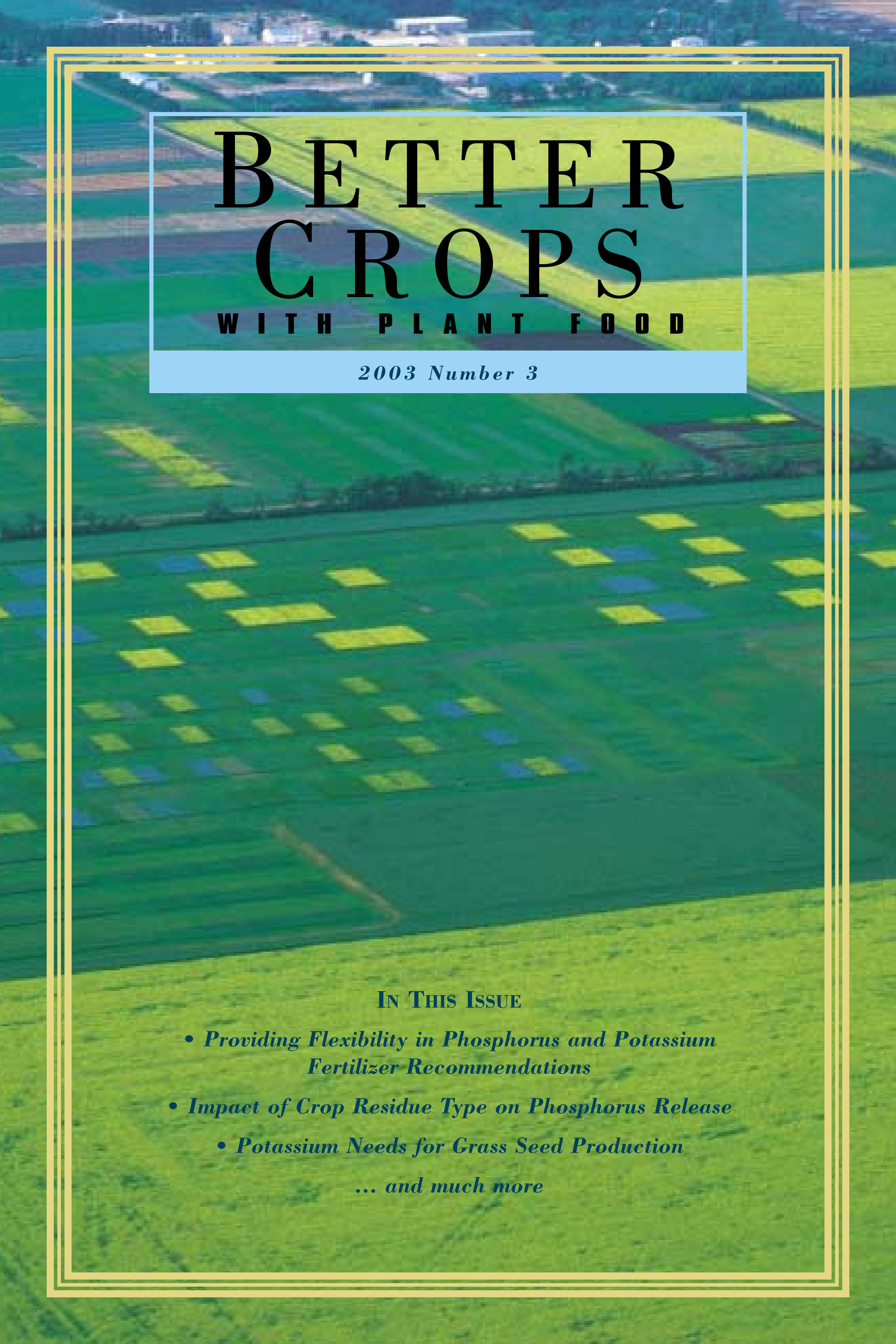

Better Crops

with Plant Food

2003 Number 3

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BETTER CROPS WITH PLANT FOOD

Vol. LXXXVII (87) 2003, No. 3

Our Cover: Cereal, oilseed, and pulse crop trials at Agriculture and Agri-Food Canada Research Farm near Melfort, Saskatchewan.
Photo Credit: Dr. Adrian M. Johnston

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.

C O N T E N T S

Fertilizer Use Efficiency: The North American Experience

By D.W. Dibb, P.E. Fixen, and M.D. Stauffer

In May 2003, the first formal meeting of the International Nitrogen Initiative was held in The Hague, Netherlands. This is a global effort with a primary focus on improving nitrogen (N) efficiency in order to optimize N's beneficial role and minimize negative effects. The Natural Resources Conservation Service (NRCS) in the U.S. is developing an incentive program to subsidize farmer practices that improve nutrient use efficiency. It is timely to summarize the North American experience with fertilizer use efficiency and contrast application of the term for N vs. phosphorus (P) and potassium (K).

> Fertilizer use efficiency is receiving increased attention today because of growing pressure for agriculture to minimize negative environmental impacts.

Properly defining efficiency in light of the properties of the nutrient in question is critical to understanding sustainable approaches to efficient nutrient management. With N, both recovery efficiency (increase in uptake per unit nutrient added) and agronomic efficiency (crop yield increase per unit nutrient added) are useful terms. In the last 25 years, the agronomic efficiency of fertilizer N use on corn in the U.S. (bu grain/lb N or kg grain/kg N) has increased 39%. However, research on farm fields in the U.S. and Asia shows that apparent single-year recovery efficiency for fertilizer N is usually below 50% and frequently below 40%, illustrating significant opportunity for improvement. Increased adoption of existing and new technologies will likely allow yields to continue to increase faster than N use for the foreseeable future.

Applying the concept of agronomic efficiency, as presented above, to P and K is problematic because highest "efficiency" occurs when inadequate amounts are applied at low soil test levels associated with reduced profitability, water use efficiency, N use efficiency, and land use efficiency. The concept of **sustainable efficiency** is more useful for nutrients where significant reserves can accumulate in the soil, as is the case for P and K.

Sustainable efficiency is the nutrient input needed to sustain the system at optimum productivity. Removal to use data show that in some major production regions of North America, sustainable efficiency will translate into increased P and K demand while in areas with significant livestock concentration it will mean reduced fertilizer demand. The thermodynamic need to replace P and K removal at some soil level sets a lower limit for sustainable P and K use. As food needs increase, the fundamentals of natural systems indicate a permanent and expanding role for fertilizers in food production.

Dr. Dibb is President, PPI; Dr. Fixen is Senior Vice President, North American Program Coordinator, and Director of Research, PPI; Dr. Stauffer is Senior Vice President, PPI International Programs, and President, PPIC. E-mail: ppi@ppi-far.org.

Summary of a presentation at the Fertilizer Demand Meeting of the International Fertilizer Industry Association (IFA) Agriculture Committee. May 26, 2003. Philadelphia, PA U.S.

The complete presentation and references are available at the website: ***>www.ppi-ppic.org<***.

Impact of Crop Residue Type on Phosphorus Release

By N.Z. Lupwayi, G.W. Clayton, K.N. Harker, T.K. Turkington, W.A. Rice, and A.M. Johnston

It is generally assumed that crop residues will decompose more slowly under no-till (NT) than under conventional tillage (CT) management. With a reduced rate of decomposition, we would expect less nutrients to be released in a given time period. This may not always be correct, given that the amount of a nutrient released from crop residue depends not only on the decomposition rate, but also on the nutrient concentration in the original crop residue. This could be affected more by crop type than any management input.

> Crop residue release of phosphorus (P) was related to P content and ease of decomposition. Tillage system had no effect on the release of P from residues.

To address these questions, a trial was initiated in an established long-term tillage and crop rotation study. The objective was to quantify how much P is released from red clover, field pea, canola, and wheat residues under CT and NT seeding systems. The trial was conducted at Fort Vermilion in northwestern Alberta in 1998-1999 and 1999-2000, using an established study evaluating two tillage systems: NT and CT, and four different crop rotations that included red clover green manure, field peas, canola, and wheat. In 1998-1999, the red clover did not survive the winter and was replaced with a field pea green manure crop. Crop residues of the green manure, field peas, wheat, and canola were collected at harvest, weighed, and analyzed for P to determine the amount of P being returned to the plot. The residues were then placed in decomposition-resistant litter bags with 1 mm mesh and either buried in the soil (CT), or placed on the soil surface (NT). The bags were sampled periodically over a 12-month period and the residues analyzed for P to determine how much P still remained in the decomposing residues and...by difference from the amounts applied...how much P had been released.

TABLE 1. Impact of previous crop on input and release of P from green manure, field pea, canola, and wheat crop residues, 1998-1999.

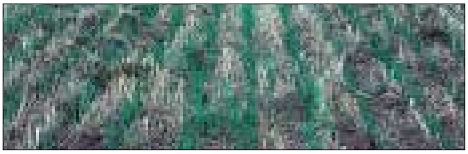
Crop residue	Residue applied DM	Residue applied P	P released 2 week	P released 5 week	P released 46 week	P released, %
	lb/A					%
Green manure[1]	3,105a[2]	6.5a	4.9a[3]	4.6a	5.1a	78
Field pea	2,061bc	1.4bc	0.1a	0.4a	0.6a	43
Canola	2,610ab	2.4b	0.3b	0.2b	1.2a	50
Wheat	1,458c	0.6c	-0.1a	0.2a	-0.0a	0

[1]Field pea
[2]For residue applied, dry matter and P, numbers in columns followed by the same letter are not significantly different at p = 0.05.
[3]For P released, numbers in rows followed by same letter are not significantly different at p = 0.05.

Crop residue dry matter (DM) returned after the different crops was considerably higher in 1999-2000, relative to 1998-1999, reflecting the higher crop production during the 1999 growing season (**Tables 1** and **2**). However, P concentration in the crop residues resulted in a large difference in the amount of total P being returned to the field. While the green manure crops returned the largest amount of P, spring wheat produced the least crop residue and lowest residue P returned to the field. The amounts of residues produced and added to the soil did not differ significantly between tillage treatments, and there were no significant interactions between tillage and crop residues in residue DM produced or P applied.

During the 46 to 52 weeks that residue samples were monitored in this study, the amounts of P released were all less than the amounts that had been applied with the residues (**Tables 1** and **2**). The green manure crops released the largest proportion of the residue P (70 to 78%), reflecting the ease of decomposition of this fresh plant material. This release was also rapid, with most of the P returned to the soil within five weeks of application. The mature crop residues proved to be more resistant to decomposition and P release. The slow decomposition and lower P content of the field pea, canola and wheat residue resulted in some immobilization of P during the 46 to 52-week decomposition period.

An evaluation of the carbon (C), lignin, and P in the plant residues was carried out and the results indicated a positive correlation between P release from the residue and percent P, and a negative correlation between P release and residue C:P ratio (data not shown). Whether the residue was buried with CT or left on the surface with NT, there was no effect on P release. **The more resistant parts of the residues, including nutrients they contain, become soil organic matter which decomposes slowly.** Therefore, although only the green manure crops released significant amounts of P, it is advisable that all crop residues be added to the soil because they maintain or increase soil organic matter. Soil organic matter is important not only as a slow-release source of nutrients for crops and soil organisms, but also for maintaining soil structure. Even nutrients added as fertilizers are not utilized efficiently when soil organic matter is low.



Soil organic matter, a slow release source of nutrients, also helps maintain soil structure.

Results of this study illustrate that the release of P from crop residues is influenced by not only the P content of the residue, but the ease of decomposition. The rapid and large release of residue P from green manure crops can be expected to contribute to plant P supply when these fields are recropped. By contrast, wheat residues added significantly less P to the soil, and were just as likely to immobilize as release P in the 46 to 52-week period. Canola and field pea fell somewhere between wheat and the green manure crop, reflecting a higher residue P contribution and lower C:P ratio. Tillage system practiced did not affect amounts of P released by residues. BC

TABLE 2. Impact of previous crop on input and release of P from green manure, field pea, canola, and wheat crop residues, 1999-2000.

Crop residue	Residue applied DM	Residue applied P	P released 2 week	P released 5 week	P released 52 week	P released %
	lb/A					%
Green manure[1]	4,788a[1]	7.6a	1.8b[3]	5.4a	5.3a	70
Field pea	5,445a	5.4ab	1.2a	1.0a	1.3a	22
Canola	4,581a	5.0b	0.9b	1.4b	2.0a	36
Wheat	1,962b	1.5c	0.3a	-0.4a	0.3a	20

[1]Red clover
[2]For residue applied, dry matter and P, numbers in columns followed by the same letter are not significantly different at p = 0.05.
[3]For P released, numbers in rows followed by the same letter are not significantly different at p = 0.05.

Dr. Lupwayi (e-mail: LupwayiN@agr.gc.ca) and Dr. Rice (retired) are with the Agriculture and Agri-Food Canada Beaverlodge Research Farm, Beaverlodge, Alberta. Drs. Clayton, Harker, and Turkington are with the Agriculture and Agri-Food Canada Research Centre, Lacombe, Alberta. Dr. Johnston is PPI/PPIC Western Canada Director, located at Saskatoon, Saskatchewan.

KANSAS

Providing Flexibility in Phosphorus and Potassium Fertilizer Recommendations

By D.F. Leikam, R.E. Lamond, and D.B. Mengel

Which is better, the sufficiency or build-maintenance approach to managing phosphorus (P) and potassium (K) crop nutrition? For a specific situation, certain risks must be evaluated. Agronomists at Kansas State University (KSU) have developed a fertilizer recommendation system that gives growers the flexibility to choose which approach to managing soil fertility best suits their needs and goals.

Historically, land grant universities have provided a single rate recommendation for nutrients such as P and K. Depending on the university, these nutrient rate recommendations are generally based on one of the two widely recognized approaches to managing soil and fertilizer P and K—the **nutrient sufficiency approach** or the **build-maintenance approach**. The goal of a nutrient sufficiency approach is to apply just enough P and/or K to maximize profitability in the year of application, but minimize nutrient applications and fertilizer costs. While inherent variability in nutrient response among fields and over time may result in more or less nutrient actually being required for maximum profitability than is recommended, near optimum rates will be recommended over the longer term. Unless initial soil test levels are high and the soil can supply all the nutrient needs of the crop when this approach is adopted, little year-to-year flexibility in nutrient application exists since applications are required every year in order to eliminate profit-robbing nutrient shortages. Specific application methods, such as the use of band placement, may also be needed.

Nutrient sufficiency recommendations are based on long-term soil test calibration field data. To address the complicated and constantly changing issue of marginal return on the fertilizer investment in the year of application, these recommendations are typically developed to provide 90 to 95% of maximum yield. Crop response and recommended nutrient application rates are highest at very low soil test levels, while recommended nutrient application rates decrease to zero as the soil test level increases to a 'critical' soil test value. The critical level is the soil test value at which the soil is normally capable of supplying sufficient amounts of P and/or K to achieve 90 to 95% of maximum yield. For nutrient sufficiency recommendations, soil test values are not viewed as a managed variable and there is little consideration of future soil test values.

The objective of build-maintenance fertility programs is to manage P and/or K soil test levels as controllable variables. At low soil test values, build-maintenance recommendations are intended to apply enough P and/or K to both meet the nutrient needs of the immediate crop and to build soil test levels to a non-limiting value, above the critical level. Typically, this build-up of soil test values occurs over a planned period of time (usually 4 to 8 years). Once the soil test value exceeds the critical value, nutrient recommendations are made to maintain the soil test levels in a target, or management range. The soil test target range is typically a range at and slightly above the critical soil test value, where the soil can generally provide adequate nutrients to meet the nutritional needs of growing crops ('medium' to 'high' levels). While nutrient applications are required for optimum yields below the critical level, farmers have great flexibility as to when fertilizer is applied once soil tests are in the target range. Above the critical level, the soil is largely capable of supplying the nutrients needed in a given year. Farmers can thus choose to apply fertilizer annually, or to combine applications and apply the fertilizer only every two or three years. This provides flexibility to manage both time and cash flow.

Build-maintenance fertility programs are not intended to provide optimum economic returns in any given year, but rather attempt to minimize the possibility of P and/or K limiting crop growth while providing near maximum yield, high levels of grower flexibility, and good economic returns over the long-run. The disadvantage of soil build-maintenance programs when soil test levels are below the critical value is that required application rates are normally higher than those recommended for nutrient sufficiency programs.

Over an extended period of time, the two approaches provide growers the choice between a system which recommends lower nutrient application rates at low soil test levels, but requires annual fertilizer application (nutrient sufficiency programs), vs. investing in higher rates for 4 to 8 years in order to gain the flexibility and potential cost savings of making multi-year applications when it is most convenient and economical (build-maintenance programs). While the short-term difference in cost between the two programs may be sizeable, the benefits from flexibility in the overall fertility program, reduced application costs, improved timeliness, and cash management can make the investment in build-maintenance programs worthwhile. Once growers understand the two approaches, they can decide if that cost is a reasonable investment.

Some land grant universities base their recommendations on the nutrient sufficiency approach, some use the soil build-maintenance approach, and others have adopted recommendations that have attributes of both approaches. Regardless of the basis for their recommendations, a single recommendation is normally made for a particular crop for all farmers, fields, and situations.

So which is better, a nutrient sufficiency or a build-maintenance P and K program? Or is an approach somewhere in-between optimal? Well-reasoned arguments supporting both approaches to managing nutrients have been made by knowledgeable people on both sides of the issue. Some farmers, agronomists, and agricultural economists staunchly support nutrient sufficiency based programs while distancing themselves from build-up and maintenance programs. Others insist that build-maintenance programs are better suited for managing complex and somewhat unpredictable crop production systems.

Figure 1 provides a conceptual representation of the characteristics of the crop sufficiency and build-maintenance approaches. There are two main risks that affect the decision on the amount of fertilizer P and/or K included in individual producers' nutrient management programs: 1) the risk that the amount of P and/or K applied is greater than the crop requires in a given year, limiting profit; and 2) the risk that the amount of P and/or K available from the soil and fertilizer in a given year is less than needed, limiting yield and profit.

At low soil test levels, there is a greater possibility that the crop will respond to fertilizer, and that the fertilizer application will be profitable in the year of application. However, the probability that P and/or K nutrition may limit yield and profitability in any given year is also higher. At higher soil test levels, there is less chance that P and/or K nutrition will limit

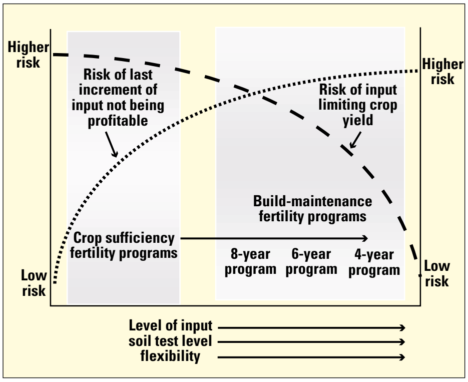


Figure 1. Crop sufficiency vs. build-maintenance nutrient management approaches.

crop yield in a given year, but the probability that a fertilizer application will be profitable in the year of application will also be lower. It should be an individual producer's decision on how to weigh and manage these risks.

Higher soil test values provide for greater flexibility in future P and K management plans (e.g. application rate, method, and frequency) and a greater cushion in the event of adverse environmental conditions (e.g. very wet, very dry, etc.) or financial conditions (e.g. unfavorable crop/fertilizer prices, cash flow, etc.). All things being equal, most producers would prefer to have soil P and K tests above the critical level (but not excessively high) as opposed to in the low, crop responsive soil test range. That's because there is greater flexibility in nutrient management options. There is, however, a cost associated with building or maintaining soil test levels in the medium-high range. Again, it should be the individual producer's decision on how much to value this flexibility.

While there are persuasive arguments supporting both approaches to P and K nutrient management, in actuality there are a continuum of valid approaches that provide for environmental stewardship as well as meeting the varying goals of individual producers. With the complexity of farm operations today, it is likely that many growers will choose to use multiple approaches.

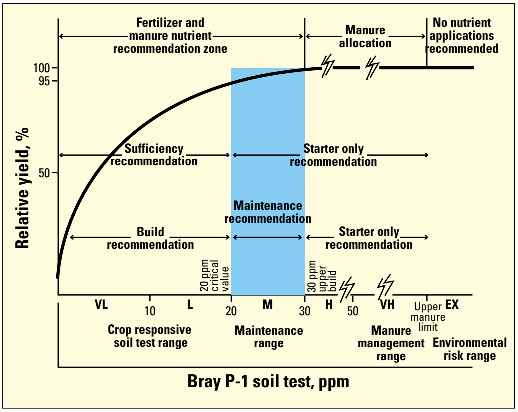


Figure 2. Phosphorus management model for Kansas crop production and manure management.

New P and K Recommendations

In the past, KSU nutrient recommendations have been largely based on the **nutrient sufficiency approach**. As we evaluated revisions to our fertilizer recommendations, it became apparent that we needed to also provide growers the guidelines for the **build-maintenance approach**. It is often stated that the nutrient sufficiency approach is most appropriate for the Great Plains and western states since yields are more often limited by available moisture than areas farther east, where the build-maintenance approach has been widely used. But these overly broad assumptions do not always fit individual growers, fields, and/or other situations.

Over the years, farm operators and their advisers have often requested modified recommendations that will maintain soil test levels and prevent mining of soil P and K. Sometimes it is landlords who wish to make certain that tenants leave the nutrient status of their fields equivalent to what it was prior to their lease. Other farmers have asked for guidelines for building soil test levels since the program they have used has resulted in soil test levels that remain in the low-medium range after a decade of fertilizer application. Growers have also inquired as to what recommendation would be appropriate if they anticipate controlling the land only for the current year. For others, cash flow challenges have resulted in farmers desiring fertility recommendations that minimize cash requirements for a particular year.

These and other issues come up every year, regardless if the farmer is in western or eastern Kansas, the Great Plains or the Corn Belt, if it is an area of corn-soybeans or winter wheat production, or if the field is dryland or irrigated. Some argue that economics, pure and simple, drive farmers' decisions relative to inputs such as fertilizer. Others maintain that there are different, valid, though somewhat subjective, reasons why some farmers make the decisions they do.

Another factor which has become more important in recent years is the possible requirement of nutrient management planning for some targeted USDA farm programs.

Typically, these plans require land grant university-based crop nutrient recommendations. Previous KSU recommendations would have provided only a single rate recommendation that would effectively eliminate flexibility for producers developing individualized nutrient management plans. In essence, a key management decision would be taken out of producers' hands. This is undesirable from the perspective of KSU and the individual farmer.

One objective of revising the KSU crop nutrient recommendation system was to provide flexibility, based on sound science, for developing management options that meet an individual producer's goals and objectives, while providing for environmental stewardship. **Figure 2** presents the general P management model adopted for Kansas crop production and manure management. The general concept for K management is similar. Research data from Kansas and other states generally support a P soil test critical value of about 20 parts per million (ppm) Bray P-1. Thus, we now provide both nutrient sufficiency recommendations and build-up recommendations at Bray P-1 soil test values of 20 ppm and below, and soil test maintenance recommendations at soil test values of 20 to 30 ppm. No fertilizer P is recommended for soils testing 30 ppm Bray P-1 or greater, except for starter applications at rates less than maintenance.

The faculty of KSU and Kansas personnel of the Natural Resources Conservation Service (NRCS) agree that there is only minor environmental concern at soil test levels of 50 ppm Bray P-1 or less. Thus, by providing fertilizer recommendations that will maintain soil test levels below 30 ppm P, concerns about P will be minimal as long as soil erosion and runoff are controlled.

With the revised recommendation system, the farmer is able to maintain flexibility in developing individual nutrient management plans while providing for environmental protection and maintaining compliance with NRCS farm program provisions. A summary of the KSU recommendations on P for corn appears in **Table 1**. Other crops and K recommendations are handled similarly. Both the nutrient sufficiency and build-maintenance guidelines are provided, allowing individual producers to choose the recommendations they feel are most appropriate for specific field conditions. Note that estimated crop removal values are provided for informational purposes with nutrient sufficiency recommendations, starter fertilizer applications may be suggested regardless of P and/or K soil test (if starter attachments available), and including some portion of the overall fertility program as a band application for fields with low soil test values are a part of the recommendations. All of these concepts are to be included in our overall nutrient management educational program and other publications.

Future Recommendation Direction

The initial objective of revising KSU nutrient recommendations for P and K was to develop the framework for providing producer-specific flexibility in nutrient management plans. Combining the nutrient sufficiency and soil build-maintenance approaches provides this overall framework. However, adding this flexibility requires much more producer input/involvement than previous recommendation systems that provided the same crop-specific P and K rate recommendations for all farmers, fields, and situations. While some farmers are comfortable with developing individualized nutrient management plans based to some degree on subjective factors, others may want recommendations based on specific questions related to their particular operation. Questions such as: How does expected length of land tenure affect the most profitable nutrient management program? For this field, should I utilize the nutrient sufficiency or build-maintenance approach? If the build-maintenance approach is used, how quickly should I build soil test levels? Does length of land tenure affect the targeted soil test value to build to?

Another article in this *Better Crops* issue (see page 14) authored by KSU colleagues in Agricultural Economics and Agronomy presents a crop response modeling approach to identifying the best P management strategy. In this approach, expected crop response curves, sufficiency recommendation models, expected length of land tenure, crop/fertilizer prices,

TABLE 1. Examples of Kansas State University corn P recommendation options based on the sufficiency and build-maintenance approaches.

Crop sufficiency P recommendations for corn[1]

Bray P-1 soil test, ppm	Yield goal, bu/A: 60	100	140	180	220
	lb P_2O_5/A				
0-5	55	60	70	75	80
5-10	40	45	50	55	60
10-15	25	25	30	30	35
15-20	15	15	15	15	15
20+	0[2]	0[2]	0[2]	0[2]	0[2]
Crop removal[3]	20	33	46	59	73

Corn sufficiency P Rec = [50 + (Yield goal x 0.2) - (Bray P x 2.5) - (Yield goal x Bray P x 0.01)]

If Bray P is greater than 20 ppm, then only an NP, NPK, or NPKS starter fertilizer is suggested.

If Bray P is less than 20 ppm, then the minimum P recommendation = 15 lb P_2O_5/A.

Build-maintenance P recommendations for corn[5]

Bray P-1 soil test, ppm	4-year build timeframe, Yield goal, bu/A: 60	140	220	8-year build timeframe, Yield goal, bu/A: 60	140	220
	lb P_2O_5/A					
0-5	99	125	151	59	86	112
5-10	76	102	129	48	74	101
10-15	54	80	106	37	63	89
15-20	31	57	84	25	52	78
20-30[4]	20	46	73	20	46	73
30+	0[2]	0[2]	0[2]	0[2]	0[2]	0[2]

Corn build-maintenance P Rec =

$$\frac{(20 - \text{Current P soil test}) \times 18}{\text{Years to build}} + P_2O_5 \text{ removal in crop}$$

[1]Crop P and K recommendations are for the total amount of broadcast and banded nutrients to be applied. At low to very low soil test levels, applying at least 25 to 50% of total as a band is recommended.

[2]Application of an NP, NPK, or NPKS starter fertilizer may be beneficial regardless of P or K soil test level, especially for cold/wet soil conditions and/or high surface crop residues. Do not exceed N + K_2O guidelines for fertilizer placed in direct seed contact.

[3]Crop removal numbers provided for comparative purpose only — 0.33 lb P_2O_5 and 0.26 lb K_2O/bu of harvested corn. If crop removal exceeds nutrient applications, soil test levels are expected to decline over time.

[4]Recommended amounts of P_2O_5 and K_2O are based on crop nutrient removal at the indicated yields (0.33 lb P_2O_5/bu and 0.26 lb K_2O/bu).

[5]The 4-year and 8-year timeframes are examples only. Build programs can be over longer timeframe. However, build-maintenance recommendations should not be less than crop sufficiency based fertility programs.

and other information is used to estimate the optimal amount of P fertilizer to invest each year. In the future, we intend to incorporate this type of decision aid tool into the framework of the KSU recommendation system and our overall educational program.

In summary, we believe nutrient management programs must be tailored to fit the specific conditions affecting each field of individual growers. The nutrient recommendation system employed by KSU is intended to provide the flexibility needed to develop these individualized nutrient management programs while providing for environmental stewardship. BC

Dr. Leikam (e-mail: dleikam@ksu.edu), Dr. Lamond, and Dr. Mengel are in the Agronomy Department, Kansas State University, Manhattan.

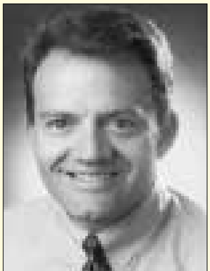
Robert E. Wagner Award Winners Announced by PPI

Two outstanding agronomic scientists have been selected to receive the 2002-2003 Robert E. Wagner award by the Potash & Phosphate Institute (PPI). The award encourages worldwide candidate nominations and has two categories...Senior Scientist and Young Scientist, under the age of 45. Each recipient receives $5,000 as part of the award.

Dr. John L. Havlin

Dr. John L. Havlin, Professor, Department of Soil Science, North Carolina State University (NCSU), Raleigh, was selected in the Senior Scientist category. **Dr. Newell R. Kitchen**, Soil Scientist with the USDA-ARS, Cropping Systems and Water Quality Research Unit, Columbia, Missouri, receives the Young Scientist honor.

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



Dr. Newell R. Kitchen

"We are pleased to add Dr. Havlin and Dr. Kitchen to the list of distinguished winners of the award. Both are highly worthy recipients of this honor and exemplify the high standards it represents," said Dr. David W. Dibb, President of PPI.

Dr. Havlin is a renowned educator, researcher, and leader in North American agriculture and worldwide. His contributions to agriculture through research and education on yield-limiting factors related to soil and crop management have resulted in improved nutrient and water-use efficiency, soil productivity, and environmental quality in the Great Plains and Southeast U.S. His groundbreaking work on the spatial distribution of phosphorus (P) and its correlation with wheat grain P led to improved soil-sampling strategies and P recommendations now in use by soil test laboratories in the Midwest. The studies he initiated on variable rate nitrogen (N) management have caused increased N-use efficiency in corn production. His innovative demonstration programs on precision agriculture technologies have educated and benefited producers, fertilizer dealers, and agriculture advisers throughout the country. Dr. Havlin co-authored and revised the book *Soil Fertility and Fertilizers*, which has proven to be an outstanding resource for students and crop advisers throughout North America. He is also recognized as a Fellow in the Soil Science Society of America and the American Society of Agronomy.

Dr. Kitchen is nationally recognized for his research and outreach activities on nutrient management, water quality, and precision agriculture. He has been a leader in investigating the impact of cropping systems on water quality. Results from his research programs have improved N management strategies for cropping systems in different climate/soil regions of the country, resulting in improved N use efficiency. His innovative work with soil electrical conductivity as an indirect method of measuring depth to claypan and moisture holding capacity has been instrumental in the development of management zone concepts and maps for use in precision farming. He has been described as an excellent scientist with a thorough understanding of the fundamental science at work in the world of production agriculture. BC

J. Fielding Reed PPI Fellowships Awarded to Six Graduate Students

Six outstanding graduate students have been announced as the 2003 winners of the "J. Fielding Reed PPI Fellowship" awards by the Potash & Phosphate Institute (PPI). Grants of $2,500 each are presented to the individuals. All are candidates for either the Master of Science (M.S.) or the Doctor of Philosophy (Ph.D.) degree in soil fertility and related fields.

The six winners for 2003 are:

- Soraya Alvarado, University of Kentucky
- Pedro Barbagelata, Iowa State University
- Dennis L. Coker, University of Arkansas
- Kristy Gibson, Brigham Young University
- Myron P. Kroeker, University of Manitoba
- Matías Ruffo, University of Illinois

"Since these awards began in 1980, a total of 141 graduate students have now been awarded Fellowships by the Institute. Each year, it is reassuring to identify and recognize such excellent individuals in agronomic sciences," 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 for the Fellowships. Following is a brief summary of information for each of the 2003 recipients.

Soraya Alvarado, a native of Cañar, Ecuador, graduated with a B.S. from the Higher Polytechnic School of Chimborazo in 1997. She is presently pursuing the M.S. degree at the University of Kentucky. Her thesis, "Chemistry and Fertility of Basic Nutrient Cations (potassium, calcium, and magnesium) in Acidic Ecuadorian Andisols", is studying the chemical status and behavior of macronutrients in the acidic, volcanic ash soils of Ecuador. Ms. Alvarado was recognized as the best graduate student, 1997-98, at the Faculty of Sciences Doctorate Program at the Chemistry School, Higher Polytechnic School of Chimborazo. She received a Scholarship from the Ecuadorian Government's National Agricultural Modernization Program to carry out her graduate studies in the U.S.

Pedro Barbagelata was born in Paraná, Entre Ríos, Argentina. He graduated from the National University of Entre Ríos in 1996 with a B.S. Following graduation he worked as a teaching assistant at the National University and most recently as a researcher at the National Institute of Agriculture Technology (INTA) in Paraná. He was recognized with an Honor Title for academic excellence at his undergraduate university, received a Research Fellowship for Professionals from INTA, and in 2002 was awarded a Fellowship from INTA to pursue graduate studies at Iowa State University, where he has entered a Ph.D. program. The title of his dissertation is "Field Calibration of Soil Potassium for Corn and Soybean Using Traditional Plots and Field-Scale Trials Based on Precision Agriculture Technologies." His graduate work will evaluate four potassium soil test methodologies and compare their ability to predict response of corn and soybeans in Iowa.

Dennis L. Coker, a native of Coleman, Texas, received his B.S. degree from Tarleton State University in 1989 and his M.S. degree from Texas A&M in 1992. Dennis has been the recipient of the Houston Livestock Show & Rodeo scholarship; the Tarleton

Academic scholarship; the Spooner Scholar Award of the Crop, Soil, and Environmental Sciences Department at University of Arkansas; and other recognitions. Following his graduation from Texas A&M, Dennis worked as a research specialist and technician, and in the retail fertilizer industry. He began working on a Ph.D. in Crop Physiology at the University of Arkansas in 1998. His dissertation is titled "Effect of Water Deficit Stress on Potassium Partitioning and Efficiency of Foliar-Applied Potassium." Its objectives are to evaluate the effects of water stress and potassium deficiency on the yield and quality of cotton, as well as various plant physiological characteristics.

Kristy Gibson was born in Tucson, Arizona. She received her B.S. degree from Brigham Young University in 2002 and then entered the M.S. program at Brigham Young. Kristy has received the Brigham Young University Graduate Assistantship and Scholarship, the National Merit Scholarship, the Casa Grande Foundation Scholarship, and other awards. She is a member of the Golden Key National Honor Society. Her M.S. thesis is titled "Simplified Soil Testing Methods for Use in Developing Countries." Its goal is to develop soil testing methods appropriate for use in third-world countries that are easy to use and calibrated against established procedures in the developed world.

Myron P. Kroeker grew up in Rosenort, Manitoba. He completed his B.S. in 1998 at the University of Manitoba and began his M.S. program at the same institution in 2002. Myron has been the recipient of numerous awards, including a Natural Science and Engineering Research Council Scholarship, the Zeneca Agro Achievement Award, and the University of Manitoba Faculty of Agricultural and Food Science BSA Medal. His thesis title is "Agronomic Evaluation of Homogeneous NPS Fertilizer." The objectives of this research are to determine the availability of the phosphorus and sulfur in a new homogenous granular fertilizer product relative to other commercial fertilizers.

Matías L. Ruffo, a native of Buenos Aires, Argentina, received his B.S. degree from the University of Buenos Aires in 1998 and his M.S. degree from the University of Illinois in 2001. He is currently working on a Ph.D. at the University of Illinois where he is studying the "Site-Specific Nitrogen Response Functions for Maize." The objectives of his doctoral research include studying the profitability of variable-rate fertilization using on-farm experiments. Matías has received the University of Illinois Fellowship, the College of ACES Graduate Student Research Award, and the M.B. Russell Award. Papers from his M.S. research have been accepted for publication.

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.

The Fellowship winners were selected by a committee of PPI scientists. Dr. Tom W. Bruulsema, PPI Eastern Canada and Northeast U.S. Director, served as chairman of the selection committee for the 2003 Fellowships.

(Information about applications for the 2004 J. Fielding Reed PPI Fellowships will be available at the website: www.ppi-ppic.org).

GREAT PLAINS

Understanding Phosphorus Investment in Crop Production

By T.L. Kastens, J.P. Schmidt, and K.C. Dhuyvetter

Differences in philosophies and/or implicit yield response models result in differences in phosphorus (P) fertilizer recommendations among laboratories. Those wanting to improve the P investment decision would be wise to consider several agronomic and economic factors.

Anecdotal evidence seems to be mounting that farm operators in the Great Plains want to consider P as more than an annual fertilizer issue, even to the point they consider soil test P (STP) as a capital investment with the usual time dimension associated with investments. Both landowners and tenants increasingly want to be compensated for their investments that presumably "caused" STP levels to be in the higher ranges. Quotes such as: "I'm sure not going to apply P on land that I won't have after next year" or "I've built up soil test P and want to be sure my tenant doesn't mine it out" are becoming ever more common. Although few fertilizer recommendations from university or commercial soil testing laboratories currently consider the capital investment aspect of P, this topic should increase in importance over the coming years if producer concerns are any indication.

That farmers observe STP levels do change over time is probably an artifact of fertilizer recommendations, which typically suggest fertilizer P (fertP) rates that are higher than crop removal on low testing soils. Thus, STP will increase over time when following the fertilizer recommendations. Additionally, a location's STP will change over time in the face of uniform application rates coupled with crop yields that vary due to other limiting factors that persist over time.

What is not well known is whether farmers view the situation passively or actively. That is, do they view "accidentally" higher STP sites to represent potential fertilizer savings in the future, thus imparting value to those sites? Or, do they wish to managerially target higher STP levels by applying additional fertilizer, believing that such strategies enhance profitability over time?

Because fertilizer recommendation providers (and users) vary in their perception of P as a short- or long-term issue, two classes of P recommendations have evolved over time. First, the traditional "sufficiency" recommendations, which are conditional on STP levels that happen to be observed, are provided as a guide to 1-year profit maximization. Second, "build and maintain" recommendations are provided in an attempt to account for the fact that longer-term managers might enhance profit by using some build program, followed at some point in the future by rates that try to maintain STP at some target level.

At least two recent *Better Crops with Plant Food* articles suggest that producers might benefit by explicitly targeting STP over time. Considering P investment over a 10-year horizon, each article suggested that an especially fast (essentially over 1 year) build up of STP would be appropriate. In one article (Lowenberg-DeBoer and Reetz, 2002), the authors compared a 1-year build, followed by a maintenance fertilizer P application in the corn year of a corn-soybean rotation, to a more gradual build program. Relative to the 1-year build program, the more gradual program applied roughly the same total fertilizer over the study period, but placed less in year 1 and more in each successive application. Since the 1-year build program allowed more years to recoup the investment of additional fertilizer, it was easy to show that the 1-year program netted more profit. However, the authors did not reveal whether the underlying yield response model considered only response to STP and not fertilizer P, nor whether a strategy closer to some sufficiency recommendation might have been even more profitable over the 10-year horizon.

In another article (Kastens et al., 2000), the authors used a wheat yield response (to both fertilizer P and STP) model generated from farm-level data to show that applying a large amount of fertilizer in year 1, followed by none in successive years of the 10-year period, was the most profitable strategy. The authors indicated that this result arose because the estimated yield model happened to reveal a large response to STP and a weak response to fertilizer P. Other work by these authors suggested a more balanced model would be more appropriate for the same farm's data. Further, the "STP build" recommended by the more balanced model would be much more gradual than the 1-year build suggested by the Kastens et al. *Better Crops* article.

Whatever the outcome to the farmer perception questions posed earlier, what will be most needed from interested researchers is a better understanding of the substitutability of fertilizer P and STP in the yield response function. Closely related to that need is a better understanding of how STP changes over time given fertilizer rates and crop yields. More explicitly, is the transformation of excess (above crop removal) fertilizer P (EfertP) to a change in STP a constant? Or, does it vary significantly by soil type, by level of STP, by time, or by some other factor? Information about EfertP-to-STP transformation allows "costing" STP on a per unit basis, such as parts per million (ppm). Then, given an expected number of future years or crops, information about fertP-STP substitutability (or, more simply, yield response to STP) allows "valuing" STP on a per unit basis. Finally, the cost and value of STP, along with the decision-maker's time horizon, should determine the optimal P investment strategy.

Fertilizer P recommendation models from soil testing laboratories provide an indication of what soil scientists behind the recommendations likely believe about yield response to fertilizer P and STP. As such, the implicit underlying yield response models have the potential to significantly further the study of the P investment decision. Unfortunately, the implicit yield response models are not always consistent across soil testing laboratories covering the same

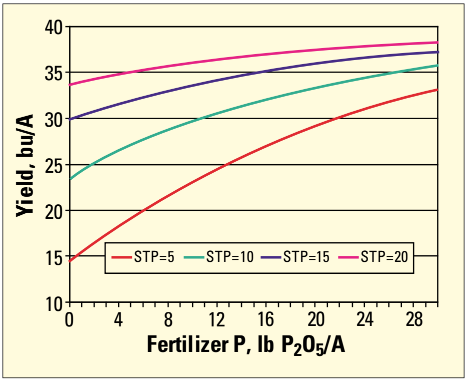


Figure 1. Predicted wheat response to fertilizer P (OAL-based model).

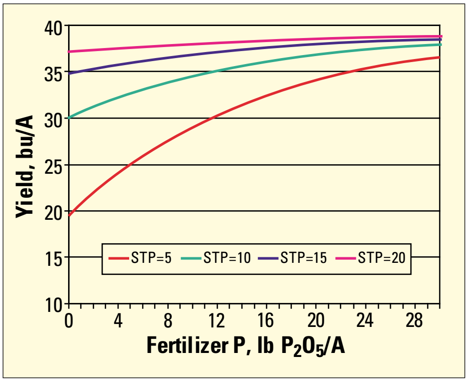


Figure 2. Predicted wheat response to fertilizer P (KSU-based model).

geographical production area, complicating the P investment decision.

We examined fertilizer nitrogen (N) and P recommendations for wheat from four soil testing laboratories (one private, three public): Olsen's Agricultural Laboratory, McCook, Nebraska (OAL); Kansas State University (KSU); University of Nebraska (UNL); and Colorado State University (CSU). Each laboratory's recommendations were considered suitable for wheat production in northwest Kansas (Rawlins County). Each was considered to be a sufficiency recommendation, thus assuming a 1-year management horizon for the farm operator. **Figures 1** and **2** depict expected yield response to fertilizer P at different Bray P-1 STP levels for two of the laboratories studied. As seen by the slope of the lines and relative to the KSU model (shifted down), the OAL model suggests that wheat yield is more responsive to fertilizer P at each of the STP levels considered.

The different yield responsiveness implied by the different laboratories' recommendations greatly impacts the STP annual value for farm operators following the laboratories' (sufficiency) fertilizer recommendations over time. Given the non-linear EfertP-to-STP transformation rate from our work, where it takes more EfertP to change STP by 1 ppm at low levels of STP than at high levels, **Figure 3** shows the expected STP at the beginning of each year (starting at 5 ppm) associated with each of the different laboratories. The steady-state (SS) STP levels, where the recommended fertilizer P rate equals crop removal (here assumed to be 0.6 lb P_2O_5/bu of wheat), vary substantially across the four models. It is worth noting that using a constant EfertP-to-STP transformation rate would change the shape of the curves but not the final STP levels. Clearly, if laboratories use this approach to target some "build and maintain" STP level in an attempt to guide the P investment decision, the recommendations will appear inconsistent across laboratories.

What if laboratories approached the P investment decision from the standpoint of choosing the fertilizer P rate each year that maximized discounted future profits? **Figure 4** shows the resultant STP annual value for these four laboratories. For operators with especially long horizons, such as those who might own their land, the difference between the ending STP (30 years in the future) can be large. For example, KSU followers end up at an STP level of about 21 ppm and OAL followers at about 36 ppm. Although not shown, OAL followers start out applying 82 lb/A of P_2O_5 and end up applying around 24, which approximately equals crop removal. Though KSU followers also ended up applying 24 lb/A, they start out applying only 55.

Notice that none of the optimal STP time paths in **Figure 4** suggests especially

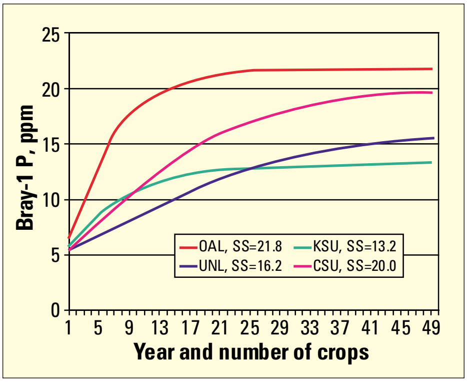


Figure 3. STP over time for different yield models (profit maximizing 1 year at a time, i.e., sufficiency).

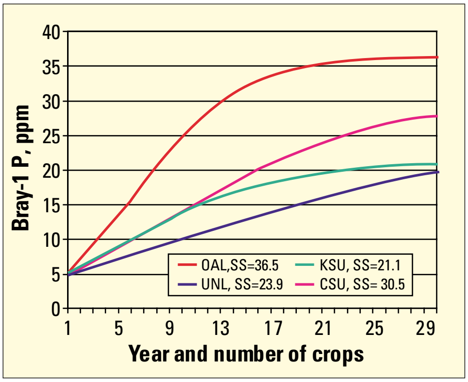


Figure 4. Optimal STP over time for different yield models (first 30 years of a 50-year or longer time horizon).

fast build programs. Rather, they suggest a continued build of STP, though at a diminishing rate, across the 30 years shown. Thus, assuming these laboratories have confidence in their sufficiency recommendations, it probably would be inappropriate for them to accommodate the P investment framework by suggesting an especially fast build program. To evaluate this issue, we consider two P investment strategies: a) an infinite-horizon optimal strategy (referred to as IHO), such as that underlying the lines in **Figure 4**, and b) an infinite-horizon 6-year build and maintain program (referred to as B&M). With B&M steady-state STP values shown in **Figure 4** are targeted by applying each year for 6 years an amount of fertilizer P equal to crop-removal P plus one-sixth of the amount needed to reach the SS target in 6 years, followed by only crop-removal P thereafter. Then, we can ask the question: How much more profitable would a producer following these infinite-horizon strategies be over simply following sufficiency recommendations? The answer is conditional on having the land for only 1 year, 2 years, and so on.

Figure 5 shows the expected outcome of the two P investment strategies described, and for only two of the soil testing laboratories, OAL and KSU. Results are presented as annually amortized $/A, thus $/A/year. For example, an OAL B&M program follower who happened to lose his land after 6 years would have been $8.62/A worse off each year of the 6 years than he would have been if he had simply followed the sufficiency recommendations over the 6 years. Clearly, large losses accrue to those who lose their land in the early years of a fast build program. Also, the B&M program is not more profitable than a sufficiency program, unless the operator controls the land for at least 20 years (OAL) or 28 years (KSU). On the other hand, the IHO strategy is not more profitable than a sufficiency program unless the operator controls the land for at least 14 years (OAL) or 15 years (KSU). Despite the seemingly small profits associated with the P investment strategies of **Figure 5**, it should

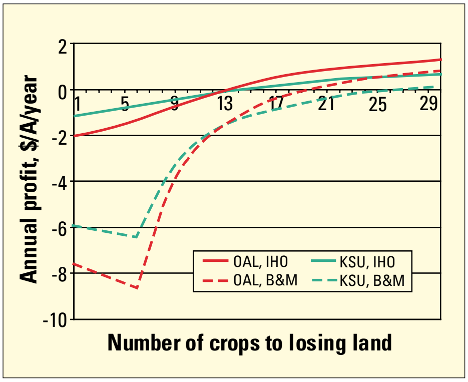


Figure 5. Returns to P investment over sufficiency (OAL and KSU).

be noted that, if an operator knows in advance exactly how long he will control land, then optimal P investment strategies will be more profitable than those shown. That's because he can intentionally "mine" P in the last years of his time horizon.

Given the large variations in results shown, it should not be surprising to see a number of successful farms, especially those adopting precision agriculture technologies, wanting to generate their own yield response and fertilizer recommendation models.

Whether farmers or university researchers, those wanting to improve the P investment decision would be wise to consider: a) the substitutability of fertilizer and STP (i.e., develop accurate yield response models); b) how to quantify expected changes in STP over time given fertilizer P rates (i.e., understand the transformation rate); c) the explicit purpose behind build and maintain P programs; d) time-value-of money issues; and e) the risk associated with making the wrong recommendation.

Failure to consider each of these issues simultaneously can easily lead to fertilizer decisions that are less profitable and more risky than ignoring the P investment idea altogether. BC

Dr. Kastens (e-mail: tkastens@ksu.edu), Dr. Schmidt, and Dr. Dhuyvetter are with Kansas State University, Manhattan.

Meeting Potassium Needs for Pacific Northwest Grass Seed Production

By J.M. Hart, D.A. Horneck, M.E. Mellbye, and R.L. Mikkelsen

Perennial grass seed production is a major industry in parts of Oregon and Washington. When grass seed is harvested, considerable amounts of straw remain in the field. Management of the grass straw following seed harvest is an important consideration in maintenance of the stand and for achieving high seed yields. For many years, burning was the most common practice of straw management and removal. The practice of field burning eliminates straw residues and helps rid fields of weeds, insects, and diseases (**Figure 1**).

In the past decade, regulations in Oregon and Washington state have severely restricted burning of grass fields. This action has occurred in response to health concerns and to address potential air quality problems related to burning. The change in crop residue management practices has prompted a re-evaluation of the nutrient requirements for seed production.

> With recent restrictions on straw burning, removal of straw in grass seed production has greatly increased nutrient removal from the field. Grass has a fairly constant potassium (K) demand throughout the growing season and soil K should be maintained above 100 parts per million (ppm).

Most grass straw is now baled and removed from production fields. Since 1997, export tonnage of grass straw from Oregon increased 78%, to 588,862 t/year. Interestingly, each of the major Asian export markets prefers a specific type of grass. Japan utilizes most of the perennial ryegrass straw, Korea imports most of the tall fescue, and Taiwan focuses on bentgrass straw. In addition, some grass seed straw is used locally for animal feed. Growers not only save time and effort dealing with straw removal, they also

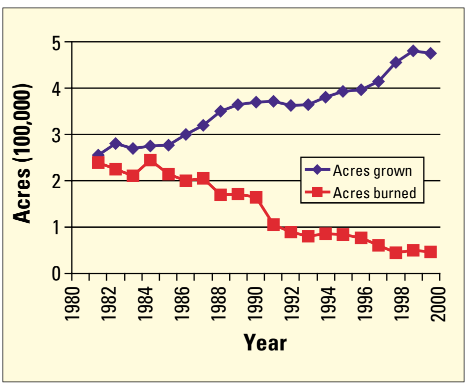


Figure 1. Grass seed production acreage and field burning acreage in the Willamette Valley, Oregon.

Grass seed crops are swathed and dried in the field for later threshing with combines. Baling and removing straw increases nutrient removal.

TABLE 1. Estimated average nutrient content for perennial ryegrass seed production. The amount of straw assumed is 3 t/A and a 1 t/A seed yield.

Perennial ryegrass	Nutrient, lb/A N	P_2O_5	K_2O
Straw	60	16	72
Seed	40	16	14
Total	100	32	86

TABLE 2. Potassium concentrations and removal amounts in perennial ryegrass straw in three farmer fields.

Aboveground biomass, lb/A	Tissue K, %	K in straw, lb K_2O/A
6,300	1.5	117
7,000	1.7	143
8,000	1.7	163

receive a small payment for the straw that is sold.

Relatively few nutrients are removed while harvesting only grass seed. Burning the straw recycles most of the K and several other nutrients used by a crop. However, the transition from burning to baling and straw removal has prompted a re-examination of nutrient needs of grass.

Measurements were made over a 3-year period for two fields each of perennial ryegrass and tall fescue in Linn County, Oregon. During each year, 32 plots were harvested from the fields. The average straw yield for tall fescue was 4.0 t/A and the average seed yield was 1,400 lb/A. Perennial ryegrass seed yield averaged 1,600 lb/A and straw yield averaged 2.75 t/A.

Nutrient removal rates in the harvested seed were relatively low. On average, the seed of these grasses contains approximately 2% nitrogen (N), 0.35% phosphorus (P), and 0.6% K. A ton of seed contains approximately 40 lb N, 16 lb P_2O_5, and 14 lb K_2O. However, when straw and seed were both removed from the field, nutrient removal increased substantially (**Table 1**).

Table 2 shows K concentrations and removal amounts in perennial ryegrass straw in three farmer fields.

Unlike seed, where the K concentrations are relatively constant, the K concentration in perennial ryegrass straw increases as soil test K increases (**Figure 2**).

The relationship between soil test K (extracted with 1 M ammonium acetate) and tissue K concentration provides support for the use of 100 to 125 ppm K as the soil test range below which K fertilizer application is recommended (**Figure 2**). The data suggest a straw tissue concentration of approximately 1.25% when the K soil test is greater than 125 ppm, which is sufficient for maintenance of maximum yields.

To avoid depletion of soil K by perennial ryegrass, in fields where the soil test K falls between 100 and 150 ppm, K fertilizer

(continued on page 23)

As the combine harvests orchardgrass seed in the Willamette Valley, the full straw load is left in the field.

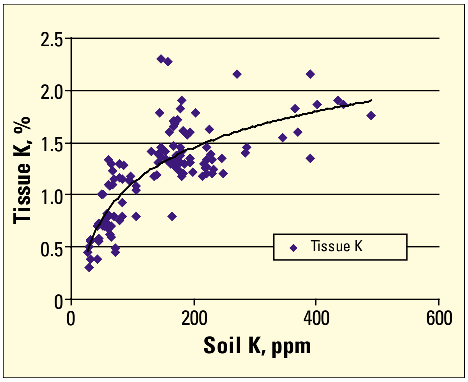


Figure 2. Influence of soil test K on K tissue concentration of perennial ryegrass straw at harvest (fitted with a log function).

INDIANA

Improved Phosphorus Management Enhances Alfalfa Production

By W.K. Berg, S.M. Brouder, B.C. Joern, K.D. Johnson, and J.J. Volenec

Improved alfalfa yield with P fertilization has been documented, but little is known of how this essential nutrient promotes increased growth and stand longevity. Complex P-soil mineral interactions and fertilizer costs make effective P acquisition and utilization vital.

In plants, P has many essential functions, including nitrogen (N) fixation, protein synthesis, carbon partitioning (production of starches and sugars), cell division (DNA synthesis), and production of cellular energy as ATP, to name but a few. Although P is involved in a tremendous number of plant processes, the mechanisms responsible for P-induced increases in forage yield of alfalfa are not yet known.

> Research in Indiana shows that nutrient imbalance ...adding phosphorus (P) without potassium (K)...has more severe consequences for alfalfa survival than anticipated.

An alfalfa study established in 1997 at the Throckmorton Purdue Agronomy Center near West Lafayette, Indiana, had initial soil test K and P concentrations of approximately 90 parts per million (ppm) and 5 ppm in the top 8 in., respectively. Five K treatments (0, 100, 200, 300, and 400 lb K_2O/A) and four P treatments (0, 50, 100, and 150 lb P_2O_5/A) were applied annually in a split application. Half of the specified amount was applied after the first hay harvest in May and the remainder after the last hay harvest in September. Forage was harvested four times annually. Roots were dug in May and December to monitor plant populations over time and to confirm whether plant death occurred in summer

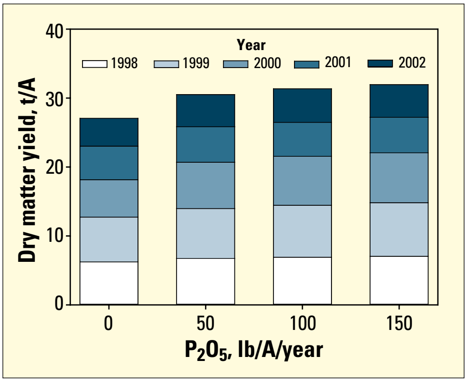


Figure 1. Yield as influenced by P fertilization rate. Data averaged over the K fertilizer rates.

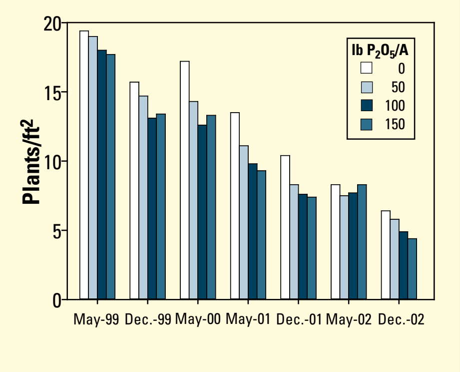


Figure 2. Plant population as influenced by P fertilization rate. Data averaged over the K fertilizer rates. Plants/ft² declined with addition of P from May 1999 to the present.

(May to December) or during winter (December to May). Shoot and root concentrations of P and K were determined, and P and K uptake calculated.

Addition of P dramatically increased yield in each year of the experiment. Application of 150 lb P_2O_5/A/year increased alfalfa yield by 1,640, 2,520, 3,600, 560, and 1,440 lb forage/A over control plots where no P application occurred in 1998, 1999, 2000, 2001, and 2002, respectively (**Figure 1**). In total, the dry matter yield increase resulted in an additional $560/A of return (considering $100/t value for alfalfa) when supplied triple superphosphate at 0.82 t/A ($200/A using $240/t cost for triple superphosphate) in the 5 years.

Alfalfa yield results from the interaction of three yield components: (plants/area) x (shoots/plant) x (mass/shoot). Understanding increases in forage yield in response to P fertilization should begin with understanding how individual yield components are affected by P applications. Plant populations (plants/area) have declined since the experiment was initiated in 1997 [Berg et al., Enhancing alfalfa production through improved potassium management. *Better Crops* 87(1): 8-11, 2003]. Phosphorus fertilizer applications have influenced plant population, but in an unexpected manner. Increased P fertility has resulted in decreased plants/ft^2 at each sampling since May 1999, except for plant counts obtained in May 2002 (**Figure 2**). Addition of P greatly increased alfalfa growth and development, which enhanced interplant competition when compared to plots where no P was added. Plants provided P characteristically attain greater crown and root size (**see photo**), which intensified competition for light, water, and nutrients. This greater size and increased competition likely led to the demise of slower growing, less competitive plants in the stand.

As alfalfa population decreases with stand age and P fertilizer application, increased shoots/plant is thought to compensate for plant loss to sustain high yields. Plant counts, yield information, and mass/shoot data obtained at Harvest 1 in May permit us to calculate shoots/plant at this harvest. Although forage yield has increased and plant populations have decreased with P fertilizer application, shoots/plant has not changed significantly as a result of P fertilizer application. However, shoots/plant did increase by two between May 2000 and May 2001, perhaps due to the loss of plants over time (**Figure 3**).

In the first five years, increases in alfalfa yield have occurred primarily because of increased mass/shoot of plants in P-fertilized plots (**Table 1**). Neither of the other

Increased crown and root size resulting from P fertilization enhanced competition between plants and resulted in greater plant losses in P-supplied plots (see **Figure 2**).

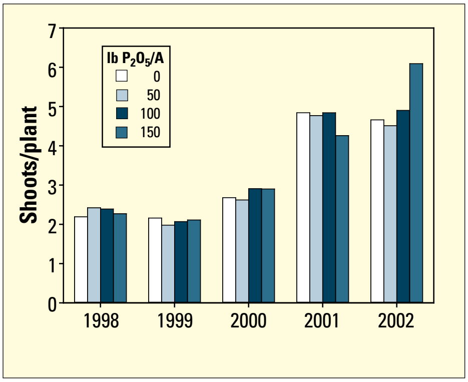


Figure 3. Shoots/plant as influenced by P fertilization. Data averaged over the K fertilizer rates and are for the May forage harvest of the year indicated.

TABLE 1. Mass/shoot (g/plant) as influenced by P fertilization. Data averaged over K fertilizer rates.

P_2O_5, lb/A/year	2000 H1	2000 H2	2000 H3	2000 H4	2001 H1	2001 H2	2001 H3	2001 H4	2002 H1	2002 H2	2002 H3	2002 H4
0	0.86	0.76	0.55	0.42	0.59	0.51	0.61	0.32	0.63	0.61	0.43	0.36
50	1.34	0.96	0.71	0.56	0.70	0.64	0.73	0.39	0.87	0.81	0.48	0.44
100	1.46	0.95	0.72	0.61	0.79	0.63	0.73	0.44	0.89	0.81	0.50	0.46
150	1.47	0.99	0.73	0.65	0.91	0.69	0.77	0.44	0.92	0.81	0.51	0.48
$LSD_{0.05}$	0.15	0.10	0.08	0.06	0.09	0.06	0.09	0.05	0.09	0.11	0.05	0.07

yield components has increased with addition of P, and plants/area has actually declined with P fertilization. Increased shoot mass with P fertilizer applications is a result of two different mechanisms: rapid initiation of regrowth immediately following hay harvest, and increased rate of stem elongation (**see photo**). Increased initiation of regrowth may be a result of enhanced mobilization of stored reserves in taproots following cutting.

Very extensive stand losses have occurred recently that are associated with specific fertility treatments, prompting detailed examination of the physiological basis for plant death in these plots. On the poorest fertility soils, severe stand decline occurred where P had been applied without K. These stand losses were even greater than those observed in plots where no P and K fertilizer had been applied for 6 years.

Responses of the 0K plus P plots were compared to those of plots provided 200 lb K_2O/A/year with the same P rates. The 200 lb K_2O/A/year rate provided good agronomic performance at moderate P application rates, and several of the 200K plus P plots were immediately adjacent to the 0K plus P plots that suffered extensive stand loss.

Trends in plant populations for these treatments were similar to those observed for the entire study, with plants/ft^2 declining from 15 to approximately 10 between May 2000 and May 2002 (**Figure 4**). Extensive stand loss occurred in all plots between May and December of 2002, but losses were especially acute in 0K plus P plots. Stand counts in December confirmed that these plots contained less than 2 plants/ft^2, below the 4 plants/ft^2 minimum generally used to define an "acceptable" alfalfa stand.

The rapid decline in plant population found in the 0K plus P plots also had a substantial effect on total forage yield in 2002.

Increased mass/shoot found in P-supplied plants primarily resulted from rapid initiation of shoot regrowth after hay harvest. Seven days after harvest, plants supplied P had substantially greater herbage regrowth than did plants not supplied P.

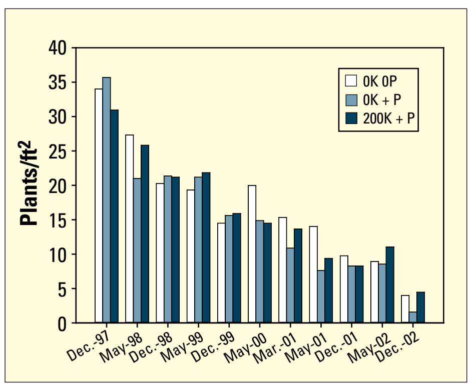


Figure 4. Changes in alfalfa stand between December 1997 and December 2002 as influenced by P and K fertilization. In the 0K plus P plots, plant populations declined below the critical density of 4 plants/ft^2 in December of 2002.

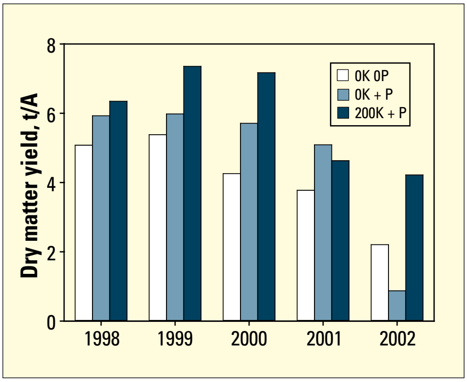


Figure 5. Yield as influenced by P and K fertilization of selected treatments. See **Figure 4** heading for definition of the treatments.

In the first 4 years of the study, the 0K plus P plots had yields comparable with the 200K plus P plots; both of these treatment groups consistently out-yielded the plots receiving no fertilizer (**Figure 5**). Due to the loss of plants in the 0K plus P plots, yields were low at the first and second forage harvests of 2002. These plots were abandoned at the third and fourth harvests because of low plant populations and weed invasion. Yield of the 0K plus P plots in 2002 were actually lower than yield in plots receiving no fertilizer for five years. The plant populations in the 0K 0P plots are still economical and yield determinations will continue into 2003.

Clearly, nutrient imbalance (adding P without K) has more severe consequences for alfalfa survival than we had anticipated. **Regarding alfalfa persistence and total yield over the life of a stand, producers should soil test and apply P and K as recommended to meet yield goals set for their alfalfa stand.** BC

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Meeting K Needs for Pacific NW Grass Seed Production *(cont. from p. 19)*

application rates should be adjusted to replace the amount removed in the straw.

In addition to meeting the total seasonal nutritional requirements, an adequate nutrient supply must be available for uptake to meet periods of peak demand. As a result of intensive plant sampling, both biomass and tissue K accumulation were found to be fairly constant during the growing season (**Figure 3**). This is in contrast with N accumulation, where the majority of the nutrient was taken up in the first half of the growing season. As adequate nutrient supply is essential for top yields, it must be present at both the correct time and in the proper quantity for the plant.

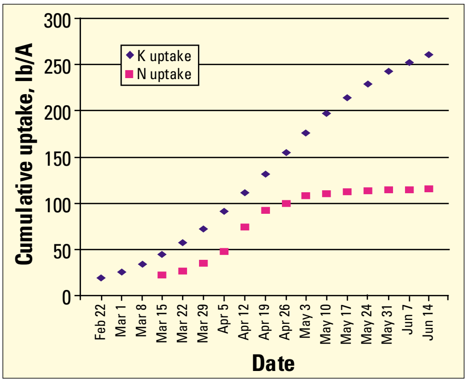

Figure 3. Accumulation of K and N by tall fescue during the growing season.

These results suggest that the removal of K from grass seed fields has greatly increased since the straw is now routinely removed from the field. Potassium removal is as much as five times greater when straw is removed in addition to the seed. Soil test K concentrations should be maintained above 100 ppm in the surface 6 in. and replacement of removed nutrients should be part of an ongoing soil fertility program. BC

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Understanding the Need for Phosphorus and Potassium

I've spent nearly 40 years promoting sound nutrient management planning, and I still can't figure out why it is so difficult for some folks to accept the fact that phosphorus (P) and potassium (K) are essential to successful crop production.

Along with nitrogen (N), P and K are called 'primary' nutrients because plants require them in large quantities. Most soils can't supply enough P and K to meet the needs of high yielding crops without supplemental fertilization. Agronomically, they are essential. Economically, they can make the difference between farmer profit and loss.

There are several factors farmers and their advisers should consider when developing P and K fertilization plans and deciding the appropriate rates to use.

- **As long as crops are responsive to P and K,** crop and/or fertilizer price makes little difference in the amounts that should be applied. Cutting back or cutting out P and K use results in lost yields and profits.
- **Although N is usually the first limiting nutrient** for crops such as corn, wheat, and cotton, it doesn't work in isolation. Science-based P and K fertilization, in balance with N, results in increased N use efficiency. In other words, the crop is able to use a higher percentage of applied N.
- **In addition to boosting N use efficiency,** P and K protect the environment. By helping to increase the amount of N getting into the crop, they help keep soil N levels lower, reducing the potential for damage to groundwater quality from excess soil nitrate-N.
- **Adequate P and K also contribute to improved crop quality, as well as overall improved crop health.** Quality is becoming a more important aspect of food production as its relationship to human health and disease suppression is better understood.

This fall is an ideal time to commit to a more cost effective, profitable, and environmentally friendly nutrient management plan. That plan should include the proper use of P and K. Begin its implementation by arranging for soil samples to be taken and analyzed this fall and winter. **Only then will you be able to begin to understand the importance of P and K in crop production.**

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