



NUTRIENT MANAGEMENT IN TODAY'S ENVIRONMENT

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Introduction

Farmers today operate under the watchful eye of the public, government regulators, and environmental activists. Nutrient use is carefully scrutinized. Dead zones at the mouths of some rivers, contaminated surface and ground waters, declining air quality, and increasing greenhouse gases are often blamed on excessive or inappropriate fertilizer use.

The reduction or elimination of synthetic fertilizers is advocated by many for the social, economic, and environmental sustainability of agriculture. However, farmers could not feed 6 billion people, nor hope to meet the world's future food demands without commercial fertilizers. There just is not enough manure and other organic nutrient sources available to produce the needed food, feed, fiber, and fuel. At least 40 to 60% of crop yield in temperate regions, and more in the tropics, is attributed to the use of commercial fertilizers (Stewart et al. 2005). All nutrient inputs must be managed wisely for sustainable crop production, but improved fertilizer use efficiency is vital to alleviating public concerns about nutrient impacts on the environment and farmer concerns about recent increases in fertilizer:crop price ratios.

Concepts and definitions of nutrient use efficiency vary widely. Agronomic efficiency may be defined as the nutrients accumulated in above-ground plant parts or total nutrients recovered in the soil-crop-root system. Economic efficiency occurs when farm income is maximized from proper use of nutrient inputs, but it is not easily predicted or always achieved because future yield increases, nutrient costs, and crop prices are not known in advance of the growing season. Environmental efficiency is site-specific. Nutrients not taken up the crop may be lost to the environment via leaching, volatilization, denitrification, or erosion. Loss of unused nutrients depends on the nutrient, soil and climatic conditions, and landscape and is only a concern when nutrients are applied at rates above agronomic need.

Fertilizer management should strive for a balance between high short-term efficiency and long-term cumulative crop yield response. Additional benefits from increases in residual fertilizer availability and nutrients immobilized in soil organic matter to be released later should also be considered in evaluating fertilizer efficiency. Accounting for both nutrients taken up by crops and those that build soil nutrient supply are described as a system level efficiency.

Definition and Status of Nutrient Use Efficiency

Nutrient use efficiency can be expressed in several ways (Mosier et al. 2004) and varies depending on the system being considered; the soil-plant system, the whole plant, the above-ground portion of the plant, or the harvested portion. Recovery efficiency and removal efficiency are two common methods of expressing nutrient use efficiency. Crop recovery efficiency is the percentage increase in uptake by the plant per unit of added nutrient, usually for the first crop following application. Crop removal efficiency is the removal of nutrient in the harvested crop as a percentage of nutrient applied. Applied to the data in Table 1, nitrogen (N) recovery in the above-ground biomass was 37% while N removal efficiency was 100%.

Table 1. Average corn yield and N uptake from on-farm studies in the U.S. Midwest (from Bruulsema et al. 2004).

N applied, lb/A	Corn yield, bu/A	N uptake, lb/A	
		Total	Grain*
0	95	130	73
92	122	164	92

* calculated assuming an N harvest index of 56%

Bruulsema et al. (2004) explain why efficiency estimates can differ so widely. The data in Table 1 are based on 55 on-farm studies in the U.S. Midwest where efficiency was calculated at several levels of N fertilization. Averaged across these experiments, application of N at the optimum rate of 92 lb/A increased total N uptake by 34 lb/A more than the unfertilized corn, or 37% (i.e.



[$164-130/92 \times 100$]. Assuming the grain contains 56% of the above-ground N, a typical N harvest index, only 21% of the applied fertilizer was removed in the grain (i.e. [$92-73/92 \times 100$]). Such a low recovery of N prompts the question ... where is the rest of the fertilizer going and what does a recovery efficiency of 37% really mean?

Corn fertilized with N took up 164 lb N/A: 130 from the soil and 34 from the applied fertilizer. The total amount of N in the grain would be 56% of 164, or 92 lb/A which is equal to 100% of the N applied. Which best describes fertilizer efficiency — a recovery of 21% as estimated from a single-year response recovery in the grain or 100% as estimated from the total uptake (soil N + fertilizer N)? An understanding of the long-term dynamics of N cycling is needed to answer that question. Applied N that is not taken up by the plant is incorporated into soil organic matter, lost to the atmosphere via denitrification and volatilization, or leached below the rooting zone. Nitrogen incorporated into organic matter is available for plant use later when the organic matter decomposes. Mineralization of N from soil organic matter is a large, but unsustainable source of N for plant uptake. Soil organic matter can be maintained and built up with good N management or it can decline with poor N management.

Sufficient N must be applied for uptake by the plant to build biomass and protein, but 100% of the applied N rarely makes it directly into the plant. Experimental research data from around the world report single-year fertilizer N recovery efficiencies of 65% for corn, 57% for wheat, and 46% for rice (Ladha et al. 2005). However, fertilizer recovery efficiency in small plot research is much higher than that obtained on the farm because of differences in the scale of operation and management. Nitrogen recovery by farmer grown crops normally ranges from about 20 to 30% under dryland conditions and 30 to 40% under irrigation.

Recovery efficiency of fertilizer phosphorus (P) can be measured in similar ways as N. And like N, removal efficiency can be 100% when P release from soil organic matter and other sources is considered. First-year recovery efficiency of applied P is normally 15 to 25%, but because of differences in the dynamics of the soil P cycle long-term recovery efficiency can be much higher than N. Unlike N, P is not subject to leaching or atmospheric losses. Applied P that is not taken up by the crop may be incorporated into organic matter, transformed into less available forms, and adsorbed or precipitated with other soil minerals. Unless the P is lost through soil erosion, it remains in the soil and depending on the soil chemical and biological conditions can remain available to crops for many years. This residual availability means that long-term P recovery efficiency can range from 50 to 90%.

Recovery efficiency of potassium has not been measured to the same extent as N and P, but short-term recovery of applied K ranges from 20 to 60%. Initial recovery of K is higher than N and P because it is immobile in most soils, has no gaseous losses, and does not undergo the same fixation reactions as P.

In summary, fertilizer use efficiency is an important measure for both economic and environmental reasons, but the definition and context in which it is used must be understood if we want to do a better job of managing applied nutrients.

Improving Nutrient Use Efficiency

Much can be done to improve fertilizer use efficiency through better management — through awareness and application of fertilizer best (beneficial) management practices (BMPs). Fertilizer BMPs focus on management practices that apply the right nutrients at the right rate, right time, and in the right place. The goal is to match nutrient supply with crop demand, minimize losses to the environment, and not deplete soil fertility. Because climate, soils, crops, and management vary from one farm to the next, or even within fields on the same farm, fertilizer BMPs must be site-specific.

Fertilizer BMPs have been reviewed by Johnston (2005) and Roberts (2006), and a good deal of additional information on BMPs is available on the IPNI website (www.ipni.net). Table 2 summarizes nutrient management practices that lead to improved nutrient use efficiency.

Nutrient interactions are known to have a major impact on crops yields, but they also impact fertilizer use efficiency, especially for N. That is because a deficiency of one nutrient can restrict the uptake of another. A recent literature review of almost 250 site-years of data found that balanced fertilization with N, P, and K increased first-year recoveries of N an average of 54% compared to 21% where N was applied alone (Fixen 2005).



Table 2. Summary of best management nutrient practices.

Right rate	Pre-season soil analysis is essential for making correct fertilizer decisions. Establish realistic yield goals and follow laboratory recommendations designed to meet target yields. Over- or under-application will result in reduced nutrient use efficiency or losses in yield and crop quality. Track nutrient budgets — account for nutrients used and removed by all the crops in rotation.
Right time	Match nutrient applications to plant uptake, especially for N. Spring pre-plant versus fall application or split applications of N during the growing season can increase N use efficiency. Utilize tissue testing to assess nutrient status of growing crops. Other diagnostic tools are also available (e.g. chlorophyll meter, N sensors, remote sensing). Slow or controlled release fertilizers are effective in synchronizing nutrient supply with crop demand.
Right place	<p>Application method is critical in ensuring fertilizer nutrients are used efficiently. Numerous placements are available, but most generally involve surface or sub-surface applications before or after planting. Pre-plant nutrients can be broadcast, broadcast and incorporated, banded on the surface, or deep banded. Applied at planting, nutrients can be banded with the seed, below the seed, or below and to the side of the seed. After planting, application is usually restricted to N and placement can be as a topdress or a subsurface sidedress.</p> <p>In general, nutrient recovery efficiency tends to be higher with banded applications because less contact with the soil lessens the opportunity for nutrient loss due to leaching or fixation reactions. Placement decisions depend on the crop and soil conditions, which interact to influence nutrient uptake and availability.</p> <p>Nutrient source must also be considered with placement options. Broadcast application without incorporation is not the best option for urea because of the potential for gaseous losses, but it is a good option for elemental sulfur (S) because it encourages conversion to sulfate, which is the form plants take up S.</p>

Summary and Conclusion

Higher fertilizer efficiency is a worthy objective, but it does not ensure greater environmental protection and sustainability, nor does it ensure greater economic returns to the farmer. The highest fertilizer use efficiencies occur at lower crop yields and lower levels of soil fertility. Lower crop yields are not sustainable for the farmer or the land. Poor crop growth associated with lower yields mean less crop residues to protect the soil from wind and water erosion and to build soil organic matter. Just as the law of diminishing returns says that each additional unit of input yields less and less additional output, additional pounds of fertilizer are used less efficiently as crop yields increase.

Fertilizer must be used efficiently and effectively. We have the knowledge and tools to improve the efficiency of applied nutrients, but improvements in nutrient use efficiency should not come at the expense of the farmer’s economic viability or the environment. Applying fertilizer nutrients at the correct rate, time, and place can increase both crop yield and nutrient use efficiency meeting the farmer’s needs and society’s expectations for wise use of our environment.

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BIOHEAT: A GROWING OPPORTUNITY FOR GREEN ENERGY ON THE PRAIRIES

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A combination of factors including the rising costs for fossil energy, the need to create demand enhancement in the agricultural sector and the need to reduce greenhouse gas emissions are creating unprecedented opportunities for biofuel development. These opportunities include the production of liquid biofuels, biogas and bioheat. To date there has been much pioneering emphasis on liquid fuel development from the farm sector such as grain ethanol and biodiesel. However, second generation agricultural biofuels are now being developed that provide greater opportunities to expand bioenergy development. Bioenergy is becoming a major new energy industry in Europe with 70,000 pellet boilers now installed in Sweden and 3000 on-farm biogas digesters installed in Germany. Recent advances in combustion technologies have allowed densified fuels derived from crop-milling residues and energy crops to emerge as a promising new alternative to reduce heating costs and greenhouse gas emissions while also reducing reliance on fossil fuels.

Pelletized agri-fibres from dedicated energy crop grasses are poised to become a major new source of renewable energy as the world recognizes wood residues are a finite resource. The cost-effectiveness of BioHeat from energy grasses are due to its ability to efficiently capture and store solar energy on marginal farmland, the minimal fossil fuel inputs required in production and conversion to pellets, the efficient conversion of energy to heat in advanced combustion appliances and the fact that grass pellets can replace costly energy forms such as natural gas, heating oil and electricity.

In Canada in 2006, 3 densification plants began operating to process crop milling residues into fuel pellets for the commercial heating industry and for export to European power plants. To greatly expand the agri-fibre resource base, high yielding warm season grasses were commercially planted by Canadian farmers in 2006. The aim is now to create a viable raw material supply base for this emerging industry.

The prairies are well positioned to become an important player in this emerging new biofuel industry because of the large agricultural land base, low-cost forage production, and existing infrastructure and experience in herbaceous crop densification. Western Canada could produce up to 500,000 tonnes of crop milling residues per year as a bioenergy feedstock, the energy equivalent to 1.5 million barrels of oil. Crop milling feedstocks for this emerging industry include oat hulls, wheat bran, flax shives and sunflower hulls. Energy crop grasses such as switchgrass, big bluestem and prairie sandreed are also likely to become commercially viable sources of alternate energy in the prairies. The Prairie Provinces could produce more than 25 million tonnes per year of energy crop grasses for the north American and European markets. Bio-fuel diversification will create genuine demand enhancement in the farm sector, leading in turn to increased commodity prices for farmers.

Contrary to the prevailing wisdom that reducing greenhouse gas emissions will raise society's energy costs, pelletized biofuels can provide consumers with stably priced, low-cost heat while dramatically cutting emissions. Because agricultural commodity prices are declining in real dollars, agri-fibre fuel pellet sources are likely to become cheaper over time, in contrast with wood-based pellets that are rising in cost and in short supply. The development of an agri-fibre biofuel pellet industry has great potential to revitalize the rural economy of North America by absorbing the surplus production capacity of the agricultural sector and cutting on-farm fuel costs in heating intensive sectors like greenhouses.