ZINC SOURCES AND THEIR RELATIVE EFFECTIVENESS FOR CROPS

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ABSTRACT

Zinc fertilizers are widely used in the Great Plains region. Choice of Zn source depends upon intended method of application, relative agronomic effectiveness, price per unit of Zn, compatability, and convenience in application alone or with other fertilizer. Relative agronomic effectiveness of Zn sources should be determined by applying several Zn rates throughout the response range in replicated field experiments. Periodic soil tests for available Zn are suggested when Zn deficiency is suspected, or to check for Zn accumulation in soils which already are being fertilized with Zn. Published Zn recommendations are available in every State in this region. The grower selects Zn sources and determines Zn rates after consulting with his fertilizer dealer and the appropriate extension and industry representatives. Everyone involved is obligated to see that the best information is made available to the grower.

ZINC USE

Zinc fertilizer use in the Great Plains region (West North Central and Mountain States) has increased from 5,810 tons (elemental basis) in 1968, the first year that such data was obtained, to 19,490 tons in 1984 (16). This increase in Zn use has resulted from increased awareness of Zn needs, use of soil tests for Zn, and published Zn recommendations for one or more crops in the region.

ZINC SOURCES

The most common Zn fertilizers are $ZnSO_4$ and ZnO, although Zn oxysulfates (ZnO products partially acidulated with H_2SO_4), inorganic Zn complexes, and several synthetic chelates and natural organic complexes also are used (14). Industrial by-products containing Zn also have been used as Zn fertilizers in increasing amounts during the past decade although they have been marketed for more than 25 years. Sources of these by-products are spent acids from the galvanizing industry, battery production facilities, and other industries. Ammoniation of spent acids containing Zn results in neutral products supplying N and S as well as Zn. Baghouse dusts and flue dusts from Zn smelters and other industries also are sources of Zn. Use of certain industrial by-products as fertilizers allows their beneficial disposal, depending on whether or not their constituents may have harmful side effects (13).

Some industrial by-products also may contain heavy metal contaminants, such as Cd, Ni, and Pb. Concentrations of these heavy metals in the by-products usually are low. Therefore, their application rate to soil also would be low, especially in Zn fertilizers. For example, application at a rate of 5 lb/acre of Zn as $ZnSO_4 \cdot H_2O$ (36% Zn) containing 100 ppm of Cd would result in a Cd application rate of 0.001 lb/acre. Concentrations of Pb in some industrial by-products range from 1 to 5%, so the Pb application rate would be proportionately higher.

APPLICATION WITH MIXED FERTILIZERS

Zinc fertilizers can be applied with mixed NPK fertilizers by incorporating them during the manufacturing process, bulk blending with granular fertilizers, coating granular fertilizers, or by mixing with fluid fertilizers just before application to soil (12). Foliar sprays of soluble Zn sources also are applied for some crops, pecan trees, and some other fruit and vegetable crops (2).

Zinc sources can be uniformly distributed throughout NPK fertilizers by incorporation during manufacture. Because the Zn source is in intimate contact with fertilizer components under conditions of high temperature and moisture, the rate of chemical reactions which may influence the immediate plant availability of some Zn sources is enhanced. Residual availability of this applied Zn may not be affected, however.

Application of Zn sources with bulk-blended fertilizers is very popular because of the ease with which grades may be changed to meet specific crop needs in a given field. Granular Zn products which match the particle size of the NPK components are needed to minimize the possibility of segregation during handling and application.

Coating Zn fertilizers onto granular fertilizers greatly reduces the possibility of segregation but results in increased costs. Liquid binders are required as coating agents. Water, oils, waxes, and some fertilizer solutions have been used as binding agents. Some oils bleed through fertilizer bags. Other binding agents are unsatisfactory because they do not maintain the coating during handling. This results in segregation of the powdered Zn sources from the granular NPK components. Fertilizer solutions are preferred as coating agents because the fertilizer grade is not decreased appreciably.

Applying Zn sources with fluid fertilizers also allows the fertilizer dealer and the grower to be flexible. Because solubility or compatibility of Zn sources with solution or suspension fertilizers is required, selection of Zn sources is important.

SOLUBILITY AND PARTICLE SIZE EFFECTS

Agronomic effectiveness of Zn sources is partially related to their solubility. Highly soluble Zn fertilizer, such as $ZnSO_4$, will dissolve soon after soil application, and Zn will diffuse from the application site into the surrounding soil. The volume of soil affected by applied Zn is related to the solubility of Zn fertilizers per unit of applied Zn. Since plant uptake of Zn depends upon root interception of Zn-affected soil, Zn uptake from applied fertilizers should be related to the volume of soil affected by the fertilizer.

Particle size also may affect agronomic effectiveness of Zn fertilizers. Decreased particle size results in increased numbers of particles per unit of applied Zn. Therefore, more soil should be affected by Zn if the fertilizer is uniformly applied. Decreased particle size also increases the specific surface of a fertilizer. This should increase the dissolution rate of fertilizers with low water solubility, such as ZnO.

Importance of particle size to the relative agronomic effectiveness of $ZnSO_4$ and ZnO was demonstrated in a greenhouse study (1). Two Zn sources of three particle sizes were mixed with a Zn-deficient soil. Corn forage yields and Zn uptake were similar with fine (-100 mesh) $ZnSO_4$ and ZnO. While granular (-10+14 and -16+20 mesh) $ZnSO_4$ was somewhat less effective than fine $ZnSO_4$, granular ZnO with the same particle size ranges was completely ineffective during the six-week growth period. Response of corn to Zn also was related to level of water-soluble Zn in several fertilizers (3). Greater crop response was slight to fertilizers with levels of water-soluble Zn greater than 50% of the total Zn, depending on the fertilizer. The level of water-soluble Zn and its immediate agronomic effectiveness also decreased with increasing degree of ammoniation when added as $ZnSO_4$ to phosphate fertilizers (10). However, applications of Zn with ammoniated phosphate fertilizers should provide residual Zn for crops.

SOURCE EVALUATIONS

Agronomic effectiveness of a Zn source is the degree of crop response per unit of applied Zn. Field experiments using two or more non-zero rates of each Zn source are needed to best determine the relative agronomic effectiveness of several Zn sources. An excellent example of such an experiment is summarized in Table 1. Five Zn sources each were banded with 10-34-0 at rates of 0.1, 0.3, 1.0, and 3.0 lb/acre of Zn. Effectiveness of Zn sources, based on average corn yields over all Zn rates, decreased in the order: ZnEDTA, $ZnSO_4$, $Zn(NO_3)_2$-UAN, Zn-NH_3 complex, and ZnO, but average yields only ranged from 132 to 143 bu/acre.

TABLE 1. Response of Corn to Zn Sources Banded with 10-34-0 to a Nebraska soil, pH 7.6. (5,6).

Zn source	Zn applied, lb/acre					
	0	0.1	0.3	1.0	3.0	Avg.
	yield, bu/acre					
--	62					
ZnEDTA		138	139	155	141	143
Zn-NH_3 complex		118	138	134	140	133
$ZnSO_4$		132	141	131	144	137
ZnO		124	124	134	144	132
$Zn(NO_3)_2$-UAN		131	131	142	141	136
(average)		129	135	139	142	

Relative agronomic effectiveness of Zn sources varied widely with Zn rate. For example, ZnEDTA was much more effective than ZnO and the Zn-NH_3 complex at the lowest Zn rate, but all sources were equally effective at the highest Zn rate (Table 1). Other conclusions possibly could be drawn by examining data at the other Zn rates. Obviously, more than one Zn rate in the response range is needed for an objective evaluation of the merits of one Zn source as compared with another. Despite the greater effectiveness of ZnEDTA, other Zn sources might be more economical even if higher Zn rates were required.

Data from three papers are given as examples of crop response to two or more Zn sources. In Michigan several Zn sources each were banded with 6-24-12 fertilizer for pea beans on a Zn-deficient soil (7). Yields were increased by ZnEDTA, ZnNTA, and powdered ZnO at both locations. Granular ZnO and a Zn frit were not effective at either location, and yields with $ZnSO_4$ were only slightly higher at one location. In Virginia several rates of Zn as ZnEDTA and $ZnSO_4$ were broadcast and incorporated for corn (15). Results showed that yields were significantly increased with both Zn sources at both locations. Unfortunately, these Zn sources were not applied at the same Zn rate so no direct comparison could be made. ZnEDTA was more effective with band than with broadcast application at one location. Both ZnEDTA and $ZnSO_4$ were equally effective with seed applications for corn, but higher $ZnSO_4$ rates were required for band or broadcast applications (9). In another study, several Zn sources applied with suspension fertilizers were compared in a greenhouse experiment (11). Effectiveness of the Zn sources decreased in the order: ZnEDTA, Zn-citric acid, $ZnSO_4$, ZnO, and $ZnCl_2$. Meaningful values of relative agronomic effectiveness of Zn sources cannot be determined from greenhouse results, but such studies give some indications of expected effectiveness under field conditions.

Numerical values of the relative agronomic effectiveness of Zn sources are sometimes used. These numbers are the ratios of the pounds per acre of Zn needed by one Zn source to produce the same yield increase that one lb/acre of another source would produce. Because ZnEDTA generally requires the lowest Zn rate, the ratios of Zn generally are compared with ZnEDTA set at one. The relative effectiveness of ZnEDTA as compared with $ZnSO_4$ or ZnO generally has been found to range between 2.5 to 5.0, although ratios as high as 10 have been reported. Many of these values have been obtained from experiments where similar Zn rates were not always used. Therefore, it was not possible to know if lower rates of the less effective Zn source could have resulted in similar yields. Again, multi-rate field experiments are needed to best determine the relative effectiveness ratios. Results from greenhouse experiments should not be used to give these ratios, as greenhouse conditions do not closely simulate those in the field. While relative effectiveness of Zn sources is important, other factors to consider are cost per unit of Zn, compatability with other fertilizers, and convenience in application alone or with other fertilizers.

RESIDUAL EFFECTS OF ZINC

Residual effects of applied Zn should be considered in making Zn recommendations. Several states have reported increases with time in soil test levels for Zn. This buildup of Zn has resulted in reduction of the recommended Zn rate for crops after Zn has been applied for a number of years. Many states are reporting that the incidence of Zn deficiencies has decreased significantly with time. While crop responses to applied Zn still are reported, the magnitude of such increases is not as great as it was 10 to 20 years ago.

Because available Zn levels increase in soils after repeated applications, Zn soil test results should be continually monitored, and recommended Zn rates should be decreased as soil Zn levels increase. If not, Zn levels could be reached that would cause toxicities in some sensitive crops, although such toxicities have not been reported.

ZINC RECOMMENDATIONS

Recommendations for Zn applications in the States of the Great Plains region are summarized in Table 2. Soil tests for Zn by university soil testing laboratories generally are made only on request in these States. The main soil test methods for Zn are the DTPA (8) and AB-DTPA (4) procedures, although several other procedures also are used. Interpretation of Zn levels extracted by DTPA is: 0 to 0.5 ppm--low, 0.51 to 1.0 ppm--medium (marginal or moderate), and > 1 ppm--adequate.

Because the AB-DTPA procedure extracts more Zn from soils, the interpretation of Zn levels is: 0 to 0.9 ppm--low, 0.91 to 1.5 ppm-medium, and > 1.5 ppm--adequate.

Corn and dry beans are the main crops grown in the Great Plains region which are fertilized with Zn. Several other crops, however, including sorghum, sudan, potatoes, soybeans, flax, and pecans also are fertilized with Zn. Methods of application, soil pH level, and irrigated conditions affect the recommended Zn rates in some States.

Each state has published Zn recommendations. Fertilizer dealers and growers should consult with extension specialists and industry representatives if there are specific questions. Appreciation is given to those who provided information for this Table.

TABLE 2. Summary of zinc soil tests and recommendations - Great Plains Region

State	Extractant	Zn recommendation[a]		
		Crop	Zn rate, lb/acre	
			low Zn	marginal Zn
Colorado	AB-DTPA	Corn, dry beans, sorghum, sudan, potatoes	5 (10)	0 (5)
Kansas	DTPA	corn	8-10 (8-10)	2-5 (2-5)
		sorghum, soybeans, dry beans	2-5 (8-10)	0 (2-5)
Montana	DTPA	corn, dry beans	5 (10)	0 (5)
Nebraska	0.1 N HCl[b]	corn, dry beans	5-8 (5-8)	3-5 (3-5)
	DTPA[c]	corn, dry beans	10-15 (10-15)	5-10 (5-10)
New Mexico	DTPA	corn, sorghum, alfalfa, wheat	(7.5-15) (5-10)	(1-7.5) (1-5)
North Dakota	DTPA	corn, flax, dry beans, potatoes	10-15	10-15[d]
Oklahoma	DTPA	corn	2-5	
		pecans	foliar spray	
South Dakota	DTPA	corn	10 (5)	
Texas	DTPA	corn, sorghum, pecans	1	
Wyoming	AB-DTPA	corn, dry beans, potatoes	5 (10)	0 (5)

a/ Values in parenthesis are Zn rates for irrigated crops.
b/ For acid soils
c/ For calcareous soils (pH > 7.3)
d/ Broadcast rate recommended for a trial basis only, banded rate should be 2 lb/acre.

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