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Foliar application of Zn: Best way to mitigate drought stress in plants; A review

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Abstract
Drought is one of the most important factor limiting agriculture crop production. It negatively affects plant mechanisms such as formation of proteins, nucleic acid, lipids and carbohydrates which reduces the final crop growth and production. There are many ways to mitigate drought under field conditions but the best and the easiest method is foliar application. Zinc is a vital element that plays an important role in many biological processes. Moreover, Zinc application significantly reduced the negative effects of droughts on plants by reducing photo oxidative damages. The present review directly focuses on the role of foliar application of Zn in improving agriculture crop production under drought conditions and indirectly focuses on Zn deficiencies induced in plant due to its absence.

Keywords: Drought, foliar application, Zinc

1. Introduction
Agriculture is the growing of crops and rearing of animals while some factors like climatic, natural, anthropogenic and drought deteriorate quality of land and degraded it for agriculture use (Toor *et al*., 2020) [40]. Drought is one of the most problematic issue disturbing the agriculture sector worldwide. (Abolhasani and Saeidi 2004; Adnan 2020) [1,2]. During drought condition, micronutrients absorption by plant roots is negatively affected (Heidarian *et al*., 2011) [22]. It reduces water potential, stomatal conductance, transpiration ability and photosynthesis of plants. It acts as a factor which cause negative effects on seed propagation, development and enlargement of many crops like sugar beet. sunflower, kochia, sorghum and maize (Moussa and Abdel 2008) [27], However, proper application of fertilizer is the finest way to combat drought and improve agriculture crop production. Zinc is an important element for plant and human development. It is an essential for many enzymatic, metabolic, and oxidation reduction reactions. It is necessary for nitrogen metabolism, energy transmission and protein production (Cakmak 2002) [13]. Many enzymes in plants like hydrogenase, carbonic anhydrase, ribosomes and cytochrome synthesis is influenced by Zn (Tisdale *et al*., 1984) [39]. It is needed for many enzymes which are required for stability of cellular tissues, protein amalgamation, auxin production and pollen synthesis (Marschner 1995) [24]. Many plant stresses are regulated by Zn because it is used in regulation and preservation of many genetic factors (Cakmak 2000) [13]. It decreases the antagonistic effects of temperature and salinity which disturbs capability water transportation in plants (Tavallali *et al*., 2010) [38]. Its deficiency restricts plants to complete their life cycle or enzymatic reaction. Moreover, negatively affects the crop quality. Its severe deficiency leads to cause plant injury by temperature or mycological infections (Marschner 1995) [24].
Plant growth and production can be improved by foliar application of micro-nutrients that are required to be sprayed on particular plants (Habib 2012) [18]. The foliar application absorbed the specific nutrient in short time and reduce the nutrient losses (Rehman *et al*., 2014) [32] and It is very important strategy for crop management (Adnan *et al*., 2020) [3]. Application of micronutrients in the soil is 6 to 20 times less valuable than foliar of nutrients (Arif *et al*., 2006) [9].
Foliar application of zinc greatly improved the paddy zinc concentration only when applied at flowering stage and larger increase was noted at repeating application.

A positive correlation was found between zinc concentration and seed germination. Therefore, zinc ratio in grains of rice could be effectively improved by bio fortification of zinc (Yaseen *et al*., 2013) [43]. The present review directly focuses on the role of foliar application of Zn in improving agriculture crop production under drought conditions and indirectly focuses on Zn deficiencies induced in plant due to its absence.

2. Importance of Zinc

Zinc is one of the most important elements in the carbohydrates metabolism, most of the enzymes that play a key role in carbohydrates metabolism are activated by zinc. Zinc is main building part of many enzymes and it is necessarily required for the formation of some important plant enzymes. In addition, it activates many enzymatic reactions (Akay 2011) [5]. It is the functional, structural and regulatory co-factor of a great number of enzymes (Grotz and Guerinot 2002) [16]. It plays an important role in many biological processes (Broadley 2007) [12]. It is required in many enzymes for their proper functioning and plays a crucial role in transcription of DNA (Kumar *et al*., 2012) [23]. More functions of zinc involve: catalyzing the process of oxidation in plant cell and is great importance for the transformation of carbohydrates and it controls the formation of chlorophyll, auxins and growth regulating compounds. It plays a key role in protein and starch formation, and consequently a low zinc concentration induces accumulation of amino acids and reduced sugar content in plant tissues. The activity of many enzymes in which zinc is a fundamental part is decreased in zinc deficiency condition, resulting in carbohydrate accumulated in plants leaves (Taheri *et al*., 2011) [37]. Furthermore, zinc contributes in pollination due to its role in pollen tube formation (Pandey *et al*., 2006) [30]. The availability of Zinc to plant roots is limited and the uptake of zinc by plants is reduced due to low water availability in the soil (Marschner 1995) [24]. Zinc application can greatly reduce effects of drought stress on plant growth by controlling the activity of membrane-bound NADPH oxidase, stopping photooxidative damages, reducing generation of reactive oxygen species and increasing the activities of SOD, POD and CAT involved in detoxifying ROS (Hajiboland 2012) [21]. The other principal interaction with other micronutrient ions is with Cu2þ, which can reduce or impede Zn uptake as well as compete for transport sites within the plant. In interaction of Zinc with the macronutrient, P is highly available it leads to cause zinc deficiency. It is still under debate that whether the P and Zn interaction takes place mostly in the soil or the plant. Divalent cations such as Mg2þ and Ca2þ can also interfere with Zn uptake by competition. Zinc deficiencies increase when the soil is waterlogged. These deficiencies could come from the precipitation of Zn or by increases in Zn–organic complexes. (Welch and Shuman 1995) [42].

3. Role of Zinc in Crop Growth and Development

Zinc takes part in lots of physiological processes; its irregular or reduced supply can effect crop growth and yield to a great extent. Its deficiency is a main problem almost all over the world and it greatly affect all type of soils including calcareous, sandy, loam and peat etc. Soils with high percentage of P and silicon are also expected to cause zinc deficiency. Insufficient supply of zinc causes negative effects on plants by stunting growth, stopping the tillering process, chlorosis in younger and older leaves, delaying crop maturity duration, sterility of spikelet and poor quality of harvested products (Hafeez *et al*., 2013) [20]. Ahmad *et al*. (2018) [4] conducted an experiment to observe the impacts of bio fortification of forage sorghum with zinc under different nitrogen levels. He reported that bio-fortification of zinc and nitrogen increased height of plant, leaf area, fresh forage yield, dry matter content, percentage of protein content and zinc content in the plants under study but decreased the acid detergent fiber, neutral detergent fiber and ash percentage. Application of 10kg ha^{-1} zinc and 120 kg ha^{-1} nitrogen showed an average increase of 7.3 and 18.6% in green fodder production while 12.1 and 15.8% in yield of dry matter content. Similarly, 6.1 and 7.5 percent rise in crude protein was noted than control. In conclusion, Zn and N gave the best results in term of quality and yield of forage sorghum. (Mousavi *et al*., 2013) [26] conducted an experiment to study the effects of micronutrient such as zinc, iron, boron and manganese. Results of their study clearly proved that the use of micronutrients (copper, zinc, iron, boron and manganese etc.) significantly increased the plant growth because these micronutrients take part in important metabolic processes in plant growth and development, therefore these are known as essential elements or micronutrients. Zinc performs important physiological functions in all living things and life processes i.e. maintenance and development of structure and functions in integrity of biological membranes and assistance of protein synthesis and energy production, gene expression, enzymes structure and Kreb's cycle. In short zinc has great impact on quantitative and qualitative aspects of crops.

4. Deficiency of Zinc

Zinc is a micronutrient which is very important for the regular development, healthy growth and fertile production of plants, animals and human beings. In plants, Zn plays a key role as a structural constituent or regulatory co-factor of a wide range of different enzymes (Barak and Helmke 1993) [10]. These enzymes are important in biochemical pathways concerned with carbohydrate metabolism, photosynthesis and in the conversion of sugars to starch. In addition, it is also vital for protein metabolism, auxin metabolism, pollen formation, maintenance of the integrity of biological membranes and those related to the resistance to infection by certain pathogens (Alloway 2008) [6].

Fig 1: Stages of Zinc deficiency symptoms

Generally, its deficiency is expected in calcareous soils, sandy soils, peat soils, and soils with high phosphorus and silicon (Alloway 2008) [6]. The flooded soils are very well accepted for the absence of Zn to the plants; predominantly due to the response of Zn with permitted sulphide (Mikkelsen 1977) [25]. Submerging take about a substantial deterioration in accessible Zn because of the variations in pH rate and the materialization of unsolvable Zn mixtures.

Temporarily, the unsolvable Zn complexes formed are possible to be with Mn and Fe hydroxides from the itemization of oxides and adsorption on carbonates, definitely magnesium carbonate. In the flooded circumstances for rice farming, Zn is distorted into shapeless oxides precipitates or franklinite; ZnFe2O4 (Sajwan 1988) [33]. Zinc shortage demonstrate numerous signs which typically seem 2 to 3 weeks after transferring of rice, with leaves emerging brown blotches and bands that may temper to fully cover older leaves, and plants stay stunted, while in severe cases, the plants might be expire, while those which improve will show considerable deferment in ripeness and clear decrease in produce (Neue *et al*., 1994) [29]. Hacisalihoglu *et al*. (2003) [19] showed that Cu/Zn superoxide dismutase (SOD) plays a direct role in resistance to Zn deficiency stress. Zinc deficiency may be an abiotic stress that causes increased production of active oxygen species and/or decreased activity of antioxidative enzymes such as Cu/ZnSOD. A study with black gram (Vigna mungo) suggests that activities of Cu/ZnSOD and CA are positively correlated with Zn supply and could be used as indicators of Zn deficiency (Pandey *et al*., 2002) [31].

5. Role of Foliar Application of Fertilizers

The best method for application of essential plant nutrients is complete foliar application to achieve highest intensities of profitable production. Soil application practice is very easy and cast operational but fertilizer is compulsory in larger amount (Sharifi *et al*., 2016) [34]. A large amount of fertilizer is wasted by soil application. Conversely foliar fertilization keeps fertilizer damages which are produced through outflow and fertilizer is also rapidly accessible to plant. Application through soil typically based on soil examination but foliar system based on plant examination. Foliar and soil both can apply at once for better results. Foliar method is collectively with fungicides, herbicides and insecticides yield could be enhanced and cost of application can also be compact as it keeps time and employment cost (Fageria *et al*., 2009) [15]. Soleymani *et al*., (2012) [35] conducted an experiment to examine effects of different fertilization practices on forage sorghum. They described that foliar application is more effective than the all other different approaches of providing nutrient to the crops. Furthermore, foliar application had positive consequences on no. of leaves, height of plants, fresh yield, no. of tiller, dry leaf yield, leaf area, leaf weight/stem weight ratio, dry stem biomass, total dry yield and ash percentage. Fertilization method play key role for attaining best absorption of nutrients. This study elaborated that, iron, zinc and manganese had positive effects on quality and quantity of sorghum fodder.

All yield results and quality parameters showed positive results by foliar bio fortification of zinc plus iron. Maximum tillers were recorded by combined effects of Zinc and iron (Boonchuay *et al*., 2013) [11] examined impact of bio fortification of zinc on seed biomass of rice crop. Different eight levels of zinc sulphates were used in the experiment. All were applied by using foliar spray technique at different rice growth stages. The obtained seeds germinated to calculate effects of seed zinc on seedling growth. Foliar application of zinc greatly improved the paddy zinc concentration only when applied at flowering stage and larger increase was noted at repeating application. A positive correlation was found between zinc concentration and seed germination. Therefore, zinc ratio in grains effectively improved by bio fortification of zinc after flowering. (Yaseen *et al*., 2013) [43] arranged a research on calcareous soils to check the effects of micronutrient deficiency especially zinc and iron. Analysis of his study showed that a great yield losses were occurred by nutrient deficiency, mostly micronutrients on calcareous soils throughout last 10 years. Pakistan's 90% soils are lacking micronutrients, especially iron and zinc. This research explains that foliar fertilization technique is very effective to overcome these deficiencies in different crops. This research proved that foliar fertilization of zinc, copper and iron on cotton crop can effectively improve the seed-cotton yield. Foliar fertilization also developed the nutrient high ratio in leaves as compared to the soil applied fertilizers. This agronomic method has increased economic yield of cotton crop and improved its quality to a great extent.

6. Role of Foliar Application of Zinc in Improving Crop Production Under Drought Conditions

Drought is one of the most important factor limiting agriculture crop production. It negatively affects plant mechanisms such as formation of proteins, nucleic acid, lipids and carbohydrates which reduces the final crop growth and production. Drought not only hinders plant growth and metabolism at various stages but also affects crop quality and yields (Guo *et al*., 2018) [17]. Average yield increases with Zn use are: 22 percent in potato and sunflower, 18 percent in maize, 13 percent in wheat, 12 percent in rice, 11 percent in soybean, and 8 percent in cotton and sugarcane. In Citrus fruit size, fruit weight, and Vitamin-C content are improved with Zn use. In general, 5 kg Zn ha^{-1} is adequate for 3-4 crop seasons. (Anonymous 1998) [8]. The experiments conducted to study the effect of zinc fertilization on growth and yield of many plants such as alfalfa, wheat, maize, barley, cotton and potato and observed an increase in yield with zinc application (Efe and Yarpuz 2011) [14]. Sultana *et al*. (2016) [36] conducted an experiment to evaluate the impact of foliar application of Zn on wheat (BARI gom-25) with skipping irrigation at various growth stages. The design of experiment was slit plot with four Zinc levels (0.0, 0.02, 0.04 and 0.06%) and four irrigations (regular irrigation, skipped irrigation at booting stage, skipped irrigation at crown root initiation and skipped irrigation at grain filling stages of wheat growth). They reported that interaction of both treatments significantly affected the yield components of wheat. The maximum yield (5.59 t ha^{-1}) was observed in normal irrigation with 0.04% foliar application of zinc. However, skipping irrigation at crown root initiation stage had the most negative effect on growth and yield. Moreover, they recommended 0.04% foliar application of zinc for grain yield of wheat. Wasaya *et al*. (2017) [41] conducted an experiment to evaluate the effect of foliar application of boron and zinc on maize grown under rain fed conditions. They observed that combined application of B and Zn significantly increased the SPAD chlorophyll values, relative water contents, LAI, crop growth rate and grain yield of maize. Furthermore, combined application gave higher net returns. They recommend that combined application of B and Zn is best to improve the maize production under rain fed conditions. Movahhedi *et al*., (2017) [28] conducted an experiment to evaluate the effect of zinc and boron on sesame under drought conditions and reported that foliar application of zinc and boron improved the physiological traits of sesame under drought conditions. Anees *et al*. (2016) [7] conducted a field experiment to evaluate the impact of foliar application of zinc and potassium on maize under rain fed conditions. They used nine treatments recommended rate of zinc (RRZn) to soil @ 15 kg Zn2SO4 ha^{-1}, control, foliar zinc spray (FZS) @ 0.1%, recommended rate of potassium to soil (RRK) @ 75 kg K2O ha^{-1}, RRK+ FZS, RRK + RRZn, foliar potassium spray (FKS) at 1% concentration, FKS + RRZn, FKS + FZS. They observed maximum grain yield (kg ha^{-1}) and 1000 grain weight (g) when potassium and zinc (FKS + FZS) was applied in combination. All the foliar treatments gave higher benefit cost.

7. Conclusion

Our extensive review has shown that drought is the most important factor limiting agriculture crop production but negative effects of drought can be minimized by the foliar application of Zn. Zn is very important plant nutrient for all crops. Foliar application of Zn fertilizer is recommended for correcting deficiencies and mitigating drought because foliar sprays have no residual effect and fresh applications must be made to each crop

8. References

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