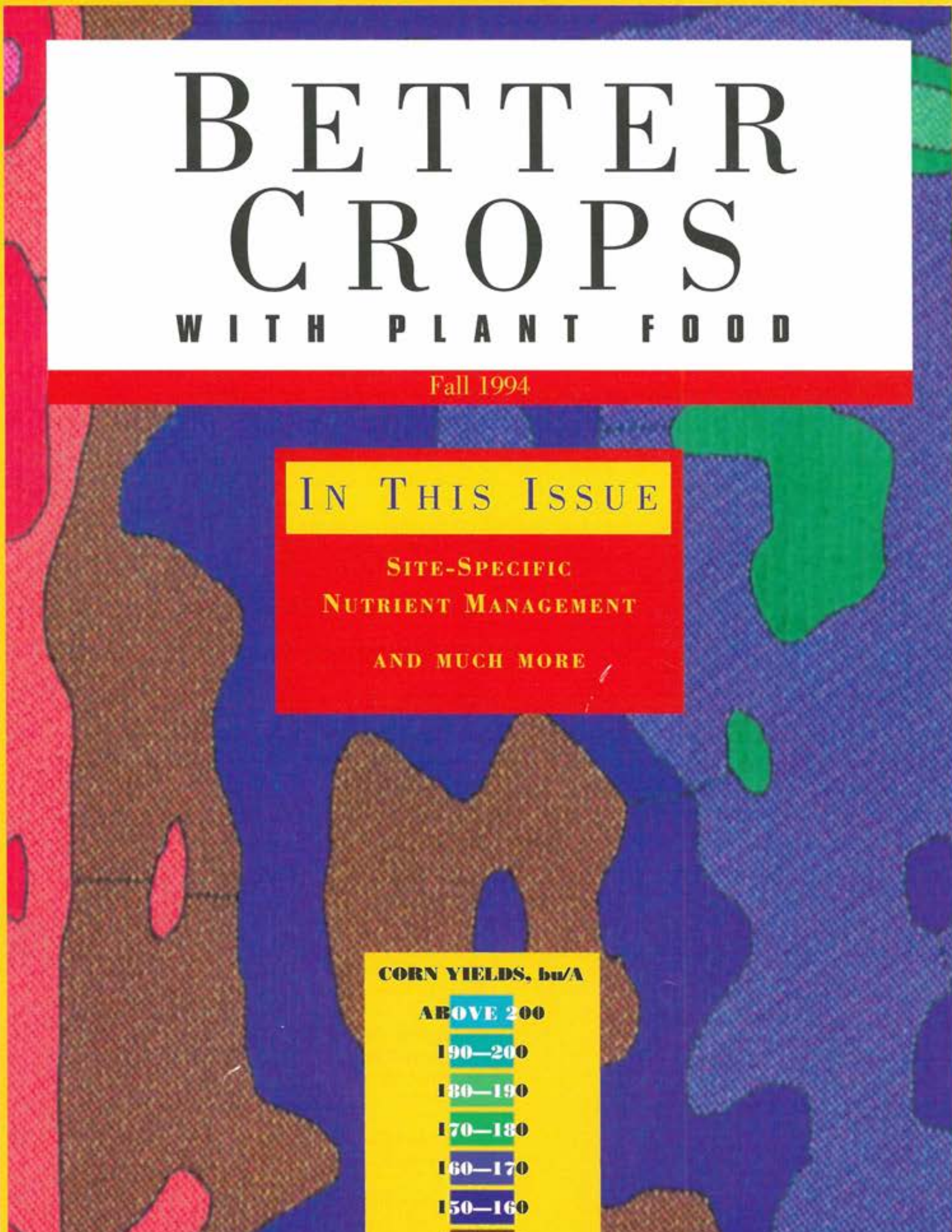
BETTER CROPS

WITH PLANT FOOD

Fall 1994



BETTER CROPS WITH PLANT FOOD

Vol. LXXVIII (78), No. 4 Fall 1994

Our Cover: Corn yield variability in a field. Printout courtesy of Applications Mapping, Frankfort, IL.

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CONTENTS

Site-Specific Management Impacts P and K Use and Productivity

By Paul E. Fixen

Soil variability can cut crop yields and profitability. More intensive soil sampling coupled with modern technology has the potential to improve fertilizer recommendations, increase nutrient use efficiency, increase yields and boost profits while maintaining environmental protection.

THE VARIABILITY of some fields is readily apparent. Other fields may appear uniform. Detailed soil sampling often reveals hidden variability that can rob farmers of yields and profitability. Multiple limiting factors frequently reduce yields in significant portions of fields that, on the average, test high or very high in phosphorus (P), potassium (K) and other nutrients. See the article titled "Soil Test Level Variability in Southern Minnesota" on page 24 of this issue.

Today's technology has the potential to unleash the true yield potential of soils and at the same time accommodate the application of nutrients only where they are needed.

Grid soil sampling is the key that unlocks hidden yield potential. This is a method of soil sampling in which several soil cores are collected at each point in a grid that divides a field into small, more uniform areas. The interval between grid points changes, depending on field variability and other factors, but is usually in the 200 to 440-foot range.

BOTH dry and fluid applicators can vary fertilizer rate based on a grid map and other factors.

Impacts on Recommendations

The impact of grid sampling on total P and K recommended may not be the same in all regions. However, results from Minnesota and Ontario indicate that gridding will increase the total P and K recommended for fields having high variability that average near the soil test level where the recommendation drops to 0. To illustrate the effect of grid sampling on the total amount of P recommended, a simulation was conducted on 140 grid sampled fields in western Minnesota. Phosphorus recommendations were calculated based on the field average soil test level to simulate a conventional sampling approach. This recommended rate was then compared to the average of recommendations

Table 1. Field average soil test level and variability influence the increase in P recommended due to grid sampling.

Soil test category[1] Olsen P, ppm	Field soil test variability[2] Low (<6)	Med. (6-10)	High (>10)
	Increase, lb P_2O_5/A		
<12 (L,M)	1	6	17
12-19 (H,VH)	5	14	25
>19 (VH)	0	3	16

Based on MN-ND-SD tri-state university recommendation for 140 bu/A corn which drops to zero at 16 parts per million (ppm). Data source: Agvise Labs
[1]Low, Medium, High, and Very high.
[2]Value in parentheses is standard deviation in ppm.

Dr. Fixen is PPI Northcentral Director, located in Brookings, SD.

based on individual grid points from the same field. Grid sampling increased the P rate recommended by an average of 51 percent. **Table 1** shows how the average soil test level for the field and field variability influenced the magnitude of the difference between these soil sampling approaches. For these 140 fields:

- Grid sampling **never** decreased the amount of P recommended.
- The largest increase occurred when the field average soil test was near the level where the recommendation dropped to zero (between high and very high).
- As field variability increased, the increase in P recommended due to gridding increased.

Ontario research indicates that a similar recommendation/gridding relationship may exist for K. Their studies show that field variability increases the optimum K rate compared to standard recommendations developed from uniform small plot calibration. The increase in K rates becomes larger as field variability increases and as the average soil test level for the field approaches the point where the recommendation drops to zero. Refer to the article on page 20 of this issue.

Gridding and Yield Potentials

How does grid sampling reveal hidden yield potential? Table 2 shows the results of a grid-sampled field from central Iowa where the data are summarized by soil mapping unit. Even though past yields varied little among mapping units, soil test levels were quite variable. Soil test calibration data for pH, P and K suggest that some soils were yielding at only 73 percent of their potential and that the field as a whole was at 88 percent of its potential. These limiting factors could not be identified without a site-specific management approach based on grid sampling.

The field average soil test levels that would be measured with conventional soil sampling are shown at the bottom of **Table 2**. Calculating the field yield potential from these average soil test levels suggests

Table 2. Soil test levels and relative yields in a central Iowa corn field.

Soil	pH	Current levels P,ppm	Current levels K,ppm	Relative yield,%
Clarion	5.5	16	95	78
Nicollet	5.2	22	91	73
Canisteo	7.4	17	168	97
Webster	6.3	37	134	98
Field averages	6.5	20	134	88

USDA Soil Tilth Laboratory

that the field is currently at 96 percent of its potential rather than 88 percent as shown in **Table 2**. Unrealized yield potential is hidden by the averaging effect of conventional soil sampling.

Yield records collected by soil type can be combined with the relative yields from **Table 2** to generate an estimate of the true yield potential for the field, as shown in **Table 3**. In this case, the field yield potential is estimated to be 173 bu/A if pH, P and K are removed as limiting factors using site-specific management techniques. This represents an increase of 16 bu/A over conventional methods, based on field average soil test levels (151 bu/A ÷ 0.96 = 157; 173-157=16).

Soil fertility is often more variable than expected. For example, a private consulting firm reports in the article on pages 24 and 25 of this issue of *Better Crops* that 86 percent of nearly 400 grid sampled fields in southern Minnesota had 4 or 5 soil test P categories present in the field; 61 percent had 4 or 5 soil test K categories present (categories were very low, low, medium, high, very high). The monetary benefit of recognizing that kind of variability in management programs can be substantial.

Table 3. Estimated corn yield potentials after soil test correction.

Soil	Past yield, bu/A	Relative yield,%	Yield potential, bu/A
Clarion	145	78	187
Nicollet	151	73	208
Canisteo	154	97	159
Webster	147	98	151
Field	151	88	173

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PPI Announces T.W. Bruulsema as Director for Eastern Canada and Northeast U.S.

DR. THOMAS W. BRUULSEMA is joining the staff of PPI as Eastern Canada and Northeast U.S. Director. He will be responsible for the agronomic research and education programs of the Institute in the region, beginning in December 1994.

Dr. T.W. Bruulsema

"We are proud to welcome Tom Bruulsema to the organization," said Dr. David W. Dibb, President of PPI. "He has excellent credentials as an agronomic scientist and proven skills in working with people."

A native of Ontario, Dr. Bruulsema was active in the operation and management of his home farm for several years during high school. In 1983, he graduated with distinction from the University of Guelph with a B.Sc. in agriculture, then completed his M.Sc. in crop science in 1985.

From 1986 to 1990, Dr. Bruulsema and his wife, Elizabeth Anne, worked as volunteers in Bangladesh . . . he as a research agronomist, she as a family nutrition advisor.

After returning to North America, Dr. Bruulsema studied and conducted research from 1991 to early 1994 at Cornell University. Following completion of requirements for his Ph.D., he moved to the University of Minnesota. As a Research Associate studying fertility management of soil spatial variability, he worked with Dr. Gary Malzer.

In his new responsibility, Dr. Bruulsema will direct PPI programs in the Canadian provinces of Ontario, Quebec, New Brunswick, Nova Scotia, Prince Edward Island, and Newfoundland. His region will also include Pennsylvania, New Jersey, New York and the New England states.

Dr. Bruulsema will be located at Guelph, Ontario. He and his wife have two young children. ■

Site-Specific Management . . .

Site-Specific Management of P and K Offers Many Benefits

Its easy to get excited about appropriate, site-specific approaches to P and K management. Clearly, the benefits will be greater for some landscapes and crop rotations than others and all the questions have not yet been answered on how to optimize the benefits. However, this new style of management offers great promise to the future of crop production.

Farmers benefit through greater profits and improved efficiency of all inputs. Properly *managing* variability instead of ignoring it means more profit. Higher yields from the acres that were being underfertilized and reduced input costs from the acres that were being overfertilized translate into profit potential. The more variable the fields, the greater the profit increase will be.

Fertilizer dealers benefit by marketing more services and sometimes even more fertilizer.

Rural communities benefit from circulation of additional dollars and from the creation of new jobs in this intensive approach to crop management.

General public benefits from a more efficient food production system that has a reduced potential for surface and groundwater impacts. ■

Grid Soil Sampling

By N.C. Wollenhaupt and R.P. Wolkowski

Site-specific nutrient management depends on a sound inventory of soil nutrient availability. Some suggestions are presented for a workable grid soil sampling procedure to support more precise nutrient management.

SITE-SPECIFIC nutrient management for crop production begins with an inventory of soil test nutrient levels in a field. Fertilizer recommendations are based on expected response to fertilizer application as a function of soil test levels. Therefore, site-specific fertilizer applications can be no better than the accuracy of the soil test map from which the fertilizer recommendations are based. Precision usually increases as fields are divided and sampled as smaller areas.

The common approach to achieve systematic soil sampling is to overlay a square or rectangular grid on a map or photograph of the field, identify and drive to the middle of each grid cell, and collect a soil sample at that point (**Figure 1**). The soil sample consists of several soil cores collected within a small radius of the cell center. The soil cores are composited and bagged as one soil sample for analysis at a soil testing laboratory. The purpose of compositing several cores is to average or "bulk" out variability in soil test properties that occurs over small distances.

Grid cell sampling can be efficiently conducted by counting crop rows and using distance measuring devices to locate sampling points. While easy to implement in the field, this practice can lead to bias. Tillage, fertilizer application,

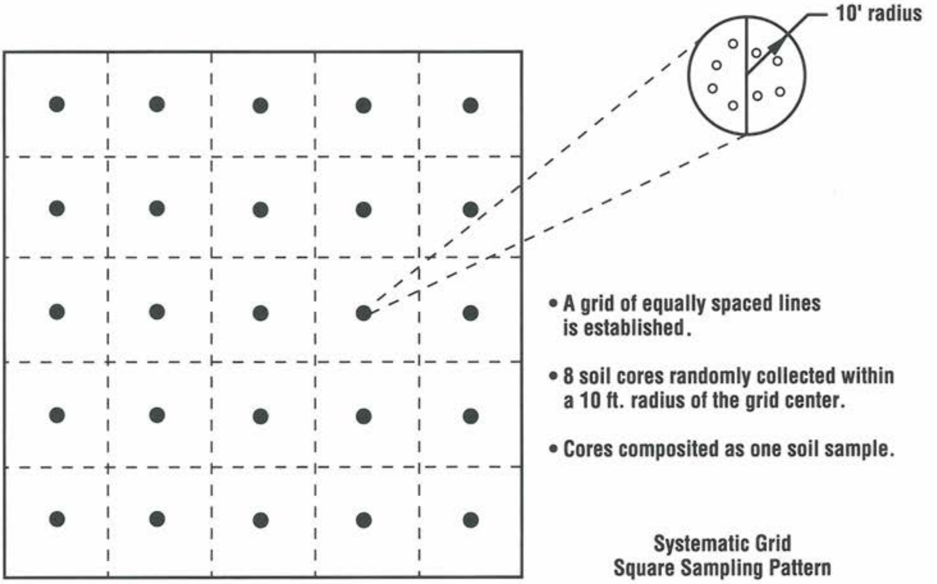

Figure 1. Schematic showing the layout of a square grid and locations where soil cores would be collected.

The authors are with the Department of Soil Science, University of Wisconsin, Madison.

Systematic Grid - Diamond Sampling Pattern

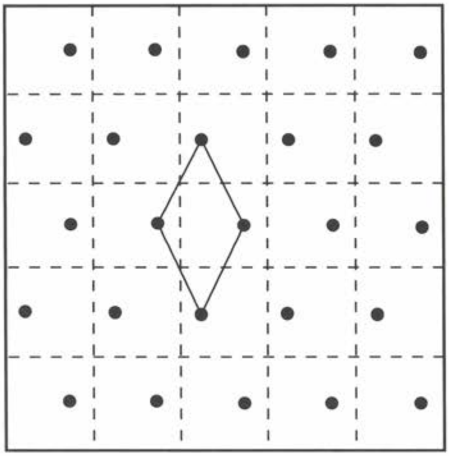

Figure 2. Modification of a square grid where alternating rows of sample points are shifted one half the distance from the cell center and edge.

Systematic Unaligned Grid

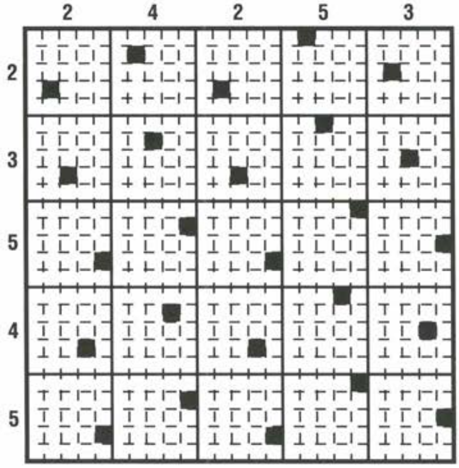

Figure 3. Schematic showing the layout of a systematic unaligned grid. The x,y coordinates were determined from a random number table.

drainage, old field boundaries and cropping patterns tend to occur in regular patterns across fields. If the grid sampling pattern is a multiple or fraction of other patterns, the soil samples may not correctly represent the soil test variability within the field.

The potential for bias can be minimized by shifting the sampling locations to the right or left of the cell center in alternating rows perpendicular to the management pattern (e.g. row direction). The resulting sampling grid takes on the appearance of a diamond pattern (**Figure 2**). This sampling pattern can also be implemented by counting rows and measuring distances.

With the development of the Global Positioning System (GPS), we can now navigate to locations in a field without counting rows or physically measuring distance. As farm level GPS hardware and software become available, we recommend adopting a **systematic unaligned** sampling protocol. This method combines the best of systematic sampling and random sampling.

Systematic unaligned sampling locations as illustrated in **Figure 3** can be determined for a field by the following procedure (adapted from R. Webster and M. A. Oliver, "Statistical Methods in Soil and Land Resource Survey, Oxford University Press", 1990, pp 46-47).

- Divide the field into cells by means of a coarse grid. Square cells are the norm but not mandatory.
- Superimpose a finer grid (reference grid) in each coarse cell. For example, if there are 5 rows and 5 columns in the coarse grid, you might choose to divide each coarse cell into 25 smaller cells.
- Choose a corner of the coarse grid, say top left, and randomly select a reference cell–in this example, one of the 25 reference cells.
- Move horizontally to the next coarse cell in the top row and keep the X coordinate the same but randomly select a new Y coordinate.
- Repeat the process for all the coarse cells in the top row.
- Return to the upper left corner and repeat the process down the first column

(continued on page 9)

Costs Associated with Variable Rate Phosphorus and Potassium Applications

By N.C. Wollenhaupt and R.P. Wolkowski

SOIL SAMPLING, fertilizer application and data management are costs associated with variable rate application of phosphorus (P) and potassium (K) fertilizers. These costs must be subtracted from any change in gross returns attributed to variable rate (VR) fertilizer application in order to evaluate VR profitability.

Initial grid soil sampling is a substantial cost associated with site-specific fertilizer management. Grid soil sampling studies conducted in Wisconsin show that soil test map accuracy depends on sampling method and sampling density. Soil sampling points in a field on a systematic grid improve mapping accuracy over sampling cell areas on a grid. Increasing the number of sample points also improves mapping precision.

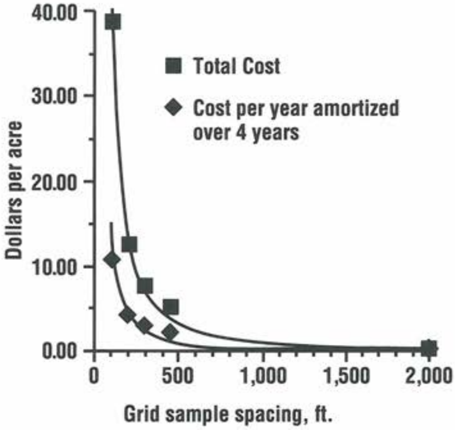

Figure 1. Costs associated with variable rate P and K applications. Soil sampling and soil testing costs increase with a decrease in grid spacing.

The costs in **Table 1** are based on the authors' experiences and limited data shared by fertilizer and fertilizer equipment dealers. Labor was billed at $25.00 per hour and soil testing at $6.00 per soil sample. Our goal was to develop a cost estimate that included a profit margin for the fertilizer dealer and/or crop consul-

Table 1. Variable-rate soil sampling, fertilizer application, and data management costs.[1]

	Grid spacing			
	450 ft. (=5 acres)	300 ft. (=2 acres)	200 ft. (=1 acre)	100 ft. (=0.25 acre)
	$/acre			
Sampling				
2 hr (20 samples)	$1.70	–	–	–
5.7 hr (48 samples)	–	$4.29	–	–
10.9 hr (106 samples)	–	–	$9.09	–
36 hr (436 samples)	–	–	–	$35.16
Data summary and mapping	$2.00	$2.00	$2.00	$ 2.00
Fertilizer application (additional variable-rate charge)	$1.50	$1.50	$1.50	$ 1.50
Total Cost	$5.20	$7.79	$12.59	$38.66

[1] 100-acre field with labor @ $25.00/hr and soil testing @ $6.00/soil sample

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tant, and soil testing laboratory. Note the fertilizer application charge is annual and represents the additional charge for variable rate application versus use of a single rate applicator.

Costs associated with variable rate P and K applications increase rapidly at grid spacings smaller than 200 feet (**Figure 1**). The costs are easier to accept if they are amortized over a period of four years or longer. We speculate that intense (expensive) grid sampling is required only once if soil test information, fertilizer applications, and crop removals (yield) are georeferenced so that a nutrient balance budget can be maintained. Additional soil sampling at a later date may be needed in fields with contrasting soil types (textures) where the general fertilizer response function may not apply equally well to all soil types or to spot check for changes in soil test levels.

One cost not shown is mis-application of fertilizer based on random soil sampling which can lead to an incorrect map of soil test variability. We have observed yield and income losses when soils were classified as not needing additional fertilizer when in fact they were nutrient deficient. Any assessment of the profitability of variable rate fertilizer application must also include an evaluation of the effects of soil test map accuracy. ■

Grid Soil Sampling . . . from page 7

of cells, this time keeping the Y coordinate the same, but changing the X coordinate in each successively lower coarse cell.

- The remaining positions are determined by the X coordinate of the point in the left-hand square of its row and the Y coordinate of the point in the uppermost square of its column.

With this procedure a constant interval both along the rows and down the columns is maintained without alignment. A more complete discussion on sampling and estimation can be found in the reference by R. Webster and M. A. Oliver cited on page 7. ■

Note: Soil sampling for variable rate application is different from soil sampling to determine the field average for a single rate application. Many Extension soil sampling guidelines for field-average recommendations call for dividing fields into smaller areas (five acres according to UW recommendations), but it is recommended that the soil cores within small areas be collected while walking a zigzag pattern across each area. The intent is to obtain a representative soil sample which averages out soil test variability within each small field area. An average or median value is calculated from the multiple soil test results to arrive at a single rate fertilizer application for the field.

Illinois

Nutrient Management with Intensive Soil Sampling and Differential Fertilizer Spreading

By D.G. Bullock, R.G. Hoeft, Paul Dorman, Ted Macy and Ron Olson

Managing plant nutrients within field boundaries is gaining interest as a result of growing environmental concerns about water quality, narrow profit margins for farms and new fertilizer equipment which can adjust fertilizer rates on-the-go within a field.

MOST FARMERS recognize variations in soil texture, color and/or productivity within fields. Soil type variations affect crop productivity and the amount of nutrients removed from each area of the field. In addition to natural differences in soil fertility, soil nutrient availability may vary within fields as a result of manure applications that covered parts of the field or concentrated in specific areas. The shape of the field, including contour strips and uncrossable waterways, can also impede uniform fertilizer applications.

Illinois soil test sampling procedures call for one soil sample to represent an area no larger than 2.5 acres, and suggest that areas within a field of varying soil types or representing different past management histories be sampled separately. However, the results are then averaged and one fertilizer grade is prepared and spread over one or several similar fields. The net result is that some areas within a field receive more nutrients than are required for optimum crop yields, while in other areas nutrients may remain limiting to crop production. Neither situation is economically or environmentally desirable.

Scientists who map soils have long recognized that soils vary spatially across a landscape. Only recently has it been possible to describe this spatial variation numerically through the use of an emerging field of study called geostatistics. The

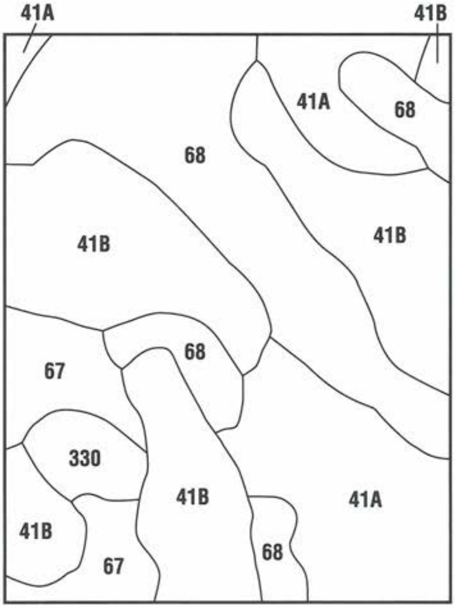


Figure 1. Soils map for one field site.

LaSalle County, IL; 32 acres; scale 300 ft/in.

Soil Summary

	Soil Type	Acres	--- Yield --- Corn	Beans
41A	Muscatine silt loam, 0-2% slope	6.6	167	51
41B	Muscatine silt loam, 2-4% slope	12.1	165	50
67	Harpster silty clay loam	2.6	136	44
68	Sable silty clay loam	9.7	156	51
330	Peotone silty clay loam	1.0	123	42
			159	50

Dr. Bullock is Associate Professor and Dr. Hoeft is Professor, Department of Agronomy, University of Illinois. Mr. Dorman is Field Agronomist and Mr. Olson is President, Top-Soil Testing Service; Mr. Macy is with Applications Mapping, Frankfort, IL.

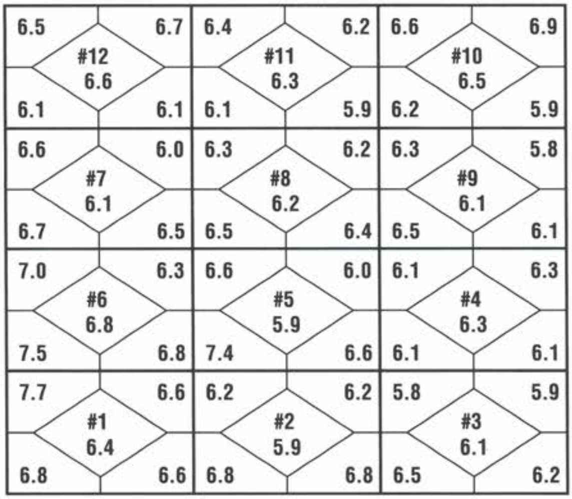


Figure 2. Soil pH distribution, 2.5 acre and 0.6 acre grids. The larger rectangular areas represent 2.5 acre grids in a field, each identified by a number in the center and a soil test value. The other numbers within each rectangle are values for four 0.6 acre grids.

Weighted Field Average = 6.3 for 2.5 acre grids, 6.4 for 0.6 acre grids

Recommendation:		For 2.5 A grids	For 0.6 A grids
> 6.7	Avoid Limestone	2.7 acres	5.9 acres
6.3-6.7	No Limestone Needed	13.2 acres	12.6 acres
5.9-6.2	2 tons/acre	16.1 acres	12.1 acres
5.6-5.8	3 tons/acre	0.0 acres	1.3 acres

challenge we face is how to use geostatistics to help generate soil test nutrient availability maps that can be used with confidence as a correct representation of actual field conditions. We need to know what geostatistical procedures are best suited for creating nutrient management maps. A second need is to evaluate whether managing nutrients within a field is cost effective and environmentally sound.

Illinois Studies

Eight sites in a corn/soybean rotation were selected for study. Field soil sampling was conducted on 2.5 and 0.6 acre bases in a fixed grid at each site. At grid intersection points, 8 cores located within a 10 foot radius were composited to represent the sample point. Kriging was conducted on the 2.5 and 0.6 acre grid sets as well as the combination of the two sets (i.e. five points for each 2.5 acre area). Soil test analyses were performed on each sample including phosphorus (P), potassium (K), pH and organic matter.

Soil test data are being used to create single nutrient maps. The individual nutrient information will be used to develop fertilizer management maps. Each cooperating farmer is also equipped with yield monitoring equipment. Detailed yield maps have been constructed for each site.

Results

This study has demonstrated that grid size can, but does not always, make a substantial difference in soil test results. One site of 32 acres, shown in **Figure 1**, consisted of Muscatine silt loam 0-2 percent slope (6.6 acres), Muscatine silt loam 2-4 percent slope (12.1 acres), Harp-

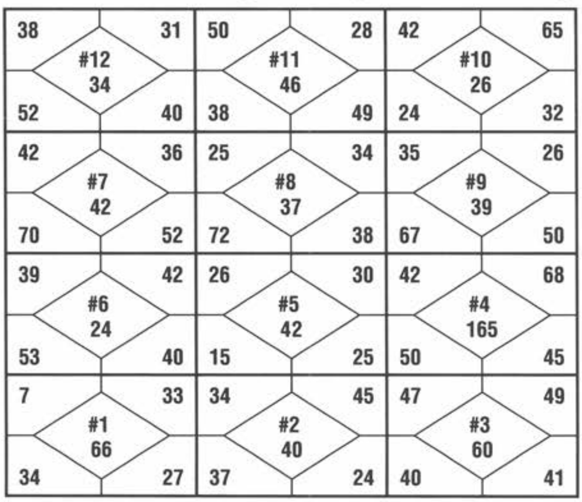


Figure 3. Soil P distribution, 2.5 and 0.6 acre grids.

Weighted Field Average = 52 for 2.5 acre grids, 40 for 0.6 acre grids

Recommendation:		For 2.5 A grids	For 0.6 A grids
> 99	Excessive	2.7 acres	0 acres
60-99	Maintenance	5.3 acres	3.3 acres
36-59	Build-up	16.1 acres	16.7 acres
< 36	Low	7.9 acres	12.0 acres

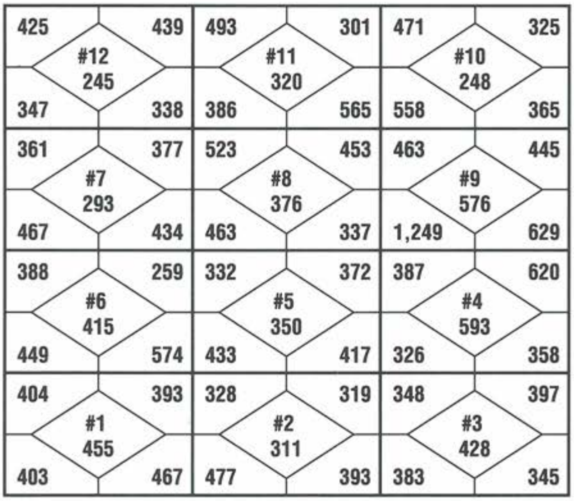


Figure 4. Soil K distribution, 2.5 acre and 0.6 acre grids.

Weighted Field Average = 385 for 2.5 acre grids, 433 for 0.6 acre grids

Recommendation:		For 2.5 A grids	For 0.6 A grids
> 499	Excessive	5.4 acres	4.7 acres
400-499	Maintenance	7.9 acres	11.2 acres
240-399	Build-up	18.6 acres	16.1 acres
< 240	Low	0.0 acres	0.0 acres

ster silty clay loam (2.6 acres), Sable silty clay loam (9.7 acres), and Peotone silty clay loam (1.0 acre).

Soil pH. Figure 2 shows how pH values for the 0.6 acre grids compare to that for a 2.5 acre grid. In most cases, the mean of the four 0.6 acre grids is similar to the value for the 2.5 acre grid, but there are exceptions. For example, 2.5 acre grid #5 provided a pH estimate of 5.9 while the four 0.6 acre grids within it had pH values ranging from 6.0 to 7.4 and a mean pH estimate of 6.7. Recognition and mapping of such small-scale variation offers the potential for increased productivity and profit via site-specific application. It is also of interest to note that the weighted field averages are similar (6.3 vs. 6.4). The additional soil sampling would not have changed liming recommendations if the field is treated as a unit.

Soil P. Soil analysis for P demonstrated similar small-scale variability. Differences between the 2.5 and 0.6 acre grid sampling systems were larger than those for soil pH. For example, 2.5 acre grid #1 (**Figure 3**) had a soil P value of 66 while the four 0.6 acre grids within 2.5 acre grid #1 had soil P values of 34, 27, 7 and 33. Even more striking is 2.5 acre grid #4 which had a soil P value of 165. It was two to three orders of magnitude greater than the four 0.6 acre grids within that portion of the field. The field averages are not similar (52 vs. 40), and this difference is very much due to the soil P value of 165 reported for 2.5 acre grid #4. If grid #4 is deleted, the 2.5 acre grid systems provide a weighted field average similar to that of the 0.6 acre grid system (41 vs. 40).

Soil K. Soil analysis for K demonstrated small-scale variability and an increase (433 vs. 385) in the weighted field K average when 2.5 acre grids and 0.6 acre grids were compared (**Figure 4**). This increase was largely due to an exceptionally high cell in one 0.6 acre grid, which had a soil K test value of 1,249. This was at least twice as high as any other cell in the field and over twice as high as 2.5 acre grid #9, which represents the same part of the field. If that large value is excluded, the weighted field averages are much closer (385 vs. 416) although they fall in different recommendation categories. The soil K value of 385 from the 2.5 acre grids would have resulted in a recommendation for a build-up program while the soil value of 416 from the 0.6 acre grids would have resulted in a recommendation for only a maintenance K application.

Summary

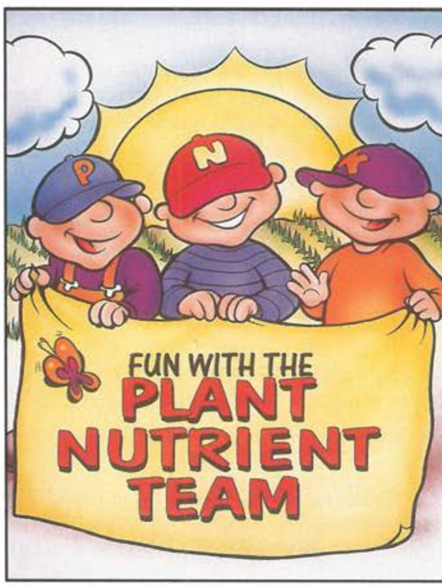
These results should not be interpreted to discredit current soil sampling techniques. They do indicate that more intensive soil sampling provides a different picture of a field than do conventional sampling procedures. More work remains to be done in using intensive grid sampling for more efficient mapping, improved fertilizer recommendations and increased profitability, but the potential certainly appears to be present and reasonable. ■

FUN WITH THE PLANT NUTRIENT TEAM

AN EDUCATIONAL activity book for use in kindergarten through third grade is now available. The book, a project of PPI and FAR, encompasses information about the importance of plant nutrients and basic concepts of food and fiber production.

"Because so many children today don't grow up on farms, they may not realize how plants grow and where food and fiber products originate," said Dr. David W. Dibb, President of PPI. "Our challenge was to produce an activity book that will be entertaining but also educational for young children. We believe we have met the challenge with *Fun with the Plant Nutrient Team*."

The 24-page book features nitrogen (N), phosphorus (P) and potassium (K) as characters in a variety of activities such as dot-to-dot, word puzzles, coloring, mazes, matching pictures and experiments. Principles such as soil conservation and science as part of modern agriculture are included.



Fun with the Plant Nutrient Team can be purchased for $1.00 per copy, plus shipping/handling. A teacher's guide with additional information, experiments, facts and resources is also available on request.

To order, contact: PPI, Circulation Manager, 655 Engineering Drive, Suite 110, Norcross, GA 30092-2821. Phone 404-447-0335. Fax 404-448-0439. ■

Site-Specific Nutrient Management Systems for the 1990s

By H. F. Reetz, Jr.

Space-age technology is providing some important tools for farmers, with the help of their various suppliers and advisers, to meet the challenges of the 1990s and beyond. With new technology now available, farmers should be developing record systems and management plans for each of their fields that include site-specific referencing of variability within the field.

PROFITABLE AND ENVIRONMENTALLY SOUND nutrient management planning may be enhanced by managing within-field variability. Site-specific nutrient management planning involves recording yield, soil test and soil properties with a precise description of the location within the field where the data were collected (geo-reference). Nutrient applications are varied based on maps that are created from geo-referenced records of soil test values, soil yield potential, previous yield histories and nutrient applications that can be coded into the computerized record keeping system.

New computer software allows the geo-referenced records to be analyzed and displayed as management maps. Computers use the maps to automatically change fertilizer rates and blends during application.

The Tools

- **Computerized records** form a data base of information about cropping history, nutrient applications, and soil tests for individual fields. Each record is identified within a field by specific coordinates.
- **Computer software called geographic information systems (GIS)** provides a means of graphically presenting, analyzing and interpreting the data, linking management information and records to specific points within a field.
- **The Global Positioning System (GPS)** of earth-orbiting satellites, established by the U.S. government, allows field operations and measurements to be precisely located within an area during the operation (real time).

The Applications

- **Using GPS technology** to pinpoint soil sample sites on a grid basis, soil test maps (through GIS) can be generated that then serve as the basis for GPS-guided variable rate nutrient application.
- **Pesticide application** can also be guided with GPS capability to fit rates to soil types and to specific pest trouble spots in the field.
- **Portable electronic scouting** tools allow instant on-site analysis of soil and crop nutrient status to aid in identifying management problems in the field.
- **Electronic communication systems** permit ready access to suppliers, advisers, and other information sources to provide support services and reduce down-time during critical seasons. Cellular phones, fax machines, satellite and phone-modem communications are becoming common farm "tools". Hand-held, pen-based and voice-activated computers will soon be common tools in the field.
- **On-the-go yield monitors** allow the collection of site-specific yield data during harvesting. The yields can be displayed and/or stored for later analysis, including the creation of yield maps. Furthermore, GIS applications can be used to create map overlays, which will permit the study of relationships between yield and other mapped attributes such as soil

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type, soil fertility, weed populations, drainage and other factors.

This description of tools for the high-tech farm of the future is built around technology and services that are available today. The technology costs are falling rapidly and are economically viable in many farming operations. New developments and refinements could further reduce costs and increase technology applications. But the technology will be useful only to those who make a commitment to begin the detailed monitoring and record keeping system necessary to build a farm data base.

How to Start

Begin a computerized record keeping system. Select a software package that will allow you to organize and link your field data with precise locations within the field. Select a position referencing system such as latitude - longitude or state plane coordinate system to spatially link all records. Soil test information, nutrient application, and yield records referenced to specific locations within a field are important components of the field records. Additional information from photographs and other maps can be digitized into the record keeping system as the availability of time and technology permits.

Investigate GIS computer software packages that can analyze and display your geo-referenced field data as maps. You may choose to work with a consultant or adviser in analyzing your computerized records to develop site-specific interpretations for individual fields. Farm level GIS applications are rapidly evolving with several companies developing farm level applications for sophisticated GIS packages currently used in research and education.

Collecting Soil Samples

Sample collection is the most critical part of soil testing for developing variable rate fertilizer application maps. Research is underway on how to optimize sampling for various combinations of soil properties, cropping systems, and fertilization/manuring histories. For example, it is likely that sampling requirements in the unglaciated Great Plains where neither manuring nor fertilizing has been done extensively will be less intensive than in the heart of the Corn Belt.

Research in Wisconsin and Illinois has resulted in the following sampling suggestions.

Soil Sample on a Systematic Grid Pattern

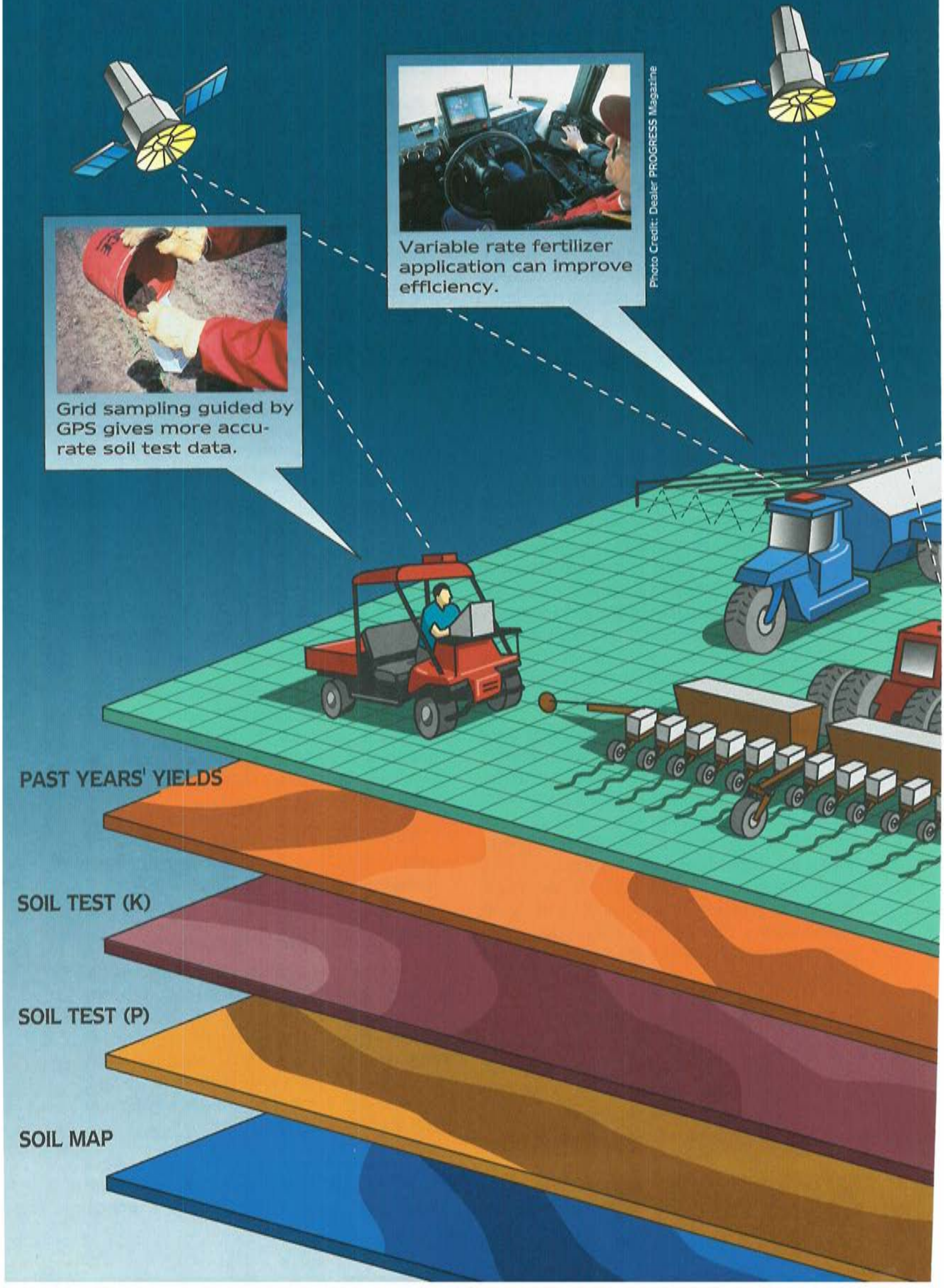
- Overlay the field with a grid.
- For the initial sampling, each grid cell should be no larger than 1 acre unless the field has a history of high soil test values and fertilizer applications in excess of normal crop removal. In the latter case a 2 acre cell may be acceptable. Be prepared to sample portions of the field on a finer grid if responsive sites are identified with the first sampling pass.
- Future sampling of the field may be done using a larger grid size or by nutrient management areas, depending on the outcome of the initial sampling.
- Locate the sample point by counting rows and measuring distances, or preferably navigate to the point using GPS.
- Taking samples in straight rows across the field may be biased by previous management such as fertilizer application patterns. A systematic but unaligned pattern may be a better choice, especially if GPS-referencing is available.
- Collect at least 5 to 8 soil cores for each grid cell, taking the cores from within a radius of 10 feet of the sample point.

Sample at a Uniform Depth

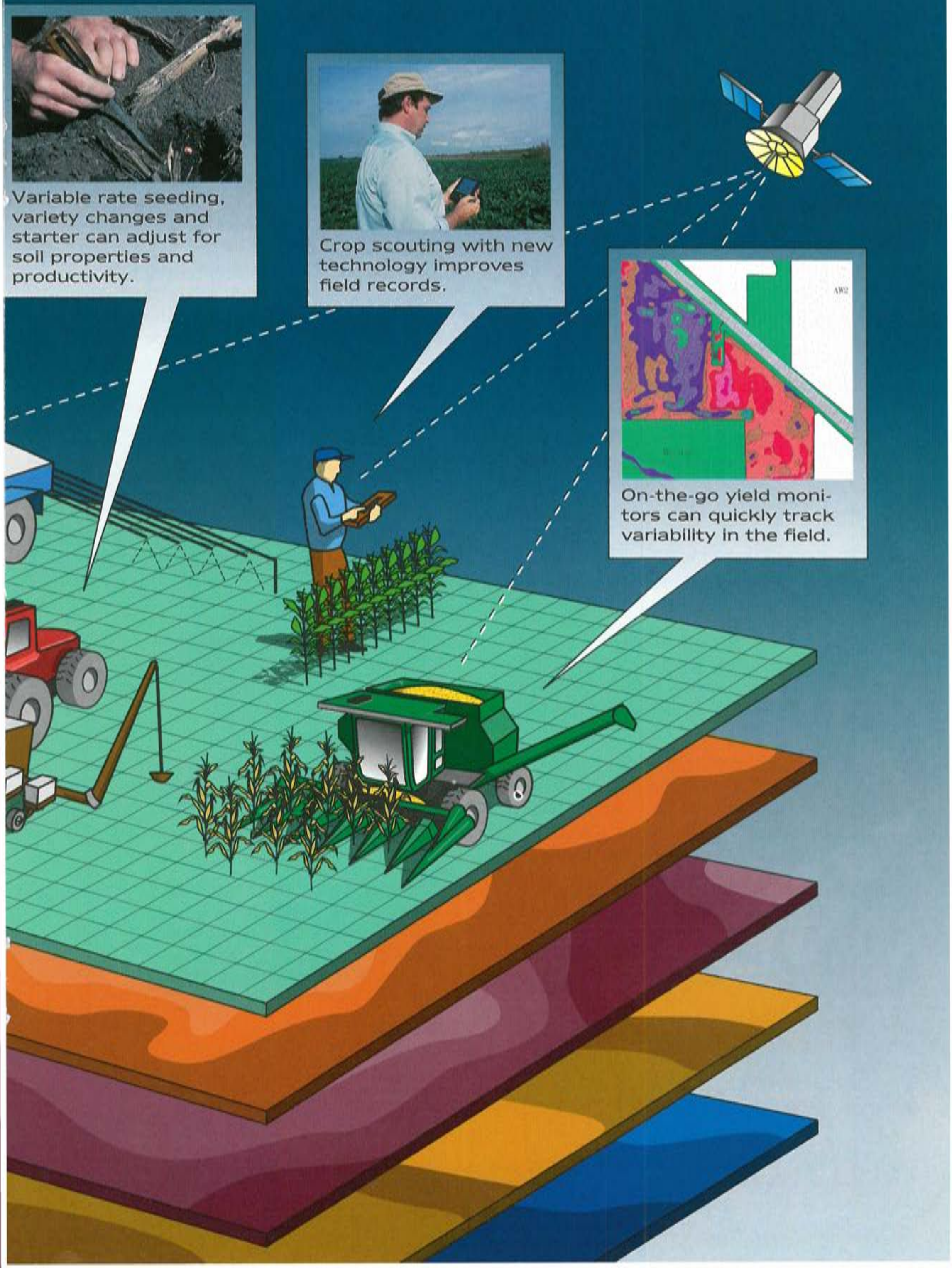
Soil tests are usually calibrated on the basis of an acre furrow slice, approximately 2 million pounds of soil. Check with the analytical lab for its recommendation on sampling depth, because some labs use their own calibration data set that is based on a sampling depth different from the 6⅔-inch standard.

For no-till fields, consider collecting a set of samples at the standard depth and another set to represent the top 2 inches.

HIGH-TECH TOOLS FOR SITE-SPECIF



IC CROP NUTRIENT MANAGEMENT



This will help identify stratification of nutrients, and is especially important for pH determination.

Site-Specific Nutrient Management Action Plan

A goal of every farmer should be to develop a strategic plan that works toward detailed, site-specific nutrient management:

- Make a commitment to keep accurate, detailed records of production inputs and yields for each field, including variability within the field.
- Begin collecting soil test, nutrient application and crop yield data on a grid basis. Identify each sample with its exact location in the field. Use GPS location-referencing if possible.
- Analyze records and develop a nutrient management plan that takes into account the variability within a field. Use spot spreading or variable rate application where appropriate.
- Measure yields for each field. Using on-the-go yield measurement to develop a yield map of each field is even better. Individual field yield records are a good starting point, but yield variation across the field must be measured to get an accurate check on response to site-specific management.
- Continue to add information each year and begin more detailed analysis of the records to refine the site-specific nutrient management plan. Even though the level of detail of different data sets will vary, each point in the field can be associated with each data set if all of the

Implementing Site-Specific Management

Present Plan	Future Enhancements
Accurate, detailed records of all inputs and yields for each field, with spatial referencing for any variable rate applications.	Computerized data base of multiple-year records for each field.
Detailed soil sampling . . . preferably on an organized pattern, spatially referenced so samples can be related from one year to another.	GPS-referencing of each sample location, to be correlated with soil survey, fertilizer application and yield maps.
Spot-treat or double spread parts of the field to account for variability in soil test and yield potentials. Reference variable locations on application records.	GPS-guided, variable rate nutrient application related to soil test and yield records and other data mapped with GIS techniques.
Individual field yield records based on actual scale weights or weigh-wagon strip tests. Note areas of the field with obviously high or low yields.	GPS-referenced, on-the-go yield measurement to provide a detailed yield map of each field. Yield monitoring may be the most important starting point in building a site-specific management system.
Adjust the nutrient management plan according to the records and samples collected.	Build on the detailed crop record data base and utilize geostatistical analysis and various management decision aids to refine site-specific nutrient management plans for each field.

records are properly geo-referenced. As technology improves, some data sets can be replaced with more accurate or more detailed data sets for the same parameters.

Nutrient Management Plan

Every field should have a nutrient management plan that integrates the information from all sources of data available for the farm. The plan should integrate the specific experience, preferences and goals of the farmer. Yield goals should be realistic and profitable, but also progressive. Assessment of potential environmental impact and compliance with applicable regulations should be a part of the plan.

Plans should be written out in detail, with appropriate supporting records and other information.

Nutrient management plans should include proper credits for previous crops, manure, sludge or industrial by-product applications. Consider all of the nutrient resources available and select the best combination for each field. Good nutrition may be expensive, but **inadequate** nutrition may be even more costly in terms of **lost yield potential . . . and lost profits!**

Start Now–Build for the Future

A site-specific nutrient management system begins with a commitment to develop a good record keeping system that will document the past and help plan the future management practices and crop responses. Other components, including yield monitoring, grid soil sampling, and variable rate fertilizer application, can then be added as best fits the management and economics of the operation.

To begin the process requires no major capital investment of specialized equipment. Computers and satellite-based positioning systems may be important tools in the long run, but they are of little value until the basic management strategy is established. Much can be done to implement site-specific management, even before new technology is added. The important step is to make a commitment and get started with accurate, detailed records and careful attention to management details.

Impact on Recommendations

Where nutrient management has been based on field average soil tests and fertilizer applications have followed the soil test results, moving to site-specific application based on detailed sampling will often result in increased fertilizer rate recommendations, or at least redistribution of rates within the field. This is because high-testing areas of the field overshadow low-testing areas when computing the field average soil test.

Site-specific nutrient management is not designed to remove variability in the nutrient levels in the field, but rather to capitalize on the inherent variability and build soil tests in more productive areas of the field and reduce fertilizer application in the less productive areas. Ultimately, that should lead to the most agronomically sound, economically efficient, profitable and environmentally responsible nutrient management plan for each field. ■

New Brochure– Site-Specific Nutrient Management Systems for the 1990s

A COLORFUL eight-panel brochure which presents the high-tech information featured in the article "Site-Specific Nutrient Management Systems for the 1990s" will be available soon from PPI.

If you would like further information regarding this brochure, pricing and availability, please contact the PPI Circulation Department, 655 Engineering Drive, Suite 110, Norcross, GA 30092-2821; phone (404) 447-0335, fax (404) 448-0439. ■

Field Scale Fertilizer Recommendations and Spatial Variability of Soil Test Values

By R. Gary Kachanoski and Gordon L. Fairchild

Often farmers and crop advisers indicate that economical response to fertilizer application occurs at soil test levels higher than what is indicated by soil test calibration research. In this article, Ontario researchers explain why this might happen.

IT IS WELL KNOWN that many fields have significant spatial variability of soil fertility. This is the basis behind the development of technology to spatially vary the application rate of fertilizer within a field. However, a majority of fields still have a single rate of fertilizer applied evenly across the field. Soil test calibration relationships (i.e., recommended fertilizer rate versus soil test values) are used to obtain the recommended fertilizer rate from a soil test on a composite soil sample from the field.

Research has shown that the relationship among yield response, applied fertilizer, and soil test levels is highly non-linear. In other words, yields increase with increased fertility up to some level, after which they remain constant. Unfortunately, there are significant problems with estimating spatial averages of non-linear relationships.

Spatial Variability and Response

Suppose you have two fields (Fields 1 and 2) as given in **Table 1**. Both fields have the same **average** soil test value of 23, but three areas within each field have different soil test values. Note that the only difference between the two fields is the relative proportion of each of the three areas. The average soil test is obtained from the sum of the value of the soil test in each of the different areas multiplied by the proportion of the field occupied by each area. This average soil test would be equal to the average soil test from a composite soil sample taken from the field.

It is assumed that a relationship between maximum yield gain from applied fertilizer and soil test exists and is known. It is also assumed that no additional response occurs above a soil test of 30. The values of the yield increases from soil test values of 20 and 10 are assumed to be 16 bu/A and 48 bu/A, respectively. The average maximum yield gain for each field is calculated from the maximum yield gain in each of the three areas with different soil test values multiplied by the proportion of the field occupied by each area. This average yield gain would be the

Table 1. An example of the spatial scaling problem.

	Field 1			Field 2		
Field area	% of field	Soil test, ppm	Crop response, bu/A	% of field	Soil test, ppm	Crop response, bu/A
1	50	30	0	20	60	0
2	30	20	16	30	20	16
3	20	10	48	50	10	48
Average		23[1]	14[2]		23[3]	28[4]

[1](0.5 x 30) + (0.3 x 20) + (0.2 x 10) = 23.
[2](0.5 x 0) + (0.3 x 16) + (0.2 x 48) = 14.
[3](0.2 x 60) + (0.3 x 20) + (0.5 x 10) = 23.
[4](0.2 x 0) + (0.3 x 16) + (0.5 x 48) = 28.

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yield increase obtained from the entire field (machine harvested yield).

The average maximum yield increase possible from applied fertilizer is 14 bu/A in Field 1 compared to 28 bu/A in Field 2, even though both fields have the same average soil test value and the same yield response for a given soil test level within the fields. The different average yield responses of the two fields is caused by the non-linear relationship between soil test and crop yield response. If yield response decreased linearly with increasing soil test values then both fields would have the same average yield increase. The sharp non-linear change in yield response near the critical value is the main cause of the spatial averaging problem. Since many . . . perhaps all . . . nutrient calibrations have similar yield response relationships, the problem is widespread.

Examples from Ontario

In this study, equations were developed to describe the average field yield increase from fertilizer applied evenly to the whole field in a field with variable soil fertility. Mathematical and verbal descriptions of the process used are given in *Nutrient Management on Highly Productive Soils*, PPI/FAR Special Publication 1994-1.

Although generalized equations were developed, the illustrations used here are for nitrogen (N) and potassium (K) for corn in Ontario.

The relationship between optimum fertilizer N rate and soil nitrate levels at planting time is given in **Table 2** for different levels of variability. The column labeled "Low" is the calibration curve for fields with zero variability. This column is similar to calibration data reported by researchers in the humid north-central areas of the U.S. As variability of a field increases, the optimum rate of N fertilizer also increases. The largest increase in fertilizer rate occurs at the soil test level where the optimum rate drops to zero when no variability exists, 100 in this example.

Table 2. Influence of soil nitrate variability on optimum N fertilizer rate.

Average soil nitrate-N	Soil nitrate variability[1] Low[2] (0)	Med. (30%)	High (53%)
lb/A to 2 ft.		N, lb/A	
35	131	142	146
50	97	128	137
100	0	23	75

[1]Value in parentheses is the coefficient of variability.
[2]Standard recommendation of Univ. of Guelph.

The impact of spatial variability on optimum phosphorus (P) and K fertilizer rates was similar to the previous results for N. Optimum K fertilizer rates at various average soil test levels and variability levels are given in **Table 3**. Again, the most dramatic increase occurred at the soil test level where the optimum rate dropped to zero.

Table 3. Influence of soil test K variability on optimum K fertilizer rate.

Average soil test K, ppm	Soil test variability,[1] lb K_2O/A Low[2] (0)	Med. (53%)	High (131%)
45	100	101	106
90	50	58	77
135	0	30	58

[1]Value in parentheses is the coefficient of variability.
[2]Standard recommendation by Univ. of Guelph.

The major implications of spatial variability in extending soil test calibration data to farm fields follows:

> Since the relationships among yield response, soil test, and applied fertilizer are non-linear, a single calibration (recommended fertilizer versus soil test) cannot exist for fields with different spatial variability. Calibrations obtained from sites with low variability of soil test values (small plots) will not hold for sites with higher variability (farm fields). Calibrations obtained from sites with low variability of soil test values will underpredict the optimum fertilizer rate for maximum economic yield for sites with high variability of soil test.

(continued on page 23)

Comparison of Phosphorus and Potassium Utilization with Conventional and Variable Fertility Management

By Max W. Hammond

Studies in Washington state show that use of grid sampling and variable rate fertility management can reduce errors in fertilizer application rates.

VARIABLE RATE application of fertilizers to accommodate spatial variations of soil phosphorus (P) and potassium (K) in potato fields of the northern Columbia Basin of central Washington began in 1986. Due to the sandy, arid soils in this area, these spatial variations are best defined by intensive sampling on a 200 ft x 200 ft grid basis. The soil analysis data are then analyzed via geostatistics to delineate the nutrient variations in the fields. Variable rate fertilizer applications are made utilizing Soilection(TM) technology.

Washington Studies

In a previous study, an analysis was made of variable fertility management for P and K utilizing three nutrient content levels . . . high, medium and low. The results indicated that fertilizer input on a per field basis was generally the same . . . but the fertilizer was placed where it was needed. The study did reveal significant errors of over and under-application of P and K when applied on a conventional basis.

To further study fertilizer application efficiency, six fields were selected from those grid sampled and mapped in 1993 and 1994. These fields can be considered average for farm management in the area.

The field variations for P and K were mapped into five management levels based on nutrient content . . . very high, high, medium, low and very low. Fertilizer recommendations for potato production were made for each of the management levels and total amounts of P_2O_5 and K_2O were calculated for acreages of each management level. Overall field averages were calculated from all of the grid sample test results for each field, corresponding fertilizer recommendations were made for each field and the total amounts of P_2O_5 and K_2O per field calculated.

Results

The effect of variation management on total pounds of P_2O_5 and K_2O used across the six fields studied is shown in **Table 1**. Four of the six fields had an increase in P application. However, only one out of six

Table 1. Change in amounts of P_2O_5 and K_2O recommended due to variable application technology.

Field	Acres	P_2O_5, lb/field[1]	P_2O_5, lb/A	K_2O, lb/field	K_2O, lb/A
1	135	(637)	(4.7)	(1,038)	(7.7)
2	150	1,528	10.2	8,367	55.8
3	153	5,216	34.1	(614)	(4.0)
4	142	2,392	16.8	(4,918)	(34.6)
5	130	(5,054)	(38.9)	(1,355)	(10.4)
6	140	247	1.8	(3,692)	(26.4)
Average per-acre change over 6 fields			3.2		(4.6)

[1]Values equal conventional application minus variable application. Numbers in parentheses ( ) indicate a decrease in total application, others represent increases due to variable application management.

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Table 2. Examples of application error due to use of conventional fertilizer application.

Field	Acres	Under-application	Over-application
1	135	60 lb/A P_2O_5 on 34.9A 100 lb/A K_2O on 18.3A	70 lb/A P_2O_5 on 29.2A 45 lb/A P_2O_5 on 26.7A
2	150	105 lb/A P_2O_5 on 14.8A 80 lb/A K_2O on 84A	
3	153	75 lb/A P_2O_5 on 47.4A 85 lb/A P_2O_5 on 33.8A 45 lb/A K_2O on 87.9A	155 lb/A K_2O on 20.1A
4	142	55 lb/A P_2O_5 on 37.7A 85 lb/A P_2O_5 on 18.8A	175 lb/A K_2O on 13.3A 75 lb/A K_2O on 25.5A
5	130		120 lb/A P_2O_5 on 12.1A 95 lb/A P_2O_5 on 23.3A
6	140	70 lb/A P_2O_5 on 39.1A 40 lb/A K_2O on 83.1A	

had an increase in K application. When the changes were calculated on a per acre basis, the changes were minor and support the findings of the previous study.

Of more significance is the reduction in application rate error. A comparison of efficiency between conventional and variable application was made across all five management levels.

The results of this comparison revealed the most serious errors using conventional application were under-application of P and K in the low and very low testing zones. Under-application errors in these zones will contribute to yield loss and, more importantly, quality reductions in potatoes. Over-application is neither economically nor environmentally acceptable. While there were over-application errors in some fields in the high and very high testing zones, in most cases the acreage involved was small. Examples of application rate errors are provided in **Table 2**.

The utilization of five levels of nutrient management gave more versatility to accommodating field variation.

While the average across the six fields showed little change in fertilizer usage, some fields did show appreciable changes in application rates of P and/or K. Thus, there are fields which will require more . . . or . . . less P and K due to variable fertility management.

Comparison of total P and K utilized may be of interest in nutrient management budgeting. However, it is more important to demonstrate the reduction in application error that occurs through the use of variable rate fertility management. ■

Field Scale . . . from page 21

Summary

The previous statements, if accurate, are rather disturbing. A majority of fertilizer recommendations from soil tests are made from a composite soil sample from a field and a calibration relationship obtained from research plots selected for uniformity (i.e., low spatial variability of soil test). The results may also help explain why many farmers and fertilizer dealers insist they get an economical increase in yield with fertilizer application rates higher than those predicted by such calibration relationships. If they have a variable field, the theory presented here suggests they will get economic yield increases with higher rates. This does not invalidate the calibration relationship. It just suggests that we have to utilize the calibration relationship in a different manner. In fact, because of the spatial variability problem, it is more important than ever to have accurate calibration relationships among soil test, yield response, and applied fertilizer. The challenge is to combine these calibrations with additional knowledge about the spatial distribution and field scale variability of soil test values. ■

Soil Test Level Variability in Southern Minnesota

By Tom McGraw

How variable is the fertility of Corn Belt fields? This is a critical question as we continue to push crop production efficiency to the limit. In the following article, the owner of a successful crop consulting business in Minnesota shares his data on the extent of soil test variability within fields. The grid sampling results will be shocking to some and perhaps expected by others.

AS VARIABLE RATE FERTILIZATION, site-specific farming, farming by the foot and similar concepts become better known, the extent of soil test variability will become a major issue. If soil test variability is high, is that variability due to differences between soil types or are there differences within soil types that are large enough to allow differentiation of management inputs, including fertilizer?

Minnesota Studies

To better answer questions regarding soil variability, Minnesota Crop Monitors assembled data from approximately 50,000 acres of grid soil sampling carried out in the Fall of 1993 in west central, south central and extreme southern Minnesota. Grids were approximately 4.4 acres each; 7 to 10 cores per sample were taken in a radius of 20 to 30 feet from the center point of the grid. Using an open-faced hand probe, cores were taken to a depth of approximately 6 inches. Samples were analyzed for available phosphorus (P), exchangeable potassium (K) and available zinc (Zn) at Minnesota Valley Testing Laboratories, New Ulm, MN.

Data were assembled from four geographical areas from the three regions mentioned above. Fields were subdivided into three sizes: 35 to 80 acres, 80 to 160 acres, and greater than 160 acres. There were 392 fields in the study. More than 10,000 soil samples were taken.

The Results

The study showed there was little or no difference in the variability of nutrient levels in the different geographical regions. Therefore, results for all three are combined and summarized in **Table 1**.

Table 1. Soil test variability in western and southern Minnesota fields.

Soil test	Acres in field			
	35-80	80-160	>160	All fields
	% of fields with 4 or 5 soil test classes[1]			
P	75	89	96	86
K	48	62	78	61
Zn	63	77	91	75

[1] Soil test classes were VL, L, M, H and VH.

Variability was extreme for all three nutrients. There was more variability of P than K, but that was expected from previous soil test history in southern Minnesota. No correlation existed between P and Zn availability which had been surmised in the past. Overall relative Zn levels were generally higher than P levels.

The variability of soil test levels increased with field size as shown in **Table 1**, but not to the extent expected. Very

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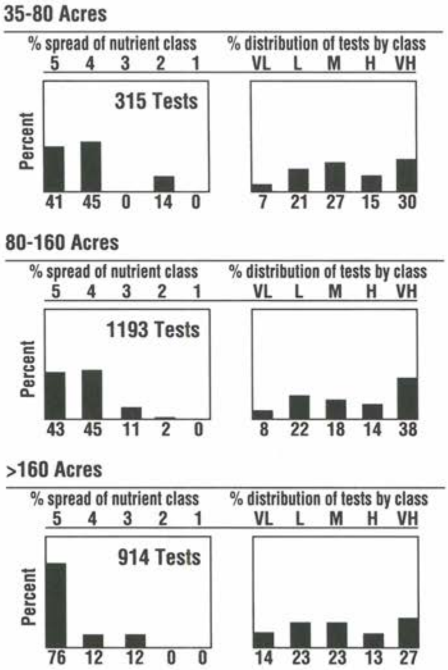

Figure 1. Soil test P variability in the Renville county region of southern Minnesota.

large fields in the study naturally had more diverse history of past farming practices and generally included a wider variety of soil types.

Overlaying the grid results on a soil survey map showed that most of the time there was no correlation between soil test level and soil mapping unit. Field histories that include small pastures, manure application close to the farmstead, and modified drainage patterns contributed more to soil test variability than that related to soil type differences.

A fairly typical set of data in a geographical subset is presented in **Figure 1**. The top two graphs show the spread of nutrient classes in the smaller fields and the distribution of tests among classes. Even in the 35 to 80 acre group, it is readily apparent that over 85 percent of the fields would require considerably different rates of fertilizer P if the data set represented one field. Obviously, submitting one sample for analysis would produce an inaccurate picture of actual field conditions...even if great care were taken in collecting the sample.

A quick glance at **Figure 1** shows that the distribution of soil test values, no matter the size of the field, assumes the same variable pattern, with the very high (VH) class having the highest frequency in every instance. The VH category is open ended. The large numbers of old barnyards, building sites, or old areas of manure application that are now farmed contribute to the large number of soil samples in this category. Furthermore, whether the soil test values in the VH class from grid sampling are averaged or the actual soil samples from these areas are mixed and then analyzed, the ultra high samples skew the average soil test value for the field. The result is a fertilizer recommendation far below that actually needed for optimum yields.

A computer program has been written to allow comparisons of crop response and rate of return using the average test level in a field or with application of nutrients based on the information provided by the grid soil sampling system. In a random check of 50 fields from the study, no economic gain was realized on two, but the other 48 showed economic gains ranging from \$2 to \$40/A. The comparison can be adjusted to reflect the expected yield, expected price per bushel, and the cost of fertilizer for corn and soybeans. When such comparisons were made, net return above additional costs of extra testing, mapping and spreading of the 48 fields averaged between \$10 and \$20/A, from the poorest to best case scenarios of yield and price, for southern Minnesota.

Summary

Several conclusions were drawn from this study. First, variation in nutrient levels in southern Minnesota fields is much greater than previously expected. Second, there can be significant economic yield increases by applying additional needed nutrients to the low and very low testing areas and conserving nutrient applications on very high testing areas. ■

Fine-Tuning Sugar Beet Fertility Management in the Red River Valley

By Dave Hilde

Few crops financially reward precision nitrogen (N) management more than sugar beet. Both yield and quality can be dramatically altered if the optimum N level is missed. Therefore, sugar beet is a natural crop for grid sampling and variable rate fertilization. This early evaluation of variable rate fertilization based on soil nitrate (NO_3-N) samples taken to a 4-foot depth shows a net profit increase from variable rate technology (VRT) of over $140/A.

SUGAR BEET PRODUCTION practices have changed drastically in the Red River Valley of Minnesota and North Dakota since the implementation of the quality payment system in 1980. Changes in the grower payment system mandated change to production of high sugar content, low impurity beets. Maximum beet yields require adequate amounts of N for fast early growth. However, **excess** N is detrimental to beet quality, because sugar content is reduced and impurities causing a sugar loss to molasses are increased. The net effect of excess N is reduced production of recoverable sugar per ton and per acre.

Prior to 1980, the N recommendation for a 20-ton crop was 170 lb/A. The present N management guideline . . . N to apply=120 minus (soil NO_3-N in zero to 2-foot depth + excess N in 2 to 4-foot depth) . . . was developed by American Crystal Sugar, North Dakota State University and the University of Minnesota, Crookston. A significant increase in the production of recoverable sugar per ton of beets and per acre has occurred with improved grower N management practices. For example, the 1993 Red River Valley sugar beet crop averaged 55 lb more recoverable sugar per ton than the 1980 crop. Based on an average 6.8 million ton crop at present sugar values, the 1993 sugar beet crop increased grower revenues by approximately $81.6 million over the 1980 crop.

Room for Improvement

While progress in increased sugar production has been good, there is still room for improvement. Many sugar beet growers have reached a production plateau with conventional soil sampling and fertilizer application methods and are looking at fine-tuning their N management program with grid sampling and VRT for fertilizer applications. One such grower is Dan Jacobsen who farms near Moorhead, MN. With help from Dave Braaten, American Crystal agriculturist, he conducted a side-by-side comparison of VRT with conventional fertilizer management.

The trial field was 83 acres and was soil sampled in the fall of 1992 to determine N, phosphorus (P), and potassium (K) requirements for the 1993 sugar beet crop. The standard sampling method was used, taking 20 cores in a random weave pattern on the entire 83 acres. Available N (after adjustment for excess N at the 2 to 4-foot depth) averaged 50 lb/A and the available P averaged 18 lb/A. Potassium tested very high at 430 lb/A.

Jacobsen then applied the required N and P on 10 acres which became the standard check. The field was then soil sampled in 440 ft. square grids (4.44 acres) and tested for N, P and K. Available N (after adjustment for excess 2 to 4-foot N) ranged from 31 to 149 lb/A. Phosphorus ranged from 10 to 31 lb/A and K ranged from 353 to 766 lb/A. The required N and

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P were applied on each grid by VRT on 73 acres. No additional K was required on either field. The standard and VRT areas were contracted separately so yield and quality data could be accurately determined at harvest using conventional harvesting machinery and standard beet sampling procedures at the receiving station.

Yield and quality results from VRT versus standard fertility management are shown in **Table 1**, the economic analysis in **Table 2**.

Table 1. Comparative effects of VRT and standard fertility management on sugar beet yield and quality.

Field report data	VRT	Standard
Yield, tons/A	18.70	18.00
Sugar, %	17.89	16.59
Sugar loss to molasses, %	1.41	1.56
Recoverable sugar, lb/ton	330	301
Recoverable sugar, lb/A	6,171	5,418
Brei nitrate grade	2.1	3.4

Jacobsen, 1993

Table 2. Economic comparisons of VRT and standard fertility management.

Field data	VRT	Standard	Difference (VRT-Standard)
Cost/A (soil test, fert. appl.)	$15.00	$5.00	+$10.00
Cost/A, N + P	16.89	23.17	-6.28
Beet payment/ton	39.32	33.31	+6.51
Beet payment/A	744.51	599.51	+145.07

VRT Net Profit = $141.35/A   Jacobsen, 1993

Summary and Conclusions

This comparison shows how VRT can boost farm profits. The dramatic increase in beet quality and the subsequent increase in beet payment are attributed to reducing the N variability in the field. With high rainfall the past two years, ponding occurred in low areas of the field, resulting in N losses through denitrification and possibly leaching.

Conventional soil sampling methods did not account for the uneven N patterns in the field. With VRT, the deficient areas received the needed N and the high testing areas received less N, or none at all, so both yield and beet quality increased. Another contributing factor to slightly higher yield per acre in the VRT field may be reduced P variability. Some grids were low in P. With VRT, these areas received adequate P for fast early growth required for top yields. The variations were not detected in the standard sampling method.

Grid soil sampling and VRT by Red River Valley sugar beet growers continue to increase each year. The quality payment system provides the financial incentive for sugar beet growers to fine-tune N management for maximum production of recoverable sugar and maximum income per acre. ■

IDEALLY, N deficiency as shown by the yellowing foliage in this field should occur 6 to 8 weeks prior to harvest for maximum production of recoverable sugar.

EXCESS available soil N at harvest, as indicated by the dark green foliage in parts of this field, results in reduced sugar content, increased impurities and lower sugar production.

Getting Specific with Soil Test Summaries

By Bob Deutsch and John Lee

Periodically, PPI summarizes and publishes soil testing data from commercial and public laboratories in the U.S. and Canada on a state or provincial basis. During this process it has become apparent that marked variation in typical soil test levels exists among regions within states or provinces. In this article, two soil testing professionals offer their views on summaries and demonstrate a more refined summary protocol than has been used in the past.

SOIL TEST SUMMARIES have become a useful educational tool to promote soil testing in the past 10 years. Vast improvements in computer technology have made it possible and convenient to extract summaries and trends from computer data bases past and present. Getting even more specific with soil test summaries is a challenge. Soil test summaries are used by university and industry scientists, fertilizer manufacturers, fertilizer dealers, crop production consultants and many others. These summaries are generally used to:

- Inform fertilizer dealers, crop consultants and growers of significant shifts in nutrient levels such as yearly fluctuations in residual soil nitrates in the Northern Plains.
- Increase knowledge of how changing fertilizer management strategies affect soil test levels of non-mobile nutrients such as phosphorus (P) and potassium (K) across large areas over time.
- Increase knowledge of how various farming practices such as livestock production, no-till farming, banding of fertilizer and crop rotation affect soil test trends over time and across large regions.

Examples of soil test summaries for portions of Minnesota, North Dakota, South Dakota and Manitoba are shown in **Figures 1, 2 and 3.** Soil pH and P and K soil test averages were determined by zip code (i.e. 581, 582, 583) of sample origin. Summaries such as these may be used to point out factors contributing to differ-

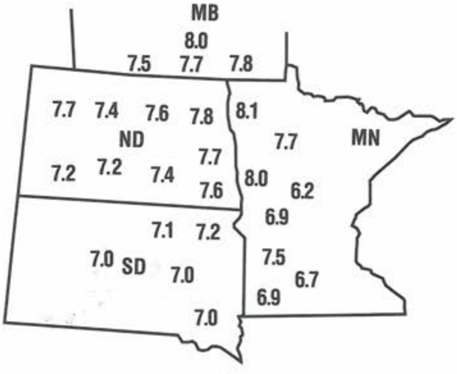

Figure 1. Soil test pH averages, 1993. Values are averages of zip code areas only. A current soil test for each field or site should be used to develop specific fertilizer rates.

Figure 2. Olsen phosphorus soil test averages (ppm), 1993. Values are averages of zip code areas only. A current soil test for each field or site should be used to develop specific fertilizer rates.

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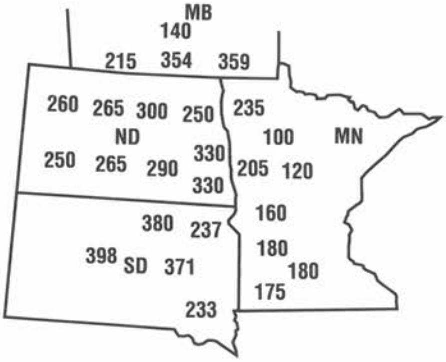

Figure 3. Potassium soil test averages (ppm), 1993. Values are averages of zip code areas only. A current soil test for each field or site should be used to develop specific fertilizer rates.

ences in soil test levels within a state, province or larger region . . . for example, soil parent material, climate, management practices and crop rotations. One weakness of these summaries, however, is that soil test data from one zip code still represent a very large area.

Soil test summaries could be made more specific if the exact location of tested areas were known, but that may never be practical. In areas where best management practices (BMPs) are being introduced, there may be a temptation to use state soil test averages as a benchmark of sorts. **Figures 1, 2 and 3** illustrate the point that there is no way to utilize areas as large as states . . . or even counties . . . as useful tools for managing individual fields.

As scientists, we must communicate with those who develop state, provincial and federal regulations concerning the proper use of soil test summaries . . . informing them that BMPs such as soil testing are best developed on a local basis.

Soil test summaries are another educational tool for stressing the importance of testing each field. Their use in publications and by the media benefits agriculture by helping increase public awareness of the good science and technology used to produce our food and protect the environment. ■

Environotes from TVA

By John E. Culp

A MAJOR NEW DIRECTION for the Tennessee Valley Authority (TVA) Environmental Research Center is conducting studies and developing strategies for watershed protection. One of the key areas of this work involves restoring abused and drastically disturbed lands.

The region has severely eroded and gullied agricultural and forested lands, abandoned mine land, industrial spoil areas, eroded reservoir shorelines, land disturbed by construction activities, and many other disturbed lands. Problems are significant. Soil erosion in the region, for example, averages almost 10 tons/A per year. Some soils are eroding at twice that rate.

TVA scientists at Muscle Shoals are conducting laboratory, greenhouse and field studies on selected environmentally abused or disturbed lands. The purpose is to mitigate nonpoint source pollution and restore the productive capacity of the lands. Some specific objectives include the following.

- Select and screen plants such as legumes, grasses and shrubs, for their use in restoring drastically disturbed lands. Emphasis is on plants that are adapted to acid, nutrient-deficient, and phytotoxic soil conditions.
- Investigate use of land-application of several kinds of inorganic and organic

(continued on next page)

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soil amendments–including industrial, municipal, and animal wastes–in restoration of abused or disturbed lands. Scientists will also study implications of this work on water quality.

- Explore the use of microbiological applications for restoration of productivity to drastically disturbed lands. This includes the introduction of nitrogen (N) fixing microbial populations and plants tolerant to acid and harsh conditions of abandoned mine lands.
- Evaluate alternative best management practices (BMPs) and technologies such as hydroseeding for application to revegetation and erosion control on abused or drastically disturbed lands.

Greenhouse Screening Tests/Soil Characterization

Scientists are characterizing representative soils from several mined and disturbed land areas within the Tennessee Valley, including the Copper Basin, brown iron ore, and acid, coal strip-mined land. This information will help develop long-term, cost-effective ways to reclaim and restore these lands.

GROWTH RESPONSE of aerially-seeded grass/legume cover crops and transplanted loblolly pine trees as related to broadcast P fertilization and fertilizer tree tablets is being evaluated in a research study at Copper Basin, TN.

The requirement of maintaining long-term sustainability and increasing soil productivity poses a special need to select the best plants for revegetation of specific problem soils. TVA is conducting a series of greenhouse/growth chamber screening tests to select the optimum legume and grass species for establishment on very acid, harsh soils.

As screening tests are completed, TVA is gearing up to conduct pot studies to evaluate the symbiotic N fixing capacity of select legumes grown on some soils from disturbed land. The quantity of symbiotic N fixed will be determined by ^{15}N isotope dilution method.

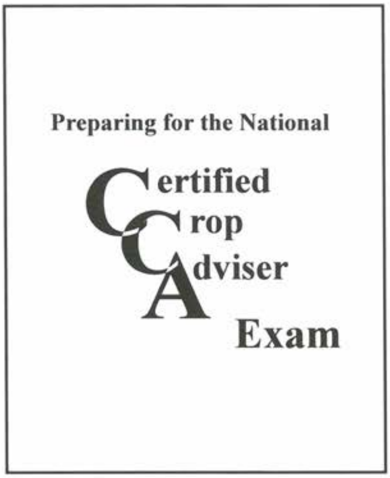
Field Research/Demonstrations in Environmentally Sound Land Reclamation

Beginning in 1995, field plot studies will be used to evaluate the effects of grass/legume selections and select BMPs on soil productivity and impacts on water quality. First studies will be in the abandoned brown iron ore mined lands of Franklin County, AL.

Another study will explore the use of a mixture of poultry litter and coal combustion wastes in a land restoration demonstration. This will include the evaluation of hydroseeding techniques in vegetation.

This research, development and demonstration is a part of TVA's Twenty-first Century Agriculture program. Cooperators include the U.S. Environmental Protection Agency, USDA, university researchers, and federal/state land restoration research committees. ■

Preparing for the National CCA Exam–Review Manual Available



THE Certified Crop Adviser (CCA) program has been developed by the American Society of Agronomy (ASA) in cooperation with agribusiness, retail dealers, cooperatives and manufacturers, state and national trade associations, the USDA, and independent consultants. The program is open to anyone who provides crop management recommendations to farmers. The purpose is to provide base standards for certification for these individuals.

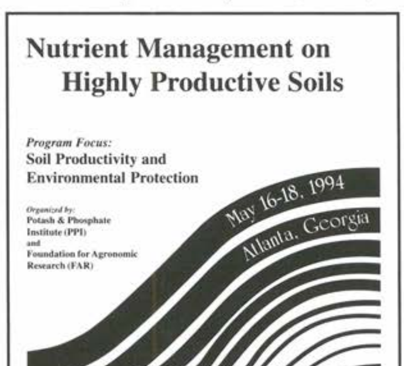
A useful manual available from PPI offers information for review in these subject areas: Soil Fertility, Soil and Water Management, Pest Management, and Crop Production. The subject matter and sample review questions can serve as a study guide for individuals preparing for the National CCA Exam.

The content of this informative review manual was organized by Dr. John Gilmour, Department of Agronomy, University of Arkansas. The 106-page booklet is presented in an easy-to-read format with numerous charts and illustrations. The review manual was recently updated.

Individual copies of the booklet (Item #50-1000) cost $25.00, including shipping and handling. Checks should be payable to PPI. To obtain a copy, contact: Circulation Department, PPI, 655 Engineering Drive, Suite 110, Norcross, GA 30092-2821; phone (404) 447-0335, fax (404) 448-0439. ■

Nutrient Management Conference Proceedings

PROCEEDINGS of a recent conference, "Nutrient Management on Highly Productive Soils," are available from PPI. The Conference took place May 16-18, 1994, in Atlanta, GA. It was organized by PPI and the Foundation for Agronomic Research (FAR), with co-sponsorship from government and industry sectors.



Conference discussion topics covered in the proceedings include: importance of maintaining soil fertility; fertilizer recommendations and spatial variability; site-specific nutrient management; individualized nutrient management recommendations; role of fertilizer placement in improved productivity; economic and environmental impacts of intensive cropping systems; a discussion of regulatory effects on fertilizer use, and numerous other topics.

The Proceedings (PPI/FAR Special Publication 1994-1, 187 pages) is available by mail at a price of $15.00. For more information or to order copies of the proceedings, contact: PPI, 2805 Claflin Road, Suite 200, Manhattan, KS 66502; phone (913) 776-0273, fax (913) 776-8347. ■

Check Your Soil, Sir?

How much easier it is to be critical than to be correct.

Sixty-five years ago I was among the few who were enthusiastic about soil testing. Calibrations and correlations between soil tests and field response were in the early stages. Methodology left much to be desired, ranging all the way from spot plates and color charts to long, tedious laboratory analysis designed to define "available" nutrients.

Today there is increasing acceptance of the soil test, alone, as a means of determining exact needs for fertilizers or soil amendments. One reason for this is the marvel of modern chemical methods and the widespread computerization of analysis and recommendations.

Some scientists, especially non-agricultural scientists, accept the soil sample as defining accurately the area involved, and the test itself as a highly precise method for determining that year's fertilizer needs. Then, let the computer do the rest.

Many such scientists have never had first-hand involvement with soil sampling practices, or field experiments for calibration, or soil test variation with seasonal changes, or the effects of physical properties not reflected in chemical tests, or with different interpretations by different labs.

Twenty years ago, Reed and Nelson wrote, "Soil testing is an excellent diagnostic tool, a very useful means of monitoring soil fertility status. It is most useful when used with other diagnostic tools by those with experience and knowledge."

Let's be careful not to misuse these tools...by assuming more than the current research on sampling, calibration and correlation can deliver.

J. Fielding Reed

BETTER CROPS WITH PLANT FOOD
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