Technical Bulletin TB08-04 December 2008

Agricultural Experiment Station

College of Agricultural Sciences

Department of Soil and Crop Sciences

Extension

Zinc Fertilizer Efficiency Ratios

VALIDITY OF ZINC FERTILIZER EFFICIENCY RATIOS

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INTRODUCTION:

Recent Studies have shown that water soluble Zn fertilizers are the most effective way to correct Zn deficiencies in soils used for crop production (Shaver et al., 2007, Gangloff et al., 2000, Amrani et al., 1999, 1997, Mortvedt et al., 1993, Mortvedt, 1992). Zinc fertilizer water solubility levels of 40-50% are needed to meet the Zn requirements for the current crop (Amrani et al., 1999, Mortvedt et al., 1993.), and high correlations have been found between Zn fertilizer water solubility and plant growth and Zn uptake (Amrani et al., 1999).

Zinc sulfate ($ZnSO_4 \cdot 2H_2O$) fertilizers have been found to be a very reliable because of their relatively high water solubility. However, there are new Zn fertilizer products continually being brought to the market. Some of these products claim an "efficiency ratio" meaning that one unit of their product is equal to several units of traditional Zn fertilizers, such as $ZnSO_4$ when applied in the field. One new Zn fertilizer with a claimed efficiency ratio is Wolftrax® DDP (dry dispersible powder), which claims an efficiency ratio of 9:1 because of a "micro-static adhesion" that allows the Zn fertilizer (in powder form) to stick to every granule of NPK fertilizer thereby increasing efficiency. Another Zn fertilizer with a claimed efficiency ratio is Origin® 10% LS (lignosulfonate) which claims a 7:1 efficiency ratio due to natural organic agents that protect the metal ions from tie-up by soil particles and conversion to an insoluble form of Zn. The validity of these claims must be examined because some products simply rely on residual soil Zn to justify reduced application rates.

The objective of this study was to evaluate the advantages and limitations of the "efficiency ratio" claims of these Zn fertilizers using $ZnSO_4$ as our reference standard by applying these fertilizers according to their efficiency ratios. By examining plant biomass production as well as plant Zn uptake and Zn concentration we can better understand what Zn fertilizers are effective in supplying Zn to the plant.

EXPERIMENTAL PROCEDURES:

Greenhouse Experiment:

This study was conducted in Colorado State University's on-campus greenhouse facilities to create the most uniform conditions possible for plant growth and Zn fertilizer use.

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Soil:

This study was conducted using a Zn deficient soil that contained 0.4 ppm DTPA extractable Zn. The natural pH level of this soil is 5.6; however the soil was limed to a pH of 7.4, since Zn deficiencies are more pronounced at alkaline pH levels.

Fertilizers:

Three commercially available Zn fertilizer sources were tested, these Zn sources, including the laboratory analysis of total and water soluble Zn and claimed efficiency ratio, are listed below.

Source	Total Zn (%)	H_2O Soluble Zn (%)	Efficiency Ratio
Tetra ® $ZnSO_4 \cdot 2H_2O$	36.5	35.7	1:1
Wolftrax® Zinc DDP	64.8	6.0	9:1
Origin® 10% LS	8.9	8.5	7:1

The Zn fertilizers were applied one inch below and to the side of the seed at planting. Each material was applied in the form received from the manufacturer. No modifications were made to the Zn fertilizer product. Pre-plant Zn application rates were based on the efficiency ratio of each source. The $ZnSO_4$ source (1:1 ratio) had application rates equivalent to 0, 3, 5, and 10 lbs of total Zn per acre and was the standard that the other source application rates were compared to. The Wolftrax® source (9:1 ratio) had application rates equivalent to 0.335, 0.550, and 1.10 lbs of total Zn per acre (9 times less than the $ZnSO_4$ source) as specified by the efficiency ratio. The Origin® source (7:1 ratio) had application rates of 0.425, 0.700, and 1.45 lbs of total Zn per acre (7 times less than the $ZnSO_4$ source) as specified by the efficiency ratio. There was also a check treatment with 0 lbs/ac of Zn (no Zn applied). At the V6 corn growth stage all pots across all sources and application rates showed visual Zn deficiencies. This suggested that the initial rates applied were insufficient for this soil. At this time we made a side-dress application of Zn at the same rates that were applied preplant. This resulted in overall application rates equivalent to 0, 6, 10, and 20 lbs Zn/ac, using $ZnSO_4$ as the standard rate. Actual application amounts for each source are listed in Table 1.

Supplemental fertilizer (N-P-K, etc.) was applied on a soil analysis basis. Reagent grade materials were used for all supplemental fertilizer needs to insure that no Zn contamination occurred.

Crops:

Corn was selected as the test crop because it is highly susceptible to Zn deficiencies, and it is a major crop in the U.S. Five corn plants were planted in each pot. Ten days after emergence the pots, (each containing 8.0 lbs of soil) were thinned to three plants per pot. The early growth stage Zn deficiency of all plants resulted in reduced growth, even up to the V12 growth stage. At the V12 growth stage the plants were harvested, oven dried, and biomass weight was recorded. The corn plant tissue was ground and analyzed for Zn concentration using nitric acid digestion and Inductively Coupled Plasma (ICP) analysis. Zinc uptake was calculated using the biomass weights and Zn concentration

Experimental Design:

The study was conducted using a randomized complete block design with three Zn fertilizer sources and four Zn fertilizer rates with three replicates. All differences in the parameters measured and mean separations were performed using the Proc GLM program in Statistical Analysis Software (SAS).

RESULTS:

Zinc concentration and uptake levels for each source and rate applied are shown below in Table 1. Zinc fertilizer sources significantly affected both Zn concentration and Zn uptake. No significant differences were observed across equivalent Zn application rates nor were there any source by rate interactions, (NOTE: We express the rates as “equivalent” rates based upon the efficiency ratios claimed by the manufacturer).

Table 1. Corn Zn concentration, Zn uptake and corn biomass weight as affected by Zn source and rate applied.

Source	Equivalent Zn Rate (lbs Zn/ac)	Actual Zn Applied (lbs Zn/ac)	Zn Concentration (mg/kg)	Dry Biomass (g/pot)	Zn Uptake (mg/pot)
Check	0	0	4.10	20.05	0.83
LS10	6	0.85	4.39	22.50	0.97
LS10	10	1.40	3.99	21.06	0.84
LS10	20	2.90	4.83	20.49	0.99
Average			4.40	21.35	0.93
Wolftrax	6	0.67	6.82	21.57	1.57
Wolftrax	10	1.10	3.59	22.27	0.79
Wolftrax	20	2.20	6.42	22.76	1.36
Average			5.61	22.20	1.24
$ZnSO_4$	6	6	5.32	18.43	0.97
$ZnSO_4$	10	10	7.77	22.48	1.75
$ZnSO_4$	20	20	9.70	23.72	2.22
Average			7.60	21.54	1.65

	Zn Concentration		Dry Biomass		Zn Uptake	
	p-value	$LSD_{0.10}$	p-value	$LSD_{0.10}$	p-value	$LSD_{0.10}$
Source:	0.084	2.17	0.8341	-----	0.0695	0.46
Rate:	0.2712	-----	0.5550	-----	0.2102	-----
Rate*Source:	0.5578	-----	0.4305	-----	0.1748	-----

Only the $ZnSO_4$ source showed a positive trend in increasing Zn concentration and uptake with increasing application rate. Zinc concentration levels of 5.32, 7.77, and 9.70 mg/kg (ppm) were observed at the 6, 10, and 20 lb Zn/ac rates, respectively (Table 1). Zinc uptake also followed this trend with 0.97, 1.75, and 2.22 mg of Zn observed at the 6, 10, and 20 lb Zn/ac rates, respectively. The Origin® LS10 and Wolftrax® sources did not show the same trend with Zn application rate; Zn concentration and uptake values were not directly related to rate. The Origin® LS10 source had similar concentration (4.39 and 4.83 mg/kg) and uptake (0.97 and 0.99 mg) levels at the 6 and 20 lb equivalent Zn/ac rates, and a lower concentration (3.99 mg/kg) and uptake (0.84 mg) at the 10 lb equivalent Zn/ac rate (Table 1). The Wolftrax® source also did not show a positive relationship between rate and Zn uptake or concentration with Zn concentration (6.82 and

6.42 mg/kg) and uptake (1.57 and 1.36 mg) levels at the 6 and 20 lb equivalent Zn/ac application rates with the 10 lb equivalent Zn/ac rate having a concentration of 3.59 mg/kg and an uptake of 0.79 mg).

The Zn concentration and uptake levels observed in the Origin® LS10 source treatment were essentially identical to the levels observed for the check treatment. There was a trend for the Wolftrax® source Zn concentration and uptake to be higher in the plants as compared to the check and Origin® LS10 treatments. However, these differences were not statistically different. Concentration and uptake did not increase with increasing rate, and the 6 lb equivalent Zn/ac treatment performed equally to the 20 lb/ac rate. Greater concentrations and uptake levels were observed with $ZnSO_4$, but again these levels were not statistically higher when comparing rate, or rate by source, but the elevated levels suggest that $ZnSO_4$supplied greater levels of Zn to the plants than the other sources when applied according to the efficiency ratios suggested by the manufacturers.

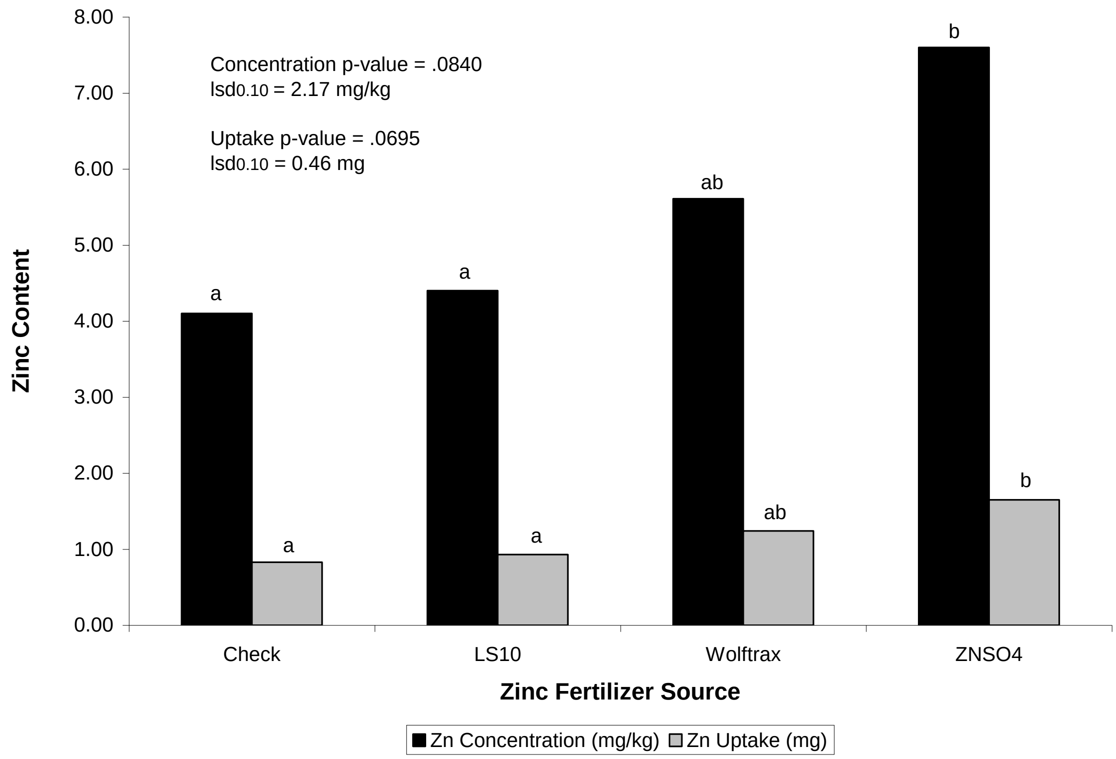

Figure 1. Corn Zn concentration and uptake averaged over Zn rate.

Significant differences were observed in both Zn concentration and uptake when averaged across rates for each source (Table 1, Figure 1). The $ZnSO_4$ source had the highest levels of Zn concentration and uptake with 7.60 mg/kg and 1.65 mg/kg, respectively, but was not statistically different from Wolftrax® . Wolftrax® was also in the same statistical array as the check and Origin® LS10 (Figure 1). The Origin® LS10 source contained only 8.5% water soluble Zn and numerous studies have shown that water soluble Zn content is the most important factor influencing Zn content and uptake (Shaver et al., 2007, Gangloff et al., 2000, Amrani et al., 1999, 1997, Mortvedt et al., 1993, Mortvedt, 1992). The concentration and uptake levels also were probably low because the amount of Zn applied was 1/7 the amount applied as $ZnSO_4$ source based on the manufacturer's claimed 7:1 efficiency ratio. The actual Zn applied rates for this source were only 0.85, 1.4, and 2.9 lbs Zn/ac.

The Wolftrax® Zn source contained only 6.0% water soluble Zn and due to the claimed efficiency ratio of 9:1, 1/9 the amount of Zn was applied compared to $ZnSO_4$. The Wolftrax® did appear to supply an intermediate quantity of Zn based on the numeric results, but it was not significantly different than the check. The intermediate concentration and uptake levels across sources observed in this study were probably due to the smaller particle size of this product. Wolftrax® is supplied by the manufacturer as a very fine powder; it has a very large surface area when compared to more traditional granular fertilizers. The greater surface area creates a greater opportunity for the plant root to encounter the fertilizer. This could also explain the variability in biomass production and Zn concentration and uptake observed with this source. With the relative insolubility of this source and the extremely low recommended application rates the plant root could easily miss the source entirely. This could lead to a large variability in concentration and uptake and explains why the 6 and 20 lb/ac application rates performed equally and better than the 10 lb/ac rate in this case.

The $ZnSO_4$ source contains 35.7% total Zn and is essentially 100% water soluble and resulted in the highest plant Zn concentration and uptake levels. No claims are made regarding "efficiency ratios," and therefore it was applied on a 1:1 basis, which resulted in higher amounts of Zn being applied compared to the other two sources. Since previous studies demonstrated the importance of water solubility coupled with the fact that $ZnSO_4$ source was applied at a total Zn rate 7 to 9 times higher than the Origin® LS10 or Wolftrax® sources, it is logical that this source would have the highest availability. High water solubility allows the Zn to dissolve and move with the soil solution until it becomes attached to the soil exchange sites where it is still available to the plant. Our results did not substantiate the "efficiency ratios" claimed by the fertilizer manufacturers (Figure 2).

CONCLUSIONS:

The $ZnSO_4$ source produced the highest plant Zn concentration and uptake levels compared on the efficiency ratio basis with Origin® LS10 or Wolftrax® Zn fertilizers. The $ZnSO_4$ was also the only source that produced a positive and consistent trend in Zn concentration and uptake in response to application rate. The Origin® LS10 source showed no significant increase in Zn uptake or plant Zn concentration as compared to the check treatment (0 Zn/ac) suggesting this source provided little or no Zn for crop uptake. The Wolftrax® source did supply Zn to the crop in quantities intermediate to the amount supplied by the $ZnSO_4$ and Origin® LS10 sources, but these concentrations and uptake values were not significantly different than the check. However, the Wolftrax® levels were in the same statistical array (not different) from the $ZnSO_4$ material when averaged across all rates. However, no positive relationship between rates and plant Zn concentrations or uptake were detected with the Wolftrax® material. Due to the relatively low Zn water solubility and extremely low actual Zn application rates of the efficiency ratio based sources, the plant roots have a low probability of encountering the Zn material, which greatly reduces the opportunity for plant uptake. The opposite is true of the highly water soluble $ZnSO_4$ source where Zn is in the soil solution and/or on the exchange sites. The $ZnSO_4$ source outperformed the other two materials evaluated in this study. These results are consistent with our previous studies as well as other studies reported in the literature. Water solubility remains as the major factor controlling Zn availability of fertilizer Zn to plants. Our results do not confirm the “efficiency ratio” principle proposed by the fertilizer manufacturers.

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ACKNOWLEDGEMENTS:

This research was supported by the Colorado State University Agricultural Experiment Station, Tetra Micronutrients, Inc., and Bay Zinc Company. Appreciation is expressed to all sponsors of this research project.

Figure 2. Zinc deficiency symptoms on corn at the V12 growth stage of the three different Zn sources applied at equivalent rates of 20 lb Zn/A (based on Zn efficiency ratio claims of each fertilizer) and the check.