3	26
	30	77.1	30.7	32.1	595	11.1	25
	60	80.0	30.0	31.1	643	10.9	23

Disease rating was determined on the percent of leaf rust on the flag leaf.

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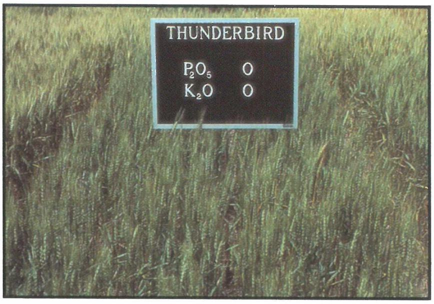

FERTILIZATION with P and K increased wheat yields by more than 30 bu/A with some high-yielding varieties. Plot shown at left received no P or K; plot at right received 30 lb/A P_2O_5 and 40 lb/A K_2O. Phosphorus produced large increases in tillering and head numbers. Potash significantly decreased the incidence of leaf rust, further increasing yields.

crease ranged from 34 to 60 percent. Yield increases due to added P were greatest with AgriPro Thunderbird and least with Caldwell. Even though P effects on heads per square yard varied with variety, P application effects were probably due to marked increase in the initial plant stand, winterhardiness, and/or tillering.

Kernel weight and the number of kernels per head were minimally affected by P applications. However, P effects on the number of kernels per head did vary with variety **(Table 1).** In the final analysis, the major reason for yield increases due to P was probably due to increased heads per square yard and not to kernels per head or kernel weight.

Potassium fertilization increased yields an average of 12 percent, but effects

(continued on page 30)

Table 2. Effects of K fertilization on yield, yield components, grain protein, and disease rating of six wheat varieties (1988 and 1989).

Wheat Cultivar	K_2O Rate, lb/A	Yield, bu/A	Kernel Weight, mg	Kernels per Head	Heads per Sq. Yard	Protein Content	Disease Rating
						---------- %	----------
Thunderbird	0	67.3	32.0	31.3	520	11.9	9
	40	71.4	33.2	29.7	536	12.0	7
	80	71.8	33.2	28.5	577	11.9	4
Bounty 205	0	59.9	31.5	35.0	473	12.3	23
	40	72.7	32.3	33.2	538	11.9	12
	80	73.7	32.5	33.4	575	12.3	9
Caldwell	0	69.6	24.7	39.3	598	10.5	14
	40	79.4	26.9	37.3	577	10.3	10
	80	76.1	27.1	37.4	497	10.2	8
Karl	0	71.5	30.4	28.7	583	12.2	23
	40	73.4	32.3	27.5	590	12.1	19
	80	71.8	32.2	27.2	602	12.3	17
Newton	0	60.0	28.3	33.6	520	11.0	58
	40	66.3	29.6	33.2	521	11.1	47
	80	68.2	30.4	31.7	556	10.9	47
TAM 107	0	63.4	30.9	28.6	588	11.3	52
	40	74.1	34.4	27.5	543	10.6	40
	80	73.1	35.0	26.6	578	10.8	45
Average K Effects							
	0	65.3	29.6	32.7	547	11.5	30
	40	72.9	31.4	31.4	551	11.3	22
	80	72.5	31.7	30.8	553	11.4	22

Disease rating was determined on the percent of leaf rust on the flag leaf.

Nitrogen Fertilizer Use, Computer Modeling and Nitrates in Groundwater

By Dale Pennington

In the Fall 1989 issue of this publication, Dr. Pennington discussed the complexity of evaluating the level of nitrates in groundwater, with emphasis on Texas. In the following article he evaluates a computer model used to predict the relationship between nitrogen (N) fertilizer use and the occurrence of nitrates in groundwater. Again, he uses Texas conditions to document his position.

THE PRIMARY METHODS used to evaluate groundwater nitrates have been computer-generated models such as the USDA-ERS report of Nielsen and Lee (1987). Their report, *The Magnitude and Costs of Groundwater Contamination from Agricultural Chemicals: A National Perspective,* is essentially based on three assumptions (proxys). The weaknesses of this model are:

1. **The assumption that 25 years of groundwater nitrate data are ample to describe the nitrate problem and its relationship to N fertilizer use is incorrect.** One must find and analyze groundwater nitrate data that are older than the introduction of nitrate fertilizer use in an area before a relationship can be established.

   For example, in 1946, excessive groundwater nitrate levels were being found in the Rolling Plains region of Texas (an area Nielsen and Lee suggest is potentially groundwater-contaminated from N fertilizers) . . . predating N fertilizer use.

   Note: Wells in this same area in Texas were tested for nitrates in the 1960s and again in the 1980s. After 20 years of N fertilizer use, half the wells were lower in nitrates in the 1980s.

2. **A second assumption is that if crops are planted, the national average of N fertilizer is applied per acre.** If this assumption were true, Texas would be applying 2.1 million tons of N per year instead of the 700,000 tons now used. **Table 1** compares the amount of fertilizer N sold in 1987 in designated Rolling Plains counties to the amount the Nielsen and Lee model assumes was applied at the 52 lb/A rate for their medium fertilizer rate. This model assumes the nitrate levels in the wells within these counties was from N fertilizer. The nitrates predate N fertilizer use.

Table 1. Comparison of actual N sales versus assumed N applied for five selected counties in the Rolling Plains area of Texas with groundwater nitrate problems (1987).

County	Actual N Sold	Assumed N Applied as Modeled by Nielsen and Lee
	---tons/year---	
Baylor	2,819	2,615
Jones	1,206	5,957
Knox	1,381	4,932
Wilbarger	2,724	4,692
Wichita	6,016	2,305

Obviously, N use in the five counties did not even come close to the assumed fertilizer rates suggested by the Nielsen

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and Lee model. The model accurately predicted N use only in Baylor County. It underestimated the amount sold in Wichita County by nearly 300 percent. Examination of the data for planted acreage in Wichita County (92,200) strongly suggests that farmers in neighboring rural counties were buying N in the more populous Wichita County.

The principal weakness to large scale modeling for the U.S. is the inability to ground validate the data utilized in the model . . . illustrated in the example above.

3. **No attempt to use information related to crop removal of N . . . common to almost every effort to predict fertilizer N and its effect on groundwater N.** Neither the Nielsen and Lee paper nor the new Soil Conservation Service-USDA model (SEEPPAGE: A SYSTEM FOR EARLY EVALUATION OF THE POLLUTION POTENTIAL OF AGRICULTURAL GROUNDWATER ENVIRONMENTS, Moore, 1988) accounts for fertilizer N removal by harvested crops.

   In every case, only the figures for purchased or applied N are being considered without regard to crop removal. If these approaches are allowed, then Texas, where conservative N application programs have prevailed, will be the long-term loser.

To check possible nitrate build-up in Rio Grande Valley soils, applied fertilizer N was compared to N removal by crops. Data in **Table 2** indicate that fertilizer N is not adding to the soil budget. **If N removal by vegetables and citrus were included, net gain would be even lower in Cameron and Hidalgo Counties.** Starr and Willacy Counties indicate high net losses. Figures in **Table 2** do not account for denitrification, ammonia volatilization losses or nitrate leaching. Each of these factors would reduce the net gain . . . increase the net loss of N.

When one has this type of background information, research data begin to make more sense. For example, in 1975, researchers in the Rio Grande Valley investigated the return flow of nitrate in drainage water from irrigated land. They reported that nitrate losses for sorghum were negligible when 100 lb/A N rates were applied on a sandy loam soil . . . according to soil test. The research data and removal budget **(Table 2)** are in agreement. This approach to documenting N groundwater pollution potential should be more widely used.

Summary and Conclusion

The impact of fertilizer N on groundwater quality must be monitored. Incorrect conclusions, based on misinformation, can be drawn concerning N use and the groundwater nitrate levels, possibly affecting the incomes of future generations of Texans. Groundwater nitrate levels precluded the use of fertilizer N in parts of Texas . . . information now ground validated.

The challenge facing computer modelers generating reports without ground validation is to use computer technology toward "active" groundwater pollution programs rather than a "reactive" program which may generate misinformation. An example of an "active" program follows:

- Use historical data and statistical data bases for determining mean nitrate levels in shallow wells. Sta-

(continued on next page)

Table 2. Estimated soil N accumulation in four Rio Grande Valley counties for 1974-75.

County	Estimated N applied	Crop N removal	Stubble and Crop Stover N	N loss or gain	Crop land	N loss or gain
	tons/year				Acres	lb/A
Hidalgo	14,506	11,506	2,063	+ 933	907,616	+ 2.06
Cameron	8,209	6,675	1,093	+ 441	523,608	+ 1.68
Willacy	3,622	4,742	733	−1,893	76,160	−49.71
Starr	1,013	1,144	228	− 359	154,496	− 4.65

Nitrates . . . from page 29

tistically monitor new nitrate levels to determine if they are increasing significantly.

- Use analysis of soil nitrates for determining soil N levels in regions with shallow wells. Monitor these soil nitrate levels and determine if they are increasing significantly.
- Use crop yield and removal studies to monitor N use and establish when N is a potential problem.
- Adapt soil analysis N recommendation programs that identify areas with groundwater nitrate problems directly related to fertilizer N use. Generate special handling and application programs for safe use. This capability exists with the current soil fertility recommendation programs developed by the Texas Agricultural Extension Service. ■

Wheat . . . from page 27

levelled off at 40 lb K_2O/A. Yield increases varied from 3 to 21 percent depending on variety **(Table 2).** The yields of Karl and Thunderbird were only slightly affected by K. Yields of Newton, Caldwell, TAM 107, and Bounty 205 increased 10 percent or more with K application. Average kernel weight of all varieties was consistently increased by K application.

Increases in kernel weight for Caldwell and TAM 107 were 10 percent or more with K. The number of heads per square yard was not increased as much with K as by P, but was higher than the zero K treatment for all varieties except Caldwell and TAM 107.

Protein

Grain protein content was reduced approximately 10 percent by P. However, since P increased yield, nitrogen (N) available to the grain (75 lb N/A) may have been limited and grain N content (protein) may have been diluted. The possibility of limited N for protein is supported by the fact that N concentrations in the plant at the boot stage were reduced by P, even though P concentrations were increased. This emphasizes the importance of sufficient N for varieties with high yield potential so adequate yields of good quality grain can be produced. Potassium had little effect on grain protein in this study.

Plant Disease

Fertilization with K decreased the amount of leaf rust on the flag leaf by an average 27 percent. Leaf rust incidence was decreased in all varieties by K, but the magnitude of K effects varied with varietal susceptibility to disease. Regardless of K rate, Thunderbird and Caldwell had the lowest incidence of leaf rust on the flag leaf, Newton and TAM 107 the highest. Potassium decreased the incidence of leaf rust 48 and 29 percent in Bounty 205 and Caldwell, respectively. Reductions of leaf rust could account for the improvement in kernel size and yield, as shown with Caldwell and TAM 107.

Phosphorus had less effect on leaf rust than did K, but better plant nutrition did tend to lower disease incidence.

Summary

The data from this two-year study indicate that high-yielding varieties respond differently to P and K fertilization. Phosphorus increased yield primarily by increasing the number of heads. Phosphorus also increased plant N use and may require additional N fertilization to maintain desirable grain protein levels. Potassium influenced yield by increasing kernel weight and reducing incidence of leaf rust. The potential for disease suppression by K may be even greater under high rainfall conditions where disease pressure is often greater. ■

International Canola Conference Proceedings Available Soon

PROCEEDINGS OF THE 1990 International Canola Conference are being prepared, with completion expected about July 1. The meeting April 2-5 in Atlanta, GA, was attended by more than 200 persons. The Potash & Phosphate Institute (PPI), Potash & Phosphate Institute of Canada (PPIC) and Foundation for Agronomic Research (FAR) served as organizers of the event. Co-sponsors included the American Society of Agronomy, Canola Council of Canada, Clemson University, Crop Science Society of America, Soil Science Society of America, The Sulphur Institute, Tennessee Valley Authority, University of Georgia, U.S. Canola Association and USDA-ARS.

Thirty-three speakers from Canada, the U.S. and other countries covered topics ranging from nutrient requirements of canola to storage, marketing and processing of the crop. Additional information on canola breeding, genetics, crop adaptation, production practices, oil quality and use was presented in 23 poster papers.

Copies of the Proceedings can be obtained by contacting: PPI, 2801 Buford Hwy., N.E., Suite 401, Atlanta, GA 30329. Costs are $12 per copy in the U.S., $15 per copy in Canada and other countries. Checks should be made payable to "PPI". ■

Sustainable Agriculture

"The next few decades present a greater challenge to the world food systems than they may ever face again. The effort needed to increase production, while retaining the essential ecological integrity, is colossal . . . "

In a recent article featured in *Better Crops With Plant Food,* Dr. E.T. York quoted this statement by a special panel of the World Commission on Environment and Development. They added: "Given the obstacles to be overcome, it can fail more easily than it can succeed."

Though world food production went up 2.6-fold from 1950 to 1984, **per capita** production of cereals has declined each year since 1984. The World Bank estimates that over 700 million people do not have enough calories for an active working life. Indeed, 15 million children worldwide die each year from hunger!

Dr. York relates these challenges to low-input agriculture, environmental concerns, and agricultural chemical needs, and he emphasizes:

- **More intensive production systems,** including the use of chemical inputs, have been the product of decades of research.
- **If some practices** are contributing to environmental or human health problems, **our research institutions** are the ones to solve these problems.
- **There is no adequate substitute for commercial fertilizers** if agricultural systems, worldwide, are to satisfy the food needs of increasing numbers of people at prices which most can afford to pay.

Better Crops With Plant Food helps keep you informed on the complex issues of "sustainable agriculture" and environmental concerns. In the Winter 1989-90 issue, Orville Freeman vividly describes world food needs—a challenge of unprecedented magnitude. In the current issue you'll find an excellent article on "Sustainable Innovations," one on "Sustainable Agriculture: Vision or Division," and others on current research. Take time to read them . . . then make your own decision.

— J. Fielding Reed

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