Zinc Nutrient Initiative

Zinc Fact Sheet: Zinc Fertilizer Overview

Introduction

Zinc is an essential micronutrient for the growth and development of plants, animals and human beings. Zinc is required in small amounts but for very critical functions. Zinc plays an important role in biological systems, such as maintenance of structural integrity of biological membranes and direct contributions to protein synthesis and gene expression. Among all metals, zinc is required by the largest number of proteins for their catalytic functions. Zinc-binding proteins make up nearly 10% of all proteins in biological systems. If the amount of zinc available is not adequate, physiological and developmental processes rapidly impaired, leading to significant health complications in human and animal systems, including weakened immune systems, debilitated brain function, and severe decline in proper growth.

The Food and Agriculture Organization (FAO) has determined that zinc is the most commonly deficient micronutrient in agricultural soils; almost 50% of agricultural soils are Zn deficient. Plants growing on potentially zinc-deficient soils have reduced productivity and contain very low concentrations of zinc in the edible parts (such as in cereal grains). Therefore, zinc deficiency represents a serious nutritional and health problem in human populations, especially in the developing world where cereal-based foods are the dominating source of diet.

Zinc Deficiency in Soils and Plants

In most cases, zinc deficiency symptoms are developed on young or middle-aged leaves. The main visible symptoms are:

Leaf chlorosis – the change of leaf color from the normal green to pale green or yellow due to the reduced amount of chlorophyll in the leaf or oxidation of chlorophyll. Generally, the leaf chlorosis appears between the ribs in monocotyledons (grains and grasses) and between the veins of dicotyledon (broad leaf) plants (also referred to as interveinal chlorosis).

Necrotic spots on leaves – occurs in areas of chlorosis due to death of plant tissue. In cases of wheat plants, necrotic spots very commonly occur on the middle-aged leaves.

Bronzing of leaves – reflects the development of reddish-brown spots/ lesions on leaves, and it is very typical in rice plants.

Rosetting of leaves – occurs when the internodes on the stems of dicotyledonous crops fail to elongate normally, and consequently,

Soil conditions most commonly associated with zinc deficiency:

- Low total zinc content (such as sandy soils low in organic matter)
- Neutral or alkaline pH (calcareous soils)
- High salt concentrations (saline soils)
- Low pH, highly weathered parent materials (e.g. tropical soils)
- Peat and muck (organic soils)
- High phosphate status
- Prolonged water-logging or flooding (paddy rice soils)

the leaves form close together in a cluster instead of being spread out between nodes in a healthy plant. Rosetting is very typical in fruit trees.

Stunting of plants – a consequence of reduced stem elongation.

Dwarf leaves – also called "little leaf".

Malformed leaves – leaves are noticeably narrow and/or have wavy edges instead of straight edges.

Soil and Plant Analysis

The zinc status of soils and crops can, in most cases, be easily assessed by soil or plant analysis. Where poor yields are obtained without other obvious explanations - such as drought or disease - especially in areas with highly susceptible soils, farmers should investigate potential zinc deficiency. Likewise, crops displaying visible symptoms of zinc deficiency should also be investigated. Hidden zinc deficiency in crop plants is a well-known problem and may be responsible for reductions in yield up to 40% without appearance of distinct leaf symptoms. It is therefore important to monitor zinc status of plants regularly.

Measurement of diethylene triamine pentaacetic acid (DTPA)-extractable zinc is the most widely used soil test method to characterize the zinc status of the soils. Generally, soils containing less than 0.6 ppm DTPA-extractable zinc are classified as zinc-deficient. Distinct increases in crop production as a result of zinc fertilization are found on soils containing less than 0.25 ppm DTPA-extractable zinc, which are severe Zn deficient. In the case of plants, the critical zinc deficiency concentrations of leaves range between 15 to 20 ppm. In zinc-deficient leaves with distinct zinc deficiency symptoms, such as necrotic spots in wheat, bronzing in rice, or little leaf formation in fruit trees, zinc concentrations are generally below 10-12 ppm. In zinc-deficient locations, zinc concentrations of cereal grains are found to be below 15-20 ppm.

Treatment of Zinc Deficient Soils and Plants

Once identified, zinc deficient soils can easily be treated with zinc-containing fertilizers. Several different zinc compounds are used as fertilizers, but zinc sulphate is by far the most widely used material. Because of the varied soil conditions under which zinc can be deficient, it is always best to identify and treat soils based on soil and plant analysis. The rate of soil zinc application varies between 10 to 100 kg $ZnSO_4.7H_20$ per hectare. Zinc can be also applied into soils after fortification of commonly applied NPK fertilizers. One-percent zinc-containing NPK and urea fertilizers are available in many countries.

4R

4R Nutrient Stewardship

Right Source **Right Rate**

Right Time **Right Place**

The 4R Nutrient Stewardship Concept is a recent innovative approach to best management practices for fertilizers. It can be applied to managing crop nutrients in general or fertilizers specifically.

This concept can help farmers understand how the right management practices for fertilizer contribute to sustainability goals for agriculture. For example, the 4R Nutrient Stewardship Concept involves crop producers and their advisors selecting the right source-rate-time-place combination from practices validated by research conducted by agronomic scientists.

Adequate and balanced nutrient inputs are critical to producing and maintaining optimum yields that result in maximum profit. Although considered a micronutrient, proper zinc nutrition is just as essential as any other crop nutrient, large or small. Deficiencies often occur when nutrients get out of balance, reducing yields and profits. Due to extensive depletion of plant-available zinc in soils by cultivating high-yielding cultivars, balanced fertilization programs must include zinc applications.

Zinc Fertilizer Compounds

Three different types of compounds are used in zinc fertilizers. These compounds vary considerably in zinc content, price and effectiveness for crops on different types of soils. The sources of zinc include: (1) inorganic compounds, (2) synthetic chelates and (3) natural organic complexes.

- Inorganic sources include: zinc sulphate, zinc oxide, zinc carbonate, zinc nitrate, and zinc chloride. Zinc sulphate is the most commonly used zinc fertilizer worldwide and is available in both crystalline monohydrate and heptahydrate forms.

Table 1. Zinc containing compounds

Compound	Formula	Zinc Content (%)
	Inorganic Compounds	
Zinc sulphate monohydrate	$ZnSO_4.H_2O$	36
Zinc sulphate heptahydrate	$ZnSO_4.7H_2O$	22
Zinc oxysulphate	$ZnO.ZnSO_4$	20-50
Basic zinc sulphate	$ZnSO_4.4Zn(OH)_2$	55
Zinc oxide	ZnO	50-80
Zinc carbonate	$ZnCO_3$	50-56
Zinc chloride	$ZnCl_2$	50
Zinc nitrate	$Zn(NO_3)_2.3H_2O$	23
Zinc phosphate	$Zn_3(PO_4)_2$	50
Zinc frits	Fritted glass	10-30
Ammoniated zinc	$Zn(NH_3)_4SO_4$	10
	Organic Compounds	
Disodium zinc EDTA	$Na_2ZnEDTA$	8-14
Sodium zinc HEDTA	NaZnHEDTA	6-10
Sodium zinc EDTA	NaZnEDTA	9-13
Zinc polyflavonoid	--	5-10
Zinc lignosulphonate	--	5-8

- Synthetic chelates are special types of complexed micronutrients generally formed by combining a chelating agent such as Ethylene Diamine Tetra-acetic Acid (EDTA) with a metal ion. The disodium salt of ZN-EDTA (Na2Zn-EDTA) is the most commonly used chelated source of zinc. With their high stability, synthetic chelates are eminently suitable for mixing with concentrated fertilizer solutions for soil, fertigation and hydroponic applications. They can also be used for foliar sprays, but their relatively low zinc content means that repeat applications may be required for moderate to severe zinc deficiency situations. Recent results indicate that zinc sulphate ($ZnSO_4$) is a better and cheaper source for foliar spray of zinc than ZnEDTA in terms of correcting zinc deficiency and improving zinc concentrations of seeds/grains.

- Natural organic complexes include those which are manufactured by reacting zinc salts with citrates or with organic by-products from paper pulp manufacture such as lignosulphonates, phenols and polyflavonoids. They are generally less expensive than synthetic chelates such as ZN-EDTA.

Table 1 shows the full range of materials used as zinc fertilizer and their typical zinc contents.

Most zinc fertilizers are manufactured from residues and by-product streams of processes using primary zinc metal. These zinc sources are purified and chemically altered to create a compound that is bioavailable to crops. As zinc fertilizer usage increases around the world, it will become more common for zinc fertilizer to be manufactured from primary metal. It is important that zinc fertilizers are sourced from reputable producers to ensure that they are free from harmful contaminants and contain stated levels of zinc.

Zinc Fertilizer Applications

Zinc deficiencies are normally corrected by soil applications of zinc compounds. Foliar sprays are usually used on higher value fruit trees and grape vines and for treating annual field crops. Other methods include seed treatments and root-dipping of transplant seedlings (e.g. in rice production).

Fertigation is a relatively new application method in which both Zn fertilizers and NPK fertilizers are added together to irrigation water to improve uniform distribution, homogeneous mixing, greater availability and reduced risk of damage to plants, especially in semi arid and arid areas.

The amount of zinc fertilizer required depends on the type of crop to be grown, the type of zinc fertilizer used and the local soil conditions. Soil applications are typically in the range 5-30 kg zinc/ha, usually in the form of zinc sulphate broadcast or sprayed (in aqueous solution) onto the seedbed. Higher applications are often used for crops which are particularly sensitive to zinc deficiency, such as maize. Zinc fertilizers are also often used to fortify other fertilizers, including blended NPK fertilizers. In this application, it is common to see fortification rates in the order of 0.5% to 1.0% zinc by mass.

Where farmers are applying zinc fertilizers on a regular basis (either to the soil or as foliar sprays), regular soil or plant analysis should be carried out to determine

▶ For more information about the different kinds of zinc fertilizers, please read our fact sheet "Zinc Fertilizer Options to Consider."

Additional Fact Sheets are available for specific crops such as Wheat, Maize, Rice, and Sugarcane at www.zinc.org/crops.

whether sufficient residues of zinc have accumulated in the soil; thus, zinc applications could be discontinued for one or more years. This saves the farmer the expense of the zinc fertilizer application and helps to ensure that zinc does not accumulate to undesirably high levels. Local expert advice should be sought on all aspects of the management of the zinc status of soils as part of a balance approach to fertilization.

Benefits and Impacts of Zinc Fertilizers

Yield improvements are generally realized when zinc fertilizers are added to soils with low bioavailable zinc levels. Increases in yield will be dependent on a number of factors, including soil physical and chemical composition, pH and metal oxides and levels of organic matter and soil moisture. Crop response to zinc has been observed under almost all types of soils and agroclimatic zones. Response is high in grain crops as well as fruit and vegetable crops. Many reports are available showing significant cost-benefit effects of zinc fertilizers for resource-poor farmers, especially in regions where soil zinc deficiency is of particular concern. Table 1 shows that the benefit-to-cost ratio was as high as 38:1 on a lentil farm in India.

Table 2. Yield increase and benefit-to-cost ratio on some key crops in India

Crop	Zn Rate (kg/ha)	Zn Cost (INR/ha)	Yield Increase (kg/ha)	Value of Increase	Benefit-to-Cost Ratio
Wheat	5.25	875	1430	20,735	24:1
Rice	8.40	1400	1102	14,987	11:1
Maize	6.30	1050	1521	19,925	19:1
Chickpea	10.00	1750	855	32,063	18:1
Lentil	2.62	438	440	16,500	38:1
Groundnut	5.50	910	690	25,875	28:1
Mustard	6.30	1050	230	8,625	8:1
Cotton	5.60	945	430	16,125	17:1

Procurement / Minimum Support Price in INR/mt (2014-15): Wheat=1450, Rice=1360, Maize=1310, Chickpea=3175, Lentil=3075, Groundnut=4000, Mustard=3100, Cotton=3750. Average ZnSO4 heptahydrate price=INR 35/kg
Data source: Rattan, R.K., Datta, S.P. and Katyal, J.C., Indian J. Fert. 4(12): 93-118 (2008).

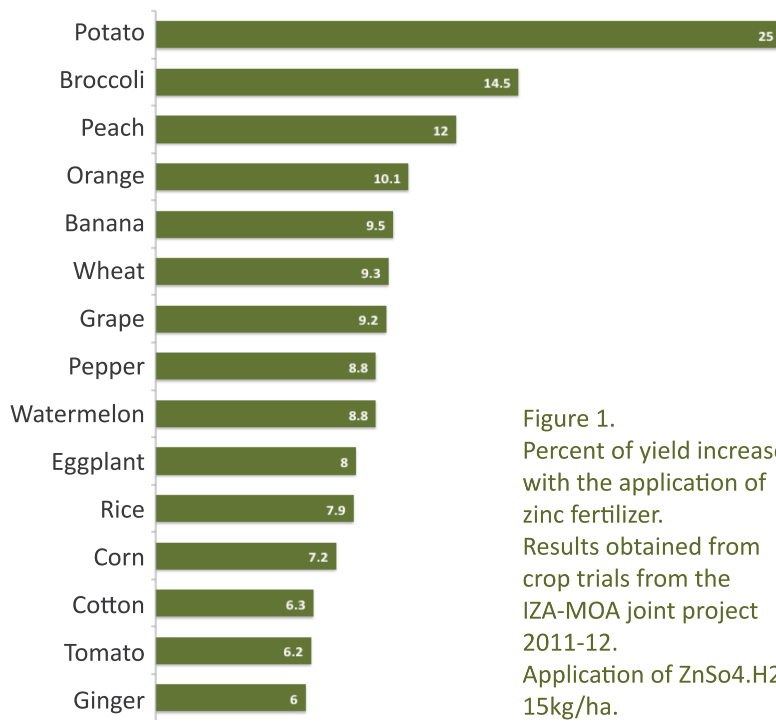

Figure 1.
Percent of yield increase with the application of zinc fertilizer.
Results obtained from crop trials from the IZA-MOA joint project 2011-12.
Application of ZnSo4.H2O, 15kg/ha.

Figure 1 shows percentage of yield increase for a variety of crops in China with the application of $ZnSO_4.H_2O$ at 15 kilograms per hectare. Figure 2 shows the increase in yield on wheat crops in India with the additon of Zn fertilizer to NPK fertilizer. Figure 3 shows impact of zinc fertilizer on a barley crop after a 14-day application.

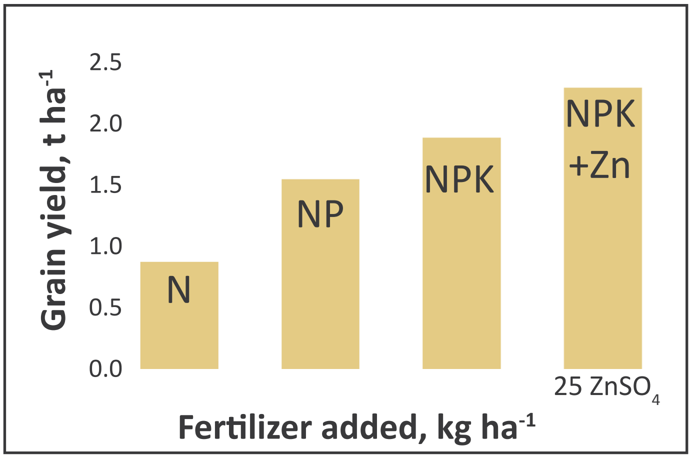

Figure 2. Wheat Grain Yield Based on Long-term Multi Location Experiments in India. N: 120, P: 60, K: 60. Source: Tandon, 1995; Cakmak, 2006

Conclusion

For millions of people around the world, a few extra milligrams of zinc each day can make the difference between illness or death and a healthy, productive life. By ensuring that crops receive an adequate supply of zinc, we can help address this global issue. Adding zinc to crops not only increases crop nutritional value, but also increases crop yield and crop resistance to environmental hazards such as drought and disease. Increased yield leads to increased income for the farmers.

Figure 3. Barley crop after 14 days of zinc treatment on zinc-deficient soil

Zinc fertilizer is a simple, sustainable solution to zinc deficiency in soils, crops, and humans, which ultimately leads to increased food and nutrition security, higher income for farmers, and a great reduction in death and disease related to zinc-deficiency.

Zinc ...essential for life

The Zinc Nutrient Initiative was launched by The International Zinc Association (IZA) in response to the critical issue of zinc deficiency in soils, crops and humans. To learn more, visit: www.zinc.org/crops.