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Review Article

A Review on Importance of Cobalt in Crop Growth and Production

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A B S T R A C T

The functions of various nutrient elements influence biochemical processes and eventually affect the overall growth of various crops and their production. The beneficial elements (Al, Co, Na, Se and Si) are not deemed essential for all crops but may be vital for particular plant. These elements are not critical for all plants but may improve plant growth and yield. Nutrients reviewed in this paper include Cobalt (Co). Cobalt is an essential component of cobalamin, which is needed for activities of several enzymes and co-enzymes and is responsible for formation of leghaemoglobin, involve in nitrogen fixation in nodules of leguminous plants (Mathur *et al.,* 2006) by improve the nodules number per plant, it also governs the number and size of the root nodules (Yadav and Khanna, 1988). Cobalt has been shown to be essential for symbiotic nitrogen fixation by legumes and it play a vital role as a cofactor of cobalamine (Vitamin B_{12}) which functions as a coenzyme involved in N_2 fixation and nodule growth (Dilworth *et al.*, 1979). Application of cobalt through seed treatments improves the germination of seed, stand establishment, growth, yield and quality. Cobalt has both beneficial as well as harmful effects to plants. However, relatively lower concentration of cobalt helped in better nodulation and consequently a better growth and yield but at higher level of cobalt reduced the bacterial population in the rhizosphere and as a result nodulation was hampered which led to a lower growth and yield of the crop. At higher cobalt concentration detrimental effects on plant growth along with chlorosis and necrosis was reported by (Caselles *et al.*, 1997) and also inhibits root growth by retarding cell division, hindering the uptake and translocation of nutrient and water (Jayakumar *et al.*, 2008).

Introduction

Plant growth is influenced by a number of factors including temperature, available water, light and available nutrients in the soil. A German scientist Justus von Liebig in the mid-19th century was one of the first scientists to show that nutrients are essential for plant growth (Tucker, 1999). (Jones and Jacobsen, 2001) In addition to the essential mineral elements are the beneficial elements, elements which promote plant growth in many plant species but are not absolutely necessary for completion of the plant life cycle, or fail to meet Arnon and Stout's criteria on other grounds. Recognized beneficial elements are: Silicon, sodium, aluminium, cobalt, and selenium. Nutrients reviewed in this paper include only Cobalt (Co). Cobalt is considered to be beneficial element for higher plants in spite of the absence of evidence for direct role in their metabolism (Gad, 2012). This is true in spite of essentiality cobalt is unequivocally essential for leguminous crops as it is required for nitrogen fixation by bacteria in root nodules (Witte *et al.,* 2002).Cobalt plays a critical role in the overall growth process of plants. Cobalt is necessary for the processes of stem growth, elongating the coleoptiles, and expanding leaf discs. It is a critical element needed for a plant to reach maturity and for healthy bud development.Although Co is an essential nutrient, excessive over doses result in a variety of adverse responses (Nagpal, 2004). Moreover, cobalt reduces the peroxdase activity which is known to affect the breakdown of Indole acetic acid (IAA). Cobalt, a transition element, is an essential component of several enzymes and co-enzymes.

It has a role in affecting growth and metabolism of plants in different stages, depending on the concentration and status of cobalt in rhizosphere and soil (Palit and Sharma, 1994). The beneficial effects of Cobalt include retardation of senescence of leaf, increase in drought resistance in seeds, regulation of alkaloid accumulation in medicinal plants, and inhibition of ethylene biosynthesis (Palit and Sharma, 1994). Cobalt is an essential element for the synthesis of vitamin B_{12} which is required for human and animal nutrition. Unlike other heavy metals, cobalt is safe for human consumption and up to 8 mg can be consumed on a daily basis without health hazard (Young, 1983).

All the relevant and important published work on leguminous crop has been reviewed and presented here under the following heads:

Effect of cobalt on growth, yield attributes and yield of leguminous crops

Effect of cobalt on nodulation and nitrogen fixation in leguminous crops

Effect of cobalt on nutrient status in leguminous crops

Effect of cobalt on growth, yield attributes and yield of leguminous crops

Kandil *et al.,* (2013) carried out an experiment on the effect of cobalt on soybean cropand revealed that the application of cobalt @ 12 mg kg^{-1} gave the highest growth parameters *viz.* length of shoot, length of root, number of nodules plant^{-1}, number of leaves plant^{-1}, number of branches plant^{-1}, fresh weight and dry weight of shoots and roots and decreased with further increased in cobalt level in the soil.

Hala, Kandil (2007) Conducted a field experiment on sandy loam soil to study the effect of cobalt as cobalt sulphate at the rate of 0, 5, 10, 15 and 20 ppm cobalt on growth and yield parameters of faba bean. Who found that the application of 20 ppm cobalt gave highest levels of growth and yield parameters of faba bean plants i.e. plant height, No. of branches/plant, No. of nodules/plant, No. of pods/plant, No. of seed/plant, seed yield/fed and dry weights of shoots and roots. The positive effect of may be due to cobalt application promotion of many developmental processes such as stem and coleoptiles elongation, opening of hypostyle hooks, leaf disc expansion and bud development.

Gad *et al.,* (2013) conducted a field experiment on sandy loam soil to study the effect of cobalt (0, 4, 8, 12, 16 and 20 mg kg^{-1}) on soybean. They observed that cobalt application upto 12 mg kg^{-1}significantly increased the nodulation, growth and yield parameters however, by increasing cobalt concentrations more than 12 mg kg^{-1}, all growth yield parameters were significantly reduced. This reduction is may be due to the effect of excess cobalt level were distinctly responsible for leaf deformation, leaves chlorophyll content and net photosynthesis.

Jaleel *et al.,* (2008) a pot experiment was conducted with five levels of cobalt (0, 50, 100, 150, 200 and 250 mg kg^{-1} soil) to study the effect on yield and yield attributing character of groundnut. The application of 50 mg kg^{-1} cobalt increased various growth parameters such as root and shoots length, numbers of nodules, total leaf area, dry weight of root and shoots. Whereas, all yield attributing characters were decreased with increase cobalt level. They also found that application of 50 mg kg^{-1} level of cobalt in the soil is beneficial for the growth of groundnut.

A pot culture experiment was conducted by Jayakumar and Jaleel, (2009) revealed that the root and shoot length of soybean were found to be higher at 50 mg kg^{-1} but it was decreased with an increased in cobalt level. Similarly, the highest dry matter of root, stem, leaf and shoot were significantly highest at 50 mg Co kg^{-1} level but it showed a gradual decline from 100 mg kg^{-1} level onwards. Significantly the highest yield was noted in 50 mg kg^{-1} of cobalt level whereas, the application of higher level of cobalt (100 to 250 mg kg^{-1}) marked reduction in yield parameters and yield.

Sahay and Singh (2012) conducted an experiment to study the effect of cobalt application on growth, yield attributes and yield of lentil. They found that the plant height was significantly increased with increasing levels of cobalt upto 6 kg ha^{-1} and decreased at 8 kg Co ha^{-1}. Application of 6 kg Co ha^{-1} significantly increased the pods $plant^{-1}$, seed $plant^{-1}$, test weight, number of branches $plant^{-1}$ and dry matter $plant^{-1}$ as compared to control. They also found that application of 6 kg Co ha^{-1} gave higher grain and straw yield of lentil.

Khan and Khan (2010) carried out a pot experiment to investigate the effect of varying concentration of nickel and cobalt on growth of chickpea and they reported that nickel at 10 ppm and cobalt at 50 ppm gave higher plant growth (root and shoot length), biomass (fresh and dry weight of shoot and root) and root nodulation as compared to other levels.

Effect of cobalt on nodulation and nitrogen fixation in leguminous crops

Cobalt at lower concentration help in better nodulation and consequently a better growth and yield, but at higher concentration cobalt reduced the bacterial population in the rhizosphere and as a result nodulation was hampered which led to a lower growth and yield of crop. In other words, 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 loghaemoglobin required for nitrogen fixation, thereby improves the nodules activity (Yadav and Khanna, 1988).

Gad, N. (2012) conducted an experiment on groundnut to study the effect of cobalt (0.0, 4, 6, 8, 10 and 12 ppm) nutrition on sandy loam soil, result revealed that Cobalt at 8 ppm recorded the maximum nodules number, fresh and dry weights. In addition the encourage happened in the nodule formation process resulted in increasing the efficiency of rhizobium bacteria to perform with N fixation at high capacity to produce healthy plants. That means cobalt can play a vital role in increasing nitrogenase enzyme activity of groundnut root nodulation as compared with untreated plants. That the increase in nitrogenase activity was parallel and related to the increase in nodules number and efficiency.

Hala, Kandil (2007) carried out an experiment to study the effect of cobalt on growth, yield, nodules formation and nutrients content of faba bean grown by using four levels of cobalt and found that the dry weights of roots, shoots, stem, pod, grain and nodules formation significantly increased by increase percentage cobalt levels in all treatments compared with control.

Yadav and Khanna (1983) studied the application of 0.0, 0.5, 1.5, 2.5 and 3.5 ppm cobalt to cowpea variety FOS-1 and soybean variety Bragg, grown each in Inceptisols and Entisols, respectively for 60 days and found that cowpea fixed 3.5 and 7.0 % higher nitrogen at 1.5 ppm Co application, while soybean fixed 3.3 and 13.4 % more nitrogen at 2.5 and 3.5 ppm Co application in the former and later soils, respectively.

Yadav *et al.,* (1984) investigated influence of cobaltous nitrate solution in combination with phosphorous in the form of KH_2PO_4 solution and revealed that at 60 days of growth the addition of 20.0 ppm phosphorous at all cobalt levels significantly increased the numbers of nodules.

Its further addition decreased the nodules except 40.0 ppm phosphorous with 1.0 ppm Co at 100 days of growth, number of root nodules increased with Co addition up to 1.0 ppm with all phosphorous levels addition of Co up to 1.0 ppm with phosphorous invariably increased the number of nodules and nitrogen fixation at both the stages.

Younis (2011) reported that cobalt at 100 µg gave significantly superior effect on growth parameters such as number of nodule plant^{-1} (24.36), fresh weight of nodules plant^{-1}(3.95 g), dry weight of shoot plant^{-1}(14.51g) as compared to rest of all treatments, while higher levels of cobalt and copper (200 µg) had decreased plant growth, dry matter accumulation of shoot and roots.

Vijayarengan (2012) He studied cowpea plant raised in pots containing the soil amended with various levels of cobalt chloride (Control, 50, 100, 150, 200 and 250 mg kg^{-1} soil). They showed that the application of 50 mg kg^{-1} cobalt chloride gave significantly higher root length (25.10 cm), shoot length (42.42 cm) and numbers of nodules (63.25), while at higher levels of cobalt all these parameters are decreased with increased levels of cobalt.

Effect of cobalt on nutrient status in leguminous crops

Kandil *et al.,* (2013) observed that application of 12 mg kg^{-1} cobalt had a significant effect on the N, P and K contents of soybean plants compared with the control. On the other hand increasing cobalt levels more than 12 mg kg^{-1}in plant media resulted in significant reduction in concentrations of these nutritive elements. The reduction seemed to be related positively to the concentration of Co.

Basu *et al.,* (2006) A field experiment was carried out to study the effect of cobalt, *Rhizobium* and phosphobacterium inoculations on growth parameters and yield of summer groundnut in an alluvial soil at three levels of cobalt viz., zero, 0.21 and 0.42 kg ha^{-1} with four levels of inoculations viz., un-inoculation, inoculation with Rhizobium, inoculation with phosphobacterium and inoculation with both

Rhizobium and phosphobacterium. He revealed that the maximum N, P and K uptake value was obtained with *Rhizobium* + phosphobacterium inoculation + Co @ 0.21 kg ha^{-1}which was followed by Rhizobium inoculation + Co @ 0.21 kg $ha^{-1}$and the difference was 27.4%.

The cause of maximum uptake of N in combined application of *Rhizobium* and phosphobacterium inoculation with cobalt @ 0.21 kg $ha^{-1}$was that, it helps in increasing the population of nitrogen fixing bacteria (*Rhizobium*) in the rhizosphere which led to more infection as well as nodule formation (Yadav and Khanna 1988).

Manal *et al.,* (2016) showed that the effect of applying cobalt as foliar application at the rate of 0.24 and 0.48 g/L in broad bean on clay loam soil (7kg/pot). The results clearly indicate that the percentage of N, P and K in response to the different rates recorded significant increase in comparison with untreated plants.

Kandil *et al.,* (2013) carried out an experiment to study the effect of cobalt (0.0, 4.0, 8.0, 12.0, 16.0 and 20.0 mg Co kg^{-1}) on soybean crop. They revealed that application of cobalt @ 12 mg kg^{-1} enhanced N, P, K, Cu, Zn and Mn content in shoot and seed but decreased with further increase in cobalt level.

Basu and Bhadoria (2008) conducted a field experiment to study the effect of cobalt, *Rhizobium* and Phosphobacterium inoculation on nutrient uptake in summer groundnut (*Arachis hypogaea* L.) using three levels of cobalt chloride (0, 0.21 and 0.42 kg ha^{-1}) in soil application. They reported that soil application of cobalt at lower dose (0.21 kg ha^{-1}) with Rhizobium inoculation had significantly enhanced nitrogen (81.4 kg ha^{-1}), P (8.9 kg ha^{-1}), K (9.31 kg ha^{-1}) and cobalt (0.27 kg ha^{-1}) uptake by kernel of groundnut.

We conclude that adequate intracellular concentrations of beneficial metal ions (in traces) are not only required for optimal growth and development of plants, but also responses at lower dose of cobalt helped in better nodulation and consequently a better growth and yield but at higher level of cobalt reduced the bacterial population in the rhizosphere and as a result nodulation was hampered which led to a lower growth and yield of the crop. At lower dose of cobalt might have increased yield due to increased rate of photosynthesis. Cobalt is required for the synthesis of leghemoglobin and, thus, for the growth of legumes relying on symbiotically fixed nitrogen, is an essential mineral nutrient. It has been established that rhizobium and other N_2-fixing microorganisms have an absolute cobalt requirement whether or not they are growing within nodules and regardless of whether they are dependent on a nitrogen supply from N_2 fixation or from mineral nitrogen. Cobalt is a necessary element to legumes. For legumes, Cobalt at lower doses enhance nodule formation, nitrogen fixation, growth, seeds and oil yield of oilseed and leguminous seeds. It is noteworthy that elements other than those discussed here may also be beneficial for plants, but more validation is needed to support these results.

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