BETTER CROPS

Now Including International Topics

2004 Number 3

In This Issue

- Phosphorus and Turf Concerns
- Understanding the Science Behind Fertilizer Recommendations
- Potassium Nutrition of Flood-Irrigated Rice

... and much more

BETTER CROPS WITH PLANT FOOD

Vol. LXXXVIII (88) 2004, No. 3

Our Cover: Forage harvesting...corn silage. Courtesy of Case-IH.
Cover Design: Kathy Hefner

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-ppic.org.

CONTENTS

Winners of Robert E. Wagner Award for 2004

Two well known agronomic scientists have been selected to receive the 2003-2004 Robert E. Wagner Award by PPI. The award encourages worldwide candidate nominations and has two categories...Senior Scientist and Young Scientist, under the age of 45. The recipient in each category receives $5,000 along with the award plaque.

Dr. E.D. Nafziger

Dr. Emerson D. Nafziger, Professor of Crop Sciences-Crop Production Extension, University of Illinois, was selected for the Senior Scientist award.

Dr. F.L. Walley

Dr. Frances L. Walley, Associate Professor, Department of Soil Science, University of Saskatchewan, receives the Young Scientist award.

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

Dr. Nafziger has provided crop producers and advisers scientifically sound research and extension programs resulting in significant impact on yields and subsequently economic return on crop production throughout the Corn Belt. His ability to conduct leading edge research and to take the results to producers in an easily understood and convincing manner has translated to rapid adoption of progressive ideas.

In recent situations related to spiking natural gas prices, Dr. Nafziger has applied sound economic principles in addressing use of nitrogen (N) cost:corn price ratios to adjust rates of fertilizer N. He has studied the potential for site-specific N fertilizer application in corn production.

Dr. Nafziger is coauthor of the book *Modern Corn and Soybean Production*. He was involved in adapting the highly popular *Illinois Agronomy Handbook* publication as an on-line, interactive resource. He created innovative features such as calculators for seeding rates, N rates, soil fertility recommendations, planting dates, replant decisions, and yield estimates, and is the author of a chapter in the *Handbook* on use of on-farm research to test and confirm crop management practices.

Each year, Dr. Nafziger is a leader in the Corn and Soybean Classics, a series of regional meetings in Illinois to provide the latest research and management information to crop producers and advisers. He is credited with encouraging higher corn populations in Illinois fields, resulting in increased yields and profits. Dr. Nafziger has an impressive record of professional publications and involvement in professional-society programs. His honors include election as Fellow of the American Society of Agronomy (ASA) and Crop Science Society of America. A native of Ohio, he received his M.S. degree at Purdue University and his Ph.D. at the University of Illinois in 1982.

Dr. Walley has played an important role in the advancement of the pulse industry (chickpeas, beans) in Saskatchewan and western Canada. Her research related to pulse crop fertility and in particular in development of inoculants and inoculation

(continued on page 5)

J. Fielding Reed PPI Fellowships Awarded to Four Outstanding Graduate Students

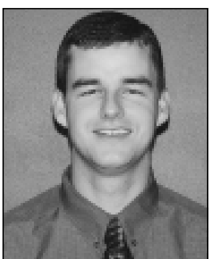
Four outstanding graduate students have been announced as the 2004 winners of the J. Fielding Reed PPI Fellowships awarded by PPI. Grants of $2,500 each are presented to the individuals. All are candidates for either the Master of Science (M.S.) or the Doctor of Philosophy (Ph.D.) degree in soil fertility and related fields.

The four winners for 2004 are:

- **Chad B. Godsey**, Kansas State University
- **Joshua L. Heitman**, Iowa State University
- **(Juan) Andrés Quincke**, University of Nebraska-Lincoln
- **Micah Woods**, Cornell University

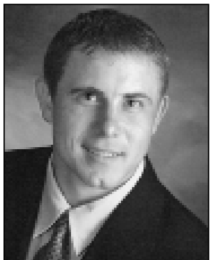
"Since these awards began in 1980, a total of 146 graduate students have now received Fellowships from the Institute," said Dr. David W. Dibb, President of PPI.

Funding for the Fellowships is provided through support of potash and phosphate producers who are member companies of PPI. Scholastic record, leadership, and excellence in original research are among the important criteria evaluated. Following is a brief summary of information for the 2004 recipients.



Chad Godsey

Chad B. Godsey is working toward a doctorate degree in soil fertility at Kansas State University (KSU). His dissertation title is "Management of Acid Soils in No-till Cropping Systems." Mr. Godsey was raised on a diversified farm in eastern Colorado and earned his B.S. degree at Colorado State University in 1999. In addition to his research and course work, he manages the daily activities of the KSU Plant and Soil Testing Laboratory. He also has considerable involvement in Extension programs, research, and teaching responsibilities, and has been involved with several community and volunteer activities. For the future, he intends to work as a professional soil scientist, enabling producers to make profitable and environmentally responsible decisions.



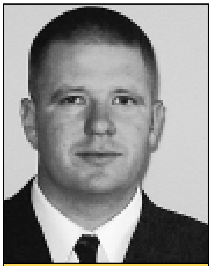
Joshua

Joshua L. Heitman is in the early stages of work toward his doctorate degree in soil physics/water resources at Iowa State University. While completing his B.S. and M.S. degrees at Kansas State University, he achieved an outstanding academic record and received numerous honors and awards. Mr. Heitman is a native of Kansas, with a farm background. His M.S. thesis problem involved quantification of nitrate leaching from the root zone of irrigated corn. He plans to incorporate field-scale watershed processes encountered by producers, such as nutrient runoff, into his Ph.D. research. Mr. Heitman's goal is to develop a research program that can help producers overcome applied agronomic problems while achieving environmental responsibility.

Andrés

(Juan) Andrés Quincke, a native of Uruguay, is currently working toward a doctorate degree at the University of Nebraska-Lincoln. His proposed Ph.D. dissertation is "Ocasional Tillage of No-till Systems to Improve Crop Yield, Soil Quality, and Carbon Sequestration." Mr.

Quincke is interested in management practices that might better favor soil microbes that directly stimulate crop growth...the thesis for his M.S. degree, completed in 2003, was on the influence of starter fertilizer on soil microbial community dynamics. While no-till is well known for soil conservation and organic matter (OM) benefits, stratification of phosphorus (P), potassium (K), and OM can become pronounced. His study will look at carbon pools, microbial community composition, redistribution of nutrients, and yield comparisons after a one-time, occasional tillage under rainfed corn-soybean or sorghum-soybean rotations.


Micah Woods

Micah Woods began his Ph.D. program at Cornell University in 2003. His research is addressing current issues regarding K fertilization and soil analysis in sand dominated systems. The lack of available information for K requirement in sand rootzones leaves practitioners without a science-based strategy for managing high value sports turf and golf course greens. A native of Oregon, Mr. Woods earned his B.S. degree at Oregon State University in 1994. He then worked at various golf courses in the U.S. before becoming a golf course superintendent in Shanghai, China, from 1998 to 2000, and later an agronomic consultant on turfgrass in Japan. He has been widely recognized for his diverse work experience and academic accomplishments. Completion of his current studies will lay the groundwork for future research into nutrient management of recreational and aesthetic turf, while also providing a valuable database of information for today's turfgrass managers.

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

The Fellowship winners were selected by a committee of PPI scientists. Dr. Tom W. Bruulsema, PPI/PPIC Northeast Region Director, served as chairman of the selection committee. BC

Wagner Award... *(continued from page 3)*

strategies for pulse crops has been key in providing growers with a wealth of practical production information and inoculant products.

Her research focuses on soil fertility and agronomy for maximized nutrient use efficiency. A focus on soil N-cycling includes testing and development of appropriate N fertilizer recommendations with applications for precision farming and optimized fertilizer use efficiency. More recently, her research has examined the variability of soil-available copper and boron with the objective of determining factors influencing variable fertilizer responses, particularly on soils testing within the marginal range.

Dr. Walley was involved in establishing two major extension events in Saskatchewan...the Field Diagnostic School and the Agronomy Training Workshop. She has also chaired the provincial Saskatchewan Soil Fertility Subcouncil. As a teacher, Dr. Walley is recognized as a dedicated, effective, and popular educator with the ability to reach many different types of students.

She is an active member of ASA, Soil Science Society of America, Canadian Society of Soil Science, and Saskatchewan Institute of Agrologists. A native of Manitoba, Dr. Walley received her M.Sc. degree at the University of Manitoba and her Ph.D. at the University of Saskatchewan in 1993. BC

CALIFORNIA

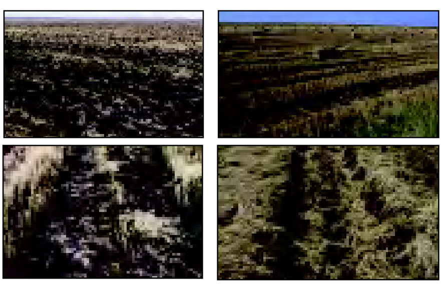
Nutrient Requirements of Rice with Alternative Straw Management

By E.W. Byous, J.F. Williams, G.E. Jones, W.R. Horwath, and Chris van Kessel

As the burning of rice straw was phased out in California, a 3-year research project was conducted to determine the effect of straw management on rice nutrient requirements, especially nitrogen (N) and potassium (K). Removal of rice straw from the field exports an additional 50 lb N/A and 140 lb K_2O/A beyond the nutrients harvested in the grain. When the straw is left in the field during winter flooding, most of these nutrients will be available for the following crop. Soil extraction with ammonium acetate was a good predictor of K deficiency.

Over 550,000 acres of rice are currently grown in California, mainly in the Sacramento Valley. These rice growers produce some of the highest yields in the world, as a result of finely-tuned management practices developed by close cooperation between public and industry-supported researchers. Grain yields frequently exceed 8,500 lb/A, with research plots exceeding 13,000 lb/A.

After harvest, rice straw has traditionally been burned to facilitate tillage and reduce potential pest problems. Due to air quality concerns, this practice has been greatly eliminated. Farmers now manage the straw in several alternative ways...incorporation of straw is used on about 75 to 80% of the acreage, burning on about 15 to 20%, and removal on less than 5% of the rice acreage. Each of these practices has a different effect on the nutrient balance and the fertility requirement for the following crop. Rice straw has a high ash content (>20%) and does not decompose as quickly as straw from many other grain crops, such as wheat or barley (5 to 10% ash).



Methods of managing rice straw include incorporation, burning, baling, and spreading.

When rice straw and stubble are incorporated into the soil following harvest and then flooded during the winter, it can improve soil properties and serve as a source of nutrients for the following crop. Since many of the plant nutrients remain in the straw following harvest [approximately 35% of the N, 30% of the phosphorus (P), 85% of the K, and 40 to 50% of the sulfur (S)], much of this can be recycled for subsequent crop growth following decomposition. As rice straw contains most of the accumulated plant K, how this resource is managed has a large impact on its long-term availability, particularly on soils with relatively low native K concentrations.

A 3-year field experiment was conducted to determine the effect of straw management and nutrient application rate on rice productivity. In the fall of 1998, 1999, and 2000, straw was either chopped and incorporated or removed from rice fields following grain harvest. The following spring, N fertilizer [as $(NH_4)_2SO_4$)] was added at five application rates (0, 45, 90, 135, or 180 lb N/A) in factorial combination with six rates of K as KCl (0, 26, 53, 80, 108, and 132 lb K_2O/A). Soil and plant parameters were measured each season.

Nitrogen management. Addition of fertilizer N significantly increased grain yield all 3 years, regardless of straw management practices (**Figure 1**). However, an increase in the soil N supply was noted when straw was regularly returned to the soil, reducing the need for N fertilizer. Since straw contains an average of 50 lb N/A, we currently recommend that when straw has been incorporated for at least 5 years, that the N fertilizer rate be decreased by 25 lb N/A. This N fertilizer savings has the potential advantages of lowering production costs and reducing off-site loss.

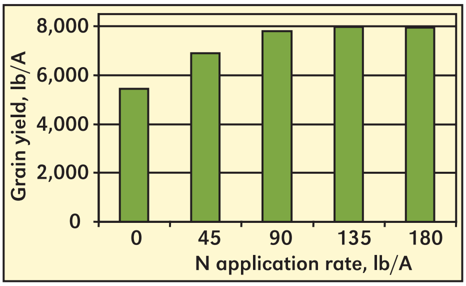


Figure 1. Average rice grain yield response to applied N fertilizer averaged over K additions and straw management during the 3-year study.

Potassium management. When straw was removed from the field following harvest, there was a significant positive response in grain yield following application of K fertilizer each year (**Figure 2**). When straw was incorporated into the soil, there was no grain response to application of K in the first 2 years of the experiment. During the third year, there was a significant increase in grain yield with the application of K fertilizer when straw was incorporated. The concentration of exchangeable soil K (extracted with 1 mol/L ammonium acetate) was found to be an excellent predictor of tissue K concentrations and grain yields, especially when soil K was low. Whenever extractable soil K concentrations fall below 60 parts per million (ppm), a loss of grain yield is anticipated. When rice straw is incorporated into the soil, this critical value may need to be increased somewhat.

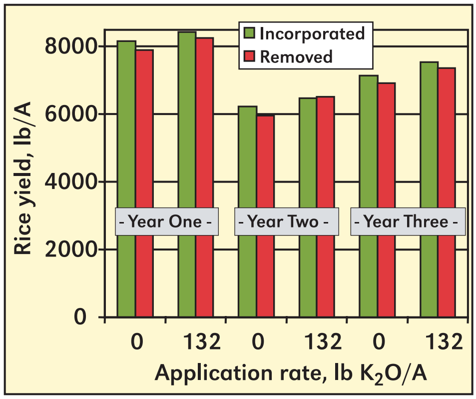


Figure 2. Average rice grain yield response to applied K fertilizer, as affected by K fertilization rate and straw management (averaged over N treatments) during the 3-year study.

Nutrient budget. Over the 3-year study, average K removal in the grain was 40 lb K_2O/A/year and averaged 140 lb K_2O/A/year in rice straw (**Table 1**). When both grain and straw are removed from the field, K depletion occurs at a rate of 180 lb K_2O/A/year. Even at the highest rate of K application tested in this study, there was a steady depletion of nutrients over the 3 years (**Figure 3**). When grain is harvested and straw incorporated back into the soil, removal of harvested K is balanced with annual applications of 35 to 45 lb K_2O/A/year.

(continued on page 11)

Symptoms of K deficiency include firing (top of center leaf) and flecking (on leaf to right of center).

Table 1. Typical amounts of nutrients removed by rice.

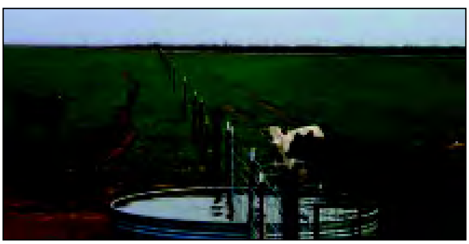
Nutrient	Content, lb/cwt Straw	Content, lb/cwt Grain	Removal in 8,000 lb/A, lb Straw	Removal in 8,000 lb/A, lb Grain	Total nutrient removal when straw harvested, lb/A
N	0.63	1.27	50	100	150
P_2O_5	0.23	0.67	18	54	72
K_2O	1.80	0.54	140	43	183
Si	11.0	2.1	880	170	1050

Phosphorus Fertilizer Impacts Forage, Beef, and Grain Production from Wheat

By D.L. Robinson, W.E. Pinchak, J.W. Sij, S.J. Bevers, R.J. Gill, D.P. Malinowski, and T.A. Baughman

Phosphorus (P) fertilizer increased 3-year average winter wheat forage yield in the Texas Rolling Plains by 55% during early production from planting to March. Season-long forage yield was increased 35% by P fertilizer. Additionally, stocker cattle gain was significantly affected by P fertilizer...beef gain increased over the no P control by 25% in the early season and 34% during the entire season. Surface applied P was consistently as good as or better than deep banded P fertilizer. Economic analyses indicated that the graze-plus-grain system was more profitable than the graze-out system. Net return to P fertilizer in the graze-plus-grain system was as high as $12/A.

Hard red winter wheat is grown on nearly 20 million acres in the Southern Great Plains, with about 6 million acres grown in Texas. The crop is uniquely used in the region as forage for winter grazing of stocker cattle, with the option of also producing a grain crop if grazing is terminated prior to jointing (graze-plus-grain system). Some producers utilize the crop entirely as forage by grazing until maturity (graze-out system). Estimates indicate that about 70% of the crop is grazed prior to jointing and 40 to 45% is grazed season-long. Regardless of how wheat is utilized, it is extremely important to the economy of the Southern Great Plains.



Four annual applications of P increased early-season wheat forage production by 55% and beef production by 25% in the graze-plus-grain system. The study confirms that grain production is still important in Rolling Plains wheat-stocker production systems.

Nitrogen (N) and P are the two most widely recognized nutrient deficiencies in soils of the Texas Rolling Plains. Unfortunately, there is very little data available to form the basis of fertilizer management practices in dual-use wheat programs. Previous work in the Rolling Plains showed that knifed NP fertilizer increased fall forage yields 50% over surface applied NP and 45% over N alone in 5 of 8 site-years. Deep-placed NP increased grain yields over surface-applied NP and N alone in 6 site-years by 2.0 and 9.9 bu/A, respectively.

Our study was conducted in the Rolling Plains on the Texas Agricultural Experiment Station's Smith/Walker Research Unit near Vernon to determine if increased forage production from P applications could be captured as additional beef gains and increased profitability. The study was on a Tillman clay loam soil. The initial average soil pH (0 to 6 in. depth) of the pastures was 7.1 (range 6.4 to 7.9), and the average organic matter content (0 to 6 in. depth) was 1.7% (range 1.2 to 2.3%). Soil potassium (K) level was very high to high in all pastures. The three fertilizers were applied pre-plant as solutions that supplied 20 lb S/A. Tillage with a field cultivator immediately followed fertilizer applications. The N rate was 65 lb/A and the P_2O_5

rate 40 lb/A applied to the same pastures each year for 4 years. Forage was available early enough to graze in 3 of the 4 years. Statistical differences were evaluated at the 5% level of significance.

Soil Test Phosphorus Effects

Like many soils in the Rolling Plains, most of the P in the soil at the experimental site was in the surface 2 in. (**Figure 1**). Original values averaged 8 to 10 parts per million (ppm) P at the 0- to 2-in. depth and 2 to 3 ppm at the 2- to 6-in. depth. Values at both depths increased during the 4 years where P was applied, reaching 24 ppm P in the top 2 in. and 8 to 10 ppm in the 2- to 6-in. layer. Method of P application did not affect soil test results. The 2- to 3-fold increase in soil P values in 4 years indicates that 40 lb P_2O_5/A/year exceeded the long-term P requirement of this soil and crop management program. Values exceeding about 15 ppm P are considered sufficient. The higher soil test values are an asset but are not accounted for in the economic analysis at this time.

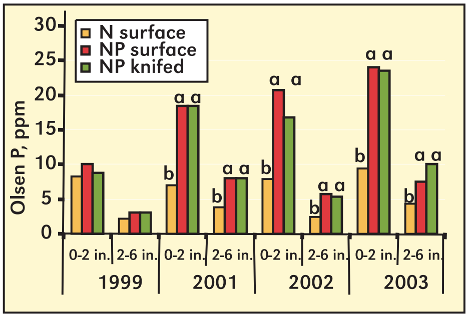


Figure 1. Phosphorus fertilizer influences on soil test P at two depths. Phosphorus was applied at 40 lb P_2O_5/A/year.

Forage Yield Responses

Forage yields consistently increased in response to P applications during the 3 years (**Table 1**), but there was no apparent advantage to deep placement of the P fertilizer. Forage production from planting until March 1, the average date of jointing, increased by 630 lb/A, or 55% where P fertilizer was applied. During the graze-out phase, from March 1 to early May, surface-applied NP increased average forage yields 740 lb/A, or 26% over N alone. Annual forage yields for the 3 years were 3,985 lb/A for N alone, 5,360 lb/A for surface-applied NP, and 4,905 lb/A for knifed NP…an increase in forage yield of 1,375 lb/A, or 35% due to surface-applied P.

Table 1. Forage production in grazed wheat pastures receiving three fertilizer treatments during 3 years.

Fertilizer	Planting to March 1	March 1 to May	Total
	lb forage/A		
N Surface	1,150[b]	2,840[b]	3,985[c]
NP Surface	1,780[a]	3,580[a]	5,360[a]
NP Knifed	1,780[a]	3,125[ab]	4,905[b]

Increases in fall forage production were clearly visible in the pastures. The higher level of forage production that continued into spring, although at a reduced rate, is a further benefit from P applications that has not been fully recognized.

Beef Gains

In the graze-plus-grain system, stocker calves (initial weight 400 to 500 lb) grazed from early December through February, when grazing was terminated to allow the wheat to produce a grain crop. In the graze-out system, stocker calves grazed wheat from early December into May, utilizing the crop entirely for forage.

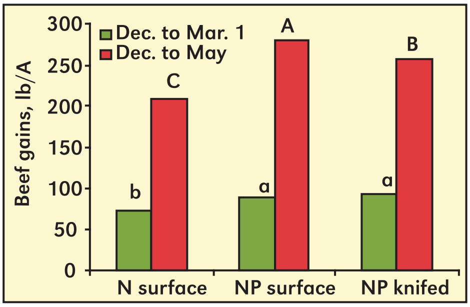


Figure 2. Phosphorus fertilizer influence on beef gain from wheat pasture during three years. December to March represents the graze-plus-grain system, while December to May is the graze-out system.

Figure 2 shows that P fertilizer increased average beef production per acre in both grazing systems during the 3 years regardless of how it was applied. In the graze-plus-grain system, there was no difference in beef gain between surface-applied or knifed NP fertilizer, with beef production increasing by 17 to 21 lb/A, or about 25% over N alone. In the graze-out system, surface-applied NP produced over 70 lb/A, or 34% more beef than N alone and 23 lb/A, or 9% more beef than knifed NP. The knifed NP treatment produced 48 lb/A more beef gain than surface-applied N alone.

Table 2. Costs and returns associated with three fertilizer treatments within two wheat management systems.

	Graze + Grain			Graze-out		
	N Surface	N+P Surface	N+P Knifed	N Surface	N+P Surface	N+P Knifed
Revenue	$/A					
Grain	74	93	85	–	–	–
Cattle	24	29	31	69	92	85
FSA [1]	17	17	17	17	17	17
Total	115	139	133	86	109	102
Expenses	83	95	96	78	93	92
Net returns [2]	32	44	37	8	16	10

[1] Land payments from USDA-Farm Services Administration (FSA).
[2] Net returns to indirect costs, land, and management.

Grain Yields

Grain yields subsequent to grazing in the graze-plus-grain system during the 3 years averaged 26 bu/A with N alone, 32 bu/A with surface-applied NP and 29 bu/A with knifed NP. Yields were not statistically different, although they trended higher where P was applied.

Economic Costs and Returns

A summary of costs and returns associated with each fertilizer treatment within each wheat management system is presented in **Table 2**. In the graze-plus-grain system, most of the income came from grain sales, which was $11 to $19/A higher where P was applied. Income from cattle was $5 to $7/A more where P was applied, resulting in total revenues of $24 to $18/A more due to P applications. The cost of 40 lb P_2O_5/A was about $12/A, accounting for most of the added expense where P was applied. Net returns to land, management, and other indirect costs from surface-applied P during the 3 years averaged $44/A, or $12/A more than where no P was applied. These returns show that surface-applied P returned $12/A above the cost of P fertilizer. No statistical differences in net returns could be detected among fertilizer treatments.

In the graze-out system, beef gains generated about three times more income than in the graze-plus-grain system, but was insufficient to compensate for the loss of income from grain. Total income from beef gains was $16 to $23/A more where NP was applied than where N was applied alone. Expenses were about $15/A higher where P was applied, due to P fertilizer costs plus additional labor costs for handling more cattle at the higher stocking rates. Net returns were lower from all fertilizer practices in the graze-out than in the graze-plus-grain system. Net returns from surface-applied P exceeded the cost of the P fertilizer and paid an additional $8/A over net returns where no P was applied. Although net returns trended higher with P application, no statistical differences were identified in the economic data.

In this Texas Rolling Plains study, application of P fertilizer to winter wheat on a Tillman clay loam soil increased soil test levels 2- to 3-fold. Phosphorus fertilizer increased forage production over 55% during fall and winter, and over 26% during spring. Beef gain per acre increased about 25% due to P applications in the graze-plus-grain system where wheat was grazed from early December until March 1. Wheat grain yields following grazing trended higher with P applications, but increases averaging as much as 6 bu/A were not significant. Beef gains in the graze-out system, where the wheat was utilized entirely as a forage crop, increased 34% where P was surface-applied and 23% where P was knifed into the soil. In all cases, surface-applied P fertilizer was equal to or better than P knifed into the soil. A greater advantage to knifed P would be expected at very low soil test P levels and very low P application rates.

Although results from economic analyses of each treatment were not statistically different, surface-applied P produced the highest net returns in each system, averaging $44/A in the graze-plus-grain system and $16/A in the graze-out system. In addition to paying for the P fertilizer, surface-applied P returned $12/A and $8/A in the two management systems.

Net returns to land, management, and other indirect costs were consistently higher in the graze-plus-grain than in the graze-out system, indicating that grain production is a major factor in profitability of wheat/stocker programs in the Texas Rolling Plains. BC

Dr. Robinson is Professor and Resident Director; Dr. Pinchak is Associate Professor; Dr. Sij is Professor; and Dr. Malinowski is Assistant Professor, all in the Texas Agricultural Experiment Station, Vernon. Mr. Bevers is Associate Professor and Dr. Baughman is Associate Professor, Texas Cooperative Extension at Vernon. Dr. Gill is Professor in Texas Cooperative Extension at Dallas.
PPI/FAR Research Project TX-44F.

Straw Management... *(continued from page 7)*

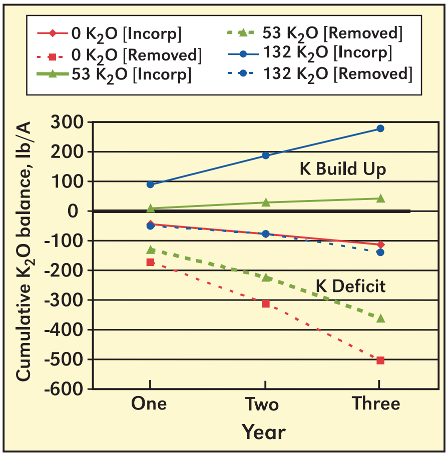


Figure 3. Potassium balance for 3 years of rice production, as affected by straw management (incorporated or removed) and K fertilizer addition (0, 53, or 132 lb K_2O/A).

Changes in straw management practices have an impact on a number of related issues. For example, an increase in methane production (a greenhouse gas) from rice fields occurs when straw is left in the field under flooded conditions. However, increases in soil carbon that follow from straw incorporation may reduce the amount of carbon dioxide emitted to the atmosphere. Additionally, winter flooding which increases the decomposition of rice straw also creates valuable habitat for millions of migratory and wetland-dependent birds along the Pacific Flyway in northern California.

Rice straw is a valuable source of plant nutrients and its management can make a significant impact on the following crop. The rice industry is working to develop off-field uses for rice straw with the goal of converting crop residues to a profitable resource. Current research shows that straw removal removes large amounts of nutrients which must be replaced to sustain yields. Careful management of rice straw will slow the export of nutrients from the soil, reduce production costs, and eliminate air quality concerns associated with burning...all while maintaining a high level of grain production. BC

Mr. Byous and Mr. Jones were graduate students, and Dr. Horwath is Associate Professor in the Department Land, Air & Water Res., Univ. of Calif., Davis. Mr. Williams (retired) was Univ. of Calif. Coop. Extension Director and Farm Advisor in Sutter and Yuba counties. Dr. van Kessel is Professor and Chair of the Department of Agronomy & Range Science, Univ. of Calif., Davis; e-mail: cvankessel@ucdavis.edu.

Acknowledgments

The financial support of the Fertilizer Research and Education Program (FREP) of the California Department of Food & Agriculture and PPI/FAR is highly appreciated. PPI/FAR Research Project CA-21F.

WISCONSIN

Phosphorus Runoff Losses from Lawns

By W.R. Kussow

Simply eliminating phosphorus (P) in lawn fertilizers will not guarantee less P in runoff water. A Wisconsin study found that a major portion of the P in runoff may also originate from the turfgrass itself. Properly maintained lawns have much lower P losses than poorly maintained lawns.

This study was conducted at the Noer Turfgrass Research and Education Facility, near Verona, Wisconsin. The experimental area had been uniformly graded to a 6% slope after which approximately 6 in. of excavated topsoil was replaced. The average Bray P-1 soil test level of the topsoil was 62 parts per million (ppm), 42 ppm above that considered optimum for established lawns.

Turf, a blend of four Kentucky bluegrass cultivars, was established. Runoff was collected with a system constructed of heavy-duty lawn edging extending 1 in. above the soil surface. At the lower end of the plots, edging was attached to 6 ft. wide weirs of a standard USDA-Natural Resources Conservation Service design. Steel chutes with 3-slot sample splitters conveyed runoff into collection devices.

Plots 8 ft. wide by 32 ft. long were fertilized according to the standard University of Wisconsin recommendation of 1.0 lb nitrogen (N)/1,000 ft^2 during the following four periods: May 1 to 15, July 1 to 15, September 1 to 15, and in late October after the last mowing of the season. Plots were mowed to a height of 2.5 in. every 3 to 5 days and clippings removed. With the exception of 1993, plots were irrigated with 0.43 in. of water only when a change in turfgrass color indicated the onset of moisture stress. In 1993, due to a miscommunication, plots were placed on a twice-weekly irrigation schedule.

Results

Early in the study, both total and soluble orthophosphate P were analyzed in runoff water. The results showed that 98 to 100% of the P was water-soluble orthophosphate. This was consistent with the observation that runoff water contained no measurable amounts of soil sediment. Consequently, only water-soluble orthophosphate P was measured during the entire length of the 6-year study. Water volume was multiplied by P concentration to calculate P load. On average, 70% of the runoff water volume and 72% of the P lost during the year came from frozen soil (data not shown).

Table 1. Potential contributions of turfgrass tissue P to runoff P.

Turfgrass clipping status	Leachable P from clippings, lb P_2O_5/A	Percent of observed P load, %
Fresh	0.53	311[1]
Air-dried	2.38	452[1]
Frozen and air-dried	2.20	417[2]

[1]Based on a 6-year average of 0.21 lb P_2O_5/A measured in runoff during the growing season.
[2]Based on a 6-year average of 0.53 lb P_2O_5/A measured in the runoff when the soil was frozen.

Sources of P in runoff water include soil, fertilizer, and turfgrass tissue. Phosphorus can leach out of fresh, living plant tissue as well as dried plant material. Although P sources in runoff were not differentiated in this study, the potential contribution of plant tissue P to P loading was investigated. **Table 1** shows that the amount of leachable P is much lower in fresh tissue, compared to dried and/or frozen tissue. In addition, P leached from plant tissue is capable of accounting for

Table 2. Estimates of lawn maintenance level and fertilizer P application on soluble P loads in runoff water during the growing season.

Maintenance level[1]	Runoff volume, gal/A	Average soluble P, 10^{-5} lb P_2O_5/gal	Runoff P load, lb P_2O_5/A
High + P	4,600	0.75	0.034
High - P	4,600	0.59	0.027
Low + P	23,000	1.70	0.403
Low - P	23,000	0.86	0.197

[1]High indicates maintenance according to University of Wisconsin recommendations.
Low represents composite values for several home lawns.

all of the P observed in the runoff in this study.

Phosphorus loads measured in university research are invariably less than estimates for home lawns. Turf quality may account for much of the difference observed. Research is lacking in this regard, but estimates can be made of the role of turf maintenance on runoff P loads. Data from this study (high maintenance level) were compared to results of studies of home lawns (low maintenance level) conducted by the United States Geological Survey and the Wisconsin Department of Natural Resources. The home lawns studied were of a quality slightly above what is considered minimally acceptable by most homeowners.

Table 2 suggests that well-maintained lawns may have P losses that are 86 to 91% lower than low maintenance home lawns. When no P fertilizer is applied to well-maintained lawns, there is a 20% reduction in the runoff P load. This number jumps to a 51% reduction for home lawns.

Applying P when it is needed can be important for reducing P loads. **Table 3** shows that while P applications increased the concentration of P in runoff water after a significant rainfall event, they also reduced the total volume of runoff, thereby reducing total P load. Consequently, simply eliminating P from fertilization strategies may actually increase, rather than decrease, P losses.

Table 3. Soluble P concentrations, volumes, and P loads determined in runoff water collected on June 30, 1997 after a 1.43 in. rainfall event.

P fertilizer rate, lb P_2O_5/1,000 ft^2	P concentration, 10^{-5} lb P_2O_5/gal	Runoff water vol., gal/A	P load, lb P_2O_5/A
0.0	2.83	146	0.00413
0.5	3.63	67.4	0.00245
0.8	4.91	57.3	0.00282
1.3	4.43	54.9	0.00243

Summary

Most of the P runoff occurs during the winter months when the soil is frozen. Phosphorus in runoff may originate from soil, fertilizer, and turfgrass tissue. Phosphorus can leach from turfgrass tissue and is of sufficient magnitude to account for all the runoff P observed in this study. Maintenance of lawns is also an important factor in P loading. Properly maintained lawns have much lower P losses than poorly maintained lawns. When needed, P applications may be important for reducing the quantity of runoff water and associated P loads. BC

Dr. Kussow is Professor, Department of Soil Science, University of Wisconsin, 1525 Observatory Drive, Madison, WI 53706-1299; phone: (608) 262-2633; fax: (608) 265-2595; e-mail: wrkussow@wisc.edu.

Phosphorus in Semiarid Forage Production

By Fernando Selles and P.G. Jefferson

Phosphorus (P) fertilization increased the yield of alfalfa-Russian wildrye forage mixtures by 21 to 34%, but had no impact on the yield of monoculture alfalfa.

There is renewed interest in alfalfa (*Medicago sativa* L.) for pasture in the semiarid region of the northern Great Plains due to its productivity, forage quality, and new technologies for ruminant bloat control. Mixtures of alfalfa and wildrye [*Psathyrostachys juncea* (Fischer) Nevski], a recommended species for summer and fall grazing, have been used in the past to reduce ruminant bloat hazard. However, alfalfa persistence in these mixtures is reduced due to the competitive nature of the grass.

Southwestern Saskatchewan soils (Aridic Haploborolls) are generally deficient in available P, and P additions have been shown elsewhere to improve the persistence of legumes growing in mixtures with forage grasses. Our objective was to determine the response to P fertilization of dry matter yield, P balances, and soil available P of monoculture alfalfa and alfalfa-Russian wildrye grass mixtures (RWRM).

This dryland trial was seeded on a silt loam soil with a pH of 6.0 in May 1997 at the Semiarid Prairie Agricultural Research Centre in Swift Current, Saskatchewan (13 in. of annual precipitation). The study was set up as a split plot design with four replicates. Main plots were three cropping treatments: monoculture alfalfa; Russian wildrye and alfalfa seeded in alternate rows; and Russian wildrye and alfalfa seeded in the same row. Subplots were seven P fertility treatments: 0 (check); 18, 36, and 72 lb P_2O_5/A pre-plant; 9, 18, and 36 lb P_2O_5/A annual. The forage was seeded in 12 in. rows and both pre-plant and annual P treatments were applied as triple superphosphate banded 1 in. deep in the center of every mid-row space. Pre-plant applications were made before seeding in 1997; annual applications were repeated annually in early spring.

Forage yield was determined by harvesting with a flail-type plot harvester. Forage sub-samples were removed and analyzed for moisture content and P concentration. In fall 2002, after forage harvest, soil samples were taken with a 3 in. diameter core sampler from the alfalfa monoculture treatments. Soil samples (0 to 6 in. depth) were removed from random locations within the plot area at the beginning of the study, and every spring (except 1998) from the mid-row band and next to the plant row of every plot; available P was determined by the Olsen method.

Olsen P in the soil (0 to 6 in. depth) at the beginning of the experiment was only 5.4 parts per million (ppm)...95% confidence limit 5.0 to 5.8 ppm. At these P levels, annual crops in this region respond readily to P fertilization. Although the level of forage production was primarily affected by growing season conditions, P fertilization...especially at the highest annual rate...produced large increases in the production of the grass-alfalfa dry matter (**Figure 1**). Annual application of 36 lb P_2O_5/A (total of 216 lb P_2O_5/A) produced the largest increase in forage yield, followed by application of 36 or 72 lb P_2O_5/A applied once pre-plant, and finally by annual application of 18 lb P_2O_5/A (total of 108

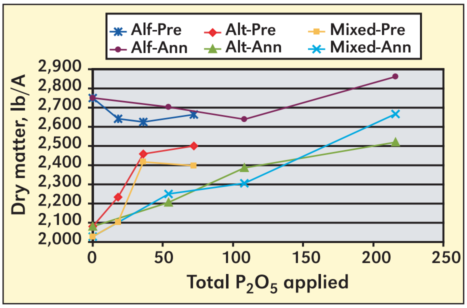


Figure 1. Total P application over 6 years and average annual dry matter production.

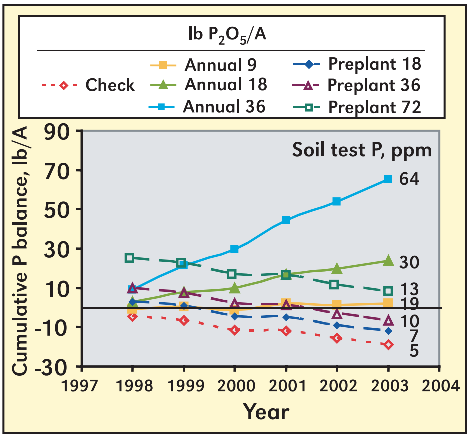


Figure 2. Cumulative P balance in response to P fertilizer application and forage P removal. Values at the end of each line represent soil test P at the end of the study (initial soil P = 5 ppm).

lb P_2O_5/A).The response of the different crop mixes, however, was not consistent. Monoculture alfalfa did not respond to P applications regardless of rate or application method, and unfertilized monoculture alfalfa yielded as much or more than the well-fertilized mixtures (**Figure 1**). The two RWRM showed marked responses to the application of fertilizer P, but there was no difference between the mixed row and alternate-row cropping configuration. We attributed this difference in response between the monoculture alfalfa and the RWRM to possible differences in arbuscular mycorrhizal (AM) infection between the systems. The RWRM may inhibit infection of alfalfa by AM in the mixtures as well as suppressing alfalfa via intra-species competition, as evidenced by the P responses of these mixtures.

The amount of P removed by the crop was highly dependent on total dry matter production. Thus the cumulative balances, calculated as the sum of the annual differences between P inputs and P outputs from the system, show a separation of the treatments that received annual applications of P from those that received a one time pre-plant fertilizer application, or no fertilization (**Figure 2**). During the study period, the concentration of Olsen P in the soil at the 0 to 6 in. depth showed the combined effects of the amounts of P applied (in bands) and the amount of P removal by the crop (data not shown). Available P concentration in the soil receiving no P fertilizer remained unchanged near the original level of 5 ppm throughout six harvests that removed in excess of 19 lb P/A (43 lb P_2O_5 /A). Treatments receiving the pre-plant P application showed minor increases in available soil P from the initial level. All annual P application treatments increased their available P levels at a rate proportional to the amount of P applied in excess of crop removal with a maximum soil P of 64 ppm for the high rate of annual applied P (**Figure 2**). Observed changes in soil P are consistent with the results of other studies at this location that have shown increases in Olsen P for treatments receiving P fertilization, and unchanged Olsen P levels in unfertilized treatments.

Difference in responses to P fertilization between cropping mixes suggests that microbial-root associations may be an important factor determining the capacity of this crop to use soil P under monoculture alfalfa. BC

Dr. Selles (sellesf@agr.gc.ca) is a soil scientist and Dr. Jefferson (jeffersonp@agr.gc.ca) is a forage agronomist with the Semiarid Prairie Agriculture Research Centre of Agriculture and Agri-Food Canada in Swift Current, Saskatchewan, Canada.
PPI/FAR Research Project SK-34F.

ONTARIO

Understanding the Science Behind Fertilizer Recommendations

By T.W. Bruulsema

Geographic and statistical analysis of crop nutrient response databases can be used to build confidence in recommendations and encourage appropriate interpretations of soil tests.

Crop producers often question the relevance of soil fertility recommendations, despite a long history and large volume of soil test calibration research. They question whether the soils they manage and the cultivars they grow are represented in the research backing the recommendations. The link between the recommendations and the research is often lost, or unclear if the data are not systematically organized.

Predicting crop response to applied nutrients remains a challenge, even after many decades of research. Soil tests effectively distinguish soils with low and high probabilities of crop response for most nutrients. However, they address only a small part of the variability in crop response that occurs across sites and years.

The reasons why soil tests fail to do better are known, but are not often quantified to a degree suitable for use in soil fertility management. Factors such as soil texture, yield potential, specific weather conditions, and cultivar differences obscure a clear relationship between soil tests and crop responses.

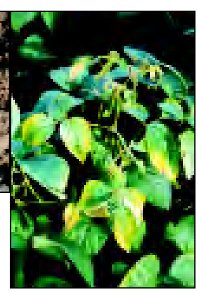
Recommendations may or may not include allowances for some of the foregoing factors. The soil test calibration database may be missing data on these factors. Filling in these missing data demands investment of effort, but the effort can be worthwhile. A couple of examples, drawn from two databases—on phosphorus (P) for corn and potassium (K) for soybeans in Ontario, Canada—are provided here to demonstrate the educational and practical value of such analyses.

Spatial Distribution

The distribution of the corn and soybean crops in Ontario, and the sites included in the databases of responses to nutrients applied in field trials, are illustrated in **Figure 1**. These maps show the locations of 99 site-years of trials evaluating corn responses to P, and 128 site-years for soybean responses to K. The research represented was conducted by many soil fertility research scientists over the past four decades.

The crop areas cultivated today extend considerably to the north and east beyond the area represented in the field trials, particularly for the soybean crop. Nevertheless, the areas of most intensive production coincide with the most intensive areas of field trials.

Maps such as these allow producers to reference their own site with respect to the sites included in the databases. This in itself could enhance their acceptance of the recommendations derived.



Corn and soybeans occasionally show P and K deficiencies in Ontario.

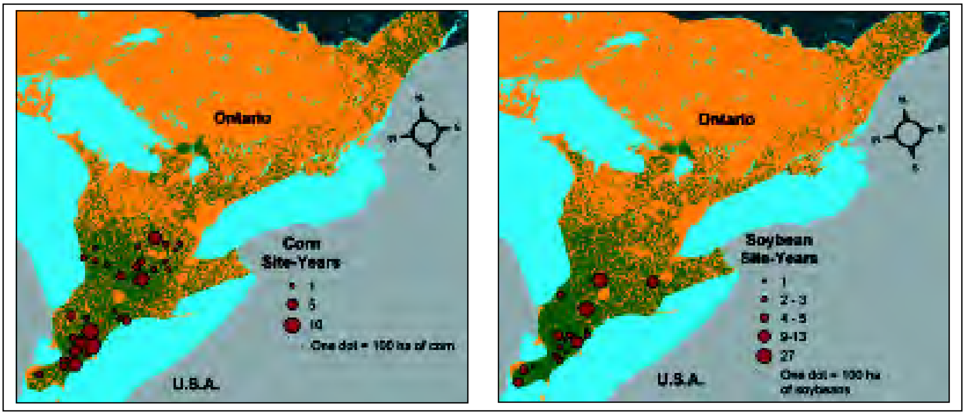


Figure 1. Distribution of corn and soybean production areas and soil fertility field trial sites in Ontario, Canada.

Mapping response parameters for each site also allows the analysis of spatial trends. Visually, no clear trends made themselves apparent. The number of sites limited the expectation of identifying such trends. Sites separated even by small distances differed considerably in soil texture. For these reasons, the analysis of the data focused on measured parameters at each site. For larger databases, geostatistical analysis could potentially identify sub-regions where response frequencies differ, or where the relationships between soil test level and crop response differ.

Impact of Soil Test Level

These databases contain sufficient data to calculate an optimum[1] rate for each site-year, using linear, quadratic, and exponential response models. Where the optimum rate was zero, the site was designated non-responsive. The frequency of responsive sites estimates the probability of crop response. The number of replications varied among site-years. Multiple levels of other factors such as tillage or cultivar resulted in very high levels of replication for some site-years: up to 60, with a median of 10, in the corn database, and up to 96, with a median of 4, in the soybean K database. All analyses across site-years used number of replications as a weighting factor.

Summarizing the response characteristics by existing soil test categories alone, **Table 1** indicates that both probability of response and mean optimum rate decreased as the soil test levels increased. Comparing response probabilities, one can conclude that applying P to corn is more critical than applying K to soybeans. Higher soil test levels imply lower probabilities of response. However, many producers would consider a 15 to 25% risk of yield loss worthy of attention, particularly if they can eliminate it with a low rate of well-placed fertilizer.

The analysis by soil test level presented in **Table 1** explained only 17% of the variability in optimum rate of P for corn and 13% in that of K for soybeans. If one applies the mean optimum rates shown at any given soil test level, there is a very high risk of applying either too much or too little. Since at lower soil test levels, the risk and size of potential yield loss is high, recommendations are usually higher than the mean optimum rates shown.

Conversely, at higher soil test levels, some recommend applying no nutrient because potential yield losses are rarer and smaller, and the amount of nutrient required is less than can be applied with typical field equipment. However, if

[1]"optimum" in this article means the most economic rate calculated from the response function (considering only the current season and not future crops) using prevailing prices for fertilizer and crop.

Table 1. Corn and soybean response characteristics in four soil test categories[1].

	Corn		Soybeans	
Soil test level[2]	Probability of response, %	Mean optimum P_2O_5 rate, lb/A	Probability of response, %	Mean optimum K_2O rate, lb/A
Low	85	45	44	48
Medium	59	25	49	35
High	19	7	15	12
Very high	25	7	24	10

[1]Based on 99 and 128 site-years of data for corn and soybeans, respectively. Analysis was weighted based on number of replications involved in each site-year.
[2]Soil test levels dividing the four classes for corn are 9, 20, and 30 parts per million (ppm) Olsen-P, and 60, 120, and 150 ppm ammonium acetate K

maintaining soil fertility is valued, then the substantial probability of crop response provides added justification for fertilizing at moderate levels in soils testing high to very high. Controlled placement of low rates using techniques such as seed-placed high P starters makes sense as a fertility management strategy for corn in these situations. Neither of these two databases contain sites with soil tests exceeding the "very high" level. For sites where such levels have been attained, these databases provide no guidance to the question of whether a starter fertilizer continues to have any value.

Impact of Soil Texture and Yield Potential

Although the soil test explains only 13 to 17% of the variability in optimum rates, that does not imply it has no value. Sites vary widely in soil test levels, and the differences in response probability and optimum rates make soil testing an economically favorable practice. However, these figures suggest an opportunity to gain considerably more by finding other factors that predictably influence the optimum rate. To date, only soil texture and yield data are factors that are reliably represented in these two databases. Yield potential is taken as the highest mean treatment yield.

When soil texture classes are taken into account, the coarser textured soils appear to have higher optimum levels of P for corn, compared to finer textures (**Table 2**). Adding soil texture to the analysis doubled the total variability explained, to 33%. However, the database contained no sites with coarser textured soils at high and very high soil test levels. Yield levels for this database averaged 132 bu/A, but the effect of yield on optimum rate was not significant ($p=0.2$).

Soil texture class influenced optimum rates of K for soybean as well (**Table 3**). Soils of finer texture appear to require more K for a given soil test level. Yield also had an influence, with optimum rate of K_2O increasing by 1.1 lb/A for each bu/A of increased yield. Mean soybean yield in the database was 43 bu/A. The combined effects of soil test level, soil texture class, and yield explained 23% of the variability

Table 2. Impact of soil texture class on mean optimum rates, in lb/A, for P_2O_5 applied to Ontario corn.

Soil test level	Soil texture: Sandy to loamy	Loamy to clayey
Low	70	42
Medium	46	16
High		7
Very high		7

Table 3. Impact of soil texture class on mean optimum rates, in lb/A, for K_2O applied to Ontario soybeans.

Soil test level	Soil texture: Sandy to loamy	Loamy to clayey
Low	50	
Medium	16	45
High	0	13
Very high	2	14

in optimum rate.

The examples in **Tables 2 and 3** show that the prediction of optimum rates from soil tests can be substantially improved by considering other factors specific to the site. But with only 23 to 33% of the variability explained, there is considerable room for improvement.

Weather is one of the most important modifiers of the relationship between soil test level and crop response. However it is difficult to determine which weather data are most representative of its influence. And even if the relationship could be deduced from these databases, the predictive value will be dependent on predicting weather.

A larger database on corn responses to nitrogen (N) is currently under review in Ontario. It includes 595 site-years of field trials with at least three rates of N. While this database did not include a soil test, an analysis found four factors—yield, preceding crop, soil texture, and application timing—explained about 28% of variability in optimum rates. A considerable amount of variability, resulting from weather and other factors, remains unexplained.

Conclusion

Even the best soil test calibration databases explain less than a third of the variability in crop response to added nutrients. This has implications for the agronomic interpretation of soil tests. It implies that there is not a single optimum rate for all producers with similar soil fertility. Rather, the optimum rate depends on the relative magnitude of risks being faced by each particular producer.

Fertilizer rate decisions are risk management decisions. Agronomically, the risk of a nutrient limiting crop yield must be balanced against cost and impact on the balance of nutrient levels in the soil. Environmentally, added risks of impacts on water or air quality must be brought into consideration.

When regulation mandates nutrient rate reductions, yield losses will vary among producers. The risk of yield loss will be only partly predictable. Site-specific assessment of both the agronomic and environmental risks is needed to determine a rate of nutrient application that maximizes its beneficial use.

Dr. Bruulsema is PPI/PPIC Northeast Region Director, located at Guelph, Ontario; E-mail: tom.bruulsema@ppi-ppic.org

Acknowledgment

The Fertilizer Institute of Ontario Foundation provided funding for development of the P and K databases.

InfoAg Ohio Valley Regional Conference August 16-17

"Equipping Today's Agriculture with Technology" will be the theme of the InfoAg Ohio Valley Conference, planned for August 16-17, 2004, at Clark State Community College in Springfield, Ohio. This is the first in an expected series of regional Information Agriculture Conferences modeled after the popular InfoAg Conference series organized by PPI/PPIC/FAR.

University and industry experts will share real-world experiences and successes with technology to help crop and livestock producers adjust to the demand of changing agriculture. The Ohio Valley event is jointly presented by PPI/PPIC/FAR, Ohio Agriculture Technology Association, Ohio Geospatial Extension Program, Ohio State University Extension Precision Agriculture, Ohio State University Extension Beef Team, Purdue University Site-Specific Management Center, University of Kentucky Precision Resource Management Team, and Kentucky Precision Ag Network. For more about the InfoAg Conference, visit these websites: >**www.farmresearch.com/infoag**< or >**www.ppi-far.org**<.

ARKANSAS/MISSOURI

Potassium Nutrition of Flood-Irrigated Rice

By N.A. Slaton, D. Dunn, and B. Pugh

Seasonal potassium (K) uptake pattern of flood-irrigated rice characterized on K-sufficient soils indicates that adequate K must be present during vegetative growth to maximize K uptake.

Our knowledge and understanding of the K nutritional requirements and K uptake trends for rice (*Oryza sativa* L.) are limited when compared to those of other essential macronutrients. The extensive, shallow root system of flood-irrigated rice…plus increased K availability after flooding… make rice an effective scavenger of soil K.

The importance of K fertilization for rice grown in the U.S. has only been realized during the past 15 years due to the annual occurrence of K deficiency in only a small percentage of commercial rice fields. The increased occurrence of K deficiency is attributed to higher rice and soybean yields and inadequate fertilization practices. For these reasons, research in the U.S. midsouth rice-growing area has focused on 1) characterizing rice K uptake and soil K availability during the growing season, 2) improving recommendations for diagnostic soil and plant analyses, and 3) evaluating K fertilization strategies. The following discussion is specific to K nutrition of drill-seeded rice grown on silt loams using the delayed flood management system (i.e., flooded at the 5-leaf stage, 20 to 30 days (d) after emergence, after urea is applied to a dry soil surface).

The majority of K fertilization trials show that maximum rice yields can be produced on soils with relatively low…80 to 100 parts per million (ppm)…soil test K (i.e., NH_4OAc or Mehlich-3 extraction). Significant yield increases from K fertilization seldom occur when soil test K is >80 ppm. Visual K deficiency symptoms [described in *Better Crops* 79(4):12-14] are usually expressed between panicle differentiation and heading, and are most likely to occur on silt and sandy loams with soil test K <50 to 60 ppm.

The K concentration of rice increases briefly after the permanent flood is applied at the 5-leaf stage and reflects the enhanced K availability in flooded soil. The K concentration of the whole-aboveground rice plant usually reaches its maximum concentration for the growing season during active tillering…2 to 4 weeks after flooding…and declines gradually for the remainder of the growing season. The K concentrations of individual leaves and stems are quite uniform during vegetative growth stages when tissue K concentrations are high (**Figure 1**). However, by the onset of reproductive growth, the whole-plant K concentration begins to decline and a K concentration gradient develops with the upper and middle leaves having greater K concentrations than the lower leaves. This concentration gradient between lower and upper leaves is most pronounced in K-deficient rice plants (**Figure 2**) and may range from 0.15 to 0.80%. Plant stems represent the majority of plant biomass and contain 50 to 75% of the aboveground K. Potassium concentrations in mature rice straw are usually >1.0% when K availability is not growth- or yield-limiting. Decreased tissue K concentration is due to dilution of plant K from rapid growth and limitations of the soil to replenish plant-available K during the season.

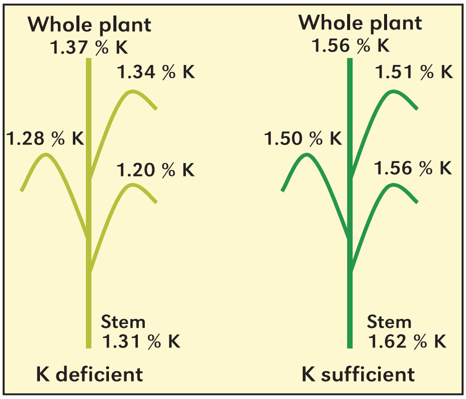


Figure 1. Potassium concentrations of the whole-plant, stem, and individual leaves shortly before panicle differentiation for K-deficient (unfertilized) and K-sufficient (fertilized) rice grown on a Crowley silt loam in Missouri in 2002.

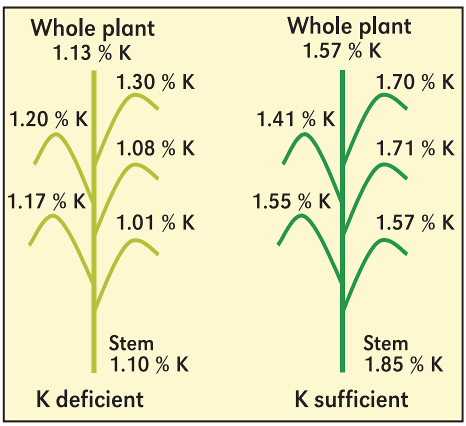


Figure 2. Potassium concentrations of the whole-plant, stem, and individual leaves at 10% heading for K-deficient (unfertilized) and K-sufficient (fertilized) rice plants grown on a Crowley silt loam in Missouri in 2002.

The crop growth rate of flood-irrigated rice managed in the direct-seeded, delayed-flood system is high (250 to 350 lb dry matter/A/day) shortly after flooding when adequate nitrogen (N) has been applied and other nutrients are not limiting (**Figure 3**). Although rice has a small, but rapidly developing, root system during the tillering stage, rice uptake of K is rapid. About 60 to 80% of the total K uptake occurs during the first 4 to 6 weeks (1,300 to 1,700 DD50 units) after flooding (**Figure 4**). Maximum K uptake rate occurs between 1 and 5 weeks after flooding, before panicle differentiation (**Figure 3**). The K uptake rate declines continuously for the remainder of the growing season (**Figure 4**) and is reflected by decreasing K concentrations in aboveground tissues. Early-season K fertilization has the greatest influence on K uptake and K uptake rates during vegetative growth (data not shown). The trends in K uptake suggest that soil and fertilizer K are absorbed rapidly and efficiently shortly after flooding. Late-season (i.e., boot stage) K applications applied into the floodwater appear to be absorbed less efficiently.

By anthesis, plant uptake of K has generally reached its season maximum and plateaus during grain fill (**Figure 4**). Although some studies show that net K uptake may increase or decrease slightly after anthesis, K uptake appears to be minimal or balanced with possible losses of K from sloughed plant tissues. Total (straw plus grain) aboveground K uptake by rice parallels total N uptake and usually ranges

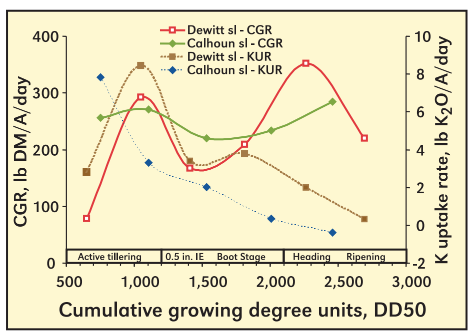


Figure 3. Postflood crop growth rates (CGR) and K uptake rates (KUR) of rice grown on a Dewitt and Calhoun silt loam in Arkansas during 2001. Each data point represents the rate of growth or K uptake for ~14 d periods (IE=internode elongation).

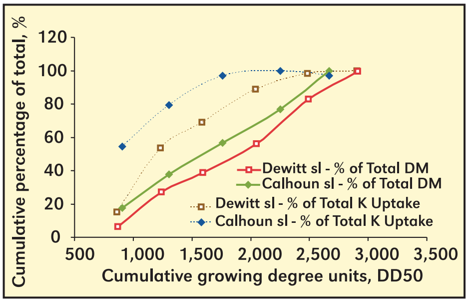


Figure 4. Cumulative dry matter accumulation and K uptake during the growing season by rice grown on a Dewitt and Calhoun silt loam in Arkansas during 2001. Each data point represents the rate of growth or K uptake for ~14 d periods.

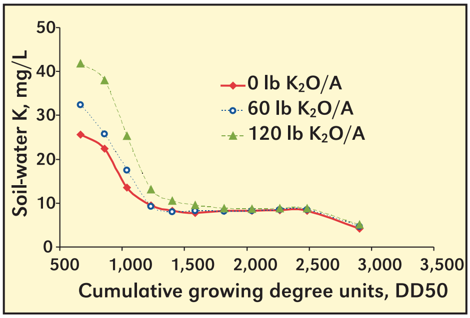


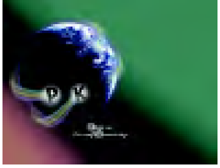
Figure 5. Postflood soil-water K concentrations as affected by K application rate for rice grown on a Dewitt silt loam soil in Arkansas during 2001. Each data point represents a 7- or 14-d interval.

from 150 to 250 lb K/A, with 10 to 15% of the total aboveground K removed with the harvested grain.

The concentration of K^+ in the soil water (soil solution of flooded soils), as well as soil test K, follow trends similar to the K concentration in rice tissues for the first few weeks after flooding. Soil-water K concentrations peak about one week after flooding, decline rapidly until 4 to 5 weeks after flooding, and then reach a consistently low concentration for the duration of the season (**Figure 5**). Soil-water K concentrations are increased by early-season K fertilization for only 3 or 4 weeks after flooding. Both soil K pools, exchangeable and solution, reach low K concentrations near the time of panicle differentiation and persist until the flood water is drained for harvest. The growth stage at which the soil K pools appear to be depleted on K-sufficient soils coincides with the general time that K-deficiency symptoms appear on K-deficient soils, as well as the time that rice tissue K concentrations and root uptake of soil K are declining. Silt loam soils apparently have a limited ability to replenish plant-available soil K during the season, which makes proper early-season K fertilization essential to avoid potential yield losses. Another possibility is that silt loam soils may be unable to retain plant-available soil K after extended flooding due to K losses via leaching, runoff, or fixation mediated by anaerobic soil conditions.

The seasonal K uptake pattern of flood-irrigated rice characterized on K-sufficient soils indicates that adequate K must be present during vegetative growth to maximize K uptake. Potassium absorbed during vegetative growth is mobilized within the plant to maintain the K nutritional status of new growth during reproductive growth. Routine soil testing and use of adequate K fertilizer rates before flooding are required to prevent K from limiting rice growth and yield. Because rice is usually rotated with upland crops such as soybean, which are more sensitive to K deficiency, K fertilization programs for rice should consider the K requirements of crops grown in rotation with rice. BC

Dr. Slaton (e-mail: nslaton@uark.edu) is Director of Soil Testing and Mr. Pugh is Graduate Research Assistant, both with the University of Arkansas at Fayetteville. Mr. Dunn (dunnd@missouri.edu) is Soil Laboratory Supervisor with the University of Missouri, located at the Delta Research Center, Portageville.



International Section

CHINA

Optimizing Fodder Grass Production for Fisheries in Hubei

By Lu Jianwei, Chen Fang, Lu Junming, and Liang Youguang

Balanced fertilization is a tool readily-available to support rapid improvements in productivity for in-land fishery enterprises in China.

The Jianghan plain region of Hubei is renowned for its ability to supply superior quality rice and fish staples. Recent adjustments to China's national agricultural development plan have designated this region as one which is particularly favorable to continued development and expansion of inland fisheries as a means for local economic improvement. For example, 5 years ago, the Datonhu State Farm operated 8,500 hectares (ha) with 7,000 ha of paddy and 1,500 ha dedicated to fish ponds plus fodder grass production. With economic readjustment, lands associated with fisheries now occupy 5,500 ha of this farm's total land base.

Fish grass field trial in Honghu County, Hubei Province, shows N fertilizer only (farmer practice) at left, compared to NPK fertilization (BF) at right.

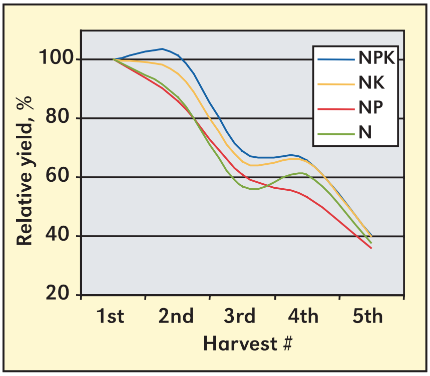
Fresh fodder grass is a crucial feedstock for in-land fisheries. Although other commercial fish fodder sources are relied upon throughout the fish growth cycle, the use of supplemental fresh grass has greatly increased land use efficiency and reduced production costs. Research has highlighted a significant feed supply gap which is hindering fishery productivity and suggests that improvements in grass yield will benefit the industry and its economic opportunity.

Currently, there are more than 130,000 ha growing fodder grass in the Jianghan plain, a portion in year-round production and the remaining area is seasonal. Although the planted area has developed quickly, it has happened despite a lack of knowledge by farmers concerning nutrient management of grass varieties. Most of this area only receives nitrogen (N) fertilizer and suffers from poor establishment and low yields. The species of grass best suited for fish fodder production in this area are Sudan grass (*Sorghum sudanense*) and perennial ryegrass (*Lolium perenne*). Research of fish fodder use efficiency suggests that

Fish ponds and grass in Honghu County, Hubei.

Table 1. Soil characteristics, Datonhu State Farm, Hubei.	
Texture	Loam
pH	8.2
O.M.	1.1 %
N	13.9 mg/l
P	13.0 mg/l
K	161.7 mg/l
Ca	3,745 mg/l
Mg	273 mg/l
S	2.4 mg/l
Fe	19.6 mg/l
Mn	14.8 mg/l
Cu	5.0 mg/l
Zn	1.6 mg/l
B	0.58 mg/l

Figure 1. Relative yield of each treatment as compared to initial harvest, Hubei.



15 to 20 kg fresh grass is required to produce 1 kg of fish.

In 2002, a Sudan grass trial established at the Datonhu State Farm evaluated the following N, phosphorus (P), and potassium (K) fertilizer treatments: (N, NP, NK, and NPK) using 540 kg N/ha, 150 kg P_2O_5/ha, and 135 kg K_2O/ha applied as urea, single superphosphate, and potassium chloride (KCl). Soil test information is shown in **Table 1**. Fertilization involved an initial broadcast application which supplied one-third of the N, all the P, and two-thirds of the K. The remaining N was divided into four topdressings applied after each harvest. The remaining K was applied after first harvest.

Phosphorus deficiency on fish grass.

Potassium deficiency on fish grass.

Both P and K, when combined with N, increased fresh grass production compared to the check. However, the highest cumulative yield over five harvests (at approximately 3- to 5-week intervals from mid-June to mid-October) was obtained with the complete NPK combination (**Table 2**). Compared to the N treatment, NP, NK, and NPK raised annual production by 11.1 t/ha (16.6%), 13.5 t/ha (20.3%), and 23.4 t/ha (35.3%), respectively. Each harvest responded to P and K fertilizer. However, the third harvest produced the greatest response as P fertilization increased yield by 28%, K by 29%, and their combined use by 49%.

The influence of each nutrient combination in supporting grass production over the five harvests is represented in **Figure 1**. Although most treatments produced their highest yields during the first cut, the complete treatment supported a marginally higher yield level for the second harvest period. The second cut for the NK treatment was only 4.8% less than the amount harvested during the initial harvest, but treatments without K showed stronger yield declines equal to 13 to 14%. Later in the season, treatment advantages were less apparent, but visual and measured observations suggest residual benefits from applying either NPK or NK. Although it is clear that K fertilization improves fodder production and provides farmers with substantial yield gains, the overriding climatic factors and

Table 2. Effect of P and K on fresh grass yield, Hubei

	Treatment	1st Harvest	2nd Harvest	3rd Harvest	4th Harvest	5th Harvest	Total
Fresh yield, t/ha	N	19.4 (100†)	16.9 (100)	11.0 (100)	11.8 (100)	7.3 (100)	66.4 (100)
	NP	23.0 (119)	19.8 (117)	14.1 (128)	12.3 (104)	8.3 (114)	77.5 (117)
	NK	21.8 (112)	20.8 (123)	14.3 (129)	14.3 (121)	8.8 (120)	79.9 (120)
	NPK	23.8 (123)	24.2 (143)	16.5 (149)	15.7 (132)	9.6 (133)	89.9 (135)

†Numbers in parentheses represent percent (%) relative yield.

Table 3. Economic evaluation of P and K application on fresh grass yield and its contribution to fishery productivity, Hubei.

Treatment	Fresh grass yield, t/ha	Yield increase, t/ha	Added income, US$/ha	Added input cost, US$/ha	Added labor cost, US$/ha	Added net profit, US$/ha	VCR[1]
N	66.4	-	-	-	-	-	-
NP	77.5	11.1	333	60	67	206	2.6
NK	79.9	13.5	405	38	81	286	3.4
NPK	89.9	23.5	705	98	141	466	2.9

[1]VCR = value-to-cost ratio. Prices: US$0.4/kg P_2O_5, US$0.3/kg K_2O, $0.03/kg grass fodder.

plant growth potential produced a general and continual decline in productivity as the growing season progressed. The economic benefit from the NPK production system increased net profits to farmers by US$466/ha (**Table 3**).

Serious K-deficiency symptoms of fish grass.

Future Requirements

Managing grass for fish production is a relatively new concept which is developing quickly and causing significant change to the agricultural landscape of the Jianghan plain region. Rapid adoption rates have identified knowledge gaps among farmers who largely apply traditional cereal crop techniques to manage these fodder grasses. Given traditional nutrient management practices, the sustainability of this production system must be questioned as soils endure multiple harvests each year, nutrient recycling is virtually non existent, and thus, nutrient demands are extremely high. Improved nutrient management can reverse the unsustainable conditions. Seasonal fodder grass production is required to augment declining productivity and the production will also require adequate nutrient supply.

Field trial shows difference between common practice (left plot) and BF (right plot).

Despite the large improvement in productivity that was achieved in these trials, more study is required to achieve a robust nutrient management strategy. Researchers need a complete understanding of the native fertility of grass-producing soils as the first step in developing suitable fertilization rates, ratios and schedules for selected grass species. An understanding of how balanced fertilization can improve fodder quality through the manipulation of key nutritive characters is also desired. BC

Dr. Lu Jianwei is Plant Nutrition Scientist/Associate Professor with the Department of Resource & Environment at Central China Agricultural University, Wuhan, China; email: jweilu@public.wh.hb.cn.

Dr. Chen Fang is Deputy Director, Southeast Region, PPI/PPIC China Program, Wuhan; email: Fchen@ppi-ppic.org.

Mr. Lu Junming is Extension Agent in Datonghu State Farm, Hubei.

Dr. Liang Youguang is Fish Scientist at Institute of Reservoir Fish, Chinese Academy of Sciences, Wuhan.

Potassium for Soybeans

By H.A.A. Mascarenhas, R.T. Tanaka, E.B. Wutke, N.R. Braga, and M.A.C. de Miranda

Development of new land and improvements to traditionally-farmed areas are responsible for the unprecedented growth of Brazil's soybean production sector. The region's climate is favorable, but the intense weathering of its soils has resulted in low cation retention and exchange. The role of potassium (K) and its management, particularly in terms of adequate application, is critical for success in soybean cropping.

After nitrogen (N), K is the nutrient absorbed in the next largest quantity by soybean plants. A large portion of plant K is partitioned to the seed, hence substantial quantities are exported from the field each year in harvest. About 20 kg of K_2O is contained in 1,000 kg of soybean seeds. By 1986/87, most soybean farms in São Paulo State were affected by soil K deficiency.

This situation was primarily a reflection of a 20-year reliance on indiscriminate use of low analysis fertilizers. Farmers typically applied 300 kg/ha of either 0-20-10 in the northeast or 4-30-10 in the southwest, thus supplying only 30 kg K_2O/ha, or enough to resupply the amount of K removed in 1.5 tonnes (t). Average yields in the mid 1980s were about 1.8 t/ha. Now that yields are much higher (2.6 t/ha), simple nutrient K input/output balance rules must be considered.

Photo 1. Symptoms of K deficiency on the leaves of soybean plants at flowering.

Local field research has since provided guidance on best K management practices…including the recommendation for 30 kg K_2O/ha as a basal application and an additional 30 or 40 kg applied as a side-dressing 35 days after planting. This practice has been especially relevant for sandy soils prone to leaching. These problems are also being addressed by the popular movement towards no-tillage farming practices.

Low soil K concentrations expose symptoms of K deficiency in soybean leaves. Acute shortages can, at maturity, cause green stems, foliar retention, and formation of parthenocarpic (seedless) fruits (**photos 1, 2, 3 and 4**).

Photo 2. Symptoms of K deficiency at maturity. Soybean plants have mature pods, but green stems would delay harvesting.

Because K influences nodule formation (and thereby biological N fixation) as well as various fungal diseases, insufficient nutrition compromises plant health. Several diseases can cause problems. *Phomopsis* causes premature drying of pods and stems (**photo 5**). *Cercospora kikuchii* is responsible for leaf blight and purple stain in seeds (**photo 6**). *Diaporthe phaseolorum f.* sp *meridonalis* is responsible for stem canker disease (**photo 7**).

Stem canker is better controlled in early maturing soybean cultivars as compared to medium or late maturing cultivars since their short duration maturity (110 and 120 days) reduces the likelihood of exposure to infection during the most susceptible R3 and R4 stages.

Inadequate soil K supply can be avoided by maintaining both a proper supply and balance among soil nutrient cations...calcium (Ca), magnesium (Mg), and K...competing for plant uptake. The equation commonly used to

Table 1. Soil analysis of areas cultivated to soybeans in southwest São Paulo State, Brazil, 1986/87.

Location	pH in $CaCl_2$	Organic matter, g/dm^3	P mg/dm^3	K	Ca	Mg	Base saturation, %	Ca + Mg K Index
				------- $mmol_c/dm^3$ -------				
1. Florínea[1]	5.8	34	22	4.2	153.2	38.8	86	46
2. Cruzália[2]	5.2	20	89	3.0	35.2	19.0	61	18
3. Cruzália[2]	5.2	32	100	3.8	35.6	19.4	63	14
4. Cruzália[2]	5.2	18	78	2.2	39.3	18.2	63	26

[1] Dark Red Latosol
[2] Ortho Dark Red Latosol

Photo 3. Symptoms of K deficiency in soybean plants showing foliar retention and green stems which would delay harvesting.

Photo 4. Symptoms of K deficiency in soybean plants at maturity; pods with few seeds and parthenocarpic fruits.

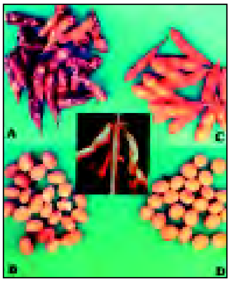
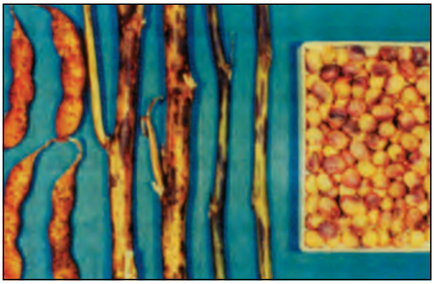


Photo 5. Incidence of *Phomopsis* sp. in soybeans pods (A) and loss of seed quality (B). Control of disease with K fertilization with healthy pods (C) and seeds (D). Center image shows stem with pycnidia and dry, empty pods.

Photo 6. Symptoms of *Cercospora kikuchii* in seeds (purple seed stain), stems and pods of soybean plants.



describe this balance is:

$$\text{Index} = \frac{Ca+Mg}{K}$$

Repeated analysis of the relationship between Ca, Mg, and K suggests the optimum range of index falls between 23 and 28. Farmers can expect varying degrees of K deficiency once this range is exceeded.

Table 1 presents example soil analyses data from four soybean fields in the counties of Florínea and Cruzália, located in the southwest region of São Paulo. The soil at Florínea tested high in available K, Ca, and Mg, but produced an index value of 46, enough evidence to generate a recommendation for K along with phosphorus (P), which tested in the medium range. Sites 2 and 3 at Cruzália produced similarly narrow indexes of 18 and 14, respectively.

Given the soil test levels, the recommended strategy for these two locations would be to monitor the effect of K removal and its impact on the index. The index value of 26 for the fourth site at Cruzália provides an example of this proper cationic balance. BC

The authors are Research Agronomists for Instituto Agronômico Campinas (IAC), São Paulo, Brazil; e-mail: hipolito@iac.sp.gov.br.

Reference:

For more on this topic, visit the Scientia Agricola website **>www.scielo.br/sa<.** Look for the paper titled “Calcário e Potássio para Cultural de Soja” (“Lime and Potassium for the Soybean Crop”), Vol. 57, No. 3, p. 445-449.

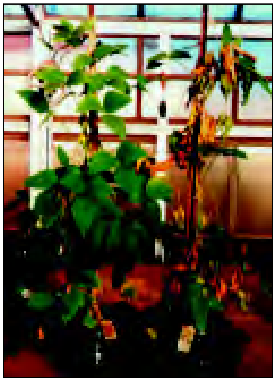


Photo 7. On the left are soybean plants inoculated with *Diaporthe phaseolorum*, showing tolerance to stem canker with 60 kg K_2O/ha (base saturation index of 40%). At right, severe symptoms of stem canker are shown in inoculated control plants.

Boosting Seed Cotton Yields in Punjab with Potassium: A Review

By M.S. Brar and K.N. Tiwari

Cotton production in India has stagnated at a level far below its potential—the main reason being unbalanced and low rates of fertilizers. A review of key research on improved potassium (K) management practices provides a clear picture of the potential yield and economic benefits available to farmers.

India has the largest area planted to cotton in the world (8.6 million hectares [M ha]), but the country ranks third in productivity. As an example, the northern state of Punjab has 470,000 ha and an average seed cotton yield of 340 kg/ha. The case is similar for Haryana and Rajasthan where cotton is grown on 560,000 ha and 510,000 ha, respectively. The average yield in the U.S. is over 2 t/ha (FAOSTAT, 2004).

Potassium fertilizer recommendations for cotton are altogether missing in these northern states despite widespread depletion of soil K reserves, increased incidence of pest problems, and evidence showing increased crop response to K. To date, state fertilizer recommendations include only nitrogen (N) and phosphorus (P) applied at 75-30 kg N-P_2O_5/ha for non-hybrid American varieties and 150-30 kg N-P_2O_5/ha for hybrids.

Cotton's indeterminate growth habit means that nutritional stress and imbalances affect both vegetative and reproductive metabolism and ultimately limit seed cotton yield as well as fiber and seed quality. Potassium plays an important role in photosynthesis, water balance, balance between mono and divalent cations, translocation of carbohydrates, and resistance against insects and diseases. These are key factors contributing to low cotton productivity in India.

This article discusses various aspects of K application for seed cotton based on greenhouse and field studies conducted in Punjab.

Unbalanced and low rates of fertilizers have resulted in stagnate cotton yields in India.

Soil K and Cotton Response

Brar et al. (1987) examined K response in seed cotton through preliminary greenhouse studies conducted on three major cotton growing, surface soils (Samana, Fatehpur, and Tulewal series). The study found clear K deficiency symptoms when available K levels were below 36 mg/kg. Although the study did not find symptoms above this soil test level, responses to applied K were observed in soils testing 50 mg/kg.

Given the cotton plant's deep-rooting nature, the distribution of K in surface and subsurface soil horizons also has an influence on plant K uptake and yield. Sekhon (1993) conducted field research at a site with 138 mg/kg available K at the surface, yet low (54 mg/kg) available K at depth. Application of 60 kg K_2O/ha produced larger plants and a higher yield, thus signifying the cotton plant's dependence on subsurface soil horizons as well as the need to provide supplemental K under these conditions (**Table 1**).

Table 1. Effect of K application on yield and yield parameters of cotton (1993) in Gahri Bhagi soils.

Treatments, kg K_2O/ha	Yield, kg/ha	Bolls, number	Boll wt., g	Plant height, cm
0	1,808	23.1	9.3	129
30	2,047	25.5	9.5	135
60	2,139	28.0	9.5	146
120	2,157	26.0	9.4	151
C.D., 5%	245	NS	NS	13

The soil tested 138 mg/kg at the surface and 54 mg/kg for the subsurface. C.D.=critical difference

Although the size of the available K pool is most important, cotton response to applied K also depends on the quantity and intensity of the release of K from the non-exchangeable pool. Dhanwinder-Singh et al. (1990) demonstrated this by comparing soils with similar amounts of total available K, but differing levels of non-exchangeable K (**Table 2**). The study found a significant yield response with the low non-exchangeable K soil, whereas the opposite scenario revealed no yield response.

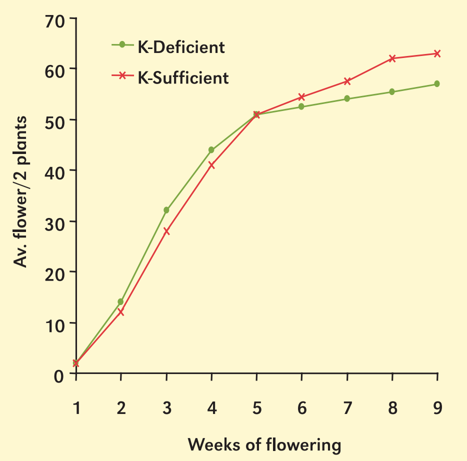
Table 2. Effect of applied K on seed cotton yield on two soils with similar amounts of available and different amounts of non-exchangeable K

Applied K_2O, kg/ha	Yield of seed cotton, t/ha	
	Site I	Site II
0	3.0	2.5
30	3.3	2.2
60	3.4	2.3
120	3.7	2.5
180	3.1	2.4
Available K, mg/kg	51.9	55.8
Non-exch. K, mg/kg	500.0	1,075.0

Flowering and Seed Yield

The cumulative rate of flowering will differ between K-deficient and K-sufficient soils. Dhanwinder-Singh et al. (1991) provided an example showing a marginally higher rate of flower development during the first 4 weeks of growth under conditions of K deficiency After that, flower development was considerably slower relative to plants grown on K-sufficient soil **(Figure 1)**. A similar trend was observed (not shown) in K-deficient soils with and without applied K, wherein flowering ceased much earlier in plots receiving no K application (Brar et al., 1987). Higher seed cotton yields are a partial reflection of this continuous improvement in flower and boll maturation throughout the season.

Figure 1. Cumulative flowering rate in soils of different K status.



Rates and Timing

Dhanwinder-Singh et al. (1991) conducted a comprehensive K delivery experiment at six coarse textured, low organic carbon (<0.40%) sites. The study found 100% basally applied K to be superior to a full application during flowering at sites I and III, while sites II and IV showed no difference between the two application timings (**Table 3**). Similar to Brar et al. (1987), yield responses to K fertilizer were significant if available K was below 52 mg/kg. Sites that were responsive to applied K showed no clear advantage for methods which split the K supply between planting and flowering.

Table 3. Effect of applied K on seed cotton yield (t/ha) at cultivators' fields in Ludhiana District, Punjab.

Treatments, kg K_2O/ha	Experimental sites I	II	III	IV	V	VI	Mean
0	1.69	2.93	2.61	3.05	1.21	2.50	2.33
30†	2.12	3.42	2.73	3.29	1.22	2.15	2.49
60†	2.46	3.44	2.85	3.41	1.39	2.26	2.64
120†	2.33	3.45	3.37	3.72	1.13	2.50	2.73
180†	2.27	3.50	3.93	3.15	1.14	2.43	2.74
30‡	2.11	3.37	3.21	3.29	1.13	2.07	2.53
60‡	1.88	3.37	2.94	3.45	1.11	2.22	2.50
120‡	1.99	3.49	3.07	3.71	0.99	2.21	2.58
60† + 60‡	1.95	3.52	3.22	3.57	1.54	2.25	2.67
120† + 60‡	2.16	3.65	3.21	3.26	1.55	2.16	2.67
C.D., 5%	0.17	0.38	0.64	0.43	NS	NS	
Avail. K, mg/kg	46.7	30.8	35.5	51.9	75.0	55.5	

†, ‡ = K applied basally and at flowering, respectively

Table 5. Seed yield and profitability for short- and long-season high yielding, American cotton varieties at different levels of applied K.

Applied K_2O, kg/ha	LH 900 Seed yield, t/ha	LH 900 Added net profit, US$/ha	F 286 Seed yield, t/ha	F 286 Added net profit, US$/ha
0	2.09	–	1.42	–
30	2.40	62.0	1.61	31.5
60	2.51	72.5	1.67	36.9
90	2.65	93.4	1.74	44.4
C.D. (5%)	0.29		0.22	

Cotton response to K fertilizer also depends on soil N availability and the amount of applied N. Milap-Chand et al. (1996) examined different N/K combinations for non-hybrids grown in the north zone and obtained their best seed yield (and profit) using 75 kg N/ha plus 50 kg K_2O/ha (**Table 4**).

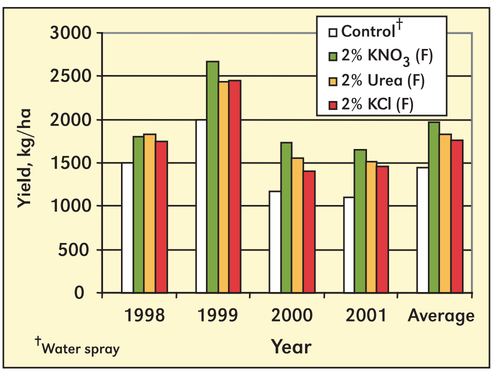


Figure 2. Effect of foliar application of nutrients on the yield (kg/ha) of seed cotton.

Foliar K Sources

The benefits of foliar-applied K and N sources, used in addition to recommended rates of basal N and P, were examined in 4 years of field experimentation (Brar and Brar, 2003). All plots received a uniform application of 75 kg N plus 30 kg P_2O_5/ha, which was followed by three mid-season foliar applications spaced at weekly intervals. Potassium nitrate (KNO_3) solution produced the highest average yield increase of 36% over the control (**Figure 2**). Foliarly applied solutions containing either urea or potassium chloride (KCl) produced significant, but lesser yield increases of 27% and 22%, respectively. Researchers noted that all test soils were unable to meet the high daily N and K requirements during flowering and boll development, hence the effectiveness of these supplemental foliar N and K applications.

Cultivar Selection

Inadequate mid-season K supply capacity was also highlighted in a study comparing high yielding American cultivars and responses to applied K (Milap-Chand and Kapoor, 1995). In particular, the short duration LH 900 variety was more responsive than the longer duration F 286 variety, a response attributed to a higher K demand per unit of time that

Table 4. Yield (kg/ha) of high-yielding American seed cotton varieties and profitability at various combinations of applied N and K in cotton production.						
Applied N, kg/ha	Applied K_2O, kg/ha 0	25	50	Added net profit, US$/ha 0	25	50
25	1,639	1,695	–	–	6.7	–
50	1,720	1,808	1,869	14.4	28.0	35.8
75	1,829	1,937	2,027	34.8	52.8	66.8
100	–	1,900	1,977	–	34.9	46.1

exceeded soil supply capacity (**Table 5**). Despite this, seed yields as well as net profits were higher for the well-fertilized, short duration cultivar, which demonstrates their suitability to conditions in northwestern India.

The inclusion of K for farmer fertilization schedules should be considered mandatory if a competitive, high yielding, seed cotton production system is desired for the states of northwestern India. BC

Dr. M.S. Brar is the Senior Soil Chemist and Professor in the Department of Soils, Punjab Agricultural University, Ludhiana, India. Dr. K.N. Tiwari is Director, PPIC-India Programme, Gurgaon, Haryana.

References

Brar, M.S. and A.S. Brar. 2003. Indian Journal of Agricultural Sciences (communicated).

Brar, M.S., A.S. Brar, P.N. Takkar, and T.H. Singh. 1987. Journal of Potassium Research 3: 148-154.

Dhanwinder-Singh, M.S. Brar, and A.S. Brar. 1991. Journal of Indian Society of Soil Science 39: 494-499.

Dhanwinder-Singh, M.S. Brar, and A.S. Brar. 1990. Journal of Potassium Research 6: 162-171.

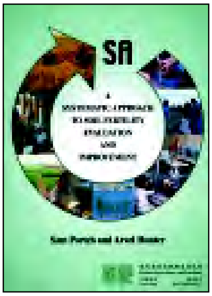
FAOSTAT, 2004. http://apps.fao.org, February 2004.

Milap-Chand, B.S. Brar, N.S. Dhillon, and M.P.S. Gill. 1996. Journal of Potassium Research 12: 370-375.

Milap-Chand and M.L. Kapoor. 1995. *In* G. Dev and P.S. Sidhu (eds.) Use of Potassium in Punjab Agricultural. PPIC (IP), Gurgaon.

Sekhon, G.S. 1993. Third Annual Report of the Project under Emeritus Scientists Scheme, Department of Soils, Punjab Agricultural University, Ludhiana. p. 1-27.

Minor Corrections to Book: *A Systematic Approach to Soil Fertility Evaluation and Improvement*



Corrections to graphs on two pages of the publication *A Systematic Approach to Soil Fertility Evaluation and Improvement* have been identified. The book, authored by Dr. Sam Portch and Dr. Arvel Hunter and produced in cooperation with Canpotex (Hong Kong) Limited, became available in 2002.

For individuals with copies of the publication, corrected graphs for pages 14 and 57 are available as PDF files by visiting this website: **>www.ppi-ppic.org/sabook<.** Those without internet access may contact the PPIC office in Saskatoon, Saskatchewan; telephone (306) 652-3535, fax (306) 664-8941, e-mail: gsulewski@ppi-ppic.org.

The 62-page book is written in six sections, each focusing on a different aspect of the systematic approach for soil fertility evaluation and improvement. It is available on request. BC

Balanced Nutrition—For People and Plants

The latest in food fashion is to reduce or eliminate carbohydrates from one's diet to lose weight. Carbohydrates are bad, some say. Even fast food stores and my local supermarkets have joined the slam-the-carb brigade. It seems the whole world is bellying up to this new, easy on the conscience concept of eating. Throw the USDA food pyramid out the window and eat all the fats you want. The new wave of nutrition has arrived.

What has happened to sensibility in eating…like taking in fewer calories than those burned to lose weight or balancing input and output to maintain an ideal weight? There is no magic formula for staying slim and fit. Don't overeat! Before you start shaking your fist and yelling, let me tell you that I've been there. During my graduate school years, I was 65 lb heavier than today, exclusively because of my affinity for food–of any variety–and my aversion to exercise.

I grew to dislike my overweight self, so set out to take control of my health before it was lost to a heart attack, stroke, or diabetes. There was no Atkins Diet for me to follow, and that's good, because one wasn't needed. My plan: eat sensibly and develop a sustainable exercise program. The excess fat came off slowly but steadily.

People can add to their quality of life simply by eating a balanced diet that includes a healthy variety of foods and food groups. (After all, what would life be without baked potatoes, orange juice, and pizza?) The same principle applies to crops farmers grow. Feed them a balanced diet, and they will return the favor in measurably higher yields of better quality. Plants require up to 17 nutrients to complete a normal life cycle. More than that, those nutrients must be applied in balance with crop needs. Apply too much of one or not enough of another, and plant performance suffers. So do farmer profits.

The best way to determine what is needed for balanced plant nutrition is to soil test. Taking soil tests on a regular basis establishes crop needs for the current year, monitors changes in soil nutrient levels with time, and guides nutrient management program development to meet long-term crop needs while helping to protect the environment. For balanced plant nutrition, soil test before you invest in fertilizers. Your crops will thank you and so will your pocket book. While you're at it, eat right!

BETTER CROPS
WITH PLANT FOOD
Potash & Phosphate Institute
Suite 110, 655 Engineering Drive
Norcross, Georgia 30092-2837

Printed on recycled paper with soy ink.

Periodicals Postage