



Zinc nutrient initiative



Introduction

Zinc deficiency is a well-studied and wide-spread problem in agricultural soils worldwide. It is estimated that 50% of agricultural soils contain low levels of available zinc, mainly due to high soil pH, low soil moisture and low organic matter.¹ Soils with high leaching capacity (e.g., sandy soils or those which are highly acidic) can sometimes lack zinc altogether. If not corrected, zinc deficiency will cause significant decreases in crop productivity and nutritional quality. Even in areas which are not prone to zinc deficient soils, zinc fertilization is necessary to replenish zinc removed by high-yielding cultivars.²

While the benefits of zinc fertilizers are well known, there are several types available. The purpose of this fact sheet is to help define the criteria needed to match the right zinc fertilizer for the specific conditions noted in the field.

Factors that influence the effectiveness of zinc fertilizer

There are several factors and site-specific conditions that influence the effectiveness of zinc fertilizers. These include: the concentration of zinc, cost, impurities (e.g., presence of contaminants such as cadmium), water solubility, soil type, and method of application. Figure 1 shows the importance of water solubility of zinc in fertilizers. Increasing the percentage of water-soluble zinc in fertilizers having the same amount of total zinc clearly enhanced dry matter production of corn grown in soils with high pH.³

Zinc fertilizers available in the market

There are several varieties of zinc fertilizers available in the marketplace. These include: $ZnSO_4$, ZnO , Zn-oxysulfates, ZnEDTA (a synthetic zinc chelate), and Zn-lignosulfonates (organically complexed zinc source). These zinc fertilizers differ in total zinc, water-soluble zinc concentration, price and composition (Table 1). Fertilizers with zinc sulfate, especially in its heptahydrate form (e.g., $ZnSO_4 \cdot 7H_2O$), are the most commonly applied zinc fertilizers due to the higher solubility and relative low cost of zinc sulfate.

Zinc-oxysulfates and ZnO are also used in zinc fertilizers. Zinc-oxysulfates representing a mixture of ZnO and $ZnSO_4$ are produced after acidification of ZnO with sulfuric acid (H_2SO_4) and sold generally in granular form.⁵ The degree of the solubility of zinc in Zn-oxysulfates depends largely on the percentages of $ZnSO_4$ (highly water soluble) and ZnO (water insoluble). Zinc oxide is nearly insoluble in water (e.g., 0.0016 grams per liter) while $ZnSO_4$ is highly soluble (e.g., 580 grams per liter).

The most common soil-applied organic source of zinc fertilizer is ZnEDTA. The agronomic effectiveness of soil-applied ZnEDTA is reported to be very high. However, due to its high cost, the use of

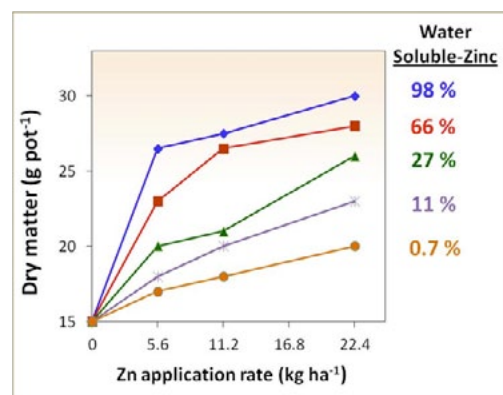


Fig. 1: Dry matter production of corn plants grown in a soil (pH: 7.4) with 5 different Zn fertilizers ranging in water solubility of Zn from 0.7% to 98%. Redrawn from Westfall et al.⁴

1. *Zinc in soils and crop nutrition*, BJ Alloway, 2008. 2. *Enrichment of cereal grains with zinc*, I Cakmak, 2008. 3. *Zinc Fertilizers* JJ Mortvedt and RJ Gilkes, 1993. 4. *Water-Solubility of zinc fertilizer: Does it matter?* DG Westfall, M Amrani, GA Peterson, 1999. 5. *Crop response to level of water-soluble zinc in granular zinc fertilizers*, JJ Mortvedt, 1992. 6. M McLaughlin, unpublished.

ZnEDTA is limited, especially in cereals and grain legumes. Zinc lignosulfonates are organically complexed zinc fertilizers, produced by reaction of $ZnSO_4$ with lignin wastes. Zinc lignosulfonates are also an effective zinc source for plants.

Table 1: Selected Zn fertilizers and their formula, Zn content, water solubility, cost and commonly applied soil types

Zinc Source	Formula	%Zn	Water Solubility	Soil Type	Cost
Zinc sulfate heptahydrate	$ZnSO_4 \cdot 7H_2O$	22%	Highly soluble	All soils	Low
Zinc sulfate monohydrate	$ZnSO_4 \cdot H_2O$	36%	Highly soluble	All soils	Low
Zinc oxysulfate	$xZnSO_4 \cdot xZnO$	20-50%	Variable*	Variable*	Low
Zinc oxide	ZnO	72-80%	Very low	Acidic soils	Low
Zinc chloride	$ZnCl_2$	50%	Highly soluble	All soils	Low
Zinc nitrate	$Zn(NO_3)_2 \cdot 3H_2O$	23%	Highly soluble	All soils	Medium
ZnEDTA	$Na_2ZnEDTA$	8-14%	Highly soluble	All soils	High

*Usage of this Zn fertilizer depends upon percentage of $ZnSO_4$ or ZnO in zinc oxysulfate.

Points to consider when choosing the right Zn fertilizer

- In addition to the total amount of zinc in a given fertilizer, farmers must also be aware of several other factors, such as water solubility of Zn and the type of soil on which it will be applied.
- Roots absorb only the nutrients that are soluble (or dissolved) in water, which is why water solubility of Zn in fertilizer is critical in determining its agronomic effectiveness, especially when applied to neutral and alkaline soils.
- Recent work has suggested that application method is major factor affecting Zn fertilizer efficiency, with ZnO being more bioavailable to the plants if it is uniformly mixed throughout the soil column versus when it is applied to the surface or banded.⁶
- When applied at very high doses, the degree of the Zn water solubility of Zn fertilizers might be less important for their impact on plant growth.
- It might be expected that water insoluble Zn fertilizers may have increasing residual availability in soil over time. However, published data is controversial about this issue.
- Fertilizer products incorporating a controlled release of zinc, through chemical and/biological actions, can use less soluble forms such as ZnO to be effective.
- When incorporated into acidic fertilizers, ZnO and $ZnSO_4$ might be similarly effective in providing Zn to plant roots.
- Soil-applied Zn fertilizers containing high water solubility of Zn (such as $ZnSO_4$, Zn-lignosulfonates and ZnEDTA) are generally equally effective in improving plant growth on Zn deficient soils; but they differ greatly in cost, and in enhancing Zn concentration of plants, being higher with ZnEDTA or Zn-lignosulfonates.

Conclusions

The results in the literature clearly indicate the importance of water-soluble zinc in fertilizers, with the percentage of soluble zinc serving as a good indicator for agronomic effectiveness. Decisions for purchasing a Zn-containing fertilizer should, therefore, be based not only on total amount of Zn, but also on the percentage of water-soluble Zn, as well as the other key factors like cost, soil type, and method of application. Due to its high water solubility along with other factors, $ZnSO_4$ is the most common form of zinc fertilizer used, and it has shown excellent results in all soil types. However, depending on the soil type or other considerations, other zinc fertilizers may also be effective. For example, in acidic soils, (i.e., soils at or below pH 5.5) water insoluble fertilizers such as ZnO can be equally effective in improving plant growth when soil is Zn deficient. When incorporated into acidic fertilizer, ZnO and $ZnSO_4$ can be also similarly effective in providing zinc to the plants. In case of enrichment (biofortification) of staple food crops with zinc, zinc fertilizers with high water-soluble Zn would be the best choice for foliar applications.