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Review Article

A Detailed Review Study of Zinc Involvement in Animal, Plant and Human Nutrition

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ABSTRACT

This present review critically discusses the detailed study of zinc (Zn) involvement in animal, plant and human nutrition. The status of micronutrients in food is unquestionable. Among all micronutrients, Zn is a vital component whose importance to nutrition is gradually more valued, and shortage may play a prominent role in the appearance of the disease. It is a crucial micronutrient for the development of living thing (animal, plant and human) and its absence persuaded poor outcome with increases the severity and possibility of a range of infections and constrained the physical growth in animal, plant and human. The Zn is essential for synthesizing many coenzymes, with three prominent biotic roles, structural, regulatory, and catalyst. Zn is also a necessary element of gene manifestation. In both agriculture and industry, Zn is widely used as fertilizers and in handling other metals as fortification against oxidization. Furthermore, Zn is involved in various physical functions; its insufficient quantity will decrease crop yield. It can also reduce the deadly effect of pollutants in plants by increasing the photosynthesis rate and decreasing oxidative anxiety. Zn also provides resistance to crop against water-deficient conditions.

Keywords: *Zinc deficiency, Human Malnutrition, Animal Diseases, Plant Growth.*

INTRODUCTION

The growth and development of plant are chiefly dependent on the availability of nutrients. Fundamentally, plants require various nutrients, divided into two different categories, such as macronutrients and micronutrients, under their need for these particular nutrients.

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These nutrients comprise nitrogen (N), phosphorous (P), potassium (K), calcium (Ca), zinc (Zn), iron (Fe), boron (B), sulphur (S), magnesium (Mg) etc. Many nutrients affect the various biochemical processes occurring within the plant system; they also support plants to fight against the various disorders that impact plant growth adversely (Toor et al., 2021; & Gondal et al., 2021). Micronutrients play a crucial role in lessening disease's rigorousness that can also contribute to its inclusion in plants' biochemical and physiological activities. Most of the vital micronutrients are included in various reactions that may influence plants' response to pathogens (Marschner, 1995). The Zn is one of these micronutrients that have either more or less or, in some cases, have no effects on plants' vulnerability to disease (Graham and Webb, 1991; & Grewal et al., 1996). Furthermore, Zn's addition lessens the extremity of infection and disease, which might be due to Zn's toxic effect on the pathogen instantly and not through the plants' metabolic reactions (Graham & Webb, 1991).

Metals that have high bulk density are called heavy metals and are generally venomous for human health as well as noxious for plants and animals even in their low concentration (LWTAP, 2004) and have a high atomic mass that is five times larger as compared to water or greater than 4 g/cm^3 (Hawkes, 1997) or larger than 5 g/cm^3 (Weast et al., 1984; & Saxena & Shekhawat, 2013). The unnecessary metals also exist on the earth's surface, which arrives from the superior soil horizon and incorporates in the food chain from different biogeochemical cycles (Tinsley, 1979). Metals and metalloids like cadmium (Cd), lead (Pb), mercury (Hg), and Zn are known as heavy metals because they have a high bulk density (Oves et al., 2012). The Zn with the atomic number 30 is one of the members of the transition metals group. Zn has an entire d shell and present in a typical concentration in the upper 71 μg/g crust of the continent (Taylor & McLennan, 1995).

Zn exists in the oxidation state of +2 in the natural environment. The significant sources of zinc in the earth crust are two ore minerals: sphalerite (ZnS) and smithsonite ($ZnCO_3$). Zn in minute concentration plays a crucial function in several biological processes and is of too much importance for the earth's living species. It also acts as an essential constructing element in all six classes of enzymes and most regulatory proteins. (Berg & Shi, 1996).

Zn entraps too much concentration of the scientific community in different disciplines. It acts as a central part in many metabolic activities in plants such as integrity of membrane (Cakmak, 2002), gene expression, carbohydrate and photosynthetic metabolism (Prasad, 2006), detoxification of reactive oxygen species (ROS), phytohormone activity and everyday activities of many enzymes (Cakmak, 2000) and lessens the toxicity of P.

For both the resource economists and environmental scientists, Zn is a material of too much attention. It is an extensively exploited metal of the industry and is vital for all organisms' nutrition in low concentration (Landner & Lindestro, 1998).

The potential supply of Zn is too much restricted, even at low prices (Tilton, 2001; & Kesler et al., 2015). For the growth of a Zn cycle, collection and characterization of info for the number of life stages like mining and processing, manufacture, use, and end of life. In the year 2008, the global pool for zinc base was predictable to 480 Tg, a 12% increment from the 2000 assessment (USGS, 2000; & USGS, 2009). In a similar era, the world observed the spectacular increment in the Chinese economy and a large financial disaster, both of which seriously exaggerated metal flows. The Zn mine production, metal production and metal consumption rise by 6%, 13%, and 16% between 2009 and 2010 throughout the world. (ILZSG, 2011; & USGS, 2010).

History of zinc

The Zn has always been an important mineral element in agricultural production. However, recognition of this significance came gradually at first (Nielsen, 2012). A student of Louis

Pasteur reported in 1869 that Zn was a required nutrient for the productivity of *Aspergillusniger*. This fungus tends to cause black mould in some agricultural products, such as peanuts, onions, and grapes. That remarkable discovery lay dormant until 1911, once Bertrand and Javillier in 1911 verified Raulin's discovery. Mazé, 1914 reported three years later that maize grown hydroponically required zinc for development and growth.

Importance of Zinc

The Zn is one of the essential components in carbohydrate metabolism; it activates most of the enzymes involved in carbohydrate metabolism. The Zn is a critical component in several enzymes and is necessary to produce many essential plant enzymes. Furthermore, it initiates a variety of enzymatic reactions (Akay, 2011). It is a physical, structural, and regulating co-factor for several enzymes (Grotz & Guerinot, 2002). It is vital in many biological processes (Broadley et al., 2007). It is needed for many enzymes' proper functioning and plays an essential role in DNA transcription (Singh et al., 2012). Other Zn functions include catalysing the process of oxidation in plant cells, which is critical for carbohydrate transformation, and controlling the formation of chlorophyll, auxins, and growth-regulating compounds. It is essential for protein and starch production, so a low zinc concentration causes amino acid accumulation and a reduction in sugar content in plant tissues. In zinc deficiency, several enzymes in which Zn plays an important role are reduced, resulting in carbohydrate accumulation in plant leaves (Taheri et al., 2011). Furthermore, zinc aids pollination by playing a part in pollen tube formation (Pandey et al., 2006).

Impact of zinc on Humans life

The Zn, the 23rd most abundant component in the earth's crust (Zn: Human Health Fact Sheet 2005), with atomic number 30 and atomic mass 65.37, is essential to life. Its pure zinc is a bluish-white, glossy metal relatively amphoteric in nature (Escobedo Monge et al., 2019). Most spectroscopic methods cannot detect Zn because it is colourless and diamagnetic (Maret, 2001). Zn is necessary because it is required for the structural or catalytic functions of over 300 proteins involved in piscine growth, reproduction, development, vision, and immune function (Watanabe et al., 1997). As a result, Zn is the second most crucial critical metal for fish, behind only iron in quantity (Watanabe et al., 1997). The diet's Zn requirements vary from 230–460 mol (15–30 mg) kg–1 dry mass of diet (Gatlin & Wilson, 1983).

Zn is such an essential nutrient in human health that even a minor deficiency is disastrous. In humans, a lack of Zn causes anorexia, loss of appetite, loss of smell and taste, and other symptoms, and it may affect the immune system, causing arteriosclerosis and anaemia. Zn deficiency results in impaired hemostasis due to defective platelet aggregation, decreased T cell number, and reduced T-lymphocyte response to phytoestrogens. In reality, Zn is the only natural lymphocytic mitogen (Keen & Gershwin 1990; & Tapiero & Tew, 2003). Zn is an essential element that performs various functions in the body since it is a cofactor in the synthesis of many enzymes, DNA, and RNA (WHO, 1996). Zinc deficiency has been linked to pregnancy and childbirth complications and growth retardation, and congenital defects in the fetus (Black, 2001).

Zn is a well-known trace element globally. In our body, Zn plays a vital role as a trace element. Other hands, it is crucial for microorganism’s growth and development. It is equally critical for plants as well as animals. It is almost present in all of the tissues and other secretions of our body in higher concentrations. Out of total Zn present in our body, 85% is found in bones and muscles, 11% is located in the liver and our skin, and the rest is found in some other tissues. The utmost Zn concentration is found in the eye’s part and prostate. In an adult body, average zinc amounts are near 1.4-2.3g (Prasad, 2009; & Bhowmik et al., 2010). It was estimated that out of the total world’s population, a third of it is facing zin deficiency risks. This risk is dominant in children (under the age of 5 years) because they have higher demands of Zn to complete their growth and for the process of their development (Wessells & Brown, 2012). Due to Zn deficiency, many children die annually, e.g. more than half-million each year (Black et al., 2008; & Krebs et al., 2014). In developing countries, deficiencies of micronutrients especially Zn is one of the primary cause of economic loss. As human health care costs increase, productivity is decreased, affecting gross national product (Darton-Hill et al., 2005; & Stein, 2014).

Problems of Zn deficiency in humans

People are using a diet based on cereals. These diets contain Zn in lower quantity, leading to malnutrition of Zn in the human body (Biesalski, 2013). Daily intakes of zinc for an average human are about 3-16 mg. Improper intake of Zn causes many diseases in the human body. Because of Zn scarcity, the global mortal community is suffering about 30%. (Welch et al., 2002).

Impact of zinc on Animal

The Zn is considered an essential part of 200 enzymes. Out of this, metabolic actions include carbohydrate metabolism, protein synthesis and its metabolism, metabolism of nucleic acid, integrity of epithelial tissues, cell division and processes of its repair, transport, and utilization of Vitamin A and Vitamin E (Bindari et al., 2013). In the immune system, zinc has a crucial part; hormones (e.g. reproductive) play a significant role (Capuco et al., 1990). Sexual maturity, capacity needs to reproduce and especially for estrus. In the maintenance and repairing of uterine lining following the parturition, return to normal reproductive functioning and estrus (Goff, 1999). In Bulls, a decrease in semen quality and reduced size and libido of testicles were observed due to Zn deficiency (Daniel, 1983).

In cows, for intensive milk production, protein and energy requirements are high. An appropriate balance between mineral and vitamins about the physical form and the interaction between feed components are provided (Strusińska et al., 2003). Inadequate intake of Zn through the diet is every day in Africa, the Middle East, and South America, associated with protein and energy malnutrition (Wessells & Brown, 2012).

It is also a vital element for the health of animals. Several proteins, enzymes and transcription factors are involved in the binding of Zn, and in return for their functioning, these are dependent upon zinc. Zn is involved in biochemical processes that are supporting life. Foremost respiration of cells, oxygen use by cells, DNA and RNA expression, maintenance of integrity of cellular membranes, free radical's sequestration and protection against peroxidation of lipids. The Zn is a central constituent of metalloenzymes, dehydrogenase lactate, carboxypeptidase, polymerases of DNA and RNA. The human body contains 1.5–2.5 g zinc; out of this, 60% is found in the body muscle and about 30% in our bones. The recommended dose of Zn daily is 11 mg for adult men, and it is 8 mg per day (Cousins, 1998; Brown, 2001; & Erdman et al., 2012).

The nutritional status of farm animals is the backbone of their performance and reproduction. Micronutrients are involved in many functions running in their body, such as free radicle's intracellular detoxification, reproductive steroid synthesis, synthesis of other hormones, metabolism of carbohydrate, protein, and nucleic acid. Deficiency or excess can cause reproductive issues in male, e.g. impair spermatogenesis and libido. And in females, it affects their fertility, development of an embryo, survival, postpartum recovery, and production of milk, growth and survival of their offspring (Smith & Akinbamijo, 2000). The Zn deficiency in animals can easily be manifested by the changes in their taste perception (as the epithelium of tongue damage), synthesis disorder (e.g. keratin synthesis), and limited growth of limb bone and infections of eyesight (Prasad, 2013).

Problems of Zn deficiency in animals

Likewise, Straw, which has a deficiency of Zn, generates issues for animals such as rice straw used for animal food (Alwahibi et al., 2020). Numerous diseases have been reported due to Zn deficiency in animals, as shown in (S1 Table 1).

S1Table 1: Zn deficiency problems in animals

Animals	Diseases	References
Rats	Modulation thyroid function, Depressive behaviour, Cardiovascular disease, Fetal heart anomalies	Baltac et al. 2003; Pathak et al. 2011; Baydas et al. 2002; Ianni et al. 2020; Ensley, 2020
Cattles	Reduced or cessation of growth, Skin parakeratosis Lethargy	Ianni et al. 2020; Ensley, 2020
Reindeer	General debility	Ianni et al. 2020; Mir et al. 2020; Ensley, 2020
Sheep	Increased susceptibility to infection, Loss of wool and wrinkled skin	Love and Laven, 2020; Wu et al. 2020; Helal, 2020
Buffalo	Gut integrity, Inflammation	Opgenorth et al. 2020
Goat	Stiff joints, Dermatitis, Foaming mouth, Miscarriages poor appetite, Sore foot	Song et al. 2020; Ulutas et al. 2020

Role of Zinc in Plant growth

For the growth of animals and human beings, zinc is vital. For plants, it is required to nutrition crops and involves numerous reactions of enzymes, metabolic and redox reactions. Enzymes associated with the transfer of energy, synthesis of protein and metabolism of nitrogen depend on Zn (Cakmak, 2002, & Graham et al., 2001). In biochemical reactions, these enzymes play a significant role, i.e. in the metabolism of carbohydrates, photosynthesis, and sugar conversion into starch. It is also alarmed with the metabolism of protein and auxin, formation of pollen, maintenance of the biological membrane's integrity, and such enzymes related to infection resistance caused by any pathogen (Alloway, 2008).

In hydrogenase activities, carbonic anhydrase, ribosomal functions stabilization and cytochrome synthesis are under Zn influence (Tisdale et al., 1984). The zinc activates some enzymes of plants. Those are involved in the metabolism of carbohydrates, the integrity of cell membranes is maintained, synthesis of protein, regulation and synthesis of auxin and pollen formation (Marschner, 1995). In plants, tolerance against environmental stresses is done by some specific genes and maintenance and regulation of such gene expression required (Cakmak, 2000). The deficiency of Zn in plants resulted in many abnormalities that can be noticed as visible symptoms of deficiency like stunted growth, reduced leaves size, leaves chlorosis, and spikelet sterility. The poverty of micronutrients such as Zn affects the quality of mature and harvested crop products; infection resulting from fungal or disease attacks is increased, and plant susceptibility for injury caused by higher intensities of light and temperature is also enhanced (Marschner, 1995; & Cakmak, 2000).

Role of Zinc in Plants Facing the Drought Stress

Stress-induced by non-living factors influence all the living organisms that exist on the surface of the earth. Drought stress is one of the most disturbing abiotic stress on crops' production among these stresses (Qados, 2011). Drought stress is becoming more common stress of the plants day by day because of irregular rainfalls and alteration in climate pattern (Whitmore, 2000). The quick increment in the atmosphere's temperature has maximized the crop acquaintance to the stress that is because of drought (Fahad et al., 2017; & Naeem et al., 2018). The extremity of the drought stress is unstable because it depends on many factors such as the dissemination and amount of rainfall, evapotranspiration and ability of soil to store moisture in it (Saud et al., 2016). Drought stress reduces crop productivity, thereby lessening the uptake of water by plants, lower leaf water status, and gas exchange rates (Farooq et al., 2017).

Furthermore, in agriculture, drought is the most devastating factors for agricultural crop productivity. It adversely impacts plants' mechanisms like the formation of proteins, nucleic acid, lipids, and carbohydrates, which reduce crops' growth and production as shown in Table 2. Many different solutions are present which can lessen the drought stress but the best and calmest method to cope with drought stress is foliar application. The Zn is an essential element that plays a crucial role in many biological processes occurring on the earth crust. Besides, Zn use remarkably reduces the adverse effects of water deficit on plants' growth, thereby decreasing photo-oxidative damages (Toor et al., 2020).

Table 2: Zn sensitivity of different crops

Low Sensitive	Medium Sensitive	Highly Sensitive
Asparagus	Alfalfa	Bean
Carrot	Barley	Citrus
Forage grasses	Clover	Cowpea
Mustard	Cotton	Maize
Oat	Sorghum	Millet
Pea	Sugar beet	Onion
Rye	Sugar can	Rice
Wheat	Sunflower	-
Paper mint	-	-

Sources: (ILZRO, 1974; Rashid & Fox, 1992; Martens & Westermann, 1991; & Tariq et al., 2002)

Sources of Zinc

List of different organic and inorganic sources that enhance the growth of the plant and the availability of Zn in soil and plant as shown in figure 1. Data collected from various sources enhance the Zn availability and plant growth in multiple crops (Rashid, 1996).

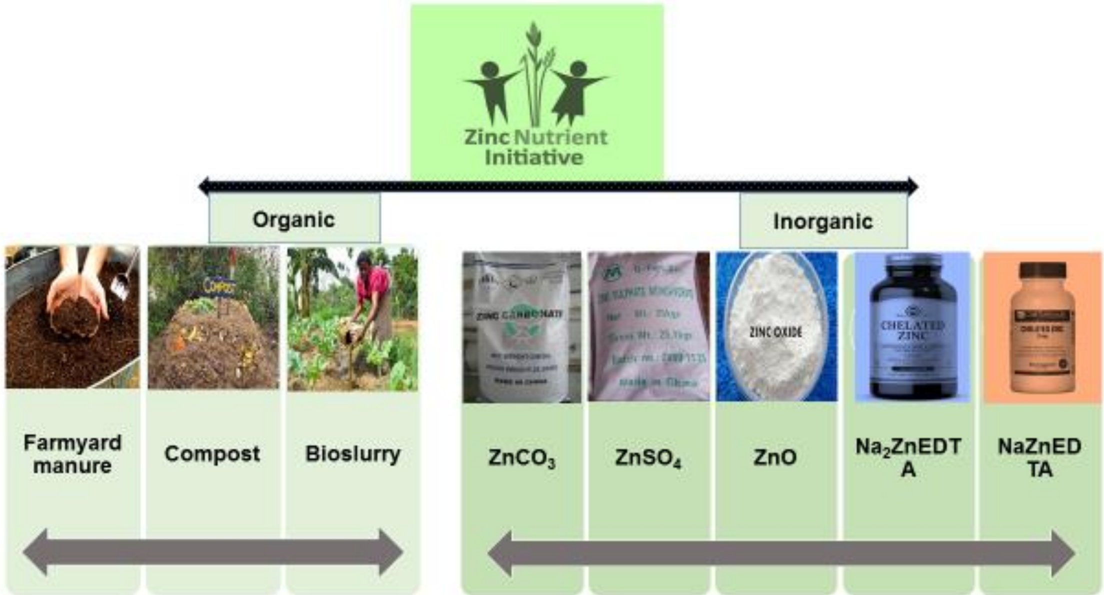

Figure1.various sources of Zn that can be used for the reduction of Zn deficiency

CONCLUSION

According to the current inclusive review, Zn is an essential micronutrient and plays a vital role in animal, plant and human nutrition. Zn provides resistance to plants against many diseases, which can directly or indirectly reduce crops' yield. In human, Zn works as a dominant healing nutrient in counter to many diseases. In animal, Zn is responsible for proper sexual development, and its deficiency can reduce the size of testicular in males.

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