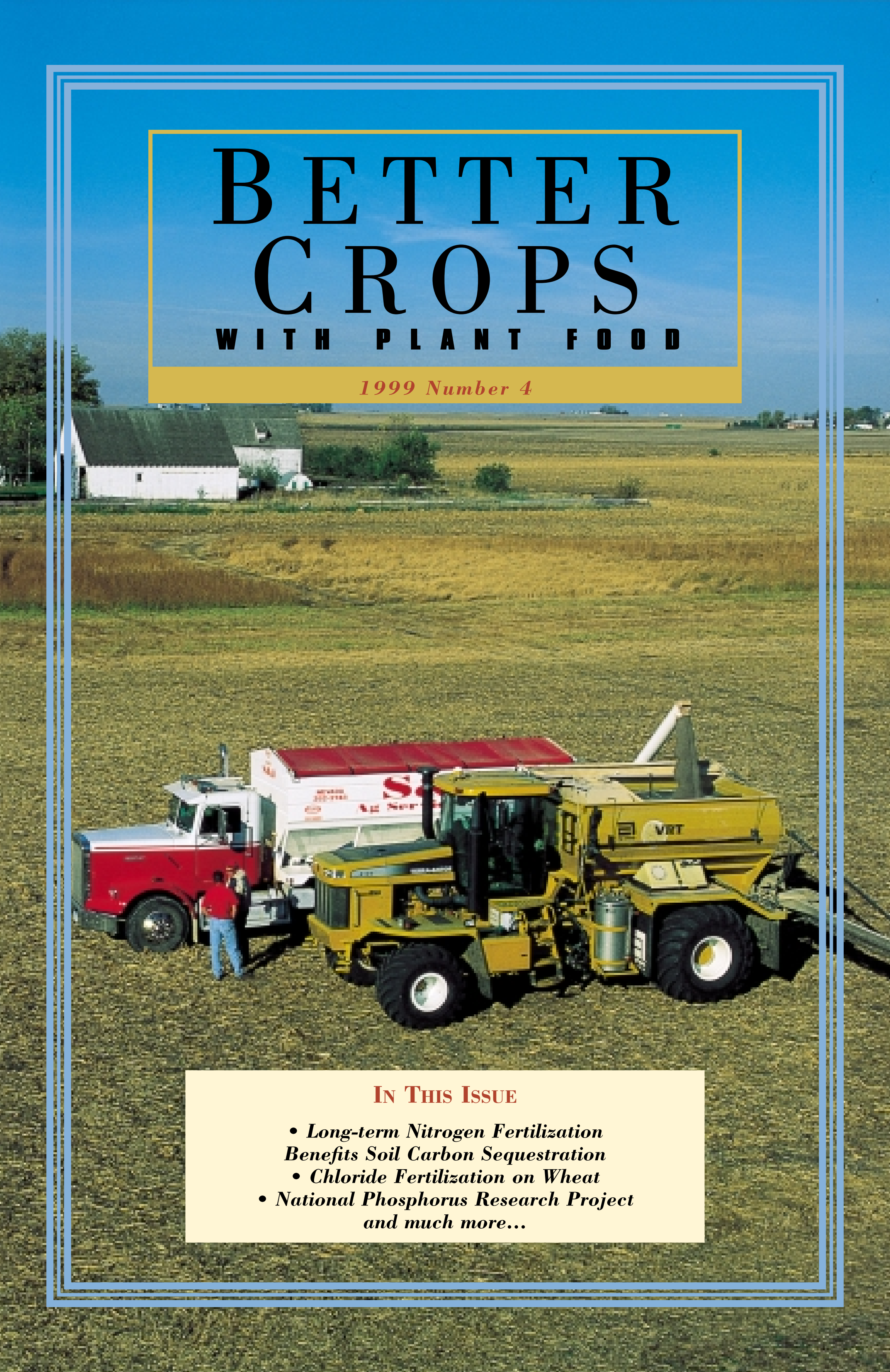
BETTER CROPS

WITH PLANT FOOD

1999 Number 4



In This Issue

- *Long-term Nitrogen Fertilization Benefits Soil Carbon Sequestration*
- *Chloride Fertilization on Wheat*
- *National Phosphorus Research Project*

and much more…

BETTER CROPS
WITH PLANT FOOD

Vol. LXXXIII (83) 1999, No. 4

Our Cover: Fall fertilizer application.
Photo Source: Bob Elbert

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

Potash & Phosphate Institute (PPI)
W.J. Doyle, Chairman of the Board
Potash Corporation of Saskatchewan Inc.
C.S. Hoffman, Vice Chairman of the Board
IMC Global Inc.
H. Mathot, Chairman, Finance Committee
Cargill, Incorporated

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

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

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

INTERNATIONAL PROGRAMS-Saskatoon, Saskatchewan
M.D. Stauffer, Senior Vice President, International Programs (PPI), and President, Potash & Phosphate Institute of Canada (PPIC)
G. Sulewski, Agronomist
L.M. Doell, Administrative Assistant
D. Craig, Executive Secretary
K. Segi, Receptionist

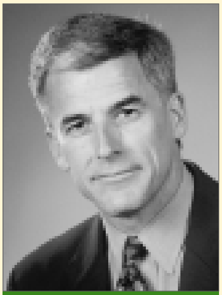
INTERNATIONAL PROGRAM LOCATIONS
Brazil T. Yamada, POTAFOS, Piracicaba
China S.S. Portch, Hong Kong
J. Wang, Hong Kong
Ji-yun Jin, Beijing
Fang Chen, Wuhan
Shihua Tu, Chengdu
Ronggui Wu, Beijing
Rongle Liu, Beijing
India K.N. Tiwari, Gurgaon, Haryana
T.N. Rao, Secunderabad, Andhra Pradesh
Northern Latin America J. Espinosa, Quito, Ecuador
Latin America-Southern Cone F.O. Garcia, Buenos Aires
Mexico I. Lazcano-Ferrat, Querétaro
East and Southeast Asia E. Mutert, Singapore
T.H. Fairhurst, Singapore

BETTER CROPS WITH PLANT FOOD
(ISSN:0006-0089) is published quarterly by the Potash & Phosphate Institute (PPI). Periodicals postage paid at Norcross, GA, and at additional mailing offices (USPS 012-713). Subscription free on request to qualified individuals; others $8.00 per year or $2.00 per issue. POSTMASTER: Send address changes to **Better Crops with Plant Food**, 655 Engineering Drive, Suite 110, Norcross, GA 30092-2837. Phone (770) 447-0335; fax (770) 448-0439. www.ppi-far.org
Copyright 1999 by Potash & Phosphate Institute.

CONTENTS

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

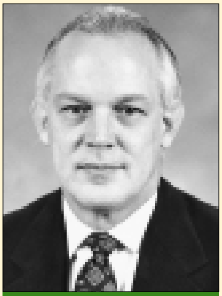
William J. Doyle Elected Chairman, C. Steve Hoffman Vice Chairman of PPI and FAR Boards of Directors



William J. Doyle

William J. Doyle, President and Chief Executive Officer (CEO) of the Potash Corporation of Saskatchewan Inc. (PCS) was elected Chairman of the PPI Board of Directors at a recent meeting. He will also serve as Chairman of the Foundation for Agronomic Research (FAR) Board of Directors. **C. Steve Hoffman**, President, IMC International, and Senior Vice President of IMC Global Inc., was elected Vice Chairman of the PPI and FAR Boards.

"We value the willingness of these industry leaders to serve in key responsibilities for the Institute in the coming year," said Dr. David W. Dibb, President of PPI. "Their management talents are important to continuing the mission of PPI."



C. Steve Hoffman

Mr. Doyle has served on the PCS Board since 1989 and was appointed CEO effective July 1, 1999. He became President and Chief Operating Officer of PCS in 1998 and prior to that was President of PCS Sales. Before joining PCS in 1987, Mr. Doyle was International Vice President of International Minerals and Chemical Corporation. He is past Chairman of Canpotex Limited and continues to serve on its Board. Mr. Doyle is Vice President-Canada for the International Fertilizer Industry Association's Potash Committee.

Mr. Hoffman is an officer of IMC Global Inc. and is responsible for international phosphate and potash marketing and sales activities, as well as overseas business development. He joined the Company in 1974 as a sales trainee. In 1982, he joined the Company's fertilizer group as Manager, Latin America. He was named Director, Asia Pacific, and then promoted to Vice President, International Division, in 1987. In 1989, Mr. Hoffman was promoted to Vice President, Domestic Wholesale Marketing. In 1994, he became Senior Vice President, International, of IMC Global Inc. He was promoted to his current position in 1998.

Mr. Hoffman is President and a Director of the Phosphate Chemicals Export Association (PhosChem). He serves on the Board of Directors for the Canadian Potash Export Association (Canpotex) and the Sulphate of Potash Information Board.

In other action of the PPI Board, Henk Mathot, President of Cargill Worldwide Fertilizer Operations, was elected Chairman of the Finance Committee. New members of the PPI Board include: Steven J. Demetriou, Senior Vice President, IMC Global Inc.; Patricia E. Rogers, Vice President-Fertilizer, Worldwide Wholesale Distribution, Cargill; and Al Giese, President of Cenex/Land O'Lakes Agronomy Company, representing CF Industries Inc.

During the FAR Board meeting, Dr. B.C. Darst, Executive Vice President of PPI, stepped down as President of FAR, after serving since 1988. Dr. Terry L. Roberts, PPI/PPIC Latin America Program, was elected as the new President of FAR. New members of the FAR Board include: Dr. Roberts; R.L. Moore of Mississippi Potash; Charles Adams of Helena; and Dr. Michael Broadhurst of Zeneca. For the first time, three honorary members were named to the FAR Board. They are Dr. R.E. Wagner, Dr. E.T. York, Jr., and Dr. Darst. BC

ALABAMA

Cotton Response to Sulfur on a Coastal Plain Soil

By G.L. Mullins

Since the early 1960s, the Southeast has experienced a reduction in the use of S-containing phosphorus (P) fertilizers, reductions in industrial emissions of atmospheric S, the use of higher yielding varieties, and the adoption of improved production practices, all of which could increase the need for fertilizer S.

The acreage of cotton in the Coastal Plain region of the Southeast has increased in recent years. Soils of the southern Coastal Plain are typically sandy and have low levels of extractable sulfate-S (SO_4-S). Many of these soils have low S adsorption capacities which result in limited residual effects of applied S due to leaching. It is on these deep, sandy soils that a response to S fertilization would be expected.

Cotton yield responses to sulfur (S) have been documented on some Coastal Plain soils, but most of the research was conducted in the 1950s and early 1960s. Alabama is no exception. The current recommendation in Alabama is that all crops receive 10 lb of S/A per year.

In the spring of 1993, a non-irrigated field test was initiated on a Lucy loamy sand at the Wiregrass Substation in Headland, Alabama.

The purpose of the study was to evaluate the response of cotton to S. Treatments included rate, source, and timing of S fertilizer applications. Sulfur was preplant broadcast as ammonium sulfate [$(NH_4)_2SO_4$, 24 percent S and 21 percent nitrogen (N)], elemental S (90 percent S), potassium sulfate (K_2SO_4, 19 percent S and 50 percent K_2O), potassium-magnesium sulfate [$K_2SO_4 \bullet 2MgSO_4$, 22 percent S, 22 percent K_2O, and 11 percent magnesium (Mg)], and potassium thiosulfate ($K_2S_2O_3$, 2.1 lb S/gal. and 3.0 lb K_2O gal.).

Each source was applied at rates of 0, 10, 20, and 40 lb S/A. Timing of S application was evaluated by applying $(NH_4)_2SO_4$ at rates of 10, 20, and 40 lb S/A at first square. In 1995 (last year of the study), additional treatments were added to evaluate cotton response to Mg. The first treatment received 20 lb Mg/A as Mg chloride hexahydrate ($MgCl_2 \bullet 6H_2O$, 11 per-

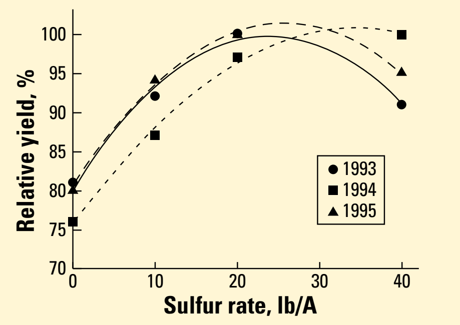


Figure 1. Cotton lint yields as affected by the rate of S on a Lucy loamy sand in Alabama.

TABLE 1. Effect of the source of S fertilizer on cotton lint yields on a Coastal Plain soil in Alabama.

Sulfur source	1993[1]	1994	1995
	lb lint/A		
Ammonium sulfate	277	768	754
Elemental sulfur	294	629	758
K-Mg sulfate	291	786	802
Potassium sulfate	282	629	712
Potassium thiosulfate	296	691	740
$LSD_{(0.10)}$	NS[2]	124	NS

[1] Low yields in 1993 resulted from low rainfall.

[2] NS = non-significant.

cent Mg) without S, and the second treatment received 20 lb Mg/A and 20 lb S/A, the S being applied as $(NH_4)_2SO_4$. All treatments received uniform annual applications of 90 lb N/A and 140 lb K_2O/A.

The Lucy soil had low organic matter and a low level of extractable SO_4-S, which averaged 4 lb/A in the surface 18 inches. Under rain-fed conditions, a positive yield response to S rate was obtained during all three years of the test (**Figure 1**). Lint yields peaked at a rate of ≈20 lb S/A, which is twice the current recommended rate of 10 lb/A for cotton production on this soil. Applying S at a rate of 20 lb/A increased lint yields by an average of 21 percent as compared to the no S check treatment.

In this test, five sources of S were compared: $(NH_4)_2SO_4$, elemental S, K_2SO_4, $K_2S_2O_3$, and $K_2SO_4 \bullet 2MgSO_4$ (**Table 1**). Lint yields were not affected by the source of S during the first and third years. However, during the second year (which was extremely wet), $(NH_4)_2SO_4$ and $K_2SO_4 \bullet 2MgSO_4$ produced slightly higher yields as compared to the other sources.

Preplant versus first square applications of S as $(NH_4)_2SO_4$ did not affect lint yields during the first and third years of the study (**Table 2**). In the second year, applying S preplant gave higher yields as compared to first square applications. The response due to timing of S application during the second year was attributed to heavy rainfall soon after the first square application.

In 1995, additional treatments were added to evaluate the effects of Mg on lint yields, primarily due to the favorable performance of $K_2SO_4 \bullet 2MgSO_4$ in 1994. The Lucy soil had 87 lb/A Mehlich I extractable Mg, which would correspond to a "high" rating according to the Auburn University Soil Testing Laboratory. Results from a single season suggest that S response and Mg response were additive on the Lucy soil. The response of cotton to Mg and S when applied alone and together needs further investigation.

TABLE 2. Cotton lint yields (means averaged across rates) as affected by applying S as $(NH_4)_2SO_4$ at preplant or at first square.

	1993	1994	1995
Time of application		lb lint/A	
Pre-plant	294	768	753
First square	296	587	720
$LSD_{(0.10)}$	NS[1]	129	NS

[1] NS = non-significant.

Sulfur-deficient cotton leaves.

Summary

Results of this three-year field test on a sandy Coastal Plain soil with low levels of organic matter and extractable SO_4-S in the surface 18 inches showed that cotton may require annual applications of 20 lb S/A to achieve high yields. These results also suggest that for lint production, differences among available commercial S fertilizer sources should be minimal. Sulfur should be applied to cotton preplant. However, in this test delaying application to first square was acceptable in two out of three years.

Note: *Article adapted from Mullins, G.L. 1998. Cotton response to the rate and source of sulfur on a sandy coastal plain soil. J. Prod. Agric. 11:214-218.*

Dr. Mullins is with Virginia Tech, Dept. of Crop and Soil Environmental Sciences, 424 Smyth Hall (0403), Blacksburg, VA 24061. E-mail: gmullins@vt.edu.

TEXAS

Nitrogen and Phosphorus Applications Increase Yields and Profits from Irrigated Ryegrass in Southwest Texas

By Hagen Lippke

In southwest Texas, the 400,000-acre base of ryegrass and small grains is expanding as irrigation water supplies are restricted. These cool-season grasses require a third to half as much supplemental irrigation water as do traditional row crops, making them attractive economic alternatives, particularly when they are grazed by stocker cattle. Current and impending legal restrictions on pumping from the Edwards Aquifer and from various river basins in the region provide added pressure to convert to cool-season crops on much of the irrigated acreage in this region. Furthermore, the development of a water market by the City of San Antonio makes high profits imperative if intensive agriculture and its service industries are to compete for the water resource and continue to support the rural communities in the area. Cool-season grasses have the potential to meet this challenge.

The experiment reported in this article was undertaken to provide the basic response curve data for the effects of nitrogen (N) and phosphorus (P) fertilizer on forage yield and composition of annual ryegrass on calcareous soils of southwest Texas.

Much of the irrigated acreage along the southern edge of the Edwards Aquifer is on clay soils that are characterized by high levels of calcium (Ca), potassium (K), and high pH. There is little information available from controlled experiments testing appropriate levels of N and P applications for forage production from irrigated cool-season annual grasses. Soil test recommendations usually indicate application of less than 30 lb P_2O_5/A.

The Study

The study area was established on a Knippa Clay site that had been used for grazing winter annual grasses for more than 10 years and, according to tests on preliminary soil samples, was very low in N and moderate in available P. Using four replications of a factorial arrangement of 20 treatments, N (as ammonium nitrate, NH_4NO_3) was applied at annual rates of 0, 120, 240, 360 (all in three applications), or

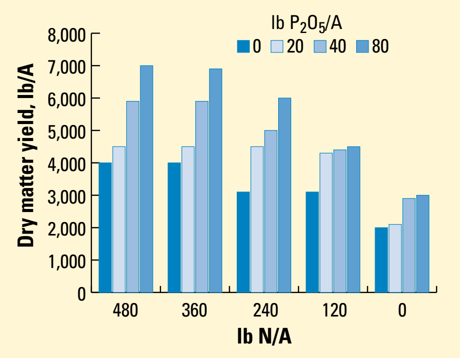


Figure 1. Effect of N and P fertilization on ryegrass yield in year one (1995-1996).

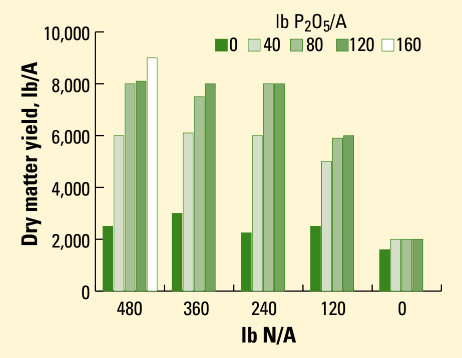


Figure 2. Effect of N and P fertilization on ryegrass yield in year two (1996-1997).

480 lb N/A (in four applications). Phosphorus (as triple superphosphate, TSP) was applied at 0, 20, 40, or 80 lb P_2O_5/A in year one and 0, 40, 80, or 120 lb P_2O_5/A in years two and three. An additional treatment in years two and three combined 480 lb N/A with 160 lb P_2O_5/A. All of the P and a fourth to a third of the N were incorporated preplant. Remaining N was top-dressed after the first (December) and second (February) of six harvests, as well as after the third harvest (March) for plots receiving 480 lb N/A. Ryegrass (TAM-90) was planted at the rate of 30 lb/A during the first week in October each year and irrigated within a few days unless rainfall provided sufficient moisture for seedling emergence.

Plots were harvested at a 3-inch stubble height whenever the anticipated yield of the most productive plots exceeded 1,200 lb/A and at the end of the growing season. Each clipping was weighed, and a sample was taken for determination of dry matter (DM), crude protein (CP), and acid detergent fiber (ADF).

The software program, FORAGVAL, was used with data from CP and ADF determinations to estimate average daily gain (ADG) and dry matter intake (DMI) by stocker steers for each clipping. These estimates, together with the yield data, were used to calculate total body weight gain per acre (EGA). Income per acre was then calculated from EGA (adjusted downward an assumed 40 percent for trampling loss under grazing), and from a sliding-scale pasture lease rate (based on ADG) ranging from \$0.30 to \$0.37/lb EGA.

Cost per acre was calculated assuming \$0.25/lb for N (adjusted downward for an assumed 30 percent N recycling under grazing), \$0.20/lb for P_2O_5, and \$40/A for all other costs.

Yield and Quality Response

Total forage dry matter yields for the first year of the experiment are shown in **Figure 1**. Ryegrass yields responded to the highest level of P application (80 lb P_2O_5), but only if N application was at least 240 lb/A. Conversely, yields responded to the highest levels of N application only with the highest level of P. The yield advantage for high levels of balanced fertilization was most pronounced during the coolest months. Forage quality is normally higher in cooler weather. Consequently, the higher production during these months is partially responsible for the better overall quality of fertilized grass (data not shown).

The response to N where no P was applied in the first year was not apparent in the second year (**Figure 2**), indicating that the pool of available P had been mined to low levels by the first year's crop in plots that received no P fertilizer. In year two the yield response curve to N application increased up to 240 lb/A and then flattened for all levels of P (except 0). In the second and third years of the experiment, 120 lb P_2O_5/A was applied to those plots assigned to 20 lb P_2O_5 during the first year. This change was made in order to learn whether forage yields were at their peak with 80 lb of P_2O_5. **Figure 2** shows that response to P reached a plateau at 80 lb P_2O_5/A in the second year.

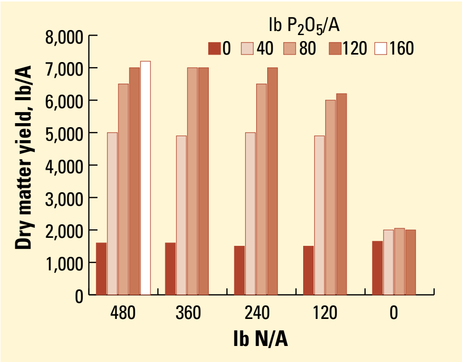


Figure 3. Effect of N and P fertilization on ryegrass yield in year three (1997-1998).

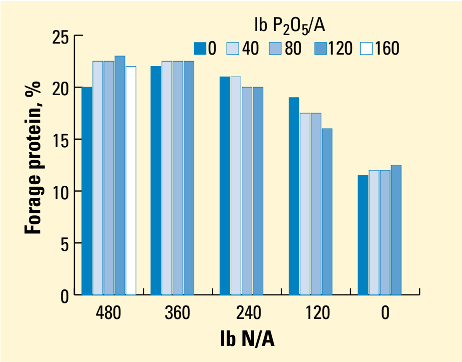


Figure 4. Average ryegrass protein for year two (1996-1997).

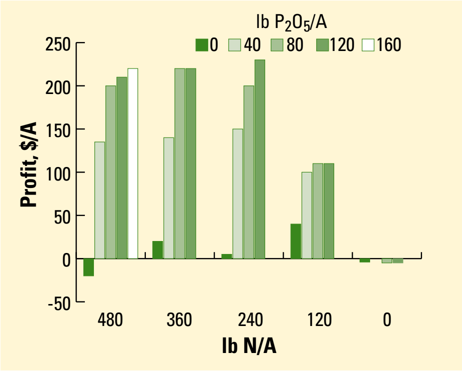


Figure 5. Estimated profit from stocker steer gain on ryegrass due to N and P fertilization (1996-1997).

In the third year, winter temperatures were colder, and spring temperatures were warmer than in years one and two, shortening the growing season and reducing yields (**Figure 3**). Forage yields from plots that received no P were proportionately much lower in the third year than yields from those plots in the first and second years. Plots that were fertilized with N but not P had yields in the third year that were less than half the yields in the first year. The uniformly low yields in the third year from plots receiving no P indicate that the pool of available soil P may have reached minimum levels. As in year two, N fertilizer rates above 240 lb N/A gave no response at any level of P, and at 40 lb P_2O_5/A N fertilizer showed no response above 120 lb/A. Also, as in year two, response to P reached a plateau at 80 lb P_2O_5/A.

Figure 4 shows a typical response of forage CP content to N and P applications. Increases in CP are primarily a response to N fertilizer. As with DM yield, the CP response appears to reach a plateau at 240 lb/A of N. Crude protein response to P application was small in this experiment and consistent with expectations, although the decline in CP with increasing P application at 120 lb N/A (**Figure 4**) is contrary to the usual trend. Acid detergent fiber tended to decrease with increasing N application and also decreased slightly with increasing P when no N was applied (data not shown). These trends are a reflection of the proportionately higher yields during late season in plots with no or unbalanced fertilizer application.

Economics

Estimated profit per acre from year two is depicted in **Figure 5**. Profit increased dramatically with the first increments of both N and P applications. Another major increase in profit was calculated for plots where both N and P were increased another step (240-80-0). At 240 lb/A, applied N reached a peak in profits where P was supplied. Profits for added P above 80 lb P_2O_5/A seemed to reach a plateau. The large increase in profit with the application of at least 120-40-0 was due to increased forage protein and ADG as well as to increased DM yield.

Calculated profits for the first year of the experiment (not shown) were much lower than in the second year (**Figure 5**) and peaked at 360-80-0. Higher overall profits in the second year were primarily due to higher yields. With the flattening of the yield curve at 240 lb N/A in year two, profits would be expected to decline with additional increments of applied N.

This experiment has clearly shown the advantage of higher rates of P application than have been recommended in the past for stocker cattle grazing winter annual grasses on irrigated calcareous soils in southwest Texas. Recommendations for N application may also need to be adjusted, but rates of applied N are highly dependent on uniformity of feces and urine deposition and on rate of N recycling within a season. Forage tissue testing and application of small increments of N to hold CP at 20 to 22 percent during vegetative stages of growth may be the best route to most profitable levels of N fertilization.

Dr. Lippke is Associate Professor, Agriculture Research & Extension Center, Texas A&M University, 1619 Garner Field Road, Uvalde, TX 78801-6205.

ARKANSAS

Phosphorus Fertilizer Recommendations for Rice

By C.E. Wilson, Jr., N.A. Slaton, S. Ntamatungiro, D.L. Frizzell, W.B. Koen, and R.J. Normas

Phosphorus was not recommended for rice production in Arkansas for several years prior to 1992. Dry matter responses to P fertilizer were common, but yield responses were seldom observed. Since 1992, yield responses to P fertilizer have been documented in numerous studies. Due to the variability of when and where responses occurred, several methods have been evaluated to determine P availability to rice. One method, the Mehlich 3 extraction, is used by many soil testing laboratories. While it has been shown effective for upland crops, it has received criticism for its estimation of P availability for paddy rice. This study was conducted to evaluate the effectiveness of Mehlich 3 extraction and soil pH in developing P availability indices.

Mehlich 3 extractable phosphorus (P) was not related to relative grain yields or P concentration in the rice tissue at the midtillering growth stage; however, soil pH was a reasonably good estimator of soil P fertilizer response.

Soil P availability under dryland conditions is influenced by several factors, not the least of which is soil pH. Optimum availability of P occurs in the pH range of 6.0 to 6.5. With acidic conditions, P is predominantly sorbed by iron (Fe) and aluminum (Al) oxides. The sorption of P by Fe and Al oxides decreases as soil pH increases, and more P is sorbed by calcium (Ca) and magnesium (Mg). At either extreme, P is not readily available.

It was believed in the southern U.S. for many years that rice growth was not limited due to insufficient P. This was because when a permanent flood is established, redox reactions result in reduction of trivalent Fe (Fe^{3+}) to divalent Fe (Fe^{2+}). As this occurs, the solubility of the Fe oxides increases. This leads to a subsequent increase in P availability to rice. On alkaline soils, however, more P is sorbed as Ca and Mg phosphates. Because Ca and Mg are not influenced by redox reactions associated with flood establishment, the solubility and subsequent availability of P are not necessarily increased sub-

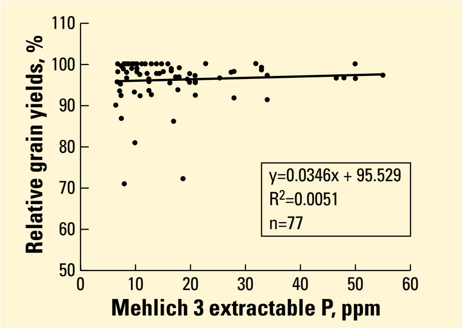


Figure 1. Relationship between relative grain yields and Mehlich 3 extractable P.

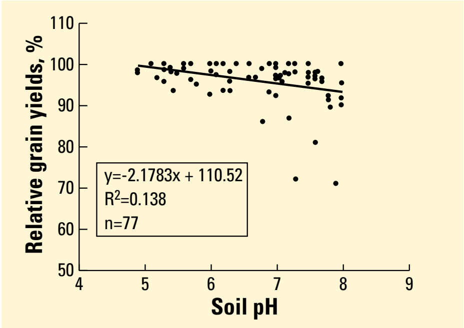


Figure 2. Relationship between relative grain yields and soil pH.

TABLE 1. Range of selected soil fertility properties from sites utilized in this study (n=99).

Soil property	High	Low	Average
pH	8.0	4.9	6.79
P ppm[1]	87	6	20.1
K ppm	255	41	101
Ca ppm	4,554	776	1,599
Mg ppm	821	85	232

[1] parts per million

TABLE 2. Phosphorus fertilizer recommendations for rice production in Arkansas, effective 1999.

Soil pH	lb/A P_2O_5 at soil test P, ppm		
	< 15	15 - 25	> 25
< 6.5	20	0	0
≥ 6.5	60	40	0

stantially after flooding. Therefore, soils that have limited available P prior to flooding will continue to have limited available P after flooding. The objective of the current study was to evaluate the ability of Mehlich 3 extractable P (M3P) and soil pH to predict P response by rice.

Experimental Approach

Eighty field studies were conducted between 1994 and 1998 in the rice-producing region of Arkansas evaluating various soil fertility problems. While the specific objectives varied, each study also evaluated response to P fertilizer. For studies located in production fields, the cultural practices utilized for the main fields were utilized in the plot area except for the fertilizer treatments in question. For studies located at the University of Arkansas Experiment Stations (Pine Tree Branch Experiment Station near Pine Tree; Rice Research and Extension Center near Stuttgart; Southeast Research and Extension Center near Rohwer), plots were managed for the specific experiment in question. Fertility levels of the soils used in this study are presented in **Table 1**. Plant samples were collected from some locations for analysis of P content in the rice tissue.

Because the studies utilized different cultivars, seeding dates, and other management practices, yield response was standardized across all studies by calculating relative grain yield as the ratio of yield from the plots that did not receive P fertilizer to the yield of those that received optimum P fertilizer. Regression analysis included modeling for curvilinear functions, which were not found to be better than linear regressions.

Prediction of Relative Grain Yields and P Uptake

Linear regression of relative grain yields versus M3P showed no significant relationship (**Figure 1**). This indicates that the Mehlich 3 extraction does not adequately predict P availability to rice grown in flooded soils. While M3P has been shown to be effective for upland

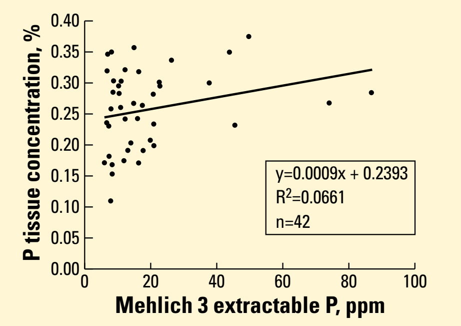


Figure 3. Relationship between rice P concentration at the midtillering growth stage and Mehlich 3 extractable P.

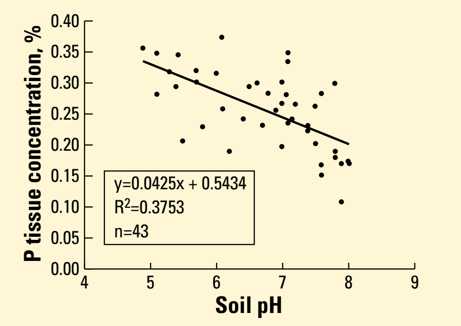


Figure 4. Relationship between rice P concentration at the midtillering growth stage and soil pH.

crops, it has been previously reported as an inadequate method for flooded rice.

Examination of the relationship between relative grain yields and soil pH indicates that soil pH is a better predictor of P fertilizer response by rice than is M3P (**Figure 2**). While predictability is still relatively low ($R^2 = 0.14$), the negative slope indicates that as soil pH increases, relative yield decreases, likely due to decreased P availability. This in turn increases dependence of rice on P fertilizer as soil pH increases and supports conclusions made in previous studies that suggest that rice response to P fertilizer is more likely on alkaline soils [*Better Crops with Plant Food*, 82(2):10-11, 1998].

Multiple regression analysis indicated that a model containing both M3P and soil pH provided the best prediction ($R^2 = 0.17$) of relative grain yields, but was only slightly better than soil pH alone.

The relationship between rice P concentration at mid-tillering (MT) and M3P indicates that Mehlich 3 does not predict P uptake by rice (**Figure 3**). The relationship between rice P concentration at MT and soil pH was highly significant ($R^2 = 0.38$, **Figure 4**). The P concentration in the plant declined significantly as soil pH increased. This decline with increased soil pH further strengthens the point that soil pH is a major factor affecting P availability to rice.

Summary

While these results suggest that soil pH is a better estimator of P fertilizer response by rice than M3P, a direct measurement of available P is more desirable. It is clear that the predictability is not high for either method, and development of a more effective method for estimating P availability to rice is sorely needed. In the interim, soil pH and M3P together provide a better indication of P fertilizer response than M3P alone.

As a result of this research, we have modified the P fertilizer recommendations for rice, effective in 1999 (**Table 2**), to consider both M3P and soil pH as contributing factors. This approach will also help to address removal of P in harvested rice (0.29 lb P_2O_5/bu) and limit soil P "mining."

The authors are with the Department of Crop, Soil and Environmental Sciences at the University of Arkansas. Dr. Wilson is Extension Rice Specialist/ Research Associate Professor, located at Monticello. Dr. Slaton is Extension Agronomist-Rice located at the Rice Research and Extension Center at Stuttgart. Dr. Ntamatungiro is research specialist and Mr. Koen is Extension Rice Research Verification Coordinator, located at Stuttgart. Mr. Frizzell is research specialist located at Rohwer. Dr. Norman is Professor of Soil Fertility located at Fayetteville. E-mail for Dr. Wilson is wilson@uamont.edu.

Acknowledgements *– Sincere appreciation is expressed for research funds provided from the following sources: Arkansas Rice Research and Promotion Board, Arkansas Fertilizer Tonnage Fees, and the Potash & Phosphate Institute. Also, sincere appreciation is extended to each of the many producers and County Extension Agents who assisted with implementation of these studies and to Ms. Nancy Wolf who provided valuable analytical assistance.*

Contact PPI/PPIC/FAR on the Internet

You can reach the Potash & Phosphate Institute (PPI), Potash & Phosphate Institute of Canada (PPIC), and Foundation for Agronomic Research (FAR) on-line. Use one of the following as a URL to reach the web site: www.ppi-ppic.org or www.ppi-far.org.

There is increasing variety and diversity of information now available in electronic form at PPI/PPIC/FAR, with more additions and changes to the web site coming soon. Current and back issues of *Better Crops with Plant Food*, *Better Crops International*, *News & Views*, and other publications are available as pdf files.

For further information, contact PPI headquarters by phone at (770) 447-0335 or fax, (770) 448-0439.

National Research Project to Identify Sources of Agricultural Phosphorus Loss

By Andrew Sharpley, Tommy Daniel, Bob Wright, Peter Kleinman, Terry Sobecki, Roberta Parry, and Brad Joern

The U.S. Department of Agriculture-Agricultural Research Service (USDA-ARS) is coordinating a National Phosphorus Research Project in cooperation with universities, the Environmental Protection Agency (EPA), and the Natural Resources Conservation Service (NRCS) to establish soil-specific threshold phosphorus (P) levels in watersheds sensitive to P losses. The results of this research will provide defensible recommendations for protecting water quality in nutrient management plans utilizing animal wastes.

Why the Concern?

Reductions in point sources of water pollution over the last 20 years have drawn attention to the role of agricultural nonpoint sources in water quality impairment. According to a recent EPA survey, most of this impairment is caused by eutrophication. Eutrophication is the process of increased aquatic productivity due to excessive nutrient inputs. While both nitrogen (N) and P contribute, P is the primary agent in freshwater eutrophication, since many algae are able to obtain N from the atmosphere. Consequently, controlling eutrophication mainly requires reducing P inputs to surface waters.

What Is the Research Need?

In many areas of intensive livestock production, manures are normally applied at rates designed to meet crop N requirements. This often results in P being applied in excess of crop needs, which can increase the amount of P in the surface soil and enrich surface runoff with enough P to accelerate eutrophication.

In response, several states have used agronomic soil tests to identify threshold soil P levels perceived to limit eutrophic runoff. However, agronomic soil tests were designed to estimate plant-available P, not to predict soil P release to surface runoff. Also, soil P must be used in conjunction with an estimate of the potential P transport from a site in surface runoff and erosion. The P Index is a tool that integrates these source and transport factors.

The P Index was developed by ARS, NRCS, and university scientists as a screening tool to rank the vulnerability of fields as sources of P loss in surface runoff. To increase its accuracy and reliability, research is needed on the soil-specific relationships between soil P and P in runoff water.

What Are the Project Objectives?

The goals of the National Phosphorus Research Project are to:

- provide a sound scientific basis for establishing threshold soil P levels in areas where P enrichment of waters (surface and subsurface) may impair water quality,
- develop a reliable indexing tool to assess and rank site vulnerability to P loss from watersheds throughout the U.S., and
- incorporate this information into an integrated nutrient management decision-making process at a watershed scale.

The time frame for these objectives ranges from two to five years. We plan to quantify the relationship between surface runoff P and soil P for several key areas and soils within the next two years. Over the following three years, we will increase the number of soils and sites investigated. With NRCS, we will develop a framework to extrapolate National Phosphorus Research Project results to the national soils data base. Working with EPA at all stages of this project will ensure that policy regarding nutrient management strategies and criteria is based on sound scientific information.

Where and How Will This Be Done?

This work will be done by ARS in cooperation with the following agencies and institutions at national, regional, state, and local levels: land grant universities, EPA, NRCS, state soil and water conservation agencies, Cooperative Extension Service, and agricultural experiment stations. Currently, there are over 20 cooperators (**Figure 1**).

Initially, eight to 10 locations will be selected throughout the U.S. Each location will have four or five soil types that are characteristic of the region. These sites will be located in areas of elevated soil test P and which have potential for water quality impacts. A total of 45 to 50 different soil types will be studied.

We will use plots (6 feet long and 3 feet wide) to determine the relationship between soil P and surface runoff P. For each soil type, sites ranging in soil P content (low to very high soil test P) will be selected. Sites will not have had manure or fertilizer P additions in the last six months, so that we will be investigating the effect of soil P on runoff P rather than recent land management. On additional plots, manure will be applied to evaluate the effect of manure rate, application timing, and manure type on P transport in surface runoff.

Soil P will be determined by agronomic soil tests and by new environmental methods [water extractable, iron (Fe) oxide strip, and P sorption saturation]. Surface runoff from simulated rainfall-runoff events will be collected and analyzed. Rainfall will be applied using simulators designed for this project (**Figure 2**). Lysimeters will be installed at sites where P movement through the soil profile has been shown to predominate or where it is a potential pathway of concern.

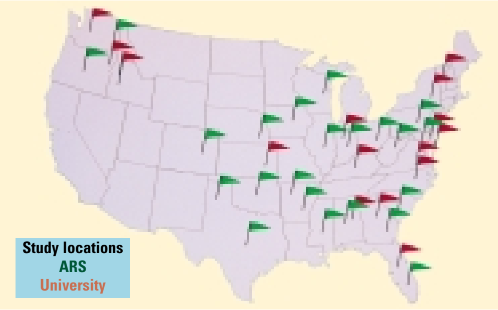


Figure 1. Flags indicate ARS and university locations currently cooperating on the National Phosphorus Research Project.

The various soil specific relationships between soil P and surface runoff P will be incorporated into the P indexing tool. The index will be modified and tested at the watershed scale throughout the U.S.

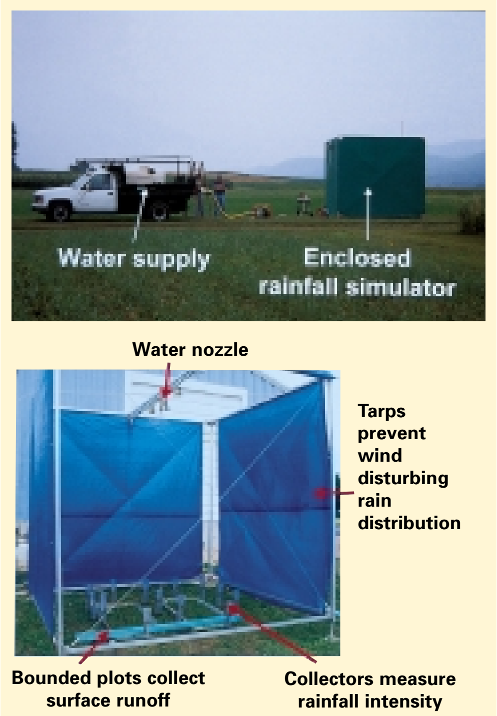


Figure 2. Prototype rainfall simulator being used in the National Phosphorus Research Project.

What Can We Expect from the Study?

This research will support a scientifically defensible environmental P index for nutrient management. This indexing tool will allow greater flexibility in managing manures, because it will allow more manure use on soils capable of retaining P while avoiding such use on soils with high risk of P loss. Manure applications will be better targeted to benefit productivity in high yield cropping systems. This will meet critical needs of NRCS and EPA as they develop guidelines for nutrient management planning to utilize manure and protect water quality. BC

Dr. Sharpley is Soil Scientist, USDA-ARS, Pasture Systems and Watershed Management Research Laboratory, University Park, PA. Dr. Daniel is Professor, Department of Agronomy, University of Arkansas, Fayetteville, AR. Dr. Wright is National Program Leader, USDA-ARS, Beltsville, MD. Dr. Kleinman is Soil Scientist, USDA-ARS, Pasture Systems and Watershed Management Research Laboratory, University Park, PA. Dr. Sobecki is Soil Scientist, USDA-NRCS, Washington, D.C. Ms. Parry is National Program Manager, US EPA, Washington, D.C. Dr. Joern is Professor, Agronomy Department, Purdue University, West Lafayette, IN.

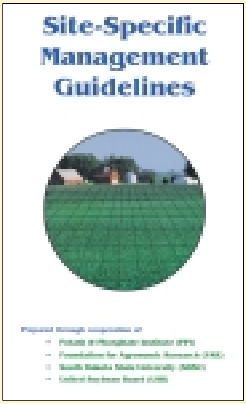
TABLE 1. Institutions participating in the National Phosphorus Research Project.

Northeast
ARS, Beaver, WV
ARS, Beltsville, MD
ARS, University Park, PA
Cornell University, Ithaca, NY
University of Delaware, Newark, DE
University of Maryland, College Park, MD
University of Vermont, Burlington, VT
Virginia Polytechnic Inst. and State University, Blacksburg, VA
Southeast
ARS, Auburn, AL
ARS, Booneville, AR
ARS, Florence, SC
ARS, Miami, FL
ARS, Mississippi State, MS
ARS, Oxford, MS
ARS, Tifton, GA
Auburn University, Auburn, AL
North Carolina State University, Raleigh, NC
University of Florida, Gainesville, FL
University of Florida, Ona, FL
University of Georgia, Athens, GA
University of Arkansas, Fayetteville, AR
Midwest
ARS, Coshocton, OH
ARS, Madison, WI
ARS, West Lafayette, IN
Purdue University, West Lafayette, IN
University of Wisconsin, Madison, WI
Great Plains/Rockies
ARS, Akron, CO
ARS, Bushland, TX
ARS, Fayetteville, AR
ARS, Lincoln, NE
ARS, Temple, TX
Brigham Young University, Provo, UT
Iowa State University, Ames, IA
Kansas State University, Manhattan, KS
NRCS, Fort Worth, TX
NRCS, Lincoln, NE
Oklahoma State University, Stillwater, OK
Texas A&M University, College Station, TX
University of Missouri, Columbia, MO
Northwest
ARS, Kimberly, ID
Oregon Graduste School, Beaverton, OR
Oregon State University, Corvallis, OR
University of Washington, Prosser, WA
Administration
ARS, Beltsville, MD
EPA, Washington, D.C.
NRCS, Lincoln, NE
NRCS, Washington, D.C.

Site-Specific Management Guidelines Series Now Available

A new series of publications called *Site-Specific Management Guidelines* (SSMG) was recently introduced at the 1999 Information Agriculture Conference (InfoAg99). The SSMG series is the result of a cooperative effort between South Dakota State University and PPI/FAR.

The objective of the project is to provide a mechanism to assemble expert knowledge in a timely fashion on site-specific management, in a form useful to farmers and their advisers.


Site-Specific Management Guidelines

Each Guideline addresses a subject or issue related to site-specific soil and crop management. The Guidelines are available individually or as a set in a three-ring binder. The format provides flexibility needed to stay current with the dynamic knowledge base surrounding site-specific technologies.

The SSMG series at present includes 29 topics, each two to four pages. Following is a list of the topics.

1. Site-Specific Use of the Environmental Phosphorus Index Concept
2. Management Zone Concepts
3. Profitability of Site-Specific Farming
4. How to Determine an Accurate Soil Testing Laboratory
5. Developing Management Zones to Target Nitrogen Applications
6. Global Positioning System Receivers
7. Variable Rate Equipment – Technology for Weed Control
8. Standardization and Precision Agriculture – 'The Promised Land'
9. Yield Monitor Accuracy
10. The Pioneer Split-Planter Comparison Method
11. The Earth Model – Calculating Field Size and Distances between Points Using GPS Coordinates
12. Assessing Crop Nitrogen Needs with Chlorophyll Meters
13. Identifying Good Candidates for Precision Phosphorus Management
14. Selecting a DGPS for Making Topography Maps
15. Scouting for Weeds
16. Remote Sensing: Photographic vs. Non-Photographic Systems
17. Setting Up On-Farm Experiments
18. Simple On-Farm Comparisons
19. Area-Wide Management Zones for Insects
20. Estimating the Timing of Weed Emergence
21. Field Testing Management Zones for VRT
22. Potential Applications of Remote Sensing
23. Getting Specific with Site-Specific Nutrient Management
24. Grain Protein Sensing to Identify Nitrogen Management in Spring Wheat
25. Weed Biology and Precision Farming
26. Interpreting Remote Sensing Data
27. Spatial Variability in Corn and Soybean Insect Pests: Precision Farming and Insect Pest Management for the Future
28. Strategic Approach to Site-Specific Systems
29. Geographic Information Systems in Site-Specific Systems

To order the complete set of 29 topics in a binder, send US$15.00 plus shipping/handling of US$6.50 (U.S. delivery) or US$9.00 (Canada delivery) to Potash & Phosphate Institute, 655 Engineering Drive, Suite 110, Norcross, GA 30092-2837. For ordering information on multiple binders or quantity purchases of separate topics, call the PPI Circulation Department at (770) 825-8082/84, or fax to (770) 448-0439.

To preview the Guidelines on-line or to learn about future updates and new topics that might be added to the series, check the web site at: **www.ppi-far.org/ssmg**.

GREAT PLAINS

Long-term Nitrogen Fertilization Benefits Soil Carbon Sequestration

By A.D. Halvorson and C.A. Reule

The potential to sequester more carbon (C) in soils by increasing cropping intensity and N fertilization in semi arid, dryland areas could contribute positively to mitigating agriculture's effect on atmospheric carbon dioxide (CO_2) levels and its effect on global climate change. The value of SOC is more than improving soil quality and fertility. Its hidden value is in its ability to help moderate the greenhouse effect on the environment by reducing atmospheric enrichment of CO_2. Thus we need to understand how management practices, such as N and phosphorus (P) fertilization, affect SOC. Converting to a NT system and cropping more intensively can potentially enhance environmental quality.

> Positive effects of nitrogen (N) fertilization on soil organic carbon (SOC) were clearly demonstrated in a long-term dryland annual cropping study under no-till (NT) conditions in Colorado.

Utilization of NT systems to conserve more water for crop production makes it feasible to crop more frequently than is done with the conventional crop-fallow system in the central Great Plains area. Increased cropping frequency and low N mineralization capacity of the soils in this region make N fertilization a requirement for economical yield levels.

As yearly residue production is increased within a cropping system and/or tillage frequency is decreased, SOC levels will probably remain constant or increase with time, depending on the quantity and types of residue input to the soil.

Available information on the long-term effects of N fertilization rates on crop residue

TABLE 1. Grain or forage yield (lb/A) of each crop from 1984 through 1994 as a function of N rate.

		N fertilization rate, lb/A					
Year	**Crop**	**0**	**20**	**40**	**60**	**80**	**120[1]**
1984	Barley	2,304	3,360	3,312	3,696	3,648	3,120
1985	Corn	3,696	4,200	5,376	5,656	5,432	5,936
1986	Barley	384	1,056	1,824	2,112	2,544	2,832
1987	Corn	Hailed out on Aug. 5, 1987					
1988[2]	Wheat	2,340	2,700	2,880	3,240	3,060	2,820
1989	Corn	2,296	2,912	2,968	3,360	2,968	3,696
1990	Barley	144	384	864	1,008	864	768
1991	Corn	3,808	4,312	5,208	5,712	5,432	5,376
1992[3]	Oat hay	654	1,619	2,742	3,238	3,908	4,433
1993	Corn	2,240	2,576	3,528	4,648	4,368	4,704
1994[3]	Oat/Pea hay	760	1,471	1,727	2,379	2,175	2,129
Total (11 crops)		18,626	24,588	30,429	35,049	34,399	35,813

[1] Actual N rate was 160 lb/A in 1984 and 1985.

[2] N rates were reduced by 50 percent due to loss of 1987 corn crop to hail and no N removal.

[3] All above-ground biomass was harvested as hay and removed from plots except for 2- to 3-inch standing stubble.

production and its subsequent effects on SOC and total soil nitrogen (TSN) in NT dryland cropping systems in the central Great Plains is limited. Therefore, we evaluated the long-term effects of N fertilization rates on crop residue production in a NT annual cropping system and determined the subsequent effects of returning this crop residue to the soil on SOC and TSN.

Study Approach

We conducted the study at the Central Great Plains Research Station, Akron, Colorado, on a Weld silt loam soil with an initial pH of 7.2 and SOC concentration of 0.69 percent (0 to 6 inch depth) or 1.2 percent soil organic matter in 1984. The sodium bicarbonate ($NaHCO_3$)-extractable soil P level (0 to 6 inch depth) was 22 parts per million (ppm)...very high...at initiation. Nitrogen as ammonium nitrate (NH_4NO_3; 34-0-0) was broadcast at planting of each crop at rates of 0, 20, 40, 60, 80, and 120 lb N/A. The 120 lb N/A rate plots received 160 lb N/A in 1984 and 1985. This N rate was reduced in 1986 because of a significant increase in residual soil nitrate-N (NO_3-N). Nitrogen rates were reduced 50 percent in 1988 because of crop failure in 1987 that resulted in no measurable N removal. Initially the N plots were split, with application of 69 lb P_2O_5/A to half of each plot in 1984. The P treatment was discontinued after the first year. A NT system of farming was used. Spring barley, corn, winter wheat, and oat-pea hay were grown in rotation (**Table 1**).

Total above-ground biomass yield (grain plus residue or forage) was determined. Grain yield was subtracted from total biomass to get an estimate of the above-ground crop residue returned to the soil surface for grain crops. Total corn biomass was estimated for 1985 using the average stover/grain ratio from other years of corn production. Because of hail in 1987, an estimate of 1987 biomass production was made by using an average of corn stover returned to the soil for the other four corn years. No above-ground crop residue was returned to the soil surface except the remaining stubble for the hay crops in 1992 and 1994. Estimates of below-ground (root) residue C in the soil were made by assuming that root C equaled grain yield times 0.57. (This method of estimating root C was obtained from published research from the central Great Plains). Hay crop contributions to root C were estimated from a linear relationship of above-ground residue C to root C for the wheat, barley, and corn crops.

Six random soil cores per plot were collected and composited after hay harvest in 1994 to assess TSN and SOC in the 0 to 3 and 3 to 6 inch soil depths. Loose surface crop residue was brushed aside before taking the samples. Soil bulk density was determined for each sampling depth. Soil samples collected in April 1985 from the 0 to 3 inch and 3 to 6 inch soil depths were also analyzed for soil C.

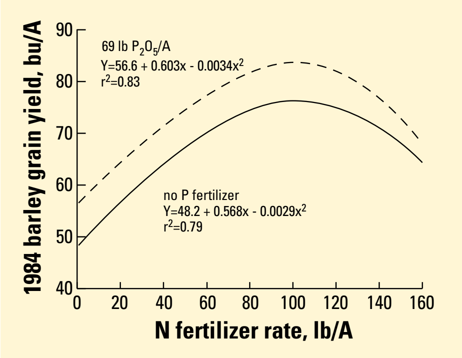


Figure 1. Barley grain yields as a function of N and P fertilizer rates in 1984.

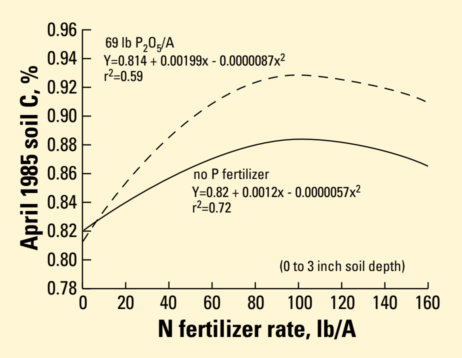
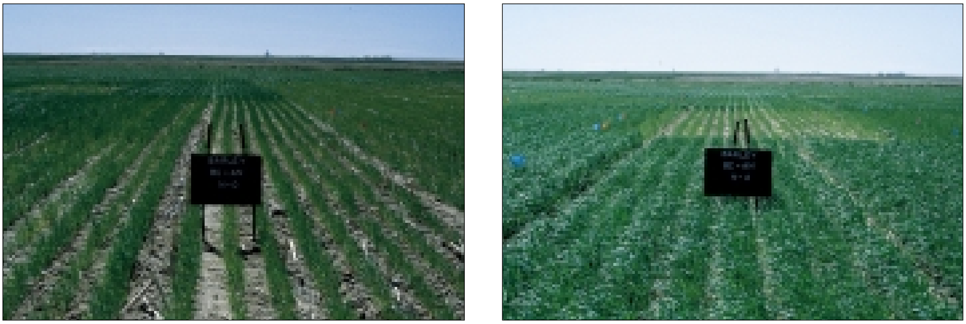


Figure 2. Soil C in 0 to 3 inch soil depth in April 1985 as a function of N and P fertilizer rates.



Barley in plot with no N added (left) had limited growth in May, compared to plot with 60 lb N/A (right).

However, soil bulk density was not determined.

Carbon sequestration efficiency for each N rate was calculated by dividing the estimated total (11 crops) residue C returned to the soil above that without N fertilization by the change in SOC above that without N fertilization.

Study Results

Despite the high soil test P level, a barley response to P fertilization was obtained in 1984, as shown in **Figure 1**. The decline in barley grain yields at the 160 lb N/A rate was the result of severe lodging at this N level. A significant N x P interaction was present in the 0 to 3 inch depth for SOC concentration following the 1984 barley crop (**Figure 2**). Phosphorus also significantly increased the level of SOC in the 3 to 6 inch depth when averaged over N rates. These data indicate that P probably stimulated root growth as evidenced by the increase in measured SOC since surface residue from 1984 had not been incorporated into the soil. Unfortunately, soil samples from subsequent years were not available to further evaluate this influence of P on SOC.

When averaged over all years, optimum grain yield was obtained with the application of 60 lb N/A (**Table 1**). Total above-ground biomass production (11 crops) increased significantly with increasing N rate to near maximum with the application of 60 lb N/A and then tended to level off with increasing N rates. Total crop residue returned to the soil surface followed similar trends (**Figure 3**).

Soil bulk density within the 0 to 3 inch depth after 11 years decreased significantly with increasing N rate (**Figure 4**), with

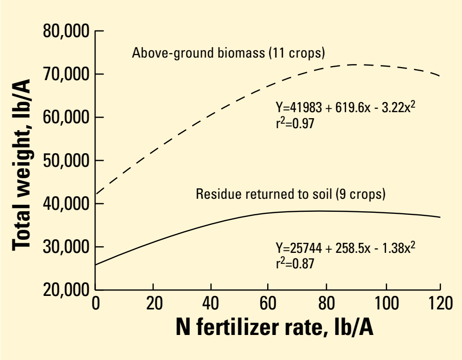


Figure 3. Total above-ground biomass production by 11 crops and total residue returned to soil surface by nine crops as a function of N fertilizer rate.

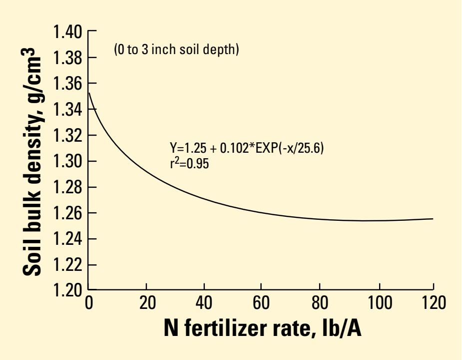


Figure 4. Soil bulk density in the 0 to 3 inch depth as a function of N fertilizer rate in 1994.

no influence of N on soil bulk density at the 3 to 6 inch depth. The decline in soil bulk density reflects the increase in crop residue returned to the soil surface with increasing N rate. There was a significant linear inverse relationship ($r^2=0.88$) between soil bulk density and increasing amounts of residue returned to the soil. The lower bulk density in the surface 0 to 3 inch soil depth enhances the performance of disk type drills in seed placement and water infiltration. These data show the positive influence of increasing amounts of crop residue returned to the soil on soil bulk density in the NT system.

Total N uptake in the total above-ground biomass of the 11 crops and the total crop residue N returned to the soil increased with increasing N rate (**Figure 5**). The total amount of N removed in the harvested grain or forage is the difference between total biomass N uptake and the N in the residue returned to the soil surface. An average of about 28 percent of the total N uptake was returned to the soil in the residue for the N fertilized plots. The increase in crop residue N returned to the soil with added N was reflected in a significant increase in TSN in the 0 to 6 inch depth with increasing N rate (**Figure 6**).

The significant increase in SOC mass with increasing N rate (**Figure 6**) reflects the response of crop biomass production to added N and the quantity of residue returned to the soil. Based on regression analyses, 1,790 lb/A more SOC had accumulated in the 0 to 6 inch soil depth after 11 crops in the 120 lb/A N rate than with the zero N rate. This equates to an annual increase in SOC of 163 lb C/A per year. At the 60 lb/A N rate, the annual increase in SOC was estimated to be 125 lb C/A per year. The annual SOC accumulation rate for the 40 lb/A N rate was 84 lb C/A per year. The soil C/N ratio was not influenced by N fertilization in this study, remaining constant across all N rates at 9.0.

Carbon sequestration is very important when considering the effects of farming practices on greenhouse gas emissions, such as CO_2. Cropping systems and practices that enhance C sequestration of atmospheric CO_2 are beneficial. In this study, N fertilization increased SOC. The percent change in C sequestration above that of the zero N rate is shown in **Figure 7**. Carbon sequestration efficiency, when based on only mass of above-ground residue C, indicates an increase of about 30 percent at the highest N rate above that of the zero N rate. However, when estimated root C was included with above-ground residue C in the total plant C estimate, C sequestration efficiency was about 11 percent higher at the highest N rate than for the zero N rate. These calculations illustrate that knowledge about the mass of C in plant roots that are incorporated into the SOC pool is critical to the calculation of plant-residue C storage efficiency. The 1985 sample

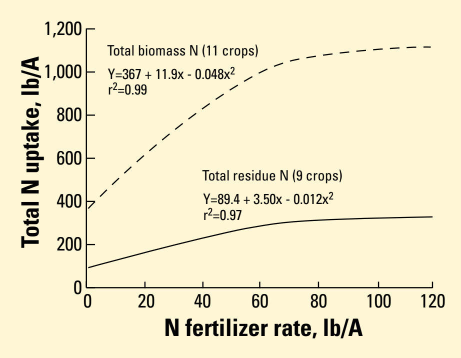


Figure 5. Total N uptake in above-ground biomass of 11 crops and total N returned to soil surface in residue of nine crops as a function of N fertilizer rate.

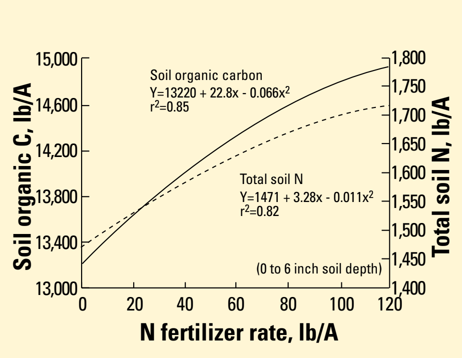


Figure 6. Total SOC and TSN in the 0 to 6 inch soil depth in the fall of 1994 as a function of N fertilizer rate.

analyses suggest that P fertilization may also play an important role in C sequestration.

There is a lack of research knowledge concerning the mass of below-ground residue C produced by plant roots from various crops. This information is extremely important when addressing the effects of cropping practices on C sequestration as it is related to concerns about global climate change.

The positive effects of N fertilization on SOC were clearly demonstrated in this long-term dryland annual cropping study under NT conditions. Nitrogen fertilization significantly increased crop residue inputs to the soil, resulting in increases in TSN and SOC after 11 crops. The increase in SOC with increasing N fertilization rate decreased soil bulk density and contributed to improving soil quality. Carbon sequestration efficiency was improved by N fertilization. This study shows that managing NT cropping systems for optimum yield with adequate N fertility will have positive environmental impacts and that N fertilization will enhance SOC accumulation and productivity in the central Great Plains. A good fertility program helps sequester atmospheric CO_2 into SOC by increasing plant growth and, subsequently, returning more organic C to the soil for storage as soil organic matter in a NT system.

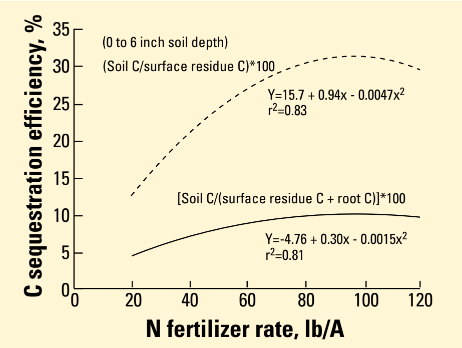


Figure 7. Estimates of C sequestration efficiency in the 0 to 6 inch soil depth as a function of N rate after 11 crop years when considering surface residue C inputs only and surface residue C plus estimated root residue C inputs.

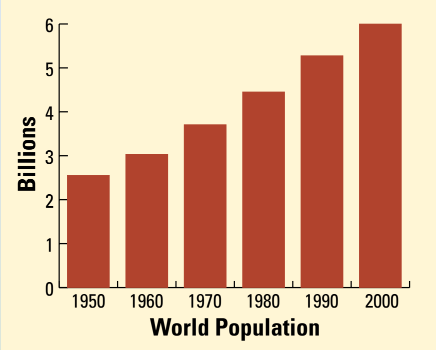
Dr. Halvorson and Mr. Reule are with USDA-ARS, P.O. Box E, Fort Collins, CO 80522. Phone: (970) 490-8230. E-mail: adhalvor@lamar.colostate.edu.

The U.S. Department of Agriculture offers its programs to all eligible persons regardless of race, color, age, sex, or national origin and is an equal opportunity employer.

World Population Reaches 6 Billion

The world's population increased to over 6 billion people on October 12, 1999, according to the United Nations (U.N.). While the population growth appears to be slowing, it is still adding more than twice as many people as were added annually at the middle of the 20th century.

In 1950, world population reached a total of 2.556 billion. The graph shown here tracks the number at each decade since then. While tremendous progress in food and fiber production has eased concerns in many areas of the world, the challenge of improving practices and developing more efficient crop and soil management systems continues.



GREAT PLAINS

Chloride Fertilization on Winter Wheat

By Ray Lamond, Vic Martin, Tom Maxwell, Robert Bowden, and Stewart Duncan

Research across the Great Plains has shown that wheat often responds to Cl fertilization, particularly when soil Cl levels are less than 20 lb/A (0 to 24 inch depth). Several researchers, however, have reported that wheat cultivars may respond differently. Research in South Dakota showed that the cultivar grown was an important consideration in determining Cl need. In Kansas, certain cultivars have shown leaf spotting, which was eliminated with Cl fertilization.

The objective of the research reported here was to evaluate the effects of chloride (Cl) fertilization on several wheat cultivars commonly grown in the Great Plains.

Studies were conducted at two sites in 1998 (16 cultivars) and 1999 (12 cultivars) to evaluate Cl fertilization/wheat cultivar interactions. Wheat was seeded in early October each year. Chloride as potassium chloride (KCl) was applied as a February topdress. The Cl rate was either 24 or 40 lb/A, depending on location. Treatments were replicated six times. Nitrogen (N) and other needed nutrients were balanced on all treatments.

Plant samples were taken at boot stage and analyzed for Cl. Grain yields as well as grain test weights and thousand kernel weights (TKW) were determined (in 1998 only). Leaf disease pressure was monitored and was rated none to very slight at both sites both years.

Effects of Cl fertilization and cultivar on wheat production are summarized in **Tables 1** to **4**. The 1998 data are reported in **Tables 1** and **2**, 1999 data in **Table 3** and a summary

Cimmaron variety wheat at Sandyland Experiment Field, Kansas, showed deficiency symptoms when no Cl was applied (left). With 24 lb Cl/A, leaf spotting was eliminated (right).

of all sites and years in **Table 4**. Chloride-sensitive cultivars (Cimarron, Triumph 64) showed Cl deficiency symptoms at every site. Symptoms were eliminated when Cl was applied (see photo). Chloride fertilization significantly increased plant Cl concentrations in all cultivars at both sites in 1998. However, significant differences in plant Cl levels were noted among cultivars in the presence or absence of Cl fertilizer, suggesting that cultivars may have different Cl needs. These results suggest that whenever Cl concentrations are less than 0.10 to 0.12 percent, responses to applied Cl are likely.

Chloride fertilization significantly increased yields of most cultivars at each site over the two years, **Table 4**. Soil Cl levels at both sites were less than 20 lb/A (0 to 24 inch depth). The addition of Cl also increased grain test weights and TKWs of most cultivars. Even though most cultivars responded to Cl, Ogallala and Custer have been consistently non-responsive, even with the low soil Cl.

TABLE 1. Effects of Cl fertilization/wheat cultivars, Sandyland Experiment Field, St. John, KS, 1998.

	Grain yield, bu/A		Test weight, lb/bu		TKW, g		Leaf Cl, %	
Cultivar	**+Cl**	**-Cl**	**+Cl**	**-Cl**	**+Cl**	**-Cl**	**+Cl**	**-Cl**
Windstar	70	63	57	54	28	24	.27	.06
Coronado	91	79	60	58	32	29	.30	.06
2180	89	78	58	54	27	25	.32	.06
Tam 107	83	69	56	56	32	26	.32	.05
Tam 200	77	64	61	57	23	19	.36	.05
7853	81	77	61	59	34	32	.29	.05
Custer	78	78	60	59	32	31	.35	.07
Cimarron	84	71	61	58	30	26	.37	.05
2163	77	71	55	55	25	24	.38	.06
Ogallala	70	72	61	58	24	21	.31	.06
Triumph 64	75	63	62	61	34	29	.35	.06
2137	80	73	57	57	31	29	.35	.06
Champ	76	76	59	60	30	27	.31	.05
Mankato	82	78	61	56	32	28	.33	.06
Jagger	89	81	59	58	29	26	.40	.06
Karl 92	83	78	60	58	30	29	.35	.06
Mean	80	73	59	57	30	26	.33	.06
LSD (0.10)								
Between columns	3		1		1		.02	

Soil test Cl: 7 lb/A (0 to 24 in.)

TABLE 2. Effects of Cl fertilization/wheat cultivars, Saline County, KS, 1998.

	Grain yield, bu/A		Test weight, lb/bu		TKW, g		Leaf Cl, %	
Cultivar	**+Cl**	**-Cl**	**+Cl**	**-Cl**	**+Cl**	**-Cl**	**+Cl**	**-Cl**
Windstar	88	83	51	51	30	28	.40	.11
Coronado	90	85	60	60	29	31	.38	.12
2180	88	82	62	60	29	29	.51	.13
Tam 107	98	94	58	55	30	28	.43	.17
Tam 200	69	61	61	61	21	22	.43	.13
7853	96	88	64	63	34	34	.42	.15
Custer	100	103	62	61	31	31	.43	.14
Cimarron	80	63	61	59	29	29	.46	.15
2163	98	95	58	57	26	25	.48	.12
Ogallala	76	75	60	60	22	22	.34	.12
Triumph 64	68	61	65	62	33	30	.48	.17
2137	113	106	61	60	31	31	.43	.15
Champ	88	86	60	60	28	27	.47	.12
Mankato	75	63	60	60	28	27	.50	.14
Jagger	105	87	60	58	27	26	.44	.14
Karl 92	114	95	63	62	31	3	.40	.14
Mean	90	83	61	59	29	28	.44	.14
LSD (0.10)								
Between columns	3		1		NS		.01	

Soil test Cl: 7 lb/A (0 to 24 in.)

The most yield-responsive cultivars were the same ones that showed leaf spotting or Cl deficiency symptoms. Many cultivars that failed to exhibit leaf spotting still produced higher yields when Cl was applied.

Summary

Results to date suggest that when Cl soil test levels are low (< 20 lb/A, 0 to 24 inch depth), most wheat cultivars are likely to economically respond to Cl fertilization. Whenever wheat plant tissue Cl concentrations (boot stage samples) are less than 0.10 to 0.12 percent, response to Cl fertilization would be likely.

These results and other wheat nutrient management considerations can be found on our virtual wheat field day site at http://www.oznet.ksu.edu/wheat.

The authors are with Kansas State University. Dr. Lamond is Professor/Extension Specialist, Soil Fertility; Dr. Martin is Associate Professor/Research Agronomist, Sandyland Experiment Field; Mr. Maxwell is Saline County Agricultural Extension Agent; Dr. Bowden is Professor/Extension Specialist, Plant Pathology; Dr. Duncan is Associate Professor/Area Extension Specialist, Agronomy.

TABLE 3. Effects of Cl fertilization/wheat cultivars, 1999.

	Sandyland Exp. Field				Saline County			
	Grain yield, bu/A		Test weight, lb/bu		Grain yield, bu/A		Test weight, lb/bu	
Cultivar	+Cl*	-Cl	+Cl	-Cl	+Cl	-Cl	+Cl	-Cl
Custer	71	66	59	56	86	79	57	55
Cimarron	74	57	61	60	65	53	56	57
2163	68	65	59	56	7	55	51	52
Ogallala	72	72	60	60	86	84	57	57
Triumph 64	63	52	59	60	58	52	53	55
2137	76	67	58	58	90	83	57	56
Champ	68	62	57	56	75	70	54	52
Mankato	74	71	57	58	72	63	54	54
Jagger	82	73	58	60	81	77	54	55
Karl 92	64	60	59	58	77	73	55	57
Betty	68	67	60	59	75	71	54	54
Heyne	63	60	59	59	80	77	54	54
Mean	70	64	59	58	75	70	55	55
LSD (0.10)								
Between columns	3		1		4		1	

*Cl applied at 24 lb/A as KCl topdressed in February.
Soil test Cl: 15 lb/A (0 to 24 in.)

TABLE 4. Wheat grain yield response to Cl across sites and years.

	1998		1999		
	Sandyland	Saline	Sandyland	Saline	Mean
Cultivar	Yield response, bu/A				
Windstar	7	5	–	–	6
Coronado	12	5	–	–	9
2180	11	6	–	–	9
Tam 107	14	4	–	–	9
Tam 200	13	8	–	–	11
7853	4	8	–	–	6
Custer	0	-3	5	7	2
Cimarron	13	17	17	12	15
2163	6	3	3	2	4
Ogallala	-2	1	0	2	0
Triumph 64	12	7	11	6	9
2137	7	7	9	7	8
Champ	0	2	6	5	3
Mankato	4	12	3	9	7
Jagger	7	18	9	4	10
Karl 92	5	19	4	4	8
Betty	–	–	1	4	3
Heyne	–	–	3	3	3
Mean	7	7	6	5	7

CALIFORNIA

Effects of Potassium Fertilization on Soil Potassium Distribution and Balance in Pistachio Orchards

By David Qiupeng Zeng, Patrick H. Brown, and Brent A. Holtz

Potassium (K) fertigation by microsprinkler significantly increased soil K content throughout the 0 to 30 inch soil profile in the three-year study. Available soil K was rapidly depleted where K was not applied, but increased for all K treatments. Yield and quality of pistachios were appreciably improved by K fertilization as reported in the previous issue of *Better Crops with Plant Food*, 1999, No. 3, pp. 10-12.

This study was conducted from 1996 to 1998 in two commercial pistachio orchards to determine the distribution of applied K and the soil K balance in the soil profile. In California, the distribution of applied K and K balance in the soil profile of pistachio orchards have never been addressed. Traditionally, soil K status and K fertilization requirements are evaluated on the basis of ammonium (NH_4)-extractable K (referred to as exchangeable K in the remainder of this article). Soil samples are frequently taken to a 0 to 6 inch depth. This approach to soil K analysis may not be suitable for irrigated pistachio since root distribution and soil moisture regime may not be well represented by exchangeable K. In microsprinkler-irrigated orchards, K availability in the surface soil may change rapidly due to fluctuating soil moisture in summer in response to wetting and drying, a process that may enhance soil K fixation.

The orchards in the study were located in Yolo and Madera, California, where the initial soil exchangeable K in 0 to 6 inches of soil was 156 and 97 parts per million (ppm), respectively. The plant density was 247 trees/A in both orchards. Soil texture was silt loam and sandy loam in the Yolo and Madera orchards, respectively. Potassium was applied annually at one-month intervals from May to August at the rates of 0, 1.1, 2.2, and 3.3 lb K/tree/year as potassium sulfate (K_2SO_4) via a specially designed fertigation system. Equal rates of nutrients other than K were applied to all treatments. Individual plots consisting of five adjacent trees were arranged in a randomized

TABLE 1. Soil K balance (lb K/tree) in 0 to 30 inch profile after three years of K fertilization in the Madera soil.

3-yr K input, lb/tree	ΔK, lb/tree	K accumulation in fruit and leaves, %	Soil K balance, lb/tree
0	-0.37 d	2.05 c	-1.68 c
3.3	0.38 c	2.85 b	0.07 c
6.6	1.08 b	4.16 a	1.36 b
9.9	1.56 a	4.13 a	4.21 a

*Values with different letters are significantly different at $P \leq 0.05$.

TABLE 2. Soil K balance (lb K/tree) in 0 to 30 inch profile after three years of K fertilization in the Yolo soil.

3-yr K input, lb/tree	ΔK, lb/tree	K accumulation in fruit and leaves, %	Soil K balance, lb/tree
0	-0.34 d	1.65 c	-1.32 c
3.3	0.21 c	2.40 b	0.69 c
6.6	0.70 b	2.90 a	3.01 b
9.9	1.19 a	3.07 a	5.64 a

*Values with different letters are significantly different at $P \leq 0.05$.

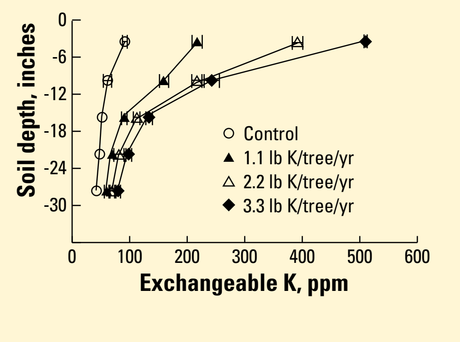


Figure 1. Potassium distribution in the soil profile after three years of K fertilization at various rates in the Madera orchard. Each value is the average of five repli cates ± standard error.

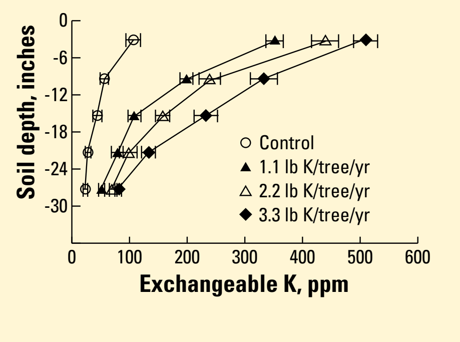


Figure 2. Potassium distribution in the soil profile after three years of K fertilization at various rates in the Yolo orchard. Each value is the average of five replicates ± standard error.

complete block design with five replications.

Soil samples were collected in 6-inch increments from the 0 to 30 inch profile in the fertigated zone before and after the experiment to determine soil K distribution and balance after three years of K fertilization based on mass balance of exchangeable K in the 0 to 30 inch profile: Soil K balance = 3-year K inputs - ΔK - crop K accumulation.

Crop K accumulation was estimated as the amount of K accumulated in fruits and leaves, and ΔK represents the net change of exchangeable K in the 0 to 30 inch profile in the fertigated zone. A negative soil K balance suggests that K was released from non-exchangeable forms while a positive balance indicates conversion of applied K to non-exchangeable forms.

Potassium Fertilization Increases Soil Available K

Initially, the soils had low exchangeable K, suggesting the need to apply K for adequate K supply to the trees. Potassium fertilization significantly increased soil exchangeable K over the control (**Figures 1** and **2**). When K was applied at a rate of 2.2 lb K/tree/year, exchangeable K in the surface 12 inch depth more than tripled following three years of K fertilization. In contrast, soil K declined sharply in control plots, resulting in further soil K depletion.

Distribution of Applied K in Soil Profile

Soil K content decreased with depth in both soils. In K-treated plots, K applied to the soil surface moved downward in the soil profile, resulting in significantly higher soil K content than in control plots (**Figures 3** and **4**). As K input increased, more K moved to deeper soil depths. Soil K content was significantly higher in the surface soil than in the subsoil, suggesting that the majority of applied K was held in the surface soil and that downward movement was slow. Slow downward movement of applied K may be partially attributed to net upward flux of soil water in the soil profile as a result of high evaportranspiration in summer.

The magnitude of soil K increases and movement of surface-applied K fertilizers were greater in the Madera than in the Yolo soil. The differences can be explained by the differential potential buffering capacity for soil K (PBC^k, data not shown). The Yolo soil, which has abundant vermiculite and montmorillonite clays, had a higher PBC^k value than the Madera soil, which has primarily kaolinite clay.

Soil K Balance

Potassium fertilization significantly influenced soil K balance. Without it, exchangeable K in the 0 to 30 inch depth decreased by 0.37 and 0.34 lb K/tree in the Madera and Yolo soils, respectively, resulting in depletion of soil available K. In contrast, after three years of K fertilization, there was a net increase of exchange-

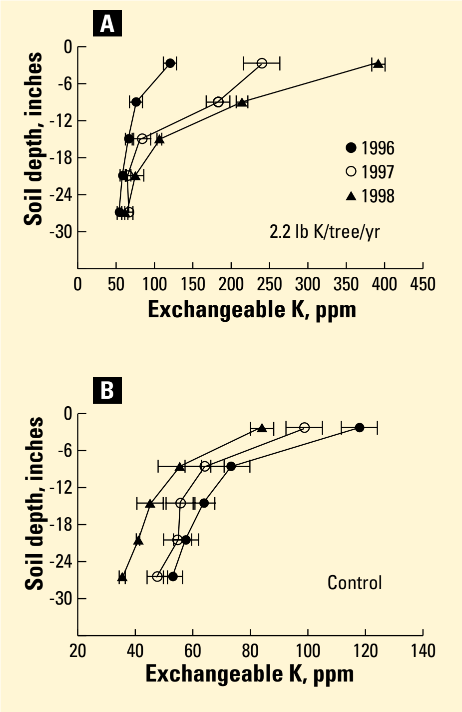


Figure 3. Changes of soil exchangeable K in soil profile with time with (A) and without (B) K fertilization in the Madera orchard. Each value is the average of five replicates ± standard error.

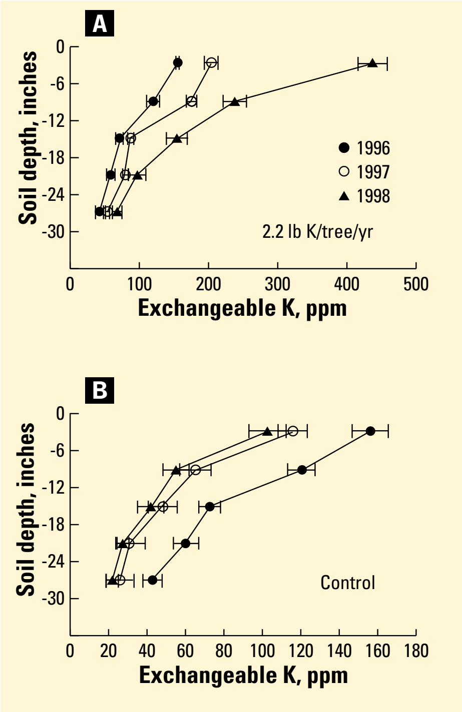


Figure 4 Changes of soil exchangeable K in the soil profile with time with (A) and without (B) K fertilization in the Yolo orchard. Each value is the average of five replicates ± standard error.

able K of 0.38 to 1.56 lb K/tree in the Madera soil (**Table 1**) and 0.21 to 1.19 lb K/tree in the Yolo soil (**Table 2**), leading to soil K accumulation.

Pistachio trees accumulated significantly more K in K-treated plots than in control plots (**Tables 1** and **2**). The control trees accumulated 2.05 and 1.65 lb K/tree in fruit and leaves in the Madera and the Yolo soils, respectively. Trees receiving K fertilizer accumulated 2.85 to 4.16 lb K/tree in the Madera soil and 2.40 to 3.07 lb K/tree in the Yolo soil. Higher K accumulation in fruit and leaves is a result of increased K concentration and increased crop yield in K-treated plots (data not shown).

Conclusions

Potassium distribution in the soil profile is characterized by decreasing soil K content with depth. Potassium fertilization significantly increased soil K content throughout the 0 to 30 inch soil profile, even though the movement of surface-applied K in the soil profile was slow. More K was accumulated in the fruit and leaves in pistachio trees treated with K. Soil K balance data showed that without K fertilization, soil available K was rapidly depleted. To accurately diagnose soil K deficiency and to determine K fertilization requirements in pistachio, it is important to examine K status in the irrigated soil profile. BC

Dr. Zeng is a former graduate research assistant and Dr. Brown is Associate Professor, Department of Pomology, University of California, Davis. Dr. Holtz is Pomology Farm Adviser, Madera County, CA.

***Acknowledgements** - The authors appreciate the research grants from the California Pistachio Commission and the Potash & Phosphate Institute.*

Annual Carbon Fluxes from No-Till Corn and Soybeans (Illinois)

(Correction from previous issue of *Better Crops with Plant Food*)

By S.E. Hollinger and T.P. Meyers

The article titled "Annual Carbon Fluxes from No-Till Corn and Soybeans" which appeared in the previous edition of *Better Crops with Plant Food* (1999, Issue No. 3), contains some numbers which are not correct.

An error was made in calculating the carbon dioxide (CO_2) sequestered in the grain of corn and soybean. This error resulted in an underestimation of the CO_2 removed in the grain. **Table 1** in the original article is reproduced below with corrected values in the last column.

The new values for tons of CO_2 removed by grain exceed the total measured CO_2 exchange for the entire period. The period includes approximately three fallow seasons, but only two growing seasons. A more accurate estimate of the CO_2 balance for the corn and soybean rotation is obtained if the period from October 20, 1996 to October 19, 1998 is used. This period includes one soybean fallow season, one corn growing and fallow season, and one soybean growing season. When this two-year period is used, the net CO_2 exchange between the no-till ecosystem and the atmosphere is a gain of 0.19 tons CO_2 per acre to the ecosytem.

The CO_2 flux measurements account for mineralization of soil organic matter and decomposition of the surface residue as well as the net CO_2 fixed through photosynthesis. The net loss of CO_2 from the ecosystem during the soybean growing season is due to the relatively slower photosynthetic rate of soybeans and the rapid decomposition of the corn residue from the previous year. The flux measurements do not allow for the separation of the CO_2 released by soil and plant respiration and the residue decomposition. However, the flux measurements do provide an accurate measure of the net CO_2 exchange between the no-till ecosystem and the atmosphere.Thus, the flux measurements support the hypothesis that a no-till corn-soybean rotation maintains a balance of carbon (C) in the soil. In fact, the measurements indicate that the crops are adding as much or more new C to the soil as is being respired from the soil. The corn crop, because of its large vegetative biomass, is the main contributor of CO_2 to the ecosystem.

TABLE 1. Seasonal net CO_2 exchange from a no-till field with corn in 1997 and soybeans in 1998.

Crop	Period	Net CO_2 exchange, tons	Evapotranspiration, in.	Precipitation, in.	Grain CO_2, tons
Soybean	Oct 20 1996 - Apr 18 1997	-1.56	5.05	6.42	–
Corn	Apr 19 1997 - Oct 19 1997	9.20	14.45	9.01	-5.60
Corn	Oct 20 1997 - Jun 1 1998	-1.58	8.33	10.67	–
Soybean	Jun 2 1998 - Oct 19 1998	2.22	14.46	7.59	-2.49
Soybean	Oct 20 1998 - Mar 31 1999	-1.15	3.95	5.06	–
Total	**Oct 20 1996 - Mar 31 1999**	**7.13**	**46.24**	**38.75**	**-8.09**

A negative CO_2 value indicates a C loss by the ecosystem.

Note: *The original article appeared in Better Crops with Plant Food, Vol. 83 (3), pages 13-15. The complete article with corrections is available in pdf format at the web site: ppi-far.org*

Dr. Hollinger is Senior Professional Scientist, Illinois State Water Survey, Champaign, IL. Dr. Meyers is a Research Meterologist at the National Oceanic Atmospheric Administration, National Research Laboratory, Atmospheric Turbulence Diffusion Division, Oak Ridge, TN. Contact Dr. Hollinger by e-mail at: hollinger@uiuc.edu, phone (217) 244-2939, or fax (217) 244-0220.

OKLAHOMA

Sulfur and Chloride Response in Oklahoma Winter Wheat

By J.M. LaRuffa, G.V. Johnson, S.B. Phillips, and W.R. Raun

In the fall of 1995, three locations were identified in Oklahoma for annual evaluation of wheat response to S and Cl. The Carrier location is a silt loam and the Hennessey location is a sandy loam, both typical of the environment for wheat production in the large north central Oklahoma region. The Perkins location is on a deep, sandy, low organic matter soil, subject to leaching of mobile nutrients such as Cl and S.

At each location 0, 50, 100, and 200 lb S/A were applied preplant as gypsum ($CaSO_4 \bullet 2H_2O$, 17 percent S). The Cl trials were similar except 0, 30, and 60 lb Cl/A were applied preplant as calcium chloride ($CaCl_2$, 60.7 percent Cl) and only grain was harvested. Nitrogen (N), phosphorus (P), and potassium (K) were adequate, or supplied, except at the Perkins location where N inadvertantly was not applied and, thus, became yield-limiting.

Plot size for all trials was 16 by 20 ft. In 1995-96 only grain was harvested because extremely dry weather did not support significant fall and winter forage. Both grain and forage were harvested in 1996-97 from the S experiment. Grain production for 1996-97 was hurt by late freezing (April 13-15), but helped by excellent grain filling conditions.

Sulfur (S) and chloride (Cl) are two essential plant nutrients, occasionally found to be deficient in winter wheat. These nutrients have received considerable attention in various parts of the U.S. in the past 20 to 30 years. Sulfur functions in plants as an important element in three amino acids and is thus critical to the normal development of proteins in plants. Chloride is believed to be essential in plant regulation of water. Both are absorbed in chemical forms that are mobile in soils; that is, they move with water. Consequently, deficiencies of S and Cl should be expected when high yields are produced in deep, sandy soils that are low in soil organic matter.

In the fall of 1995, surface soil samples, 0 to 6 inch depth, were taken at each location. Soil Cl in the upper 6 inches ranged from about 25 to 40 lb/A, and S ranged from 23 to 37 lb/A. Subsurface soil samples, 6 to 24 inch depth, were not taken in 1995. Therefore, the initial amounts of S and Cl present in the upper 2 ft. of the soil profile cannot be accurately determined. Soil samples to 2 ft. were taken after harvest in 1997 for S and Cl at all three locations. Although the soil test data may not reflect a response to S or Cl since the samples are taken post-harvest, the data are indicative of the range of nutrient levels found and present for the next production year. Values for these samples ranged from 46 to 219 lb S/A and 70 to 102 lb Cl/A in the upper 2 ft. of soil.

1995-96 Yields

Grain yields were exceptionally good at Carrier and Hennessey, in spite of the relatively dry year. Nevertheless, there was no significant response to Cl at these two locations (**Table 1**). The yield response to Cl at Perkins was statistically significant and was likely a result of the sandy location that allowed Cl to be leached out the previous year (above average rainfall) and drought stress in the 1995-96 season. There were no significant responses to S applications at any of the three locations in 1995-96 (**Table 1**).

1996-97 Yields

Wheat grain response to Cl in 1996-97 (**Table 2**) was similar to that for 1995-96. Yields were relatively high at Carrier and Hennessey, and there was no significant response to Cl, although the Hennessey location showed an 8.8 bu/A response to 60 lb Cl/A. At Perkins, yields were extremely poor, but there was a small and significant response to the 60 lb Cl/A rate.

Wheat grain yields responded significantly to the addition of 200 lb S/A applied as $CaSO_4 \bullet 2H_2O$ at Hennessey where the yield was 8.2 bu above the no-S control (**Table 2**). At Carrier, where yields averaged 60 bu/A, there was no response to S. Similarly, there was no grain response to S at Perkins, although yields were much lower.

TABLE 1. Wheat response to Cl and S at three locations in 1995-96.

Cl rate, lb/A	Carrier	Hennessey	Perkins
		yield, bu/A	
0	42.1	42.9	19.0
30	41.5	41.6	20.7
60	43.5	41.9	25.0*

S rate, lb/A	Carrier	Hennessey	Perkins
		yield, bu/A	
0	44.8	41.0	23.2
50	44.7	41.0	22.9
100	41.7	40.7	25.8
200	43.6	41.0	21.3

*Significant at the 0.05 probability level.

TABLE 2. Wheat response to Cl and S at three locations in 1996-97.

Cl rate, lb/A	Carrier	Hennessey	Perkins
		yield, bu/A	
0	54.0	30.7	9.4
30	55.0	32.2	9.8
60	55.3	39.5	12.4*

S rate, lb/A	Carrier	Hennessey	Perkins
		yield, bu/A	
0	60.4	37.5	15.8
50	60.2	38.6	16.0
100	57.0	35.4	19.2
200	61.4	45.7*	16.3

*Significant at the 0.05 probability level.

Total forage production from fall (Feekes 4) and winter (Feekes 10) harvests showed no response to S at either Carrier or Hennessey. At Perkins there was a significant response to 100 lb S/A, but not to 50 lb or 200 lb S/A. This is unusual, since $CaSO_4 \bullet 2H_2O$ is non-toxic, and one would expect that if the 100 lb rate caused a positive response, so would the 200 lb rate.

Twelve site-years of examining wheat grain response to Cl and S have resulted in three significant positive responses. Two have been to the application of Cl at the Perkins site, where no N was applied and yield levels were relatively poor (11 to 22 bu/A). A significant grain response to S was found at the Hennessey site, but only at the 200 lb S/A rate in 1996-97. In the same production year, forage yields were abnormally high, but there were no significant responses to applied S at this site. The only significant forage response to S came at the Perkins site at the 100 lb S/A rate.

Sulfur deficiencies in Oklahoma are rare since rainfall annually adds approximately 6 lb S/A to the soil. Further, if there is an N requirement of 80 lb/A, the S requirement is only 4 lb/A. Considering the post-harvest soil samples had from 46 to 219 lb S/A (0 to 24 inch depth) at the various locations, it is not surprising that there were few yield responses to the addition of $CaSO_4 \bullet 2H_2O$ since a significant amount of S has accumulated in the upper 2 ft. of the soil profile.

Research in South Dakota led to the designation of 60 lb Cl/A as the amount necessary in the surface 2 ft. of the soil profile for optimum yields in spring wheat. In addition, Kansas research has shown that winter wheat response to Cl is very likely when soil Cl is less than 20 lb/A in the surface 2 feet. The initial soil test data indicated Cl contents of 21 to 51 lb Cl/A in the surface 6 inches alone. Analysis of the soil samples taken post-harvest indicated 70 to 102 lb Cl/A in the surface 2 ft. at the various locations.

Small grain responses to fertilizers containing Cl have been found in the Great Plains. This is often the result of disease suppression rather than correction of an actual nutrient deficiency in the plant. Inconsistencies in the response of wheat grain and forage to the application of Cl and S fertilizers point to the need for additional research. Of particular interest in this study was the recurring response to Cl in an environment deficient in N at the Perkins location. BC

The authors are researchers at Oklahoma State University, Stillwater.

Good Sources of Potassium Abound in Foods

Looking for healthy sources of potassium (K) in your diet? Check out foods such as bananas, orange juice, and potatoes.

According to the U.S. Department of Agriculture's Nutrient Database, one medium-sized banana contains 467 milligrams (mg) of K. One cup of orange juice (frozen concentrate, diluted) has 473 mg. Either will help you toward the recommended minimum of 2,000 mg of K a day.

By the way, that 2,000 figure really is a "minimum." Some guidelines recommend as much as 3,500 mg a day – that's what's used as the "Daily Value" reference when K content is listed on food labels.

Either way, most people get plenty of K because it's in such a variety of foods: a cup of baked acorn squash contains 895 mg of K; a 7-ounce baked potato contains 844 mg; a cup of baked beans, 752 mg; a cup of boiled zucchini, 455 mg; a 6-ounce can of tuna, 407 mg; a large fast-food hamburger, 394 mg; a 1.5-ounce box of raisins, 323 mg; a medium-sized tomato, 273 mg. Even an 8-ounce cup of coffee isn't a bad source of K, with 128 mg.

It's good that K is so prevalent in the diet. It works within cells to help muscles contract, help nerves send messages, and generally help cells do what they're supposed to do. It also works with other minerals – sodium (Na), calcium (Ca), and magnesium (Mg) – to help the body maintain a proper balance of fluid, which promotes normal blood pressure and heartbeat. It does that in a variety of ways. If your body gets bloated, K is the hero that sends excess fluid to the bladder. Reducing the body's fluid levels leads to a reduction in actual blood volume. That, in turn, decreases blood pressure. With the fluid goes excess Na, which, in some people, is linked with high blood pressure.

Also, some high blood pressure medications may cause K levels to dip, so people taking them are also given a K supplement and encouraged to eat K-rich foods. Luckily, those foods aren't hard to find. BC

Source: Ohio State University and USDA.

Richard Roberts Retiring at PPI after Nearly 32 Years of Service

Richard T. Roberts

Completing a dedicated career spanning almost 32 years, Richard T. Roberts, PPI Vice President-Administration, will officially retire at the end of 1999. Mr. Roberts joined the Institute March 1, 1968, when the headquarters were in Washington, D.C. He helped supervise the move to Atlanta, Georgia.

During his years at PPI, Mr. Roberts served under three presidents...Dr. J. Fielding Reed, Dr. R.E. Wagner, and current President, Dr. David W. Dibb. During his tenure, the name of the organization changed from the American Potash Institute to the Potash Institute of North America, and later to the Potash & Phosphate Institute (PPI).

In addition to other duties, Mr. Roberts had key responsibility in helping develop and in managing annual budgets at PPI, supervising the headquarters staff, overseeing statistics reports, and arranging and coordinating certain meetings each year.

Those who have been fortunate enough to work with Mr. Roberts will miss his managerial skills, his good humor, his caring for fellow employees, and his unfailing ability to focus on the problem at hand.

"Richard had a well-deserved reputation for his keen abilities in helping the Institute steer a safe course with lean budgets and for watching expenditures to assure the most efficient operation of Institute programs," said Dr. Dibb. "He is highly respected by all who have worked with him...he will be missed by staff as well as by the Board of Directors and member companies of the Institute. We all wish Richard a long and happy retirement." BC

David W. Dibb Receives ASA Agronomic Industry Award

David W. Dibb

Dr. David W. Dibb, President of PPI, received the Agronomic Industry Award at the recent annual meeting of the American Society of Agronomy (ASA) in Salt Lake City. The honor recognizes outstanding performance by a private sector agronomist in the development, acceptance, and implementation of advanced agronomic programs, practices and/or products. Personal relations, professionalism, integrity, and credibility are some of the values considered for the award, as well as innovation and good citizenship.

Dr. Dibb joined the PPI staff in 1975 as a regional director. In 1981, he was named Latin America Coordinator and Southeast Director, and in 1985 he became Vice President for Domestic Programs. He was promoted to Senior Vice President in 1987 and has served as President since 1988.

A native of Draper, Utah, Dr. Dibb received his B.S. degree at Brigham Young University and earned his Ph.D. degree from the University of Illinois in 1974.

Dr. Dibb has been active as a member of ASA, including service on various committees and a term as President of the Agronomic Science Foundation. He is Fellow in both ASA and the Soil Science Society of America and is an Honorary Professor at the Chinese Academy of Agricultural Sciences (CAAS). BC

Originality

Someone once said that originality is nothing more than undetected plagiarism. I suspect that many 'original' ideas, concepts and thoughts **were** borrowed from others. At the same time, originality has driven research and development that provide us the technology we enjoy today. The information age is overloaded with new ideas and concepts.

More than 30 years ago, Dr. R.E. Wagner, Institute agronomist (and, later PPI President), introduced the concept, **maximum economic yield** (MEY) ...a production system of best management practices that economically maximizes yield and profit per acre. Was the MEY concept original with Dr. Wagner? Perhaps the name, but many of its parts are older than the Institute itself.

The following appeared in *Southern Cultivator* in 1870: "Use more and better machinery, plant the best seeds...cultivate effectively, and apply the kind and amount of commercial fertilizers that will produce the highest yields to reduce costs per unit." That 130 year-old quote sounds a lot like MEY.

Sometimes it doesn't matter whether an idea, concept or thought is original. The issue is, will it make a difference? Can it be used to make something better? As we incorporate space age technology into our crop production practices, we need to remember those basic agronomic, economic, and environmental truths that have brought us this far. Maybe a little 'originality' will help.

B.C. Darst, Executive Vice President

BETTER
CROPS
WITH PLANT FOOD

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