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Zinc Biofortification: Strategy to Conquer Zinc Malnutrition through Zinc Solubilizing PGPR's

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Introduction to Zinc deficiency

Zinc (Zn) is a required micronutrient for all living form including plant, humans and microorganisms. Human and other living organisms require Zinc throughout life in little quantities to orchestrate a complete array of physiological functions [1]. Zinc is also important micronutrient for plant which plays numerous functions in life cycle of plants. The aim of biofortification is to produce plants that have an augmented content of bioavailable nutrients in their edible parts [2]. Cereals and other staple plant serve as the main food for a large proportion of the world population but have the shortage in term of micronutrient, from a nutrition perspective, of being low in zinc and other essential nutrients. In the process of Biofortification the major drawback is the root or shoot barriers and the process of grain filling. Research has shown there are possible ways to combats the situation and distribution of zinc can be controlled mainly by heavy metal transporting P -ATPase and the metal tolerance protein (MTP) family. A greater understanding of zinc transport mechanism is needed to improve grain quality and to help alleviate accumulation of any hazardous metals [3].

Majority of the soil are either Zinc deficient or contain Zinc in fixed form which is unavailable to plant, thus them appears a Zinc deficiency. According to FAO reports, 50% of the soils are deficient in Zinc [4]. Deficiency of Zinc is frequently in calcareous and neutral soils, paddy soils, soils with elevated level of phosphorous and silicon, sandy soils, extremely weathered acid and coarse textured soils [5]. Zinc deficiency may also be related with the nature of soil such as in calcareous soils. Zn may exist as low as 10-11 to 10-9 M and can reduce crop growth [6]. Approximately in India zinc deficient soils has engaged almost 50% of the agricultural part and the same is the situation in Turkey. In Pakistan, 70% of agricultural land has been reported as Zinc deficient [7] and half of the agricultural soil in China has been affected by zinc deficiency. while Occurrence of Zinc in soil is found as ZnS (sphalerite), Further less frequent Zinc containing mineral ores include: smithsonite ($ZnCO_3$), zincite (ZnO), zinkosite ($ZnSO_4$), franklinite ($ZnFe2O_4$) and Hopeite [$Zn_3(PO4)_2.4H_2O$]. However, availability of Zn from these sources depends on various factors [8].

Role of rhizospheric microorganism in micronutrient deficiency

The term Plant Growth-Promoting Rhizobacteria (PGPR) was termed over three decades ago, they are non-pathogenic, strongly root colonizing microbes on the surface of plant's roots which promotes plant's yield by various mechanisms [9]. Plant growth promoting rhizobacteria can influence plant growth by different direct and indirect mechanisms [10]. PGPR influence direct growth promotion of plants by nitrogen fixation, phosphate solubilization, enzyme production such as chitinase cellulase, secreting phytohormones such as IAA, GAs, and Kinetins besides ACC deaminase production [11], which helps in regulation of ethylene.

Induced systemic resistance (ISR), antibiosis, competition for nutrients, parasitism, production of metabolites (hydrogen cyanide, siderophores) suppressive to deleterious rhizobacteria are some of the mechanism that ultimately benefit plant growth. According to study, numerous species of soil bacteria which thrive in the rhizosphere of plants, but which may grow in, on, or around plant tissues, and stimulate plant growth by a superfluity of mechanisms are collectively known as PGPR [12]. Recently study reveal that the PGPR associations range in the degree of microbial proximity to the root and intimacy of association. In general, they can be extracellular (ePGPR), existing in the rhizosphere, on the rhizoplane, or in the spaces between cells of the root cortex, and intracellular (iPGPR), which exist inside root cells, generally in particular nodular structures [13].

Role of Plant growth promoting rhizobacteria

Biological nitrogen fixation is considered major mechanisms by which plants get benefited from PGPR. According to an estimate, global contribution of biological nitrogen fixation is 180 × 106 metric tons per year. Of this contribution, 83% comes from symbiotic associations, while the rest part of it is provided by free living or associative systems [14]. Archaea and bacteria are the major living forms that can fix the atmospheric nitrogen and enrich the soil with this form of nitrogen [15]. These include symbiotic nitrogen fixers (*Rhizobium* in legumes, *Frankia* in non-leguminous trees) and non-symbiotic nitrogen fixers such as *Azoarcus, Acetobacter diazotrophicus, Azotobacter,Azospirillum, cyanobacteria* etc. Plants require an adequate supply of nutrients for their appropriate growth and development. Plants growing on the soils enriched with nutrients may still exhibit nutrient deficiencies due to unavailability of these mineral nutrients. However, plant growth promoting rhizobacteria are actively involved in the solubilization of important minerals such as phosphorous, iron, zinc, potassium etc thereby enhancing the availability of these essential nutrients to plants [10]. The optimistic role of PGPR in stimulating the plant growth by improving solubilization (releasing siderphores or organic acid) and nutrient uptake by the plants has been reported [16].

Role of microorganism in zinc solubilization

Plant growth promoting rhizobacteria (PGPR) are the main factors that have been studies for their important functions in sustainable agriculture. PGPR are a diverse group of microbes that are found in the rhizosphere on root surfaces as well as in association with roots [17]. These microbes move around from the immensity of soil to the living plant rhizosphere and antagonistically colonize the rhizospheric region of plant [14]. A soil microbe which directly or indirectly promotes the plant growth is termed as plant growth promoting rhizobacteria (PGPR) [18]. These are comprised of naturally occurring beneficial microorganism in soil that make available nutrients to plant through several mechanisms by fixing atmospheric nitrogen, solubilize the nutrients fixed in soil and by producing phytohormones [19]. PGPR can be estranged into two groups according to their association with plants: symbiotic bacteria and free living rhizobacteria [20]. PGPR's have important role in phosphate dissolution and in bioavailability of soil phosphorus, potassium, iron, zinc and silicate to plant roots [2]. Many studies have revealed that inoculations of potent strain of Zinc mobilizer rhizobacteria increase the yield of field crop such as rice wheat barley and maize. Recent study describes the effect of Zn mobilizing PGPR which significantly conquer the deficiency symptoms of Zn and regularly by increasing the total biomass and grain yield [21].

Furthermore inoculation of Zn mobilizing PGPR had a optimistic impact on root weight (74%), root length (54%), root area (75%), root volume (62%), shoot weight (23%) panicle emergence index (96%) and exhibited the maximum Zn mobilizing efficiency as compared the un- inoculated control plant [22]. Besides efficacy of PGPR strains can efficiently solublize the Zinc in liquid culture which showed notable increased concentration in rice plant. Interestingly, the yield results have indicated that the PGPR contributed superior storage of assimilates in rice grains [23]. Likewise, higher Zn solubilization was reported with ZnO as compared to other Insoluble ores. Practicable relevance of PGPR has been studied and is repeatedly promising; however, high-quality sympathetic use of microbial interactions is needed in plant growth increase, which will significantly raise the success rate of field application [12].

Future Aspects

Agronomic approaches such as application of Zn-containing fertilizers appear to be a rapid and simple solution to the Zn deficiency problem. Combination of breeding and fertilizer strategies is an excellent complementary approach to alleviate zinc-deficiency related problems in human nutrition. New research programs are needed to develop or improve Zn application methods in terms of form, dose, and application time of Zn fertilizers. It is important to highlight that use of agronomic biofortification approach to improve grain Zn concentrations might be limited in various developing countries/regions, because resource-poor farmers cannot afford application of mineral fertilizers, especially micronutrient fertilizers. Under such situations plant breeding becomes a high priority approach to the problem.

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