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Cobalt: The Essential Nutrient for Plant Growth?

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SUMMARY

Cobalt has been considered an essential element for human beings, and other mammals, but its essentiality for plants remains confusing or unclear. In this article, we will discuss that cobalt (Co) is a potentially essential micronutrient of plants. Cobalt is essential for the growth of many lower plants, such as marine algal species including diatoms, chrysophytes, and dinoflagellates, as well as for higher plants in the family *Fabaceae* or *Leguminosae*. The confirmation of Cobalt as an essential micronutrient will enrich our understanding of plant mineral nutrition and improve and increase our practice in crop production. In legumes, cobalt is important for nitrogen fixation by the bacteria that associate with legumes. It is also a component of vitamin B_{12} so is important for human consumption. Some research suggests that cobalt plays a role in the production of ethylene by plants. Interestingly, high levels of cobalt can reduce the amount of cadmium that is up taken by plants.

INTRODUCTION

The essentiality of cobalt was proposed by Ahmad and Evans, in 1959. Cobalt (Co) fertilization is occasionally reported to benefit crop growth, but the need for supplemental Co is rather rare. Cobalt is a nutrient that is recognized as a potentially essential nutrient for plants. Cobalt is necessary for nitrogen (N) fixation occurring within the nodules of legume plants. Cobalt is a metallic element located in the same row of the chemical periodic table like many other micronutrients. This group of metals is vitally important for biochemical reactions in most organisms, especially for the reactions which are involved in enzymes. Cobalt has been long known as essential for animals. However, the understanding of the essential role of Cobalt in plant enzyme reactions is still incomplete. The best-known function of Cobalt in plants is for N-fixing microorganisms, such as *Rhizobium*, which is lives symbiotically with legume plants. In N-fixing bacteria, Cobalt is a vital component needed to synthesize vitamin B_{12}, which is necessary to form haemoglobin. The haemoglobin content in legume root nodules is directly related to successful N fixation.

Why cobalt is essential for plants?

Cobalt (Co) is a metallic element, neighbouring manganese, iron, nickel, copper, and zinc in the periodic table of elements. It was established long ago that cobalt is essential for living beings that belong to different genera, from microorganisms to mammals.

Some of its central roles in their lives stem from being an essential component of vitamin B12, and of some specific enzymes found in nitrogen-fixing bacteria, whether or not living symbiotically within the nodules of legume plants (e.g. rhizobia). Cobalt application is occasionally reported to benefit crop growth; however, its essentiality for higher plants' physiology cannot be proven, perhaps because the plant requirement for it, measured in parts-per-billion, is always found in the soil or as a contaminant of other nutrients.

Cobalt is found in most soils at low concentrations. Its incidence depends on soil's parent material, soil's texture, and its contents of organic matter. Sorption by mineral surfaces and organic matter decreases with rising pH, in a similar way to that of zinc (Zn) and nickel (Ni). Weathered, coarse-textured soils are generally low in cobalt (Co) because they don't resist its leaching. Finer-textured soils, and soils containing higher levels of organic matter, tend to have greater Co concentrations. And soils developed from minerals such as olivine and pyroxene have ample Co. It is largely present as Co2+. Its highest masses are required in trace amounts by atmospheric nitrogen-fixing microorganisms.

Role of cobalt in plants

Cobalt was isolated by Brandt in 1735 and recognized as a new element by Bergman in 1780 (Lindsay and Kerr, 2011).

Cobalt plays an important role in biological nitrogen fixation

Cobalt addition increased the nodules formation of root and atmospheric nitrogen fixation by microorganisms which increase the nitrogen content in leguminous plants. This was confirmed by Abdel-Moez and Nadia Gad (2002). Moreover, cobalt application increases the formation of leghaemoglobin required for nitrogen fixation, thereby improving the nodule's activity (Yadav and Khanna, 1988).

Cobalt is essential for lower plants

- Lower plants are commonly known as non-vascular plants because they do not have xylem and phloem vascular systems. Non-vascular plants are generally divided into bryophytes and algae.
- Cobalt forms a complex with N in a porphyrin structure that is needed for vitamin B_{12} and this complex is known as cobamide coenzyme.
- Co is involved in leghaemoglobin-metabolism and ribonucleotide reductase in Rhizobium.
- Cobalt content in the crust of the earth ranges from 15 to 30 mg/kg (Roberts and Gunn, 2014). Co in soils is closely related to the weathering of parental minerals, such as cobaltite, smaltite, and erythrite (Bakkaus et al., 2005) as well as Co pollution (Mahey et al., 2020).
- Cobalt at low concentrations can also promote the growth of non-leguminous crops. Co applied to a sandy soil at 1 mg/kg enhanced shoot and root dry weights of wheat by 33.7 and 35.8%, respectively compared with the control (Aery and Jagetiy, 2000), and the same Co rate applied to a sandy loam soil increased shoot and root dry weights of wheat by 27.9 and 39.6%, respectively, compared with the control.

Deficiency Symptoms

Adequate Co is required for N fixation, and leguminous plants growing in Co-deficient soil will develop N deficiency symptoms due to inadequate vitamin B_{12} synthesis. Non-legume plant species (i.e., grasses) can grow on soils lower in Co availability compared to legume plant species, but animals grazing on the forage may develop Co deficiency symptoms. There are no known visual Co deficiency symptoms for non-legume plants. Its deficiency symptoms include leaf chlorosis and necrosis, growth retardation, and reduced crop yield, resembling N-deficiency in plants (Liu, 1998). Co deficient legumes have reduced plant size, smaller and pale yellow leaves, and smaller pods compared with non-deficiency plants. Root growth is also affected by exhibiting an overall reduction of root volume and root lengths. Nodule size and numbers are less abundant than the plants without Co deficiency. Co deficiency causes reduced synthesis of methionine, thus limiting protein synthesis and contributing to the smaller-sized bacteroids (Marschner, 2011). Sweet lupin is particularly sensitive to Co deficiency (Robson et al., 1979). In field-grown lupins, Co deficiency reduced bacteroid number per gram of nodule (Chatel et al., 1978) and affected nodule development and function at different levels (Dilworth et al., 1979). Co deficiency in legumes can be assessed by analysis of Co contents in shoots. In general, deficient symptom appears when shoot Co falls in a range from 0.04 (Ozanne et al., 1963) to 0.02 mg/kg based on dry weight (Robson et al., 1979). To correct Co deficiency in leguminous crops, application of Co in a range of 1.8 to 145.6 g per hectare was reported (Havlin et al., 2013).

Toxicity of cobalt in plants

Due to foolhardy use of fertilizers, wastewater discharge, coal, and motor fuel combustion processes increased mining of the cobalt ore, the concentration of naturally occurring Co has increased. Cobalt is not relegated as an essential element for plants. Nevertheless, it is usually distinguished as a beneficial element having a role in certain biochemical and physiological processes of plants. Higher levels of Co in the soil cause toxic impacts on plants that are reflected in their morphology as well as physiology. Some studies reported that increased concentration (10, 50, 100, 150 mM) of heavy metals (Ni, Co, Fe) decreased the rate of seed germination, root length, shoot length, protein, and phenolics content in broad beans (*Vicia faba* L.). The metal toxicities of various metals studied were found in the order Co > Ni > Fe.

CONCLUSION

Cobalt in soils ranges from 15 to 25 mg/kg, wherein plant roots can absorb Co from soils and transport absorbed Co from roots to shoots in a controlled manner. Co concentrations in shoots vary with plant species but are comparable to those of essential elements of Cu, Ni, and Zn. Co was well-documented as a constituent of cobalamin, which is required by symbiotic, endophytic, and associated bacteria in the fixation of N2. Biological N fixation contributed significantly to the production of economically important crops, including beans, soybeans, rice, corn, barley, wheat, and sugarcane. The current view of plant-microbe association as a phytomicrobiome resulted from millions of years of co-evolution. The coevolution between plants and N2 fixing bacteria should remind us of the critical role Co plays and its potential essentiality to plant growth and development. Additionally, plants must have Co-enzymes or proteins that are specifically responsible for Co metabolism. Due to its similar properties to other transition elements, its biological roles in plants have been largely ignored and simply attributed to its ability to substitute for those elements.

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