**Management Options for Increasing Nutrient Use Efficiency**

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**Introduction**

There has never been a time when more people are aware of the interest in increased nutrient usage efficiency. The fertiliser industry is under increasing pressure to increase nutrient usage efficiency due to a growing public perception that crop fertilisers are excessive in the environment and farmer worries about rising fertiliser prices and stagnating crop prices (Dibb 2000). However, efficiency can be interpreted in a variety of ways and is frequently misinterpreted. Depending on the viewpoint, definitions might change. Maximizing efficiency may not always be wise or useful since environmental nutrient use efficiency might differ significantly from agronomic or commercial efficiency. The nutrients collected in the plant's leaves or the nutrients recovered across the entire soil-crop-root system are two ways to quantify agronomic efficiency (Fageria et al. 2008). Farm revenue is maximised through the right use of nutrient inputs, but economic efficiency is not always possible to anticipate or attain since crop prices, nutrient costs, and future yield increases are unknown prior to the growing season (Tilman 2000). Studying local targets that are sensitive to the influence of nutrients is the only way to measure environmental efficiency since it is site-specific (Ghosh et al.). The environment is at danger of losing nutrients that aren't being utilised by the crop, but how susceptible it is depends on the nutrient, the soil and climate, and the terrain. Nutrient loss to the environment is often only a problem when fertilisers or manures are applied at rates above what is required for a given crop. Agronomic nutrient use efficiency is the cornerstone of economic and environmental efficiency, notwithstanding the divergent viewpoints. Economical and environmental efficiency will increase as agronomic efficiency rises. Globally, a rise in the use of nitrogen and phosphorus fertilisers has been seen in recent decades. Global fertilisation of nitrogen is anticipated to grow by 2.7 times, and that of phosphorus by 2.4 times, by 2050. (Tilman 2001). However, rising fertiliser application rates show declining marginal returns, making it unlikely that subsequent fertiliser increases will be as effective at raising grain output as in the past. According to estimates, only 30–50% of nitrogen fertilisers now applied (Samuel 2002; Ladha et al. 2005) and 45% of phosphorus fertilisers (Smil 2000) are used for crops. For instance, in intensive wheat cultivation, only 20–60% of nitrogen fertilisers are retained by the crop, 20–60% are left in the soil, and around 20% are lost to the environment (Pilbeam 1996). According to Syers et al. (2008), the phosphorus-use efficiency can range from 10 to 20 percent in highly phosphorus-fixing soils to as high as 90 percent for well-managed agroecosystems (Bolland and Gilkes 1998).

**Nutrient Use Efficiency Terminology**

There are several ways to express nutrient usage efficiency. Partial factor productivity (PFP, kg crop yield per kg nutrient applied); agronomic efficiency (AE, kg crop yield increase per kg nutrient applied); apparent recovery efficiency (RE, kg nutrient taken up per kg nutrient applied); and physiological efficiency were the four agronomic indices that Mosier et al. (2004) described as commonly used to describe nutrient use efficiency (PE, kg yield increase per kg nutrient taken up). Nutrient efficiency is also frequently explained in terms of crop removal efficiency, which measures the amount of nutrients removed from the crop as a percentage of the nutrients applied. Which word best depicts nutrient utilisation efficiency depends on the aims and data that are available. Fixen (2005) gives a thorough explanation of these various terminology along with examples of possible applications. It is essential to comprehend the nomenclature and the context in which it is used in order to avoid misunderstandings and incorrect applications. A disconcertingly low recovery of 37% in the applied N's aboveground biomass indicates that N could be hazardous to the environment. Only 21% of the applied fertiliser N is transmitted in the texture, while simulating the grain has 56 percent of the aboveground N, a normal N harvest index. If the land can continue to provide N over the long run, is the recovery assessed at 21 percent based on a one-year response, 100 percent based on the overall intake of N (soil N + fertiliser N), or both at 100%? Without an understanding of the long-term dynamics of N cycling, the consequence cannot be identified. The apparent usage efficiency of fertiliser nutrients that are applied but not absorbed by the crop is affected by losses from leaching, erosion, denitrification or volatilization in the case of nitrogen, or they might be temporarily trapped in soil organic matter to be released at a later time. In order to take into consideration the contributions of extra nutrients to both crop absorption and soil nutrient delivery, Dobermann et al. (2005) used the phrase "system-level efficiency."

**Optimizing Nutrient Use Efficiency**

The plant food business endorses the best management practise (BMP) of administering nutrients at the ideal rate, at the ideal time, and in the ideal location to achieve maximum nutrient efficiency.

Right Rate- Since the majority of crops are location- and season-specific dependent on cultivar, management techniques, climate, and other factors, it is crucial to set realistic yield targets and apply nutrients to produce the desired results. Nutrient utilisation efficiency will be diminished or fruit and crop quality will suffer from over- or under-application. One of the most effective tools for determining the land's ability to deliver nutrients is still soil testing, but accurate calibration data are also required to be relevant when recommending the right fertiliser. Unfortunately, soil testing is not applicable everywhere in the globe due to the absence of trustworthy laboratories or the availability of calibration data that is pertinent to current agricultural practises and yields. Other strategies, including omission plots, are beneficial in reducing the amount of plant food needed to reach a return objective (Witt and Dobermann 2002). This approach applies N, P, and K at rates high enough to prevent output from being limited by a lack of the other nutrients. Plots with infinite NPK can be used to calculate the desired yield. To assess nutrient-limited production, one nutrient is left out of the plots. An N omission plot for the lesson receives no N but enough P and K fertiliser to ensure that those nutrients are not yield-limiting. The deficit between the crop's need for nitrogen and the natural supply of nitrogen, which must be filled by fertilisers, results in the difference in grain production between a completely fertilised plot and a N omission plot. Another important factor is the nutrients lost during crop production. Soil fertility will be lost if nutrients lost in harvested grain and crop wastes are not replenished.

**Right Time**- To increase nutrient usage efficiency, especially for N, a greater synchronisation between crop demand and nutrient delivery is required (Johnson et al. 1997). Splitting up N applications over the growing season rather than making a single, massive application before embedding is known to increase N use efficiency (Cassman et al. 2002). A well-known technique for determining the N status of growing crops is tissue testing, although other diagnostic tools are also useful. In-season N management has been improved with the use of chlorophyll metres (Francis and Piekielek 1999), and leaf colour charts have been very effective in guiding split N treatments in Asian rice and now maize production (Witt et al. 2005). On-the-go N sensors that may be used in conjunction with variable rate fertiliser applicators to automatically rectify crop N shortages on a site-specific basis have been developed by precision farming technology and are now commercially available. N stabilisers and controlled-release plant feeds are another method for coordinating the release of nitrogen from fertilisers with crop demand. Nitrogen stabilisers (such as nitrapyrin, DCD [dicyandiamide], and NBPT [n-butyl-thiophosphorictriamide]) prevent nitrification or urease activity, which delays the fertilizer's conversion to nitrate (Havlin et al. 2005). When the soil and surrounding environment are conducive to nitrate losses, stabilising the treated area will frequently boost fertiliser N efficiency. Compounds with poor solubility and coated, water-soluble plant meals are two categories of controlled-release plant foods. The majority of slow-release plant feeds are more costly than water-soluble N fertilisers and have historically been applied to turf grass and high-value horticultural crops. However, technological advancements have reduced production costs, making it possible to utilise controlled-release fertilisers in maize, wheat, and other cereal grains (Blaylock et al. 2005). The goods with polymer coatings, which are anticipated to release nutrients in a controlled manner, show the most promise for widespread agricultural application. When average temperature and moisture conditions can be estimated, nutrient release rates may be controlled to remain consistent and are often predictable.

**Right Place**- The best manner to apply fertiliser has always been essential for maximising nutrient use. Finding the right job is just as crucial as figuring out the right application rate. Although there are several placement options, the majority often include surface or subsurface applications before or after embedding. Nutrients can either be spread about (placed uniformly on the soil surface with the possibility of incorporation), used as a band on the surface, or used as a subsurface band, typically 5–20 cm deep, prior to planting. Nutrients can be distributed with the seed, below the seed, or below and to the side of the source when applied at planting. Following planting, N is often the only nutrient applied, and placement options include top dressing and subsurface sidedress. Because banded treatments have less soil contact, there is often less chance of food loss owing to leaching or fixation reactions. As a result, nutrient recovery efficiency tends to be better with banded applications. The crop and soil conditions, which interact to influence nutrient availability and uptake, affect placement decisions. Rarely do plant nutrients function alone. Because a lack of one vitamin limits the absorption and use of another, interactions among nutrients are crucial. Many studies have shown that interactions between N and other nutrients, particularly P and K, have an effect on crop yields and N efficiency. One of the most popular techniques for increasing the effectiveness of N fertiliser is the equal and balanced distribution of plant food ingredients, which is equally effective in both growing and developed plants. A recent assessment based on 241 site-years of trials conducted in China, India, and North America found that balanced fertilisation with N, P, and K boosted first-year recoveries by an average of 54% as opposed to just 21% when N was employed alone (Fixen et al. 2005). The scientific literature suggests a variety of practises and enhancements to boost nutrient use effectiveness in farming, such as adoption of different cropping systems, enhanced crop rotations, or intercropping. Due to the rising costs of chemical plant feeds, field crops' nutrient absorption and utilisation should be improved in order to lower production costs and increase profits for farmers with limited resources. It's critical to recognise and improve nutrient consumption efficiency in order to reach these goals. Agroforestry, which integrates trees into a cropping system, may enhance pest management and boost the efficiency of nutrient- and water-use. In the same way, cover crops and little tillage can lessen nutrient leaching. Applying fertilisers correctly and better synchronising nutrient supply and absorption in time and space will boost the efficiency of nutrient usage (Tilman et al. 2002). Applying fertilisers at or close to the site of absorption (roots and leaves), during peak crop uptake periods, and in smaller, more frequent applications may decrease losses while maintaining or enhancing crop output quantity and quality (Cassman et al. 2002). However, many farmers in underdeveloped nations tend to find the cost of precision farming or the regulated release of nitrogen (e.g., by utilising nitrogen inhibitors) to be prohibitive (Singh 2005). By focusing research, many of the management techniques outlined above can be delayed (e.g., on improving efficiency and minimising losses from both inorganic and organic nutrient sources; on improvements in timing, pacing, and splitting of fertiliser applications, as well as by judicious investments, for exemplar, in soil testing).

**Different Computation Methods**

**Nitrogen Fertilizer Use Efficiency**

 In fertiliser studies using isotopic techniques, a labelled fertiliser is put to the soil, and the quantity of fertiliser nutrient that a plant has absorbed is measured. Different fertiliser techniques (placement, timing, sources, etc.) can be taken into account in this way.

Ndff, or the percentage of nitrogen generated from fertiliser

The proportion of nutrient in the plant obtained from the (labelled) fertiliser, or fdff (fraction derived from fertilizer), is the first parameter to be measured when analysing the fertiliser consumption by a crop using isotopic methods.

Y= S/F× 100;

where Y = Amount of labeled fertilizer N in the sample (%Ndff)

 S = Atom % 15N excess in sample

 F = Atom % 15N excess in the labeled fertilizer

2. Uptake of nitrogen by plants: The grain and straw uptake of nitrogen is calculated as follows:

Uptake by grain or straw (kg/ha) = %N content in grain or straw grain or straw yield (kg/ha)/100

3. N use efficiency (NUE) = Total N uptake (kg/ha) ×% Ndff/ Rate of fertilizer N applied (kg/ha)

4. Residual fertilizer N in soil (kg ha-1) = Total N in soil (kg/ha) × % Ndff/100

5. Unaccounted fertilizer N (%) =100-[fertilizer - N recovery% + residual fertilizer - N in soil]

15N as tracer studies have yielded valuable information on the aspects of: Studies of biological exchange where mineralization and immobilisation take place concurrently in the same organisation. Denitrification loss in or from soil. Influence of added available N on mineralization. The relative uptake of NH4 + and NO3 ions by crop plants and microbes. Placement. The availability of native soil N to crops. The influence of N carriers associated with the plant recovery studies. The impact of immobilisation in soil for plant consumption.

**Phosphorus Fertilizer Use Efficiency**

In general, erosion and surface runoff account for the majority of phosphorus losses (Shepherd and Withers 2001). However, P leaching can happen in sandy soils and when P fertiliser is applied repeatedly in areas where soil P sorption is poor. When there is a large intake of P and there are plenty of severe rainstorms, the problem of P leaching is increased (Sims et al. 1998). P leaching from a sandy loam soil with low P sorption saturation was greater than from a clay soil (Djodjic et al. 2004). Inorganic fertiliser may drain phosphorus down to 1.1 metres of soil depth (Eghball et al. 1996).

**Nutrient Efficient Plants**

A nutrient-efficient plant is one that, in the presence of relatively limited nutrient availability in the soil or growth medium, absorbs, translocates, or uses more of a certain nutrient than another plant. Nutrient-efficient plants will play a significant role in increasing crop yields in the twenty-first century compared to the twentieth, primarily because there are fewer land and water resources available for crop production, inorganic fertiliser inputs are more expensive, crop yields are trending downward globally, and there are more environmental concerns. Plants that provide better returns per unit of nutrient utilised or absorbed than other plants (standards) under similar agroecological circumstances are defined as being nutrient efficient (Fageria et al. 2008). Numerous studies have been conducted over the past three decades to identify and/or breed nutrient-efficient plant species, genotypes, or cultivars within species, as well as to learn more about the mechanisms behind nutrient efficiency in crop plants. However, the rate of success for the release of nutrient-efficient cultivars has remained fixed. The genetics of plant responses to nutrients and plant interactions with environmental factors are difficult to understand, which is one of the main reasons for limited success. Progress in this area has been impeded by the complexity of the genes involved in nutrient consumption efficiency for macro- and micronutrients and the paucity of cooperative efforts involving breeders, soil scientists, physiologists, and agronomists to assess nutrient efficiency concerns holistically. Therefore, agricultural scientists have enormous hurdles as well as possibilities in the twenty-first century when it comes to creating crop plants that are nutrient-efficient and creating optimum management strategies that improve the ability of plants to use applied fertilisers. Breeding for nutritional qualities has been advocated as a tactic to increase fertiliser usage effectiveness or yields in low-input farming systems during the twentieth century. The development of nutrient-efficient agricultural genotypes should continue to be given high emphasis during the twenty-first century (Fageria et al. 2008).

**Conclusion**

The fertiliser business and farming in general face the fundamental issue of improving nutrient efficiency. To improve the effectiveness of applied nutrients, there are chances and techniques at our disposal. However, we must exercise caution to ensure that efficiency gains do not come at the price of the environment or the financial survival of farmers. Farmers, society, and the environment will all gain from the wise use of fertiliser BMPs, right rate, right time, right site, and correct agronomic practise aiming both high yields and nutrient efficiency.

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