BIOLOGICAL ACTIVITY OF HYPOXANTHINE DERIVATIVES AS PLANT GROWTH AND GERMINATION STIMULATORS

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ABSTRACT

Hypoxanthine, a naturally occurring purine base involved in nucleic acid metabolism, exhibits significant biological activity and coordination ability with metal ions. In this study, hypoxanthine-based bioactive compounds and their coordination complexes were investigated as potential stimulators of seed germination and plant growth. The synthesis of hypoxanthine derivatives and their metal complexes was carried out using cost-effective and environmentally friendly methods. The structural features of the obtained compounds were characterized using spectroscopic techniques, and their biological activity was evaluated under controlled laboratory and greenhouse conditions.

The results demonstrated that hypoxanthine-based compounds significantly enhanced seed germination rate, root and shoot development, and overall plant vigor compared to untreated controls. The coordination of hypoxanthine with essential metal ions improved the stability and bioavailability of the compounds, leading to a more pronounced stimulatory effect on early plant development. These findings indicate that hypoxanthine-based coordination compounds represent a promising class of eco-friendly plant growth stimulators with potential applications in sustainable agriculture.

Introduction

Coordination compounds play a crucial role in the life processes of plants and animals. For many years, scientists have been deeply interested in studying the biochemical processes occurring in plant, animal, and human organisms. Long-term studies have shown that by the end of the 19th century, all chemical compounds were classified into two major groups: atomic compounds and molecular (or complex) compounds. Later, atomic compounds were referred to as first-order compounds, while molecular compounds were classified as higher-order compounds[1-10].

Simple substances belong to the group of first-order compounds, and their formation follows classical valence rules. Higher-order compounds are formed through the interaction

of simple compounds. Among these, relatively stable higher-order compounds were later defined as complex (coordination) compounds[11-24].

A coordination compound is a compound whose molecule or ion contains a central atom or ion surrounded by several ions or molecules known as ligands. Such compounds tend to retain their structural integrity even in solution, although partial dissociation into ions may occur. If the positive charge of the central ion exceeds the total negative charge of the surrounding ligands, the compound is classified as a cationic complex. If the central ion charge is lower than the total ligand charge, the compound is considered an anionic complex. When the difference between the central ion charge and the total ligand charge equals zero, the compound is referred to as a neutral complex.

Numerous biologically important coordination compounds are found in living systems. For instance, chlorophyll, which plays a key role in photosynthesis in green plants, is a coordination compound of magnesium, while hemoglobin, responsible for oxygen transport in living organisms, is a coordination compound of iron. Coordination compounds can be synthesized through association, substitution, and oxidation–reduction reactions.

At present, excessive application of mineral fertilizers has led to significant changes in soil composition, resulting in increased acidity or alkalinity. Therefore, the synthesis of herbicides, dyes, plant growth stimulators, and stabilizers represents an important task of modern chemistry. One of the most pressing challenges today is the development of mineral and bioactive compounds capable of enhancing plant growth, development, and crop productivity. These compounds should demonstrate higher efficiency compared to existing analogues, be obtained by rapid and cost-effective synthesis methods, and significantly promote plant growth and yield.

The simplest coordination compounds occurring in living organisms are metal complexes formed with amino acids, in which amino acids act as dentate ligands, forming five- or six-membered chelate rings depending on their coordination mode.

Hypoxanthine and its derivatives, belonging to the purine class of heterocyclic compounds, possess significant theoretical and practical importance. Hypoxanthine is a naturally occurring purine base involved in nucleic acid metabolism and exhibits notable biological activity. Due to its ability to act as a donor ligand through nitrogen and oxygen atoms, hypoxanthine readily forms coordination complexes with metal ions. These complexes demonstrate promising physiological properties and can be effectively applied in the development of plant growth stimulators, metabolic regulators, and agrochemical preparations.

In our previous studies, the synthesis of hypoxanthine-based derivatives and their coordination complexes was investigated, along with an evaluation of their effects on plant growth, development, and selected biological systems.

Materials and Methods

Hypoxanthine was used as the primary bioactive ligand. Its coordination complexes were synthesized with selected essential metal ions (Co^{2+}, Zn^{2+}, Cu^{2+} and Fe^{3+}) using aqueous–ethanolic media. Hypoxanthine was dissolved in a hot EtOH:H_2O (70:30) mixture, followed by the gradual addition of the corresponding metal salt solution at a molar ratio of M:L = 1:2. The reaction mixture was stirred at 60–70 °C for 1–2 h, then slowly cooled to room

temperature to promote complex formation. The obtained precipitates were filtered, washed with ethanol, and dried under vacuum.

The synthesized compounds were characterized using IR spectroscopy to confirm coordination through nitrogen and oxygen donor atoms. Changes in characteristic bands corresponding to N–H and C=O groups were used to verify metal–ligand interactions.

Biological Evaluation

The biological activity of hypoxanthine-based compounds was evaluated through seed germination and early growth tests. Seeds of a selected agricultural crop were surface-sterilized and treated with aqueous solutions of the synthesized compounds at low concentrations (10^{-4}–10^{-6} M). Untreated seeds served as the control. Germination percentage, root length, shoot length, and seedling vigor index were measured under controlled laboratory conditions after 7–10 days. All experiments were performed in triplicate, and the results were statistically analyzed.

Results and Discussion

The experimental results demonstrated that hypoxanthine-based compounds exhibited a pronounced stimulatory effect on seed germination and early plant development. Compared to the control group, treated seeds showed a higher germination percentage and significantly improved root and shoot growth. The most notable effect was observed for hypoxanthine coordination complexes, which outperformed free hypoxanthine in all evaluated parameters.

The enhanced biological activity of the complexes can be attributed to increased stability and bioavailability resulting from metal coordination. Essential metal ions present in the complexes likely contributed to enzymatic activation and metabolic regulation during early plant growth. Root elongation was particularly sensitive to treatment, indicating improved nutrient uptake and cell division activity.

The results confirm that hypoxanthine-based coordination compounds act as effective plant growth stimulators, especially at low concentrations. Their eco-friendly nature, combined with efficient synthesis and significant biological activity, makes them promising candidates for application in sustainable agriculture.

Conclusion

The present study demonstrates that hypoxanthine-based compounds, particularly their coordination complexes with essential metal ions, exhibit significant stimulatory effects on seed germination and early plant development. The synthesized complexes enhanced germination rate, root and shoot growth, and overall seedling vigor compared to untreated controls and free hypoxanthine. The improved biological activity is attributed to increased stability, bioavailability, and synergistic effects of metal coordination. Owing to their eco-friendly nature, low effective concentrations, and cost-efficient synthesis, hypoxanthine-based coordination compounds represent promising plant growth stimulators with potential application in sustainable agricultural practices.

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