BETTER CROPS

WITH PLANT FOOD

1998 Number 1

IN THIS ISSUE

Research Needs for Site-Specific Nutrient Management to Benefit Agriculture

and much more...

BETTER CROPS
WITH PLANT FOOD

Vol. LXXXII (82) 1998, No. 1

Our Cover: Fertilizer application, photo courtesy of Ag-Chem Equipment.

Editor: Donald L. Armstrong
Assistant Editor: Katherine P. Griffin
Editorial Assistant: Melody Martin Danner
Circulation Manager: Carol Mees
Design: Debbie Nguyen, S.O.H.O.

Potash & Phosphate Institute (PPI)
J.M. Van Brunt, Chairman of the Board
Agrium Inc.
J.H. Sultenfuss, Vice Chairman of the Board
CF Industries, Inc.

HEADQUARTERS: NORCROSS, GEORGIA, U.S.A.
D.W. Dibb, President
B.C. Darst, Executive Vice President
R.T. Roberts, Vice President
C.V. Holcomb, Assistant Treasurer
S.O. Fox, Executive Assistant
W.R. Agerton, Communications Specialist
S.J. Couch, Information Management Specialist
S.K. Rogers, Statistics/Accounting

NORTH AMERICAN PROGRAMS
Brookings, South Dakota
P.E. Fixen, Senior Vice President

REGIONAL DIRECTORS-North America
T.W. Bruulsema, Guelph, Ontario
A.E. Ludwick, Bodega Bay, California
T.S. Murrell, Minneapolis, Minnesota
H.F. Reetz, Jr., Monticello, Illinois
T.L. Roberts, Saskatoon, Saskatchewan
C.S. Snyder, Conway, Arkansas
W.M. Stewart, Lubbock, Texas
N.R. Usherwood, Norcross, Georgia

INTERNATIONAL PROGRAMS
Saskatoon, Saskatchewan, Canada
M.D. Stauffer, Senior Vice President, International Programs (PPI), and President, Potash & Phosphate Institute of Canada (PPIC)

INTERNATIONAL PROGRAM LOCATIONS
Brazil T. Yamada, POTAFOS, Piracicaba
China S.S. Portch, Hong Kong
J. Wang, Hong Kong
Jin Ji-yun, Beijing
Wu Ronggui, Beijing
Liu Rongle, Beijing
India G. Dev, Dundahera, Gurgaon
T.N. Rao, Secunderabad, Andhra Pradesh
N. Latin America J. Espinosa, Quito, Ecuador
Mexico I. Lazcano-Ferrat, Querétaro
Southeast Asia E. Mutert, Singapore
T.H. Fairhurst, Singapore

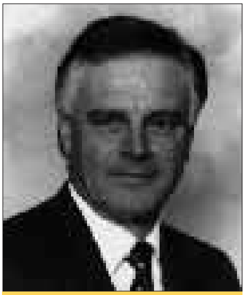
BETTER CROPS WITH PLANT FOOD (ISSN:0006-0089) is published quarterly by the Potash & Phosphate Institute (PPI). Periodicals postage paid at Norcross, GA, and at additional mailing offices (USPS 012-713). Subscription free on request to qualified individuals; others $8.00 per year or $2.00 per issue. POSTMASTER: Send address changes to **Better Crops with Plant Food**, 655 Engineering Drive, Suite 110, Norcross, GA 30092-2837. Phone (770) 447-0335; fax (770) 448-0439.

C O N T E N T S

Members: Agrium Inc. • Cargill, Incorporated • CF Industries, Inc. • Farmland Hydro, Inc.
Great Salt Lake Minerals Corporation • IMC Global Inc. • Mississippi Chemical Corporation
Potash Corporation of Saskatchewan Inc.

John M. Van Brunt Elected Chairman, John H. Sultenfuss Vice Chairman of PPI and FAR Boards of Directors

John M. Van Brunt, President and Chief Executive Officer of Agrium Inc., was elected Chairman of the PPI Board of Directors at a recent meeting. He will also serve as Chairman of the Foundation for Agronomic Research (FAR) Board of Directors. John H. Sultenfuss, Senior Vice President, Marketing and Sales, CF Industries, Inc., was elected Vice Chairman of the PPI and FAR Boards.


John M. Van Brunt

"We value the experience and achievements of these industry leaders as they accept these responsibilities with PPI and FAR in the coming year," said Dr. David W. Dibb, President of PPI.

Mr. Van Brunt attended Queen's University in Kingston, Ontario, and received his BSC in Chemical Engineering in 1965. He began work with Cominco Ltd. and served in a series of positions in production, operations, and industrial relations. In 1985, he was named Vice President, Operations, and in 1991 became Senior Vice President and Chief Operating Officer, Cominco Fertilizers, Calgary, Alberta.


John H. Sultenfuss

Mr. Van Brunt was appointed President and Chief Executive Officer in January 1993, and has guided Agrium Inc. through the public offering in April 1993 and a number of strategic growth initiatives. He is a director of the company.

Mr. Van Brunt has served as a director of several industry organizations, including Canpotex Ltd., and is currently Vice Chairman of the Canadian Fertilizer Institute and Vice Chairman, Canada, for the International Fertilizer Industry Association (IFA).

Mr. Sultenfuss has held a number of management and executive positions during his twenty-five year career with CF Industries, an interregional cooperative headquartered in Long Grove, Illinois. In 1972, he joined the company at its phosphate complex in Plant City, Florida. Throughout the 1970s and 1980s, his positions included General Manager of the phosphate complex in Bartow, Florida; Vice President, Nitrogen Operations; and Vice President, Supply & Distribution. He was named Vice President, Marketing and Sales, in 1988, and became Senior Vice President in 1995. Mr. Sultenfuss earned a bachelor's degree in Chemical Engineering from the University of Florida in 1969.

He serves as Chairman of Canadian Fertilizers Limited, a nitrogen fertilizer manufacturing entity jointly owned by CF, Coopérative Fédérée de Québec, Growmark, and Western Canadian Fertilizers Limited.

In other action of the PPI Board, William J. Doyle, Executive Vice President of PCS Inc. and President of PCS Sales was elected Chairman of the Finance Committee. BC

IOWA

No-Till Corn Grain Yield Responses to Band Applications of Potassium

By A.P. Mallarino and T.S. Murrell

Recent Iowa studies indicate corn yield benefits with deep banding of potassium (K) in no-till corn-soybean rotation systems. The advantage, related to increased K availability, was detected even on soils testing optimum to very high in K.

Managing nutrients in no-till systems can be a challenging task. No-till usually creates higher levels of K at the surface of the soil and lower levels of K just a few inches below the surface. This stratification can result from minimal mixing of broadcast and shallow band applications, as well as from cycling of nutrients from deep to shallow soil layers.

Under normal conditions, corn grown under no-till generally draws a higher percentage of its nutrients from the soil nearer the surface, because of the higher nutrient and moisture levels present. However, this uptake can be affected by weather conditions. When surface soil layers become drier, root development in deeper portions of the soil profile increases. When this happens, the portion of the root system actively taking up nutrients can be below the zone of highest nutrient concentration. Conversely, under more moist conditions, the surface residue cover will keep the soil surface wetter and cooler. These conditions can inhibit root growth and nutrient uptake early in the season. In no-till systems, proper placement of fertilizer K may be critical for optimizing yields.

To investigate the effects of K placement in no-till corn-soybean rotation systems, long-term trials were established at Iowa research centers. The two crops were grown each year, and treatments were applied every year for both crops. Only results for corn and for the first 3 years of the study (1994 to 1996) are presented in this article. Each trial included two K fertilizer application rates (35 and 70 lb K_2O/A), three fertilizer application methods...planter banding (S), deep banding (D), and broadcast (B)...and two control treatments...no fertilizer (BO) and one

TABLE 1. Long-term research sites showing positive corn grain yield responses to banded applications of K.

Soil test K category	Soil test K range, ppm	Number of site-years in category	Number of site-years showing corn grain yield increases in the following comparison: Deep banding compared to broadcast	Planter banding compared to broadcast	Deep banding compared to planter banding
Optimum	91-130	4	4	2	3
High	131-170	5	5	3	5
Very High	171+	6	4	2	4

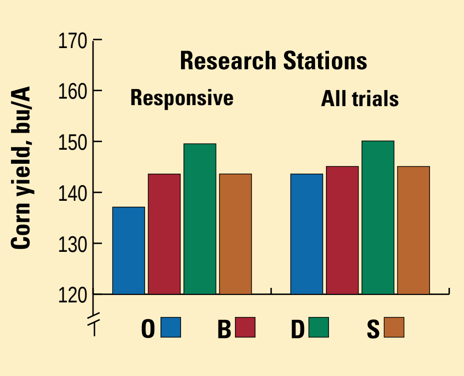


Figure 1. The effects of K placement on corn grain yields at research stations when combined over responsive sites only as well as over all sites. O = combination of both control treatments, B = broadcast, D = deep band, and S = planter band.

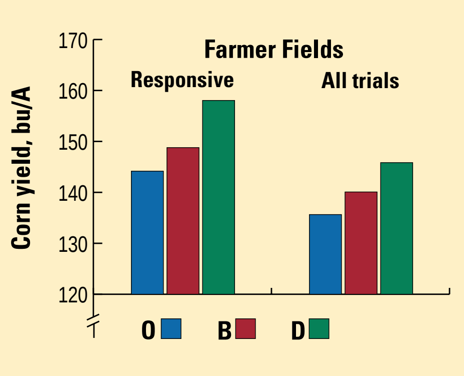


Figure 2. The effects of K placement on corn grain yields in farmer fields when combined over responsive sites only as well as over all sites. O = combination of both control treatments, B = broadcast, and D = deep band.

pass with a deep band applicator without fertilizer (DO). The planter bands were placed 2 inches to the side and 2 inches below the seed. Deep bands, 30 inches apart, were placed 6 to 8 inches below the soil surface. Corn was planted directly above the deep band. In the first two years, broadcast and deep band treatments were applied in the spring, 3 to 5 weeks before planting. In the last year, both treatments were applied in the fall.

In addition to the research centers, 11 short-term (1-year) trials were conducted on farmer fields. Treatments were similar to those at the research centers, except that the planter band treatment was excluded. In addition, the two K rates were 35 and 140 lb K_2O/A. Two trials received fertilizer applications in the spring, prior to planting. Potash was applied to the remaining trials in the fall.

All research center sites were first analyzed separately and then combined in an overall analysis. Separate analyses for each site showed that K fertilization increased grain yields significantly at 4 of the 5 research sites. Yield response to fertilizer **placement** was statistically significant at only one site, where deep banding produced higher yields than other placement methods. However, when the data from all sites were analyzed together, K fertilization was found to produce significantly higher yields than where no K fertilizer was applied. The reason that only the combined analysis detected these significant increases may be that yield increases to K fertilization and deep band placement were small, but fairly consistent.

Table 1 shows that deep band applications increased yields above those where K was broadcast at 13 of the 15 site-years. In addition, deep banding outperformed planter banding at 12 of the 15 site-years. Planter band applications increased yields above broadcast applications at seven sites.

The data in **Figure 1** show that when only the responsive sites were considered, broadcast and planter band K applications both increased yields by about 6 bu/A. However, deep banding increased yields by approximately 11 bu/A. When responsive and non-responsive sites were considered, broadcast and planter band applications increased yields by about 2 bu/A, while deep banding increased yields by approximately 6 bu/A. Yield increases were observed on soils testing in the optimum and high categories.

TABLE 2. Short-term research sites showing positive corn grain yield responses to banded applications of K.

Soil test K category	Soil test K range, ppm	Number of short-term sites in category	Number of sites with an average corn grain yield increase from deep banding compared to broadcast
Optimum	91-130	4	3
High	131-170	3	3
Very High	171+	4	3

Results from the studies conducted on farmer fields were similar to those from the research sites. As before, significant yield increases from K fertilization and deep banding were detected only when a combined analysis was performed. **Table 2** shows that deep banding was fairly consistent in increasing yields above those from broadcast applications. When only the responsive sites were considered, broadcast applications increased yields by about 5 bu/A, whereas deep banding increased yields by approximately 13 bu/A (**Figure 2**). Across all sites, broadcast applications and deep banding increased yields by 4 and 9 bu/A, respectively.

It is likely that the responses to deep banding were related to weather conditions, particularly soil moisture. The increase in yield observed for deep banding above that of broadcast applications increased with higher May rainfall, but decreased with higher June rainfall.

Other correlation analyses suggest that May rainfall may have sometimes been excessive, while June rainfall may have sometimes been deficient for optimum corn growth. It is likely that plant uptake from shallow soil layers was reduced during the drier conditions in June. Deep banding provided K at lower levels, and could have alleviated the uptake deficiency. The results from these studies show that deep banding may provide distinct yield advantages by making K more available, even on soils that test optimum to very high in K. BC

Dr. Mallarino is Assistant Professor, Department of Agronomy, Iowa State University, Ames. Dr. Murrell is Northcentral Director, PPI, Andover, Minnesota.

Building a Smarter Fencepost

The need for field recordkeeping and assuring that production practices are matched to the proper crop in the correct field have never been more important. Precision management and applications tailored to specific genetic varieties increase the reasons for accurate communication.

A new signpost marking system uses identification decals applied to a plastic sheath that fits over a steel post. The user can mark individualized stickers or obtain custom pre-printed stickers for identification of crops and fields. This deters application mistakes and aids in tracking crops. The system is also compatible with bar coding and electronic identification systems which can retain and transfer information. The product is called POSTMARK™ Field Identification Systems. BC

Source: Agricultural Information Technologies, Inc., Iroquois, South Dakota.

Research Notes

Natural Streamside Buffers Help Safeguard Water Quality

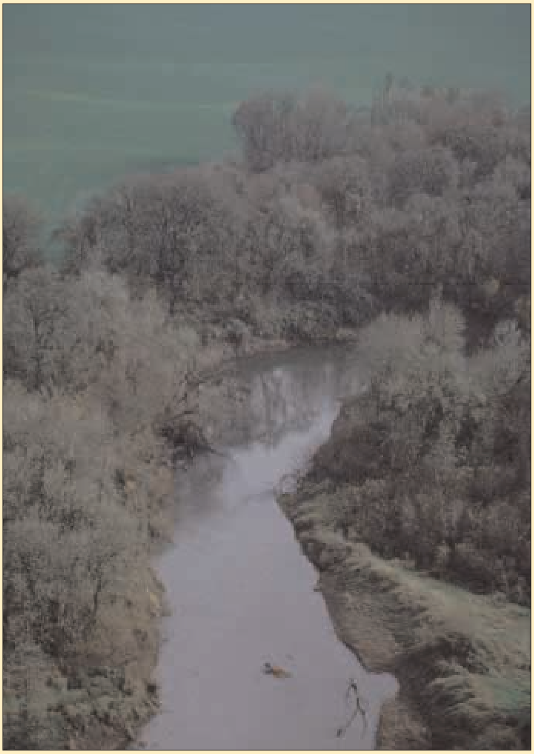
Planting land closest to streams with native species of trees, shrubs and grasses – rather than crops – can help preserve water quality, Agricultural Research Service (ARS) scientists say. Studies have shown that the plantings create highly effective natural riparian buffers that capture field runoff of sediment, fertilizers and other potential pollutants and keep it out of the stream.

In Georgia, ARS scientists recently completed a study tracking herbicide runoff from a corn field into a 150-foot-wide grass and forest buffer. At the edge of the field, the scientists detected chemical concentrations of 34 parts per billion (ppb). But in the buffer, they detected concentrations of only 1 ppb or less.

Elsewhere, ARS scientists are testing various warm- and cool-season grasses farmers can grow to reduce nitrate, another danger to streamwater. The goal: identify grasses that foster a soil environment necessary for converting dissolved nitrate into gaseous forms that enter the atmosphere instead of streamwater. Research shows up to 50 percent of a riparian zone's dissolved nitrate can be removed this way.

ARS scientists also provide scientific expertise to state and federal action agencies, like USDA's Natural Resources Conservation Service. These agencies help farmers, landowners and others restore or manage riparian buffers to protect water quality.

A more detailed report on the latest ARS buffer research appears in the February issue of *Agricultural Research* magazine. BC



Various types of plantings are being studied as buffer areas along streams. Grass and trees between fields and streams serve to trap run-off and protect water quality.
Photo source: ARS/USDA.

MINNESOTA

Phosphorus in Surface Waters: The Minnesota River Case Study

By David J. Mulla

A closer look at phosphorus (P) concerns in the Minnesota River basin indicates recent gains in management of agricultural land, reducing losses from both point and non-point sources. Municipal sources of P are also significant. Wetter than average climate in recent years is also a factor.

Phosphorus is often a limiting factor for growth of algae in surface waters. Enrichment of surface waters with P can stimulate excessive growth of algae. When large populations of algae die, they sink through the water and decay, thereby consuming large amounts of dissolved oxygen. When flow in the river is at low levels, there is not enough oxygen in the flowing water to replenish that lost by the biological oxygen demand. The result is eutrophication, which is often associated with the death of fish and other aquatic organisms.

The rivers in many states of the Corn Belt have summertime occurrences of eutrophication brought on by P enrichment. As a result, state and federal regulatory agencies are developing plans, programs, and policies to control P deposition into affected surface waters. One of the policy solutions being discussed involves placing a concentration limit of 1 part per million (ppm) on P levels in municipal wastewater effluent discharging to surface waters. Other policy solutions involve education to accelerate the adoption of P best management practices on agricultural lands, including soil testing, fertilizer placement and banding, and the use of conservation tillage to control erosion.

Much of the confusion about P and its role in surface water eutrophication arises from two issues. The first is that the amounts of P needed to stimulate algal growth are quite small compared to typical concentrations in the soil and those from point or non-point sources of P. In lakes, it may only take a concentration of 0.025 ppm to produce eutrophication, whereas levels for soil test P typically run about 1,000 times higher. The second is that it is often not clear whether the predominant source of P in surface waters is from point or non-point sources. Point sources include the effluent from wastewater treatment plants and industries. Non-point sources include sediment and/or runoff waters from farms, feedlots, and septic tanks.

The Minnesota River basin illustrates many of the issues that are typical in a discussion of P management for improved surface water quality. The Minnesota River is currently one of the 20 most endangered rivers in America due to pollution by sediment, P, and pathogens. This basin is located in the southern part of Minnesota (**Figure 1**), covers an area of about 10 million acres, consists of 12 major watersheds, and has land use patterns dominated by corn-soybean row-cropping. The Twin Cities metropolitan area, with its nearly 2 million residents,

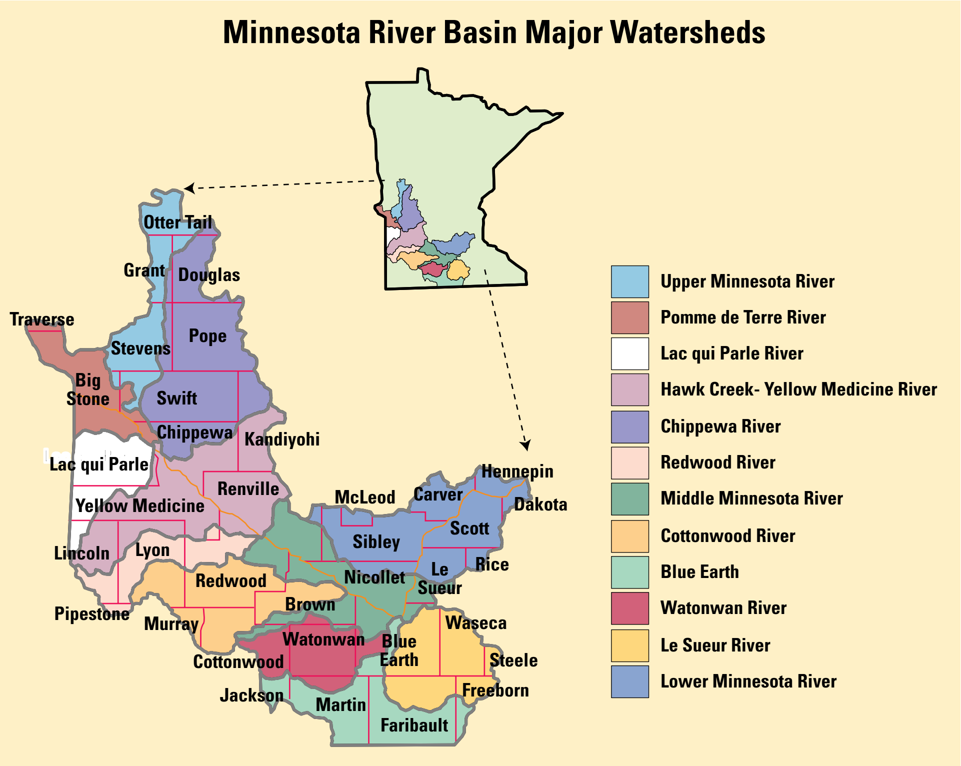

Minnesota River Basin Major Watersheds

Figure 1. This map shows the 12 major watersheds and 37 counties located in the Minnesota River basin.

and the Mississippi River are at the mouth of the Minnesota River basin. Eutrophication and low levels of dissolved oxygen are common during summer low flows near the mouth of the Minnesota River. Downstream of the Twin Cities, the Mississippi River widens to form Lake Pepin, a prime recreational area for residents of Minnesota and Wisconsin and which also experiences severe eutrophication during summer low flows. A large proportion of the P which causes eutrophication in Lake Pepin originates in the Minnesota River basin.

Monitoring data collected during the period from 1968-1994 by the Minnesota Pollution Control Agency (MPCA), the U.S. Geological Survey (USGS), and the Metropolitan Council Environmental Services (MCES) show that near the mouth of the Minnesota River, dissolved oxygen concentrations violate federal water quality standards about 4 percent of the time, mostly during summer low flows. Eutrophication problems are even more serious farther downstream in Lake Pepin. The low levels of oxygen are indirectly caused by elevated levels of P, which are higher near the mouth of the Minnesota River than the basin-wide mean river concentration of 0.25 ppm about 75 percent of the time.

An analysis of P monitoring data by our group at the University of Minnesota shows that from 1968-1994, three of the 12 major watersheds generated two-thirds of all the P that flows to the mouth of the river. The major source of P is the Lower Minnesota watershed, one of the 12 major watersheds in the basin, which accounted

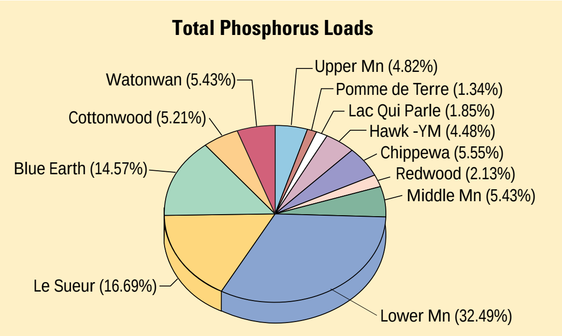


Figure 2. Comparison of P loadings generated within each of the 12 major watersheds in the Minnesota River basin.

for 33 percent of all the P discharged into the Minnesota River (**Figure 2**). Two wastewater treatment plants (at Blue Lake and Seneca) discharge treated sewage from hundreds of thousands of households directly into the Lower Minnesota watershed. During average river flow years, these treatment plants generated about one-third of all the P discharged into the Minnesota River from the Lower Minnesota watershed. In addition, the Lower Minnesota watershed contains a region of very steep cultivated slopes with high rates of erosion due to a relatively high mean annual precipitation. These two factors, namely; discharge of large quantities of P in wastewater effluent and erosion or runoff generated from steep agricultural fields account for the large amounts of P discharged into the Minnesota River from the Lower Minnesota watershed.

Two other watersheds account for nearly 32 percent of the P discharged into the Minnesota River; the Blue Earth and Le Sueur watersheds (**Figure 2**). They are dominated by agricultural land use and do not have significant P discharges from point sources. Much of the land in each of these two watersheds is prone to runoff and erosion due to steep slopes and heavy precipitation.

Other significant sources of P to the Minnesota River include discharges from septic tank systems and runoff from manure in fields and feedlots. It is estimated that there are about 60,000 septic systems in the Minnesota River basin and that about 400 million tons of manure are annually applied to agricultural lands.

When all sources of P are taken into account, it is estimated that for the period from 1968-1994, approximately 60 percent of the P entering the Minnesota River originated from non-point sources, including agricultural lands receiving P fertilizer and manure. The remaining 40 percent of the P was generated from point sources, primarily municipal wastewater treatment plants. These figures assume an average flow in the river.

Since eutrophication near the mouth of the Minnesota River generally does not occur during medium to high flow conditions, it makes sense to evaluate the relative contributions to P in the river from point versus non-point sources during low flow conditions. During low flow conditions, greater than 90 percent of the P near the mouth of the river originated from point sources. Thus, during low flow conditions that lead to eutrophication, it is very important to control P emissions from point sources, especially wastewater treatment plants. This is exactly what has happened recently at the two largest wastewater treatment plants on the river. The Blue Lake and Seneca wastewater treatment facilities near the mouth of the river have adopted a biological treatment method for removing P from the wastewater effluent stream. This new approach has been a great success, and P concentrations in wastewater effluent have been reduced from about 3 ppm to slightly less than 1 ppm.

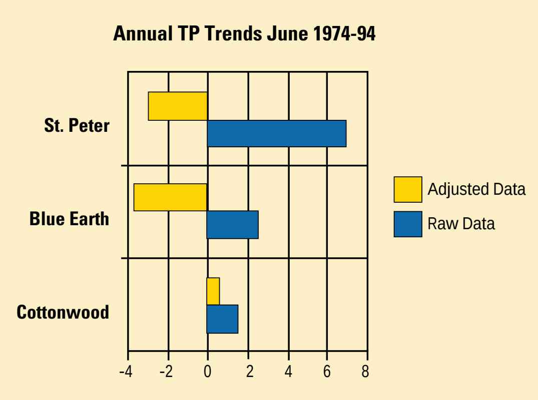


Figure 3. Trends in total phosphorus (TP) loadings (tons/year) for selected locations in the Minnesota River basin for the month of June from 1974-1994. The gold bars represent annual trends after adjusting for climatic changes.The blue bars represent annual trends when climatic effects are included in the analysis.

Occasionally, there are significant discharges from wastewater treatment plants during storm and flood events. For instance, high flows in the Lower Minnesota watershed during the flood of 1997 caused a pipe to break which delivers raw sewage from the city of St. Peter to its wastewater treatment plant. About one million gallons of raw sewage was directly discharged into the Minnesota River each day for several weeks until the pipe was repaired. As a result of this disaster, the city has decided to relocate its wastewater treatment plant to a less vulnerable area.

It is also important to control P losses from agricultural lands during medium and high flows because sediment bound P transported downstream during medium and high flows can be deposited in sensitive areas, to be released during low flow conditions. Farmers in the Minnesota River basin have employed a wide range of activities for improved P management. These include the adoption of conservation tillage, which reduces erosion and losses of adsorbed P, soil testing, and P credits for manured lands. As a result of these improved management practices, there has been a significant reduction in the P loads generated from agricultural lands in the Minnesota River basin during the month of June over the last 20 years. After compensating for the effects of wetter precipitation patterns, there has been an annual reduction of almost 4 percent in P loads from agricultural lands in the Blue Earth watershed (**Figure 3**). Over a period of 20 years, this translates to a reduction of about 53 percent in P loads from agricultural lands during June.

The analysis of P issues for the Minnesota River basin is typical of those in many regions of the north central Corn Belt. There are significant municipal sources of P, and these sources dominate water quality impacts during low flow periods in the river. There are also significant agricultural sources of P, which dominate water quality impacts during medium and high flow periods. In the Minnesota River basin, significant progress has occurred in managing P emissions to surface water from both point and non-point sources. Some of the gains in P management on agricultural lands have been offset, however, by an increasingly wetter climate in recent years. This has caused greater than average rates of erosion, runoff, and delivery of P to surface waters from agricultural lands. The full extent of benefits from improved farm management of P will only be realized if and when climate returns to a more benign pattern.

Dr. Mulla is Professor and W.E. Larson Chair for Soil and Water Resources, Dept. Soil, Water and Climate, University of Minnesota, St. Paul, MN 55108.

TENNESSEE

Site-Specific Nutrient Management: Variability in Cotton Yield Response and Soil Chemical Characteristics

By S.A. Smith, M.E. Essington, D.D. Howard, D.D. Tyler and J. Wilkerson

In 1996, a multi-disciplinary precision farming study was initiated at The University of Tennessee Agricultural Experiment Station in Milan, Tennessee. One of the goals of the study was to examine the variability in soil chemical properties in a cotton field and to relate nutrient variability to yield variability. The objective of this article is to illustrate, using selected soil chemical characteristics, the influence of soil sampling grid size on the estimated soil fertility levels of the field. Soil fertility data are also correlated with cotton yield to evaluate the feasibility of site-specific soil sampling.

The physical and chemical properties of soils change over short distances. As a result, the soil's ability to produce crops can vary with location in a field. Conventional fertilizer management strategy relies on the premise that soil fertility and the production potential of a soil can be assessed over large areas. This strategy can result in fertilizer under-application to some areas of a field and fertilizer over-application to other areas. The consequences of both have economical as well as environmental repercussions.

Precision farming, or site-specific farming, can be defined as a management system with the flexibility to adjust agrochemical inputs to satisfy needs of specific areas in a field to achieve the soil's yield potential, rather than using uniform applications based on average field characteristics. With precision farming, producers have the ability to place crop nutrients where they are needed.

Milan Study

A 5-acre, no-till cotton field located at the Milan Experiment Station was selected for study based on the variability in cotton yields observed in previous production years.

The field had not been used for any small plot research and the variability present was attributed to natural variation and that introduced by normal field-scale production practices, consistent with a long, continuous cotton production history.

The field contains six different soil series (Routon, Henry, Grenada, Loring, Memphis, and Calloway) as well as a fragipan that varies in depth from 24 to more than 60 inches. A rectangular design was applied, resulting in 182 sampling grids, each measuring 20 ft. x 60 ft. At the grid intersections, soil samples were collected within a 10-foot radius to a depth of 6 inches, approximately one month after fertilization. Samples were composited and analyzed as follows: pH in water and salt solution; lime requirement using the Adams-Evans buffer test; Mehlich-1 phosphorus (P) and potassium (K); Mehlich-3 P, K, calcium

(Ca), copper (Cu), iron (Fe), magnesium (Mg), manganese (Mn), and zinc (Zn); cation exchange capacity (CEC); exchangeable bases; salt-extractable aluminum; and organic carbon content. Cotton yield data for the 1996 cropping season were obtained at harvest using on-the-go yield monitoring and were referenced to position using global positioning systems (GPS).

Soil Chemical Properties

Standard soil fertility assessment of the Milan cotton field, performed according to the UTAES guidelines (18 to 20 random subsamples representing no greater than 10 acres of similar soil), resulted in 'high' soil test ratings for both P and K. A 'high' rating suggests that the crop will yield at or near 100 percent of its potential without fertilization. That is, little or no response to fertilizer application would be expected. Site-specific sampling for soil K provided results that were similar to those obtained by the field-composited sampling. Of the 182 grids, 124 rated a 'high' soil test K and 56 rated a 'very high' soil test K. Only two rated a 'medium'. Increasing grid size reduced the sensitivity of soil test K estimates, but predicted crop response to fertilizer K was not affected.

Soil test P ratings for the cotton field were spatially variable and ranged from 'low' to 'very high'. A nine-fold increase in the grid size from 20 ft. x 60 ft. to 60 ft. x 180 ft. (0.25 acre) did not impact the estimate of soil P availability across the field. However, an additional increase in grid size from 60 ft. x 180 ft. to 120 ft. x 360 ft. (1-acre) had a pronounced impact on the perceived spatial variability of soil P. The 1 acre grid size also illustrates how grid point sampling can heavily weight extreme values, resulting in an incorrect estimate of the fertility level of the field. Indeed, site-specific P fertilization based on the 1-acre grid would result in over-fertilization.

The impact of expanding grid size on soil P availability estimates was also evident for other soil chemical properties. Mehlich-3 extractable Mg for the cotton field ranged from 76 to 542 lb/A and tended to be inversely correlated to soil P. Like soil P, the estimate of extractable Mg across the field was not greatly influenced when grid size was increased from 20 ft. x 60 ft. to 0.25 acre. However, increasing the grid size to 1 acre did significantly alter the extractable Mg estimate.

While site-specific soil testing can provide a detailed characterization of soil fertility across a field, the true test of the utility of precision farming, with respect to nutrient management, is the ability to correlate soil fertility to crop response (resulting in the more efficient application of nutrients).

The seed cotton yield for the production field ranged from 1,920 lb/A to 3,800 lb/A. Yield variability, however, was not related to soil fertility. A comparison of seed cotton yields, aver-

TABLE 1. Mean, standard deviation, minimum and maximum seed cotton yield as a function of soil test P.

Soil test P[1]	n[2]	Mean	Standard deviation	Minimum	Maximum
		Yield, lb/A			
L	31	2,818	343	2,078	3,417
M	37	2,940	384	2,336	3,821
H	98	2,904	407	2,203	3,812
VH	16	2,849	425	1,924	3,543

[1] Extractant for P is Mehlich-1 (HCl and H_2SO_4); L is less than 18 lb/A, M is 19 to 30 lb/A, H is 31 to 120 lb/A, and VH is greater than 120 lb/A extractable P.

[2] Number of 60 ft. x 20 ft. monitoring units within the 5-acre cotton field that were identified with the soil test level.

aged for each soil test P level, further illustrates that yields were not impacted by soil fertility status (**Table 1**). The mean seed cotton yield of 'low' P rated plots was only 31 lb/A less than the mean yield of 'very high' P rated plots. Further, mean yields of both the 'medium' and 'high' P rated plots were higher than the mean yield of the 'very high' P rated plots.

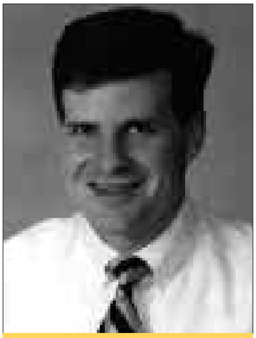
The lack of correlation between yields and measured soil fertility levels does not necessarily indicate that yields are not impacted by soil fertility. It is possible that low fertility areas are low currently because of past draw-down associated with good crop yields and nutrient removal. This could cause yields to become equalized among different fertility regions in the field over time. Also, fertility levels may not change independently of other soil parameters. To properly assess the potential for response to fertilizers in the field, treatments would need to be included in the study to measure possible yield increases, with collection of data over several years.

Summary

Precision farming research conducted at Milan identified the soil chemical variability that can exist in a production field and should help producers increase fertilizer use efficiency. However, important concerns still remain. Sampling grid size must be adequate to estimate the fertility level of a field while maintaining economic feasibility. Commercial operations generally rely on a 2.5-acre grid size for soil sampling. In the Milan field, a 1-acre grid size was too large to provide an accurate estimate of soil fertility. A site-specific assessment of soil fertility must provide information for cost effective nutrient management, relative to management based on field-average fertility levels. In 1996, cotton yield was not correlated with soil P, (or any of the other measured chemical properties) indicating that a whole-field sampling strategy was adequate for P fertilizer management. The results from the first year of study on this field indicate the importance of understanding the scale of variability before extensive sampling commitments are made. Several years of study will be necessary to determine the effectiveness and appropriate methodology for precision farming in Tennessee production agriculture. Fertilizer treatments should be included in precision agriculture research to more accurately evaluate the need for, and potential response to, nutrient additions in areas of fields with soil tests ranging from low to high. In large fields, as opposed to small plots, fertility levels may be positively or negatively correlated with other factors, such as: clay content, organic matter, soil drainage, compaction, acidity, water holding capacity, populations of plant parasites and diseases. Unless the variability and influence of these other factors are considered, as well as their relationships with soil fertility, there is a risk of making preliminary conclusions that could be in error. BC

Ms. Smith is Graduate Research Assistant and Dr. Essington is Associate Professor, Dept. of Plant and Soil Sciences, The University of Tennessee, Knoxville, TN. Drs. Howard and Tyler are Professors, West Tennessee Experiment Station, Jackson, TN. Dr. Wilkerson is Associate Professor, Dept. of Biosystems Engineering, The University of Tennessee, Knoxville.

PPI Announces Steve Couch as Information Management Specialist


Steve Couch

Steve Couch has joined the staff of PPI in the new responsibility of Information Management Specialist. He is a 1995 graduate of the Georgia Institute of Technology and holds the degree of Bachelor of Industrial and Systems Engineering. He is located at PPI headquarters in Norcross, Georgia.

"With his educational background and focus on new technology in information transfer, Steve brings new strength to our efforts in serving the needs of our member companies and other audiences," said Dr. David W. Dibb, President of PPI. "His familiarity with existing programs of the Institute is also an asset." Mr. Couch has a strong background in database design and maintenance, including coursework in computer programming while at Georgia Tech. His degree was focused on systems analysis.

In his new role, primary responsibilities will include development of a searchable database containing information on phosphorus (P), potassium (K), and other nutrients. He will be the key liaison with PPI's web server provider and will work closely with PPI staff and others in preparation of presentations and projects involving information technology. BC

Dr. B.C. Darst Receives Soil Science Award


B.C. Darst

Dr. B.C. Darst received the Soil Science Professional Service Award at the 1997 annual meeting of the Soil Science Society of America (SSSA) in Anaheim, California. Dr. Darst is Executive Vice President of PPI and President of the Foundation for Agronomic Research (FAR). He earned his B.S. degree from Oklahoma State University and his M.S. and Ph.D. degrees from Auburn University.

Dr. Darst is currently Chair of the American Society of Agronomy (ASA) Agronomic Industry Committee (A835), has served on several committees for ASA and SSSA, and is a Fellow of both Societies. He has also served in leadership roles in several other organizations, including the Council for Agricultural Science and Technology (CAST) and the American Forage and Grassland Council (AFGC). Dr. Darst received the AFGC's Merit Certificate and Medallion Award. He has served on the boards of more than a dozen other industry and educational organizations. BC

Research Needs for Site-Specific Nutrient Management to Benefit Agriculture

By P.E. Fixen

The nature of many of the questions related to site-specific nutrient management suggests that at least some studies must be conducted on a field scale and be systems oriented, nutrient management being just one component. The multitude of potentially interacting factors influencing response that vary across a field limits the reliability of controlled studies where all factors except one or two are fixed. Such traditional studies are still necessary, but their results need to be tested on a field scale in an integrated cropping system. A network of linked experiments, with potentially diverse designs, conducted at a regional level is one approach being utilized. The geographic boundaries of such studies are defined based primarily on agronomic interpolation potential rather than political lines on a map.

> The potential benefits cited most frequently for site-specific nutrient management include increased profitability through higher yields and/or crop quality or through lower costs of nutrient management, improved quality of the soil, water, and air resources upon which agriculture and society depend; and increased accountability for agriculture. In some cases these benefits are already occurring.

Built on partnerships. The cost of technologies required to conduct the research, the rate of change of the technologies, the immediate need for results, and the need for scientific guidance in the direction of technology change demand that research be done via partnerships of significant stakeholders. The alternative is useless technology or useless science. Potential partners in design, conduct, outcome implementation, and funding include universities, government agencies, technology suppliers, input and service suppliers, commodity groups, and the "watchers." The watchers may also be referred to as the skeptical clients of agriculture...consumer groups, environmental groups, food safety activist groups, etc. It may not always be easy to involve these groups, but if industry and universities are going to partner, as they must, the stakeholders most skeptical of that partnership must be included.

Long term and short term. Patience appears to be in very short supply today, yet many of the needed changes at specific locations within landscapes will take many years to make. For example, removing mineral nutrients as limiting factors from the infertile eroded hills of much of the western Corn Belt and Great Plains will not be very effective unless water infiltration into those hill-top positions is improved. That can be done with improved residue management and production, but it takes time. Many other examples could be offered, but the main point is that long-term studies are needed.

Dr. Mark Alley of Virginia Tech is one of 22 scientists cooperating in a Mid-Atlantic regional interdisciplinary cropping systems project.

An example. The Foundation for Agronomic Research (FAR) and PPI recently initiated a Mid-Atlantic regional interdisciplinary cropping systems project, involving a research team of 22 scientists. A total of 10 experiments in Virginia, North Carolina, Maryland, and Pennsylvania, all with a common objective, are being conducted. Nine compliment the main study located in Virginia, which compares various cropping systems at a field scale.

A complimentary experiment located in North Carolina focuses on variable rate nitrogen (N) management and will generate results that will be applied and tested in the main study. Cash and in-kind contributions from commodity groups, private industry, and agencies support the project.

Priority Research Themes

The following is a set of suggested priority research themes that were developed in part from input received from other symposium presenters and PPI staff.

Maximum yield research. For every yield monitor that's purchased, there is one more individual eager to learn about yield limiting factors...nutrient or otherwise. An Illinois farmer by the name of Herman Warsaw taught us in 1985 how much yield potential we don't normally realize when he produced a corn yield of 370 bu/A. That was the potential of the technology and genetics of 1985. What is the potential of one-acre areas of the fields of 1998? We need smartly designed research to answer that question.

Soil sampling efficiency. One approach or size does not fit all. How is the optimum sampling approach for a given field determined, for variable rate application as well as for uniform rate, considering what we now know about nutrient variability? A host of issues surround this theme.

Improvement or verification of soil test calibration and interpretation. Because management systems are dynamic and today's soil tests are empirical, ongoing soil test calibration is a must. Numerous examples can be given of situations where recent calibration research resulted in major changes in nutrient recommendations.

Development of multi-variate soil test interpretation. We have known for a long time that more than one factor determines the nutrient supply available to a growing crop. The model developed is one of the simplest nutrient uptake models ever developed, and it has 11 parameters. It should not surprise us if current soil test interpretation systems fail to accurately predict response across fields. A recent study of winter wheat

There is a need for research at a field scale, where nutrient management is just one of the components being evaluated.

Research with soil sensors will be important in nutrient management.

response to phosphorus (P) across eastern Colorado landscapes may well be a reflection of reality in many fields. In that study, 62 percent of the sampling locations testing less than 14 (ppm) Olsen P respond to P while 50 percent of the sites testing greater than 14 ppm did. We now have the technology to utilize multi-variate approaches to determining nutrient needs.

Continued development of geographic information system (GIS)-based nutrient management decision aids. Site-specific nutrient management is a potentially wonderful customer for many of the relationships that are currently hidden away in scientific journals. Research focus on integrating what we already know about how nutrients, soils, plants and weather interact and delivering it through a user-friendly interface is sorely needed and would be very well received. Temporal variability in crop nutrient demand needs to be considered in such programs.

Development of models to predict soil fertility status over time. Without a doubt, soil sampling will be more intensively done in the future than it is now and there will be increased pressure to sample less frequently. A need exists for more accurate approaches to predicting soil fertility status between sampling times based on nutrient additions, crop removal, and other site-specific factors that may change among fields and across individual fields.

Plant and soil nutrient sensing (remote and otherwise). Can satellites tell us which parts of a field contain corn plants that are deficient in a specific nutrient or contain specific weed species and can the information be delivered in an acceptable, timely and cost effective manner? What can soil sensors deliver to the nutrient management table? These are researchable questions.

Waste disposal. Like it or not, agriculture is being asked and will continue to be asked to dispose of municipal and industrial wastes. Many of these contain essential plant nutrients, but may also contain potentially toxic materials. Animal manures continue to be a challenge for sound nutrient management in many regions. Research to determine the short and long term consequences of these practices and the appropriate role of site-specific nutrient management is needed.

Conclusion

Research topics are challenging and abundant, exciting technologies exist that are poised to utilize the fruits of science, and a user group is ready to pounce on every piece of practical knowledge that can be offered. One can speculate that there has never been a better time to be an agronomic scientist with interest in plant nutrients. BC

Dr. Fixen is Senior Vice President and North American Program Coordinator of PPI. He is located at Brookings, South Dakota.

GEORGIA

Cotton Fertility and Soil Test Calibration

By Glen Harris

Cotton has made a comeback in Georgia in recent years. Planted acres have increased from a low of 120,000 in 1983 to 1,440,000 in 1997. Most of this resurgence can be attributed to the boll weevil eradication program that was initiated in 1987 and successfully completed in 1991. Cotton yields in Georgia are also on the rise. Lint yields were equal to or above the 750 lb/A mark in most years since 1991. This increase is also due largely to the boll weevil eradication program. Improved varieties (including Bt), increased irrigation, integrated pest management, nutrient management, and overall better management have also contributed greatly to entering this higher production level.

Increasing acreage and yields of cotton are causing renewed interest in fertilization and soil test calibration. In Georgia, fertilizer recommendations for cotton are now given according to yield goal, based partly on soil type and previous history.

The recent increase in both acreage and yields has focused much attention on fertilization of Georgia cotton and soil test calibration. Unfortunately, budget cuts and lack of interest in soil fertility for production agriculture have eroded the research support in this area. Nonetheless, progress is being made. Starting in the fall of 1997, fertilizer recommendations from the University of Georgia Soil Test Laboratory will be given according to yield goal levels of 750, 1,000, 1,250 and 1,500 lb lint/A. Total nitrogen (N) rates recommended for these yield goals are 60, 75, 90 and 105 lb N/A, respectively. Realistic yield goals based on soil type and previous history are emphasized. In addition, guidelines for adjusting the N rate according to previous crop, insect control, and use of growth regulators are included. Modest increases in phosphorus (P) and potassium (K) recommendations based on crop removal will be made. All liming, secondary nutrient and micronutrient recommendations will remain unchanged and will be the same for all yield goals. An N-P-K fertilization experiment is being conducted to support these recommendations.

As a result of the recent popularity of cotton and waning interest in corn and peanuts, more cotton is being planted following cotton in Georgia (versus following another crop). An on-going field study, initiated in 1993, indicates that N rates need to be increased when cotton is followed by cotton. The optimum N rate for second-year cotton was 80 lb N/A...for third-and fourth-year cotton it was 100 lb N/A. Yield levels for all years of the study were between 1,250 and 1,500 lb lint/A. This study is also being used to verify nutrient sufficiency levels for the current petiole and tissue testing programs.

Increased cotton acreage in Georgia

has created the need for development of fertilizer recommendations on soil types in new growing areas. For example, cotton acreage has recently expanded into the Atlantic Coast Flatwoods soil region. These soils are deep sands that may or may not have a seasonably high water table. Traditional crops in this area include tobacco, corn and soybeans. The second-year of a two-year field study investigating N and K rates for these soils will be completed in 1998. First-year results indicated that N rates, in the 120 lb N/A range, may be needed regardless of depth to water table. Current K recommendations appear to be adequate for this region.

Despite some setbacks, cotton production has increased in Georgia and other areas. On-going research in soil fertility is needed to evaluate practices and guide recommendations.

Coinciding with the recent increase in cotton production in Georgia, the poultry industry has also expanded throughout the state. As a result, millions of tons of poultry litter are available as a fertilizer source for agronomic crops, including cotton. Both on-farm and experiment station research conducted during the last three years indicates that poultry litter is a viable and useful fertilizer. Currently, a preplant incorporated rate of 2 tons/A is recommended. In-season adjustments of additional N and K fertilizer can then be made at sidedress. Higher rates (up to 4 tons litter/A) can be used to meet all the N requirement in some situations. Phosphorus and zinc (Zn) buildup are long-term concerns. Late-season rank growth due to N was an initial concern but does not appear to be a major problem. Having poultry litter analyzed for nutrient content, using a nutrient management plan, and using in-season plant nutrient monitoring are all highly recommended when using poultry litter on cotton.

During recent growing seasons, a significant number of K deficiency problems in Georgia cotton have been reported. This soil fertility problem was really brought to attention by the increased presence of related secondary leafspot diseases. While some leafspot is common in Georgia cotton late in the season, a good number of severe cases have been reported early in the season (around fourth week of bloom). In addition to leafspot fungal organisms common to Georgia, even a relatively new species (Stemphylium), not seen in Georgia since the 1960s, was isolated. Dry weather and drought stress during the last two years has no doubt contributed to the K deficiency problems observed. However, a number of cases have also been reported with irrigation. In these cases, higher yield production with newer varieties is thought to play a significant role. The current strategy to help avoid this problem is to soil test, split the K rate (half at planting and half at sidedress) and possibly apply foliar applications of K. Foliar K sprays are being encouraged when soils test low in K, on deep sands, under high-yield conditions and where K deficiency has been a problem in the past. Field studies to address this fertility problem are currently being planted.

In addition to the soil fertility research indicated above, a number of new practices, or old practices being used under new conditions, need to be addressed. A significant portion of Georgia cotton is currently being grown using conservation-tillage and that will likely increase. This production practice creates unique challenges for soil sampling and fertilization that need to be investigated. Due to recent increases in landfill costs, more and more by-products are becoming available for land application. These materials may be from agricultural, municipal or industrial sectors and may have value as fertilizer, lime or soil amendments for cotton. The soil fertility aspect of precision agriculture is certainly an important and popular topic that will continue to require attention, especially after the development of a cotton yield monitor. Finally, profitable cotton production in Georgia has resulted in the development of a great number of non-traditional growth regulator and nutritional in-furrow and foliar treatment products. These products need to be tested under randomized, replicated, and unbiased conditions to verify their effectiveness. BC

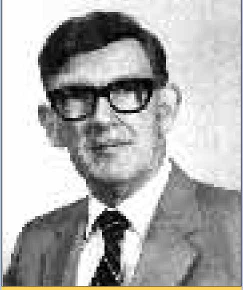
Dr. Harris is Extension Agronomist, Crop and Soil Sciences Department, University of Georgia, Tifton, Georgia.

In Memory of Eugene D. Dixon, 1917-1998

Mr. Eugene D. Dixon, a retired longtime employee of PPI, passed away January 18, 1998. Mr. Dixon, who was 81 years of age at the time of his death, began his career with the Institute in 1937.

A native of Brunswick, Maryland, he graduated from Strayer College in Washington, D.C., with a degree in accounting. He served in the U.S. Army Air Corps in 1945 to 1946.

Mr. Dixon officially retired from PPI as Assistant Treasurer in 1986, but continued on a part-time basis through 1988.



Eugene D. Dixon

In his more than 50 years of dedicated service, he held a variety of responsibilities, spanning the terms of the first four presidents of the Institute.

"Gene Dixon was always interested in the well-being of the Institute and its programs of research and education," said Dr. David W. Dibb, PPI President. "He thoroughly enjoyed the association with his colleagues as well as those he met through other activities. Gene will be dearly missed by his family and by all who were fortunate to know him." BC

TEXAS

Alfalfa Response to Boron at Variable Soil pH on Coastal Plain Soils

By Vincent Haby, James V. Davis and Allen Leonard

Alfalfa is not a common forage on Coastal Plain soils of the southern U.S., but recent advances in the development of grazing tolerant varieties have increased interest in alfalfa production in the region.

Significant advances in the soil fertility and fertilizer requirements of alfalfa are being developed through research on the acid, Coastal Plain soils of east Texas. Research is continuing to determine relationship of variable levels of soil boron (B) and pH for best yield response under these conditions.

In one study, growth response of alfalfa (var. Alfagraze) to residual and applied levels of B was measured. Tests were run on a Darco loamy fine sand (thermic, Grossarenic Paleudult) at varying soil pH levels.

Alfalfa was overseeded into the sod of Coastal bermudagrass at a 27-inch row spacing. Prior to the alfalfa study, specific plots had received 0, 1, and 2 tons/A of calcitic limestone with an effective calcium carbonate equivalent (ECCE) of 64 or 100 as part of a 4-year study of clover response to limestone and B. The limestone contained 4 percent magnesium (Mg). Annual B rates for clover were 0, 1, and 2 lb/A, applied as 14.3 percent Granubor®.

To adjust soil pH for alfalfa production following the clover research, an additional 2 and 4 tons/A of ECCE 64 and 100 limestone was applied (annual split applications) to appropriate plots. Lime-stone was left on the soil surface except for the final 1 and 2 ton/A rates that were lightly disked into the surface 1.5 inch depth of soil in fall of 1992, immediately before seeding alfalfa. Boron rates were maintained at the same level as for clover for the first year of research on alfalfa.

Yield of alfalfa was lower than expected, even for the seedling year, so the B rate was increased to 2 and 4 lb/A for the second and third years of the study. Phosphorus (P) was applied to all plots at a rate of 125 lb P_2O_5/A in 1992 and 1993 and 80 lb/A in 1994. Potassium (K) application was maintained above 300 lb

Alfalfa response to four different treatments is shown in this photo. Area at upper left received no limestone or B. Lower left received 2 tons/A of ECCE 62 limestone and no B. Lower right received 2 lb/A B annually, but no limestone. Upper right recived 4 tons/A of ECCE 100 limestone and an annual B rate of 4 lb/A.

K_2O/A each year. Sulfur (S) and Mg were applied annually at rates of 60 and 30 lb/A, respectively. Nitrogen (N) was applied at rates varying from 80 to 100 lb/A annually in an attempt to allow the bermudagrass to compete with the alfalfa. Because of the effect of applied N on decreasing pH of the surface soil, samples were collected from the 0- to 2-inch and 2- to 6-inch depths. Soils were analyzed for hot-water-soluble B, 1:2 soil:water pH, and DTPA levels of manganese (Mn).

Seventy-six percent of the variability in alfalfa yield was attributed to soil pH, soil B, applied B, and soil Mn. Estimated yields at varying levels of hot-water-soluble soil B and pH in the 2- to 6-inch soil depth, with applied B at 2 lb/A and soil Mn at 7.4 parts per million (ppm), are indicated in **Table 1**. Yields were increased by increasing B levels at all levels of soil pH and, conversely, by increasing pH at all levels of soil B. At pH 5.7, alfalfa yield was increased over 400 percent by raising the soil B level from 0.3 to 0.7 ppm. Although the rate of response to increasing soil pH declined at higher pH, the exponential response of alfalfa to soil B continued to increase as soil pH was increased. Alfalfa dry matter yield at the 27-inch row spacing was increased by 7.0 tons/A at the highest soil pH and residual level of B compared to levels of these variables in check treatments. This amounts to an increased growth efficiency approaching 740 percent due to increasing soil pH and levels of soil B. Alfalfa yields were continuing to increase at pH 7.7 with soil B at 0.7 ppm.

Alfalfa response data for increasing rates of applied B at variable soil pH were generated using the same regression equation (not shown) as for **Table 1**, but with soil pH increasing from 6.0 to 8.0 and soil B at a constant 0.5 ppm (**Table 2**). The estimated yields increased at decreasing rates as both variable soil pH and applied B levels were raised. Alfalfa yield was maximized at 3 lb/A of applied B under the conditions set for this regression equation. Yield was increased greater than 400 percent with the 3 lb/A B rate at pH 8 compared to pH 6.0 in the 2- to 6-inch soil depth. At the same level of applied B and with soil pH at 6.5, yield was increased only 246 percent.

TABLE 1. Estimated response of alfalfa to soil pH_W and hot water-soluble B in the 2- to 6-inch depth of a Darco loamy fine sand with applied B at 2 lb/A and soil Mn at 7.5 ppm in 1994.

Soil pH	Soil B, ppm 0.3	 0.4	 0.5	 0.6	 0.7
			D.M., tons/A		
5.7	0.97	1.17	1.90	3.15	4.94
6.2	2.05	2.24	2.98	4.23	6.01
6.7	2.93	3.14	3.86	5.16	6.91
7.2	3.64	3.84	4.57	5.82	7.60
7.7	4.16	4.36	5.08	6.34	8.13

TABLE 2. Estimated response of alfalfa to soil pH_W in the 2- to 6-inch depth and to B applied to a Darco loamy fine sand with hot-water-soluble B at 0.5 ppm and DTPA extractable Mn at 7.5 ppm in 1994.

Soil pH	Applied B, lb/A 0	 1	 2	 3	 4
			D.M., tons/A		
6.0	1.10	1.98	2.57	2.85	2.83
6.5	2.06	2.94	3.53	3.81	3.80
7.0	2.84	3.72	4.31	4.59	4.58
7.5	3.43	4.32	4.90	5.18	5.17
8.0	3.84	4.72	5.31	5.59	5.58

Acid soils of the Coastal Plain usually need to be limed for economic alfalfa

(continued on page 26)

Chloride Fertilizer Effects in Winter Wheat and Interactions with Foliar Fungicides under Severe Leaf Rust Pressure

By Travis D. Miller

Responses to Cl fertilizers in winter wheat have been widely documented in the Great Plains and the Pacific Northwest. Increased yields have been attributed to micronutrient response as well as reduced incidence of fungal disease associated with enhanced Cl nutrition. In Texas trials, topdress applications of Cl have significantly reduced leaf rust and septoria ratings at bloom and increased wheat yields.

In the trial reported in this paper, chloride (Cl) had positive and significant interactions with systemic foliar fungicides which are commonly used in wheat production. Use of Cl resulted in lower leaf rust ratings and significant yield increases when used either in combination with or in sequence with wheat fungicides. Previously reported data do not document such interactions.

Materials and Methods

A test plot was established in a winter wheat (var. 2163) field heavily infested with leaf rust near Hillsboro, Texas. Plot size was 15 x 40 feet. Plots were replicated 3 times in a randomized block design. Alleys were cut 5 feet wide, with a resulting plot harvest of 35 feet by 4.5 feet. Plots were direct harvested with a research plot combine.

The soil at this site is a Houston Black Clay with a pH of approximately 8.0. It is poorly drained, and the wet winter had caused frequent standing water and conditions which favored the proliferation of wheat leaf rust.

Chloride was applied as a foliar solution of magnesium chloride ($MgCl_2$) at the rate of 40 lb Cl/A at Feekes stage 6 on March 5. Wheat fungicides, Bayleton and Tilt, were applied with a CO_2 backpack sprayer at 35 psi in a water volume of 19 gpa. Both fungicides received a non-ionic surfactant at 0.25 percent volume to volume (v/v). Initial treatments were applied on March 6. Sequential fungicide applications were made on April 7 at Feekes growth stage 9, or flag leaf fully emerged.

Thirteen treatments involving rate, time of application and sequential treatments were applied (**Table 1**). Bayleton 50 percent DF was applied at the 2.0 oz/A rate topdress either alone or in combination with $MgCl_2$. The 2 oz/A with $MgCl_2$ was also evaluated with a sequential 2 oz/A application at stage 9. A treatment evaluating a 2 oz/A topdress application of Bayleton followed by a 4 oz/A sequential application of Tilt at stage 9 was included. Tilt was applied at the 2 oz/A rate, either alone or in combination with $MgCl_2$ at topdress. Tilt at the 4 oz/A rate was also applied as a single treatment either at topdress or at Feekes 9. Magnesium chloride was applied at the 40 lb Cl/A rate at topdress either alone or in sequence with the Bayleton or Tilt 2 or 4 oz/A rate at Feekes 9.

Leaf rust ratings were taken visually once per week, beginning about 1 week after initial treatments were made. The first three ratings reflect whole plant values, or estimates of the percentage of the entire leaf mass damaged by overwintering leaf rust. After March 29, the uppermost leaf with a significant infection of leaf rust was selected and rated.

Results and Discussion

Conclusions from this trial should be tempered by the fact that leaf rust was severe to the extent that more than half of the plant canopy was destroyed prior to initial treatments. Plots treated topdress with Bayleton had significantly lower leaf rust ratings than the untreated check for 6 weeks following treatment, whereas plots treated with the 2 oz rate of Tilt were significantly less injured than the untreated check for only 2 weeks. Neither of these treatments yielded more than the check.

Wheat treated with the combination of either Bayleton or Tilt at 2 oz/A plus Cl at 40 lb/A was significantly less affected by leaf rust than the untreated check for 7 weeks, with the Cl treatment resulting in 1 and 5 weeks of added protection, respectively. The Cl plus fungicide combination provided more protection from leaf rust than either the 2 or 4 oz fungicide rates. Both 2 oz/A topdress treatments yielded significantly more than plots treated with fungicide only. The Cl topdress treatment alone resulted in 5 weeks of leaf rust suppression. This treatment did not yield significantly lower than the fungicide-Cl treatments, but leaf rust suppression was not as persistent.

Treatments with 2 oz/A of either Bayleton or Tilt in combination with Cl followed by a second 2 oz/A rate at flag leaf exsertion gave essentially season long protection from damaging levels of leaf rust, with a slight advantage observed in the Tilt plus Cl treatments. Topdress Cl followed by a full 4 oz/A rate of Bayleton or Tilt also gave good season-long protection against rust and yielded comparably with the sequential fungicide plus Cl fungicide treatments. The Cl topdress treatment followed by 4 oz/A Bayleton at flag leaf gave the best grain yield and overall leaf rust protection across the season with the exception of the last rating date of May 10. This corresponded with 10 days post bloom.

From this trial, it is obvious that the effect of Cl and foliar fungicides are complementary and additive. Light or full rates of fungicides applied early season (Feekes 6) in a heavy leaf rust infestation reduced damage from the disease

TABLE 1. Leaf injury by rust and yield of winter wheat treated with Cl fertilizer and fungicides (Hill County, Texas 1996-97).

	Fungicide		Leaf injury by rust, %					
	Rate, oz/A		F-1 on April 19		Flag leaf on May 10		Grain yield, bu/A	
Treatment	Mar 5/6	Apr 7	0	40 lb Cl/A	0	40 lb Cl/A	0	40 lb Cl/A
Check	0	0	44	30	92	74	25.8	26.6
Bayleton	2	0	58	17	79	72	20.8	30.1
Bayleton	2	2	–	19	–	67	–	30.0
Bayleton	0	4	43	14	79	72	21.4	31.3
Tilt	2	0	44	14	94	85	22.8	29.6
Tilt	2	2	–	16	–	60	–	29.4
Tilt	4	0	46	–	85	–	24.1	–
Tilt	0	4	20	13	58	32	24.1	30.5
(B) + (T)	2(B)	4(T)	15	–	34	–	27.7	–
LSD.05				18		19		5.2

temporarily, but were inadequate to relieve pressure from the disease through grain fill. Chloride alone reduced crop injury from the disease for about 5 weeks, but was not different from the check at season's end. Chloride and fungicides applied as a combination at topdress, or sequentially at topdress, gave significant relief from crop injury due to leaf rust for most of the growing season and improved yields over treatments not using both products. Sequential fungicide applications (Bayleton 2 oz/A followed by Tilt 4 oz/A) did not give leaf protection equal to combination or sequential treatments with Cl and fungicide.

Leaf rust infestations of the magnitude observed in this study are the exception rather than the rule, occurring only every 4 or 5 years. The topdress Cl and fungicide strategy which was employed in this study has the potential to allow farmers to scout fields and make applications of Cl fertilizer and/or fungicide as needed to deal with a major disease problem in wheat. BC

Dr. Miller is Professor and Extension Agronomist-Small Grains and Soybeans, Texas A&M University, College Station, TX 77843.

Alfalfa Response to Boron...

(continued from page 23)

production. Liming these soils to raise pH to 6.5 or higher is often recommended. Based on results from this research, pH 6.5 is not sufficiently high for maximum alfalfa yield on a Coastal Plain Darco soil. The additional cost of limestone needed to raise soil pH to 7.0 is rapidly offset by the estimated additional 0.78 tons of dry matter (0.87 tons of 12 percent moisture hay) produced. When low organic matter, acid soils are limed, residual, plant-available B is adsorbed by hydroxy aluminum compounds in the pH range of 6 to 9. Adsorption decreases the availability of B to plants, creating the need to apply B to B-deficient soils for crops such as alfalfa that have an elevated need for this nutrient.

Alfalfa response to increased levels of hot-water-soluble soil B appears to be greater than its response to rates of applied B over a varying soil pH range. This indicates the importance of maintaining adequate levels of hot-water-soluble soil B to optimize yield as long as pH is in a favorable range. The higher the pH, the greater is the adsorption and retention of plant-available soil B against leaching with water. In this study, the critical level of hot-water-soluble soil B for alfalfa approximated 0.4 ppm. Alfalfa yield increased only 0.2 tons/A between 0.3 and 0.4 ppm B, but the estimated yield increase was 0.73 tons/A as soil B increased from 0.4 to 0.5 ppm. The hot-water-soluble soil B level considered adequate for alfalfa production on limed acid soils could not be determined in this research because estimated yield was still increasing at the highest level of soil B attained. Additional research is needed at even higher variable levels of soil B and pH to determine the maximum yield response on Coastal Plain soils. BC

Dr. Haby is Professor, Mr. Davis is Research Associate, and Mr. Leonard is Research Assistant, in the soil chemistry research group at the Texas A&M University Agricultural Research and Extension Center at Overton, Texas Agricultural Experiment Station, P.O. Box E, Overton, Texas. E-mail: V-haby@tamu.edu

Digital Cameras — A New Diagnostic/Record Tool

A digital camera can be a useful tool for field scouting and record keeping. The old adage, "A picture is worth a thousand words", still applies.

More growers are moving to electronic forms of field record systems. Any picture (print or slide) can be converted to electronic format, so it may not be absolutely necessary to buy a digital camera. Most photo labs can convert photos to electronic images, either on a diskette or a photo-CD. These images can then be attached to records, incorporated into reports for landlords, or used in other farm management situations. The images can also be transmitted via internet to others, such as a diagnostician who might help identify a field problem.

Cameras that can be used to take pictures, store the images electronically, and copy them to a computer for storage, viewing, and printing are available at prices in the range of $500 to $1,000. There is no film to buy or process. Many of the digital cameras have settings for close-up images, various light adjustments, and capability to view the image immediately. This feature helps to verify, at the location, that the images are of acceptable quality. More expensive lenses or equipment may be needed for higher resolution or sharpness of image.

Images should be "backed up" just as with other electronic files. Their value may become greater as a reference for decisions in future seasons. Several views of a field situation and notes at the time of the images are recommended.

If global positioning system (GPS) service is available for the location, the coordinates should be recorded. With other tools such as a hand-held computer, useful scouting and diagnostic information can be easily stored, retrieved and transferred as needed. BC

Source: Dr. Harold F. Reetz, Jr., Midwest Director, PPI, Monticello, Illinois.

Annual Statement of Ownership

Statement of ownership, management, and circulation (required by 39 U.S.C. 3685) of Better Crops with Plant Food, published four times a year at 655 Engineering Drive, Suite 110, Norcross, GA 30092-2837, for October 1, 1997. General business offices of the publisher are located at 655 Engineering Drive, Suite 110, Norcross, GA 30092-2837. Name and address of publisher is Potash & Phosphate Institute, 655 Engineering Drive, Suite 110, Norcross, GA 30092-2837. Name and address of editor is Donald L. Armstrong, 655 Engineering Drive, Suite 110, Norcross, GA 30092-2837. There is no managing editor. Owner is Potash & Phosphate Institute, 655 Engineering Drive, Suite 110, Norcross, GA 30092-2837. There are no known bondholders, mortgagees, or other security holders owning or holding 1 percent or more of total amount of bonds, mortgages, or other securities. The average number of copies of each issue during the preceding 12 months is: (a) Total number of copies printed: 19,198; (b) Paid circulation: (1) Sales through dealers and carriers, street vendors, and counter sales: 6,349; (2) Paid or requested mail subscriptions: 6,370; (c) Total paid and/or requested circulation: 12,719; (d) Free distribution by mail: 4,103; (e) Free distribution outside the mail: 154; (f) Total free distribution: 4,257; (g) Total distribution: 16,976; (h) Copies not distributed: (1) Office use, leftovers, spoiled: 2,222; (2) Return from news agents: not applicable; (i) Total: 19,198; Percent paid and/or requested circulation: 75%. The actual number of copies of single issue published nearest to filing date is: (a) Total number of copies printed: 18,350; (b) Paid circulation: (1) Sales through dealers and carriers, street vendors, and counter sales: 6,349; (2) Paid or requested mail subscriptions: 5,162; (c) Total paid and/or requested circulation: 11,511; (d) Free distribution by mail: 3,963; (e) Free distribution outside the mail: 275; (f) Total free distribution: 4,238; (g) Total distribution: 15,749; (h) Copies not distributed: (1) Office use, leftovers, spoiled: 2,601; (2) Return from news agents: not applicable; (i) Total: 18,350; Percent paid and/or requested circulation: 73%. I certify that all information furnished above is true and complete. I understand that anyone who furnishes false or misleading information on this statement or who omits material or information requested on the statement may be subject to criminal sanctions (including fines and imprisonment) and/or civil sanctions (including multiple damages and civil penalties).

Donald L. Armstrong, Editor

OKLAHOMA

Expectations of Precision Phosphate Management

By Mick Goedeken, Gordon Johnson and Bill Raun

Variability of Available Soil Phosphate

Among-Field Variability. Soil test P (STP) varies greatly within and among fields. **Figure 1** shows the variability of STP among 50 wheat fields tested from a major wheat growing county (Garfield) in Oklahoma in 1996. Results are from composite soil samples representing the surface soil (0 to 6 inches) of fields averaging 80 acres in size. It is not surprising that variability is quite great among fields in a county with 450,000 acres of wheat. This variability is a result of large scale differences in soil types, past production levels and fertilizer use.

Several questions accompany the advent of precision agriculture in crop production...how variable are fields; what happens when this variability is treated? This article examines variability of available soil phosphorus (P) and some of the expected outcomes of its treatment.

Within-Field Variability. Variation in STP on a smaller scale is illustrated in **Figure 2a**, which shows STP values for 50 samples taken from 10 x 10 foot plots along a 500 foot transect in a 50 x 500 foot area used for correlating STP and wheat forage yield. Although not as great as the among-field variability, within-field variability in this small area included a 4-fold difference between the lowest and highest value.

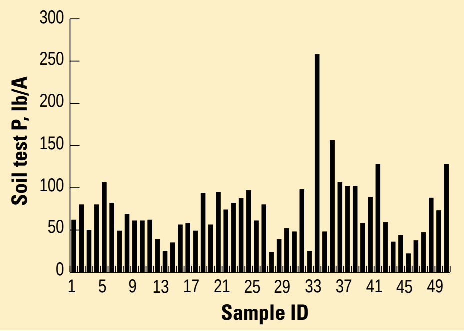


Figure 1. Soil test P variability among 50 soil tests for wheat in Garfield County, Oklahoma (1996).

Treating Field Variability

Variable Rate. It is well established and accepted that STP variability among fields will diminish if high testing fields receive less, or no fertilizer P, and low testing fields receive more, relative to past fertilizer P inputs. Similarly, if areas within a field are fertilized in relation to variable STP values, variability might decrease in time. This hypothesis was tested by applying a response model to the data in **Figure 2a**.

The model uses soil test values which have been calibrated on a percent sufficiency basis, whereby yields at each soil test level were expressed as a percent of the maximum yield obtained when adequate, but not excessive, fertilizer P was applied. For example, the soil test value of 20 is 80 percent sufficient. Without P fertilizer, the predicted yield would be 80 percent of the 40 bu/A yield goal (0.80 x 40 = 32 bushels). The soil test calibration

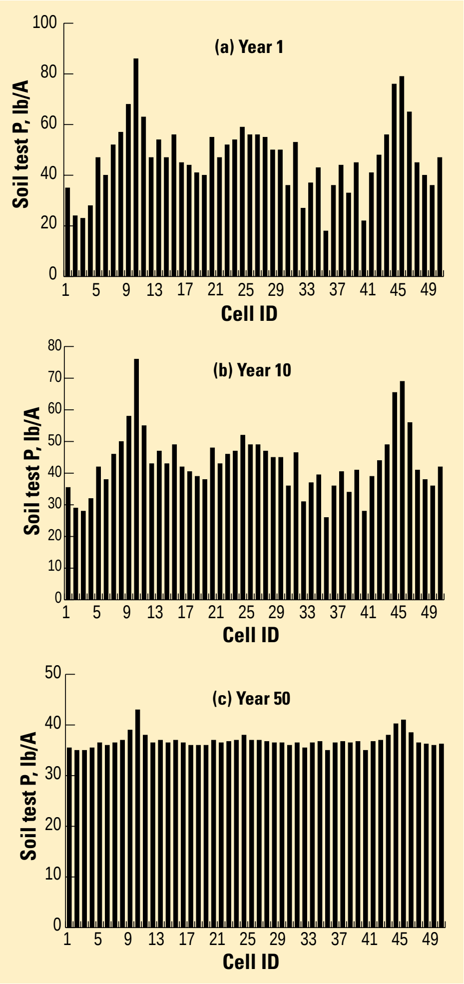


Figure 2. Effect of variable rate treatment on field variability with time.

identifies a rate of 40 lb/A P_2O_5 broadcast-incorporated would be needed to correct the deficiency for one year.

We then use the model to calculate wheat yield, P removal, and change in STP for each 10 x 10 foot plot as if it had been fertilized and with a wheat response according to local STP calibration (Mehlich III or Bray P-1) for a projected 50 year period. The yield potential was assumed to be constant across the field at 40 bu/A and P the only yield limiting factor (acknowledged unrealistic assumptions). Grain P concentration was assumed at 0.4 percent for calculating P removal. STP was assumed to decrease one unit for every 20 lb P_2O_5 removed by the crop in excess of fertilizer addition, and STP was assumed to increase one unit for every 20 lb P_2O_5 added to the soil in excess of crop removal.

Because grain harvest does not remove large quantities of P, and relatively small amounts of fertilizer P are required to correct the annual crop deficiency even in low STP areas, there is little change in STP variability the first 10 years (**Figure 2b**). After 20 to 30 years, most of the STP variability in the field has been removed, and after 50 years the levels of STP are almost constant across the field (**Figure 2c**).

These projections support the hypothesis that variable rate P fertilization, according to some measure of potentially available soil P, should reduce the need for variable rate applications.

Constant Rate. When a constant rate of P fertilizer is applied to a field made up of many areas that differ in available soil P, variability in STP for the field does not change over time. Using the same approach as for developing **Figure 2**, the effect over time of a constant 46 lb/A rate of P_2O_5 (100 lb/A of DAP is a common rate) was evaluated (**Figure 3**). This figure shows variability remains almost the same after 10 years.

Field Element Size. Of particular interest to the consideration of precision agriculture is the treatment resolution, or field element size. That is, how small should grids be to best identify variability in the field, and what is the smallest size that should be treated? To examine these questions, the response model was used to calculate projected wheat yields, P_2O_5 applied, and marginal profit associated with variable rate treatment for the 50 plots measuring 10 x 10 foot when a

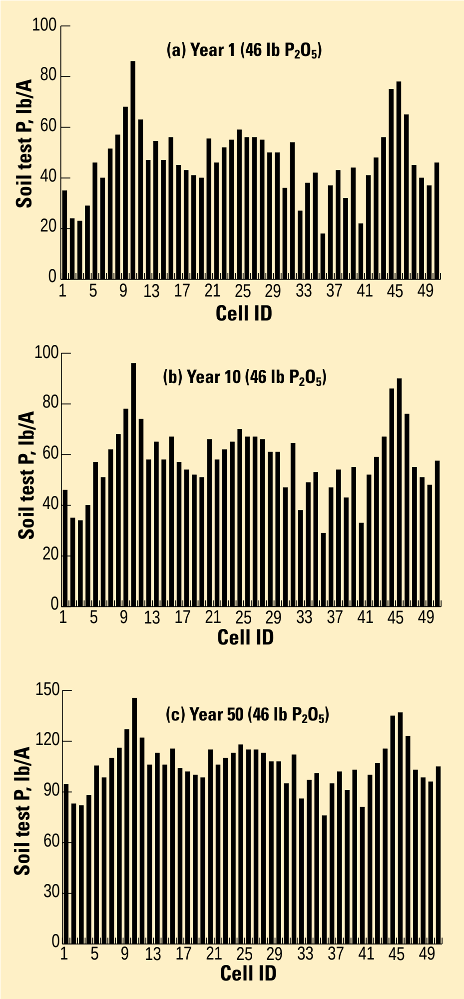


Figure 3. Effect of constant rate treatment on field variability with time.

constant P_2O_5 rate was applied to smaller and smaller sections of the field.

Initially the average STP of the 50 plots (47 lb/A) was used to identify a "field" rate of P_2O_5 to apply. Yield for the field was predicted by using the model to calculate response for each plot based on its STP value and summing these values. Yield without P_2O_5 addition was similarly calculated for estimating the marginal return from fertilizing. Next, the first 25 plots and the last 25 plots were treated as separate areas of the field, each receiving a constant P_2O_5 rate based on the average STP for the 25 plots involved. Smaller and smaller areas of the field were independently treated until finally each 10 x 10 foot plot was treated separately. Each time smaller groupings were considered, projections for the treated area (field element size) were made. Yield, P_2O_5 and marginal profit totals for the field were compared to that obtained when a single P_2O_5 rate was applied to all 50 plots. These results show that as the field element size decreases, there is a gradual and then rapid increase in total yield, P_2O_5, and profit (**Figure 4**).

Discussion and Conclusions

General. Crop yield and profit are maximized when the ability to treat smaller units increases to that size representing the smallest identifiably "different". That is, maximum economic yield (MEY), based on marginal profit from fertilizer, is achieved when the smallest variable unit is treated. This assumes costs of identifying and treating small variable units in a field are negligible compared to conventional approaches.

Among-Field Variability. When the above conclusion is applied to variability among fields, it indicates that when fields have different fertilizer needs they should be treated differently. Although this may seem clearly obvious, a survey of Garfield county wheat producers, participating in a free soil testing program, showed: 1) only 58 percent of the fields had been soil tested within the last three years; and 2) 67 percent of the participants treated the five fields they had tested the same, even though tests indicated large differences in fertilizer needs. Results illustrated in **Figure 4** also indicate that as more and more individual fields in a community (or fertilizer dealers retail area) are regularly soil tested and treated according to the soil test recommendations, there should be an increase in fertilizer use efficiency and farmer profit. If, on the average, fields in the community need fertilizer, then individual field treatment, rather than using a common fertilizer program for groups of fields, will result in increased sale of fertilizer.

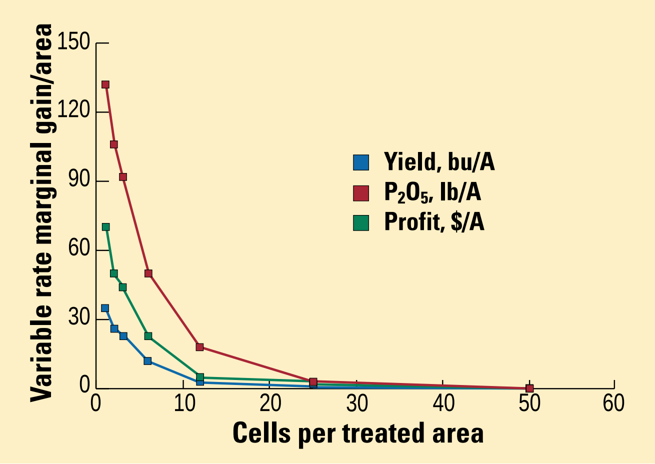


Figure 4. Relative effect of field element size on field yield, P_2O_5 used, and marginal profit.

Within-Field Variability. Variabil-ity of STP in fields has been shown to exist over distances of only a few feet (**Figure 2a** and other intensive soil sampling data). While identification of soil P deficiency by conventional means at this level of resolution may be cost prohibitive (435 soil tests per acre), separately soil testing large portions of a field that appear to be different based on visual observation of soil color, soil type, or crop yield, should be economical. Results in **Figure 4** were obtained by systematically reducing the treated area in half, without regard to whether a grouping of cells by STP level could be done. In many field situations, large areas can be logically identified for soil testing and fertilizing independently based on soil survey and yield monitor maps.

High resolution field element size, such as 10 x 10 feet, may be economical to manage in precision farming when nutrient deficiencies can be identified at low cost, such as with GPS-coupled, sensor-based mapping. When that is possible, it may be important to speed the transition of buildup and depletion shown in **Figure 2** by adding higher rates than required for annual correction of deficiencies. If uniformity could be achieved in five years, then a constant rate could be used. With this approach, costs associated with each application of variable rates could be minimized.

Finally, this treatment of data clearly shows farmers will benefit economically in relation to the extent to which they are able to detect and treat variable fertilizer needs on the land they manage. Until new technology replaces conventional soil testing, its value for increasing yields, farmer profits, and fertilizer use could not be more clear. BC

The authors are researchers and members of the precision agriculture team at Oklahoma State University, Stillwater.

CAREERS

Let's consider two basic approaches to one's life and professional career. One says, "To be successful, to make the greatest contribution, confine your program to a narrow field. Become an expert in one area and be highly specialized." A conflicting approach believes, "As you go through life, change your outlook – try something new and different. If you don't change jobs, change what you are doing on the same job." It is not a matter of one approach being right and the other wrong. Everyone must shape his or her own destiny. Let's look at different paths taken by three great agronomists.

One became a geneticist and plant breeder. His professional life has been devoted to research in grasses. He has lived in the same small town for over 60 years, turning down offers of administrative positions. His grasses are grown throughout the world, contributing millions of dollars to the economy and untold enjoyment of lawns and golf courses.

Another went from teaching and research to department head, Extension Director, USDA leadership, and Dean...involving moves throughout the country. He became president of a great university and then Chancellor of an entire university system. When he retired from that position he devoted his energies to meeting world food needs.

A third agronomist confined his professional life to one area. He taught the introductory course in Soil Science for over 50 years at the same institution. He did no research, no Extension, just teaching, though he did write the leading textbook in Soil Science. Just teaching? But he was magnificent. No one ever did a better job. And thousands of students carried the impact of his teaching throughout their lives.

Three agronomists – three different careers. Who can say that one contributed more than the other? Early in one's career, every person has the opportunity to choose a route to follow and a way to pursue it.

J. Fielding Reed

BETTER
CROPS
WITH PLANT FOOD

Potash & Phosphate Institute
Suite 110, 655 Engineering Drive
Norcross, Georgia 30092-2837

Periodicals
Postage