Providing Flexibility in Phosphorus and Potassium Fertilizer Recommendations

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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.

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.

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' lev-

els). 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

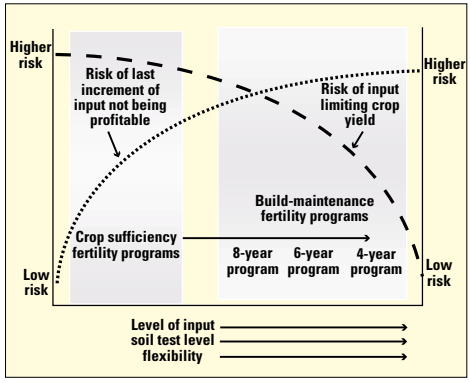

Figure 1. Crop sufficiency vs. build-maintenance nutrient management approaches.

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.

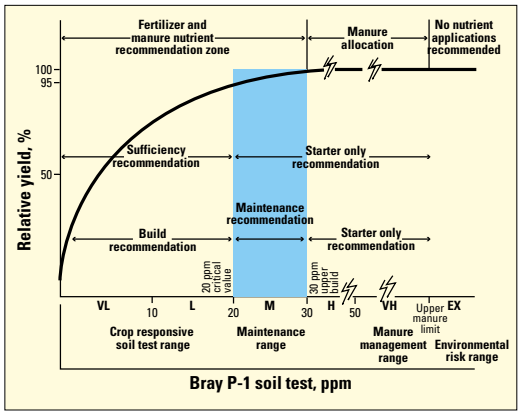

Figure 2. Phosphorus management model for Kansas crop production and manure management.

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

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