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NEW TECHNOLOGIES FOR THE SYNTHESIS OF VARIOUS COORDINATION COMPOUNDS BASED ON COBALT(II) NITRATE AND THEIR APPLICATION IN MAIZE USING HYDROGEL SYSTEMS

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Abstract: *This study focuses on the development of new technologies for synthesizing coordination compounds based on Cobalt(II) nitrate and their application in maize using hydrogel systems. Cobalt(II) ions form stable complexes with organic and inorganic ligands, exhibiting catalytic and growth-regulating properties. The encapsulation of Co(II) complexes in polymer-based hydrogels allows controlled release, improved nutrient absorption, and enhanced drought resistance in maize. The research explores synthesis conditions, structural characterization, release kinetics, and biological efficiency under laboratory and field conditions. The results provide a foundation for sustainable agricultural applications of cobalt-based biostimulants with high efficiency and environmental safety.*

Keywords: *Cobalt(II) nitrate, coordination compounds, hydrogel, controlled release, maize, biostimulant, sustainable agriculture.*

Introduction

The development of innovative technologies in coordination chemistry has become one of the central directions in modern materials science, catalysis, and agrochemical applications. Cobalt(II) nitrate and its coordination compounds are of particular interest due to their diverse oxidation states, rich coordination chemistry, and significant biological and catalytic activities. In recent years, researchers have focused on the synthesis of cobalt-based complexes with various ligands, as these compounds exhibit excellent redox stability, magnetic properties, and the ability to form stable coordination networks. These features make cobalt(II) coordination compounds suitable for use in catalytic reactions, environmental protection systems, and more recently, in agricultural biotechnology as components of smart fertilizers and plant growth stimulants.

Cobalt is a vital micronutrient for plants, playing an essential role in nitrogen fixation, enzyme activation, and chlorophyll formation. In legumes, for instance, cobalt contributes to the activity of nitrogenase enzymes in root nodules, facilitating atmospheric nitrogen assimilation. However, cobalt deficiency in soil can lead to reduced plant productivity, weaker resistance to stress, and slower metabolic activity. Therefore, the use of cobalt-containing compounds in agriculture has attracted attention as an effective way to increase yield, improve plant resilience, and enhance biochemical processes in crops such as maize (Zea mays L.), one of the world’s most important cereal crops.

Traditional forms of micronutrient fertilizers, however, often suffer from low bioavailability and high leaching rates. To overcome these limitations, recent studies have introduced the concept of hydrogel-based delivery systems, which can encapsulate metal complexes and release them gradually into the rhizosphere. Hydrogels are cross-linked polymeric materials capable of absorbing and retaining large amounts of water while maintaining structural integrity. When used as a carrier for coordination compounds, hydrogels can regulate the release of nutrients, minimize losses, and enhance plant uptake efficiency under various soil moisture conditions. Moreover, hydrogels provide a microenvironment that protects active cobalt species from degradation, ensuring their long-term stability in agricultural applications.

The synthesis of new cobalt(II) nitrate-based coordination compounds has been explored using a variety of organic and inorganic ligands such as amino acids, heterocyclic bases, and carboxylic acids. The coordination behavior of cobalt ions depends strongly on the nature of the ligands and synthesis conditions including solvent polarity, temperature, and pH. By adjusting these parameters, researchers can obtain mononuclear, polynuclear, or polymeric cobalt complexes with distinct physicochemical and biological properties.

In agricultural practice, the integration of cobalt(II) coordination compounds into hydrogel matrices represents a promising technology for sustainable crop production. Such systems can provide controlled nutrient delivery, improve water retention in the soil, and promote uniform root development. For maize, which has a high nutrient and water demand, hydrogel-assisted cobalt fertilizers may significantly improve physiological parameters such as chlorophyll content, root-shoot ratio, photosynthetic activity, and grain yield. Additionally, the slow and consistent release of cobalt ions can mitigate the risks of toxicity that may occur due to excessive or uneven application of traditional cobalt salts.

Recent experimental studies have demonstrated that cobalt(II) nitrate-based hydrogels influence plant metabolic activities by enhancing the activity of antioxidant enzymes, improving protein synthesis, and accelerating cell division. The molecular mechanism behind these effects involves cobalt's participation in redox reactions and its role as a cofactor in key enzymatic systems. Moreover, cobalt ions interact with plant hormones such as cytokinins and auxins, thereby modulating gene expression and growth regulation pathways. Understanding these molecular-level interactions can lead to the rational design of more effective cobalt-based biostimulants tailored to specific crop needs.

From an environmental perspective, hydrogel-supported coordination systems also contribute to resource conservation. By reducing nutrient leaching and evaporation losses, these materials help maintain soil fertility and minimize pollution of water bodies. In arid and semi-arid regions where water scarcity is a major constraint, hydrogels can act as moisture reservoirs, supporting plant growth even under limited irrigation. Consequently, the combination of coordination chemistry and polymer science offers a strategic solution for climate-resilient agriculture.

The purpose of the present research is to develop new technologies for synthesizing various cobalt(II) nitrate coordination compounds and evaluate their potential application in maize cultivation through hydrogel systems. The study aims to:

1. Synthesize and characterize cobalt(II) complexes with different organic ligands.
2. Incorporate these complexes into hydrogel matrices for controlled nutrient release.
3. Assess the effects of cobalt(II)-hydrogel formulations on maize growth parameters, biochemical indices, and yield.
4. Analyze the physicochemical stability and release dynamics of cobalt species from hydrogels under simulated soil conditions.

This research is expected to contribute to the growing field of smart agrochemical technologies by introducing innovative materials that bridge coordination chemistry and agricultural science. The successful development of cobalt-based hydrogel fertilizers will not only enhance maize productivity but also pave the way for eco-friendly and sustainable agricultural practices. Ultimately, these findings could serve as a foundation for future work on multi-metal coordination systems and polymer-supported micronutrient formulations designed to improve plant health and soil management across diverse agroecosystems.

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