Nulex® Liquid Zinc
INFORMATIONAL REPORT

Field Evaluations of Zinc Sources Band Applied In Ammonium Polyphosphate Suspension[1]

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ABSTRACT

Although the importance of the addition of Zn to a fertilizer program for corn (Zea mays L.) production has been recognized for some time, the question of effectiveness of source and rate has not been completely resolved. This is especially true for situations where Zn is applied in fluid fertilizer. The objective of this study was to evaluate the effect of five Zn sources [ZnEDTA, Zn-NH3 complex, ZnO, ZnS04, and Zn(NO3)2] applied at five rates (0, 0.11, 0.33, 1.12, and 3.36 kg Zn ha-1) on the growth and yield of irrigated corn on sandy soils. The experiments were conducted at four locations during a 2-yr period. All Zn sources were suspended in ammonium polyphosphate and applied to the side of and below the seed at planting. Whole corn plants were collected at two growth stages and analyzed for Zn. Significant differences among Zn sources for Zn uptake were shown. ZnEDTA performed poorly at two sites due to early season leaching; however, it was the superior source at a calcareous site. The Zn-NH3 complex was the superior source at one of the sites. The 0.1 M CHl and DTPA soil tests correlated well with early Zn uptake for the noncalcareous sites. The critical DTPA soil test level for grain response at these locations was near 0.4 mg kg-1. Grain yields were increased by Zn fertilization at only two locations and there were no differences among Zn sources or significant Zn rate by source interactions. Regression equations for the responsive sites showed that between 1 and 2 kg Zn ha-1 was required to attain maximum yield. Although Zn uptake indicated differences in performance of Zn sources, the differences were not reflected in grain yield.

Additional Index Words: zinc fertilizers, fertilizer suspensions, fertilizer application methods, zinc chelate.

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The effectiveness of different zinc (Zn) fertilizers for corn (Zea mays L.) production has been compared since research on correcting Zn deficiency first began. Because of cost considerations a primary concern has always been the effectiveness of chelated vs. inorganic Zn sources. Over the years various ratios have been reported comparing the effectiveness of chelated vs. inorganic sources of Zn (Boawn et al., 1957: Judy et al., 1964; Vinande et al., 1968; Schnappinger et al., 1969; Shukla and Morris, 1967; Martens et al., 1973; Brinkerhoff et al., 1967; Wallace and Romney, 1970). Reviews of earlier research point out the conflicting results among experiments (Murphy and Walsh, 1972; Lindsay, 1972; Giordano and Mortvedt, 1972).

As noted by Boawn (1973), much of the earlier work did not include comparable rates of each Zn source studied. For example, several low rates of chelated Zn were compared with one higher rate of an inorganic Zn salt. Many of the early differences attributed to Zn source may have been due to fertilizer distribution (Sorensen et al., 1970).

Boawn (1973) did use comparable rates of Zn from $ZnSO_4$ and ZnEDTA in the field to evaluate fertilizer effectiveness. The Zn sources were powdered and coated onto concentrated superphosphate and K_2SO_4 granules. To overcome distribution problems both materials were screened to provide approximately equal numbers of granules for a given area. For ploweddown Zn, ZnEDTA was 1.5 to 2.5 times more effective than $ZnSO_4$ as measured by Zn uptake in the plant. For banded Zn, the ZnEDTA was 2.5 times as effective as $ZnSO_4$ according to Zn uptake. The minimum rate of Zn required, even with the chelated source, was between 1 and 2 kg Zn ha-1.

The use of fluid and suspension fertilizers grew steadily during the 1970's. Mortvedt and Giordano (1967) reported that ZnO included in fluid fertilizer was more effective than ZnO on granular fertilizer because of distribution. Giordano and Mortvedt (1972) cited the need for evaluation of Zn sources applied in fluid form to overcome the problems of uniform distribution of this nutrient. Rehm et al. (1980) compared corn grain yield and Zn uptake response to Zn suspended in liquid orthophosphate and polyphosphate. The type of P carrier had no effect on grain yield. They found significant differences among Zn sources for Zn uptake but no effect on grain yield.

Comparisons of Zn materials for grain crops based on economic considerations ultimately need to be conducted in the field to evaluate grain yield response. The research in this paper was an extension of the Rehm et al. work. It was designed to include two additional low Zn rates, an additional Zn source, and a wider range of Nebraska soils and climatic conditions. Differences in

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TABLE 1. Soil properties at the experimental sites for the 0 to 0.15-m depth.

Soil and Classification	Site	Year	pH	Organic Matter Content g kg^{1}	HCL-Zn[a]	DTPA Zn	Bray-P1[b]	K[c]
					mg kg-1			
Valentine ls, Typic Ustipsamments	I	1975	6.4	11	1.25	0.39	7	117
Thurman lfs, Udorthentic Haplustolls	II	1975	6.3	17	1.70	0.48	3	90
Valent ls, Ustic Torripsamments	III	1976	7.6	9	2.60	0.30	7	239
Thurman lfs, Udorthentic Haplustolls	IV	1976	5.4	11	2.50	0.75	40	204

[a]0.1 *M* HCL extract. [b]Bray and Kurtz no. 1 P. [c]1 *M* NH_4OAc extract.

Table 2. Effects of Zn rate and source on Zn uptake of corn.

		Sites							
		I		II		III		IV	
		Harvest		Harvest		Harvest		Harvest	
Zn Source	Zn Rate	1[a]	2	1	2	1	2	1	2
	kg ha^{-1}	μg plant^{1}							
ZnEDTA	0.11	16	89	106	328	13	226	217	1148
	0.33	24	163	100	303	17	273	321	986
	1.12	31	138	130	428	22	384	266	1030
	3.36	38	195	137	431	35	670	418	1367
Zn-NH_3 Complex NULEX	0.11	23	80	95	267	12	156	253	1179
	0.33	30	144	109	345	16	209	307	1223
	1.12	35	185	169	408	20	231	350	1176
	3.36	66	474	257	647	21	283	310	1186
ZnO	0.11	16	98	110	309	9	170	265	1084
	0.33	22	129	119	294	14	198	235	1148
	1.12	36	184	161	422	17	195	333	1486
	3.36	49	269	249	676	22	314	428	1336
$ZnSO_4$	0.11	16	115	104	279	12	166	238	877
	0.33	22	161	110	354	16	213	238	1017
	1.12	36	178	164	369	17	223	364	1089
	3.36	41	324	226	484	26	299	381	1188
$Zn(NO_3)_2$	0.11	-	-	-	-	12	179	282	1075
	0.33	-	-	-	-	12	211	305	1105
	1.12	-	-	-	-	17	210	280	1068
	3.36	-	-	-	-	23	327	433	1173
Check	0	14	73	72	272	9	120	208	1187
Analysis of variance effects:									
Zn Rate		**	**	**	**	**	**	**	NS
Zn Source		**	**	**	**	**	**	NS	NS
Rate x Source		NS	**	**	**	NS	**	*	NS
Error mean square		73.42	3125.5	382.6	4261	21.87	3954	4366	126584

* = Significant at 5% level, ** = 1%, NS = no significant difference.
[a] Harvests 1 and 2 were 3-4 and 6-7 weeks, respectively.

Zn source effectiveness as shown by Zn concentration and uptake are important but may not always be reflected as differences in grain yields. The objective of this research was to determine the effectiveness of different Zn sources mixed with ammonium polyphosphate (APP) suspensions and row-applied (banded) at planting on young plant zinc uptake and on grain yield.

METHODS AND MATERIALS

Two experimental sites in western Nebraska and two sites in northeastern Nebraska were selected for the study. Relevant soil properties are listed in Table 1. All sites were recently developed for irrigation and had no history of Zn fertilization. Sites were purposely selected for a wide range in pH.

The fluid fertilizer used was prepared from ammonium polyphosphate (10-15-0) and clay. The clay content (Na bentonite) of the suspension was 2.5% and the final analysis was 8-9-0. This material was applied to all treatments about 50 mm to the side of and below the seed at a rate of 224 kg ha-1. With this fixed rate, the various Zn sources [ZnEDTA, Zn-NH_3 complex[3], ZnO, $ZnSO_4$, and $Zn(NO_3)_2$][4] were mixed with the suspension at concentrations to supply 0, 0.11, 0.33, 1.12, and 3.36 kg Zn ha-1 By using this

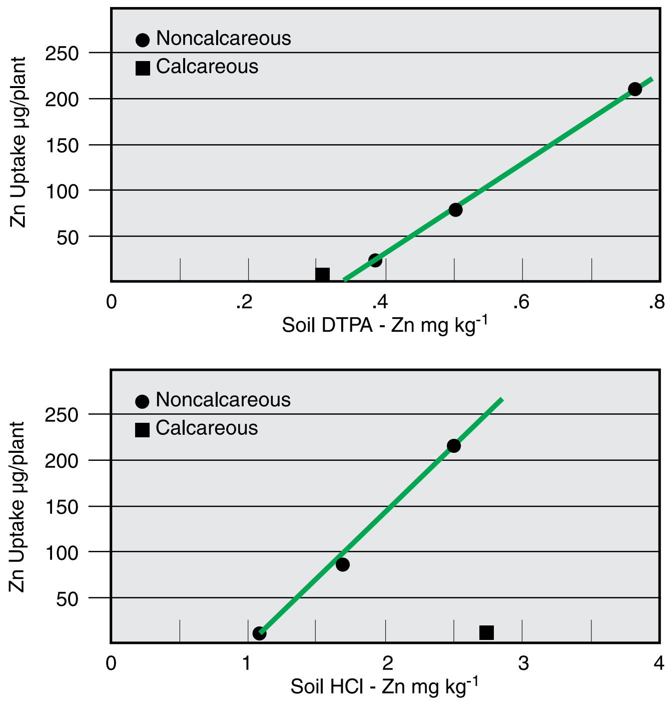

Figure 1. Relationship between zinc uptake in 3 to 4 week old plants in the unfertilized check plot and Zn soil test level.

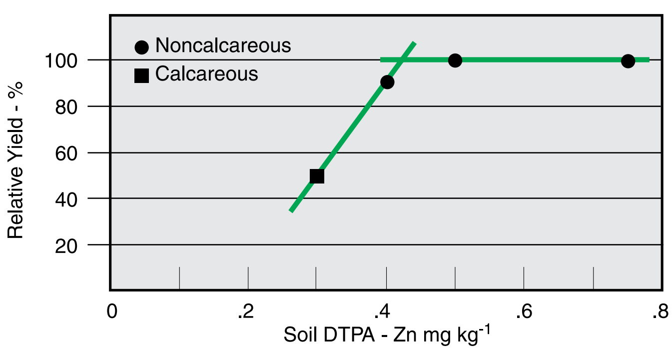

Figure 2. Relationship between DTPA soil test level and relative check grain yields in unferilitzed checks.

Table 3. Effects of Zn rate and source on grain yield of corn.

		1975		1976	
Zn Source	Zn Rate	Site I	Site II	Site III	Site IV
	kg ha^{-1}	Mg ha^{-1} x 10			
ZnEDTA	0.11	72.3	130.5	86.2	131.2
	0.33	73.2	125.0	87.4	138.0
	1.12	95.5	128.9	94.5	137.0
	3.36	72.8	131.9	88.3	138.0
$Zn\text{-}NH_3$ Complex NULEX	0.11	73.4	121.3	77.8	137.3
	0.33	80.3	128.8	86.3	130.4
	1.12	78.7	127.2	84.7	136.5
	3.36	82.3	131.3	88.1	136.7
ZnO	0.11	65.9	129.5	82.2	135.1
	0.33	72.6	132.6	81.6	136.9
	1.12	84.8	131.0	85.7	136.2
	3.36	83.1	132.2	90.5	136.7
$ZnSO_4$	0.11	61.8	130.8	82.7	135.5
	0.33	72.9	127.7	88.5	137.2
	1.12	78.7	128.5	86.5	140.7
	3.37	77.6	126.7	90.5	134.8
$Zn(NO_3)_2$	0.11	-	-	82.1	137.3
	0.33	-	-	82.4	135.3
	1.12	-	-	88.9	135.6
	3.36	-	-	88.3	139.4
Check	0	67.6	130.1	39.1	133.6
Analysis of variance effects:					
Zn Rate		**	NS	a	NS
Zn Source		NS	NS	NS	NS
Rate x source		NS	NS	NS	NS
Error mean square		115.8	34.9	94.5	23.3

* = Significant at 5% level, ** = 1%, NS = no significant differences.
[a] Significant at 11% level.

procedure for formulating the fertilizers used, the rate of N and P in the row was held constant while the amount of Zn applied could be varied.

A randomized complete block design was used at all locations with four replications of each treatment. Sufficient N, P, K, and S were applied to all treatments to provide for maximum yield. The P, K, and S were broadcast and incorporated before planting. The N was supplied by a combination of preplant anhydrous ammonia (82-0-0) and urea ammonium nitrate solution (28-0-0) with the irrigation water.

Plot size was 3 by 18.3 m (4 rows). Final plant population ranged from 58 000 to 62 000 plants ha-1. Whole plant samples were collected 3 to 4 weeks and 6 to 7 weeks after emergence. Sample size was 6 to 8 plants per plot. Samples were dried, weighed, ground to pass through a l-mm screen and analyzed for Zn by dry ashing and atomic absorption spectroscopy. Grain yield was determined from a harvest area of 1.5 by 7.6 m (2 rows) and is expressed on a 15.5% moisture basis.

RESULTS AND DISCUSSION

Zinc Uptake

Zinc rate significantly increased Zn uptake at all locations (Table 2). Zinc uptake data integrate treatment effects on dry matter production and Zn concentration. Dry matter yields at sites II and IV were not increased by Zn rate but Zn concentration was (data not shown). There were no differences shown on dry matter production at sites II and IV among Zn sources but sources differed in their effects on Zinc concentration which is reflected in Zn uptake (Table 2).

Zinc source differences were shown at sites I, II, and III (Table 2). At site I the Zn-NH3 complex was superior to other sources at both sampling dates. The $Zn\text{-}NH_3$ complex and ZnO produced significantly higher Zn uptake than other sources at site II, especially at the highest zinc rates. At the calcareous site (III) uptake of Zn from ZnEDTA was superior to all other sources at both dry matter harvests. The zinc rate by source interaction at sites I and II generally resulted from lower Zn uptake from ZnEDTA vs. other sources, especially at the two higher Zn rates. The interaction at site 111 was primarily due to much higher uptake of Zn from ZnEDTA vs. other sources.

The effectiveness of chelated materials on calcareous soils is well documented by increased Zn uptake and agrees with the better performance of ZnEDTA at site III. ZnEDTA at sites I and II was inferior because of its high mobility and it is speculated that part of the ZnEDTA may have been leached. At site I, June and July precipitation was 95 mm above the normal of 64 mm. At site II, June precipitation was 60 mm above the normal 109 mm. The mobility of ZnEDTA in sandy soils has been shown to be high (Sorensen et al., 1970). The superior performance of the Zn-NH_3 at site I and II and ZnO at site II is unexplainable. There were no significant differences among Zn sources at site IV.

A comparison of the 0.1*M* HCl and DTPA tests can be made from this data. Zinc uptake from check plots at the first dry matter sampling and soil test levels shows a good relationship for the noncalcareous soils of sites I, II, and IV for either test (Fig.1). The 0.1M HC1 test performs poorly, as expected, for the calcareous soil. The DTPA test, while not perfect, is in the proper order of plant available Zn.

Based on Zn uptake, the availability of Zn differed among sources. This information is correct for interpretations regarding source effectiveness on producing differences in nutrient uptake. It does not necessarily apply to grain yield.

Grain Yield

Neither source nor rate of applied Zn had a significant effect on grain yield at sites II and IV (Table 3). Even though all soils tested low in available Zn according to Lindsay and Norvell (1978), the crop was able to take up sufficient Zn at these two sites for maximum grain production. The high yields recorded also indicate that other management or environmental factors were not limiting.

A plot of the DTPA soil test levels and check grain yield as a percentage of maximum yield shows that the critical soil test level in these field experiments may be somewhat different than those established in the greenhouse by Lindsay and Norvell (Fig. 2). For these data the critical level appears to be nearer 0.4 mg kg-1 Zn than 0.8 mg kg-1 Zn.

Response to Zn occurred at sites I and III although differences among Zn rates at site III (excluding the check) were significant at only the 11% level (Table 3). Even though sources produced significant effects on Zn uptake at these two locations (Table 2), these differences were not reflected in corn grain yield. Because the Zn rate by Zn source interaction term was not significant, yield response can simply be related to Zn rate. The regression equations for yield are:

	Equation	R^2
Site I	$\hat{Y} = 61.1 - 10.5X + 29.1\ (X)^{1/2}$	0.99
Site III	$\hat{Y} = 78.1 - 4.7X + 14.6\ (X)^{1/2}$	0.99

where X is Zn rate in kg ha-1 and Y is Mg ha-1 X 10 grain. The site III equation was calculated excluding the check. The check yield was extremely low due to extreme Zn deficiency enhanced by P-Zn interaction on this low P and Zn soil (Ganiron et al., 1969).

CONCLUSIONS

Many sources of zinc are available to correct zinc deficiency in soils. The increased emphasis on row-application of fluid fertilizers and large differences in cost of various zinc sources stresses the need for source comparison and effectiveness. The data collected from this research supports the following conclusions:

1) Zinc uptake in whole plants differed with Zn sources. Uptake of Zn with ZnEDTA applications was superior to other sources on the calcareous soil but performed poorly when early season leaching was high at two of the sites. Higher mobility of ZnEDTA was the likely cause for differences. The Zn-NH_3 complex performed better than other sources at site I for unexplained reasons. At site II, ZnO and Zn-NH_3 were superior, again for unexplained reasons.

2) On the slightly acid soils (sites I, II, and IV) both the 0.1M HCL and DTPA soil tests for Zn showed good relationships with Zn uptake. The DTPA test performed satisfactorily on the calcareous soil but the 0.1M HCl did not.

3) The critical DTPA soil test level for these sites was near 0.4 mg kg-1 Zn.

4) Grain yield from sites I and III did not support the conclusion drawn from Zn uptake that row applied sources of Zn in APP suspension were significantly different. Sources differed in their effects on Zn concentration and Zn uptake but not on grain yield.

5) Regression equations showed that 1 to 2 kg Zn ha-1 were required to maximize yield, regardless of source. These results are consistent with other reported research (Boawn, 1973; Rehm et al., 1980).

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[3]Trade name Nulex Liquid Zinc of Nutra-Flo Company, Sioux City, Iowa. Mention of the trade name or commercial company is for reader information and does not imply endorsement by the University of Nebraska.

[4]Trade name NZn of Allied Chemical Company is zinc nitrate dissolved in urea ammonium nitrate.