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Role of Slow-Release Nitrogenous Fertilizer in Sustainable Agriculture

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Abstract

Sustainable agriculture aims to balance productivity with environmental stewardship. Nitrogenous fertilizers are crucial for crop growth but often lead to environmental issues such as leaching, volatilization, and eutrophication. Slow-release nitrogenous fertilizers (SRNFs) provide a promising solution by minimizing nutrient loss, enhancing crop uptake, and reducing environmental impact. This review explores the mechanisms, benefits, and future prospects of SRNFs is promoting sustainable agricultural practices.

Introduction

Agricultural productivity depends significantly on nitrogen (N) fertilizers. Conventional nitrogen fertilizers, such as urea and ammonium nitrate, release nitrogen rapidly, leading to inefficiencies and environmental concerns. Slow-release nitrogenous fertilizers (SRNFs) are designed to release nitrogen gradually, ensuring sustained nutrient availability for crops while mitigating adverse environmental effects.

Mechanisms of Slow-Release Nitrogenous Fertilizers

SRNFs function through physical barriers, chemical modifications, or microbial interactions that regulate nitrogen availability. The primary types include:

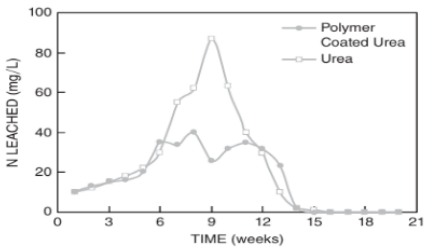
1. **Coated Fertilizers** – Encapsulated with polymer, sulfur, or resin coatings that degrade over time.
2. **Chemically Modified Fertilizers** – Urease and nitrification inhibitors slow down nitrogen transformation.
3. **Organic and Natural SRNFs** – Bio-based materials like compost and biochar gradually release nitrogen through microbial decomposition.

Different types of slow-release nitrogenous fertilizer

N Source	*Base compound*	*Common name*	*N content (%)*
S-coated urea	urea	SCU	30-42
Urea formaldehyde	Ureaforms	Nitroform	38
	methylene urea	Folocron	29
		Nutralene	40
		Hydrolene	
Isobutylidene diurea	isobutylidine urea	IBDU	31
Polymer- or resin-coated urea	urea	Polyon, Osmocote	38-44
Polymer/S-coated urea	urea	Polyplus-Poly-S Trikote	38–42

Benefits of Slow-Release Nitrogenous Fertilizers

1. **Enhanced Nitrogen Use Efficiency (NUE)** – SRNFs ensure steady nitrogen supply, improving crop uptake and reducing losses.
2. **Reduced Environmental Pollution** – Mitigates nitrate leaching into groundwater and lowers greenhouse gas emissions from volatilization.
3. **Reduced Leaching Loss**: NO_3-N, urea or NH_4-N are present in all traditional water-soluble N fertilizers. Soil organisms easily convert the latter two

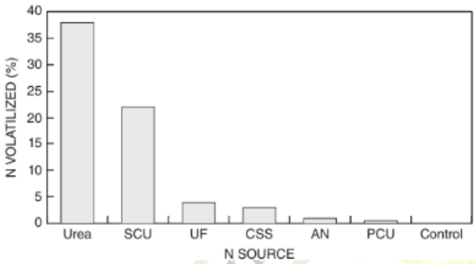


Effect of polymer-coated urea on N leached in

sources to NO_3-N. As a result, NO_3-N is by far the most prominent source of nitrogen in well-aerated soils. It causes leaching of nitrate nitrogen when high amounts of water travel through the soil profile. Although all SRN fertilizers eventually convert to NO_3-N. However, because their conversion is delayed, there may be less NO_3-N in the soil when leaching occurs (heavy rains or excess irrigation).

4. **Minimized Volatilization Losses**: The release of NH_3 from surface-applied urea or NH_4^+salts, or the release of N_2 or N_20 from denitrification of NO_3-N in flooded soils, can all contribute to nitrogen loss to the atmosphere.

As a result, SRN fertilizers that dissolve or solubilize slowly may help to reduce losses. Similarly, denitrification loss from SRN fertilizers may be lower than from soluble fertilizers due to a lower supply of NO_3-N.



SCU = sulphur-coated urea
UF = urea formaldehyde
CSS = composted sewage sludge
AN = ammonium nitrate
PCU = polymer-coated urea

Effect of urea products on N volatilization in (Knight *et al*., 2007)

5. **Economic Advantages** – Fewer applications are needed, reducing labor and input costs for farmers.
6. **Improved Soil Health** – Encourages microbial activity and organic matter retention, promoting long-term soil fertility.
7. **Optimized Crop Yields** – Provides sustained nutrition, leading to healthier plant growth and higher productivity.

Limitation of slow-release nitrogenous fertilizer

➢ **High Initial Cost**

The initial investment for slow-release nitrogen fertilizers can be significantly higher than conventional fertilizers. This can make them less accessible, especially to smallholder farmers or those in developing regions.

Potential Soil Compatibility Issues

Soil compatibility plays a vital role in fertilizer success. Some slow-release nitrogen fertilizers, particularly those with specific coatings, may interact differently with various soil types. For instance, the pH, texture, and organic matter content can affect the breakdown and release of nutrients. Thus, compatibility issues may arise in soils that are either too acidic or too alkaline.

➢ **Variable Environmental Conditions**

The effectiveness of slow-release fertilizers can be influenced by environmental factors such as temperature, moisture levels, and soil type. For instance, if the soil is too dry or too wet, the rate at which the fertilizer releases its nitrogen can be altered.

➢ **Microbial Interactions**

The breakdown of slow-release fertilizers often relies on microbial activity in the soil. In soils with poor microbial activity or an imbalance in soil microbiota, SRNs may not release nitrogen efficiently, reducing their effectiveness.

Conclusion

Slow-release nitrogenous fertilizers represent a crucial advancement in sustainable agriculture. By optimizing nitrogen use efficiency, reducing environmental harm, and supporting long-term soil health, they offer a viable path toward eco-friendly farming. As agricultural practices evolve, integrating SRNFs into mainstream farming can contribute significantly to global food security while protecting natural resources. Furthermore, their widespread adoption can help mitigate climate change, conserve water resources, and promote biodiversity. By fostering a more balanced agricultural ecosystem, SRNFs can play a pivotal role in ensuring the resilience of global food systems for future generations.

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