COLORADO

Water-Solubility of Zinc Fertilizer: Does It Matter?

By D.G. Westfall, M. Amrani, and G.A. Peterson

Colorado research indicates that total zinc (Zn) content of a fertilizer is not enough to determine its effectiveness for a crop grown on soils low in available Zn. A greenhouse study found that degree of water solubility is an important factor.

Zinc is an essential nutrient for plant growth and is commonly deficient in soils. While a Zn deficiency can severely impair crop growth and decrease yield, it can be easily and economically corrected by applying Zn fertilizers. Zinc sulfate ($ZnSO_4$) is the traditional Zn fertilizer, but many other sources are available, ranging from chelates to industrial by-products, such as those that contain zinc oxide (ZnO). Sulfuric acid (H_2SO_4) added to ZnO forms granular Zn oxysulfates. The greater the quantity of H_2SO_4 reacted with the ZnO (to form $ZnSO_4$), the greater the water solubility of Zn in the final fertilizer material. Zinc oxysulfates vary widely in their water solubility. In a greenhouse study, we evaluated the effectiveness of some commercial Zn granular fertilizer materials in correcting Zn deficiencies in soils testing low in plant-available Zn.

A Zn-deficient loamy sand soil with a DTPA soil test of 0.48 parts per million (ppm) Zn (low) and an organic matter content of 0.5 percent was used in this study. The soil initially had a pH of 5.1, but was limed to pH levels of 6.3 and 7.4 by adding 0.1 and 1.5 percent calcium carbonate ($CaCO_3$), respectively. Commercial granular Zn fertilizer materials used in this investigation were given different symbols, shown with some of their characteristics in **Table 1**.

Corn was grown in pots containing 12 lb of soil in a greenhouse. Zinc fertilizer granules were added to each pot, placed about 2 inches below the seed, at rates equivalent to 0, 5, 10, and 20 lb Zn/A. In order to evaluate these materials under conditions similar to those found in the field, we used the Zn sources in the physical condition found in the fertilizer bags. The granule mesh size was typical for each source. Materials were not ground or altered. Alteration of the physical granule characteristic of the fertilizer (grinding) would have artificially increased agronomic performance.

All six Zn sources were evaluated on the soil amended to a pH of 7.4. Only four were evaluated at pH 6.3 (**Table 1**). Above-ground corn forage was harvested 40 days after planting.

TABLE 1. Total Zn content and water solubility of Zn materials used in study.

Zn source	Zn fertilizer symbol	Total Zn, %	Water soluble Zn, %	Soil pH evaluated	
				6.3	7.4
$ZnSO_4 \cdot H_2O$	$ZnSO_4$	35.5	99.9		x
Zn oxysulfate	Zn20	20.4	98.3	x	x
" "	Zn27	27.3	66.4	x	x
" "	Zn40	39.9	26.5	x	x
" "	ZnOxS	37.7	11.0		x
" "	ZnOS	17.5	0.7	x	x

Visual Symptoms

Within 5 days after emergence, corn grown with no Zn and that receiving ZnOxS and ZnOS showed distinct Zn deficiency symptoms (**Photo 1**). Pronounced bands of chlorosis occurred on the leaves, starting near the leaf whorl. By the end of the growing period, one- to three-fold variations in plant height were observed among the fertilizer materials.

Growth response to $ZnSO_4$ at the four application rates is shown in **Photo 2**. A rate of 5 lb Zn/A from $ZnSO_4$ satisfied the Zn requirement of the plant. Similar results are shown for Zn20 in **Photo 3**.

Corn Growth

Dry matter production for the soil pH 7.4 study is plotted in **Figure 1**. Based on the growth response, three groups of granular Zn fertilizer materials can be identified: (1) ZnOS resulted in no significant response to Zn application; (2) Zn40 moderately increased dry matter production as Zn rate increased, particularly in the more acid pH 6.3 soil; (3) $ZnSO_4$, Zn20, and Zn27 increased dry matter production substantially. The very low agronomic effectiveness of ZnOS and ZnOxS is related to their lower water solubility and subsequent low Zn availability.

Water solubility appears to be the key to Zn availability for crops grown on soils low or deficient in Zn. This is substantiated by the

Photo 1. Zinc deficiency symptoms of corn ... bands of chlorotic tissue developing, starting at the whorl and progressing up the leaf. Within 5 days after emergence, corn plants that had received Zn fertilizers with low water solubility showed Zn deficiency symptoms.

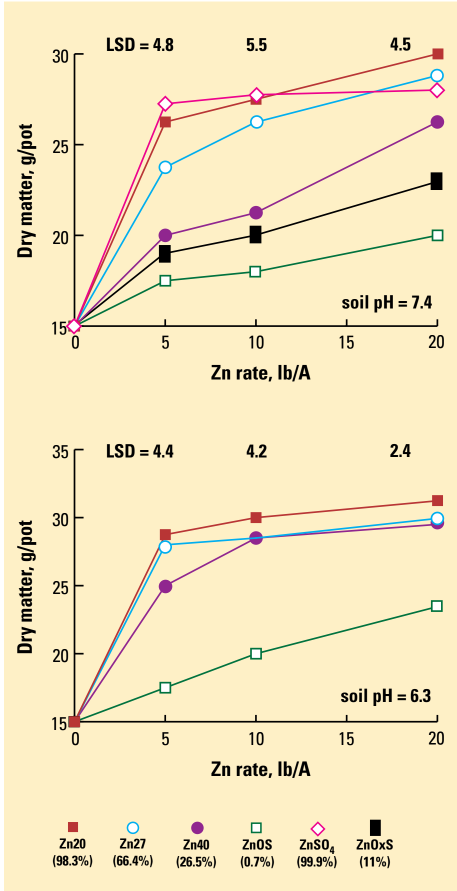

Figure 1. Corn dry matter production from six Zn fertilizers at soil pH 7.4 and four Zn fertilizers at soil pH 6.3. Fertilizers with low Zn water solubility showed limited effectiveness in increasing plant growth.

Photo 2. A high water soluble Zn fertilizer, $ZnSO_4$ (99.9 percent total water soluble Zn), supplied enough Zn at the 5 lb Zn/A rate to satisfy the plants' needs.

Photo 3. A zinc oxysulfate Zn fertilizer, Zn20 (98.3 percent total water soluble Zn), with a high water soluble Zn content, was able to supply enough Zn to satisfy the plants' needs.

fact that the increase in dry matter production was highly correlated with water-soluble Zn. Maximum dry matter production was related to percentage water solubility of the Zn fertilizer. An increase of 10 percent in Zn water solubility resulted in an increase in dry matter production of 5 percent. The increase in dry matter production for all Zn application rates as a function of percent water soluble Zn is shown in **Figure 2**. The higher the content of water soluble Zn in the fertilizer material, the lower the Zn application rate that is required to obtain maximum production.

Zinc Uptake

The ranking of the Zn fertilizers in relation to their ability to supply Zn to the plant was: $ZnSO_4$ > Zn20 > Zn27 > Zn40 > ZnOxS > ZnOS. This order matches the order of decreasing water-solubilities of Zn fertilizers, as shown in **Table 1**.

Conclusions

The long-term availability of these Zn fertilizer sources was not evaluated. It is not known if Zn from lower water soluble Zn sources would be more available in future years. If low water soluble materials do increase the soil Zn levels over time, the increase in Zn availability would be detected in the soil test levels in future years.

Our short-term greenhouse work conclusively showed that corn growth and Zn uptake were increased by increasing Zn application rates of fertilizers that are high in water-solubility. We suggest that granular Zn fertilizers should have water soluble Zn levels of about 50 percent to be effective in supplying adequate Zn levels to the current year crop. Knowing the total Zn content of a fertilizer is not enough to successfully determine the Zn fertilizer requirement

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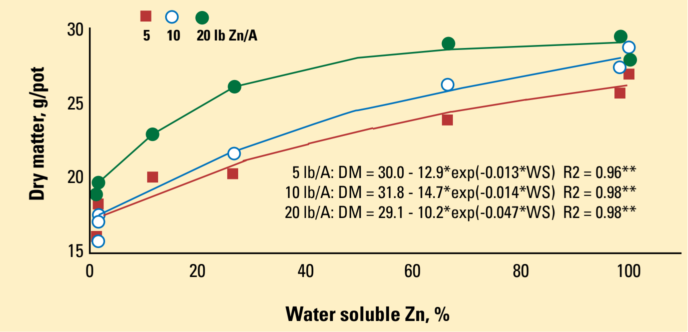

Figure 2. Effect of percentage water-soluble Zn in the fertilizer materials on dry matter production at three Zn application rates. Zinc fertilizers should have about 50 percent water soluble Zn content to be effective in correcting Zn deficiencies.

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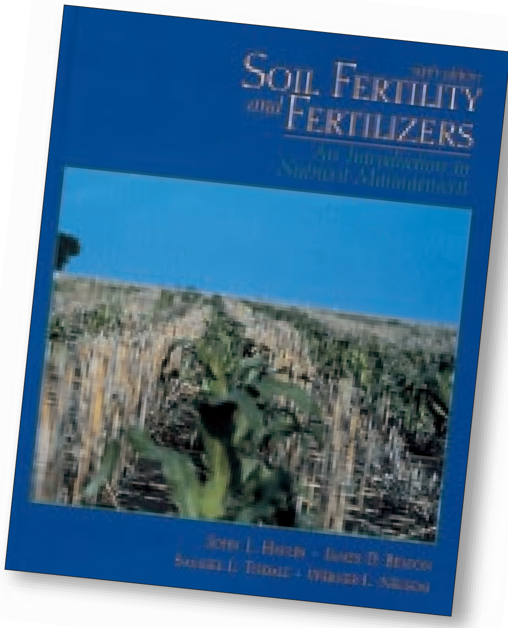

Water Solubility of Zinc Fertilizer... *(continued from page 20)*

for a crop. Farmers need to know the degree of Zn water solubility of granular Zn fertilizers.

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