Smart Fertilizers for Enhancing Nutrient Use Efficiency

Anshul Bhushan[1]*, G. D. Sharma[2], Sandeep Manuja[3], Saurav Sharma[4], Vinod Sharma[5] and Deepanshu Kumar[6]

[1,6]M.Sc. Scholar, [2,5] Principal Scientist, [3]Professor Agronomy, [4]SMS Agronomy, Department of Agronomy, CSK HPKV, Palampur, HP, India-176062

Corresponding Author
Anshul Bhushan
Email: abhushan034@gmail.com

OPEN ACCESS

Keywords

Smart Fertilizers, Nutrient Use Efficiency (NUE), Controlled Release Fertilizers, Nano-fertilizers

How to cite this article:

Bhushan, A., Sharma, G. D., Manuja, S., Sharma, S., Sharma, V. and Kumar, D. 2026. Smart Fertilizers for Enhancing Nutrient Use Efficiency. *Vigyan Varta* 7 (05): 142-144.

ABSTRACT

Agriculture at the global level is coming under increasing strain to increase its production and decrease environmental damage. The traditional approach of fertilizers uses nutrients inefficiently, where most of the nutrients are wasted through leaching, volatilization and denitrification before the crop plants can utilize them. Nutrient use efficiency (NUE) for nitrogen is never greater than 35 per cent to 40 per cent. With the use of smart fertilizers like controlled-release, slow-release, nano-fertilizers, and stabilization of formulations, this issue is being minimized by matching nutrient supply with crop demands.

INTRODUCTION

The present-day agriculture is caught in a contradiction, on the one hand, fertilizers are necessary for obtaining high yields and on the other hand, due to improper utilization of fertilizers, there occur considerable economic losses and adverse effects on the environment. The use of traditional fertilizers in large amounts usually causes rapid release of nutrients which cannot be used by plants instantly. Therefore, up to 50–70 per cent of nitrogen and a considerable part of phosphorus are lost via leaching, runoff and emission of nutrients to the atmosphere (Tilman *et al.* 2002). In this way, NUE is reduced and there arise environmental issues such as eutrophication, pollution of groundwaters and release of greenhouse gases. To cope with the above-mentioned problems,

smart fertilizers have been developed as innovative technologies for nutrient delivery to crops.

The Concept of Smart Fertilizers

Smart fertilizers are modern nutrient delivery systems based on controlled or selective release of nutrients, depending on environmental factors or plant requirements (Shaviv, 2001). Unlike traditional fertilizers, they provide timely release of nutrients.

Major Types of Smart Fertilizers

- Controlled-release fertilizers (CRFs)
- Slow-release fertilizers (SRFs)
- Nano-fertilizers
- Stabilized fertilizers (with urease and nitrification inhibitors)

Each type of the smart fertilizer has its mechanism but shares the goal of improving nutrient synchronization with plant uptake.

Methods for Improving Nutrient Utilization Efficiency

1. Controlled Release of Nutrients

Controlled-release fertilizers employ polymer coatings or encapsulation methods to control nutrient release from the fertilizer granules. Nutrients are released slowly according to the needs of crops, thus preventing losses (Trenkel, 2010). In comparison to conventional fertilizers, which demonstrate rapid nutrient release and depletion, smart fertilizers maintain a constant nutrient level that correlates with crop requirements.

2. Use of Inhibitors

The stabilized fertilizers utilize urease and nitrification inhibitors such as N-(n-Butyl) thiophosphoric triamide (NBPT) and 3,4-Dimethylpyrazole phosphate (DMPP). These prevent nitrogen transformation into ammonia and nitrogen dioxide, respectively, hence reducing the losses caused by volatilization and denitrification and making nitrogen available to the plant.

3. Use of Nano-Fertilizer Technology

Nano-fertilizers use technologies on the nano-level to provide nutrients effectively to the plants due to their increased reactivity and surface area, hence requiring smaller amounts of fertilizer.

4 Prevention of Nutrient Loss Pathways

Smart fertilizers reduce greatly:

- Leaching losses (particularly nitrate)
- Ammonia volatilization losses
- Run-off losses

Thus, more nutrients remain available to plants resulting in better NUE.

Advantages of Smart Fertilizers

There are some advantages offered by smart fertilizers:

- Higher efficiency in utilizing nutrients due to synchronized nutrient release with crop demands
- Lesser impact on the environment due to lesser nutrient loss and pollution
- Crop yield and quality improvement due to effective nutrient utilization
- Economical use of fertilizers

According to research studies, smart fertilizers reduce the amount of fertilizer used by 20-30 per cent, without affecting yields (Trenkel, 2010).

Challenges and Constraints

Although smart fertilizers have various advantages, there are certain disadvantages associated with them, which include the following:

- The high cost of smart fertilizers compared to traditional fertilizers
- The subsidy policy in India favours traditional urea over smart fertilizers
- Differences in standards of certification from one country to another
- Inadequate awareness among the farming community
- Need for technical expertise for application of the product
- Regulatory issues pertaining to nano-fertilizers

CONCLUSION

The introduction of smart fertilizers has taken a huge step towards appropriate nutrient management due to their ability to solve problems created by poor fertilization practices. These fertilizers allow efficient nutrient uptake through loss reduction of nutrients and higher yields of crops. The use of smart fertilizers is greatly beneficial to areas such as Himachal Pradesh, where vulnerable ecosystems call for sustainable farming practices.

REFERENCES

Shaviv, A. (2000) Advances in Controlled Release of Fertilizers. Advances in Agronomy, 71, 1-49. http://dx.doi.org/10.1016/S0065-2113(01)71011-5

Tilman, D., Cassman, K.G., Matson, P.A., Naylor, R. and Polasky, S. (2002) Agricultural Sustainability and Intensive Production Practices. Nature, 418, 671-677. http://dx.doi.org/10.1038/nature01014

Trenkel, M.E. (2010) Slow-and Controlled-Release and Stabilized Fertilizers: An Option for Enhancing Nutrient Use Efficiency in Agriculture. International Fertilizer Industry Association (IFA), Paris.