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Synergistic Effects of Nano-Sulfur and Animal Protein-Based Urea Coatings on Crop Performance

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Abstract

Farmers must constantly meet broad consumer expectations: more food, in appropriate quality, and of course, sustainably. Food security is not an issue nowadays, but within the European Union, increasingly strict legal conditions must also be met. The Green Deal, particularly the drastic reduction in the use of pesticides and synthetic fertilizers, pose a fundamental challenge for farmers. Integrated pest management is essential in crop production, one element of which is that the later protection of the crop is based on balanced nutrient supply. As nitrogen remains the primary limiting macronutrient in agricultural production, it represents an extensively researched domain where continuous innovation is imperative to pivot growers toward a more resilient and sustainable future. Moreover, due to commercial anomalies, supply chains can be compromised overnight, causing commodity prices to escalate exponentially. Consequently, optimizing Nitrogen Use Efficiency (NUE) is no longer just an environmental goal but an economic necessity. Urea fertilizer and its solutions are used in the largest volume worldwide for N supply (CAN and AN are also common in Europe). Despite the significant active ingredient content, it is prone to leaching and environmental ammonia emission, which makes the development of new, innovative solutions urgent in agricultural practice. Additionally, we must consider that the availability of synthetic nitrogen does not necessarily coincide with the physiological needs of the plant. This study examines a new, multifunctional approach by developing a slow-release urea (SRF) coating which follows the principles of the circular economy and originates from slaughterhouse by-products (meat and bone meal), the effects of which are enhanced by soil-acting biostimulants. We investigate a new multi-stage nutrient delivery system aimed at synchronizing urea hydrolysis with the uptake needs of plants using a biomimetic coating strategy and microbial priming. These protein-rich matrices do more than regulate N-release; they serve as potent rhizosphere primers, stimulating beneficial microbial activity. The goal of the research is to develop a multilayer coating system that not only slows down release but also enriches the soil with organic matter and an essential microelement (nano-sulfur). Sulfur participates in the research not only as a nutrient; it has a fungistatic effect, aids nitrogen incorporation, and plays an outstanding role in the development of Systemic Acquired Resistance, thus increasing the resilience of plants. Our research aims to verify the effectiveness of this multi-stage nutrient delivery system, which simultaneously mitigates environmental load and ensures sustainable yield growth.

Keywords: nano sulfur, blood meal, meat meal, urea