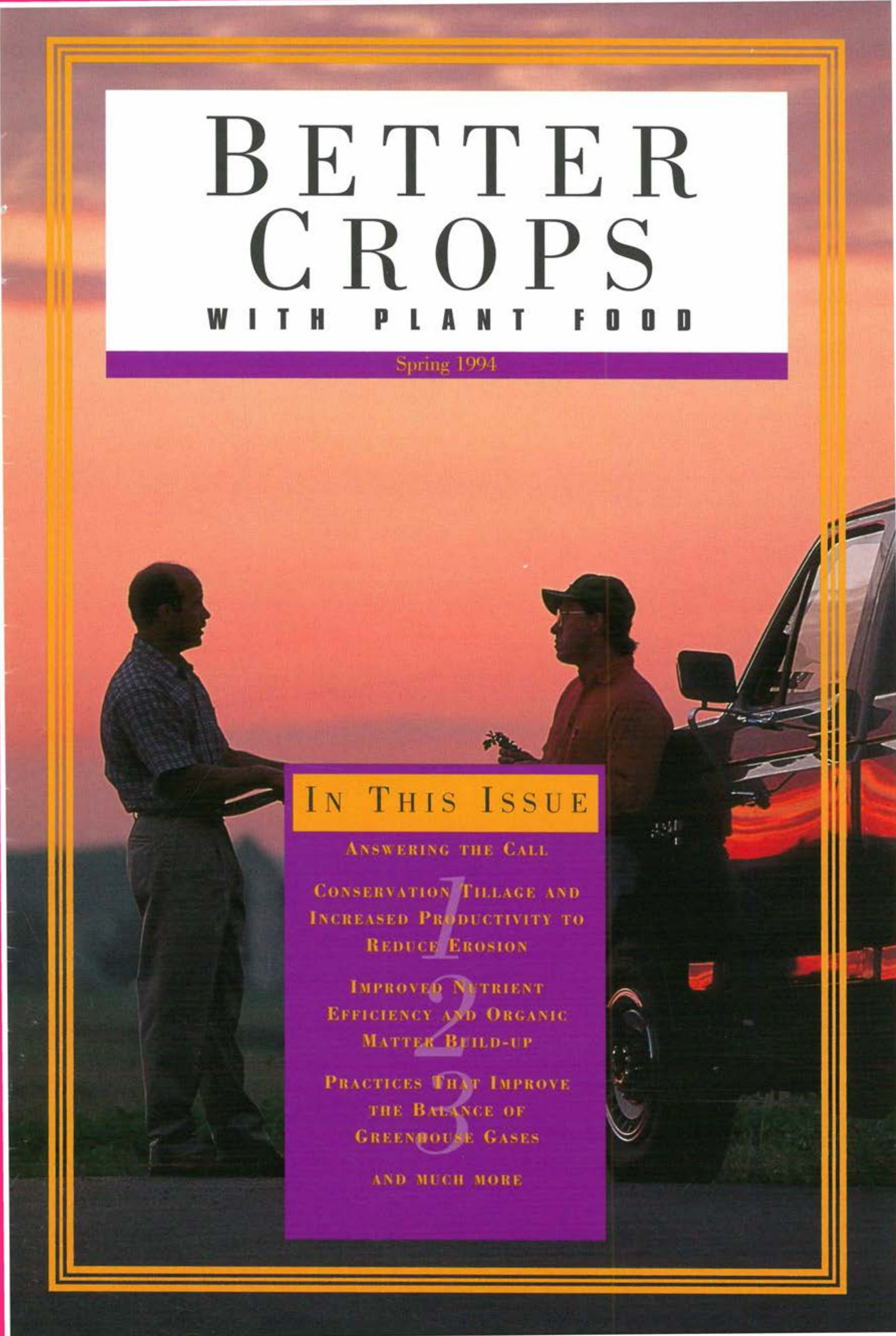
BETTER CROPS WITH PLANT FOOD

Spring 1994



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BETTER CROPS
WITH PLANT FOOD

Vol. LXXVIII (78), No. 2 **Spring 1994**

Our Cover: Preparing for another day.
Photo Credit: Larry Lefever from Grant Heilman
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BETTER CROPS WITH PLANT FOOD

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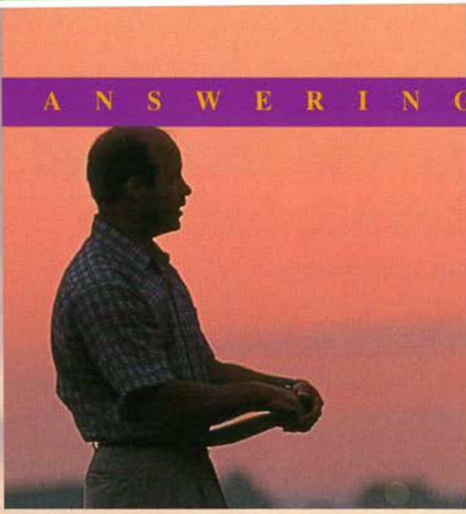

A Familiar Trait of the North American Grain Farmer

FARMERS have, by the very nature of their chosen profession, a dedication to the stewardship of our soil, water and natural resources. Today, the modern grain farmer is using this sense of stewardship and has made many changes in the way soils are managed and crops are grown, with the thought of environmental protection in mind. These grain producers are well aware of their environmental responsibilities. Since the "environmental age" began, the possible negative effects of agriculture on the environment have been brought to their attention. Now, many farmers are concerned that burdensome government policies may be formulated to improve perceived non-point pollution problems which they are already bringing under control. Without minimizing the severity of environmental problems in certain critical areas, we must not overlook changes that are taking place.

Jeff Hopkins at The Ohio State University recently completed a Master's thesis concluding that modern technology on typical Ohio grain farms requires little or no tradeoff among the environment, productivity and profit. The thesis points out that it is possible at once to maintain a safe environment, plentiful food supplies and farm profits. Credit for this revolution goes to agribusiness for developing such things as no-till drills, more precise fertilizer applicators, improved products and practices that control weeds and insects using ounces rather than pounds of ingredients, and better crop varieties that get more crop output per pound of plant nutrients. Credit also goes to science and education at our universities and USDA who share in the development and use of these new technologies.

Major credit goes to the innovative and progressive farmers who bring all these improved inputs and practices together on the farm. They have used these traits in the past to answer the call for more productivity per crop acre in order to meet the food demands of a growing world population. They have utilized this same initiative to overcome hardships brought on by droughts, floods and market instabilities.

Today, U.S. and Canadian farmers are answering the environmental call by implementing new technologies, changing soil management practices, and improving crop production efficiencies. Together these changes are having a dramatic and positive impact on solving environmental problems associated with crop production. The following series of articles highlights some of these changes and the impact they are having on such environmentally related issues as soil erosion, carbon sequestering, organic matter build-up, fertilizer use efficiency, and greenhouse gas production as it relates to global warming. BC

The authors of the following series of articles are Dr. Luther Tweeten, Anderson Professor, Agricultural Economics, Ohio State University; Dr. Lynn Forster, Van Buren Professor, Agricultural Economics, Ohio State University; Dr. W.K. Griffith, retired Eastern Director, PPI; and Dr. H.F. Reetz, Jr., Midwest Director, PPI.

Answering the Call:

Conservation Tillage and Increased Productivity to Reduce Erosion

By Luther Tweeten and Lynn Forster

THE OUTLOOK for the 21st century is rosy for many dimensions of agriculture. The great farm-to-urban exodus is behind us. More operators will enter farming than will leave in mid-career if the 21st century is like the 1980s. The family farm will be around for decades, although numbers will continue to fall modestly. The modern North American farm, on average, is performing well financially and will continue to do so into the 21st century. There is good evidence that major environmental problems associated with grain farms are under control. Small farms are successfully combining off-farm income to achieve total household income comparable to that of non-farm households. These impressive achievements are a triumph of initiative and hard work by farm families. They are also a tribute to the successful interaction of markets, education, science and industry.

Conservation Tillage

The progress in conservation tillage is apparent from the benchmark for corn. In the 1950s, virtually all corn ground was tilled with a moldboard plow, leaving only 2 percent residue on average. Erosion rates were high, but farmers needed to bury stalks to control the pesky corn borer. Now biological predators have been introduced by scientists to control the corn borer. That has helped free farmers to turn attention to erosion control.

According to USDA numbers, in the Corn Belt in 1991 only 12 percent of corn ground was prepared by conventional moldboard plow. The remaining 88 percent was prepared as follows:

- 49 percent with chisel plows, disc harrows and other tools, leaving 16 percent residue on average;
- 25 percent with mulch till, leaving 37 percent residue on average;
- 12 percent with no-till, leaving 64 percent residue on average;
- 2 percent with ridge-till, leaving 45 percent residue on average.

The already considerable use of no-till and other conservation tillage systems continues to expand. The 1993 National Crop Residue Management Survey conducted by the Conservation Technology Information Center puts conservation tillage systems such as no-till, mulch-till and ridge-till at nearly 35 percent of the total acres planted in the U.S. That is within 4 percent of the acres that are clean tilled. Conservation tillage could soon be considered the "conventional" practice. While some additional machinery may be required initially, conservation tillage systems lessen trips over the field, reduce labor requirements, consume less fuel, and generally result in lower machinery costs in the long run because a smaller machinery component is required. Experiences from crop farmers are that conservation tillage systems need not reduce, and may even enhance, net farm income while maintaining output. However, some conservation tillage systems are not profitable on poorly drained soils.

USDA data show that no-till requires 0.2 hours per acre to grow corn in the Corn Belt. Conventional moldboard tillage takes 0.8 hours per acre . . . four times as much. This means a farm family can handle four times as many acres with conservation tillage, which supports the trend toward fewer, larger family farms.

Machinery power requirements also are less with conservation tillage. The declining power and machinery requirement helps to explain why farm machinery depreciation has exceeded capital expenditures every year since 1980 without creating machinery shortages.

The Decreasing Rate of Soil Erosion

Soil erosion causes on-farm and downstream damage. Costs of both types of damage are being cut by an impressive reduction in erosion. Based on data reported in the 1938 Yearbook of Agriculture and the 1987 Conservation Needs Inventory, sheet and rill erosion fell from over 3.5 billion tons in 1938 to 1.6 billion tons in 1987. Led by the Conservation Reserve Program, soil erosion was 650 million tons less in 1991 than it was in 1986 and now averages about 3.5 tons/A. Two major reasons for the dramatic improvement in holding our soil resources on the farm are the expanding use of no-till and other conservation tillage systems and the continual increase in productivity per acre.

The societal benefits (of reducing erosion and sedimentation) to downstream water users are substantial. For example, research results indicate that a 10 percent reduction in soil erosion allows local communities using surface water to reduce their water treatment costs by 4 percent. Similarly, conservation tillage reduces the need for dredging of ditches, rivers, lakes and harbors while it enhances recreational water uses. A 16-year Ohio study completed in 1990, based on 6,000 observations from three river systems, found that the phosphorus (P) load to Lake Erie had been reduced by 39 percent, or 1,414 tons annually from the 3,650 tons deposited in 1975.

Environmental Benefits from Improved Productivity

As illustrated in **Figure 1**, total U.S. crop production in 1990 would have required 734 million acres if produced with 1950 technology as measured by yields. That's 393 million acres more than the 341 million acres that were harvested in 1991. The nation doesn't have 393 million additional acres of prime farmland. Had the expansion of crops onto fragile soils been necessary, soil erosion would have increased dramatically.

About 1 acre in each thousand of prime farmland is annually converted to urban and other non-farm uses . . . a 10 percent loss in a century. Also, estimates are that erosion, if continued at current rates of soil loss, will reduce productivity by another 3 percent in the next century. Current productivity gains of 1.5 percent per year would offset these losses in only nine years. ■

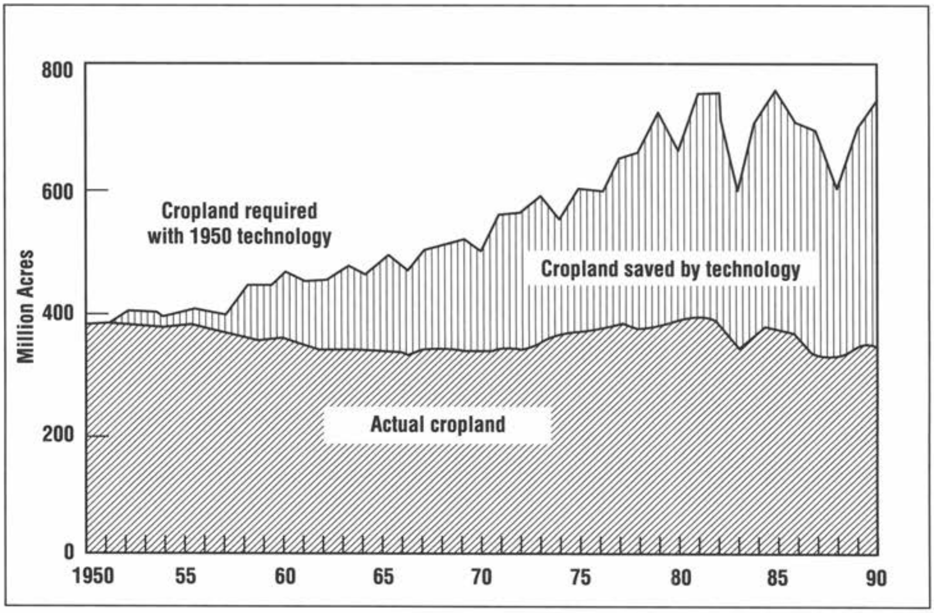

Figure 1. Acres required for crop production with 1950 technology, 1950-1990.

Answering the Call:

Improved Nutrient Efficiency and Organic Matter Build-up

By William K. Griffith and Harold F. Reetz, Jr.

THE American crop farmer, wherever possible, combines the use of conservation tillage with improved soil fertility management practices. The integration of these two best management practices (BMPs) increases grain yields, crop residues, nutrient use efficiency, and carbon (C) assimilation. It also improves the soil medium for sequestering C and the build-up of organic matter.

- Crop residues totaled 513 million tons in 1992, 186 million tons more than in 1973.
- Crop residues contained 232 million tons of C in 1992 . . . 85 million tons more than in 1973.
- Commercial fertilizer accounts for 35 percent of grain and crop residue yield, or 81 million tons of the 232 million tons of C in 1992 crop residues.
- Nitrogen (N) efficiency on corn (bu/lb N applied) was 1.03 in 1992, an increase from 0.87 in 1982.
- Phosphorus (P) efficiency on corn was (bu/lb P_2O_5 applied) 2.80 in 1992, an increase from 2.01 in 1982.
- The ratio (nutrient uptake/nutrients applied) on corn was 1.82 in 1992. That compares to a ratio of 1.42 a decade earlier.
- In 1992 a total of 7.0 million tons of plant nutrients was exported off farms through grain sales. That compares to 6.1 million tons in 1982.

Studies have shown that soil organic C content is a linear function of the amount of crop residue added to soils. Crop residue production is increasing on North American farms as yields have increased, as shown in **Figure 1**.

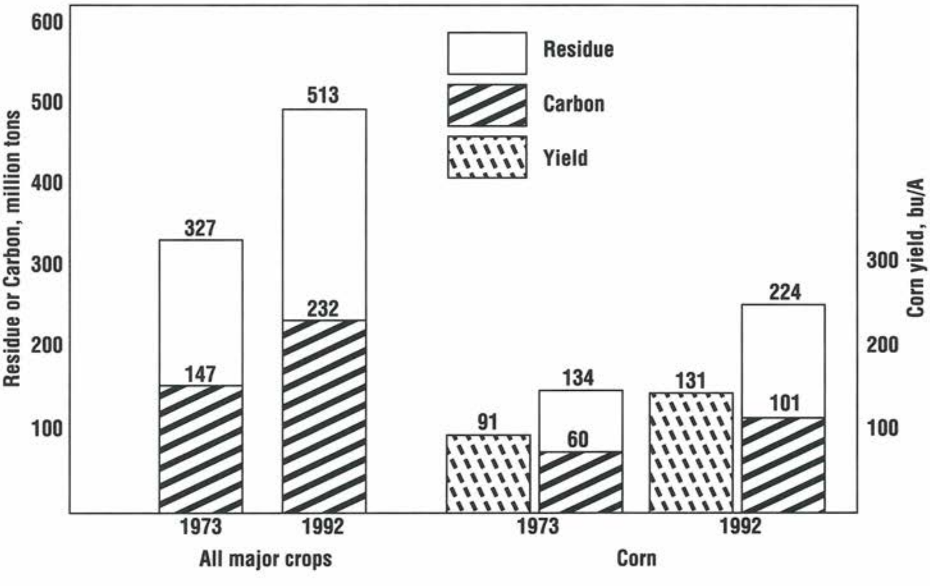

Figure 1. Crop residue and organic carbon production by all major crops and a comparison with corn (1973 versus 1992).

During the past 20 years, residues produced by the major crops in the U.S. have increased more than 50 percent, from 327 to 513 million tons. Corn residue accounts for approximately 44 percent of the total crop residue produced. Increased crop residue production parallels the improvement in grain yields. Corn yields, for example, increased 40 bu/A in this 20-year time span. Total crop acreage in 1973 and 1992 was about the same . . . 236 and 242 million acres, respectively (not shown in **Figure 1**). Approximately 45 percent of crop residue dry matter is C. In 1992, crop residues contained approximately 232 million tons of C which was potentially available for sequestering into soils and organic matter build-up.

Several long-term experiments and farmer experiences have shown that the three management practices most closely associated with the build-up and maintenance of organic matter are: 1) conservation tillage practices, 2) an adequate and balanced soil fertility program, and 3) crop rotations.

Commercial fertilizer use accounts for approximately 35 percent of grain and crop residue yields annually, or 81 million of the 232 million tons of C in 1992. Dr. Ron Follett, USDA/ARS said, "Soil fertility is essential for plants to grow and sequester carbon in soils. Conversely, the soil carbon level is often an indicator of a soil's fertility."

Through the continual development of better agronomic and conservation BMPs and the implementation of new technology by crop farmers, soil nutrient storage capacity, nutrient efficiency, and the production and environmental benefits associated with these factors are all increasing. Comparisons of corn yields, corn residue and C production, and fertilizer use efficiency for 1982 and 1992 are shown in **Table 1**.

It is estimated that crop yield potential increases more than 20 percent for each 1 percent increase in soil C content. Corn yields and residue production increased substantially during the period from 1982 to 1992. Higher amounts and better management of crop residue improve the soil medium for sequestering C and building organic matter. As a result, a soil's capacity to retain plant nutrients in the rooting zone is enhanced.

The increased soil nutrient storage capacity is a partial explanation for the gradual increase in crop yield potential, higher nutrient use efficiency, organic matter build-up, and reduced environmental problems associated with higher crop yields.

However, plant nutrients exported off the farm have also increased as grain yields increased. This depletion, particularly for P and K, unless restored by plant nutrient sources outside the system, will reverse the positive soil/fertilizer/yield/environment relationships now taking place on North American grain farms. ■

Table 1. A comparison of corn grain yield, residue and C production and their relationship to fertilizer use and efficiency in 1982 and 1992.

		1982	1992
Corn acreage, million		73.2	72.1
Yield, bu/A		114	131
Corn stover residue, million tons		197	224
Carbon in corn residue, million tons		89	101
Fertilizer use per acre:			
(USDA)	N	131	128
	P_2O_5	57	47
	K_2O	72	57
Fertilizer efficiency, bu/lb applied:			
	N	0.87	1.03
	P_2O_5	2.01	2.80
	K_2O	1.59	2.31
Nutrients (NPK) removed in grain, million tons		6.1	7.0
Nutrients (NPK) remaining in residue, million tons		7.4	8.3
Total nutrient uptake, million tons		13.5	15.3
Total nutrients applied, million tons		9.5	8.4
Ratio nutrient uptake/nutrient applied		1.42	1.82

Answering the Call:

Practices that Improve the Balance of Greenhouse Gases

By William K. Griffith and Harold F. Reetz, Jr.

"**AGRICULTURE** has a great opportunity to help mitigate climate change by stashing carbon dioxide as carbon in soil and vegetation. Practices requiring good agricultural husbandry, which should be implemented anyway, can be quite effective for sequestering carbon. For cropland, these practices include building soil organic matter levels, improving soil fertility, and growing more food on less land."

Dr. C.E. Hess, Former Assistant Secretary of Agriculture for Science and Education

- U.S. crop production assimilated 1.6 billion tons of carbon dioxide (CO_2) in 1992. This total will increase as yields increase.
- North American grain farms are now thought to be a net sink for CO_2 through carbon (C) sequestering in soils.
- Agricultural soils contribute an estimated 11 percent of the annual nitrous oxide (N_2O) emissions worldwide.
- In the U.S., nitrogen (N) fertilized crops are estimated to contribute 3.5 percent of the 4.4 million tons N_2O emitted annually.
- North American grain farmers are adopting N management technologies that increase the efficiency and decrease the losses via denitrification.

Gases such as CO_2, N_2O and methane (CH_4) are labeled greenhouse gases because they absorb the long-wave invisible solar radiation as glass absorbs radiation in a greenhouse rather than allowing the heat to be radiated away from the earth. A steady enrichment of the atmosphere by greenhouse gases is suggested to cause global warming. While agriculture is considered a minor source of these gases, policy debates tend to target agriculture as a major factor.

Carbon Dioxide

Fixation of CO_2 by photosynthesis is the ultimate source of organic C in soils. Crop production practices that enhance photosynthetic activity and help retain the sequestered C in soils can reduce atmospheric CO_2 and any effects that it might have on global warming. Estimated CO_2 assimilated, oxygen (O_2) released, and the potential C levels available for sequestering in soils are shown in **Table 1**.

Table 1. Estimated carbon dioxide assimilated, potential carbon levels available for sequestering, and oxygen released by U.S. crop production in 1992.

Crop	Total production grain + residue (DM)[1]	Carbon dioxide assimilated	Total carbon in residue	Oxygen released
	----------	million tons	----------	
Corn	448	739	101	537
Wheat	160	264	43	192
Soybeans	143	236	39	171
Grain sorghum	38	63	9	46
All other crops	176	290	40	211
Total	965	1,592	232	1,158
Fertilizer contribution	338	557	81	405

[1]Root dry matter (DM) would add to these totals, but has not been included.

Past estimates have shown U.S. agriculture to have a relatively small negative CO_2 balance, emitting about 150 million tons annually. This compares to an estimated total emission from all sources in the U.S. of 4.9 billion tons CO_2. The major factors considered in net CO_2 losses from agriculture are fossil fuel burning and electricity uses.

Estimated CO_2 emission from agriculture is dwarfed in comparison by the almost 1.6 billion tons CO_2 assimilated by the major crops grown in the U.S. in 1992. The positive CO_2 assimilated value for the major crops produced will increase further as crop yields continue to increase.

In the past, the amount of CO_2 assimilated by production agriculture has not been included in global analyses because it has been assumed that CO_2 assimilation and emission levels from the soil/vegetation complex (including forests, range, grasslands . . . all vegetation) are equal. Some recent estimates indicate that U.S. agriculture may now be a net CO_2 sink. This positive indication seems more likely because of the tremendous contribution from production agriculture.

Nitrous Oxide

Biological denitrification is believed to be the major source of N_2O. The energy for this reaction and a prerequisite for the process is a readily available supply of organic materials. Denitrification proceeds most rapidly in soils with a limited O_2 supply.

It is estimated that agricultural soils, on a global scale, contribute approximately 11 percent to the total atmospheric N_2O level. Non-agricultural soils contribution is estimated to be 43 percent. The total U.S. N_2O emission, from all sources, is estimated at 4.4 million tons per year.

An approximate value of the N fertilizer used in agriculture escaping as N_2O is 1.84 percent, although the range for this value estimate is very large. It is difficult to be very precise because actual N_2O emissions are greatly affected by soil type, soil temperature, type of crop grown, type of fertilizer used, method of fertilizer placement, timing of fertilizer application and other factors. Based on the estimated amount of N used for crop production in the U.S. (8.55 million tons in 1992), and the 1.84 percent loss approximation, then 156,000 tons N_2O would have been emitted from fertilized crops. This value is about 3.5 percent of the 4.4 million tons N_2O emitted from all sources in the country.

Grain producers, along with help from the fertilizer industry, are adopting crop production practices which reduce current levels of N_2O emission. Modern fertilizer application equipment has the ability to place N fertilizer below the soil surface and at a time for optimum plant uptake.

Other developments include the use of nitrification inhibitors. These compounds inhibit the activity of soil bacteria which convert ammonium to nitrite. Effective use of inhibitors extends the time N fertilizer sources are held available in the ammonium form for crop use. In addition, agronomic best management practices such as soil N and tissue testing, balancing phosphorus (P) and potassium (K) and other nutrients with N, optimum plant populations, earlier planting dates, and more careful selection of varieties and hybrids are being adopted to improve N use efficiency and diminish the level of denitrification.

Legumes, animal manures and sewage sludge can all contribute N_2O to the atmosphere in levels equal to, or greater than, commercial fertilizer. On a per acre basis, soil N from legumes contributes more N_2O to the atmosphere than do commercial fertilizers.

Methane

Methane is produced during microbial decomposition of organic materials under strict absence of O_2. Two major sources associated with soils are paddy rice production and natural wetlands. There is little CH_4 production associated with commercial fertilizer use. The replacement of commercial fertilizers with animal manures or legumes

(continued on page 11)

Phosphorus Reduces Grain Moisture and Improves Corn Profitability

By Kevin Dhuyvetter and Alan Schlegel

Phosphorus (P) fertilization offers several benefits in corn production, including higher yields, hastened maturity, lower grain moisture at harvest, and higher profits. This article reports results of recent Kansas research.

PHOSPHORUS fertilization is essential for optimum production and profitability from irrigated corn in western Kansas. Corn plants deficient in P yield less and mature later than plants receiving adequate P. The role of P on crop maturity is often overlooked when analyzing the economic benefits from P.

A long-term nitrogen (N) and P study has indicated an optimal N rate for irrigated corn of about 160 lb N/A, **Figure 1**. Over the past six years (1988-1993), application of P (40 lb P_2O_5/A) has increased grain yields by about 80 bu/A annually.

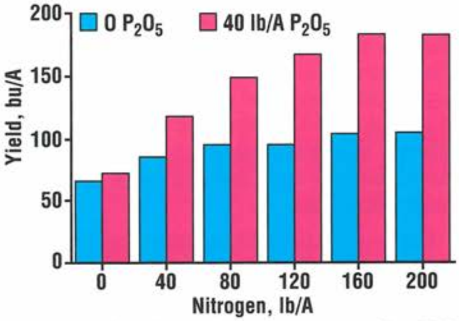

Figure 1. Phosphorus increases corn grain yield.

Phosphorus is essential for seed development and hastens crop maturity. In this study, the corn was not allowed to completely dry in the field prior to harvest. Earlier harvest reduces the potential for crop losses from lodging and adverse weather conditions. **Figure 2** shows that application of P significantly reduced grain moisture. At the optimal N rate, grain moisture was reduced from 27 percent moisture without fertilizer P to 22 percent with P.

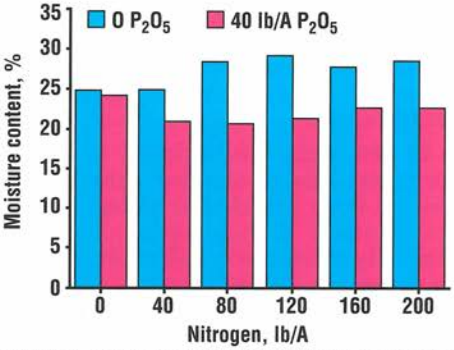

Figure 2. Phosphorus reduces corn grain moisture at harvest.

Artificial drying of corn is expensive. Estimated drying costs for each fertilizer treatment were calculated using a drying charge of 2¢ per bushel for each

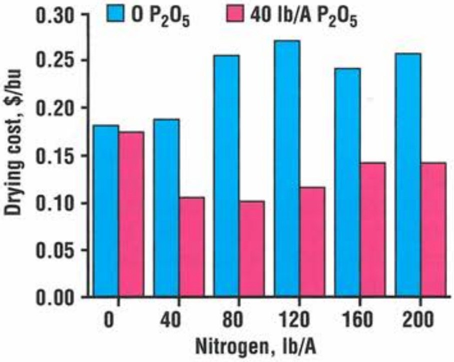

Figure 3. Phosphorus reduces corn grain drying cost.

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percent of moisture above 15.5. The addition of P reduced drying costs an average of 10¢/bu, **Figure 3**. At the optimal N rate, the drying cost was 24¢/bu without fertilizer P compared to 14¢/bu with fertilizer P.

The economic benefit from fertilizer P was calculated as the difference in net revenue at each N rate with and without P. Net revenue was calculated as gross revenue less drying and fertilizer costs. As shown in **Figure 4**, the economic benefit from P varied with corn prices and ranged from about $125/A with a corn price of $1.75/bu to over $200/A with a corn price of $2.75/bu.

The economic benefit from fertilizer P is twofold: it increases yield and decreases drying costs. Phosphorus increased grain yields by 80 bu/A and reduced drying costs by 10¢/bu. Based

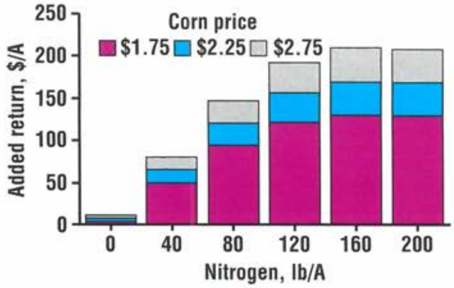

Figure 4. Phosphorus increases economic returns.

on a corn price of $2.25/bu, P fertilization increased net revenue by about $170/A.

In addition to the direct economic benefit of fertilizer P, there are intangible benefits of corn maturing faster, such as: timeliness of field operations, reduced crop lodging, and increased marketing flexibility. It is important that these benefits of P are not overlooked. ■

WHEN adequate P is supplied, corn may mature 7 to 10 days earlier. Notice in this photograph with P applied that the shucks have already turned brown and plant drydown is advancing.

WITHOUT adequate P, plant maturity is significantly delayed. This photograph shows that P-deficient corn still has green leaves, stalks and shucks.

Greenhouse Gases . . . from page 9

as an alternate N source would have a negative effect on CH_4 emission levels, that is, more CH_4 would be emitted into the atmosphere.

Atmospheric CH_4 has been increasing 1 percent per year. The contribution from U.S. agriculture is estimated to be 7.7 million tons, or about 14 percent of total U.S. emissions. While it is estimated that rice paddies contribute 28 percent of the world's CH_4 emissions, the amount from this source in the U.S. is negligible. Ruminant animals are a large contributor of CH_4. Methane production from ruminant animals is still increasing on a global basis, but in the U.S. it is believed to be decreasing as animal production efficiency increases. ■

Maryland

Long-Term Studies Revisited – Fertilization Key to Continued Productivity

By V.A. Bandel and W.K. Griffith

One of the most popular notions concerning nutrient management is that soils in the U.S. have been over-fertilized with phosphorus (P) and potassium (K). Concomitant with that notion is the belief that efficient nutrient management is equivalent to reduced use of commercially produced fertilizers in preference to other sources, e.g. legumes, animal manures and other organics. The intent of this article is not to argue the points of over (or under) fertilization, nor the relative merits of various nutrient sources. Rather, the authors simply present data which show the relationship between sustainability and crop fertilization.

BEGINNING in the early 1970s and continuing through the mid 1980s, a fertilizer trial on corn was conducted at the University of Maryland's Wye Research and Education Center on the Eastern Shore of Maryland. Its design was simple. A complete N-P_2O_5-K_2O fertilizer (160-160-160 lb/A/yr) was compared to a nitrogen (N) only treatment (160-0-0 lb/A/yr). The corn was not irrigated. Ten-year results are shown in **Table 1**. Several points can be made from the data, including the following.

- The N rate was probably close to optimum. However, the P_2O_5 and K_2O rates were higher than those needed to produce best economic yields. Perhaps a 160-80-120 lb/A/yr rate would have been more appropriate.
- Both 1980 and 1983 were drought years. Even under stress conditions, yields were still respectable when P and K were a part of the fertilizer program.
- For the first two years, yield differences were small and might not have been detected under real farm conditions. However, the losses were there. What are the implications of skipping a year or two of P and K fertilization to 'save' money?

In 1984, those plots which had received no P and K for 10 years were fertilized with 68 lb P_2O_5/A and 0, 40, 80, 120 or 160 lb K_2O/A. The reason for holding the P_2O_5 rate constant and varying the K_2O was that K was thought to be the more limiting of the two nutrients. The 68 lb P_2O_5/A rate was according to soil test. Results are shown in **Figure 1**.

Even with N and P, the zero K plot yielded only 33 bu/A compared to 184 bu/A where both P and K were applied for 11 years ... continuing the trend developed in the first 10 years. Yields increased with increasing K_2O rates, yet fell 41 bu/A short of plots receiving

Table 1. Ten-year results of N-P_2O_5-K_2O vs. N fertilization of dryland corn.

N-P_2O_5-K_2O, lb/A/yr	Yield, bu/A for year:									
	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
160-160-160	151	149	159	153	134	159	122	190	182	125
160-0-0	146	139	116	80	104	37	13	52	23	21
Difference	5	10	43	73	30	122	109	138	159	104
Accumulated yield, bu/A										
160-160-160	151	300	459	612	746	905	1,027	1,217	1,399	1,524
160-0-0	146	285	401	481	585	622	635	687	710	731

Maryland

Dr. Bandel is retired Extension Soils Specialist, University of Maryland. Dr. Griffith is retired Eastern Director, PPI, Great Falls, VA.

LONG-TERM studies in Maryland showed the importance of balanced fertilization for productivity of corn over a period of several years.

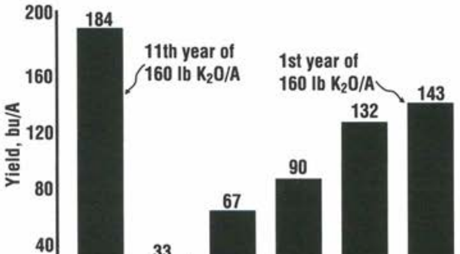

Figure 1. Influence of K_2O fertilization on corn yield (Maryland).

N-P_2O_5-K_2O throughout the course of the study. These data imply that mining soil of its fertility can have extended negative consequences on crop production even after corrective measures have been taken. A "rescue" treatment does not overcome years of neglect.

At the end of the study, soil tests for P and K on the 160-160-160 lb/A/yr plots were high or very high. The zero P_2O_5 and K_2O treatment plots were low in K and medium to low for P. In a qualitative way, these fertility ratings tell the story of adequate fertilization as compared to the practice of mining soils of their fertility . . . and future productivity. This entire study is, in fact, a lesson well learned. That is, proper nutrient management is critical to long-term productivity . . . sustainability.

Postscript: An Environmental and Economic Exercise

Recognizing that the 160-160-160 lb/A/yr N-P_2O_5-K_2O fertilizer rate was most likely not 'site specific' nutrient management, consider the consequences of balanced fertilization as opposed to N only fertilization.

- Environmental - As noted in **Table 1,** 1,524 bu of corn were produced in 10 years when a complete N-P-K fertilizer treatment was used. That is close to a bushel of corn (0.95) for every pound of N used. Assuming that a pound of N per bushel of corn is near optimum for this location, then on the plots where P and K were omitted only 768 lb of N would have been used . . . leaving 832 lb of unused N in the soil over the 10 years.
- Economic - If the following are assigned as 10-year averages . . . corn \$2.50/bu, N \$0.20 lb, P_2O_5 \$0.25/lb, K_2O \$0.12/lb . . . the economics of the two fertilization schemes can be compared, assuming a farm producing 200 acres of corn per year.

Complete fertilizer . . . Gross income less fertilizer cost: \$579,600.

N only fertilizer . . . Gross income less fertilizer cost: \$301,500. ■

Soil Test Summaries: Phosphorus, Potassium and pH

SOIL TESTING provides a road map . . . of where we have been and where we are headed in terms of maintaining the productive capability of our soils. The information in this article is an update of the percentage of soils in the U.S. and Canada that would routinely receive recommendations for supplemental phosphorus (P), potassium (K) and lime.

Soil testing data from commercial and public laboratories across the U.S. and Canada indicate that a significant percentage of soils are medium or lower in available P and/or K or have pH values of 6.0 or less. These data emphasize the importance of paying close attention to soil nutrient availability levels in order to maintain productive capability and farm profitability while providing environmental protection.

Phosphorus and Potassium

High P and K soil test values are important in providing plants with nutrients needed to take advantage of optimum growing conditions and best management practices (BMPs). High soil levels of available P and K provide greater flexibility in adoption of reduced tillage cropping systems, plus more options in fertilizer placement, time of application, nutrient application rates, and frequency of soil sampling.

As important as they are, however, high P and K soil test values alone do not account for all the factors influencing the need for supplemental nutrient applications. Increased use of heavy residue conservation tillage cropping systems has expanded the need for starter applications of P and K, even under soil P and K fertility. High residue cropping systems tend to depress soil temperatures and increase soil moisture. Those factors combined with the possibility of increased soil compaction lower plants' ability to absorb nutrients early in the growing season and emphasize the importance of starter applications of P, K and other nutrients. It is important to remember, too, that mainte-

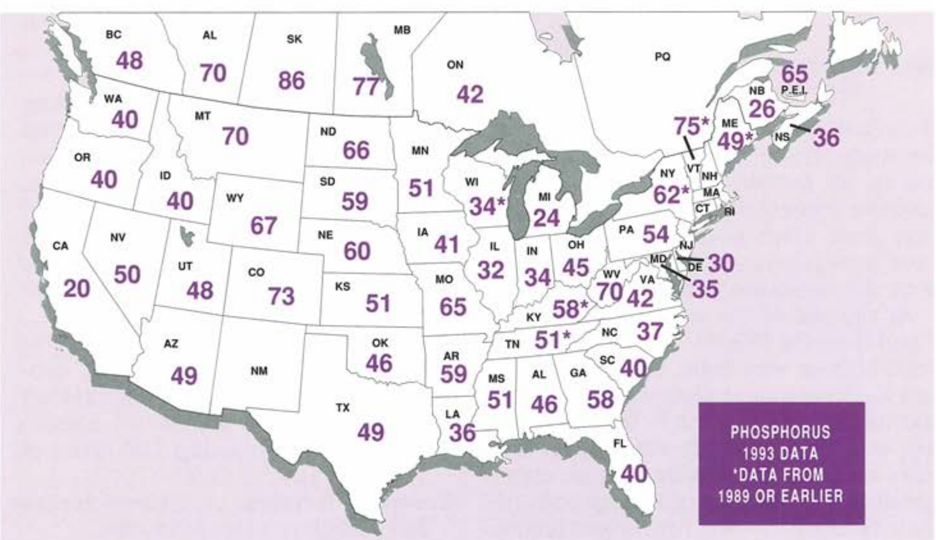

Figure 1. Phosphorus soil test summary–percent testing medium or lower.

nance of high soil test levels by replacement of nutrients removed in the preceding crop is an investment in maintaining the productive capability of the soil.

The categories of medium or lower for P and K soil tests were chosen as an indication of the percentage of soils that would likely receive a recommendation for supplemental P and K for crop production. See **Figures 1 and 2**. These state- and province-wide summaries are useful in providing some idea of crop production needs for P and K. But, the values could be misleading in the sense that differences among areas within states or provinces are ignored and the vital aspects of site specificity in crop management are not revealed.

Examples of variation in soil test summary values within states are demonstrated in **Figures 3, 4 and 5**. Minnesota data in **Figure 3** show the influence of differences in types of farming operations and soil conditions. For example, the percentage of soils testing medium or lower in P is much lower in the eastern two-thirds of Minnesota where animal production is more commonly a part of farming operations. Return of P to the soil through manure applications has probably influenced those P soil test summaries compared to values in other areas of the state.

Figure 3. Percent of soils testing medium or lower in P and K, pH 6.0 or less, in eastern and western Minnesota.

The percentage of soils testing medium or lower in K in eastern Minnesota is much higher than in the western one-third where younger, less weathered soils dominate. Similarly, the intensive cropping systems of the western one-third of the state are associated with a much lower average P availability as indicated by the map. Higher soil pH values in the area affected by samples from the Red River Valley are indicated by the low percentage of soils below pH 6.

Summaries of P and K soil tests from Michigan, Illinois, Indiana and Ohio dem-

Figure 2. Potassium soil test summary–percent testing medium or lower.

onstrate the same type of regional variation. For instance, **Figure 4** shows the percentage of soils testing medium or less in P is much lower in the thumb area of Michigan, a highly intensified crop production area. Similarly, in **Figure 5**, a high percentage of medium or lower K testing soils in southern Illinois reflect the older, more highly weathered soils in that part of the state.

These differences among regions within states emphasize the importance of more and more area specific and site specific assessment of soil fertility needs. County-by-county soil test information would be even more helpful in assessing nutrient availability status of soils and could help focus attention on the importance of variations in soil fertility within individual fields.

In the future, research and education will focus even more dramatically on the importance of modifying nutrient management according to needs within individual fields determined either by grid sampling or sampling by soil type and modification of nutrient applications to fit those more precise needs.

Soil Acidity

Liming to neutralize soil acidity has long been recognized as one of the foundations of crop production. Increasing soil pH by liming provides a means of improving atmospheric nitrogen (N) fixation by legumes, improves the availability of other nutrients such as P, lowers the toxicity of aluminum (Al) and manganese (Mn) under extremely acid conditions, provides additional amounts of essential calcium (Ca) and magnesium (Mg) and enhances the activity of several classes of herbicides.

Soil test summary information for pH is shown in **Figure 6**. A pH of 6.0 was selected as a breaking point for this summary because soil pH above 6.0 is desirable for most cropping systems. Historically, soil pH values have tended to be more acid where rainfall is higher and where large amounts of vegetation have helped to acidify the soil. Those conditions have been associated with areas east of the Mississippi River in the U.S. and in the eastern Canadian provinces. But, continued research has revealed that soil acidity problems are not limited to those areas. Intensive cropping and the addition of N to the soil as commercial fertilizer, legume residues, manure or sewage sludge tend to produce soil acidity. The effect of N on soil acidity occurs through the nitrification process in the conversion of ammonium N to nitrite and eventually to nitrate. This process, mediated by soil bacteria, occurs irrespective of the source of the ammonium N. Inattention to soil acidity can lead to significant problems, severe restriction of crop yields and lowered profitability.

With the continued adoption of conservation tillage systems, it is increasingly important to pay attention to soil acidity and to the distribution of nutrients in the soil profile. Minimal incorporation of N can result in spectacular drops in soil pH near the soil surface. Special sampling to about 2 to 4 inches for pH determination

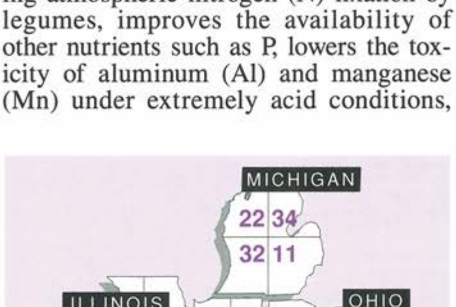

Figure 4. Percent of soils testing medium or lower in P varies by regions in states.

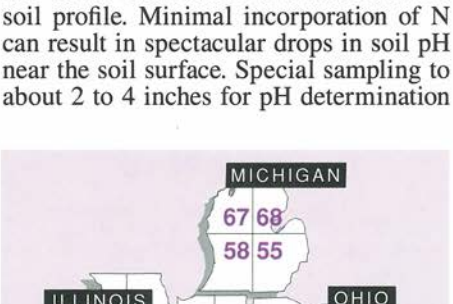

Figure 5. Percent of soils testing medium or lower in K varies by regions in states.

helps monitor these changes and can alert farmers to lime needs that may not be indicated by a deeper sample.

Determination of available P and K on shallow samples can also help evaluate nutrient stratification which can occur from long-term conservation tillage with minimal opportunity for nutrient incorporation. Surface stratification of P and K may alert growers to special needs for deep placement of nutrients to offset these positional accumulations. Nutrient stratification may be of lesser importance if subsoil nutrient levels are adequate and if crops are grown under normally adequate moisture conditions. However, under water-limiting conditions in the dryer areas of the U.S. and Canada, nutrient stratification may hinder nutrient uptake because of limited amounts of moisture in surface soils.

Interpretation of surface soil nutrient availabilities can also mask problems that exist in some areas with low subsoil availability of nutrients which can severely limit crop production. Surface accumulations of K in several important cotton producing areas of the U.S. have masked nutritional problems associated with low subsoil K availability and high K demand late in the growing season. Potassium fertilization, even on these nominally high-testing soils, has resulted in highly profitable yield increases and significant improvement in fiber quality.

Similarly, university research has demonstrated an increased need for supplemental K by corn produced under conservation tillage systems even with medium or higher surface soil K tests. Differences among corn hybrids and their response to supplemental K under these conditions may reflect differences in rooting patterns and root-to-shoot ratios. While more remains to be learned in this area, the indication of greater need for attention to K nutrition under conservation tillage is clear.

Summing it Up

Soil sampling, soil analysis and application of soil test results to individual crop management systems continue to develop into a very site-specific aspect of management. Soil testing is one of the important tools in a nutrient management system of BMPs that can continue to provide profitable crop production with positive environmental effects. ■

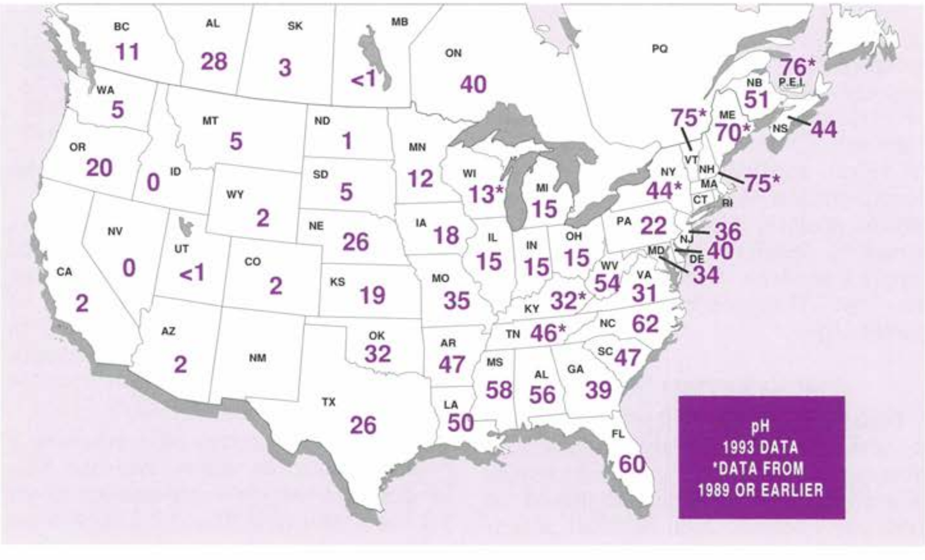

Figure 6. Soil test summary for pH–percent testing 6.0 or less.

Do We Need More Phosphorus Calibration Work?

By T.L. Roberts

About 75 percent of soils in the Canadian prairies test low in available phosphorus (P). Despite this, responsiveness to P fertilization and soil P analysis are being questioned because routine analysis doesn't detect the residual soil P that has built up over years of fertilizer use. This paper reviews recent P calibration studies and discusses the validity of existing P benchmark data.

PRAIRIE SOILS in western Canada have lost 40 to 50 percent of their organic matter since they were first brought under cultivation at the turn of the century. Much of this occurred within the first 20 years of breaking sod. The initial loss of soil fertility prompted early investigators to conduct fertilizer trials and to conclude that P, at that time, was the most likely nutrient to limit plant growth. Plant available P has been, and continues to be, low in most prairie soils. A recent survey suggested 75 percent of the Canadian prairie soils contain less than 20 parts per million (ppm) soil test P.

Although available P remains marginal in most prairie soils, it's commonly accepted that prairie soils are now less responsive to P fertilization due to buildup of residual P from past fertilization practices. Crop responses to residual P fertilizer application have been well documented in western Canada. However, routine analysis does not detect residual forms of fertilizer which are able to supply P to plants. Because of this, use of the "old" P response curves has been questioned.

Past Calibration Studies

Historic P calibration studies conducted in western Canada clearly demonstrated crop response to P fertilization decreased as available soil P increased. Based on these early studies, John Mitchell, a Saskatchewan soil scientist, stated: "Soils showing an availability of less than 20 parts per million phosphorus seem likely to give very substantial increases from phosphate applications." A soil test less than 20 ppm P is still considered marginal, and responsive, by most labs today.

Wheat response in early P calibration experiments varied with location and year. Typical yield increases in response to applied P are shown in **Table 1**.

Table 1. Average wheat yield increases in a Saskatchewan P trial (1939-1943).

P_2O_5, lb/A	Yield increase, bu/A		Yield increase, %	
	Mean	Range	Mean	Range
7	4.6	2.5-5.3	20	14-22
12	6.0	2.4-8.6	25	14-32
17	7.8	3.9-10.7	33	22-40
24	9.3	3.7-12.7	39	21-48

Source: Mitchell (1946)

In these Saskatchewan wheat trials, yield increases over the control ranged from 2.5 to 12.7 bu/A or 14 to 48 percent. Significant response occurred in 215 of 299 sites. Poorest response occurred in years when moisture was in short supply. On average the greatest increases occurred with the highest application rates.

Table 2 summarizes Saskatchewan P response data for wheat. Average Saskatchewan wheat yield response was about 5.2 bu/A prior to 1970 and 2.5 bu/A since

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Table 2. Wheat response (bu/A) to applied P in Saskatchewan trials.

	Prior to 1970			Since 1970		
	Trials	Control	Fertilized	Trials	Control	Fertilized
Stubble	238	20.8	23.9	130	30.4	31.9
Fallow	636	23.8	29.7	122	31.6	35.6

Source: Cowell and Doyle (1993)

1970. Comparable responses to P fertilization have been observed in other calibration studies throughout the prairies.

Prior to 1970, the probability of obtaining a P yield response in Saskatchewan wheat was 92 percent on stubble and 96 percent on fallow. After 1970 these dropped to 70 and 90 percent, respectively. More recently, yield responses in P fertility trials have appeared more difficult to find. For example, only 50 percent of irrigated trials in southern Alberta responded to P fertilization in a 1987 study, and only 15 percent of P fertility trials showed significant response in a Saskatchewan study in 1990. This type of reduced response has been attributed to improved fertility of P deficient soils due to a build up of residual fertilizer P and increased cycling (release) of organic P. Perhaps more important, the lack of response on soils that were expected to respond to P fertilization has caused the predictability of the P soil test to be questioned.

Current Calibration Studies

Few current P fertility experiments are ongoing in western Canada. However, recent studies have suggested that western Canadian prairie soils continue to be responsive to P fertilization and that P soil tests being used in western Canada do a fairly good job of indicating the need for supplemental P.

An extensive study was recently initiated in Alberta to assess the responsiveness of cereal and oilseed crops to P fertilization and to correlate crop response with the different P soil tests.

Wheat response to P fertilization occurred in 78 percent of the sites in 1991, 89 percent of the sites in 1992, and 82 percent of the sites in 1993 (**Table 3**). Yield increases ranged from about 3 to more than 5 bu/A. A similar or greater response occurred with barley and canola.

Phosphorus benchmarks were recently evaluated in Saskatchewan over a range of available soil test P (STP) levels using a direct seeded semi-dwarf wheat. Seven sites (including one irrigated site) with varying amounts of soil test P were selected.

All seven sites responded to P fertilization. **Figure 1** shows that the greatest response occurred at the lower soil test P levels. Yield increases in the fertilized treatments were as high as 93 percent and ranged from 5 to 31 bu/A. These increases

Table 3. Wheat response in Alberta P calibration trials (1991-1992).

	Number of sites		
	1991	1992	1993
Responsive (yield increase >5 bu/A)	25	25	25
Marginally responsive (yield increase 2-5 bu/A)	12	20	15
Total sites	48	51	49

Source: McKenzie, et al (1994)

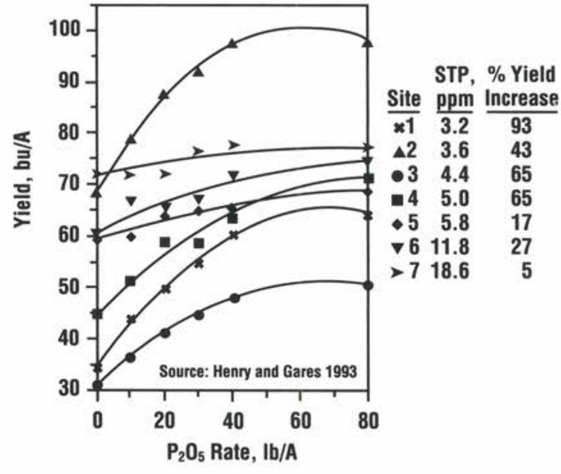

Figure 1. Wheat response to applied P at different soil test P levels in Saskatchewan soils.

Phosphorus Calibration . . . from 19

were considerably higher than those obtained in previous P calibration studies using hard red spring wheat. However, semi-dwarf wheats usually yield about 25 percent more than hard red spring wheat and are perhaps more responsive to P fertilization.

Although many believe western Canadian soils are not as responsive to P fertilization as they once were, and that P soil tests now in use are not as effective as they once were, the recent studies in Alberta and Saskatchewan would suggest otherwise.

If crops grown on P deficient soils still respond to P fertilization, why haven't recent studies been more consistent in their observations and conclusions? Part of the explanation is likely due to residual fertilizer P. In addition, because there are fewer P fertilizer experiments, the chances of obtaining variable results are greater, especially if crop responses are smaller because base-line available P levels have increased.

With fewer P fertilizer trials being conducted, researchers need to take greater care to ensure responsive events are recognized. Natural variability in fields and plot areas can easily mask smaller crop response. **Table 4** shows results from a recent P rate study in Saskatchewan where wheat was grown on summerfallow. Composite soil samples were taken from each site and from each plot within sites to assess P variability.

The large variability in grain yield within treatments was attributed to the variability in soil P levels at each site.

Table 4. Range in means of soil test P (lb/A) and wheat yields (bu/A), and variability at 9 locations in Saskatchewan.

	$NaHCO_3$ Extractable P, lb/A	Wheat yield, bu/A
Mean	10-27	22-46
Coefficient of variation,%	18-50	4-27
Number required[1]	4-62	5-294

Source: Liang et al (1991)

[1] Number of subsamples required to obtain a soil test P accuracy within ±3 lb/A or number of replicates required to detect a 5 percent grain yield response.

Although statistical analysis showed response was not significant at any site, when considered on a per plot basis, the probability of a positive P response ranged from 65 to 78 percent. Possible responses to P fertilization were masked because comparisons of mean yields were based on averaging "responsive" areas with "non-responsive" areas. This demonstrates that spatial variability of a site must be determined prior to carrying out an experiment and the numbers of experimental replications must reflect the yield differences being sought.

Past fertilization practices are also complicating soil P variability, particularly in no-till systems. When tillage is reduced, there is minimal disturbance and mixing of soil. And because P is relatively immobile, differences between row and interrow areas will become greater, making proper soil sampling even more important in predicting P response.

Yield increases in semi-dwarf wheats suggest they are potentially more responsive to P fertilization than traditional hard red spring wheat, and differential P response within varieties is also possible. North Dakota researchers have demonstrated faster growing, earlier maturing varieties of wheat require more P fertilizer for adequate tillering and grain yield than slower growing varieties.

Summary

Soil test P levels remain marginal in many prairie soils, and although residual fertilizer P is difficult to account for using routine soil analysis, crops continue to respond to P fertilization when soil test P is low. Albeit, the responses to P fertilizer may not be as great as when P was first applied to prairie soils, that does not invalidate past P calibration work.

Recent calibration studies in Alberta and Saskatchewan show that crop response to P fertilization is widespread and can be substantial. They also show P soil tests are still effective at predicting response. However, because of the changing nature of soil P and the introduction of newer crop varieties and cropping systems, P soil tests and P calibration curves need constant refining to better reflect today's cropping needs. ■

1994 Intensive Wheat Management Conference Proceedings Available

PROCEEDINGS of the 1994 Intensive Wheat Management Conference held in Denver, CO, March 10-11 are available from PPI. The Conference addressed wheat production practices across the U.S. and Canada in a series of presentations by growers, researchers, Extension personnel, consultants and representatives of agricultural supply industries. The Conference focused on the why and how of intensified crop management; the effects of intensified management on production and grower profitability.

Topics include: intensive management; the relation of plant growth stages to crop management decisions; use and practicality of tramlines; individualized phosphorus and potassium management decisions; yield variability and optimum fertilization; using chloride to suppress diseases and boost yields; pest management for intensive cropping systems; the impacts of intensive cropping systems on water use efficiency, pest management, input needs, economics and environment; economic impacts of better crop management for individuals and communities; and risk management in wheat production.

Copies of the Proceedings are available at a price of $15 from PPI, 2805 Claflin Road, Suite 200, Manhattan, KS 66502; phone (913)776-0273, fax (913)776-8347. ■

Great Plains Soil Fertility Conference Proceedings Available

PROCEEDINGS of the 1994 Great Plains Soil Fertility Conference, March 8-9, Denver, CO, are available through PPI.

The Conference is a biennial event including reports and discussion of current research and educational programs in soil fertility and crop production from the Great Plains states and Prairie provinces of the U.S. and Canada. States and provinces contributing reports at the 1994 Conference included Alberta, Saskatchewan, Manitoba, Montana, North Dakota, South Dakota, Wyoming, Colorado, Nebraska, Kansas, Oklahoma, Texas and New Mexico.

The Proceedings include papers on nutrient management for intensified dryland cropping systems; economic incentives for alternative dryland cropping systems; nutrient stratification and effects on yields; nitrogen source effects on soil characteristics and quality; role of agricultural phosphorus in surface water quality; chloride nutrition in Great Plains crops; fertilizer and water use efficiency; alternative crop rotations to winter wheat-fallow; spring wheat, barley and canola needs for phosphorus; and fertilizer application method effects on soil sampling procedures. A total of 36 presentations and poster paper topics are covered by the Proceedings.

Copies of the Proceedings are available at a price of $15 from PPI, 2805 Claflin Road, Suite 200, Manhattan, KS 66502; phone (913)776-0273, fax (913)776-8347. ■

Thank You for Your Response

In our Fall issue we asked a favor of you . . . to return the response card to continue your subscription to *Better Crops With Plant Food.*

Thank you to all those who took the time to return the card. We at Potash & Phosphate Institute read every card and have to tell you how delighted we are by many of your comments.

We thought you might find some of the comments entertaining and interesting. Many of you requested topics on specific information so we are compiling those suggestions for possible future articles.

Results of the vote for a possible change in the size of *Better Crops With Plant Food* were overwhelming: Keep it the way it is! "If it ain't broke, don't fix it."

"I wouldn't want to be without it. An excellent publication packed with very useful information!"
Ohio Farmer

"Due to the advice of this publication, I have increased the per acre yield of wheat on my farm."
Pakistan Farmer

"Very good articles. Keep up the excellent advice and information on nutrient management."
SCS Staff, Pennsylvania

"Better Crops is one of the more valuable and interesting publications I receive. I save one or more articles from nearly every issue."
Research Agronomist

"Meaningful research reported on a variety of crops is a long-term feature of this magazine. Your efforts are truly appreciated."
University Professor

"Some articles have very good information to help make fertilizer decisions about corn and soybeans."
Farmer

"GREAT INFO–USE FOR SPEECHES. The 'back' is *always* read first."
Oregon Ag Educator

"I like this research-based magazine. Keep up the excellent work."
Ag Education Instructor

"Excellent publication–great reference."
Illinois Field Sales Agronomist

We take great pride in *Better Crops With Plant Food* and we thank you again for taking an enthusiastic interest in our publication.

Environotes from TVA

By John E. Culp

DURING the next 10 years, Tennessee Valley Authority (TVA) and the land grant universities in the Tennessee Valley will establish more than 100 demonstrations with farmers. Purpose of these projects is to develop and demonstrate profitable and sustainable agriculture for the 21st century. The emphasis is being placed on seeking sustainable, efficient, profitable, and environmentally and socially acceptable agricultural technology.

New Farm Demonstrations

Several demonstrations in the seven Tennessee Valley states are up and running. Called AGRI 21 Farming Systems, these farms are showing farmers and professional agricultural workers how to cope with rapidly changing economic and environmental conditions that impact farm sustainability. In effect, these demonstration farms are serving as local applied research stations where innovative techniques are tested, evaluated and introduced to others. New cost-effective sustainable agricultural practices and alternative enterprises are being developed to help farmers remain competitive, productive and environmentally acceptable.

Strategy driving work in the AGRI 21 program is to focus on the quality of life on farms as well as in the rural community impacted by agriculture. Major areas of program emphasis include environmental improvement, increased profitability, leadership development, education and improved family finances.

Because environmental concerns have significant potential impact on agricultural sustainability, various pollution prevention practices are being introduced. These include best management practices (BMPs) for conservation compliance, integrated pest management, nutrient management (including prescription fertilization), use of biotechnology and genetic engineering advances, wetlands management, environmental assessments, agrichemical handling and storage systems, waste management, groundwater quality, and other related technologies.

Financial planning techniques for sustainable agriculture are also being used in the AGRI 21 program. Comprehensive financial and business plans using the latest FINPACK computer analysis program are a key part of the process. Other financial aspects include improving agribusiness and service institutions in concert with sustainable goals, economical uses for farm wastes and introduction of alternative enterprises that will complement sustainability goals.

Another component of the AGRI 21 process is environmental education. TVA, the land grant universities, farmers and other partners are conducting field days to show a wide range of advances essential in sustaining a competitive agricultural system. Workshops, short courses, and educational materials are also included in this phase of the program.

The AGRI 21 program is directed by an Executive Management Committee which is made up of officials from TVA, the Extension Service leaders of the land grant universities, an official of the 1890 land grant institutions, and a state department of agriculture official. USDA is also participating. The key contact person in TVA is Dr. Larry Johnson, phone 205-386-2887. He is located at TVA in Muscle Shoals, AL.

TVA Center Renamed

TVA has renamed its National Fertilizer and Environmental Research Center to recognize the shift that has been made in the Center's work. The new name is TVA Environmental Research Center. The work of the Center has been totally redirected to solving environmental and waste problems.

Future 'Environotes from TVA' will detail the new directions the organization is taking. ■

It's a Complicated Life – Try Something Before You Decide You Don't Believe It

Last year my neighbor had a garden – 12 rows, each 20 feet long. He mixed four shovels of soil and sent two samples to the soil testing laboratory. He grew tomatoes, carrots, cabbage and seven other vegetables.

The recommendations, based on soil tests, included different rates and kinds of fertilizer for each vegetable, plus two rates of lime. When I told him an atomic absorption spectrophotometer was involved in the tests, his awe knew no bounds – the gospel according to "St. Science."

He followed the instructions to the letter, buying many different bags of fertilizer – a real bookkeeping job. How did his garden turn out? Very well.

Has the precision of soil testing reached a new level? While soil testing and plant analysis are valuable diagnostic tools, we may be guilty of over-estimating their accuracy . . . not because of the electronic instrumentation, which is highly sophisticated . . . but because of the errors which are easily made in getting a "representative" sample . . . or because recommendations and interpretations are based on old yield levels with outdated varieties.

The key element in precision farming is the soil test. To interpret it properly requires a vast knowledge of physical as well as chemical soil characteristics and past production history.

Latest analytical equipment, grid patterns, computers, variable rates . . . do we have research data to justify the use of these new tools.? If not, perhaps we need to focus resources, because agriculture needs new, innovative thinking and new, innovative practices. ■

J. Fielding Reed

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