Fertilizer Economics – Allocating Funds Across Nutrients

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Introduction

The most common question expressed at crop production meetings this past summer and fall has been **"How much can I cut back on fertilizer and not decrease my crop yields?"**,there is no simple answer to this question. The correct answer is "It depends.", and it is important to understand what plant nutrient applications will most affect the yield of a specific crop, on a specific field. Fertilizer prices have increased dramatically over the past four years. For example nitrogen (N) has gone from around \$0.40/lb of N in year 2005 to as high as \$0.90/lb N in year 2008, the same comparisons for phosphorous (P) and potassium (K) are respectively \$0.30/lb P2O5 to \$1.00/lb P2O5, and \$0.15/lb K2O to \$0.59/lb K2O. However, just cutting back on fertilizer applications may end up decreasing yield to the point where lower net incomes result. It can be useful to understand some of the basic principles of allocating funds across nutrients when a grower is in a situation where all needed nutrients cannot be purchased.

Allocating Funds to One Nutrient

If there is a necessity to cut back on the amount spent when one nutrient is needed, it is important to apply the nutrient to areas of a field where the greatest yield response is expected. Figure 1 demonstrates a conceptual model of crop response to soil nutrient supply. In this example, crop yield increases until a point of sufficiency is reached, after which crop yield doesn't increase (Murrell and Bruulsema 2008). The three smaller graphs to the right of the main graph give a visual description of the size of the short-term economically optimum rate (EOR). In graph A, when a nutrient is low in availability the EOR from applying the nutrient is quite narrow due to the excellent response to the nutrient. In graph B the EOR is wider because the response to the added nutrient is less and the optimum point is more affected by fertilizer prices. I the final graph C, there is no EOR because the soil contains a sufficient level of the nutrient so no yield response is obtained by adding more of the nutrient as fertilizer.

Allocating Funds across Two Nutrients

If a crop responds to two or more nutrients there becomes a necessary choice as to how to divide the allocation of funds between the two nutrients applied as fertilizer. In Figures 2 and 3 the curved lines illustrate the effect of supplying different levels of each nutrient on the yield of a crop. The three lines shown represent possible yields at a low yield, medium yield and high yield respectively. The crop yield is consistent all along the curved line but the amount of each fertilizer nutrient relative to the other changes. The optimum point economically is the point of the curves where there is no room for reduction of either nutrient, rates of nutrients are minimized and costs for nutrients are also minimized without negatively affecting yield.

The Effect of Placement in Confined Bands near the Seed-Row of a Crop

Figure 4 illustrates the comparative effect of placing a lower rate to a higher rate of one nutrient where it will be intercepted sooner by crop roots, compared to broadcasting and incorporating the fertilizer nutrient throughout the topsoil. The low rate response is more affected by placement than the high rate response. This is typical of the positive yield response we observe for P and K when seed-row applied compared to broadcast incorporation applied.

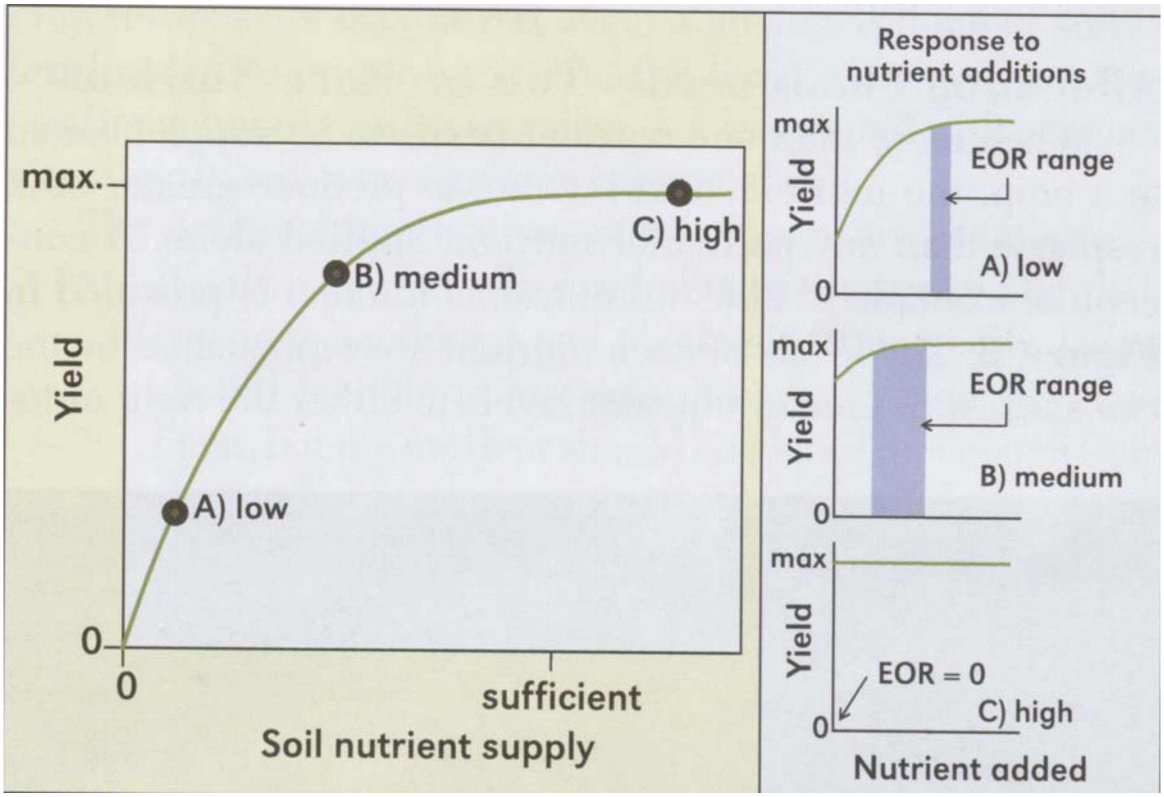


Figure 1. A conceptual model of crop response to soil nutrient supply. Also shown are model crop responses to nutrient additions for A) low, B) medium, and C) high soil nutrient supplies. The shaded areas below the curves in A) and B) show the range in short-tem economically optimum rates (EOR) based on various crop and nutrient prices. (Murrell and Bruulsema 2008)

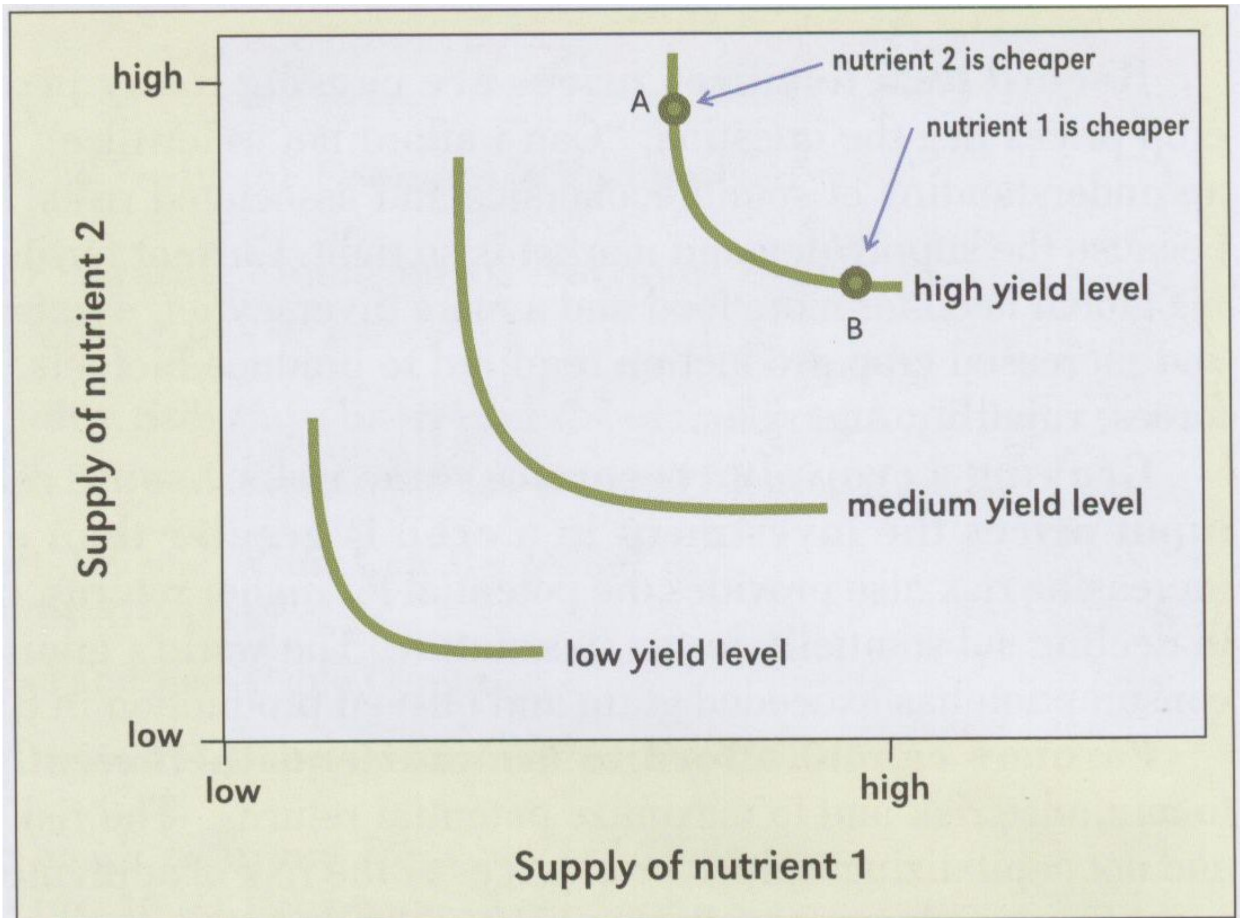


Figure 2. A conceptual model of the interaction of two nutrients on crop yield. Each curve represents a single yield level, indicated as low, medium, or high (adapted from Figure 2-4 on p. 99 in Black, 1993), (Murrell and Bruulsema 2008).

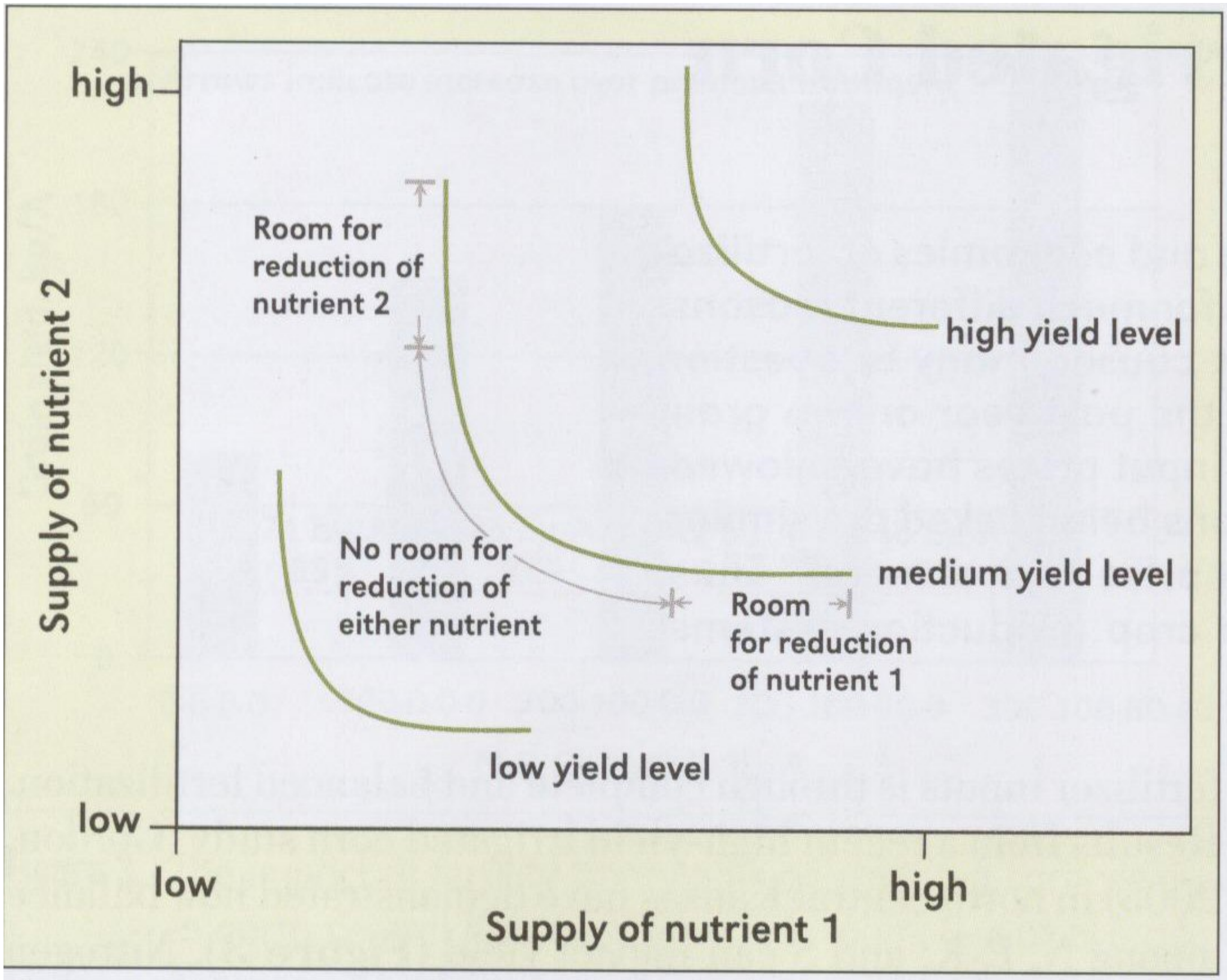


Figure 3. The conceptual model described in Figure 2 with risk assessments imposed.

(Murrell and Bruulsema 2008)

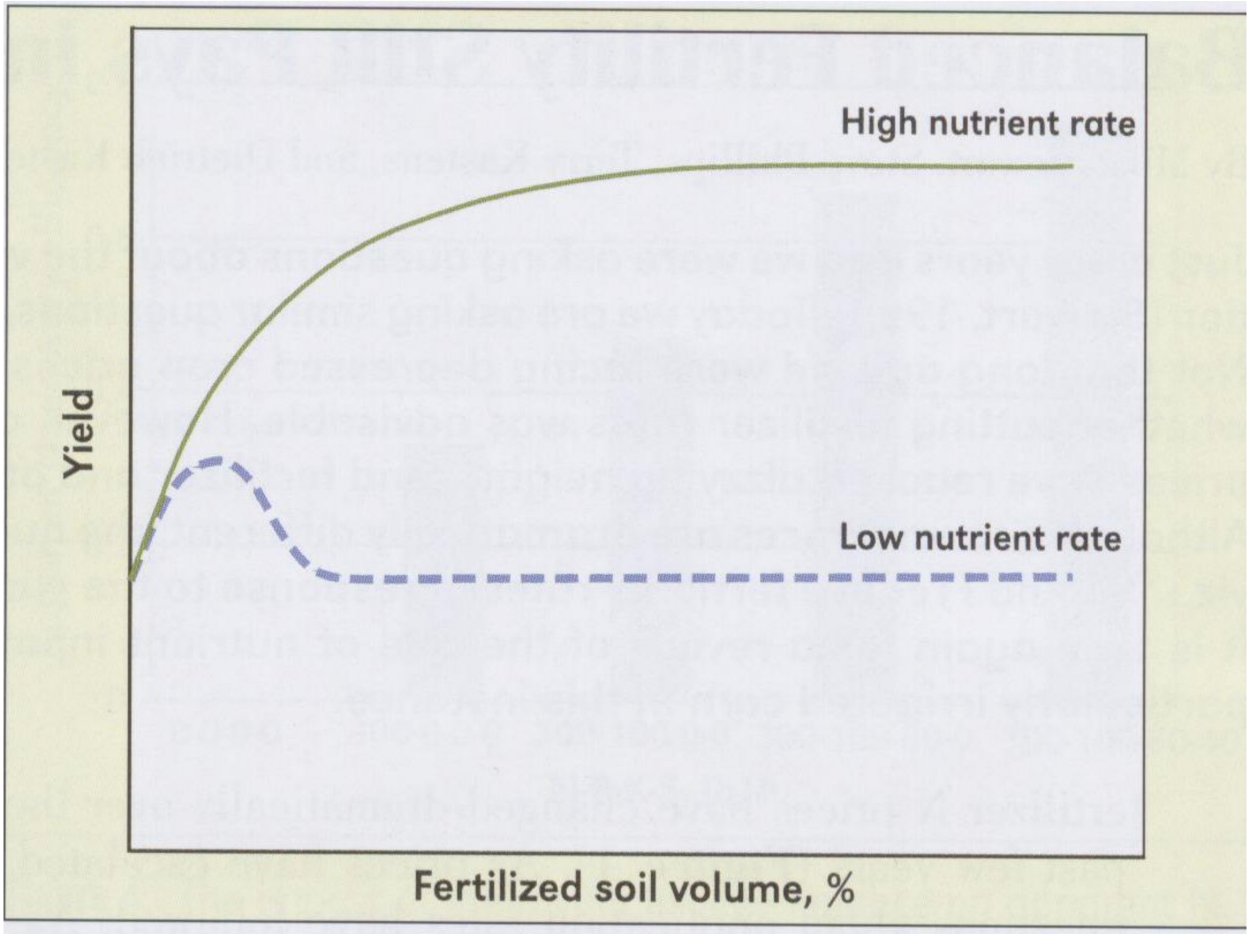


Figure 4. A conceptual model of the interaction of nutrient rate with placement upon crop yield (adapted from Anghinoni and Barber, 1980).

(Murrell and Bruulsema 2008)

Applying the Conceptual Theories in Real Life Situations

When asked by a farm customer "How much can I cut back on fertilizer and not decrease my crop yields?" it is useful to ask some questions of the customer to gain a better understanding of what information is really wanted. Such questions that can encourage a response so you can better understand are as follows.

- What do you mean when you say you will cut back on fertilizer?
- Do you think your regular fertilizer rates are excessive?
- Are you only looking at decreasing your rates because fertilizer prices have increased?
- Have you considered each field separately and how a broad, general "cut-back" in fertilizer rates on all fields will affect yield on specific fields?
- Will you increase your fertilizer rates again when fertilizer prices decrease relative to crop prices?

Responses to the Question "What do you mean when you say you will cut back on fertilizer?"

1. **"I won't reduce my N rates much as this will adversely affect my yields right away. I'll just fine tune my rates of N."**

In this instance it is useful to base fertilizer rate decisions on soil-test results, or apply based on crop uptake and removal. The key is to add sufficient N to obtain a crop yield that yields well while maximizing returns to the fertilizer investment. This means add enough but not too much.

2. **"For P, K, S and micronutrients, I will apply two-thirds to one-half as much P, and skip K, S, and micros."**

This approach may be valid if used in the short-term (1 to 2 years) on a field where there has been a consistent program of applying more than what the crops require as a minimum and the background availability of P, K, S and other secondary and micronutrients is sufficient. However, lower yields and decreased net returns may result if used on a field where there has not been building up of these other nutrients and soil-test results show marginal to deficient availability.

Specific Challenges with Reduced Phosphorous Rate Strategies

1. **Designer P-based liquid starter applied at about one-third the normal rate of P.**

Designer P-based liquid starter solutions are applied at about one-third the normal rate of P. For example a 6-24-6 analysis solution can be applied at 3 US gal/A, this supplies P at about 8 lb of P2O5/A. This is in contrast to a common low rate of 24 lb P2O5/A if 46 lb of 11-52-0 is seed-row applied. This practice is marketed on the features of convenience and lower cost, but P rates are usually significantly lower than harvested crop removal. Also, the actual cost per lb of P2O5 is greater than when 11-52-0 is used. Even though crop yields may not decline significantly in the short-term the soil is being mined of P and in the longer-term crop yields and net returns will decline.

2. **A grower will apply P at rates one-half of the normal rates.**

It costs less per acre, but even though crop yields may not decrease in the short-term (i.e. 2 to 3 years), there is an effectual mining of the more easily available P out of the soil, and in the Longer-term lower crop yields will result.

3. **A grower can get a good deal on Rock Phosphate and will apply P at the regular rate (e.g. 24 lb P2O5/acre). For example $500/tonne for rock phosphate compared to $1150/tonne for 11-52-0, both farm delivered prices.**

Rock phosphate does contain P, but it is in a form that is less soluble and available to crops than the soluble forms of processed phosphate fertilizers such as granular 11-52-0, or liquid 10-34-0 (See Table 1). These more soluble fertilizer products are produced by acidulation (treating ground rock phosphate with sulfuric acid) and filtering to produce phosphoric acid and then this acid is reacted with anhydrous ammonia to produce granular ammonium phosphate, or liquid ammonium poly-phosphate respectively.

Rock phosphate applications can work quite well on very acidic soils (<pH 5.0) because the natural soil acidity reacts with the rock phosphate to produce phosphoric acid, but the rock phosphate needs to be ground finely and subsequently granulated to be used as a granular fertilizer. Unfortunately on high pH soils (>7.0) the natural acidulation process doesn't happen and additions of rock phosphate are often less effective.

Table 1. Comparison of the Solubility and Cost of Rock Phosphate and Mono-Ammonium Phosphate (11-52-0)

Product	P2O5 Content (% solubility)	Soluble P2O5 Content	Cost $/tonne	Cost $/lb P2O5 Total	Cost $/lb P2O5 soluble
Rock Phosphate	26.6% (21.9%)	5.8%	$500	$0.85	$3.90
11-52-0	52% (91.0%)	47.3%	$1150	$1.00	$1.10

Efficiency of P Fertilizers

The use of P fertilizer in the year of application by target crops has been measured using isotope ^{32}P-labeled fertilizer. Usually the amount used is 25 percent or lower (Syers et al 2008, pg 28). This is called calculating fertilizer use by the "Direct Method" and is calculated as the amount of labeled P taken up in the crop as a percentage of labeled P fertilizer applied. However, the P not used in the first year is residual in the soil and contributes to a pool of labile P that can be used over a number of years by subsequent crops. This means that the efficiency of applied P is much greater overtime. For example a conclusion by Syers et al (2008, pg 54) is that on many soils, added P is not irreversibly fixed in forms that are unavailable to plants. Consequently, the efficiency of use of P added in fertilizers is often high (up to 90 percent) when considered over an adequate time scale and when evaluated using the balance method. The "Balance Method" defines P use as the total P in the crop divided by the P applied, expressed as a percentage.

Ideal P Management

It has been suggested that an efficient management strategy for P fertilizer is to build up available P levels in a soil to a so-called "Critical Value", then to add P fertilizer to replace P removed with the harvested portion of a crop (Syer et al 2008, pg 54). It is further suggested that the soil be sampled at least every four to five years and tested to monitor the level of plant available P, if the test value is lower than the critical value then P rates should be increased, if the test value is greater than the critical value the P rates could be decreased (Figures 5 and 6). Under the soil, climate and crop conditions of the United Kingdom the current recommendation is to maintain soils at a level of 15-25 mg kg^{-1} of Olsen soil test P.

FIGURE 5
The theoretical realtionship between crop yield and the level of readily-plant-available P and K in soil

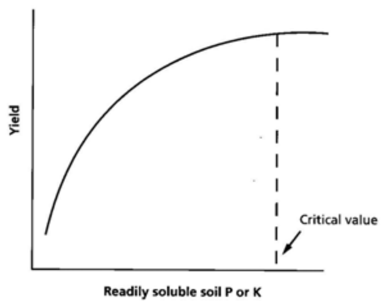
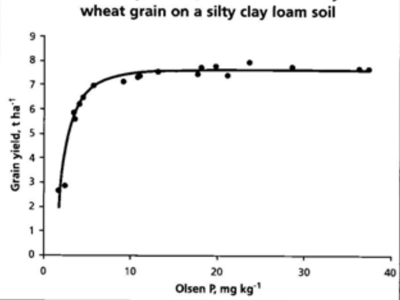


FIGURE 6
The relationship between Olsen P and the yield of wheat grain on a silty clay loam soil



(Adapted from Syers et al 2008, pg 40.)

Conclusions

1. The lower the amount of soil available nutrient in a field, there is less opportunity to cut back and save money, as crop yield will decrease along with a decrease in revenues greater than the amount saved by using less fertilizer.
2. When deciding how to allocate funds spent between two or more nutrients, it is important to know the costs of each nutrient and the expected yield response curve of each.
3. Help farm customers understand that each field they manage may have different background levels of available plant nutrients and that a broad cut-back on fertilizer rates on all fields, in response to an increase in fertilizer prices may result in lower net incomes.
4. Even though the apparent efficiency of P fertilizer may appear low (e.g. %25 or less) in the year of application using the direct method of measurement, the reality is that using the balance method over longer periods of time (e.g. 10 years or more), the efficiency of use can be as high as 90%.
5. Ideal P fertilizer management is to add P fertilizer to a soil specific critical response level and then maintain this level by replacing P removals in harvested portions of crops with equal amounts of P fertilizer.

References

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