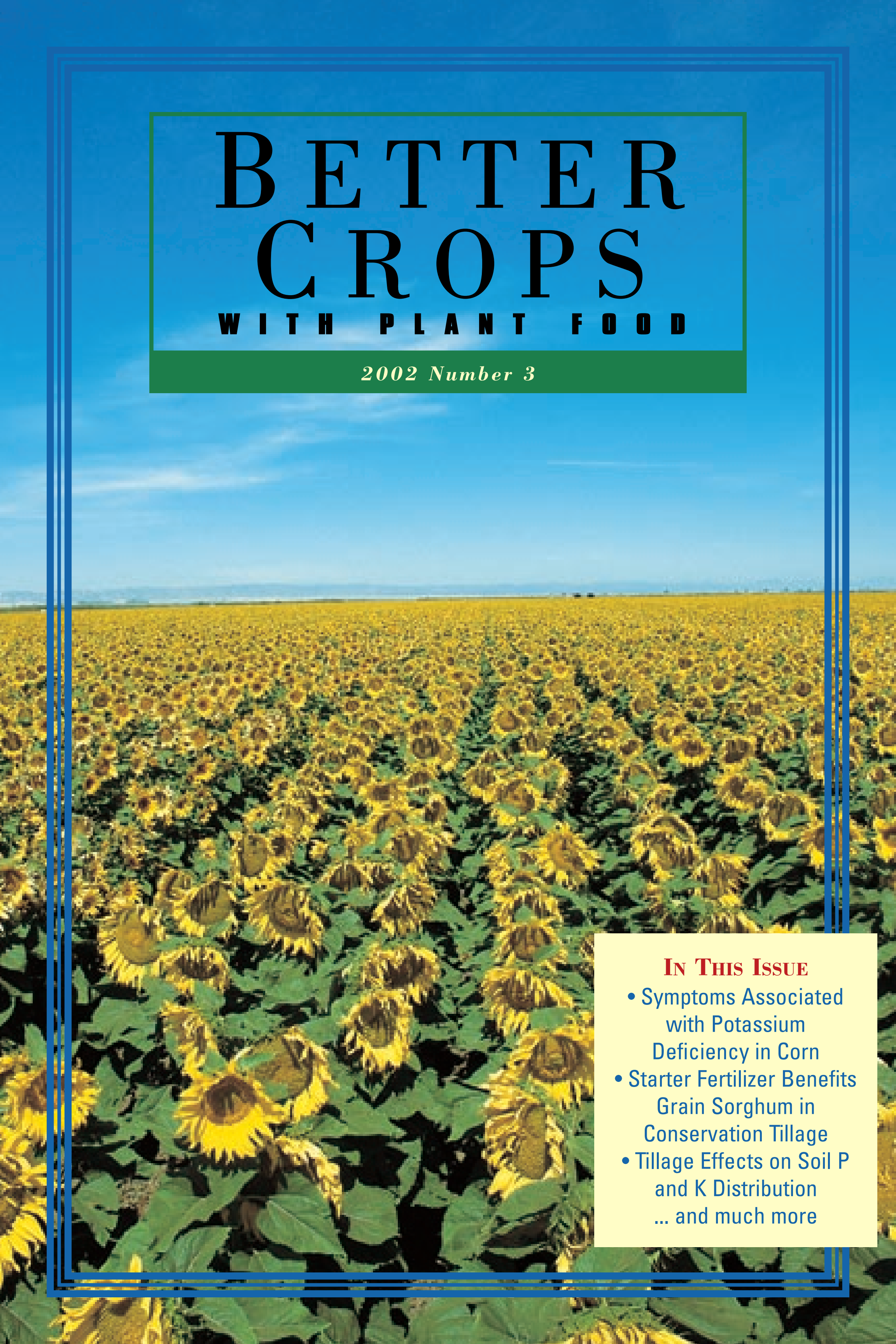
BETTER CROPS
WITH PLANT FOOD

2002 Number 3



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BETTER CROPS
WITH PLANT FOOD

Vol. LXXXVI (86) 2002, No. 3

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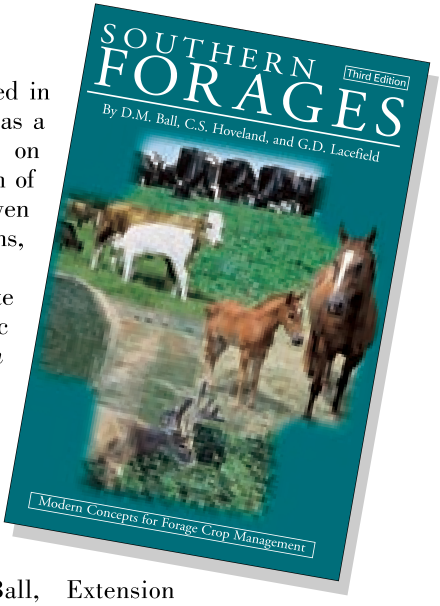
Third Edition of *Southern Forages* Book Now Available



The book *Southern Forages* was first introduced in 1991 and has since gained wide recognition as a practical and reliable source of information on modern forage crop management. The Third Edition of *Southern Forages*, released in May, 2002, is an even more valuable book, with extensive chapter revisions, topic updates, and other improvements.

Published jointly by the Potash & Phosphate Institute (PPI) and the Foundation for Agronomic Research (FAR), the Third Edition of *Southern Forages* includes new chapters on "Forage Ecology" and "Minimizing Stored Feed Requirements," plus an expanded chapter on grazing management. Fifteen additional pages of information have been added to the popular appendix section. Other improvements include color drawings of forage seed and new diagrams in various chapters.

Authors of the book are Dr. Don Ball, Extension Agronomist/Alumni Professor, Auburn University; Dr. Carl Hoveland, Terrell Distinguished Professor, University of Georgia; and Dr. Garry Lacefield, Extension Agronomist/Professor, University of Kentucky. All are former presidents of the American Forage and Grassland Council and have many years of experience working with forage/livestock production.

Southern Forages is written for a wide range of audiences. It is used by livestock producers, by seed, equipment and fertilizer dealers, by Extension and conservation workers, and by teachers as a text for students learning about forages. More than 50 colleges and universities have included the book as a text or resource in forage classes.

While the content is focused on forages for the southern U.S., many of the principles and species of plants discussed can be adapted to other regions. Chapters discuss forage systems for beef, dairy, horses, sheep, goats, and other types of livestock. Wildlife, soil conservation, and environmental benefits of forages are also emphasized.

The Third Edition of *Southern Forages* is a 6 x 9-inch paperback book containing 332 pages. It features more than 150 color photos, including over 60 close-up images of grasses and legumes. Discussions of management and utilization, forage adaptation zones, seasonal growth curves, seeding rates, and nutrient content of fertilizer materials are examples of subject matter helpful to many readers.

Southern Forages is priced at US$30.00 per copy, plus shipping and handling. To order one book for delivery in the U.S., send a check payable to "Potash & Phosphate Institute" for $34.00 to: 655 Engineering Drive, Suite 110, Norcross, GA 30092-2837. To inquire about multiple book or international orders, phone (770) 825-8082 or 825-8084; fax (770) 448-0439; e-mail: circulation@ppi-far.org; or order online at www.ppi-ppic.org. BC

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WESTERN CANADA

Conservation Tillage Effects on Soil Phosphorus Distribution

By Fernando Selles, Cynthia A. Grant, and Adrian M. Johnston

Conservation tillage seeding systems are the most rapidly adopted tillage practice in western Canada. Because conservation tillage seeding encompasses a broad range of seeding and fertilization methods, there are questions regarding the long-term impact of reduced tillage on soil fertility.

The role of tillage on soil nutrient levels is largely determined by the nature of each specific nutrient, and the impact that the changes in the soil environment have on its transformations. Thus, immobile nutrients in the soil such as P and potassium (K) tend to be affected substantially by the adoption of reduced tillage management. Most notable is their tendency to become concentrated near the surface of the soil in response to the reduced soil disturbance and elimination of soil inversion characteristic of conventional tillage systems.

> While soil phosphorus (P) was found to accumulate near the surface in no-till fields, no negative impact on crop production was recorded due to this nutrient distribution. In-soil band placement of fertilizer P is an effective means of increasing soil P content in the absence of tillage for incorporation.

One of the main benefits achieved with the adoption of conservation tillage is the maintenance of soil moisture for crop production. By increasing the amount of plant-available water in the soil, both the cropping intensity, and diversity of crops grown can be increased. Previous research in the U.S. Corn Belt has found that while soil P and K were considerably higher in the surface 3 in. depth of no-till treatments, the plowed treatments had uniform nutrient levels down to 9 in. depth. Given the density of corn roots in this soil layer, the stratification of P and K were not considered to be as big a problem as first thought. In fact, by concentrating roots in a zone of higher fertility, nutrient availability may be increased. A similar scenario exists for the root development of crops on the Canadian Prairies, and the maintenance of surface residues helps to maintain plant-available water for crop uptake near the soil surface.

Soil P in long-term tillage studies has been evaluated at the Swift Current Research Centre on a silt loam soil and the Brandon Research Centre on fine sandy loam and silty clay soils. Both of these facilities are part of the Agriculture and Agri-Food Canada Research Centre network on the Canadian Prairies. Swift Current is located in a semiarid region (13 in. annual precipitation, 29 in. potential evapo-transpiration), while Brandon (19 in. annual precipitation, 25 in. potential evapo-transpiration) is in the sub-humid region. Spring wheat was grown at each location, with the fertilizer P applied in the seed row at Swift Current and pre-plant banded at Brandon.

Conventional tillage at both locations involved use of a cultivator with sweeps that mixes but does not invert the soil above the depth of tillage. Soil samples were collected from the experimental plots to include both the crop row and inter-row area, and segmented into varying depths for further analysis. At Swift Current, soil P fractions were determined using the Hedley fractionation procedure. It partitions P into inorganic and organic P fractions of varying availability. Labile P is that soil P that is available or becomes available to plants and microorganisms in a time span of days to a few weeks. Moderately labile P, while not immediately available to plants, has the potential to become available over a period of months to a few years. At Brandon, soil P was determined using the 0.5 M sodium bicarbonate extraction procedure.

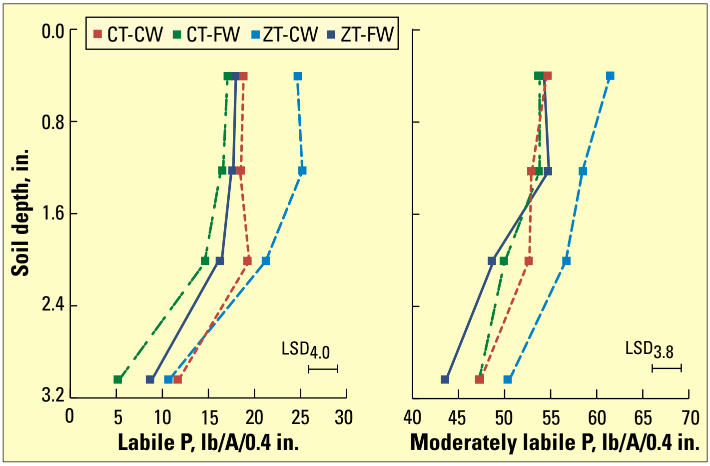


Figure 1. Distribution of labile and moderately labile P in the surface 4 in. of soil (May 1990 sampling).

At Swift Current, results showed that 12 years after converting from conventional till wheat-fallow (CT-FW) to no-till continuous wheat (ZT-CW), forms of P easily available to the crop accumulated in the surface 2.5 in. layer (**Figure 1**).

This was not the case for the no-till fallow-wheat (ZT-FW), or the conventional till continuous wheat (CT-CW), where the concentration of labile P was uniform in the top 4 in. of the soil. The labile P fraction (inorganic P extracted by an anion resin plus organic and inorganic P extracted by 0.5 M sodium bicarbonate) is the soil P that is immediately available, or becomes available to plants within days to a few weeks. This specific treatment difference was attributed to the accumulation of organic materials (crop residues and soil organic matter) at the surface of zero-tilled soils, resulting from the reduction of soil disturbance and mixing of the soil. However, it is important to note that in this study, where 15 lb P_2O_5/A were seed-placed each year, the increased soil P in the surface of no-till continuous wheat fields did not result in increased plant uptake of P. This was attributed to the proven yield increase shown by crops that receive starter P at seeding in soils that remain cool in early spring.

An enhanced P supply, arising from an increased accumulation of available forms of P, would benefit mid-season uptake of P by a high yielding crop. This is illustrated by the increase in moderately labile soil P (sodium hydroxide extractable P). Adoption of no-till seeding with continuous wheat cropping resulted in a substantial increase in plant-available P in the surface 2.5 in. of soil. In soils under zero-tillage management for some time, soil sampling procedures for P determination and P fertilizer recommendations may have to be modified to account for the accumulation of labile forms of P near the soil surface. Furthermore, the accumulation of bioavailable forms of P near the soil surface may have a substantial impact on surface water quality, if soil materials are transported from the field to surface water bodies, despite the reduced erosion risk characteristic of zero-tillage management systems.

At Brandon, soil P distribution was evaluated after completion of a four-year study comparing no-till and conventional tillage. In this study, P accumulation was recorded at the depth of banding under both conventional and no-till, and on both the sandy loam and silty clay soil types (**Figure 2**). In this trial, soils were sampled down to a depth of 6 in., in 1 in. increments. The P accumulated at the 4 in. depth, and was attributed to the repeated application of the nitrogen (N)+P bands throughout the duration of the study. The soil P concentration at the banding depth was higher under no-till than tilled management, presumably due to the lack of soil disturbance

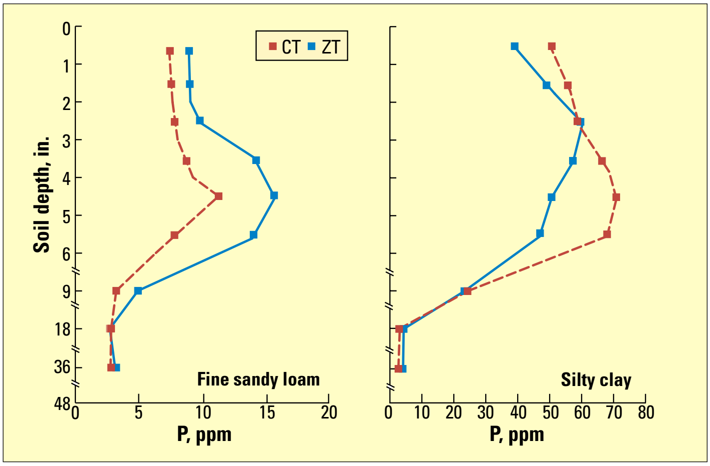


Figure 2. Effect of conventional tillage (CT) and zero tillage (ZT) on P distribution [parts per million (ppm)] through fine sandy loam and silty clay loam soil profiles.

and soil mixing with tillage. This increase in P concentration likely reflects accumulation of the nutrient from the previous year's application.

One additional project evaluated the impact of tillage on the distribution of soil P at Indian Head, Saskatchewan, also in the sub-humid (16 in. annual precipitation, 24 in. potential evapotranspiration) region in a heavy clay soil. After four years, no difference was recorded in soil P at 0 to 2 in., 2 to 4 in., or 4 to 6 in. soil depths between conventional and no-till seeding systems. This study involved a series of cereal, oilseed, and grain/legume rotations. Rotation also did not have any impact on soil P distribution.

It would appear that soil P can accumulate near the soil surface of no-till treatments, relative to conventional tillage. No negative impact was recorded in these studies due to this nutrient distribution, and is not expected to pose a problem to future production. The accumulation of surface crop residues does an excellent job of maintaining increased plant-available water in no-till fields. This will keep roots active and in a position to access accumulated nutrients. However, under drying conditions, a deficiency of P may mean that plants cannot access these surface nutrients and place an increased importance on in-soil band placement of P.

Fertilizer management with reduced and no-till seeding requires careful attention to placement in order to optimize efficiency of fertilizer-use by the crop. There is little doubt that broadcast application of P onto the residue-covered soil surface is not a realistic management option in most instances. Application of P in bands either with or close to the seed minimizes tie-up by the soil and fosters early season uptake by the crop, increasing the chances for higher crop yields.

One of the challenges facing no-till farmers is fertilizer placement. When side banding is not a choice because of the seeding opener used, the placement of starter P, K, and sulfur (S) fertilizer with the seed can often be limited by the width (spread) in which the selected opener scatters the seeds and fertilizer material. Limiting the amount of these nutrients can often reduce the response to applied N, as a result of imbalance between nutrients.

In the absence of building soil P levels prior to adopting a no-till program, deficiencies in these nutrients should be addressed with low disturbance banding operations carried out independently of seeding. Implementing the best conservation tillage practices will not make up for deficiencies, or imbalances, in soil nutrients required for optimization of crop yield and quality.

Dr. Selles (e-mail: sellesf@em.agr.ca) is a soil scientist at the Agriculture and Agri-Food Canada Research Centre in Swift Current, Saskatchewan; Dr. Grant is a soil scientist at the Agriculture and Agri-Food Canada Research Centre in Brandon, Manitoba. Dr. Johnston is PPI/PPIC Western Canada Director, located at Saskatoon, Saskatchewan.

Robert E. Wagner Award Winners Announced

Two outstanding agronomic scientists have been selected to receive the 2001-2002 Robert E. Wagner Award by the Potash & Phosphate Institute (PPI). The award encourages worldwide candidate nominations and has two categories...Senior Scientist and Young Scientist, under the age of 45. The recipient in each category receives $5,000 along with the award.


Dr. David Mengel

Dr. David B. Mengel, Professor and Head, Department of Agronomy, Kansas State University, Manhattan, was selected in the Senior Scientist category. **Dr. Michael A. Schmitt**, Professor and Associate Dean (Interim), College of Agricultural, Food, and Environmental Sciences, University of Minnesota, St. Paul, receives the honor in the Young Scientist division.

The Robert E. Wagner Award recognizes distinguished contributions to advanced crop yields through maximum yield research (MYR) and maximum economic yield (MEY) management. The award honors Dr. Wagner, President (Retired) of PPI, for his many achievements and in recognition of his development of the MEY management concept...for profitable, efficient agriculture.


Dr. Michael Schmitt

"We congratulate Dr. Mengel and Dr. Schmitt for notable achievements in their profession. The standards for this award are high, and the recipients are truly deserving of this honor," said Dr. David W. Dibb, President of PPI.

Dr. Mengel is widely recognized for his pioneering work with efficient fertilizer practices for reduced tillage and no-tillage systems in corn production. His research improved the understanding of stratification of immobile nutrients and led to management practices which reduced nutrient carryover and runoff, lessening potential impacts on water quality.

Dr. Mengel was Extension Specialist in Soil Fertility and Crop Production, Purdue University Agronomy Department, from 1979 to 1998. A native of Indiana, Dr. Mengel earned his B.S. and M.S. degrees at Purdue, then completed his Ph.D. in Soil Science at North Carolina State University in 1975.

Dr. Mengel has received numerous awards, including recognition as Fellow in the American Society of Agronomy and the Soil Science Society of America.

Dr. Schmitt has gained national recognition and respect for his excellent work with the management of both livestock manure and nitrogen fertilizer for crop production. The valuable database that has evolved from this research has been used to develop an excellent series of Extension publications focused on manure management and best management practices for nitrogen. His programs have enabled growers to integrate effective management of organic and inorganic nitrogen sources into crop production systems, thereby improving net returns.

After receiving his B.S. degree at the University of Minnesota in 1980, Dr. Schmitt completed his M.S. and Ph.D. degrees in soil science at the University of Illinois. He worked as training coordinator for CENEX/Land O'Lakes Agronomy Company before returning to the University of Minnesota, first as an Extension Agronomist and then as an Extension Soil Scientist and in the Department of Soil, Water, and Climate. He became Associate Professor in 1994 and Professor in 1999. He accepted his current position in 2000. In 2001, Dr. Schmitt was recognized as Fellow of the American Society of Agronomy. BC

J. Fielding Reed PPI Fellowships Awarded to Outstanding Graduate Students

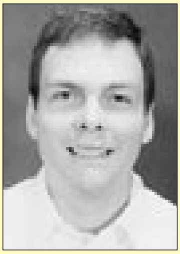
Seven graduate students have been announced as the 2002 winners of the J. Fielding Reed PPI Fellowship awards by the Potash & Phosphate Institute (PPI). Grants of $2,500 each are presented to the individuals. All are candidates for either the Master of Science (M.S.) or the Doctor of Philosophy (Ph.D.) degree in soil fertility and related fields. The winners for the year 2002 are:

- **Amy Suzanne Berg**, Purdue University, West Lafayette, Indiana
- **William Kess Berg**, Purdue University, West Lafayette, Indiana
- **Dennis Chessman**, Texas A&M University, College Station
- **Ann Kline**, Purdue University, West Lafayette, Indiana
- **Mariya Murashkina Meese**, University of California, Davis
- **Ryan Russell Paul Noble**, University of Tennessee, Knoxville
- **Mark Stephen Reiter**, Auburn University, Alabama

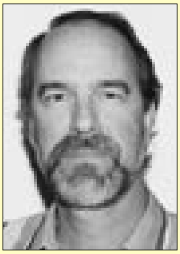
"Since the awards began in 1980, 135 students have now been named as recipients," said Dr. David W. Dibb, President of PPI. "This time we have a first. Two of the winners, Kess Berg and Amy Suzanne Berg, are husband and wife. Congratulations to all in this exceptional group."

Scholastic record, leadership, and excellence in original research are among the important criteria evaluated for the Fellowships. Following is a brief summary of information for each of the 2002 recipients.

Amy Suzanne Berg received her B.S. degree from Purdue University in 2001 and is currently working on her M.S. degree there. Ms. Berg has received numerous awards and scholarships, including the Beck Foundation Scholarship, Robert J. Woods Scholarship, Carole Thiele Agronomy Scholarship, Gentry Family Scholarship, and the Lewis Runkle Scholarship. In addition, she was a recipient of the American Society of Agronomy's Outstanding Senior Award. Her thesis title is 'Changes in Phosphorus Status in Soils of Differing Chemical and Physical Properties after Applications of Manure and Phosphate Fertilizer.' This research is striving to identify the phosphorus compounds present in livestock manures and extracts from soils fertilized with manure and commercial fertilizer. One of the objectives is to determine the mobility of specific phosphorus compounds in soils.



William Kess Berg received his B.S. degree from Ohio State University in 1996 and is completing a M.S. degree from Purdue University in 2002. Mr. Berg is a recipient of the George D. Scarseth Graduate Award. He has published his research in scientific journals and presented the findings at the American Society of Agronomy meetings and numerous extension meetings. Mr. Berg's research program integrated field-based fertility response trials with modern physiological and biochemical assays. His objective was to determine the impact of phosphorus and potassium fertilization on alfalfa yield, quality, persistence, and related physiological, biochemical, and molecular mechanisms.

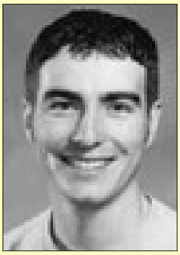


Dennis Chessman, received his B.S. degree from Stephen F. Austin State University, Nacogdoches, Texas, and his M.S. degree from Kansas State University in Manhattan. He began work on his doctorate at Texas A&M in College Station in 1999. Mr. Chessman was recognized as Outstanding

Student in Agronomy and Outstanding Agriculture Graduate as an undergraduate, and has been the recipient of the American Society of Agronomy 'Certificate of Excellence' in the publication category. The title of his dissertation is 'Alfalfa Production on Acid Coastal Plain Soils.' The objective is to evaluate the effectiveness of gypsum and a flue gas desulfurization byproduct from a coal-fired electric power generating plant in ameliorating aluminum toxicity on highly weathered soils.

Ann Kline, a native of Hudson, Indiana, began working on her Masters degree at Purdue University in 2001. In 2000 she graduated with a B.S. in Soil and Crop Science from Purdue after transferring from Huntington College, Huntington, Indiana. Ms. Kline was the Outstanding Sophomore and Junior in Purdue's Agronomy Department and was recognized for her exemplary performance by Dow AgroSciences while working as a Science Intern during the summers of 1999 and 2000. Her M.S. research is investigating the effects of deep placement of phosphorus and potassium on corn response in high yield environments.

Mariya Murashkina Meese was born in Moscow, Russia, and received a B.S. from Moscow State University in 1996. She worked as a Research Assistant in Russia until entering a Ph.D. program at the University of California, Davis, in 2000. She has authored several scientific papers and presented research results at scientific meetings in Russia, France, Japan, and the U.S. Her research is testing a new method of evaluating plant-available potassium in the high potassium-fixing soils of the San Joaquin Valley. It is also utilizing geographic information systems (GIS) technology to map the location of potassium-fixing soils that are in cotton production in the San Joaquin Valley.



Ryan Noble was born in Rosebud, Australia. He received his B.S. degree from the University of Tennessee in 2000 and is presently working on his M.S. Mr. Noble has been the recipient of numerous awards, including the University's Provost Award for extraordinary professional promise and the J.J. Bird Memorial Scholarship in Agriculture as an undergraduate. He has also been recognized as an Outstanding Senior in Plant and Soil Science, Outstanding Horticulture Student, and received the Outstanding Undergraduate Award from the Tennessee Agriculture Production Association. His thesis is titled 'The Characterization, Genesis, and Classification of Six Selected Soil Profiles of the Kursk Oblast, Russia.'

Mark S. Reiter was raised on a family farm in Dinwiddie County, Virginia. He graduated Magna Cum Laude from Virginia Tech in 2001 with a B.S. degree and is presently working toward a M.S. at Auburn University. He is a current recipient of the Frank D. Keim Graduate Fellowship and was awarded the Charles R. Drake Scholarship, the Abrahams Scholarship, and the Robert Harrison Scholarship as an undergraduate. The title of his thesis is 'Nitrogen Management for High Residue Conservation Tillage Cotton in the Tennessee Valley.' The objectives are to improve the understanding of nitrogen dynamics on silt loam and silty clay loam soils and to improve nitrogen management guidelines for cotton producers.

The Fellowships are named in honor of Dr. J. Fielding Reed, who served as President of the Institute from 1964 to 1975. Dr. Reed, who passed away in 1999, was well-known for his encouragement of students and inspiring advanced study.

Funding for the Fellowships is provided through support of potash and phosphate producers who are member companies of PPI. BC

Starter Fertilizer Application Effects on Reduced and No-Tillage Grain Sorghum Production

By W.B. Gordon and D.A. Whitney

Starter fertilizer containing nitrogen (N) and phosphorus (P) substantially increased grain sorghum yields on a soil testing high in P. The effects of tillage and starter placement methods were also evaluated in this three-year northcentral Kansas study. Starter placement, on average, did not affect yields. Likewise, tillage did not affect the way sorghum responded to starter.

Conservation tillage production systems are being used by an increasing number of producers in the central Great Plains because of several inherent advantages. These include reduction of soil erosion losses, increased soil water use efficiency, and improved soil quality. However, early-season plant growth can be poorer in reduced tillage systems than in conventional systems. The large amount of surface residue present in a no-tillage system can lower seed zone temperatures. Lower than optimum soil temperature can reduce the rate of root growth and P uptake by plants.

Starter fertilizers can be applied to place nutrients within the rooting zone of young seedlings for better availability to hasten maturity and avoid late-season damage by low temperatures. Some experiments that have evaluated crop response to N and P starter fertilizers have demonstrated improved early growth and increased yield and attributed those responses to the P component of the combination. Other studies have indicated that N is the most critical nutrient in the N-P starter on soils not low in P. Many producers do not favor 2x2 (2 in. to the side and 2 in. below the seed) placement of starter fertilizer due to high initial cost of application equipment and problems associated with knife applications in high residue situations. This research was aimed at minimizing fertility problems that arise with reduced tillage systems, thus making conservation tillage more attractive to producers.

Effects of starter fertilizer on grain sorghum development and maturity are illustrated in these photos. Plots receiving 30 lb N/A and 30 lb P_2O_5/A as starter had much larger and more developed seed heads than in no-starter plots.

Methods

The experiment was conducted at the North Central Kansas Experiment Field on a Crete silt loam soil from the spring of 1999 to the fall of 2001. Analysis by the Kansas State University (KSU) Soil Testing Laboratory showed that initial soil pH was 6.2, organic matter was 2.2 percent, Bray P-1 was high [45 parts per million (ppm)], and exchangeable K was 320 ppm (very high) in the top 6 in. of soil. Treatments consisted of two tillage systems (no-tillage and minimum tillage). The minimum tillage treatment received one discing and harrowing operation in the spring three weeks prior to planting. Starter fertilizer was placed either 2x2 or dribbled in a band on the soil surface 2 in. beside the seed at planting. Starter fertilizer treatments consisted of N and P_2O_5 combinations giving 15, 30, or 45 lb N/A with 30 lb P_2O_5/A.

Treatments consisting of either 30 lb N/A or 30 lb P_2O_5/A applied alone and a no starter check also were included. Starter combinations were made using 10-34-0 and 28-0-0. After planting, knife applications of 28-0-0 were made to bring N applied to each plot to a total of 140 lb/A. Grain sorghum (NC + 7R83) was planted at the rate of 60,000 seed/A in mid-May each year of the experiment. At the V6 stage of growth, 20 plants were randomly selected from each plot and analyzed for dry weight and N and P concentration. Starting on September 8, 2001, 10 sorghum heads were randomly selected from each plot, threshed, and grain moisture content measured. Plots were harvested in mid-October each year.

Results

Over the three years of the experiment, tillage had no effect on the way grain sorghum responded to starter fertilizer (**Table 1**). All starter treatments increased grain yield over the no-starter check plots. There was no significant difference in starter placement methods in yield of grain sorghum when averaged over starter fertilizer combinations and years (**Table 2**). However, some individual 2x2-placed starter treatments were superior to dribble applied. The highest yields occurred with applications of starter fertilizer containing higher rates of N (30 or 45 lb N/A) in combination with P. The N alone or the P alone treatments

(continued on page 15)

TABLE 1. Tillage effects on grain yield, number of days from emergence to mid-bloom and 6-leaf stage whole plant dry matter (averaged over starter treatment and placement method), Belleville 1999-2001.

Tillage	Yield, bu/A	Days to mid-bloom	6-leaf dry matter, lb/A
Reduced	113	58	906
No-Till	116	59	883
LSD (0.05)	NS*	NS	NS

*NS = not significant at the 5% level of probability.

TABLE 2. Starter fertilizer composition and application method effects on yield of grain sorghum, Belleville, 1999-2001.

Starter, lb/A		Grain yield[1], bu/A	
N	P_2O_5	2x2	Dribble
0	30	104	101
30	0	111	108
15	30	116	111
30	30	127	118
45	30	127	120
Average		117	112
LSD (0.05)		6	

[1] No-starter check = 93 bu/A.

TABLE 3. Starter fertilizer composition and application method effects on number of days from emergence to mid-bloom, Belleville, 1999-2001.

Starter, lb/A		Number of days from emergence to mid-bloom[1]	
N	P_2O_5	2x2	Dribble
0	30	62	62
30	0	58	60
15	30	55	60
30	30	55	57
45	30	54	55
Average		57	59
LSD (0.05)		2	

[1] No-starter check = 65 days.

NORTHCENTRAL

Symptoms Associated with Potassium Deficiency in Corn

By Anthony Bly, Ron H. Gelderman, James Gerwing, and T. Scott Murrell

This article provides examples of visual symptoms of potassium (K) deficiency in corn.

Most agronomic textbooks describe the visual symptoms of K deficiency as chlorosis (yellowing of plant tissue due to a reduction in the chlorophyll formation process) or necrosis (death of plant tissue) on margins of lower, older leaves. In practice, such classic symptoms may not always be seen when there is a shortage of K.

For those scouting fields, it may prove useful to have photographs of visual K deficiency symptoms associated with end-of-season grain yields and tissue concentrations. This article presents pictures of K-deficient corn plants taken from research plots in eastern South Dakota during the 2000 growing season. Descriptions are provided, along with other management information whenever possible.

In the following examples, average yields are shown (where available) for the treatments associated with the pictures. For comparison purposes, average yields and ear leaf K concentrations for the highest statistically significant treatment are shown in brackets [ ].

For digital images of these pictures, visit the PPI Northcentral Region website at http://www.ppi-ppic/northcentral and go to "Galleries."

Example 1. Visible K deficiency symptoms usually occur first on the lower, older tissue of the corn plant. At this South Dakota State University (SDSU) research location near White, SD, the K-deficient lower leaves show marginal chlorosis and necrosis. The lowest leaf has more necrotic leaf area than does the leaf above it (site 29300C, plot number 102).

Planting date: 5-22-2000

Planted population, seeds/A: 24,500

Hybrid: Pioneer 37R71

Growth stage when photo taken: R2-R3

Soil test K level, parts per million (ppm): 114

Rate of K applied, lb K_2O/A: 60

K placement: Broadcast and incorporated

K form: 0-0-60

Leaf K concentration, % – ear leaf: 1.04 [1.04]

Grain yield, bu/A: 119 [119]

Grain yield reduction, bu/A: 0

Example 2. At the same location as **Example 1**, K fertilizer (0-0-60) was broadcast at incremental rates and then incorporated. The leaf in this picture is from a check plot where no K was applied. This K-deficient leaf shows marginal chlorosis and necrosis, worse at the leaf tip, and becoming progressively less intense down the margin of the leaf (site 29300C, plot number 104).

Planting date: 5-22-2000
Planted population, seeds/A: 24,500
Hybrid: Pioneer 37R71
Growth stage when photo taken: R2-R3
Soil test K level, ppm: 114
Rate of K applied, lb K_2O/A: 0
Leaf K concentration, % – ear leaf: 0.78 [1.04]
Grain yield, bu/A: 100 [119]
Grain yield reduction, bu/A: 19

Example 3. At this SDSU research location, 40 lb K_2O/A was applied to the corn on the right, and no K was applied to the corn on the left. Potassium fertilizer was 0-0-30 (a liquid mixture of potassium hydroxide and potassium carbonate), applied 2 in. to the side and 2 in. below the seed. All corn is the same hybrid. Plot length is 50 ft. Many ears in the fertilized plot are higher from the ground than in the unfertilized plot. When ears grow too low to the ground, they become difficult to harvest and losses can occur. Such differences are influenced not only by K fertility, but also by hybrid. Some hybrids in this trial did not show such marked differences (site 29900, plot number 327 left and 328 right).

Planting date: 5-22-2000
Planted population, seeds/A: 24,500
Hybrid: Garst 8830
Growth stage when photo taken: R6
Soil test K level, ppm: 114
Rate of K applied, lb K_2O/A: 0 (left); 40 (right)
K placement: 2x2 starter (right)
K form: liquid mixture (0-0-30)
Leaf K concentration, % – ear leaf: 0.87 (left); 1.11 (right)
Grain yield, bu/A: 69, (left); 83 (right)
Grain yield reduction, bu/A: 14

Example 4. In this farmer field, corn the previous year was K deficient and ears were low to the ground. The combine missed many of the ears, resulting in harvest losses. Grain left in the field created a significant volunteer corn problem in the subsequent soybean crop. This illustrates the impacts of K deficiency on management areas other than soil fertility and plant nutrition (area to left of site 29100R).

Growth stage when photo taken: R2
Soil test K level, ppm: 126
Soybean yield, bu/A: 21 (field average)

Example 5. The leaf in the top of the picture is from a check plot where no K was applied. The lower leaf is from a plot where K was considered non-limiting. Both leaves are from the same hybrid and are from adjacent plots. Plot widths are 25 ft. The K-deficient leaf shows marginal chlorosis and necrosis. It is also more affected by disease. Potassium deficiency has long been associated with increased susceptibility to certain diseases (site 29300C, plot number 104).

Planting date: 5-22-2000

Planted population, seeds/A: 24,500

Hybrid: Pioneer 37R71

Growth stage when photo taken: R2-R3

Soil test K level, ppm: 114

Rate of K applied, lb K_2O/A: 240 (healthy leaf); 0 (deficient leaf)

K placement: Broadcast, incorporated (healthy leaf)

K form: 0-0-60 (healthy leaf)

Leaf K concentration, % – ear leaf: 1.28 (healthy leaf); 0.78 (deficient leaf)

Grain yield, bu/A: 115 (healthy leaf); 100 (deficient)

Grain yield reduction, bu/A: 15 (deficient leaf)

Example 6. Marginal chlorosis may be accompanied by other symptoms, such as this red striping exhibited by some hybrids (site 29199).

Planting date: 5-17-99

Planted population, seeds/A: 29,991

Hybrid: Pioneer 37R71

Soil test K level, ppm: 133

Grain yield, bu/A: 45 [50]

Grain yield reduction, bu/A: 5

Example 7. Marginal chlorosis may not always be present during K deficiency. The leaf on the right has an overall lighter green appearance, difficult to detect unless healthy plants are nearby.

Example 8. As a rescue treatment, 100 lb K_2O/A was broadcast and then hoed in by hand at growth stage V6 to simulate shallow tillage. The ears in the top row are from the rescue treatment, and the ears below are from the check plot (site 30300).

Planting date: Week of May 8

Harvested population, plants/A: 22,391

Hybrid: DeKalb 477

Soil test K level, ppm: 73

Rate of K applied, lb K_2O/A: 0 (no rescue K applied); 100 (rescue K applied)

K placement: broadcast/hoed (rescue K applied)

K form: 0-0-60 (rescue K applied)

Leaf K concentration, % – ear leaf: 0.51 (no rescue K applied); 0.72 (rescue K applied)

Grain yield, bu/A: 86 (no rescue K applied); 117 (rescue K applied)

Grain yield reduction, bu/A: 31

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Starter Fertilizer Application Effects…

(continued from page 11)

did not yield as well as starters that contained both N and P. For example, in the 2x2 starter placement, 30 lb N/A alone increased average yield by 18 bu/A, 30 lb P_2O_5/A by 11 bu/A, while a combination of 30 lb N and 30 lb P_2O_5/A increased yield by 34 bu/A. The yield increase from the N and P combination exceeds the additive effect of each individual nutrient, thus illustrating the importance of nutrient interaction and balanced starter fertility in optimizing grain yield.

The higher N starters were the most efficient in reducing the number of days from emergence to mid-bloom (**Table 3**). When averaged over starter treatment and years, there was no difference between 2x2 applied starter and surface dribbled starter in early season dry matter and days from emergence to mid-bloom. When averaged over tillage treatment and method of application, starter fertilizer containing 30 lb N and 30 lb P_2O_5/A decreased the number of days from emergence to mid-bloom by over 11 days compared to the no-starter check treatment. All starter fertilizer treatments increased V6-stage whole plant dry matter over the no starter check. The starters containing either 30 or 45 lb N/A with 30 lb P_2O_5/A resulted in the greatest V-6 whole plant dry matter accumulation. Grain moisture at harvest was lower in the higher N starters that also included P.

Grain moisture in the 30-30 starter treatment was lower at all sample dates compared to the no-starter check, the P alone treatment or the treatment that included only 15 lb N. Starter containing both N and P had a substantial impact on hastening grain sorghum maturity. BC

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Residual Impacts of Previous Corn Rows on Potassium Nutrition of No-Till Narrow Row Soybeans

By Xinhua Yin and Tony J. Vyn

Both leaf potassium (K) concentrations and yield were higher for no-till soybean rows positioned near previous corn rows than for those soybean rows positioned between corn rows in Ontario research. The benefit of proximity to a previous corn row was associated with higher soil test K levels in corn rows and was enhanced by K fertilizer applications (particularly deep banding) to corn. Adjustments to the current soil sampling method (using a composite sample based on random points within an area) may be needed when narrow-row no-till soybeans follow corn on low- and medium-testing K soils.

Vertical as well as horizontal K stratification occurs in surface soil horizons of no-till fields following corn production. Several recent studies have addressed the effects of vertical stratification and the benefits of broadcast versus band placement of K fertilizers before soybeans.

The issue of horizontal K stratification has been largely ignored, even though the majority of no-till soybean production in North America is in narrow-row systems following corn. The resultant soybean plants in 7.5 to 20 in. row width systems are thus at various distances from previous corn rows, but little is known about whether soybean response varies with distance to prior corn rows. The knowledge gap becomes more critical as the K fertilization strategies used by corn farmers shift from primarily broadcast K application to deep banding (and with or without starter application), when farmers rely only on biennial K application before corn in a corn-soybean sequence, and when overall soil exchangeable K is at less than optimum levels for soybean production.

The primary objectives of this study were to: 1) investigate the impacts of previous corn rows on soil K fertility, leaf K nutrition, and seed yield of subsequent narrow-row no-till soybeans; and 2) evaluate the influences of K fertilizer placement for the preceding corn on soybean response to relative proximity to corn rows.

Experimental Approach

Site 1. A corn-soybean rotation was studied from 1997 to 2000 on fields near Paris, Ontario, with a minimum six-year history of continuous no-till. Soil test K levels (0 to 6 in.) were in the low range, less than 61 mg/L [approximately equivalent to 51 parts per million (ppm)], and the soil texture was silt loam.

In 1997 and 1998, three spring tillage systems (no-till, zone-till, and mulch-till) were compared, with four K placement methods...deep band (6 in. deep), surface broadcast, broadcast + shallow band (2 in. deep), and zero K. In 1999, the same K placement methods were compared, but only in a no-till system. Only spring-applied K was evaluated in each season. When K fertilizer was applied, the rate was 107 lb K_2O/A.

The identical experimental design and plot layout in the corn year were used for the subsequent soybean seasons. Soybean variety Pioneer 9163 was no-till planted in 1998 and 1999, and NK S08-80 was grown in 2000 in 7.5 in. row widths in the same direction as the previous corn rows (30 in. widths) in each season, to evaluate the previous corn row effects on soil K fertility and soybean responses. Potassium fertilizer was not applied after corn or during soybean season in any of the experiments.

When soil, plant, or seed sampling was conducted, two separate samples were taken from each subplot. One was randomly collected from soybean rows positioned in previous corn rows, and the other was taken from soybean rows positioned between the previous corn rows (i.e. approximately 15 in. from the corn rows). Soil samples were collected to four depth intervals (0 to 2 in., 2 to 4 in., 4 to 8 in., and 8 to 12 in.) prior to soybean planting and after soybean harvest. Leaf K samples were taken at initial flowering stage. Seed samples were collected by hand harvesting 26 ft. lengths of soybean rows either in or between previous corn rows. Resulting soybean yield estimates are based on unbordered sampling areas. Soil K was extracted with 1 M ammonium acetate (NH_4OAc, pH = 7) solution. Leaf K and seed K were extracted using a dry ash method.

Site 2. Previous corn row effects on subsequent narrow-row no-till soybean yield were also monitored at Kirkton, Ontario, in 1999. The average soil test K levels (0 to 6 in.) were 90 mg/L (approximately equivalent to 75 ppm). The experiment for the corn year (1998) compared fall zone-till and no-till tillage systems, fall K application rates (0 and 90 lb K_2O/A), and spring K rates (0 and 45 lb K_2O/A). Soybeans (variety First Line 2801R) were planted in 15 in. row widths.

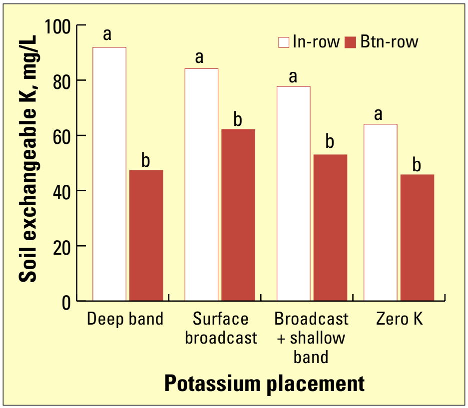

Figure 1. Previous corn row effects on soil K concentrations (0 to 8 in. depth) before soybean planting at Paris in 2000. In-row = in previous corn rows; Btn = between previous corn rows. Within K treatments, bars labeled with the same letter are not significantly different at p = 0.05 according to Fisher's protected LSD test.

TABLE 1. Previous corn row effects on leaf K concentrations at initial flowering stage at Paris from 1998 to 2000.[1]

	Year and soybean row position					
	1998		1999		2000	
K placement in prior corn year	**In[2]**	**Btn**	**In**	**Btn**	**In**	**Btn**
	Leaf K, %					
Deep band	2.1	1.6	1.7	1.1	2.8	2.3
Surface broadcast	2.1	1.9	1.6	1.2	2.7	2.4
Broadcast+shallow band	2.1	1.7	1.7	1.0	2.8	2.5
Zero K	1.7	1.4	1.3	0.9	2.6	2.3
Average	2.0a	1.7b	1.6a	1.1b	2.7a	2.4b

[1] Leaf K results are averaged over the three prior tillage systems in 1998 and 1999, and averaged over the three previous corn hybrids in 2000.

[2] In = in previous corn rows; Btn = between previous corn rows.

Means in a row within each year followed by the same letter are not significantly different at p = 0.05 according to Fisher's protected LSD test.

Results

Site 1. Before soybean planting in 2000, soil test K levels at the 0 to 2 in., 2 to 4 in., and 4 to 8 in. depth intervals in previous corn rows were higher than those between previous corn rows in both the zero K treatment and K-fertilized treatments (**Figure 1**), suggesting more available soil K was present in previous corn rows even when K fertilizer was not applied to previous corn. Neither spring tillage systems (data not shown) nor K placement methods before corn significantly

Irregular K deficiency patterns in soybeans, associated with previous corn rows.

Soybean K deficiency symptoms varied with proximity to previous corn rows.

influenced the corn row effects on soil K concentrations.

Visual K deficiency symptoms in soybeans were evident in July and August of both 1998 and 1999 at Paris in plots where K had not been applied in the previous corn year (see photos), and were more prevalent in plants positioned between previous corn rows. This coincided with higher soil K levels in prior corn rows.

Leaf K concentrations of soybeans in preceding corn rows were significantly higher than those between corn rows in all three seasons at Paris (**Table 1**). However, K placement methods significantly affected the row position effects on leaf K only in 1999. Deep banding and broadcast + shallow band resulted in greater differences in soybean leaf K in previous corn rows, versus those between previous corn rows, compared to zero K and surface broadcast. Previous corn row effects on leaf K nutrition of subsequent narrow-row no-till soybeans also occurred even when K fertilizer had not been applied to preceding corn; this may be a result of the elevated soil K levels associated with K release from the corn stover and roots in the corn row areas. Spring tillage systems used in the corn year did not affect soybean leaf K responses to row position (data not shown).

Seed yield of soybean in previous corn rows was 69 percent (14.3 bu/A) higher than those between previous corn rows with the zero K treatment in no-till in 1998 (**Table 2**). In 1999, yield increases for soybean in previous corn rows, versus between rows, averaged 11 percent (4.8 bu/A) over the three K treatments and three tillage systems. However, soybean yield was not significantly higher in previous corn rows in 2000 (**Table 2**), even though leaf K concentrations of soybean in previous corn rows were greater than those between prior corn rows. This may be because leaf K concentrations in the mid-season were very high (>2.2 percent) for both, which suggests that K nutri-

TABLE 2. Previous corn row effects on seed yield at Paris from 1998 to 2000.[1]

K placement in prior corn year	1998 In[2]	1998 Btn	1999 In	1999 Btn	2000 In	2000 Btn
	Yield, bu/A					
Deep band	ND[3]	ND	46.7	43.1	56.1	58.1
Surface broadcast	ND	ND	50.7	46.7	55.5	59.5
Broadcast+shallow band	ND	ND	ND	ND	54.9	54.7
Zero K	35.1a	20.8b	51.9	45.2	54.9	54.7
Average			49.8a	45.0b	55.4a	56.8a

[1] Values are for no-till alone in 1998, but averaged over the three prior tillage systems in 1999, and averaged over three previous corn hybrids in 2000.
[2] In = in previous corn rows; Btn = between previous corn rows.
[3] ND = not determined.
Means in a row within each year followed by the same letter are not significantly different at p = 0.05 according to Fisher's protected LSD test.

tion was unlikely to have been a limiting factor for soybean yield in 2000. The rainfall in June 2000 was 8.6 in., 2.5 times higher than the 30-year average of 3.4 in. Higher soil moisture during critical periods in the growing season could greatly increase soil K availability and plant K uptake, and thus decrease soybean responses to residual K fertilizer applications.

Site 2. At Kirkton, differences in leaf K concentrations of soybeans in previous corn rows versus between corn rows were not significantly influenced by tillage system (data not shown) or fall-applied K, but were affected by spring-applied K imposed on previous corn (**Table 3**). Soybean plants positioned in previous corn rows averaged 10 percent (4.9 bu/A) higher yield relative to those between previous corn rows on this medium testing K soil (**Table 3**). Neither fall-applied K, spring-applied K, nor fall tillage system treatments for previous corn influenced the preceding corn row effects on seed yield.

TABLE 3. Previous corn row effects on leaf K concentrations and seed yield at Kirkton in 1999.[1]

Treatment in prior corn year	Leaf K In[2]	Leaf K Btn	Yield In	Yield Btn
	%		bu/A	
Fall K_2O, lb/A				
0	1.9	1.7	55.9	49.1
75	2.3	2.1	55.2	52.3
Spring K_2O, lb/A				
0	2.1a	1.7b	55.2	49.2
37	2.1a	2.0a	55.9	52.2
Average	2.1a	1.9b	55.6a	50.7b

[1] Values are averaged over the three prior tillage systems.

[2] In = in previous corn rows; Btn = between previous corn rows. Means in a row within leaf K or yield followed by the same letter are not significantly different at p = 0.05 according to Fisher's protected LSD test.

Implications

The results above suggest that the current soil sampling protocol for soybean (using a composite sample, randomly collected from a specified area) has not only underestimated soil K levels in the zones of previous corn rows, but also overestimated K concentrations between prior corn row zones. Therefore, it may be beneficial to take soil samples from within previous corn rows and between corn rows separately, and then make separate K fertilizer recommendations correspondingly. However, this would double the costs of soil sampling and, if row effects are significant, complicate the application of K fertilizer at varying rates in such narrow zones. Alternatively, a simple and conservative approach is to take a composite soil sample only from between previous corn row areas, and use the result of this sample to make K fertilizer recommendations for the entire field. Although the latter approach may underestimate soil K fertility levels in previous corn rows – and result in over-application of K fertilizer for subsequent no-till soybean in previous corn rows – it may be a preferable strategy due to relatively low cost of K fertilizers, low toxicity of luxurious K uptake to plants, and high cost of yield loss if soil K available to soybeans is not sufficient.

Furthermore, deep banding of K fertilizers for corn has the potential to accentuate the row versus between row responses of subsequent no-till soybeans. So, particularly when overall soil-test K levels are in the low to medium range, broadcast K fertilizer application before no-till soybean is even more beneficial in narrow-row production systems following corn where K fertilizer has been deep banded.

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MISSOURI

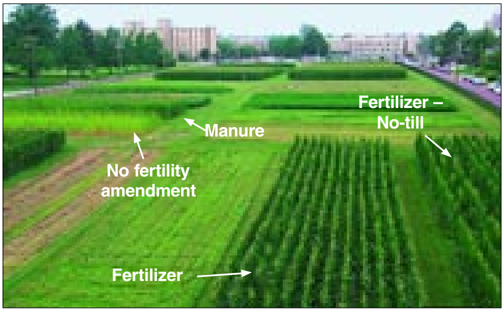
Inorganic and Organic Soil Phosphorus Fractions after Long-Term Animal Manure and Fertilizer Applications

By Peter P. Motavalli and Randall J. Miles

Maintenance of adequate amounts of soil P through application of inorganic and/or organic P sources is critical for long-term agricultural productivity. In the soil, applied P is partitioned into readily-available (labile) and less readily-available (stable) inorganic and organic forms with different desorption, dissolution, and mineralization rates that may contribute to plant P nutrition. In general, long-term studies have observed a decline in soil organic P fractions with continuous cultivation and no fertility inputs. In farming systems that rely on organic fertility amendments, such as animal manure, organic P fractions may be a more important source of plant-available P than for farming systems relying on P fertilizer.

Analysis of soil test phosphorus (P) fractions and Bray P-1 after 111 years of fertilizer or manure application on Sanborn Field indicates that cropping systems and fertility practices affect the proportion of soil inorganic and organic P.

Some have questioned whether traditional soil test procedures for plant-available P (e.g. Bray P-1) adequately assess the contribution of more stable inorganic and organic soil P fractions to nutrition of crops after long-term cultivation and repeated fertilizer P applications. We used a sequential P extraction method to determine potential differences in the form and quantity of different inorganic (P_i) and organic (P_o) soil P fractions (modified Hedley procedure) in long-term (111 years) cultivated plots and to assess the use of the Bray P-1 extractant for determining changes in soil P availability in fertility programs utilizing fertilizer or animal manure.



Sanborn Field is shown during the 2000 growing season. Note the difference in corn growth response among the historical continuous corn plots with no added fertility amendment and added manure or fertilizer.

Plots on Sanborn Field at the University of Missouri campus have been unamended or annually amended with commercial fertilizers based on soil test recommendations for Missouri or with 6 tons/A (wet weight basis) horse or dairy manure since 1888. Based on analyses initiated in 1990, dairy manure applied to Sanborn Field has had an average moisture content of 79 ± 7 percent and a nutrient content of 1.9 ± 0.4 percent total nitrogen (N), 0.4 ± 0.5 percent total P, and 0.9 ± 0.7 percent total potassium (K). Horse manure applied prior to the 1950s contained a relatively larger proportion of bedding material compared to dairy manure. All manure was broadcast-applied in the fall and commercial fertilizers were broadcast-applied in the spring. Fertilizer P was applied as crude grade acid phosphate or normal superphosphate (16 to 20 percent P_2O_5) up to the 1940s and triple superphosphate (46 percent P_2O_5) was applied afterward. Rock phosphate (30 to 37 percent P_2O_5) was also applied sporadically to fertilized plots. All plots considered in this study were tilled using a moldboard plow and then were disked twice before planting. We collected soil samples from Sanborn Field to a depth of 8 in. during the fall of 1999 from long-term cropping systems plots including continuous corn, continuous wheat, a corn-wheat-red clover rotation, and continuous timothy. Additional soil from the same plots was analyzed by subsampling stored samples taken to a depth of 8 in. in 1915, 1938, and 1962.

Yield goals for grain and forage crops on Sanborn Field increased from the cropping period of 1888-1949 to the cropping period of 1990-1999, corresponding to changes in crop genetics, fertilizer sources, and other developments in agricultural technology (**Table 1**). Higher rates of N, P, and K fertilizer were applied on fertilizer-treated plots based on University of Missouri soil test recommendations to meet the higher yield goals. However, average crop yields observed on fertilizer- and manure-treated plots during the three selected periods were below yield goals, especially on the grain crops (**Table 1**), suggesting a possible consistent over-application of nutrients due to an over-estimation of the yield potential. Over-application of animal manure, and sometimes commercial P fertilizer, can lead to soil P accumulation in agricultural soils.

Corn grain yields were consistently higher in fertilizer-amended plots compared to the manure-amended and control treatments over the three periods of Sanborn's history (**Table 1**). The relatively lower corn yields with manure can be explained by the low manure application rate (6 wet tons/A), the effects of varying amounts of bedding in the manure on N released to the crop, especially in the early periods of Sanborn's history when horse manure was used, and the fact that most of the manure additions were calculated on a wet weight basis (thereby reducing the actual amount of nutrient-containing manure applied). Wheat yields increased with either added manure or fertilizer compared to the control

TABLE 1. Yield goals, fertilizer nutrient applications, and average grain and forage yields in selected periods for Sanborn Field.

		Yield	Fertilizer nutrients applied			Grain or forage yields[1]		
		goal,	N	P_2O_5	K_2O	None	Fertilizer	Manure
Period	**Crop**	**bu or tons/A**		**lb/A**			**bu or tons/A**	
1888 - 1949[2]	Corn (grain)	79 bu/A	126	44	82	21 bu/A	42.9 bu/A	35.7 bu/A
	Wheat (grain)	40 bu/A	82	27	66	20 bu/A	20 bu/A	20 bu/A
	Clover (forage)	3.0 tons/A	128	34	130	0.7 tons/A	3.1 tons/A	1.4 tons/A
	Timothy (forage)	3.0 tons/A	—	—	—	1.1 tons/A	—	2.4 tons/A
1950 - 1989[3]	Corn (grain)	179 bu/A	167	67	144	21 bu/A	100 bu/A	64.3 bu/A
	Wheat (grain)	40 bu/A	76	23	67	13 bu/A	40 bu/A	36.6 bu/A
	Clover (forage)	NA	NA	NA	NA	1.8 tons/A	3.6 tons/A	3.2 tons/A
	Timothy (forage)	NA	—	—	—	1.0 tons/A	—	2.9 tons/A
1990 - 1999[4]	Corn (grain)	179 bu/A	208	0	0	25 bu/A	118 bu/A	64.3 bu/A
	Wheat (grain)	70 bu/A	82	32	25	17 bu/A	33 bu/A	33.3 bu/A
	Clover (forage)	4.2 tons/A	0	46	168	2.0 tons/A	1.4 tons/A	4.3 tons/A
	Timothy (forage)	4.0 tons/A	—	—	—	1.0 tons/A	—	2.7 tons/A

[1] Average annual grain or forage yields over selected period.

[2] Crop residues removed after harvest. Horse manure with bedding applied for manure treatment. Fertilizer was not applied to the timothy cropping system.

[3] Crop residues returned after harvest. Dairy manure applied for manure treatment. Information not available (NA) regarding yield goals for clover and timothy during this period. Fertilizer was not applied to the timothy cropping system. For clover, P and K fertilizer were added based on soil test recommendations and information on specific rates was not recorded.

[4] Crop residues returned after harvest. Dairy manure applied for manure treatment. N, P, and K fertilizers added based on soil test recommendations. Numbers presented are averages over years of actual fertilizer applied. Fertilizer was not applied to the timothy cropping system.

during the two periods from 1950 to 1999, but not during the period from 1888 to 1949. Clover yields were higher with added fertilizer or manure during 1888 to 1989, but were not responsive to fertilizer from 1990 to 1999. Timothy yields were consistently higher with added manure compared to the control.

The accumulation of Bray P-1 in cropping systems under different soil fertility treatments over time on Sanborn Field is shown in **Figure 1**. Under Missouri soil test recommendations, soil Bray P-1 values greater than 20 to 22.5 parts per million (ppm) are above the level required for optimal plant growth and yield response. By 1999, soil Bray P-1 levels were significantly higher in the fertilized and manure treatments under all cropping systems compared to the unfertilized check treatment (**Figure 1**). The unfertilized check treatment also showed a general decrease in Bray P-1 from 1915 to 1999, probably due to crop removal (data not shown).

Other research at Sanborn Field observed an initial marked decline in Bray P-1 in the manured plots, followed by a continuous increase. This trend in soil test P was attributed to the early use of horse manure with a high proportion of bedding. An additional effect on extractable and organic soil P occurred after 1950 when residue management was changed and straw and stalks were incorporated into the soil after cropping.

Addition of P as fertilizers or manure significantly increased readily-available P_i among all cropping systems at Sanborn Field compared to the unfertilized checks and the native prairie site (**Table 2**). With the exception of the corn-wheat-clover rotation, long-term application of P fertilizer and manure also significantly increased moderately-available P_i. Researchers in Canada have observed significant increases in P_i fractions, with 10 years of P fertilizer applications for continuous corn production in southern Ontario. In contrast, we did not observe significant increases in available-P_i, with long-term application of fertilizer, but did find significant increases in available-P_i with applications of manure in the continuous corn and wheat cropping systems (**Table 2**). Long-term application of commercial P fertilizers did not significantly increase P_o fractions or residual P (Total P - P_i - P_o), compared to the plots receiving no amendments, or to the native prairie site. The lack of increased P_o fractions in commercial P fertilized plots on Sanborn Field may have been associated with the continuous use of conventional tillage in plot preparation and the practice of removing all crop residues before 1950. Tillage may stimulate the conversion of P_o to P_i.

Long-term application of animal manure generally resulted in significant increases in most P_i and P_o fractions and total P compared to the unfertilized treatment (**Table 2**). Generally, the moderately-available P_i extract appeared to be more responsive than the readily-available P_i extract to manure applications, compared to added P fertilizer. The native prairie site had a larger proportion of total P in organic forms compared to the cultivated plots, especially in the moderately-available P_o extract (**Table 2**). Long-term cultivation of the native prairie originally present at Sanborn Field did not result in a significant decrease in either residual or total P. Total P levels on Sanborn Field appeared to be more affected by fertility treatment and not by cropping system.

Correlations of estimated plant P uptake with extracted P fractions, by fertility treatment for the four sampling years considered in this study, did not show strong relationships with sequential P fractions, Bray P-1, or total P. These results indicate that plant response on Sanborn Field is influenced by several interacting soil, plant, and climatic factors in addition to soil P availability.

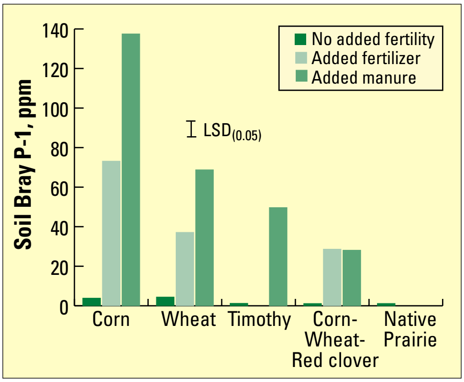


Figure 1. Soil test P (Bray P-1) of soil fertility plots on Sanborn Field and in native prairie soil in the fall of 1999.

The results of this study confirm that long-term cropping systems and fertility practices significantly alter the amounts and proportion of labile and stable soil P pools compared to the initial native prairie soil. A major factor affecting the accumulation of soil P in Sanborn Field has been the unrealistically high yield goals, leading to over-fertilization. Changes in management which have occurred over the 111 year cropping history of Sanborn Field have also had a significant impact on soil P, including changes in crop residue management and applied animal manure composition. This study also shows that long-term manure applications have significantly different effects on soil inorganic and organic P pools than applications of commercial P fertilizers. Both labile and more stable P pools are increased by long-term manure applications. These results support previous studies which have suggested that soil P availability dynamics, in cropping systems that receive predominantly organic P amendments, may differ from conventional cropping systems relying on commercial P fertilizers. **No direct evidence could be found to support the hypothesis that any individual soil P fraction, such as moderately-available P_i or P_o, has a better relationship than conventional soil test P extractants, such as the Bray P-1 extractant, with plant P uptake under contrasting fertility practices over 111 years of cultivation.**

TABLE 2. Selected inorganic and organic sequential P fractions[1] from Sanborn Field during the 1999 cropping season.

		Inorganic P			Organic P		
Crop	Fertility treatment	Readily-available P_i	Available P_i	Moderately-available P_i	Available P_o	Moderately-available P_o	Total P
		ppm P					
Corn	None	3.0	18.4	19.4	22.5	30.8	225
	Fertilizer	54.1	54.8	75.8	36.6	103.9	487
	Manure	55.5	181.2	148.6	23.0	148.6	621
Wheat	None	3.8	3.3	29.4	53.5	50.6	274
	Fertilizer	35.3	34.4	80.2	52.3	73.3	465
	Manure	47.7	82.6	198.3	76.0	135.0	709
Corn-wheat-red clover	None	5.0	6.4	15.4	30.3	69.0	203
	Fertilizer	27.1	39.3	44.6	36.3	67.7	389
	Manure	21.3	40.7	44.5	59.7	82.2	516
Timothy	None	4.3	14.8	21.0	41.8	62.5	249
	Manure	41.7	51.4	114.9	69.3	99.1	617
Native prairie	None	4.0	6.5	21.8	59.6	176.5	323
	$LSD_{(0.05)}$	8.2	50.3	40.7	42.1	82.9	226

Note: Readily-available P_i = resin; available P_i = $NaHCO_3$; moderately-available P_i = NaOH; available P_o = $NaHCO_3$; moderately-available P_o = NaOH.

[1] Hedley, M.J., J.W.B. Stewart, and B.S. Chauhan. 1982. Changes in the inorganic and organic soil phosphorus fractions induced by cultivation practices and by laboratory incubation. Soil Sci. Soc. Am. J. 46:970-976.

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For more about Sanborn Field plots, go to the website at http://aes.missouri.edu/sanborn/index.stm

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WILL YOUR CROP RUN OUT OF GAS THIS YEAR?

I've never understood why people let their cars run out of gas. Everybody knows a car won't run without gasoline in the tank. The gas gauge tells them when the tank is approaching empty, and there are gas stations on nearly every street corner. Maybe some like the challenge of seeing if they can go one more mile or reach the next station before the engine sputters to a stop. Maybe they just like taking risks. Whatever the reason, it doesn't make sense. Gasoline may be expensive, but a tank full is still cheaper than the cost of a tow truck.

Phosphorus (P) and potassium (K) are a lot like gasoline. Crops can't grow and produce an economic yield without them. Soil tests, as the gas gauge in a car, measure P and K levels and tell farmers when these (and other) essential plant nutrients should be applied. However, when farmers allow their soils to run low in P or K, they are risking much more than a car stalled on a roadside because of an empty gas tank. They are risking yield potential and profits…their very livelihood.

A recent North American soil test survey conducted by the Institute showed that between 40 and 50 percent of the more than 2.0 million soil samples evaluated tested medium or below in either or both P and K. Unlike the automobile, the soil's PK tank doesn't have to be empty before crop yields and farmer profits are negatively affected. Low and medium soil tests take away from potential yields and profits, and they do it every year fertility levels aren't rebuilt to an optimum level.

Where is the PK gauge registering in your fields or those of your farmer customers? Is it approaching the empty mark? Take the opportunity to find out, beginning during this growing season. Make visual observations. Look for deficiencies. Document potential problem areas by taking plant samples and having them analyzed. When crops are harvested this fall, have soils tested. Then put all the information together and come up with a plan to refill the soil's PK tank before next year's crop is planted.

Don't take the risk of allowing a crop to run out of P and K when it is so easy to refill the tank. Keep soil fertility levels high to help crops reach their yield potential.

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