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Coated Fertilizers and Their Role in Enhancing Nutrient Use Efficiency

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Abstract

The rising world population has intensified the reliance on fertilizers to enhance the crop yields and ensure food security. However, the reduced nutrient efficiency (NUE) of various fertilizers and their associated ecological concerns have highlighted the scope of controlled/ slow-release fertilizers (C/SRFs). These specialised fertilizers are formulated to align nutrient release with plant demand, using diverse technologies such as physical coatings, chemical modifications and compound formulations. Coated fertilizers in particular, have garnered attention due to their ease of synthesis, manufacturing and production. Important factors of these fertilizers are rate and mechanism of release, modelling approaches, to reduce/ minimize the nutrient losses, enhance the fertilizer use efficiency and improve the soil health. Advancements in research like sulphur and zinc coated urea, have proven their potential to improve soil health, maintain ecological balance through sustainable crop production and to decrease the ecological damage caused by the chemicals.

Keywords: Controlled fertilizers, Degraded polymers, Nutrient use efficiency, Slow released fertilizers

Introduction

As the global population expands, the demand for food has been increases, necessitating more efficient use of arable land to increase the crop productivity and its quality. To overcome with this challenge, natural and synthetic fertilizers are used. However, issues like nutrient leaching, water contamination and greenhouse gas emissions have not only reduced their efficiency, but also adversely affected the ecosystem. The growing demands for fertilizer formulations that regulate fertilizer application, augment nutrient use efficiency (NUE) and reduce the negative effects spurred by the conventional nutrient supply on soil physico-chemical properties, controlled/slow release fertilizers (CRFs) provide efficient and alternative solution to meet the crop nutrient demand through tailored pathways. CRFs synthesized through various mixture combinations aimed at arresting quick nutrient release, assists crop demand driven nutrient release, which is in contrast to conventional fertilizers with excessive nutrient leaching. Advancements in nanotechnology and materials engineering and its application in agriculture particularly in designing the CRF's have led to the development and synthesis of CRF's.

What are these Coated Fertilizers?

Organic or inorganic/synthetic layer applications on the surface of any fertilizer to control the nutrient release pattern over the time to enhance the efficiency are called coated fertilizers. They ensure gradual release of mineral nutrients, according to the crop requirement/ nutrient demand of the crop and enhance the fertilizer use while curbing losses that occur between application and uptake. Coated fertilizers reduce the negative impact of chemical compounds by preventing residue buildup from unused nutrients. Fertilizer dosage can be cut-down by 20 to 30% of the total RDF to achieve the same yield using conventional fertilizers (Govil *et al.*, 2024).

Recently Developed Coated Fertilizers

Neem coated urea (NCU) is prepared using a membranous layer of neem oil/neem cake which inhibits the steady nitrification process due to presence of triterpenes. Reduces the usage of normal urea and volatilization losses by 10%, upon addition of urease inhibitor to the NCU, the efficiency can be enhanced by 5%. Sulphur Coated Urea (SCU) was first manufactured at Alabama, USA in 1961, which reduces the

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rate of nutrient release through a permeable coating with sulphur. Nutrient concentration, purity and release of SCU is governed by the thickness of the coating, which sustains the release pattern over the time. Other popular coated fertilizers include; Polymer coated fertilizers, Biochar-coated Urea, Humic acid coated fertilizers (DAP, Urea), Synthetic polymer coated fertilizers (highly degradable).

Mode of Action

Controlled release fertilizers work by synchronizing the release of nutrients with the crop requirement. The mode of action is based on various mechanisms that reduces or controls the nutrient solubility and availability, reducing the nutrient loss and thereby increasing nutrient use efficiency. The slow/controlled release fertilizer are release by dissolution of coated material (Figure 1), as observed in case of polymer coated and sulphur coated fertilizers, through chemical interactions as in case of urease and nitrification inhibitors, through osmotic pressure and through thermal sensitivity.

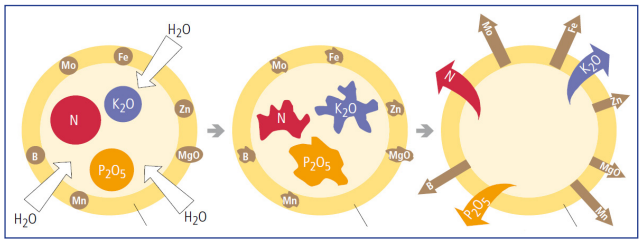

Figure 1: Mode of action of coated controlled fertilizers (Adapted from Trenkel, 1997)

Types of Slow/Controlled Release Fertilizers

The SRFs and CRFs are classified based on the type of coating materials used (Das *et al.*, 2022), which is classified as follows.

1. Low-Soluble Organic-N Compounds: Includes biologically decomposing compounds like urea-aldehyde condensation products, such as iso-butylidene diurea (IBDU).

2. Physical coatings and matrices: Nutrient release is controlled by coatings or matrices. Coatings can be organic polymer-coatings (resins and thermoplastic) or inorganic materials (mineral-based coatings), while matrices may use hydrophobic materials (*e.g.*, polyolefins) or hydrophilic gels (hydrogels) to reduce dissolution (Govil *et al.*, 2024).

3. Low-Soluble inorganic Compounds: Fertilizers developed using metal ammonium phosphates (*e.g.,* magnesium ammonium phosphate and rock phosphate acidulated).

Advantages of Controlled/Slow-Release Fertilizers

Efficient utilization of nutrients is achieved through slow/controlled release throughout the crop growth period compared to instant or split applications. This approach ensures nutrient release aligns with crop demand, often meeting seasonal needs with a single application, reducing labour cost. Additionally, CRFs and SRFs can cutdown recommended fertilizer use by 20-30% over traditional fertilizers while still obtaining the same yield (Shanmugavel *et al.*, 2023). Reduce the losses *viz*. leaching, volatilization, precipitation of nutrients and also the contribution of agriculture to GHG's (NO_x share is 2-3%) (Benlamlih *et al.*, 2021).

Disadvantages of Controlled/Slow Release Fertilizers

The production of C/SRFs fertilizers can be costly due to the need of high-end machinery and complex process. Challenges include potential antagonistic combination between either nutrient in fertilizer, coating materials, stabilizers and soil nutrients. Additionally, the design and manufacturing of these fertilizers are intricate, requiring careful formulation to ensure compatibility and effectiveness.

Conclusion

Controlled or slow release nature of coated fertilizers provide an effective solution for sustainable agriculture by enhancing nutrient use efficiency, reducing losses through leaching, volatilization and precipitation and lowering greenhouse gas emissions. S/CRF's provide the potential solution for better soil health; maintain ecological balance through sustainable crop production by reducing the negative impact of chemicals on the environment.

Future Prospects

The formulation synthesis and application of SRFs/CRFs became a new front in agriculture in developed and in few developing countries. At present few physical type S/CRFs are developed due to its better utility, apart from the complexity involved in chemical and compound type fertilizers. However, the complexity in utilization of stabilisers and inhibitors needs further evaluation before their wide spread adoption.

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