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Zinc and Salicylic Acid Mediated Response in Crops Grown under Abiotic Stress

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ABSTRACT: In order to accelerate crop growth and development, zinc EDTA and salicylic acid are critical. It is known that salicylic acid serves as an effective defence against various types of stressors, pests, and diseases. Furthermore, salicylic acid has been shown to assist plants in overcoming a wide range of environmental challenges. Salicylic acid has been shown to influence many physiological processes. It is believed that zinc is a major macronutrient that contributes to the physiological processes that are necessary for plant growth to occur properly. It also promotes the production of auxin, chlorophyll, and carbohydrates, which are necessary for the growth of plants. Zinc EDTA is considered to be the most effective chelating agent since it works better than zinc sulphate with respect to chelating metals. Furthermore, foliar EDTA application has proven to be more effective than soil EDTA application. As far as crop production results are concerned, salicylic acid and zinc EDTA are both highly efficient.

Keywords: Agriculture, Biotic, Chelators, Defence, Economy,Physiological, Salicylic, Stress, Zinc.

INTRODUCTION

Salicylic acid is a phenolic plant hormone that combines a hydroxyl group with an aromatic group found primarily in plants (Dempsey and Klessig, 2017). Salicylic acid aids in many metabolic processes in plants, including stomatal closure, glycolysis, and seed germination. Salicylic acid is used both in the soil and as an exogenous application via foliar spray. In addition to acting as an endogenous signalling molecule, salicylic acid plays an imperative role in disease resistance and pest resistance. Zinc is one of the most critical micronutrients for plants, ranking first among all micronutrients. As a result, zinc serves as the primary component of the various enzyme catalysing agents in plants for a variety of metabolic reactions. It plays several roles in plants, including resistance to various diseases, photosynthesis, cell membrane integrity, protein synthesis, pollen formation, as well as increasing antioxidant enzymes and increasing chlorophyll in plant tissue. Plants are not the only ones affected by zinc deficiency; if plants become zinc deficient, it will also affect humans, as over 3 billion people suffer from zinc and iron deficiency. This is primarily due to zinc-deficient soil in which crops are grown. It is estimated that in India, around half of the soils are zinc deficient, and if current trends continue, the proportion of soils with zinc deficiency could increase from 42 % to 63 % by 2025 due to soil fertility decline (Singh, 2008). Many studies have concluded that by applying zinc exogenously, we can compensate for zinc deficiency (Broadley *et al.,* 2007). In plants, zinc is the most abundant micronutrient and plays an imperative role in the mechanisms that control plant growth. This compound plays an active role in all sorts of physiological processes including the formation of sugar and photosynthesis, germination, seed development, growth regulation, and disease resistance.

Zinc in Biochemical and Physiological Aspects. It is without a doubt that zinc is a micronutrient that is essential for plant growth and development. In addition to zinc finger proteins, RNA polymerase, and DNA polymerase, zinc acts as a cofactor for over 300 proteins (Brown *et al.,* 1993). There is only one metal found in all six classes of enzymes (ligases, lyases, isomerases, hydrolases, transferases, and oxidoreductases). Zinc is one of the structural components of the catalytic unit, and it plays a role in protein folding as well as in stabilizing the conformation of proteins. In plants, zinc is incredibly needed for protein synthesis because if the plant is deficient in zinc, the plant's synthesis of protein will be very poor due to amino acid accumulation (Zheng *et al.,* 2019). Zinc binding sites can be divided into four types: catalytic, co-catalytic, structural, and protein interface zinc-binding sites. During zinc-binding, histidine is the most abundant, followed by cysteine, aspartic acid, glutamic acid, and water molecules. Zinc increases the amount of protein in wheat grains by increasing the concentrations of albumin, gliadins, and globulin (Yusuf *et al.,* 2008).

Activation of Enzyme and Resistance towards Stress. Several enzyme activities are regulated by zinc, and it acts as a cofactor for over 300 enzymes, the majority of which are zinc finger proteins, DNA, RNA, and polymerase. The activity of CA (carbonic anhydrase) and SOD (superoxide dismutase) was determined by zinc activity. Plants are becoming more vulnerable to abiotic stress as the climate changes, which directly reduces yield. Zinc deficiency is very common in arid and semi-arid regions due to the scarcity of water in these areas. Root absorption capacity is diminishing as a result of low yield development, particularly for zinc in water-stressed soil. The temperature is rising, which is problematic for plants since it affects their cellular function and photosynthesis process (Brown *et al.,* 1993). If the plant is suffering from salinity stress there will be extra production of ROS which can damage the plant's nucleic acid, photosynthesis, and lipids (Rasool *et al.,* 2013). If the plant is suffering from any of these biotic and abiotic stress factors, zinc will help to reduce the impacts of this stress by activating SOD. This reduces the impact of ROS and keeps the photosynthesis process going even at high temperatures. If zinc is added to wheat, it increases SOD and acid phosphatase by 96 and 75 percent, respectively. Due to its ability to regulate gene expression, zinc is essential to cope with any abiotic stress. The above discussion concludes that zinc acts as a defense mechanism in plants susceptible to any abiotic stress by maintaining root growth, detoxification of ROS, and other antioxidants like SOD, APX, and CAT (Youssef *et al.,* 2017).

Plasma Membrane Integrity and its Structure and Functions. As a nutrient, zinc plays an imperative role in maintaining the health of cellular membranes. If a plant is experiencing zinc deficiency and requires an adequate supply of zinc, it will have high levels of phosphorus. The presence of zinc on plant cell components protects the integrity of membranes and other lipid components by protecting them from ROS that would otherwise destroy the plant cell components. Normally, zinc controls ion movement in the plasma membrane. However, if the plant is deficient in zinc, ion movement shifts and becomes slow (Alloway *et al.,* 2008). Suppose, for instance, that the concentration of sulfhydryl in a plant's root is reduced when the root is zinc deficient; on the other hand, if the root is zinc sufficient, the concentration of sulfhydryl in the root will be adequate. The ability of zinc to stabilize and control the transport of ions across membranes is attributed to its ability to prevent the sulfhydryl peroxidation process. The plant absorbs zinc through foliar application and by way of the root xylem and phloem tissues (Cakmak *et al.,* 2000). Following that, zinc is detoxified and sequestered in plants. There are several physiological processes carried out by plants using their leaves, such as transpiration, photosynthesis, and respiration as shown in Fig. 1.

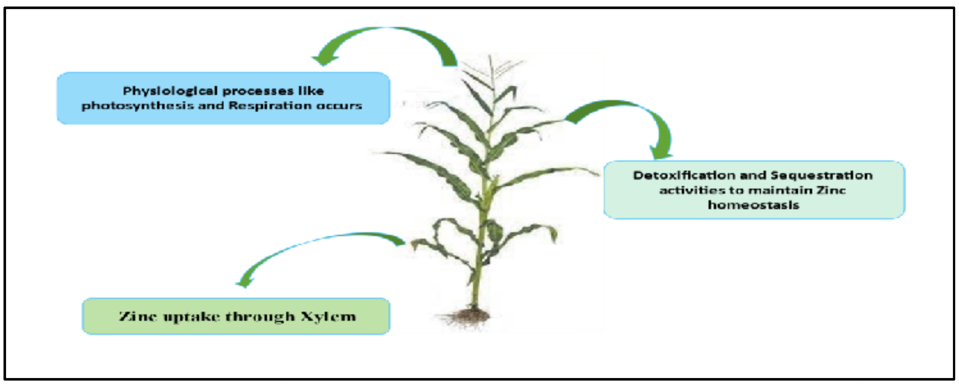


Fig 1. Mechanism of Zinc Uptake in Plants.

Zinc mediated Cell Division Response in Plants. It has been estimated that zinc is responsible for about 40% of plant reproduction because it regulates gene expression, triggers gametogenesis, initiates flowering, and is involved in flower development (Prigge and Wagner, 2001). Plants need zinc not just for growth and maturity, but also to fertilize and ensure pollen survival. In the case of plants that have a low concentration of indole acetic acid, it indicates that the plant is suffering from zinc deficiency caused by IAA inhibition (Brown *et al.,* 1993). Superoxide radicals are responsible for IAA degradation, which results in a decrease in IAA levels in plants that are zinc deficient. There can be a high level of ABA in plants, which can cause seed germination to be poor due to premature flower shedding. In addition, the structure of pollen and anthers can be altered because of ABA. There is a reduction in the number of grains when zinc pollen and stigma are deficient, which indicates zinc is involved in the formation of pollen and stigma. As long as there is enough zinc in the soil, gibberellin-producing endogenous growth-promoters are triggered, which pave the way for the growth and development of plants. Zinc, as a result, maintains IAA and IBA levels in plants as a result of controlling flowering and pollination in plants (Reid *et al.,* 1996).

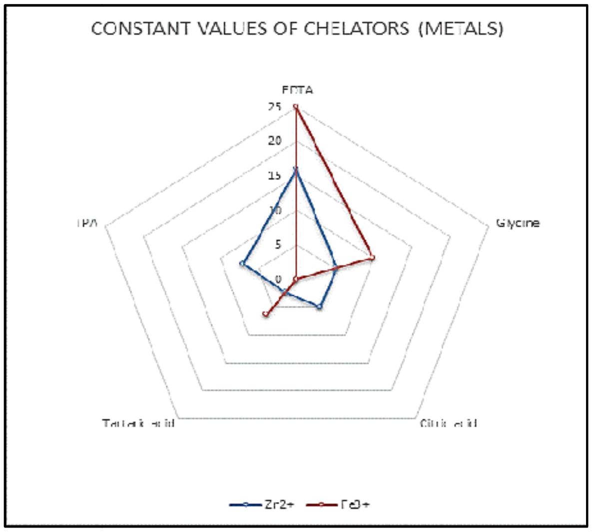
Impact of Zinc on Photosynthesis in Crops. In order to synthesize chlorophyll, zinc is a crucial element. It has been noted that due to the scarcity of zinc in plants, some changes can be seen in the structure of the chloroplasts. It is known that zinc is a mineral that regulates chloroplast function and development. It also regulates the zinc signal activity of peptide peptidase, which is already damaged by sunlight. Furthermore, it has also been determined that zinc improves photosynthesis under heat stress by altering the chlorophyll fluorescence ratio (CFR) (Brown *et al.*, 1993). During photosynthesis, zinc plays a critical role in carbonic anhydrase activity (carbonic anhydrase). It is a key component of photosynthesis. Carbonic anhydrase is found in wheat mesophyll cells and flag leaves, and it is also found in the mesophyll, where it is found in the cytosol and xylem. There is a reduction in photosynthesis due to CA activity in wheat when zinc levels are low (Gupta *et al.,* 2016). As a result of the preceding discussion, it is concluded that zinc plays a critical role in photosynthesis by maintaining the activity of CA, photosynthesis pigment, and photosynthetic function, as well as its integrity (Reid *et al.*, 1996).

Factors Affecting the Availability of Zinc. There is considerable variation in zinc concentrations between soil types, with the mean concentration ranging from 17 to 125 ug/g in contaminated soil and 64 ug/g in uncontaminated soil. Zinc concentrations are higher in saline, alluvial soils, whereas zinc concentrations are very low in organic and mineral soils. If the soil contains less than 10ug/g of zinc, it is considered deficient. The availability of zinc in roots is determined by soil physiological properties, i.e. pH, organic matter, clay content, temperature, and moisture). Because these are the factors that influence soil zinc availability (Longnecker and Robson, 1993).

Correlation between Zinc availability and pH of soil. It has been shown that soils are the most important factor that determines the availability of zinc in plants among all other factors. This is because the pH of the soil decides how much zinc is absorbed by the roots. If the pH of soil increases by 4.66.8, then the uptake of zinc decreases. If the wheat is grown in soils that have high pH or alkaline then the plant may suffer from zinc deficiency but if the soil is calcareous then the availability of zinc decreases as there is an increase in the concentration of $CaCO_3$. By chemisorption, zinc is retained as $CaCO_3$ is highly adsorptive (Gupta *et al.,* 2016). Zinc binds better to soils with pH levels between 8 and 8.3. If we talk about the estimation of zinc, DTPA is not the only method. It is estimated according to the efficacy of zinc. If it is sevenfold, 0.5% of Fe coating on calcite increased the zinc-binding strength which somehow reduced the availability of zinc which automatically leads to zinc deficiency in plants (Zheng *et al.,* 2019). In soils with high pH, there is a tendency to form complex carbonates and hydroxides, which reduces the availability of zinc. A reduction of zinc uptake is seen when there is a large increase in calcite content in soils such as loams and sandy soils (Rudani *et al.,* 2018). There has been a study that demonstrated that alkaline soil and high soil pH, as well as the sorption of carbonates on plants, inhibit zinc uptake by them, and therefore, zinc uptake by plants is inhibited.

Organic Matter and Zinc availability in soil. Zinc is a very important trace element for plants that are growing, primarily because it affects its solublization and availability in the soil. Zinc uptake is dependent on soil organic matter whether the soil has a very light texture or has various soluble complexes. Thus, it is up to the organic matter of the soil to determine how much zinc is taken up. Zinc can either be absorbed by the roots more readily or less readily depending on the situation. It appears that if the organic matter in soil is increased, this is also reflected by the increase of zinc bioavailability (Broadley *et al.,* 2007). If there is high organic matter in zinc then it will influence the adsorption of zinc but if there is low organic matter then the adsorption of zinc is decreased. The peat soil is already deficient in zinc as here it is proved that organic matter influences zinc adsorption. Furthermore, it was also reported that additional organic matter increased the amount of zinc that can be absorbed by rice plants as zinc deficiency is primarily found in calcareous soil. If manures or any soluble form of zinc is applied to the soil then it will decompose easily and enhance the mobility of zinc and root absorption (Ried *et al.,* 1996). If the zinc content is low it is due to the insoluble complexes. The accumulation of zinc is mainly in peat and organic soil as it binds the zinc in a stable form. It has been determined that the majority of zinc ions found in mineral soils are bound to organic matter due to the fact that zinc matter complexes have very low stability constant. If there is an addition of sewage, sludge, or manures it will enhance the exchangeable and zinc soluble forms as the available form of zinc by roots is in the organic matter metal complex. The organic matter chelates the zinc and avoids it by transforming it into insoluble oxides and carbonates so the rhizosphere present in the root easily absorbs the zinc. As it is concluded, organic matter influences the availability of zinc and it is also responsible for its uptake by roots (Gupta *et al.,* 2016).

Zinc Chelators and their function. Zinc EDTA functions as chelators. The chelates are natural complex molecules made up of atoms that are held in place with a part of metal so that they are not able to make contact with other substances and form insoluble structures. The chelating operators are the natural particles that can absorb the metals and utilize the particles of Calcium, Magnesium, Iron, Cobalt, Zinc Manganese, etc. The molecules of chelates have multidimensional structures because each molecule can form more than one bond with a single metal atom. In order to form them, the polydentate ligands must be linked to the central atom by polydentate bonds. The process of developing co-ordinate bonds between two or more ligands and a central atom occurs when two or more different co-ordinate bonds are formed. The ligands here are some sequestering agents and chelators etc. The metals bound in the chelate rings lost their cationic activity. The structure of chelates is not precipitated easily which is why the use of chelates is good in farming. Chelates are very important because they are used for the softening of hard water as well as for the separation of lanthanides and actinides (Dwivedi and Randhwa, 1974). Ethylenediaminetetraacetic acid (EDTA) is regarded as the best chelating agent because EDTA can form about 4 to 6 bands with the metal ions of transition metals and other metals also. They can also form bonds with the complex forms of soaps and detergents. EDTA binds the Magnesium and Calcium ions, sequesters them, and prevents them from interference. The use of chelates in micronutrients increases the efficiency of the micronutrients. There are various chelating agents that help in the natural disintegration, for example, natural acids, amino acids, lignin sulfonates, lignin polycarboxylates, sugar acids and subordinates, phenols, poly flavonoids, siderophores, and Phytosiderophores. Many chelating operators have been grown artificially. The two classes of chelating operators or complexes increment micronutrient solvency. Chelating agents have some important characteristics which are utilized in the general dependability of different metal chelates. The dependability of the micronutrient applied to the plant determines the accessibility of the applied chelate. Some synthetic micronutrients are also produced through chelating agents like Citric acid, Ethylene diamine di glycine, Nitrile tri acetic acid, Ethylene diamine acetic acid, Glucoheptonic acid, Diethylene triaminepenta acetic acid, etc. (Brown *et al.*, 1993). The constant values of metal chelators are shown in Graph 1.



Graph 1: Constant values of chelators (metals).

Advantages of Chelators. Chelates have various advantages and they can be beneficial to the growth of plants. Chelates are present in organic form so they are easily absorbed with the help of plant roots. Chelation is an easy process that can be used to remove the positive charge from micronutrients. Fortunately, the plant system is capable of assembling chelates. Physiological disorders associated with the use of chelates in plants, such as scorching, were dramatically reduced because the chelates have been added in organic form, so they will not cause any harm to any plants. The action of chelates is systematic, which is why they are easily transported in the plant. Chelates are readily adsorbed at the surface of the soil, so they are removed from the soil particles. Chelated Copper (Cu), Iron (Fe), Manganese (Mn), and Zinc (Zn) are provided as a micronutrient to crops under alkaline conditions. Chelated micronutrients are easily and properly assimilated by the plants and required in very small quantities as compared to inorganic substances or fertilizers (Tsonev and Cebola Lidon, 2012). Chelates are compatible with a wide variety of substances, such as fertilizers, pesticides, and fungicides, without causing any reaction with other components. Chelates can also be commonly added to liquid fertilizers as well as dry mixtures to ensure maximum efficiency. The adaptability of plants in terms of nitrogen fixation is influenced positively by chelates; the chelates protect the zinc from phosphate fixation, and the zinc is easily absorbed by the plants in terms of chelates (Fig. 2).

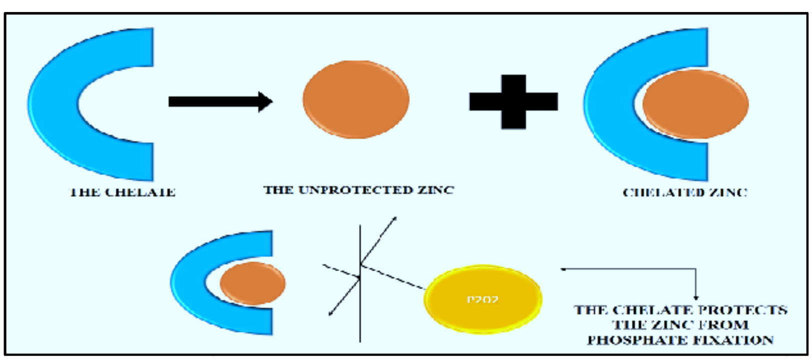


Fig. 2. Role of Chelate.

Salicylic acid-mediated response of crops. The discovery was first made in species of Salix that contain 9.5-11% of salicin compounds. SA plays a very vital role in the growth and development of the plant and helps the plant to overcome any stress (biotic and abiotic) related problem by increasing the SAR (system acquired resistance). SA stimulates the endogenous signalling or changes it which help plants to overcome the stress. There are many stress condition like dryness, heat, heavy metal stress, coldness, salinity and SA acts as a stimulant. Because SA is able to bind amino acids (proline, arginine, and other amino acids) with conjugates that help the plant to resist environmental stress, the plant is able to resist environmental stress. It is necessary to produce a specific antioxidant or a compound that aids the production of an antioxidant that acts against free radicals because ROS are produced as a by-product. The SA is able to increase the plant's ability to respond to stress or any disease imposed by nature, so when SA is introduced exogenously it also increases the level of endogenous SA as it chemically stimulates the reaction of ion absorption, flower formation, nutrient input, movement and control of the stomata as well as our ability to synthesize proteins. Additionally, the percentage of acids such as nucleic and amino acids is increased by SA, which also causes the dry matter accumulation to accelerate the formation of different plant dyes, as well as increase the level of carotene and chlorophyll in plants. Along with this it also increases the rate of metabolism. The role of SA is first coined by (De Kock *et al*., 1974). He observes and said that SA acts as a growth regulator after this various scientists and researchers show their interest in the role of SA, and many studies confirm the role of SA, it definitely acts as a defence mechanism. It is concluded by the result of Najafian of SA is sprayed in various concentrations like 150, 300 and 450 mg/l increase the significant growth rated and rate of photosynthesis as compared to control. And the most increase of growth is observed in plants where 300mg SA is applied. The activities of intracellular antioxidant enzymes like SOD, POX is managed by the application of exogenous SA. In the leaves of the plant, SA controls the antioxidant enzymes of the apoplast which are generally affected with cold stress SA influence the protein of the apoplast. It has been observed in many researches that SA if incorporated in crops increased the antioxidant activity of enzymes, basically the seeds are primed with SA increasing the yield and growth of the plant. In wheat the seeds are primed with SA enhanced the stress tolerance and potassium and magnesium in the leaves of the plant, not only this SA prevents the plant from the attack of pathogens and viruses. Furthermore, if the plant suffers from heavy metal stress, SA will mitigate the effect of the heavy metal exposure. It was observed in a recent study that the toxicity of aluminium to plants can be mitigated by the use of the sulphur-aluminium compound (Gupta *et al.*, 2016; Estaji and Niknam (2020). Salicylic acid helps in the photosynthesis of plants even when the plant is in stress conditions. Salicylic acid helps in the signalling pathways, formation of ethylene, and production of jasmonic acid as shown in Fig. 3.

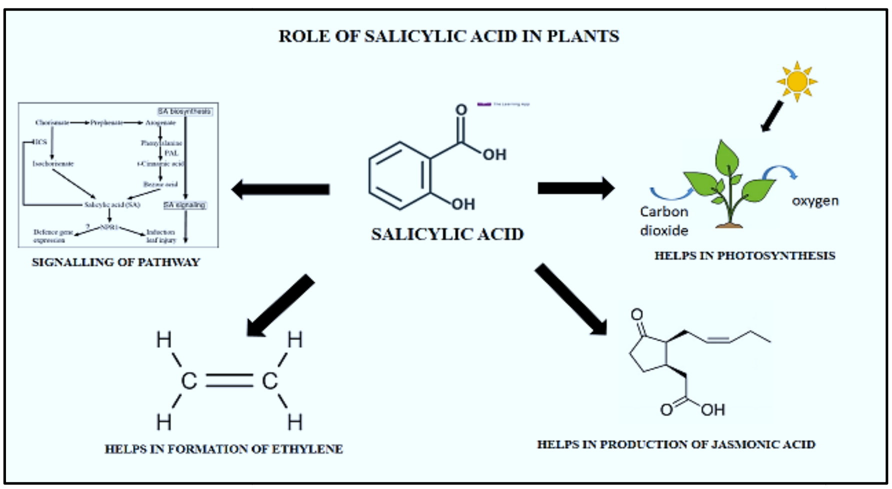


Fig. 3. Role of salicylic acid in plants.

The ferulic acid, phenols reduce the uptake of water in the split root. Salicylic acid helps in the higher yield production of wheat when submerged stress condition is provided. Some tests are performed on Salicylic acid under stress conditions like drought, waterlogged conditions on wheat plants (*Triticumaestivum* L.). In that conditions, plant shows many metabolic and physiological effects to the plants (Brown *et al.*, 1993). The treatment of the foliar application of Salicylic acid increases the antioxidant enzymes like SOD, CAT and POX etc. The seed priming of Salicylic acid at a very low concentration increases the reactive oxygen species when the cadmium toxicity is provided to the rice plants, various antioxidant enzymes then protect the plants from oxidative stress. Salicylic acid also works as a plant hormone, along with salicylic acid, abscisic acid and ascorbic acid works as a seed priming agent in various stress conditions. Mainly when the exogenous application of Salicylic acid is provided on the different growth stages of plants (Rudani *et al*., 2018).

CONCLUSION

The main reason is that EDTA fertilizers are significantly more effective for crop growth. As a result, zinc EDTA offers better results compared to its non-EDTA counterpart, which is a micronutrient or fertilizer. Salicylic acid also works as a plant protector because it provides a defence mechanism against a variety of stress conditions and other conditions which may cause harm to the crop. Salicylic acid helps the crop to withstand various harsh conditions. Based on the review of various research articles, this paper examines the effects of Salicylic acid and Zinc EDTA on their individual and combined use.

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Conflicts of Interest. None.

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