Table 1. Significant correlations between soil values and whole plant content of Ca, Mg, K, Sr, Cu, Zn, Fe, and Mn at 7 sampling dates for barley grown on Waukegan and Webster soils, 1966. Sampling interval was 7-10 days, with the 1st sampling at seeding and the 7th at harvest. Order of sampling is shown from left to right.

Plant \ Soil	Ca	Mg	K	Sr	Cu	Zn	P	Fe	Mn
K	° .75 -.62 .52 -.62 -.81 °	° ° -.77 ° -.56 -.67 °	° .72 ° ° ° ° °	° ° ° -.66 ° °	° .68 ° ° ° ° °	° .59 .80 ° ° ° .66	° -.52 .67 ° ° .50 .89	° .57 ° ° -.51 ° °	° .74° .48 ° ° .67
Ca	° ° ° ° ° ° °	° ° ° ° ° ° °	-.81 ° -.78 ° ° ° °	° ° ° ° ° ° °	° ° ° ° ° ° °	° .54 ° ° ° ° °	° ° .60 ° ° ° .89	° ° -.73 ° ° ° °	-.83 ° ° ° ° ° °
Sr	° ° ° ° ° ° °	° ° ° ° ° ° °	-.79 -.52 -.84 ° -.69 -.73 °	° ° ° ° ° ° °	° ° ° ° °-.54 °	° ° ° ° ° ° °	° ° .61 ° .50 ° °	° -.49 -.79 ° ° ° -.69	-.82 -.49° ° ° ° °
Mg	° ° -.79 °-.60 ° °	° ° -.92 ° -.63 ° -.75	-.79 ° -.63 ° ° ° °	° ° ° °-.53 ° °	° °-.58 ° ° ° °	° .52 .60 ° ° ° °	° ° .87 ° ° ° .97	° ° -.69 ° ° ° °	-.84 ° ° ° ° ° .88
Cu	° ° -.64 °-.62 ° °	° ° -.72 ° ° ° °	° ° ° ° ° ° .70	° ° ° ° ° ° °	° ° ° ° ° ° °	° ° .74 ° ° ° .92	° ° .59 ° ° ° °	° ° ° ° ° ° -.70	° .60° ° ° ° °
P	° ° -.64 °-.51 -.48 °	° ° -.78 ° -.58 -.62 -.81	.74 ° ° ° ° ° °	° °-.49 °-.53 ° °	° ° ° °-.53 ° °	° ° .72 ° ° ° °	° ° .64 ° .48 .53 .91	.73 ° ° ° ° ° °	.85 ° ° ° ° ° .93
Fe	-.73 .61 ° ° ° ° °	° ° -.56 ° ° ° -.81	° .54 ° ° ° °	° ° ° ° ° .60 °	° .60 ° ° ° ° °	° .65 .77 ° ° -.61 °	° ° ° ° ° ° .87	.76 ° ° ° ° ° °	° .56° ° ° ° .97
Zn	° .49 -.60 °-.60 -.48 °	-.68 ° -.71 ° -.56 -.54 -.80	° .55 ° ° ° ° °	° ° ° °-.54 ° °	° ° ° °-.54 ° °	° ° .72 ° ° ° °	° ° .55 ° ° ° .92	.93 .48 ° ° ° ° °	° .70° ° ° ° .94
Mn	° ° -.75 °-.56 -.65 °	° ° -.91 ° -.66 -.78 -.79	.78 ° -.61 ° ° ° °	° ° ° °-.48 ° °	° ° -.54 ° ° ° °	° ° ° -.82° -.64 °	° -.84 -.84 -.83 -.81 -.79 °	-.73 .76 .81 .83 ° ° °	° .79° ° ° ° °

°no significance

uptake, of most of the elements studied.

Of the 9 elements studied soil values for "available" Mg and P were found to be more often correlated with whole plant content of the 9 elements; however, soil values for Mg were not correlated, on any sampling date, with Ca or Sr in the plant.

In order of decreasing number of significant correlations for soil values were: Mg = P > Ca > K > Fe = Mn > Zn > Cu > Sr. This order is in reasonable agreement with the amount of these elements found in the barley plant. Sr is not considered to be an essential element. Any correlation between soil Sr and plant content of the 9 elements studied would probably derive from complementary ion relationships, or the possible substitution of Sr for Ca or Mg. The content of Mn in the whole barley plant was particularly correlated with soil Mg and P. The significant correlations were all negative, that is, high soil values for Mg and P were associated with low plant Mn.

With respect to the various plant parts sampled, stem, selected leaves, grain, and whole plant, the most significant correlations were with whole plant content; next, with stem.

B. Relationships and variability between extractable soil ions.

1. A study of the relationships between the soil extractable ions of Ca, Mg, Sr, K, P, Cu, Fe, Zn and Mn as measured at 7-10 day sampling intervals was made on the 1966 barley variability plots on the Waukegan and Webster soils.

Table 2. Significant correlations between soil values for nine elements by sampling intervals, Waukegan and Webster series, 1966. Barley plots.

Soil \ Soil	Ca			Mg			K			Sr			Cu			Zn			P			Fe		
Mg	.89	.84	.86																					
	.71	.77	.85																					
	.69																							
K	°	.91	.73	°	.86	.78																		
	.71	.59	.77	.89	.72	.82																		
	°			°																				
Sr	.74	°	°	.51	°	°	°	°	°															
	°	.54	°	°	.48	°	°	°	°															
	.70			°			°																	
Cu	.67	.77	.68	.84	.66	.62	-.60	.83	.52	°	°	°												
	.75	°	°	.60	.58	°	.78	.86	°	°	°	°												
	°			°			°			°														
Zn	-.58	°	°	-.77	°	-.54	.61	°	°	°	°	°	-.88	.52	°									
	-.61	°	-.49	-.75	°	-.61	-.90	-.55	-.80	°	°	°	-.78	-.52	°									
	°			°			°			°			°											
P	-.65	-.78	-.70	-.87	-.83	-.83	.64	-.83	-.86	°	°	°	-.92	-.85	-.55	.86	°	°						
	-.59	°	-.59	-.83	-.71	-.83	-.88	-.81	-.76	°	°	°	-.65	-.79	°	.68	°	.62						
	°			°			°			°			°			°								
Fe	.75	.72	.74	.89	.78	.62	-.51	.84	.96	°	°	°	.97	.92	.60	-.87	°	°	-.91	-.85	-.90			
	.68	°	°	.81	°	°	.94	°	.62	°	°	°	.87	°	.63	-.92	°	-.60	-.76	°	-.50			
	°			°			°			°			°			-.59			°					
Mn	.90	.85	°	.79	.70	°	°	.79	°	.70	°	°	.64	.55	°	-.51	°	°	-.50	-.56	°	.72	.57	°
	.87	.55	°	.57	°	°	.59	°	°	°	°	°	.63	°	°	-.59	°	°	°	°	°	.56	°	°
	°			-.73			°			°			°			.48			.86			°		

° Non-significant correlation

Correlations made between the soil extraction values for nine elements as determined by N NH_4Ac or 0.1 N HCl, Table 2.

The number of significant correlations between elements was in the order, Mg > Ca > P > K > Cu > Zn = Fe > Mn > Sr. By far the least number was with Sr, suggesting that soil Sr would be poorly predicted by other elements, save possibly by Ca.

Zn and P, for the most part, were negatively correlated with the other elements (except positively with each other). Ca and Mg were positively correlated at all sampling intervals.

In many instances, last sampling date correlations are lower than initial sampling equivalent (true for 25 out of 36 pairings). This may be a reflection on the extraction procedures, e.g., initially the extraction would be expected to draw first, leaving other less-readily available forms, which the N NH_4Ac or the 0.1 N HCl extraction removes with varying efficiencies for each ion.

2. Study of soil variability between initial and final sampling on 1967 soil sampling on Waukegan soil.

In 1967 initial samplings were made on the Waukegan soil at about seeding time and final samplings at plant harvesting. Samples were taken from the barley, wheat, and soybean screening areas at a sampling intensity of about 1 sample per 50 ft^2.

The results are given in Tables 3, 4, and 5.

Table 3. Measures of extractable ions and pH, and summary of significance tests for soil samples taken from barley screening area, 0-6 inches, 1967.
N = 144

	Sampling Time	
	Initial (Seeding)	Final (Harvest)
Ca	2468	2575**
Mg	498	513*
K	242*	216
Sr	12	12
Cu	1.6**	1.4
Zn	4.0	4.4**
P	49*	46
Fe	21	23*
Mn	12**	4
pH	6.3**	6.0

Values in ppm except pH.
**.01 significance level
*.05 significance level

Table 4. Measures of extractable ions and pH and summary of significance tests for soil samples taken from wheat screening areas, 0-6 inches, 1967.
N = 96

	Sampling Time	
	Initial (Seeding)	Final (Harvest)
Ca	2484	2516
Mg	503	487
K	214	204
Sr	12	14*
Cu	1.3	1.4*
Zn	4.7	4.7
P	48	47
Fe	24	24
Mn	11**	4
pH	6.3*	6.2

Values in ppm except pH.
**.01 significance level.
*.05 significance level.

Table 5. Measures of extractable ions and pH and summary of significance tests for soil samples taken from soybean screening area, 0-6 inches, 1967. N = 160

	Sampling Time	
	Initial (Seeding)	Final (Harvest)
Ca	2585	2721**
Mg	413	446**
K	125	130
Sr	12	15**
Cu	1.4**	1.2
Zn	3.8	3.8
P	28**	21
Fe	33**	27
Mn	9.8**	3.1
pH	6.5	6.5

Values in ppm except pH.
** .01 significance level.

Measured values of soil Ca, Mg, and Sr are almost always significantly higher at final sampling time. In general, values for Cu, P, Mn and pH are significantly higher at initial sampling. Most striking is the change in Mn. Values at final sampling are about half the initial values.

THE 1970 YIELDS OF TWELVE FIELDS OF SMALL GRAINS IN THE RED RIVER VALLEY BASIN FOLLOWING FERTILIZATION WITH MAJOR, SECONDARY AND MICRONUTRIENT ELEMENTS

John M. MacGregor[1]

For several years there has been an increasing interest in possible increases in small grain yields if fertilized with additional potash (K), sulfur (S), zinc (Zn), manganese (Mn), boron (B), copper (Cu), or a combination of all these elements on some soils of the Red River Valley Basin. Early in 1970, interested county agricultural agents in seven counties located 14 farmer-cooperators in their respective counties and a total of 7 experiments on oats, 2 on barley and 5 on wheat were initiated, extending from Wilkin County in the south to Kittson County in the north. Two fields of oats were not harvested due to excessive soil moisture and to other causes.

A randomized block design with 5 replications of the following 9 treatments was used on each field. Each of the 45 plots was 10' x 15', the total experimental area in each field being 75' x 90' (6750 sq. ft. or 0.15 acre). The following treatments were broadcast and worked in before seeding.

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[1]This investigation was made possible only with the cooperation of many others including the respective farm operators, the county agricultural agents, the area soil specialists, personnel at the Northwest Experiment Station and several members of the Department of Soil Science at St. Paul.

		Nutrients/A		
		N	P_2O_5	K_2O
1.	Check	None (farmers' starter fertilizer only)		
2.	$N_1P_1K_1$	40 +	40 +	40
3.	$N_1P_1K_5$	40 +	40 +	200
4.	$N_1P_1K_1$ + Zn	40 +	40 +	40 + 10 #/A zinc
5.	$N_1P_1K_1$ + Mn	40 +	40 +	40 + 10 #/A manganese
6.	$N_1P_1K_1$ + B	40 +	40 +	40 + 2 #/A boron
7.	$N_1P_1K_1$ + Cu	40 +	40 +	40 + 10 #/A copper
8.	$N_1P_1K_1$ + S	40 +	40 +	40 + 20 #/A sulfur
9.	$N_1P_1K_1$ + Zn, Mn, B, Cu, S	40 +	40 +	40 + all above elements

All treatments were broadcast before seeding the small grains and disked in, the farmer seeded over the fertilized areas using the starter fertilizer of his choice. The N_1 P_1 K_1 and the N_1 P_1 K_5 represented the total N, P_2O_5, and K_2O applied rate per acre, including that applied by the farm operator in his starter application. In short, the 40 + 40 + 40 or the 40 + 40 + 200 was the total N, P_2O_5 + K_2O applied to each soil in 1970. The sulfur and micronutrient plots (and the total) all received the 40 + 40 + 40 basic treatment as well.

Excessive rains fell during the planting season particularly to the north of U. S. Highway 10 and continued until mid-June. Many farm fields were too wet to plant, or were planted much later than normal. The latter part of the growing season was very dry, and small grain yields were adversely affected. The following table shows the different locations, cooperating farm operator, soil analyses and 1970 small grain yields

obtained with the different fertility treatments.

It is evident that there was no significant yield increase from applications of additional potash (40+40+200), or from the zinc, manganese, boron, copper, or sulfur, either alone or when all were applied as a combination treatment. The only significant yield response was on a barley field in Wilkin County, and this resulted from the basic 40+40+40 treatment. In all probability the first two nutrients (N & P) were mainly responsible for this lone response and this effect was evident during much of the growing season. This was not true in the 11 other locations.

Conclusions

The results obtained by fertilizing small grains in the unfavorable weather during the growing season of 1970 should not be considered as conclusive, but they suggest that the inclusion of such elements in fertilizers for small grains should probably not be emphasized at this time. These experiments will be repeated in 1971 and again in 1972 to further establish the value of these elements in present small grain production in northwestern Minnesota.

1970 Soil Analysis and Small Grain Yields on Fertilized Plots in Northwestern Minnesota

County	Farm Operator	Soil Analyses: Texture	pH	OM	P (lbs/A)	K (lbs/A)	Zn (ppm)	S (ppm)	Cond. mmhos/cm	1970 broadcast soil treatments (lbs/A): Checks	40+40+40	40+40+200	40+40+40 + 10 Zn	40+40+40 + 10 Mn	40+40+40 + 2 B	40+40+40 +10 Cu	40+40+40 + 20 S	40+40+40 + S + Micro +	
										Grain yields in bushels per acre									
Oats																			
Wilkin	R. Bellmore	C.L.	7.0	H	26	600+	1.9	1	0.4	65.8	56.3	57.1	55.8	60.6	58.5	66.2	65.2	63.7	N.S.
Clay	D. Atherton	Si.CL	7.0	M	95	600+	2.4	12	0.8	67.1	61.5	66.0	64.0	63.4	66.5	66.1	62.8	65.1	N.S.
Becker	J. Matter	Si.CL	8.0	H	35	510	1.6	8	0.6	72.3	74.1	67.3	80.4	73.0	74.3	78.2	69.6	73.0	N.S.
Becker	D. Anderson	S.L.	6.6	M	17	110	3.1	4	0.5	34.0	35.6	37.7	34.1	35.1	35.8	34.8	34.7	39.1	N.S.
Pennington	D. Knutson	L.S.	8.0	H	5	50	0.5	6	0.6	49.2	59.2	64.4	66.3	68.2	61.3	65.3	60.5	64.7	N.S.
Barley																			
Wilkin	W. Fredericks	C.L.	8.2	H	20	370	2.2	39	0.8	44.0a	66.8	70.0b	62.4b	60.8	59.4b	61.7b	62.2b	60.8b	Sig.
Clay	L. Anderson	Si.CL	8.1	H	17	430	1.3	1	0.5	41.9	45.5	46.4	53.3	51.0	50.7	46.4	52.6	52.8	N.S.
Wheat																			
Wilkin	R. Hoveland	C.L.	7.8	H	8	420	1.5	9	0.4	48.1	49.1	46.4	50.5	49.8	49.0	48.9	47.2	50.4	N.S.
Clay	D. Sellers	Si.CL	8.0	H	7	370	1.0	40+	1.7	30.5	31.8	32.2	31.2	28.1	30.2	30.8	31.8	32.0	N.S.
Polk	G. Meyer	Si.L	8.0	M	43	520	2.6	9	0.8	14.4	13.5	14.8	16.6	14.8	16.3	12.0	15.2	16.0	N.S.
Polk	N.W. Station	Si.L	8.3	H	18	310	2.7	9	1.1	36.6	39.4	41.6	41.9	40.2	41.6	41.2	45.0	40.0	N.S.
Kittson	O. Langen	Si.CL	7.2	M	81	600+	1.2	6	1.6	48.7	53.1	50.3	45.9	51.2	48.4	53.4	48.3	40.9	N.S.

*N.S. - not significant

Effect of Micronutrients on Soybean Seed Yields

G. E. Ham and R. D. Frazier

Micronutrients were applied to Chippewa 64 soybeans grown at Waseca. The soil treatment consisted of 10 pounds per acre sulfate source (elemental basis) and 3 pounds per acre chelate and silviplex sources broadcast and disced-in before planting. Foliar treatments consisted of 3 pounds per acre sulfate source and 0.6 pounds per acre chelate and silviplex sources applied as a foliar spray when the plants were beginning to flower.

No significant yield increases were obtained from the various treatments (Table 1). The leaf Cu and Zn levels were increased significantly by foliar applications of sulfate and silviplex sources (Table 2). In addition the sulfate source of Zn applied as a soil treatment significantly increased the Zn level of the leaf. Mn silviplex increased the Mn content of the leaf significantly.

Table 1. Effect on soybean seed yield when different micronutrients were applied to Chippewa 64 soybeans grown at Waseca, Minnesota in 1970.

Treatment	Foliar bu/acre	Soil bu/acre
Check	---------32.3----------	
Fe-chelate	30.2	32.0
Fe-silviplex	28.1	
Fe-sulfate	32.0	31.8
Mn-chelate	31.4	30.6
Mn-silviplex	28.9	
Mn-sulfate	30.5	30.0
Cu-chelate	32.0	32.1
Cu-silviplex	29.8	
Cu-sulfate	30.1	35.8
Zn-cheltate	32.5	32.4
Zn-silviplex	29.9	
Zn-sulfate	28.5	30.2

Table 2

Influence of micronutrients added as soil and foliar treatments to Chippewa 64 soybeans grown at Waseca, Minnesota during 1970

Element applied	Nutrient content of last fully matured trifoliate										
	% P	% K	% Ca	ppm Sr	ppm Fe	% Mg	ppm Zn	ppm Cu	ppm Mo	ppm Mn	ppm B
Check	.372	1.50	1.44	28.9	105	.525	50.5	9.4	6.0	49.9	58.6
Fe chelate-soil	.370	1.50	1.33	26.7	104	.517	49.2	10.5	7.6	48.6	59.3
Fe sulfate-soil	.387	1.52	1.41	29.9	105	.523	52.3	11.5	6.3	55.8	59.3
Fe chelate-foliar	.375	1.45	1.48	32.2	119	.538	51.4	6.0	6.6	45.2	59.2
Fe sulfate-foliar	.381	1.41	1.49	30.0	135	.544	49.9	7.7	8.4	57.5	58.4
Fe silviplex-foliar	.361	1.38	1.45	31.7	130	.569	51.6	9.1	7.1	47.7	58.8
Mn chelate-soil	.367	1.50	1.53	32.2	115	.572	46.4	7.9	8.2	43.8	59.4
Mn sulfate-soil	.366	1.44	1.45	31.4	120	.567	50.5	8.0	7.0	49.8	58.5
Mn chelate-foliar	.368	1.46	1.53	34.3	116	.560	51.8	9.9	7.5	51.9	56.9
Mn sulfate-foliar	.366	1.48	1.53	34.0	102	.554	49.5	10.1	6.3	63.9	57.1
Mn silviplex-foliar	.387	1.47	1.46	31.3	116	.518	49.8	9.4	7.2	78.2**	60.5
Cu chelate-soil	.368	1.52	1.48	29.7	113	.550	49.6	8.2	6.1	42.8	58.2
Cu sulfate-soil	.383	1.64	1.47	31.1	113	.524	49.7	8.9	6.3	56.9	56.8
Cu chelate-foliar	.347	1.46	1.51	33.5	119	.542	46.2	10.8	7.6	51.5	54.8
Cu sulfate-foliar	.375	1.50	1.51	32.8	112	.550	51.7	19.3**	7.9	55.0	59.5
Cu silviplex-foliar	.351	1.37	1.52	33.2	111	.587	51.1	20.3**	7.8	61.0	59.7
Zn chelate-soil	.362	1.54	1.49	32.1	117	.536	46.1	8.4	6.8	46.7	57.8
Zn sulfate-soil	.346	1.41	1.43	31.1	115	.533	63.7**	12.1	4.9	51.8	60.9
Zn chelate-foliar	.395	1.51	1.60	36.4	110	.558	51.3	6.4	6.9	52.1	55.6
Zn sulfate-foliar	.367	1.46	1.37	28.2	103	.514	64.9**	8.8	7.1	48.2	56.7
Zn silviplex-foliar	.380	1.55	1.46	30.9	101	.522	69.9**	7.6	6.4	50.8	57.0
CV (%)	9.7	12.2	8.4	16.2	89.2	11.0	9.9	42.8	30.5	21.9	6.4

** Significantly greater than the check at the .01 level

EFFECT OF RESIDUAL POTASSIUM FERTILIZER SOURCES AND RATES ON SOYBEAN YIELD

G. E. Ham

The plots were located on the University of Minnesota Sand Plain Experimental Field near Elk River on a Hubbard loamy coarse sand soil with 0-2% slope. Fertilizer and lime treatments were applied in the spring of 1968 and plowed down. The soil test values for P and K were very high and medium, respectively before treatments were applied. The treatments applied are shown in Table 1. No further treatments were appplied since 1968. Soybean seed yields were increased significantly in many cases in 1970 as shown in Table 1. At the 200 pounds K_2O per acre rate, KNO_3 produced a significantly greater seed yield than $KCl + NH_4NO_3$ with the same rates of K and N. The KNO_3 treatment increased the yield significantly at all rates.

Table 1. Effect on 1970 soybean seed yield at Elk River, Minnesota when different rates and sources of potassium fertilizer were applied in spring of 1968.

Potassium sources	Pounds K_2O/acre				
	100	200	400	800	1600
K_2HPO_4	37.8	38.6	39.4	39.9	--
K_2SO_4	37.7	38.4	41.7*	40.0	--
K_2CO_3	39.0	43.7*	36.6	42.5*	--
$K_2SO_4 \cdot MgSO_4$	37.7	39.8	39.7	37.6	--
KNO_3	42.5*	41.9*	40.7*	40.7*	--
KCl	40.3	42.1*	38.7	38.1	42.8*
KCl + P		37.7			
KCl + N		37.5			
KCl + S		39.1			
KCl + S + Mg		37.1			
Check	37.3				

*Significantly greater than check yield at .05 level

Soybean Chlorosis Studies

G.E. Ham, W.W. Nelson, S.D. Evans, G.O. Holcomb and O.M. Gunderson

Nitrogen and sulfur at the rate of 125 and 250 pounds per acre were applied to two sites at Morris and one site at Lamberton which had prevously grown chlorotic soybeans. In addition, various seed treatments were grown at these locations. Treatments, soybean varieties and seed yields are shown in Tables 1 - 4. None of the treatments consistently reduced the presence of chlorosis, increased seed yield or influenced nutrient composition of leaf samples. At Lamberton seed yields of Chippewa 64 was increased by nitrogen and sulfur. Chippewa 64 showed little or no chlorosis. The seed yield of Anoka and Hark which are very susceptible to chlorosis was not increased by nitrogen or sulfur. At Morris, the results were similar.

Table 1. Effect of seed treatments on Traverse soybeans at Morris in 1970

Treatment	Seed yield Site 1 bu/acre	Seed yield Site 2 bu/acre
Check	23.5	28.8
$FeSO_4$	24.0	26.8
$CuSO_4$	24.7	28.8
$ZnSO_4$	22.9	26.8
$MnSO_4$	23.6	22.5
$K_2Cr_2O_7$	24.6	25.0
$CoCl_2 .6H_2O$	22.4	26.3
MoO_3	22.9	19.6
Serine	24.1	26.8
Quercetin	24.6	27.5
B-naphthoxy acetic acid	21.4	----
Colchicine	23.5	22.9
Thiouracil	24.0	25.3
D-leucine	24.2	25.0
Kinetin	23.7	28.5
Gibberellic acid	25.1	27.7
N-6 benzyl adenine	23.6	25.5

Table 2. Effect of nitrogen and sulfur fertilizer treatments on soybean seed yields at Morris in 1970.

Site 1: Bruer Farm

Fertilizer treatment lbs/acre	Chippewa 64 bu/acre	Anoka bu/acre	Traverse bu/acre
Check	20.1	22.3	21.6
125 lbs N	23.4	23.7	23.4
250 lbs N	21.2	21.6	21.3
125 lbs S	21.7	24.2	22.8
250 lbs S	23.8	21.8	24.4

Site 2: Hoslin Farm

Check	16.4	----	21.0
125 lbs N	17.1	----	19.9
250 lbs N	18.2	----	22.8
125 lbs S	18.1	----	23.5
250 lbs S	16.2	----	26.5

Table 3. Effect of seed treatments on Hark soybean seed yield at Lamberton

Treatment	Seed yield bu/acre
Check	30.5
$FeSO_4$	27.0
$CuSO_4$	33.9
$ZnSO_4$	26.3
$MnSO_4$	29.6
$K_2Cr_2O_7$	35.8
$C_0Cl_2 \cdot 6H_2O$	30.7
MaO3	26.7
Serine	25.0
Quercetin	29.4
B-naphthoxy acetic acid	32.2
Colchicine	32.6
Thiouracil	28.8
D-leucine	23.4
Kinetin	35.3
Gibberellic acid	23.3
N-6 benzyl adenine	28.7

Table 4. Effect of nitrogen and sulfur fertilizer treatments on soybean seed yields at Lamberton, Minnesota in 1970

Fertilizer Treatment lbs/acre	Soybean variety		
	Chippewa 64	Anoka	Hark
Check	32.8	18.5	16.0
125 N	35.4	18.0	17.9
250 N	34.2	19.5	17.8
125 S	36.2	19.4	16.3
250 S	32.7	18.2	16.4

SOYBEAN FERTILIZER PLACEMENT STUDY

G. E. Ham, R. D. Frazier, S. D. Evans and W. W. Nelson

Different fertilizer rates and placements were studied in a factorial experiment. Main plots were broadcast P and K which were split into three nitrogen rates. Each nitrogen rate was divided into row fertilizer placements (check, seed placement, 2 x 2 band and a combination of band and seed placement). Treatments, fertilizer rates, soybean variety and yields are shown in Tables 1, 2 and 3. The response to nitrogen was not significant at any location. The largest yield responses at Lamberton and Morris associated with P increases in the plant. The largest response was obtained from broadcast fertilizer applications. Starter or row fertilizer had less effects on seed yield either with or without broadcast fertilizer even though both starter and row fertilizer were significant.

Table 1. Effect on soybean seed yield when different fertilizer placements were applied to Corsoy soybeans grown at Lamberton, Minnesota in 1970.

Starter fertilizer	Nitrogen Fertilizer Applied					
	0		50 lbs/acre		100 lbs/acre	
	No Bdcst bu/acre	Bdcst bu/acre	No Bdcst bu/acre	Bdcst bu/acre	No Bdcst bu/acre	Bdcst bu/acre
Check	30.0	35.0	29.7	35.0	30.7	36.9
Seed placement	32.1	35.8	35.7	35.9	31.8	37.8
Band	32.7	36.8	32.5	36.3	32.6	35.3
Seed placement + Band	32.6	32.5	34.4	35.8	33.6	35.1

Fertilizer rates:	Band	15 + 20 + 18
	Seed placement	5 + 7 + 6
	Broadcast	0 + 60 + 30

Soil test values: pH 5.7

P 10 lbs/acre (low)

K 290 lbs/acre (high)

Table 2. Effect on soybean seed yield when different fertilizer placements were applied to Corsoy soybeans grown at Waseca, Minnesota in 1970.

Starter fertilizer	Nitrogen Fertilizer Applied					
	0		50		100	
	No Bdcst bu/acre	Bdcst bu/acre	No Bdcst bu/acre	Bdcst bu/acre	No Bdcst bu/acre	Bdcst bu/acre
Check	52.8	53.0	56.5	52.5	55.3	54.1
Seed placement	59.0	52.3	54.3	47.1	51.3	43.5
Band	57.6	54.8	56.5	51.7	51.3	49.7
Seed placement + Band	56.7	54.8	56.1	43.6	47.3	46.9

Fertilizer rates: Band 14 + 35 + 45

Seed placement 4 + 10 + 14

Broadcast 0 + 100 + 150

Soil test values: pH 6.8

P 40 lbs/acre (very high)

K 265 lbs/acre (high)

Table 3. Effect on soybean seed yield when different fertilizer placements were applied to Clay soybeans grown at Morris, Minnesota in 1970.

Starter fertilizer	Nitrogen Fertilizer Applied					
	0		50		100	
	No Bdcst bu/acre	Bdcst bu/acre	No Bdcst bu/acre	Bdcst bu/acre	No Bdcst bu/acre	Bdcst bu/acre
Check	23.7	31.3	24.4	31.5	27.5	32.0
Seed placement	25.7	28.9	33.4	32.7	32.6	30.9
Band	26.4	30.0	31.0	32.0	33.8	32.6
Band + Zn	27.4	31.8	29.4	30.8	31.8	33.1

Fertilizer rates:	Band	10 + 20 + 10
	Seed placement	4 + 8 + 4
	Broadcast	0 + 60 + 30
	Zn ($ZnSO_4$)	10
Soil test values:	pH 7.7	
	P 7 lbs/acre (low)	
	K 3000 lbs/acre (high)	

SOYBEAN NITROGEN FERTILIZER STUDIES

G. E. Ham, W. W. Nelson, R. D. Frazier and S. D. Evans

Ammonium nitrate at the rate of 0, 5, 10 and 15 pounds N per acre was applied to soybeans grown at Lamberton, Morris and Waseca. Soybean varieties and seed yields are shown in Table 1. Nitrogen fertilizer did not increase or decrease seed yield significantly. At Morris yields were generally decreased by nitrogen fertilizer due to the extremely dry weather during the growing season. At Waseca yields were increased by the fertilizer though the increases were not significant. At Lamberton yields were decreased by the 10 and 15 pound rates. At Waseca, nodulation was increased by the 5 and 10 pound rates on both varieties. At Lamberton nodulation was increased only by the 5 pound rate of nitrogen and at Morris, nodulation was decreased by all rates of nitrogen.

Table 1 : Effect of nitrogen fertilizer placed in the seed zone on soybean seed yields in 1970

Row fertilizer nitrogen	Morris			Waseca			Lamberton		
	Soybean variety			Soybean variety			Soybean variety		
	Chippewa 64 bu/acre	Clay bu/acre	Average bu/acre	Chippewa 64 bu/acre	Corsoy bu/acre	Average bu/acre	Chippewa 64 bu/acre	Corsoy bu/acre	Average bu/acre
0	24.5	34.4	29.4	30.4	38.4	34.4	35.5	43.2	39.4
5	21.7	32.8	26.4	32.2	40.5	36.3	34.8	44.9	39.8
10	22.4	32.9	27.7	33.1	39.1	36.1	34.4	42.4	38.4
15	22.5	32.1	27.6	34.0	37.1	35.5	32.0	42.8	37.4
Average	22.8a	32.8b		32.4a	38.8b		34.2a	43.3b	
Coefficient of Variation %	8.3			11.0			5.7		

THE EFFECTS OF SULFUR APPLIED ON A HIGH pH SOIL[1]

W. E. Fenster, O. M. Gunderson, R. J. Larson, D. S. Fairchild

Questions frequently asked in western Minnesota are, how can we lower soil pH? Since sulfur is acidic in reaction, how much sulfur must be applied to change the soil pH? If liming acid soils is a feasible practice, can we spend an equal amount to lower soil pH? In an attempt to answer these questions a research experiment was established in Chippewa County in the spring of 1969.

The soil selected was typical of large acreages in the area. The soil type of the plot site was a Vallers silty clay loam with a high pH. There was adequate surface drainage on the plot area.

Sulfur rates of 30, 500, 1,000 and 2,000 pounds / acre of elemental S were used in a series of plots randomized and replicated four times. The sulfur (18 - 32 mesh) was broadcast and disked into the soil. The cost of this product was 6 cents per pound. Corn was grown on the field in 1969 and soybeans in 1970.

Soil samples of the plow layer were tested from each plot in the spring, summer, and fall of each year. The results are shown in Tables 1, 2, and 3. No yield data was collected in 1969 because of the poor corn stand and apparent nitrogen deficiency in the field. In 1970 tissue and yield analyses of soybeans were determined.

The high rates of sulfur had the immediate effect of lowering the soil pH (Table 1). From the time of application in May to July 1969,

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[1]Revision of an article written by Orville Gunderson, Area Extension Soils Agent, 1970.

the soil pH was lowered from 7.9 to 6.7 by the 2,000 lbs. per acre rate of sulfur. Rates of 500 and 1,000 lbs. per acre of sulfur had similar effects. This was just a temporary effect on soil pH as is shown by subsequent testing. The pH on all treatments increased in the fall of 1969 and were lower again in the spring of 1970. In the fall of 1970 soil pH had returned to the original level.

Table 1: The effects of varying sulfur treatments on soil pH.

Sulfur Treatments lbs. S/A	Date of Sampling					
	5/9/69	7/8/69	10/23/69	6/1/70	7/15/70	10/15/70
0	7.8	7.8	8.0	7.7	7.8	8.0
30 - annually	7.8	7.6	7.8	7.7	7.7	7.8
500 - 1969	7.7	7.0	7.7	7.2	7.4	7.6
1000 - 1969	7.8	6.9	7.6	7.0	7.3	7.7
2000 - 1969	7.9	6.7	7.2	6.7	7.2	7.9

Another effect of applying high rates of sulfur to the soil was the change in the soluble salts contents (Table 2). The initial average soluble salt content was 0.5 mmhos.. Soluble salts were increased with increasing rates of applied sulfur. In the fall of 1969 and spring of 1970 the rate of 2,000 lbs. per acre of sulfur increased the soluble salt content to 2.8 mmhos.. This is in the range where salt sensitive crops could be affected. There were no visual differences, however, on the soybeans during the growing season. The increase in soluble salts was a temporary effect. By the fall of 1970 all of the treatments had returned to their normal levels.

Table 2: The effects of varying sulfur treatments on soil soluble salts.

Sulfur Treatments lbs. S/A	Date of Sampling				
	5/9/69	10/23/69	6/1/70	7/15/70	10/15/70
	mmhos				
0	0.5	0.6	0.6	0.5	0.4
30 - annual	---	0.7	0.5	0.7	0.4
500 - 1969	---	1.3	1.3	0.9	0.5
1,000 - 1969	---	2.0	1.6	1.3	0.4
2,000 - 1969	---	2.8	2.8	2.0	0.4

There were no yield differences from any of the sulfur treatments (Table 3). There also were no differences in nutrient uptake of corn and soybean plant tissue.

Table 3: The effect of varying sulfur treatments on soybean yields, 1970

Sulfur Treatments lbs. S/As	Bu./A
0	24
30 - annual	23
500 - 1969	24
1,000 - 1969	24
2,000 - 1969	24

The only visual evidence of the sulfur treatments was in the spring of 1970 prior to field tillage. At that time there was a white crust on the surface of the plots on which the sulfur has been broadcast a year previously.

In the fall of 1970 the plots were split and additional sulfur was applied to half of the plots. On two replications the treatments with 1,000 and 2,000 lbs. of sulfur / acre were treated with an additional 1,000 and 2,000 lbs., respectively. Future plans are to continue soil testing three times a year for two more years.

A similar sulfur plot was established in Swift County in the spring of 1970. The same rates of sulfur treatments were used but with a different form of sulfur. A product called Agri-Sul (90%-S) was used at this site. There was no change in either soil pH or soluble salts on this plot. This would indicate, perhaps, that since this soil has a very high pH, 8.0, the acid produced through oxidation of the elemental sulfur may have been neutralized immediately by the free carbonates. It is also possible that the sulfur product used (Agri-Sul) may not have oxidized in sufficient quantities to effectively lower the pH. Poor moisture conditions may also have contributed to the sulfur product not oxidizing. This plot will also be monitored for a number of years.

In summary, it has been shown that under favorable conditions a soil pH can <u>temporarily</u> be lowered with high rates of sulfur. It should be noted, however, that no yield responses were realized by lowering the soil pH.

SULFUR FERTILIZATION OF CORN IN SOUTHERN MINNESOTA[1]

D. S. Fairchild, W. W. Nelson, R. D. Frazier

In the spring of 1970, a project was initiated to determine if corn will respond to additional treatments of sulfur in Southern Minnesota on soils which are high in organic matter and low to medium in available sulfur.

Two field experiments were conducted in 1970. General information on the experimental sites is given in Table 1 and Table 2.

Table 1. Location and soil type of experimental sites.

Location	Soil Type
Southwest Experiment Station Redwood Co.	Webster clay loam
Lawrence Suppalla Waseca Co.	Nicollet clay loam

Table 2. Soil test levels of experimental sites.

Location	P	K	S	Zn	pH	O.M.
	----lbs/A----		P.P.M.	P.P.M		
Redwood Co.						
0-3"	28	240	11	2.7	5.9	H
3-6"	27	235	12	2.8	6.0	H
6-12"	11	195	13	1.7	6.2	H
Waseca Co.						
0-3"	143	473	24	4.6	6.1	H
3-6"	103	437	27	4.6	6.2	H
6-12"	33	233	22	2.8	6.2	H

[1]Appreciation is expressed to Bonewitz Laboratories, Inc. and Custom Farm Service, Inc. for their assistance.

Sulfur rates of 0, 20, and 100 lbs./A of actual S were used in a series of plot randomized and replicated nine times. The sulfur was applied in the elemental form.

Redwood County Site

The fertility program of the experimental site included: (1) starter-14 + 43 + 22, and (2) sidedress - 100 lbs./A N. The sulfur treatments were broadcast in early spring before tillage.

No significant yield responses resulted with the addition of increased rates of sulfur (Table 3). Table 4 indicates that there was no significant change in plant tissue contents with increasing sulfur rates. The sixth leaf tissue has not been analyzed as of this date.

There is indicates that elemental sulfur is not effective the year of application. To look at this possibility a residual study will be continued on this plot site in 1971.

Table 3. Sulfur treatments and corresponding 1970 corn yields Lamberton.

Fertilizer Treatment lbs/S/A	1970 Yield bu/A
0	155a *
20	157a
100	154a

*Numbers followed by the same letter are not significantly different at the 5.0% level population. (Duncan's New Multiple Range Test)

Table 4. Plant analyses of corn 10" tall under variable sulfur treatments. Lamberton, 1970

Fertilizer Treatments	%						P.P.M.					
	N	P	K	Ca	Mg	S	Fe	Zn	Cu	Mo	Mn	B
lbs/S/A												
0	3.40	0.42	2.96	0.48	0.43	0.29	509.6	24.2	9.20	12.1	41.0	6.9
20	3.42	0.45	3.05	0.48	0.46	0.28	514.6	25.1	11.44	12.2	43.9	7.2
100	3.40	0.45	2.96	0.47	0.44	0.29	506.2	23.4	9.61	12.0	42.4	7.9
Signif-icance	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
F-value	0.10	2.37	1.35	0.04	1.37	1.16	0.03	1.20	1.12	0.05	0.77	1.10
C.V.	3.3	8.3	4.5	11.2	8.6	7.8	14.1	9.8	33.5	14.8	11.8	20.1

Waseca County Site

The fertility program included 202 lbs/A N + 90 lbs/A P_2O_5 + 110 lbs/A K_2O + 10 lbs/A $ZnSo_4$. It was learned after plot establishment that the nitrogen was applied in the ammonium sulphate form. This accounted for 90 lbs/A sulfate. As evidenced from Tables 5 and 6 there was no significant differences in plant tissue contents. S levels are adequate with the reported critical level of 0.20%. No yield measurements were taken because of the amounts of sulphates previously applied.

1971 Experiments

Sulfur fertilization will be looked at more extensively in 1971. The experiment established at Lamberton in 1970 will be continued as a residual study. Seven additional sites on corn and alfalfa have been established across Southern Minnesota. These experiments will have sulfur treatments from 0-100 lbs/A sulfur applied as two products: (1) K_2So_4, and (2) Sol - U - Sul.

Table 5. Plant analyses of corn 10" tall under variable sulfur treatments. Waseca, 1970

Fertilizer Treatments	%						P.P.M.					
	N	P	K	Ca	Mg	S	Fe	Zn	Cu	Mo	Mn	B
lbs/S/A												
0	3.13	0.58	3.38	0.39	0.21	0.272	187.0	28.8	6.08	4.39	47.1	7.0
20	3.24	0.57	3.24	0.40	0.23	0.279	186.8	30.6	7.88	4.82	43.1	7.0
100	3.17	0.55	3.20	0.38	0.22	0.272	179.7	39.0	6.20	4.33	52.9	6.68
Significance	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
F. Value	0.87	0.57	0.39	0.48	0.28	0.59	0.96	1.17	0.54	0.54	1.89	1.07
C.V.	5.5	11.8	13.8	13.2	24.6	4.7	15.2	46.2	24.0	24.0	22.6	8.3

Table 6. Plant analyses of sixth leaf under variable sulfur treatments. Waseca, 1970

Fertilizer Treatments	%						P.P.M.					
	N	P	K	Ca	Mg	S	Fe	Zn	Cu	Mo	Mn	B
lbs/S/A												
0	2.49	0.28	2.25	0.81	0.29	0.216#a	111.2	17.1	6.99	5.56	37.5	7.7
20	2.56	0.27	2.11	0.82	0.32	0.227b	1112.4	16.8	7.93	6.39	33.1	7.7
100	2.53	0.27	2.19	0.81	0.32	0.227b	188.3	18.1	5.63	6.20	37.4	7.7
Significance	N.S.	N.S	N.S.	N.S.	N.S.	*	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
F. Value	0.54	0.55	0.41	0.06	0.35	3.77	0.90	0.78	1.11	0.92	0.64	0.02
C.V.	5.6	9.8	15.5	9.9	30.3	4.5	102	13.1	48.0	22.6	26.0	9.3

Numbers followed by different letters are significantly different at 5.0% level. (Duncan's New Multiple Range Test)

SOIL TESTING

John Grava

Currently the University of Minnesota soil testing laboratory processes nearly twenty-two thousand samples annually. The following data show the number of various types of samples analyzed in 1970.

Regular farm, garden and lawn samples		16,441
Florist (greenhouse) samples		2,284
Specials:	Sulfur	1,241
	Zinc	809
	Soluble salts	487
	pH	526
	Organic matter	102
	Departmental research	91
	Total	21,981

The monthly distribution of regular soil samples received by the laboratory is shown in Table 1.

Table 1. Monthly distribution of soil samples received by the University of Minnesota soil testing laboratory during 1970.

Month	Number of Samples
January	387
February	595
March	1090
April	3177
May	1780
June	668
July	893
August	1178
September	2002
October	2273
November	1611
December	787

FIVE YEARS (1966-1970) OF EXPERIMENTS WITH DIFFERENT ZINC FERTILIZER SOURCES AND PHOSPHATE FOR CONTINUOUS CORN ON A ZINC DEFICIENT HAMERLY LOAM NEAR BENSON, MINNESOTA

O.M. Gunderson, J.M. MacGregor, S.D. Evans and R.G. Munter

An investigation of commercial sources of zinc and the effect of heavy phosphate fertilization was commenced with field corn in the spring of 1966 with two main objectives:

(1) To determine the relative effectiveness of several commercially available zinc compounds on corn growth, yield and composition.

(2) The comparative effect of heavy phosphate fertilization on zinc availability to growing field corn and eventual grain yields.

A zinc deficient calcareous loam had been previously observed on the Richard Mikkelson farm at the junction of Highways 22 and 29 in Swift County and 5 year lease arrangements on a 7 acre tract were completed with the owner. Two randomized block experiments were established about the middle of May, 1966, each with 7 different treatments in quadruplicate. Three rates of granular zinc sulfate ($ZnSO_4.7\ H_2O$ to supply 10, 20 and 40 pounds of zinc per acre, granular ZnMNS to supply 10 pounds of zinc per acre, and the solid granular chelated zinc (Zn45) to supply 2.5 lbs of zinc per acre, were broadcast and plowed down in 1966 and again in 1967. The seventh treatment consisted of 0.5 lbs of chelated zinc per acre as Zn 45 applied in the granular form along the corn row in each of the first 3 years, and as a liquid application along each row in 1969 and 1970.

The phosphate interaction experiment was located a few hundred feet distant, being of the same size and design with annual phosphate treatments being plowed down in each of the first four years and zinc as the granular $ZnSO_4\ .7\ H_2O$ during each of the first 2 years. The farm operator also applied a total of 100+40+40 per acre in 1966 over the entire area.

Adequate N, P_2O_5+ K_2O fertilizer was applied in succeeding years.

Zinc deficient soils in Minnesota are usually low-lying calcareous areas, subject to poor water drainage and retain excessive moisture in the spring. Late corn planting generally is the rule. These low-lying areas are also subject to relatively poor air drainage, and to early fall frosts. This necessitates the planting of early maturing corn (and even this often fails to mature). The extreme variability in zinc supplying power of such soils, even in limited areas is well known, making adequate treatment replication extremely difficult and often unsatisfactory.

The soil of each plot was sampled each fall and analyzed for available zinc, phosphorus and additional constituents, the results have been reported in previous Soil Series. Severity of visual zinc deficiencies shown by growing plants, zinc, and phosphorus analyses of the sixth corn leaf were determined, and ear corn yield have been obtained in each of the five years and the major results are shown in the following tables.
Table 1 shows the severity of zinc deficiency by actual appearance of the corn plants in mid-August of each year.

Table 1. Visual Zinc Deficiency Symptoms of Corn Plants Growing in a Zinc Deficient Loam near Benson Minnesota (Swift County) with Different Zinc and Phosphate Fertilization (1966-70).

	Years					
	1966	1967	1968	1969	1970	5 year average
Zinc Source Experiment	Visual Rating (0 = severe and 10 = normal zinc deficiency)					
No Zinc	5.1	3.2	3.0	6.8	9.5	5.5
10 as $ZnSO_4$ (P.D.)	7.9	7.1	6.5	8.2	9.6	7.9
20 " " "	8.1	8.6	8.7	9.2	9.6	8.8
40 " " "	9.0	8.5	9.0	10.0	9.9	9.3
10 as ZnMNS (PD)	8.7	8.0	7.5	8.5	9.8	8.5
0.5 Zn as Zn 45 (annually row)	2.6	6.4	6.0	8.0	9.8	6.6
2.5 Zn as Zn 45 (bdct. & P.D. in "66 & '67)	6.0	3.9	3.0	4.5	8.4	5.2
P_2O_5 - Zn Interaction Experiment						
(lbs P_2O_5/A in 1966, '67, '68 and '69)						
40 " " (PD)	7.0	7.5	7.0	6.8	9.9	7.6
80 " " "	7.0	7.0	5.7	7.3	9.6	7.3
160 " " "	5.7	8.0	6.2	6.8	9.5	7.2
320 " " "	3.9	5.0	3.2	4.8	9.1	5.2
640 " " "	2.7	3.5	2.5	2.5	6.3	3.5
320 " " " + 10 Zn as $ZnSO_4$ ('66 & '67)	8.5	8.4	8.7	9.8	9.9	9.0
640 P_2O_5 annual PD + 10 Zn as $ZnSO_4$ ('66 & '67)	7.9	8.5	8.2	8.3	9.9	8.6

PD = Plowed down.

It is evident that by the fifth year of the experiment (1970), considerable mixing of the applied zinc had occurred and even the corn plants of the originally no zinc treated plots were obtaining sufficient zinc for apparently near normal growth. However, four years of fertilizing with P_2O_5 at the rate of 640 lbs resulted in corn plants visually deficient in zinc.

Table 2 shows the actual zinc content of the sixth corn leaves at silking.

Table 2. Zinc Concentrations in the Sixth (Index) Corn Leaves Growing on a Zinc Deficient Loam near Benson, Minnesota (Swift County) with Different Zinc and Phosphate Fertilization (1966-70).

	Years					
	1966	1967	1968	1969	1970	5 year average
Zinc Source Experiment	Leaf zinc in parts per million					
No Zinc	7.2	9.2	14.8	13.8	7.1	10.4
10 as $ZnSO_4$ (PD)	11.7	13.8	16.4	17.6	10.4	14.0
20 " " "	14.0	18.2	23.4	28.0	12.1	19.1
40 " " "	18.0	26.5	29.4	42.6	22.0	27.7
10 " ZnMNS (PD)	9.3	12.8	15.3	18.2	9.4	13.0
0.5 Zn as Zn 45 (annually row)	8.6	11.8	12.1	15.6	12.5	11.4
2.5 Zn as Zn 45 (bdct. & PD in '66 & '67)	8.3	11.5	12.7	14.9	8.9	12.0
P_2O_5 - Zn Interaction Experiment (lbs P_2O_5/A in 1966, '67, '68 and '69)						
40 " " (PD) "	10.0	10.2	13.3	17.1	16.6	13.4
80 " " " "	10.2	12.5	16.1	18.4	10.0	13.4
160 " " " "	8.4	10.5	13.1	15.1	8.8	11.2
320 " " " "	7.5	9.0	12.7	14.2	8.6	10.4
640 " " " "	7.3	8.2	9.3	13.4	8.4	9.3
320 " " " " + 10 Zn as $ZnSO_4$ in ('66 & '67)	12.4	13.2	14.4	28.4	16.6	17.0
640 P_2O_5 annual PD + 10 Zn as $ZnSO_4$ in ('66 & '67)	11.0	12.0	17.3	27.1	12.6	16.0

PD = Plowed down.

The relative availability of zinc from the different sources is evident in the amount of this element present in the corn leaves growing on the variously treated soils. The effect of heavy phosphate applications to this soil during the first four years on zinc concentrations in the corn leaves is also evident, as well as the corrective effect of 10 lbs. of Zn/A plowed down in the sulfate form.

Table 3 presents the phosphorus content of the sixth corn leaves at silking.

Table 3. Phosphorus Concentrations in the Sixth (Index) Corn Leaves Growing on a Zinc Deficient Loam near Benson, Minnesota (Swift County) with Different Zinc and Phosphate Fertilization (1966-70).

	Years					
	1966	1967	1968	1969	1970	5 year average
Zinc Source Experiment	Percentage leaf P					
No Zinc	0.400	0.367	0.410	0.339	0.254	0.354
10 as $ZnSO_4$ (PD)	0.297	0.304	0.338	0.272	0.236	0.289
20 " " "	0.259	0.273	0.462	0.265	0.230	0.298
40 " " "	0.259	0.281	0.511	0.302	0.202	0.311
10 " ZnMNS	0.326	0.285	0.630	0.284	0.234	0.352
0.5 Zn as Zn 45 (annually row)	0.394	0.331	0.351	0.382	0.237	0.339
2.5 Zn as Zn 45 (bdct. & PD in '66 & '67)	0.372	0.323	0.458	0.325	0.295	0.355
P_2O_5 - Zn Interaction Experiment (lbs P_2O_5/A in 1966, '67, '68 and '69)						
40 " " " (PD)	0.351	0.317	0.410	0.362	0.268	0.342
80 " " " "	0.313	0.312	0.338	0.350	0.264	0.315
160 " " " "	0.359	0.323	0.462	0.385	0.280	0.362
320 " " " "	0.400	0.436	0.510	0.410	0.337	0.419
640 " " " "	0.486	0.570	0.630	0.600	0.482	0.554
320 " " " " + 10 Zn as $ZnSO_4$ ('66 & '67)	0.325	0.308	0.351	0.321	0.258	0.313
640 P_2O_5 annual PD + 10 Zn and $ZnSO_4$ in ('66 & '67)	0.304	0.310	0.458	0.289	0.238	0.320

PD = plowed down

The P content of the leaves was depressed where larger amounts of zinc were available in the soil resulting in higher leaf Zn. Phosphate fertilization was reflected in leaf P, and 1970 corn leaves were lower in P than in the preceding four years, this being a probable relecteion of omitting the 1970 P_2O_5 fertilization.

Yields of corn grain during the five years are shown in Table 4.

Table 4. Yields of Corn Grain Grown on a Zinc Deficient Loam near Benson, Minnesota (Swift County) with Different Zinc and Phosphate Fertilization (1966-70).

	Years					
	1966	1967	1968	1969	1970	5 year average
Zinc Source Experiment	Bushels per acre at 15% moisture					
No Zinc	92.0	56.1	71.3	90.8	81.1	78.3
10 as $ZnSO_4$ (PD)	115.4	77.5	92.4	96.1	85.7	93.4
20 " " "	111.8	75.6	94.8	97.3	84.1	92.7
40 " " "	109.3	81.7	88.8	90.1	85.8	91.1
10 " ZnMNS	103.8	79.2	86.9	94.7	87.1	90.3
0.5 Zn as Zn 45 (annually row	85.5	69.7	93.4	83.3	78.7	82.1
2.5 Zn as Zn 45 (bdct. & PD in '66 & '67)	93.3	58.4	79.0	81.0	79.6	78.3
P_2O_5 - Zn Interaction Experiment (lbs P_2O_5/A in 1966, '67, '68 and '69)						
40 " " " "	98.4	68.5	86.9	96.8	108.7	91.9
80 " " " "	96.9	65.8	94.5	104.2	93.9	91.1
160 " " " "	96.3	60.8	100.0	94.4	98.7	90.0
320 " " " "	96.8	50.2	81.4	89.7	100.9	83.8
640 " " " "	83.4	34.3	72.0	82.2	90.1	72.4
320 " " " " + 10 Zn as $ZnSO_4$ ('66 & '67)	113.6	74.8	92.6	110.6	106.5	99.6
640 P_2O_5 annual PD + 10 Zn and $ZnSO_4$ in ('66 & '67)	107.6	74.7	100.6	117.2	102.0	100.4

PD = plowed down

During the five years of the experiment, the plots to which the more effective forms of zinc was applied and plowed down produced more than 10% additional corn. Heavy phosphate fertilization at rates of 320 or 640 pounds of P_2O_5 per acre depressed corn grain production, with marked improvement when $ZnSO_4 \cdot 7H_2O$ was plowed down to supply zinc at the 10 pound per acre rate.

STUDIES ON CAUSES OF VARIATIONS IN ZINC AVAILABILITY TO CORN IN A CALCAREOUS KANDIYOHI COUNTY SOIL

Adisak Sajjapongse and J.M. MacGregor

Zinc deficiency in corn growing on certain high lime mineral or organic soils in western Minnesota has been recognized since 1961. The apparent extreme variability in zinc availability has been frequently observed to occur in problem fields within relatively short distances, with no know reason. In a zinc deficient field in southeastern Kandiyohi county, 5 year average corn yields on a soil receiving no added zinc, ranged from 28 to 52 bushels per acre on areas only 100 feet apart, with no obvious soil differences. Zinc as zinc sulfate applied at rates from 5 to 40 lbs/A resulted in markedly increased yields over the 5 year period of the field study.

These soils were sampled in 1969 to a 48 inch depth, and soil temperatures and moisture content were found to be essentially equivalent at the four depth levels of all 36 plots of the study. The samples were analyzed and little or no differenc was found in soil pH or in soluble salt content. However, there were marked differences in extractable zinc, extractable P, calcium carbonate equivalent and exchangeable K and these appeared to be associated with lower or higher corn yields. Corn yields during the 5 year field study were larger with higher extractable soil zinc, lower extractable soil P and higher exchangeable K. Higher calcium carbonate equivalent seemed to counteract the undesirable affects of high soil P levels.

Greenhouse studies on the four depths of all 36 plots (3 replications of 12 treatments) showed no additional corn growth from the 1962 zinc treatments, but where zinc had been added 8 years previously, the greenhouse corn plants contained more zinc. However, corn plants from even the untreated soils all exceeded the minimum "critical" levels of

15 ppm zinc when grown in the greenhouse. However, corn plants grown on surface soils took up much more zinc than plants grown on soils from the second and third foot depths, while plants growing on the fourth foot depth were intermediate in zinc concentration. This is explainable, in probably being due to zinc extraction by plant roots and subsequent deposition at the surface in decaying plant organic matter for many years. Apparently plant roots seldom penetrated below the 3 feet level in these heavy, cold, and wet soils, and essentially all of the original soil zinc still remains at the fourth foot depth.

Studies with radiozinc (Zn^{65}) indicated the major zinc uptake by the corn plants to be from the soil, this being especially marked where the larger amounts of zinc were applied to the surface soil in 1962.

There was essentially no penetration of the fertilizer zinc beyond the 12 inch soil depth 8 years after application.

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