CROP INSIGHTS

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Phosphorus and Potassium Fertility for Corn and Soybean

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Summary

- Consider precision soil sampling methods in conjunction with variable rate technology to improve P and K management and maximize returns on fertilizer investment.
- Soil test results can be interpreted based on management style, market conditions and risk position to maximize short-term returns following a "nutrient sufficiency" philosophy or to insure consistent returns over the long-term following a "build and maintain" philosophy.
- Nutrient sufficiency recommendations are designed to provide 90 to 95% of maximum yield and a high rate of return per unit of fertilizer applied.
- Build and maintain recommendations are designed to provide 100% of maximum yield with low risk of yield loss due to insufficient fertility.
- No matter which philosophy is used to determine P and K rates, return to fertilizer investment is greatest for low testing soils. Avoiding unnecessary fertilization of high-testing soils increases profitability.
- Banded P and K applications are best suited for specific situations, including soils that are slow to warm in the spring and soils that are managed under no-till or conservation tillage.
- Nutrient removal due to silage or crop residue harvest should be considered when determining fertilizer rate recommendations. Delaying residue harvest can reduce nutrient removal rates.

Introduction

Recent years have seen increased price volatility for both farm inputs and products. Few inputs have experienced such dramatic price fluctuations relative to grain as have phosphorus (P) and potassium (K) fertilizers (Figure 1). Given unstable market conditions, careful management of fertilizer inputs is more important than ever to maximize net returns. This *Crop Insights* describes best P and K fertility management practices for corn and soybeans in an era of high prices and market uncertainty.

Soil Sampling – Precision Methods

Regular soil testing is the foundation of sound P and K fertility. Compared to the cost of fertilizers, soil testing is inexpensive and offers a good return on investment. To provide the best diagnostic information, soil samples should be collected from a given field every two to four years. The previous *Crop Insights* on *Soil Sampling and Test Interpretation* provides a thorough overview of soil sampling techniques (Diedrick, 2011).

Fertilizer P and K are often broadcast applied in the fall following soybean harvest. Image courtesy of John Deere.

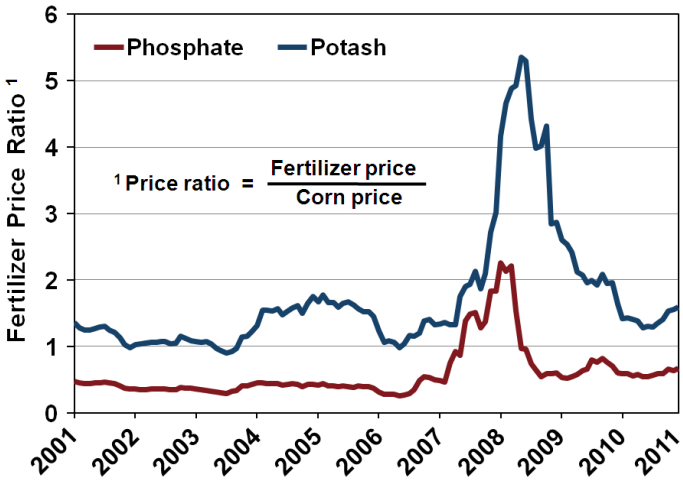

Figure 1. Monthly price ratios for phosphate and potash fertilizers over the course of the last decade.

Research has shown that precision soil sampling can improve P and K management and return on fertilizer investment when combined with variable rate application technologies (Ferguson and Hergert, 2009). Two common methods of precision sampling are management zone and grid sampling (Figure 2).

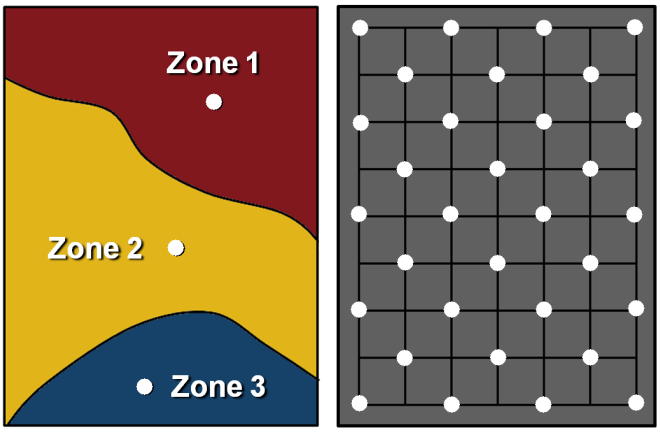

Figure 2. Left. Management zone sampling, resulting in three composite samples for a 48-acre field. **Right:** Grid sampling of the same field. Sampling points are spaced every two acres in an offset pattern, resulting in 32 composite samples.

Management Zone Sampling is an extension of good soil sampling practices and involves collecting separate samples for field areas that have different underlying soil types or management histories. Management zone sampling is most useful when pre-existing spatial information or experience provides direction on zone delineation. For management zone sampling, it is recommended that 10 cores be collected from each zone and composited into a single sample for analysis.

Grid Sampling involves collecting regularly spaced samples throughout fields. Typically, grid sampling points are spaced on 1 to 3 acre intervals, with 5 or more cores being collected at each point and composited into a single sample for analysis. Grid sampling is recommended for small and/or highly variable fields and for fields with a history of confined livestock or heavy manure applications.

Management zone and grid sampling are both suitable methods for precision soil sampling, but each has advantages and disadvantages. Sample collection and analysis costs are higher for grid sampling, while management zone sampling may fail to detect variation that isn't evident from other sources of spatial information.

Interpreting Soil Test Results – Nutrient Sufficiency vs. Build and Maintain

Whether using precision or standard sampling methods, soil test results ultimately serve as the basis for making P and K rate recommendations. Soil test interpretations and fertilizer recommendations vary among regions and states, but most approaches can be described in terms of two dominant fertility paradigms, ***nutrient sufficiency*** and ***build and maintain***:

Nutrient Sufficiency is a philosophy for P and K fertility that focuses on applying the minimum amount of fertilizer needed to maximize profitability in the year of application, with no concern for future soil test values or fertilizer requirements. Generally, recommendations based on nutrient sufficiency will provide 90 to 95% of maximum yield and a high rate of return per unit of fertilizer applied. The nutrient sufficiency approach is **most logical** when:

- fertilizer prices are high relative to grain prices
- resources are limited in a particular year
- growers are operating under a short-term land tenure situation
- soils have a high capacity to convert readily available P and K to forms that are unavailable to crops in the short-term

Disadvantages of nutrient sufficiency-based recommendations include:

- the need for regular and accurate soil testing
- precise knowledge of optimum application rates
- risk of limiting long-term crop productivity

Build and Maintain fertility programs contrast with the nutrient sufficiency approach in that they are not intended to maximize economic returns in any given year. Rather, they are designed to provide flexibility and consistent economic returns over the long-term by removing P and K as yield-limiting factors. At low soil test levels, build and maintain recommendations focus on increasing P and K to the critical test level and maintaining soil nutrient supply at or above this point through application of additional fertilizer to account for crop removal (see Table 1 for critical levels and crop removal rates). Build and maintain programs also advise that fertilizer be applied to account for crop removal in the optimum soil test range. Generally, recommendations based on a build and maintain philosophy will provide 100% of maximum yield with low risk of yield loss due to insufficient fertility.

Table 1. Critical P and K soil test levels and crop removal rates for corn and soybeans (Warncke, et al., 2004).

Crop	Critical Soil Test Level					Crop Removal	
	P	K at CEC[1]				P_2O_5	K_20
		5	10	20	30		
	- - - - - - - - -ppm - - - - - - - - -					- lb/bushel -	
Corn	20	88	100	125	150	0.37	0.30
Soybean	20	88	100	125	150	0.80	1.50

[1] Critical soil test level for K = 75 + (2.5 x CEC) for corn and soybean.

The build and maintain approach is **attractive** when:

- grain prices are high relative to fertilizer
- recent or complete soil test data are unavailable
- crop yields are expected to increase in the future
- resources are currently available and fertilizer prices are expected to increase in the future

Disadvantages of build and maintain-based recommendations include:

- higher fertilizer cost during the build phase when soil test levels are below the critical value
- risk of sub-optimal economic return in a given year

It is important to note that application of P and K at higher than economically optimal rates in a particular year can offset fertilizer requirements in future years. Both P and K are relatively stable in soils and can be, "banked" for later use if economically advantageous.

Equipment advances allow for accurate fixed- or variable-rate application of dry fertilizer. Photo courtesy of Case-IH.

Rate recommendations for P and K fertilization based on the nutrient sufficiency and build and maintain paradigms are presented in Tables 2 and 3.

Table 2. Phosphorus rate recommendations for corn and soybean based on nutrient sufficiency and build and maintain approaches. Adapted from Warncke, et al., 2004.

	Soil Test (ppm)				
Basis for Recommendation	**Very Low (0-8)**	**Low (9-15)**	**Opt. (16-20)**	**High (21-30)**	**Very High (31+)**
	lb P_2O_5/acre/yr				
Nutrient Sufficiency (corn and soybean)[1]	60-100	25-55	0-20	0	0
Build and Maintain (corn)[2]	125-165	90-110	65-85	0-65[4]	0
Build and Maintain (soybean)[3]	110-150	75-95	50-70	0-70[4]	0

[1] Calculated as: [(Critical level - soil test) x5]

[2] Nutrient Sufficiency + crop removal at 175 bu/acre yield

[3] Nutrient Sufficiency + crop removal at 60 bu/acre yield

[4] Fertilize high testing soils only under favorable crop and fertilizer prices or as a band at planting

Table 3. Potassium rate recommendations for corn and soybean based on nutrient sufficiency and build and maintain approaches. Adapted from Warncke, et al., 2004.

	Soil Test (ppm)				
Basis for Recommendation	**Very Low (0-70)**	**Low (71-110)**	**Opt. (111-150)**	**High (151-180)**	**Very High (181+)**
	lb K_2O/acre/yr[1]				
Nutrient Sufficiency (corn and soybean)[2]	110-250	30-100	0-25	0	0
Build and Maintain (corn)[3]	160-300	80-150	50-75	0-50[5]	0
Build and Maintain (soybean)[4]	200-340	120-190	90-115	0-90[5]	0

[1] Recommendations based on a K critical value of 125 ppm at CEC of 20 meq/100 g

[2] Calculated as: [(Critical level - soil test) x5]

[3] Nutrient Sufficiency + crop removal at 175 bu/acre yield

[4] Nutrient Sufficiency + crop removal at 60 bu/acre yield

[5] Fertilize high testing soils only under favorable crop and fertilizer prices or as a band at planting

It is often said that nutrient sufficiency recommendations focus on feeding the crop, while build and maintain recommendations focus on feeding the soil. Both approaches are valid. The decision to adopt one strategy over another ultimately depends on market conditions, management style and risk position (Leikam et al., 2010).

In reality, P and K rate recommendations provided by most university extension services incorporate elements of both nutrient sufficiency and build and maintain strategies. For example, Iowa State University's recommendations fall between strict interpretation of either paradigm at low soil test levels, but conform to the build and maintain philosophy at and above the optimum soil test range. In contrast, Michigan State University's recommendations embrace a build and maintain philosophy but include underlying equations allowing users to determine rate recommendations based on either approach. Kansas State University offers separate nutrient sufficiency and build and maintain rate recommendations.

Regardless of which paradigm or set of guidelines is used to develop rate recommendations, the following general rules of thumb apply (Figure 3):

- Always fertilize when soil test levels fall below the optimal range. Risk of yield loss is high and return to fertilizer investment is greatest for very low and low testing soils.

- Avoid application on high testing soils and never apply on soils that test in the very high range. Return on fertilizer investment decreases as soil test level increases.
- When in doubt, fertilize based on expected rates of crop removal.

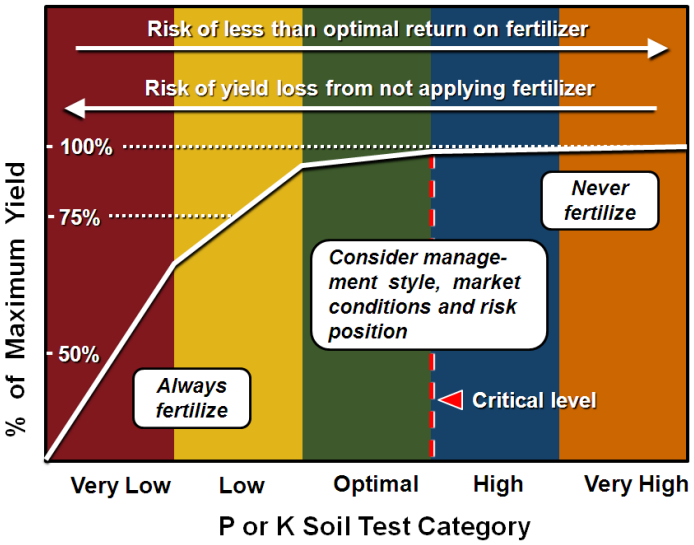

Figure 3. Fertilizer response, risk factors and general fertility guidelines with respect to soil test category.

Fertilizer Timing and Placement

It is often most convenient to apply P and K in the fall after other field operations are complete and when weather and soil conditions make compaction less of a concern. In some years, however, late harvest and/or unfavorable weather prevent fall applications. In such cases, application prior to planting in the spring is just as effective, as long as soil test levels are above the very low range. Avoid applying P and K on frozen or snow-covered fields due to high risk of loss with surface run-off. Biannual P and K applications are equally as effective as annual applications, as long as the biannual application rate accounts for the nutrient needs of two crops.

Various banded and starter application methods have been evaluated for increasing P and K efficiency. Banded and starter fertilizers can offer advantages in certain situations (Mallarino, 2009). Specific cases where banded and starter P and K applications may be beneficial include:

- Heavy or wet soils that are slow to warm in the spring
- Soils that are high testing for P and/or K, on average, but are characterized by a high degree soil test variability
- No-till, when there is evidence of P and/or K stratification at the soil surface
- Strip-till and zone-till, for which P and K are typically banded at planting
- Calcareous and high pH soils

Silage and Residue Harvest

Harvest of corn silage and crop residues for livestock feed, bedding or as industrial feedstocks will result in additional nutrient removal that should be considered when determining fertilizer rate recommendations (Table 4). While silage and residue harvest lead to slightly increased rates of P removal compared to grain harvest alone, rates of K removal with residue harvest can be moderate to significant, depending on time of harvest. Both P and K leach from corn and soybean plants following physiological maturity (Figure 4). Delayed residue harvest, therefore, can reduce P and K removal rates. Recent Iowa State research reported that corn non-grain K decreased by 25% between physiological maturity and grain harvest, while soybean non-grain K decreased by 65% over the same period.

Table 4. Nutrient removal rates for silage and residue harvest at physiological maturity (Sawyer et al., 2011.)

Crop	Removal	
	P_2O_5	K_20
	- - - - - - lb/dry ton - - - - - -	
Corn silage	5.4	12.3
Corn stover	5.9	25.0
Soybean stover	2.8	9.9

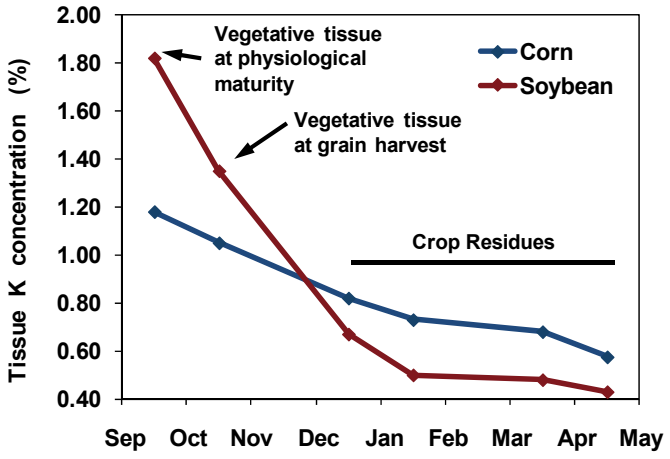

Figure 4. Decline in vegetative K by corn and soybean following physiological maturity. Adapted from Mallarino et al., 2011.

Conclusions

In an era of volatile commodity markets, careful management of P and K fertilizers is more important than ever. Soil test results can be used in conjunction with information regarding P and K removal rates to develop fertilizer rate recommendations that best fit market conditions, management style and risk position. Rate recommendations can be developed to

maximize short-term returns following a nutrient sufficiency approach, or to provide consistent, long-term profitability following a build and maintain approach. Consult state extension guidelines or local Pioneer sales professionals for region-specific rate recommendations. Precision soil sampling and variable rate technology can help to match P and K inputs to crop needs and improve return on fertilizer investment. Fertilizer placement methods can also improve fertilizer efficiency under certain circumstances. Crop residue harvest increases nutrient removal, especially K and, should be factored into future fertilizer rate recommendations.

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