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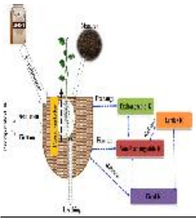

Potential of zinc solubilising micro-organisms in soil

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Zinc (Zn) is an essential element necessary for plant, humans and micro-organisms required relatively in small concentrations (5–100mg kg^{-1}) in tissues for healthy growth and reproduction of plants. It is considered as one of the eight essential trace elements required for crop growth and production. It is present on earth's crust in tune of 0.008 per cent and zinc has an important role in nutrition and metabolic activities of both eukaryotic and prokaryotic organisms and act as a cofactor or metal activator in various enzymatic systems. Plants absorb Zn as zinc ions (Zn^{2+}). Since Zn does not have variable valence, it has no role in influencing oxidation-reduction (redox) processes directly.The worldwide prevalence of Zn deficiency in crop is due to low solubility of Zn, rather than low Zn availability in soil (Iqbal *et al.*, 2010). The unavailable zinc can be reverted back to available form by application of bacterial strain capable of solubilizing it.

Functions of zinc in plant:

– Zinc is a constituent of three enzymes-carbonic anhydrase (transfer CO_2 for photosynthetic CO_2 fixation), alcoholic dehydrogenase (Plays an important role in anaerobic root respiration) and superoxide dismutase (detoxifies superoxide radicals).

– Zinc is involved in the synthesis of Indole Acetic Acid, metabolism of gibberellic acid and synthesis of RNA.

– Zinc promotes synthesis of cytochrome C.

– Because of its preferential binding to sulphydryl (-SH) group, Zn plays an important role in the stabilization and structural orientation of the membrane proteins.

– Zn influences translocation and transport of P in plants. Under Zn deficiency, excessive translocation of P results in the P-toxicity.

Conditions conductive for zinc deficiency: The worldwide prevalence of Zn deficiency in crop is due to low solubility of Zn, rather than low Zn availability in soil (Iqbal *et al.*, 2010). It is predicted approximately greater than 50 per cent of the Indian soils are zinc deficient (Ramesh *et al.*, 2014). The zinc applied to agriculture fields as zinc sulphate (soluble) gets converted to different insoluble forms like $Zn(OH)_2$ at high pH soil, $ZnCO_3$ in calcium rich alkali soils, zinc phosphate in near neutral to alkali soils with large application of P fertilizers and ZnS under reducing conditions particularly during flooding. These details advocate that the soluble form of Zn fertilizers applied to the fields becomes readily insoluble forms that cannot be assimilated by plants, leading to the Zn deficiency in crops. In soil, it undergoes a complex changes and precipitate with other elements that is greatly influenced by pH and microflora, which ultimately affects their accessibility to roots for absorption. If the amount of zinc available is not adequate, plants and animals will suffer due to physiological stress brought about by the dysfunction of several enzyme systems and other metabolic functions. Other conditions favouring Zn deficiency are light textured soil, high pH, high calcareousness**,** eroded soil, low organic matter, low land rice soils.

Deficiency symptoms: Common symptoms of Zinc deficiency include inter-veinalchlorosis,reduction in the size of younger leaves which are often clustered or borne very closely, bronzing and purple,violet, reddish brown or purple colouration of the foliage. Little leaves get mal-formed giving a bushy rosette appearance. Shortened internodes result in dwarfing of the plants.

Zinc deficiency in different plants is known as:

– *Khaira* disease of rice-deriving its origin from dark reddish brown pigmentation of the leaves of the affected plants.

– White bud of maize

– Little leaf of cotton

– Mottle leaf or frenching of citrus

– Rosette disease of apple.

Microbial Zn solubilization and its importance: The process by which plant unavailable inorganic Zn comes to soil solution form(plant available form) carried out by soil micro-organisms is known as microbial Zn solubilisation. About 96 to 99 per cent of the applied zinc is converted into different type of insoluble forms depending upon the soil types, physico-chemical reactions of the soil. The solubility of zinc is highly dependent on soil pH and moisture. Availability of zinc from these sources is guided by many factors among which biochemical actions of rhizosphere micro-organisms play an important role in converting such unavailable sources into available ones. The Zn deficiency could be surmounted by application of Zn fertilizers in the fields, but mostly chemical fertilizers are very costly and have adverse effect on environment. The zinc thus, made unavailable can be reverted back to available form by application of bacterial strain capable of solubilizing it. Many micro-organisms have been isolated from natural soil environment and grown in culture medium containing different zinc sources. The micro-organisms who have the ability to solubilize zinc take up zinc from the culture media as a result of which a solubilisation zone (halo zone) can be found in the media. After incubation zone of clearing around the bacterial colony and colony diameter are measured.The zone of clearing around the bacterial colony is indicative of zinc solubilization. The isolates showing zinc solubilisation property are then taken for 16s RNA sequencing to identify the genera and species they belong to.

$$\text{Zinc solubilization efficiency (SE\%)} = \frac{\text{Diameter of solubilization halo}}{\text{Diameter of the colony}} \times 100$$

Potential of zinc solubilising micro-organisms: Zinc solubilisation potential is found to be varying with respect to type of sources (Zn containing mineral) and type of microbial isolates from different places. It is found to be varying with different Zinc sources, days of incubation, pH, Temperature and with added sources of Carbon, NaCl and KCl. The cultures show a shift in pH towards acidic range, it gives a clue that organicacid might be involved. Dissolution of the ore and other material may be due to production of organic acids, like gluconic acids (especially 2 ketogluconic acids). The zinc phosphate solubilization by *Pseudomonas fluorescens* was investigated by Di Simine *et al.* (1998). They found that gluconic acid and 2 ketogluconic acids produced in the culture broth helped in the solubilization of the zinc salt. Available zinc levels increased with the increase in incubation period. This might be due to the presence of excess zinc even after the absorption by the microbial cells. Effects of applications of ZSBs in field conditions have also been found to be potential.Applications ZSBs increases yield attributing parameters like root length,shooth length,root volume,root dry weight,shoot dry weight etc. Both grain yield and straw yield are found to be increasing with application of ZSBs.

Few zinc solubilizing bacterial genera *viz.*, *Thiobacillus ferrooxidans, Thiobacillus thiooxidans, Acinetobacter* sp., *Bacillus* sp. (*B.aryabhattai*) *Gluconacetobacter* sp., *Pseudomonas* sp. *(P. aeruginosa), Burkholderia* sp., *Ralstonia pickettii, Klebciella pneumonia* and facultative thermophilic iron oxidizers are reported as zinc solubilizers. Microflora may increase the solubility of zinc in several ways like-

– Releasing the organic acids with causes the pH to fall.

– The decomposition of plant remains leads to a release of soluble cations.

– Oxidation of sulphide in ZnS by *Thiobacillus* which release the metal in water soluble form.

Conclusion:

Soils are naturally rich in total zinc but lack available zinc form. Application of soluble zinc sulphate to alleviate zinc and silicon deficiency in certain soils is a costly practice. Thus, the obtention of an elite culture or a consortium of strains capable of utilizing different unavailable insoluble forms of zinc and tolerant to higher zinc levels may be useful to make zinc available in the soil system. Selection and inoculation of zinc solubilizing bacteria (ZSB) either alone or along with cheaper insoluble zinc and silicon compounds, like ZnO or $ZnCO_3$, $ZnSiO_4$ will lead to lot of saving in crop husbandry, besides curtailing the expenditure on agro input.

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