Agri Articles
(e-Magazine for Agricultural Articles)
Volume: 04, Issue: 01 (JAN-FEB, 2024)
Available online at http://www.agriarticles.com

Advanced Techniques to Enhance Nutrient Use Efficiency (NUE)

(*Sanket S. Ingle and Vaishnavi S. Rajput)
PG Scholar (Department of Agronomy), ITM University, Gwalior, M.P.
*Corresponding Author's email: ssingle910@gmail.com

Out of all the essential plant nutrients for crop growth, N is the nutrient which commonly limits crop production (Mosier *et al.*, 2001). N plays a vital role in crop production system just because of its large requirement in all metabolic activities of plants and its heavy losses associated with soil-plant systems (Ladha et al., 2003). To meet the demand of N to the crop growth, globally farmers using around 120 million metric tons of nitrogenous fertilizer each year (FAO, 2014). Due to heavy losses of N because of leaching, volatilization and denitrification NUE is very low (30-50%), to meet the demand of N farmer needs to apply huge amounts of nitrogen fertilizer in agricultural crops (Fageria, 2002). Almost all the agricultural soils and cropping systems of the world deficient with nitrogen so, it is necessary to use additional nitrogen sources for the production of crops to fulfil the demands of human population (Mohan *et al*., 2015).

Essential plant nutrients used by plants when they are present in usable form. Many leguminous plants and soil microorganisms have potential to convert N into plant usable forms. Significant amounts of N contributed by them to meet crop needs, but increasing human population demand can only be fulfilled by additional nitrogen which is supplied by fertilizers (Ladha *et al*., 2003). Sustainable agriculture production requires balanced and judicious, efficient, eco-friendly and environmentally sound management practices. The aim of sustainable agriculture to get more crop output from a particular area of a land can be achieved through accurate use of fertilizers (Kumar *et al*., 2016). Efficient N fertilizer management can simply be defined as reduced various losses and maximize the amount of nutrient made available for crop (Ladha and Reddy, 2003). By 2050, nitrogen fertilization is expected to increase by 2.7 times and phosphorus by 2.4 times on a global scale (Tilman 2011). By continuously increasing the rate of fertilizer application to crops mainly cereals it shows adverse effect on the crops and followed the law of diminishing returns. It is measured that only 30-50% of applied nitrogen fertilizers and 45% of phosphorous fertilizers are used by the crops remaining fertilizers are lost or remain unused (Ladha *et al*., 2005). For example, only 20–60 % of nitrogen fertilizers applied in intensive wheat production is taken up by the crop, 20–60 % remains in the soil, and approximately 20 % is lost to the environment (Pilbeam, 1996). The phosphorus-use efficiency can be as high as 90% for well managed agro-ecosystems (Syers *et al*., 2008) or as low as 10–20 % in highly phosphorus- fixing soils (Bolland and Gilkes 1998). In recent time, there is an urgent need for improving N and P use efficiency and balance use of natural resources which is necessary for sustainable agricultural production (Kumar and Agarwal, 2013; Paul *et al*., 2014).

What is NUE/FUE?

Nutrient use efficiency (NUE) may be defined as yield per unit fertilizer input or in terms of recovery of applied fertilizer. Nutrient use efficiency (NUE) is a critically important concept in the evaluation of crop production systems.

The Concept and Importance of NUE

Meeting societal demand for food is a global challenge as recent estimates indicate that global crop demand will increase by 100 to 110% from 2005 to 2050 (Tilman *et al*., 2011). Others have estimated that the world will need 60% more cereal production between 2000 and 2050 (FAO, 2009), while others predict food demand will double within 30 years (Glenn *et al*., 2008), equivalent to maintaining a proportional rate of increase of more than 2.4% per year. Sustainably meeting such demand is a huge challenge, especially when compared to historical cereal yield trends which have been linear for nearly half a century with slopes equal to only1.2 to 1.3% of 2007 yields (FAO, 2009). Improving NUE and improving water use efficiency (WUE) have been listed among today's most critical research issues (Thompson, 2012). NUE is a critically important concept for evaluating crop production systems and can be greatly impacted by fertilizer management as well as soil- and plant-water relationships. NUE indicates the potential for nutrient losses to the environment from cropping systems as managers strive to meet the increasing societal demand for food, fiber and fuel. NUE measures are not measures of nutrient loss since nutrients can be retained in soil, and systems with relatively low NUE may not necessarily be harmful to the environment, while those with high NUE may not be harmless (Thompson, 2012).

Causes of low NUE

1) Soil erosion & surface runoff
2) Leaching
3) Volatilization
4) Denitrification
5) Immobilization

Soil erosion & surface runoff: N adsorbed on soil particles can be lost through wind as well as water erosion. N loss through wind erosion is more common in arid and semiarid climatic regions while, water erosion is most commonly reported mechanism of N loss in humid and sub humid areas. After a heavy rain surface applied nitrate can be dissolved in water and lost through the process of runoff (Fageria, 2002).

Leaching: The nitrate-nitrogen is lost in drainage or with percolating water. When soil is sandy in texture most of leaching losses of N occurs. Nitrate form of N is mobile in nature and not strongly adsorbed on soil particles so it can be easily move beyond the soil profile through the process termed as leaching (Randall *et al*., 2003). This loss of N mechanism has special significance in high rainfall areas and light texture soils where as much as 25–50% of the N applied can be lost through leaching (Bolan and Hedley, 2003).The amount of nitrogen lost depends upon the climatic and cultural conditions. Quantity of applied N, soil water content and permeability of soil system are important factor which governs the leaching loss of N from crop production system (Davis *et al*., 2003). In arid and semi-arid regions, such losses are less.

Volatilization: In this chemical reduction process, nitrogen is lost in the gaseous form when urea or ammonium fertilizers are applied on the soil surface. The process of conversion of NH_{4+} into NH_3 gas and its loss to the atmosphere is termed as ammonia volatilization. Losses of nitrogen as ammonia is occurred in, especially in alkaline soils. High concentration of ammonia is toxic to the nitrification process, resulting in an unusual build-up of nitrites. This mechanism of N loss is more severe in alkaline soil and warm sunny condition, under this condition as much as 20% of N may volatilize and lost to atmosphere within a week (Hutchinson *et al*., 2003).

$2HNO_2 + CO(NH_2)_2 \longrightarrow CO_2 + 3H_2O + 2N_2$ Nitrite urea

Denitrification: The nitrites may change to gaseous form in the lack of air or by poor drainage. Then biochemical reduction of nitrate-nitrogen to gaseous compounds by microorganism is called denitrification. The microorganisms involved are commonly anaerobic forms (Bolan and Hedley, 2003). This mechanism of N loss is most commonly reported under waterlogged condition where lower oxygen level led to increase in the population of some microorganisms which able to convert nitrate to nitrogen (N_2) and nitrous oxide (N_2O), which untimely lost to the atmosphere (Fageria, 2002). This mechanism of N loss is responsible for N losses up to 10-15% of applied nitrogen. Heavy texture soil with poor natural drainage is more susceptible for denitrification losses of nitrogen (Mosier *et al*., 2001).

Immobilization: "Immobilization is the process of conversion of inorganic N (NH_4+ or NO_3) to organic N and it is basically the reverse of N mineralization".The Microorganisms accumulate NH_4 N and NO_3 – N in the form of protein, nucleic acid and other complexes. If C:N ratio is wider than 30, it favors immobilization and lesser C:N ratio encourage mineralization.

Importance of nutrient use efficiency

- To increase the overall performance of cropping systems.
- Providing economically optimum nourishment to the crop.
- Minimizing nutrient losses from the field.
- Supporting agricultural system fertility or other soil quality components.
- NUE is a critically important concept for evaluating crop production systems and can be greatly impacted by fertilizer management as well as soil- and plant- water relationships.

Techniques to Enhance Nutrient Use Efficiency

- Fertigation
- Foliar Application
- Nanotechnology
- Site Specific Nutrient Management (SSNM)

Fertigation: Application of fertilizer through micro irrigation water. This technique was first started in Israel.

Nutrient	Surface irrigation + soil application of fertilizer	Drip	Drip Fertigation
Nitrogen	30-50	65	95
Phosphorous	20	30	45
Potassium	**50**	**60**	**80**

Fertilizer Marketing News, 2010

Advantages of Fertigation

- High nutrient availability due to maintenance of soil moisture near root zone under drip irrigation.
- Minimum loss of nutrients through leaching to around 10 per cent as compared to 40- 55 per cent in the traditional system, which further help in reducing environmental pollution.
- Unlike in traditional system, there is no damage to crop while top dressing of fertilizers.
- Fertilizers can be applied as frequently as possible in the needed amounts according to plant requirements.
- About 25-50% reduction in the quantity of fertilizer that resulted in higher fertilizer use efficiency.
- As small amounts are provided at regular intervals rather than giving in one or two big doses only, uptake and utilization of nutrients is very high with Fertigation.
- Uniform application of nutrients can be done over the field.

- Considerable saving of labour and energy in the application of fertilizers.

Limitations of Fertigation:

1. Uneven nutrient distribution when the irrigation system is faulty.
2. Chemical reactions of fertilizer with Ca and Mg may leads to chemical clogging.
3. Phosphate fertilizers and some micro nutrients may precipitate in micro irrigation systems.
4. Corrosion resistant Fertigation equipment's are needed.
5. Potential chemical backflow in to water supply source.

Foliar Application:

- Foliar feeding is a technique of feeding plants by applying liquid fertilizer directly to their leaves. Plants are able to absorb essential elements through their leaves.
- The absorption takes place through their stomata and also through their epidermis. It is the application of fertilizers to foliage of the crop as spray solution is known as foliar spray.
- This method is suitable for application of small quantities of fertilizers, especially micronutrients. Major nutrients can also be applied by this method when there is no adequate moisture in top layer of soil.
- Foliar application is not substitute for soil application, but only a supplement.

Advantages of foliar application:

- It helps in rapid correction of nutrient deficiency.
- Foliar spraying can be combined with other sprayings like insecticides.
- When the soil is deficient in nutrients foliar application is beneficial.
- When a quick growth response is desired foliar application can be sprayed.
- It will help during high fixation of P and K.
- Foliar spray can be applied when adverse condition like root rot disease, drought condition etc. were noticed in field.
- Foliar spray can also be given when there is not adequate moisture in top soil to absorb the nutrients by plant roots.
- Only use small amounts of fertilizer.
- Improved yield and yield quality parameters.

Limitations of foliar application:

- It will cause scorching or burning effect if concentration of the spray is high.
- It requires sticking agent to get more efficiency.
- To obtain good efficiency of spray leaf area should be large.
- Only small quantities of fertilizers can be applied through foliar application.
- Foliar application efficiency is depended on climatic conditions like temperature, humidity, wind velocity etc.
- Cost of multiple applications can be prohibitive. Possibility of foliar burn (with high concentration).

Nano fertilizer:

Higher nutrient use efficiency through nano-fertilizers:

- The Nano-fertilizers possess certain specific properties which facilitate higher nutrient use efficiency. The important properties are:
- The Nano-fertilizers have a higher surface area, which is mainly due to the very smaller size of the Nano particles that provide more sites to facilitate the different metabolic process in the plant system.
- This results in the production of more photosynthesis with less consumption of nutrient elements. They have high solubility in different solvents such as water.
- The particle size of Nano-fertilizers is very small (less than 100 nm), which facilitates more penetration of Nano-particles into the plant system.

- Nano fertilizer elements have the large surface area and particle size smaller than the pores of root and leaves of the plants. This increases penetration into the plant system from applied surfaces and thus improves uptake and nutrient use efficiency of the Nano-fertilizers.
- The reduced particle size of Nano fertilizer results in increased specific surface area and a number of particles per unit area of fertilizer, which provide more opportunity for contact of Nano-fertilizers and it leads to more penetration and uptake.
- The fertilizer elements encapsulated in Nano- particles increases the availability and hence uptake of the plant nutrients to the crops.

Site Specific Nutrient Management (SSNM):

- In principle, SSNM can be used anywhere fertilizers are applied.
- The terms "Site-Specific Nutrient Management" and "precision farming" are sometimes used to describe the use of geo-referenced technology to manage within-field variability.
- However, applying the principles of SSNM does not require such technology, and can be done by farmers lacking machinery.
- An alternative to blanket guidance, Site-Specific Nutrient Management (SSNM) aims to optimize the supply of soil nutrients over time and space to match the requirements of crops through four key principles. The principles, called the "4 Rs", date back to at least 1988 and are attributed to the International Plant Nutrition Institute (Bruulselma *et al*. 2012). They are:

SSNM Principles	Scientific basis	Associated practice
Product	Product Ensure balanced supply of nutrients. Suit soil properties.	Commercial fertilizer, Livestock manure, Compost, Crop residue
Rate	Rate Assess nutrient supply from all sources Assess plant demand.	Test soil for nutrients, Balance crop removal
Time	Assess dynamics of crop uptake and soil supply. Determine timing of loss risk.	Apply nutrients: Pre-planting, At planting, At flowering, At fruiting.
Place	Place Recognize crop rooting patterns. Manage spatial variability.	Broadcast, Band/drill/inject, Variable-rate application

Conclusion

- Increasing NUE in plants is important for enhancing yield and quality of crops, reducing fertilizer input cost and environmental sustainability.
- An improved NUE in plants can be achieved by careful manipulation of plant, soil, fertilizer, environmental and management practices.
- There is a great need for a multidisciplinary effort of plant breeders and physiologists, agronomists and soil scientists to formulate an effective way to increase NUE in plants.
- Nutrient management is essential in modern crop production systems for improving the long-term sustainability.
- One key technique is precision agriculture, which utilizes remote sensing, geospatial data, and computer modelling to precisely apply nitrogen fertilizers based on crop requirements and field conditions. This approach helps reduce nutrient losses and enhances NUE by delivering nutrients more efficiently to the plants.

References

1. Saito, K. 2004. Sulfur assimilatory metabolism the long and smelling road. Plant Physiology.136:2443-2450.

2. Ali A., Arshadullah, M., Hyder, S., I. and Mahmood, I., A. 2012. Effect of different levels of sulfur on the productivity of wheat in a saline sodic soil. *Soil and Environment*. **31**(1):91- 95.
3. Jamal, A., Moon, Y., S. and Abdin, M., Z. 2010. Sulphur-a general overview and interaction with nitrogen. *Australian Journal of Crop Science* **4**(7): 523-529.
4. Lucheta, A., R. and Lambais, M., R. 2012 Sulfur in agriculture. Revita Brasileira de Ciancia do Solo. 36:1369-1379.
5. Havlin, J., L., Beaton, J.D, Tisdale SL, Nelson WL. 2005 Sulfur, calcium, and Magnesium. In: Soil Fertility and Fertilizers: An Introduction to Nutrient Management (Indian edition). PHI Learning Private Ltd.pp 219-243.
6. Dutta J, Sankhyan NK, Sharma SP, Sharma GD, Sharma SK. Sulphur fractions in acid soil continuously fertilized with chemical fertilizers and amendments under maize- wheat system. Journal of the Indian Society of Soil Science. 2013;61(3):195-201.
7. Bose, N., Naik, S. K. and Das, D. K. 2009 Evaluation of nitro-sulphur and elemental Sulphur on growth and yield of rapeseed (Brassica campestris L.) in India. Archives of Agronomy and Soil Science. 55(1):79-90.
8. Mosier, A., J.K. Syers and J.R. Freney 2013. Agriculture and the nitrogen cycle: assessing the impacts of fertilizer use on food production and the environment. (65): Island Press.
9. Ladha, J.K., H. Pathak, T.J. Krupnik, J. Six and van C. Kessel 2005. Efficiency of fertilizer nitrogen in cereal production: retrospect's and prospects. Advances in Agronomy, 87:85-156
10. Ahmed, A. H., Bukhush, A, R., Ali, A., Ishaque, M. and Rehman, A. 2012. Potassium use efficiency of maize hybrids. *The Journal of Animal & Plant Science* 22 (3):728-732.
11. Kumar and Yogendra. 2012 "Nano Fertilizers for Sustainable Crop Production, Higher Nutrient Use Efficiency and Enhanced Profitability.*Indian Journal of Fertilizers* 1206-1214.