PART 2

Phosphorus and Potassium Economics in Crop Production: Net Returns

By T.S. Murrell and R.D. Munson

Soil test calibration curves are used to find soil test levels that are optimum for the production of a given crop. They link a specific soil test, long-term expected yield, and probability of yield response. Soil test calibration curves like the one in **Figure 1** show the relationship between the relative yield of a given crop, or percent of the yield goal attainable, and soil test levels. These curves are created by analyzing yield response data from P or K rate studies conducted at many different sites and initial soil test levels. Usually, P or K applications are broadcast. Relative yields for a given location and year are calculated by dividing the average yield of the plots where no P or K fertilizer was applied by the average yield of the plots receiving fertilizer at adequate or greater rates. Therefore, one rate study at a given site in a given year (site-year) produces one point on the soil test calibration curve.

Determining net returns (profit) generated by phosphorus (P) and potassium (K) use comes from experimental data. The increase in yield will largely determine the profitability of P and K fertilization. Realistically, it is not possible to collect P and K response data on every farm. Consequently, actual responses to P and K use at a particular site are usually unknown. However, guidance in the rates of P and K to use can be determined from long-term university experiments on many soils in a given state over many years. These data provide a first approximation of realistic amounts to apply and the responses a farmer may expect.

Figure 1 demonstrates the principle common to almost all calibration curves: Lower soil test levels are associated with lower yields and a higher probability of crop response to P or K inputs. An important feature of the soil test calibration curve is the *critical level*. The critical level is the soil test below which yield response to applied P or K is more probable. Above the critical level, soil test levels are not expected to limit yields, and little crop response from broadcast P or K is expected.

Yield response to P and K broadcast applications at various soil test levels can be roughly estimated from soil test calibration data. The underlying assumptions of such estimates are 1) factors other than P or K do not prevent a crop from reaching the yield goal, 2) university recommended rates are optimum for a site, 3) crop response at a particular site will reflect a response estimated from many sites and years, and 4) yields, after fertilization, will approach 100 percent relative yield. Using **Figure 1** as an example, that means that P applied at recommended rates to a soil testing 2 parts per million (ppm) Olsen P is capable, over the long-term, of increasing winter wheat yields by 35 percent. If this percentage increase is multiplied by the yield goal, it can be converted to a bushel estimate. For instance, if the yield goal is 75 bu/A, estimated increase in yield from following university recommendations for broadcast applications is 0.35 x 75 bu/A, or approximately 26 bu/A.

Examples of calibration data from several states and crops are reproduced in **Tables 1** and **2**. They should be interpreted with the

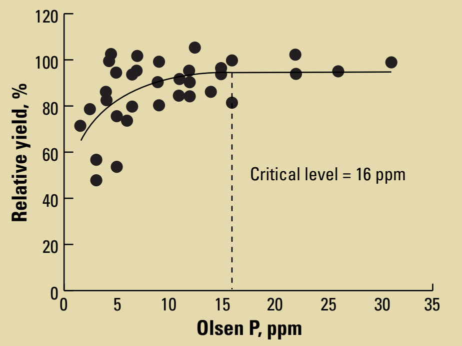

Figure 1. South Dakota soil test calibration data for winter wheat. Data from 34 site-years, 1986-1996 (R. Gelderman, J. Gerwing, C. Stymiest, and S. Haley, SDSU).

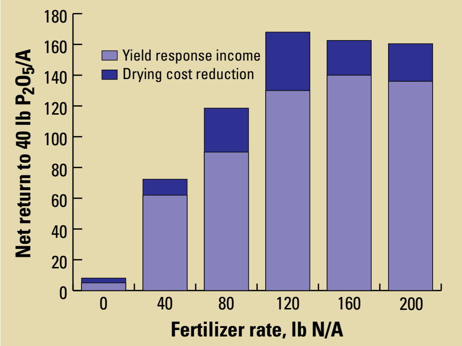

Figure 2. Phosphorus hastens maturity and lowers drying costs, adding to the return to P fertilization (K. Dhuyvetter and A. Schlegel, KSU).

assumptions outlined above. Where they exist, long-term, local data should be used to refine response estimates based on these data.

The amount of P and K required to raise soil test levels by 1 ppm (termed buffer capacity) depends on local conditions and management practices. (A review of this complex topic by D.F. Leikam is available in the 1992 Proceedings, North Central Extension – Industry Soil Fertility Conference.) Some university-Extension publications provide average values that may be used as general estimates. For instance, the University of Illinois *Agronomy Handbook* suggests that 18 lb P_2O_5/A and 8 lb K_2O/A be used as application rates needed to raise P and K soil test levels by 1 ppm. The magnitudes of crop responses to P and K in any single year can be quite variable. There are many factors that interact with P and K to influence crop growth and development. It is beyond the scope of this paper to discuss these. However, one must be aware that factors such as levels of other nutrients, diseases, insects, moisture level, etc. will influence how crops respond to P and K in a particular year.

Usually, the data comprising soil test calibration curves come from studies that focus on the influence of either P or K on yields. All other nutrients are applied at rates believed non-limiting for crop production. Results from such a study are shown in **Table 3.** These data represent a part of the larger P rate study conducted on winter wheat in South Dakota shown in **Figure 1.** It is interesting to note the differences in yield responses between two sites with similar soil test levels. The Watertown site showed dramatic wheat yield increases to P, while the Ideal site showed no response. The non-responsiveness of the Ideal site was attributed to dry weather and miner-

TABLE 1. Phosphorus calibration examples (Bray P-1, except where noted).

Soil test level, ppm	Average relative yield, % Corn Iowa	Corn or Soybean Illinois	Spring wheat N. Great Plains[1]	Winter wheat Kansas
2.5	66.5	42.0	61.2	35.0
5.0	77.3	54.8	78.0	56.4
7.5	86.7	69.3	85.9	73.6
10.0	91.3	81.3	90.4	82.1
12.5	94.1	90.2	93.3	87.9
15.0	95.9	94.7	95.4	92.3
17.5	97.1	97.3	97.0	95.0
20.0	98.0	98.0	98.2	97.1
22.5	98.7	98.6	99.1	98.2
25.0	99.3	99.1	99.9	99.3
27.5	99.6	99.5	100.0	100.0
30.0	99.8	99.8		
32.5	99.9	100.0		
35.0	100.0			

[1]Olsen P

Data: Potash & Phosphate Institute, PKMAN: A tool for personalizing P and K management. Version 1.0.

alization of P from the previous alfalfa crop. The Watertown site was fallow the previous year. These data show that responses to P and K are not always predictable for a given year. Response at any given site and year from broadcast applications can be either greater or less than these long-term averages, depending on local conditions and how many yield-limiting factors are present. Long-term studies do show that soil test levels are an important indicator for determining the long-term probability and profitability of a yield response to fertilizer additions. Keeping in mind the limitations and assumptions outlined above, producers lacking local P and K response data can use the data in **Tables 1** and **2** to begin quantifying possible risks and benefits of P and K fertilization.

Economics of Banded P and K Placement

Increasing yields with P and K can occur even on soils testing high and very high in these nutrients. The previous discussion demonstrated the importance of soil test levels on estimating crop response to broadcast P and K applications. However, it is well known that P and K, applied in starters or banded in other ways, can produce benefits even at high to very high soil test levels. Data in **Table 4** demonstrate the economic benefits of starter K on corn yield. In this example, an investment in 20 lb K_2O applied as starter increased net returns at low costs per added bushel. Banded placement of P and K provides higher concentrations of these nutrients near roots, increasing their availability. Increased availability is especially important when conditions inhibit root proliferation and/or crop development. Examples of such conditions are a cool, wet spring or a late planting of corn hybrids with longer relative maturities.

Banded fertilizer applications are especially important in reduced-tillage systems. Placement of P and/or K below the soil surface can boost yields on soils that have higher concentrations of P or K occurring near the soil surface. Data from Minnesota show the economic advantage to using banded K in a ridge-till system (**Table 5**). In this example, the highest net returns resulted from the 20 and 40 lb K_2O/A rates. Profitable responses occurred even with higher costs associated with band applications. Yield increases resulted from placing K deep in the ridge where nutrient depletion had been greatest. These are examples illustrating that there is more to economic decisions about P and K fertilization than simply soil test levels. The entire cropping system must be evaluated to determine the best strategy for managing P and K in a profitable manner.

TABLE 2. Potassium calibration examples (ammonium acetate).

Soil test level, ppm	Average relative yield, % Corn Missouri	Corn Illinois	Soybean Illinois
60	62.0	52.5	59.5
70	69.8	66.0	66.0
80	76.3	74.5	73.5
90	82.0	82.0	79.6
100	86.8	87.2	85.2
110	91.0	91.9	90.2
120	96.0	95.0	94.6
130	97.0	97.1	97.1
140	98.3	98.4	98.4
150	99.6	99.3	99.3
160	100.0	99.9	99.9
170		100.0	100.0

Data: Potash & Phosphate Institute, PKMAN: A tool for personalizing P and K management. Version 1.0.

TABLE 3. Winter wheat yields resulting from P treatments, 1995. Phosphate applied with the seed as 0-46-0.

Rate of P_2O_5, lb/A	Site: Ideal, 4.5 ppm Olsen P (bu/A)	Site: Watertown, 5.0 ppm Olsen P (bu/A)
0	33	39
25	32	49
50	34	45
75	31	56
100	32	73
Significant response?	No	Yes

Data: R. Gelderman, J. Gerwing, C. Stymiest, and S. Haley (SDSU).

Value-Added Income Associated with Fertilizer Use

Benefits of P and K fertilization go beyond yield increases. These nutrients often improve crop quality which can lead to premiums being paid. Some of the benefits of P and K are summarized below.

Benefits of P:

- Increased nodulation and greater nitrogen (N) fixation
- Better water use efficiency
- Improved disease resistance
- Higher crop quality
- Earlier maturity
- Increased root growth: can lead to improved yield under moisture stress

Benefits of K:

- Increased nodulation and development
- Increased ability to withstand drought stress
- Improved disease resistance
- Higher crop quality
- Increased grain development
- Increased kernel plumpness
- Reduced lodging
- Improved winter-hardiness
- Better N use efficiency

The contribution of crop quality to gross revenue is usually not straightforward. It is often difficult to know the true value of increased root growth or improved disease resistance. For this reason, quality is often not considered in fertilizer economics. Occasionally, however, some studies are conducted that allow contributions of crop quality to be quantified. **Figure 2** demonstrates the economic impact of earlier maturity and therefore lower grain moisture after P fertilization. Fertilizer expenses used in this calculation were annual costs of sampling, application, handling, har-

TABLE 4. Corn yield and economic benefits of row K at various soil test K levels (Wisconsin).

K soil test, lb/A	Corn yield at two K rates: 0 lb K_2O/A	20 lb K_2O/A	Added yield	Added gross return[1]	Added cost[2]	Net return	Cost per added bushel, $/bu
	bu/A			$/A			
158	105	127	22	44.00	14.59	29.41	0.66
167	117	158	41	82.00	20.67	61.33	0.50
227	143	158	15	30.00	12.35	17.65	0.82
331	142	162	20	40.00	13.95	26.05	0.70

[1]Corn price set at $2.00/bu.
[2]Added costs include additional harvest costs ($0.32/bu), potash cost (0.14/lb K_2O), band application cost of $4.00/A, and soil sampling costs of $0.75/A. (See discussion for **Table 1** in Part 3 of this series.)

TABLE 5. Deep banded K boosts yields and profitability on a soil testing 157 ppm K in a ridge-till system (Minnesota).

Deep banded K_2O/ rate, lbs/A	Corn grain yield, bu/A	Yield increase, bu/A	Added gross return	Added cost	Net return	Cost per added bushel, $/bu
			$/A			
0	153	—	—	—	—	—
20	162	9	18.00	10.43	7.57	1.16
40	162	9	18.00	13.23	4.77	1.47
60	159	6	12.00	15.07	-3.07	2.51
80	165	12	24.00	19.79	4.21	1.65

[1]Corn price set at $2.00/bu.
[2]Added costs include additional harvest costs ($0.32/bu), potash cost (0.14/lb K_2O), band application cost of $4.00/A, and soil sampling costs of $0.75/A. (See discussion for **Table 1** in Part 3 of this series.) Base cost without K: $300/A; corn sale price: $2.25/bu; band applications: $4.00/A.

vest, and drying costs listed in **Part 1**, **Table 1** (see page 21). A low corn price of $2.00/bu was assumed. Phosphate cost was not amortized.

In times of low crop prices, farmers need to understand what benefits are possible from P and K fertilization. Local data, collected over many sites and years, provide a good basis for estimating crop response to these nutrients. However, where such research does not exist, the approaches presented in this paper for estimating response provide a first approximation of yield increases that may occur. It is also important to realize that there is more to managing P and K than just soil test levels. Banded P and K applications can be profitable even on soils that test high in these nutrients. Proper P and K management strategies require knowledge about the benefits of these nutrients under management practices unique to each farmer.

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New Book Available... Fertilizer Technology and Application

A new book titled *Fertilizer Technology and Application* offers easily accessible information on the production and application of commonly used fertilizers, lime and gypsum. The intended audience of the book includes agronomists, fertilizer dealers, crop consultants, researchers and teachers of soil fertility and fertilizers, and others around the world.

The 200-page book is authored by J.J. Mortvedt, L.S. Murphy, and R.H. Follett. The price is $34.95 plus $6.00 for shipping and handling. Copies can be purchased from Meister Publishing Company, 37733 Euclid Ave., Willoughby, OH 44094; phone (440) 942-2000 and fax (440) 942-0662.

Information Agriculture Conference Rates High Marks from Participants

InfoAg99 drew more than 600 participants August 9, 10 and 11 to the campus of Purdue University, West Lafayette, Indiana. Program tracks featured data analysis, site-specific management guidelines, communications technology in agriculture, a nutrient management planning workshop, and business aspects of precision agriculture. Updates on technology such as the global positioning system, geographic information systems, remote sensing, variable rate application, and other site-specific topics were featured. New tools in nutrient management planning were introduced at InfoAg99, recognizing the importance of livestock manure considerations in crop production. A new publication series called Site-Specific Management Guidelines was also part of the proceedings.

The conference was organized by PPI/PPIC, Foundation for Agronomic Research (FAR), and Purdue, in cooperation with other sponsors and supporters. For more about the Information Agriculture Conference, call (605) 692-6280, fax (605) 697-7149, or check the website at www.ppi-far.org/infoag99.