

Sustainable Nutrient Use Efficiency in No-till Systems¹

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Nutrient use efficiency is receiving a great deal of attention today because of increasing fertilizer costs associated with natural gas costs and growing pressure for agriculture to minimize negative environmental impacts. Activity has intensified in many sectors and at various scales. Last year, the first formal meeting of the International Nitrogen Initiative was held in The Netherlands. This is a global effort with a primary focus on improving fertilizer nitrogen (N) efficiency in order to optimize N's beneficial role and minimize negative environmental effects using both scientific and policy tools. The Natural Resources Conservation Service (NRCS) is in the process of developing an incentive program to subsidize farmer practices that improve nutrient use efficiency (including fertilizers). Several fertilizer manufacturers are developing or marketing new fertilizer products that promise better yields with less nutrient loss via improved nutrient use efficiency.

Applying the concept of sustainability to nutrient use efficiency incorporates consideration of the long-term impact of a nutrient management practice on the production system. It is possible for a practice to appear highly efficient in the short term, but result in long-term negative impacts on the system or appear inefficient in the short term but have positive long-term effects.

Its time we sharpen our understanding of sustainable nutrient use efficiency.

Nitrogen vs Phosphorus and Potassium

Properly defining nutrient use 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. For example, in the last 25 years the agronomic efficiency of fertilizer N use on corn in the U.S. (bu grain per lb of N) has increased 39%. However, research on farm fields in the U.S. shows that 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 continue to increase these recovery efficiencies by better matching crop need with the amount, timing, and placement of N applied on a site-specific basis.

In most cases with N, practices that increase recovery efficiency result in less loss of N from the field via denitrification, volatilization, or leaching and thus not only make N fertilization more profitable, but reduce the potential for negative impacts on air or water quality. An exception is during the transition from conventional to no-till systems where net immobilization of fertilizer N occurs as soil organic matter levels increase. Research has shown this to be short-term, with N needs returning to levels similar to or below those of conventional tillage once the new equilibrium level of soil organic matter has been reached.

Applying the concept of agronomic efficiency as presented above to phosphorus (P) and potassium (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 (Figure 1). The concept of sustainable efficiency is more useful for nutrients where significant plant available reserves can accumulate in the soil, as is the case for P and K. Sustainable efficiency considers the nutrient input needed to sustain the system at optimum productivity, not just first year recovery by the crop of nutrient applied. It therefore considers the impact of a nutrient management practice on soil fertility. For example, banding a low rate of P may initially result in near optimum yields depending on soil test levels but will either increase future fertilizer need or result in reduced crop yield as soil tests

¹ Proceedings of the No-till on the Plains Winter Conference, January 26-27, 2004. Salinas, KS.

decline below optimum levels. The need to replace P removal at some soil level sets a lower limit for sustainable P use.

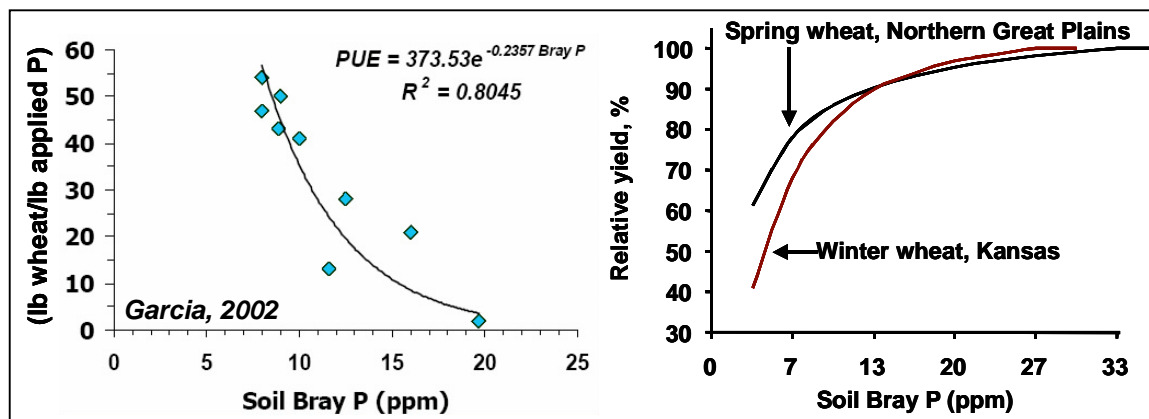


Figure 1. As soil test P level climbs, grain produced per unit of P fertilized applied (sometimes referred to as nutrient use efficiency) decreases but relative yield increases.

Nutrient Budgets as a Component of Sustainable P Use Efficiency

The previous discussion underscores the need to consider within-field nutrient budgets to avoid confusing efficient nutrient use with mining of soil nutrient reserves. Basically, use should replace removals at target soil test levels to conserve future productivity. If existing soil test levels are above targets, use can be less than removal; if below targets, use should be greater than removal. Target soil test levels are influenced by numerous factors including land tenure, crop rotation, capital supply, risk management, within-field variability, etc. Research has generally shown that even though P becomes highly stratified in no-till systems, no adjustment in target P levels is necessary. Apparently, effects such as increased mycorrhizal colonization, improved organic P cycling, or more favorable soil moisture contents generally compensate for potential problems related to P stratification.

Figure 2 shows that many soils in the Plains test medium or below in P and are generally in need of annual P additions at least equivalent to crop removal. State or province level nutrient budgets show that removal frequently exceeds P use.

These data mean nothing to P management for individual fields other than to amplify the need for soil testing and knowledge of field-specific P budgets. Free software (PKalc) to assist with calculation of P budgets for individual fields can be downloaded at www.ppi-ppic.org/toolbox.

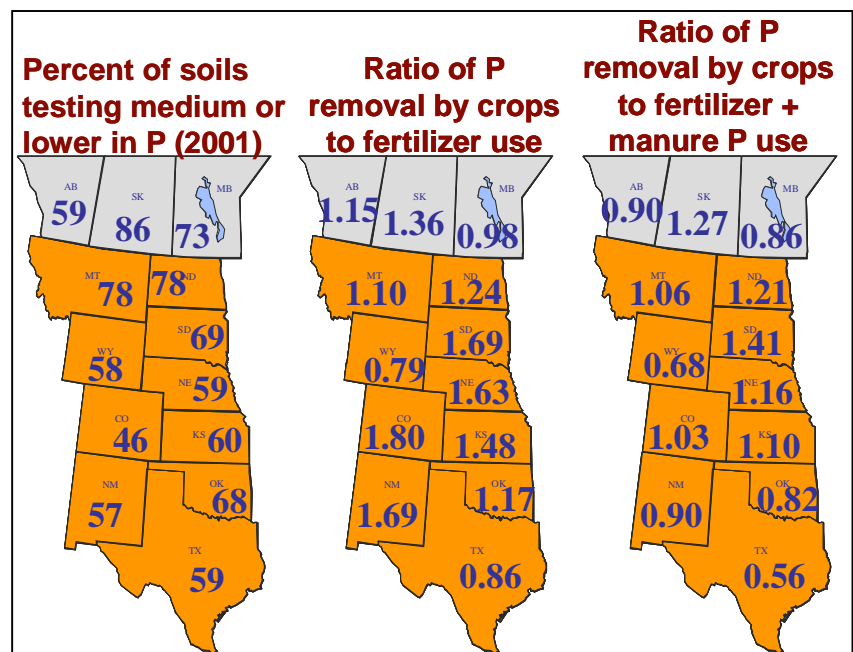


Figure 2. Soil test P levels and the ratio of P removal by crops to fertilizer P use plus recoverable P from manure.

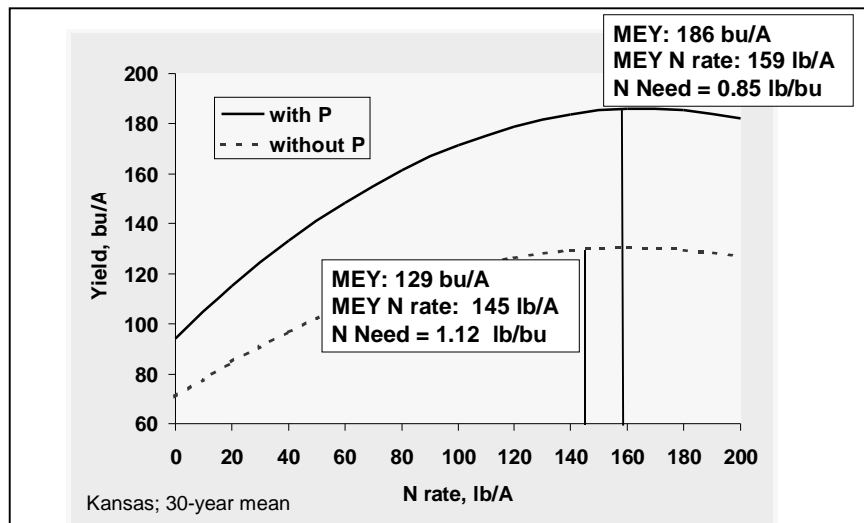
A Closer Look at P Efficiency

Because of the substantial residual effect of P fertilization on the P nutrition of future crops, first year recovery of P by the crop will usually greatly underestimate P use efficiency. The first crop following P application usually takes up only 5-30% of the P applied. However, that does not mean that 70 to 95% is lost. Long-term studies have shown response to single P applications lasting over a decade with recovery at times exceeding 75% of the P applied.

First year recovery of P is low, not because the P is immediately “fixed” into plant unavailable forms but because it moves so little in soils that crop roots are too far from much of the fertilizer-soil reaction zones to be accessed. Studies have shown that less than 30% of the surface soil volume can contribute P to a spring wheat crop simply because of the distance between adjacent roots relative to the diffusion rates of P. Roots of future crops get another shot at absorbing the P left over. Some high pH, calcareous soils in the Plains do fix P rapidly, however, these are the exception rather than the rule. In these relatively rare soils, it is unwise to attempt to increase soil test P levels and the focus should be on positional availability and annual band application.

Another way of viewing long term P use efficiency centers on the nutrient budget concepts discussed earlier. If loss of P from soil erosion is controlled, in many soils replacing P removed by the crop at optimum soil test levels comes very close to maintaining soil test P levels. In such a system, one could argue that P efficiency approaches 100%. Using this kind of logic, minimizing soil erosion as no-till does, contributes to improving P efficiency.

Importance of Balanced Nutrition in Nutrient Use Efficiency



Source: Schlegel et al., 1996

Figure 3. Influence of P fertilization on response of irrigated corn to N fertilization in Kansas.

Nutrients interact with one another meaning that a deficiency of any one nutrient can reduce the efficiency of other nutrients. An excellent demonstration of the importance of balanced nutrition is the long-term Kansas irrigated corn study summarized in Figure 3. With adequate P, 0.85 lbs of N were needed per bushel of corn produced at the optimum N level, while with P deficiency 1.12 lbs were needed at the optimum level. The components of balanced nutrition are based on crop needs, soil test levels, and nutrient credits.

Summary

- Nutrient use efficiency should be viewed differently for N than for P or K because of the substantial residual effects of P and K applications.
- P or K practices that appear efficient in the short term may simply be mining soil fertility and contribute to greater future needs. Therefore, both first year uptake and impact on soil fertility should be considered.
- Balanced nutrient budgets are a necessary characteristic of sustainable nutrient use efficiency. Target soil test levels should be set, usually in the medium or high categories. Once attained, they can usually be maintained by replacing crop removal ... with high efficiency.
- Placement of P and K is most critical at low soil test levels and is important to minimizing lost yield while soil tests are being built to target levels. Localized band applications may be important for “starter” effects on crops such as corn or wheat independent of impacts on nutrient use efficiency.
- Balanced nutrition is important for efficient nutrient use because nutrients interact with one another. A deficiency of any one nutrient can impact the use efficiency of others.