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Full Length Research Paper

A Comprehensive Analysis of Zinc's Role in Plant, Animal, and Human Nutrition

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The comprehensive investigation of zinc's (Zn) role in plant, animal, and human nutrition is critically examined in this review. It is indisputable that food contains micronutrients. Of all the micronutrients, zinc is an essential one whose value to nutrition is steadily increasing, and its deficiency may be a major factor in the development of the illness. It is an essential micronutrient for the growth of all living things, including humans, plants, and animals. Its absence led to poor outcomes, increased the likelihood and severity of a variety of illnesses, and limited the physical development of humans, plants, and animals. The synthesis of many coenzymes requires zinc, which has three important biotic functions: structural, regulatory, and catalytic. Zn is also essential for the expression of genes. Zinc is used extensively in business and agriculture as fertilizers and to fortify other metals against oxidation. Moreover, zinc plays a number of physical roles; a lack of it would reduce agricultural productivity. By accelerating photosynthesis and lowering oxidative stress, it can help lessen the lethal effects of contaminants on plants. Additionally, zinc gives crops tolerance to conditions including insufficient water.

Key words: Zinc deficiency, Human Malnutrition, Animal Diseases, Plant Growth.

INTRODUCTION

The availability of nutrients is the primary determinant of plant growth and development. At their core, plants need distinct nutrients, separated into two groups, such as macronutrients and micronutrients, according to their specific nutrient requirements.

Nitrogen (N), phosphorous (P), potassium (K), calcium (Ca), zinc (Zn), iron (Fe), boron (B), sulfur (S), magnesium (Mg), and so on are some of these nutrients. Numerous nutrients have an impact on the different biochemical processes that take place inside the plant system; they also help plants combat different diseases that negatively affect plant growth (Toor et al., 2021; & Gondal et al., 2021). Micronutrients are essential for reducing the severity of disease, which can also help plants' biochemical and physiological processes. The majority of essential micronutrients are involved in a number of processes that could affect how plants react to infections (Marschner, 1995). One of these micronutrients, zinc, can either have a greater or lesser impact on a plant's susceptibility to disease, or it may not have any effect at all (Graham and Webb, 1991; & Grewal et al., 1996). Moreover, the addition of zinc reduces the severity of infection and disease, which may be because zinc has an immediate toxic effect on the pathogen rather than through the metabolic processes of the plants (Graham & Webb, 1991).

Heavy metals are defined as metals with a high bulk density that are typically toxic to plants and animals and harmful to human health even at low concentrations (LWTAP, 2004). They also have a high atomic mass that is five times larger than water, greater than 4 g/cm3 (Hawkes, 1997), or greater than 5 g/cm3 (Weast et al., 1984; & Saxena & Shekhawat, 2013). Additionally, the earth's surface contains superfluous metals that enter the food chain from various biogeochemical cycles and come from the superior soil horizon (Tinsley, 1979). Due to their large bulk density, metals and metalloids such as cadmium (Cd), lead (Pb), mercury (Hg), and zinc are referred to as heavy metals (Oves et al., 2012). One of the transition metals is zinc, which has an atomic number of thirty. According to Taylor and McLennan (1995), zinc has a complete d shell and is often found in the top 71 μg/g of the continent's crust.

In nature, zinc is found in the oxidation state of +2. The important Smithsonite ($ZnCO_3$) and sphalerite (ZnS) are two ore minerals that are sources of zinc in the earth's crust. The earth's living species depend heavily on zinc, which is essential for many biological activities at very low concentrations. Additionally, it serves as a crucial building block for the majority of regulatory proteins and all six kinds of enzymes. Shi and Berg (1996).

Zn locks the scientific community in an excessive amount of discipline-specific concentration. It plays a key role in a variety of plant metabolic processes, including membrane integrity (Cakmak, 2002), gene expression, photosynthetic and carbohydrate metabolism (Prasad, 2006), elimination of reactive oxygen species (ROS), phytohormone activity, and the regular functions of numerous enzymes (Cakmak, 2000). It also reduces the toxicity of P.

Zn is a substance that receives far too much attention from environmental scientists and resource economists. Low concentrations of this widely used metal are essential for the feeding of all species (Landner & Lindestro, 1998).

Even at low costs, the prospective supply of zinc is too limited (Tilton, 2001; & Kesler et al., 2015). Information gathering and characterization for the many life stages, such as mining and processing, manufacturing, usage, and end of life, are necessary for the development of a zinc cycle. The worldwide zinc base pool was estimated to be 480 Tg in 2008, a 12% increase over the 2000 assessment (USGS, 2000; & USGS, 2009). During a same period, the globe witnessed a massive financial catastrophe and a remarkable growth in the Chinese economy, both of which greatly inflated metal flows. Between 2009 and 2010, global zinc mine production, metal production, and metal consumption increased by 6%, 13%, and 16%, respectively. (USGS, 2010; ILZSG, 2011).

History of zinc

Zinc has always been a crucial mineral for agricultural development. But first, acknowledgment of this importance was slow (Nielsen, 2012). In 1869, a Louis Pasteur student observed that zinc was a necessary ingredient for Aspergillus niger output. Onions, grapes, peanuts, and other agricultural goods are susceptible to black mold due to this fungus. After Bertrand and Javillier confirmed Raulin's discovery in 1911, that outstanding discovery was put on hold until that year. Three years later, in 1914, Mazé showed that zinc was necessary for the growth and development of hydroponically produced maize.

Importance of Zinc

One of the key elements in the metabolism of carbohydrates is zinc, which activates the majority of the enzymes involved. Zinc is a vital component of many enzymes and is required for the synthesis of numerous vital plant enzymes. Additionally, it starts a number of different enzymatic processes (Akay, 2011). For several enzymes, it serves as a structural, regulatory, and physical co-factor (Grotz & Guerinot, 2002). Many biological functions depend on it (Broadley et al., 2007). It is necessary for the correct operation of numerous enzymes and is crucial for DNA transcription (Singh et al., 2012). Additional zinc roles include regulating the synthesis of auxins, chlorophyll, and growth-regulatory substances as well as catalyzing the oxidation process in plant cells, which is essential for the transformation of carbohydrates. Since zinc is necessary for the synthesis of both protein and starch, low zinc levels result in a buildup of amino acids and a decrease in the amount of sugar in plant tissues. A zinc deficit causes a reduction in a number of enzymes where zinc is essential, which leads to the buildup of carbohydrates in plant leaves (Taheri et al., 2011). Additionally, zinc contributes to the development of pollen tubes, which facilitates pollination (Pandey et al., 2006).

Impact of zinc on Humans life

Life depends on zinc, the 23rd most abundant element in the crust of the earth (Zn: Human Health Fact Sheet 2005), which has an atomic number of 30 and an atomic mass of 65.37. According to Escobedo Monge et al. (2019), pure zinc is a lustrous, bluish-white metal that is comparatively amphoteric in nature. Since zinc is colorless and diamagnetic, it cannot be detected by most spectroscopic techniques (Maret, 2001). According to Watanabe et al. (1997), zinc is essential for the structural or catalytic activities of more than 300 proteins involved in the growth, development, reproduction, vision, and immune system of piscine. Because of this, zinc is the second most important metal for fish, behind iron in terms of quantity (Watanabe et al., 1997). According to Gatlin and Wilson (1983), the dietary needs for zinc range from 230 to 460 mol (15–30 mg) kg^{-1} dry mass of diet.

Because zinc is so vital to human health, even a slight shortage can have catastrophic consequences. A zinc deficiency in humans can lead to anorexia, appetite loss, loss of taste and smell, and other symptoms. It can also impact the immune system, resulting in anemia and arteriosclerosis. Due to poor platelet aggregation, a drop in T cell count, and a diminished T-lymphocyte response to phytoestrogens, a zinc deficit impairs hemostasis. Zn is actually the sole lymphocytic mitogen that occurs naturally (Keen & Gershwin 1990; & Tapiero & Tew, 2003). As a cofactor in the creation of several enzymes, DNA, and RNA, zinc is a necessary element that serves a variety of purposes in the body (WHO, 1996). Growth retardation, congenital abnormalities in the fetus, and difficulties during pregnancy and labor have all been associated with zinc deficiency (Black, 2001).

Around the world, zinc is a well-known trace element. Zinc is an essential trace element in our bodies. On the other hand, it is essential for the development and growth of microorganisms. It is just as important for plants as it is for mammals. In greater amounts, it is found in practically every tissue and other bodily excretion. Approximately 85% of the zinc in our body is found in our bones and muscles, 11% is found in our skin and liver, and the remaining portion is found in various other tissues. The prostate and the area of the eye have the highest concentrations of zinc. Zinc levels in an adult's body typically range between 1.4 and 2.3 grams (Prasad, 2009; & Bhowmik et al., 2010). According to estimates, a third of the world's population is at danger for zinc deficiency. Due to their greater zinc requirements for growth and development, children (those under the age of five) are at a heightened risk for this condition (Wessells & Brown, 2012). More than half a million children die each year as a result of zinc deficiency (Black et al., 2008; & Krebs et al., 2014). One of the main causes of economic loss in poor nations is micronutrient deficiencies, particularly those related to zinc. Productivity declines as human health care expenses rise, which impacts the GDP (Darton-Hill et al., 2005; & Stein, 2014).

Problems of Zn deficiency in humans

People are following a cereal-based diet. The human body experiences zinc deficiency as a result of these diets' reduced zinc content (Biesalski, 2013). The average person consumes 3–16 mg of zinc each day. Numerous illnesses in humans are brought on by improper zinc consumption. About 30% of the world's mortal population is suffering as a result of zinc scarcity. (Welch and others, 2002).

Impact of zinc on Animal

Zinc is thought to be a necessary component of 200 enzymes. Carbohydrate metabolism, protein synthesis and metabolism, nucleic acid metabolism, epithelial tissue integrity, cell division and repair processes, transport, and vitamin A and E usage are among these metabolic activities (Bindari et al., 2013). Zinc is an essential component of the immune system, and hormones, including reproductive hormones, are important (Capuco et al., 1990). Sexual maturity refers to the ability to reproduce, particularly during estrus. After parturition, the uterine lining is maintained and repaired, and estrus and reproductive functions return to normal (Goff, 1999). Due to zinc shortage, bulls' semen quality declined, and their testicles' size and libido decreased as well (Daniel, 1983). Cows need a lot of protein and energy to produce milk intensively.According to Strusińska et al. (2003), there is a suitable ratio of vitamins and minerals regarding the physical form and the interaction between feed components. Every day, people in South America, the Middle East, and Africa consume insufficient amounts of zinc through their diets. linked to deficiency in energy and protein (Wessells & Brown, 2012).

Additionally, it is essential for animal health. The binding of zinc involves a number of proteins, enzymes, and transcription factors, all of which depend on zinc to operate. Biochemical activities that sustain life involve zinc. First and foremost, cell respiration, oxygen consumption, DNA and RNA expression, cellular membrane integrity, free radical sequestration, and lipid peroxidation prevention. Zinc is an essential component of metalloenzymes, carboxypeptidase, dehydrogenase lactate, and DNA and RNA polymerases. About 30% of the 1.5–2.5 g of zinc in the human body is located in our bones, and 60% of it is present in our muscles. Adult males should take 11 mg of zinc daily, which is equivalent to 8 mg (Cousins, 1998; Brown, 2001; & Erdman et al., 2012).

The foundation of farm animals' performance and ability to reproduce is their nutritional health. Numerous bodily processes, including the intracellular detoxification of free radicals, the synthesis of reproductive steroids, the synthesis of other hormones, and the metabolism of carbohydrates, proteins, and nucleic acids, depend on micronutrients. Male reproductive problems, such as impaired spermatogenesis and libido, can result from either excess or deficiency. Additionally, it has an impact on females' fertility, embryonic development, survival, postpartum recuperation, milk supply, and the growth and survival of their progeny (Smith & Akinbamijo, 2000). Animals with a zinc shortage may exhibit altered taste perception (such as damage to the tongue epithelium), synthesis disorders (such as keratin production), restricted limb bone growth, and eye infections (Prasad, 2013).

Problems of Zn deficiency in animals Similarly, rice straw used for animal feed causes problems for animals due to its zinc shortage (Alwahibi et al., 2020). Animals with zinc deficiencies have been found to suffer from a wide range of illnesses, as indicated in (S1 Table 1).

Role of Zinc in Plant growth

Zinc is essential for both animal and human growth. It is necessary for plants to nourish crops and includes a variety of enzyme, metabolic, and redox reactions. Zinc is necessary for enzymes involved in energy transmission, protein synthesis, and nitrogen metabolism (Cakmak, 2002, & Graham et al., 2001). These enzymes are important in biochemical reactions, such as the conversion of sugar into starch, photosynthesis, and the metabolism of carbohydrates. Additionally, it is concerned about the metabolism of auxin and protein, pollen production, the integrity of biological membranes, and enzymes linked to infection resistance brought on by any pathogen (Alloway, 2008).

Zinc influences ribosomal stability, cytochrome synthesis, carbonic anhydrase, and hydrogenase activity (Tisdale et al., 1984). Certain plant enzymes are activated by zinc. These are involved in the production of proteins, the regulation and synthesis of auxin, the metabolism of carbohydrates, the maintenance of the integrity of cell membranes, and the development of pollen (Marschner, 1995). Certain genes in plants enable them to withstand environmental stressors, and their expression must be maintained and regulated (Cakmak, 2000). Many anomalies that are obvious as indications of a zinc shortage in plants include stunted development, reduced leaf size, chlorosis inside the leaves, and sterility of spikelets. The quality of mature and harvested crop products is impacted by micronutrient deficiencies, such as zinc; fungal or disease-related infections are more common, and plants are more vulnerable to damage from increased light and temperature intensity (Marschner, 1995; & Cakmak, 2000).

Role of Zinc in Plants Facing the Drought Stress

Every living thing on the planet is impacted by stress brought on by non-living elements. Among these abiotic stresses, drought is one of the most detrimental to crop productivity (Qados, 2011). Due to erratic rainfall and changes in the climate, drought stress is becoming a more frequent stressor for plants (Whitmore, 2000). This rapid increase in atmospheric temperature has increased crop exposure to drought-related stress (Fahad et al., 2017; & Naeem et al., 2018). Because it varies on a variety of circumstances, including the amount and distribution of rainfall, evapotranspiration, and the soil's capacity to retain moisture, the extreme of drought stress is unstable (Saud et al., 2016). Drought stress lowers crop yield, which in turn lowers gas exchange rates, leaf water status, and plant water intake (Farooq et al., 2017).

Furthermore, one of the most detrimental influences to agricultural crop productivity is drought. It negatively affects plant processes such as protein synthesis, sugars, lipids, and nucleic acids, which inhibit crop growth and yield (Table 2). There are numerous ways to mitigate drought stress, but foliar spraying is the most effective and peaceful way to deal with it. The zinc is an important component that is vital to many biological processes that take place on the earth's crust. Additionally, using zinc significantly lessens the negative effects of water deficiency on plant growth, which in turn lessens photo-oxidative damage (Toor et al., 2020).

Sources of Zinc

A list of various organic and inorganic sources that improve plant growth and soil and plant zinc availability is provided in Figure 1: Information gathered from many sources improves plant growth and zinc availability in a variety of crops (Rashid, 1996).

CONCLUSION

The present inclusive review states that zinc is an important element that is crucial for the nutrition of humans, plants, and animals. Plants that contain zinc are resistant to a variety of illnesses, which can either directly or indirectly lower the yield of crops. Zinc is a powerful therapeutic nutrient that helps humans fight off a variety of illnesses. Zinc is necessary for healthy sexual development in animals, and a lack of it can cause male testicles to shrink.

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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

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	-	-

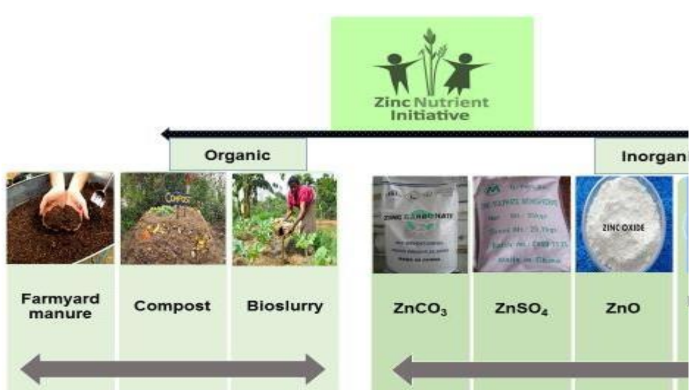

Figure1.various sources of Zn that can be used for the reduction of Zn deficiency