THE EFFECTS OF SULFUR AND MICRONUTRIENTS ON SUNFLOWER

B. R. Hilton and J. C. Zubriski

INTRODUCTION

"Better safe than sorry" is a slogan some farmers use to describe their application of sulfur and micronutrients to sunflower (*Helianthus annuus* L.). This practice is common for the use of macronutrients. To some, it seems logical to assume that the same principles apply for all nutrients. Conversely, there are those farmers who do not consider sulfur and micronutrients until a problem develops. Usually when a problem becomes evident, economic loss has already occurred.

Little information is available on the effects of sulfur and micronutrients on sunflower. Researchers have reported sunflower response to boron on boron-deficient soils in South Africa (a). A Russian researcher has reported increased sunflower seed yields from zinc and in some years from boron (3).

The macronutrients, supplied by the soil, consist of the elements nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur. These nutrients are called macronutrients because they are required in relatively large amounts by plants. The micronutrients consist of zinc, copper, boron, iron, manganese, cobalt, chlorine and molybdenum. Micronutrients are required in relatively small amounts by plants.

In past years, the macronutrients, especially nitrogen, have had great publicity because of the large yield increases due to fertilization with these elements. Micronutrients, on the other hand, have not generally produced such dramatic crop yield increases. Consequently, they are often ignored. A deficiency of copper or zinc, however, can be just as devastating to crop yield as a macronutrient deficiency. In times when farmers are struggling to maintain profitability, the proper management of macronutrients and micronutrients may mean the difference between profit and loss. The objective of this study was to determine the effect of sulfur, zinc, iron, copper, manganese, and boron on sunflower grown under field conditions.

Hilton is former graduate research assistant, Department of Soil Science, NDSU, now graduate research assistant, Department of Plant Science, SDSU, and Zubriski is professor, Department of Soil Science, NDSU.

Procedure

This study was conducted on two irrigated and two dryland sites in southeastern North Dakota. The sites and soils were: a) an irrigated Hecla loamy fine sand (Aquic Haploboroll, sandy, mixed); b) a dryland Hecla loamy fine sand (Aquic Haploboroll, sandy, mixed); c) a dryland Ulen fine sandy loam (Aeric Calciaquoll mixed, frigid); d) and an irrigated Serden fine sand (Typic Udipsamment, mixed, frigid).

Four composite soil samples were taken from each site in early spring at depths 0-6 inches, 6-12 inches, and 12-24 inches, respectively. The average values for each soil test variable (2) are presented in Table 1.

Each soil was fertilized with nitrogen, phosphorus, and potassium at rates sufficient for realistic yield goals (3000 pounds per acre sunflower seed). Fertilization treatments of N, P and K are presented in Table 2. The intent of the N, P, and K fertilization was to bring the fields up to near maximum fertility, maximizing crop growth and the total sulfur and micronutrient requirements of the sunflower plant. The Serden irrigated field was commercially fertilized with zinc and copper after soil samples were taken and prior to planting, so experimental zinc and copper treatment data are less useful.

Hybrid 894A sunflower was planted at all locations. Seven treatments were used (Table 3). Sulfur and micronutrient fertilizer treatments were banded 2 inches to the side and 2 inches below the seed at planting. Thinning was performed to achieve 12-inch plant spacing within rows for irrigated sunflower (approx. 22,000 plants/acre) and 15-inch plant spacing within rows for dryland sunflower (approx. 17,000 plants/acre). All rows were 2 feet apart.

Each plot consisted of six rows, 2 feet apart and 50 feet long. Four center rows of the six rows were treated. The outer rows of the four treated rows were used for plant sampling. Fifteen whole plant samples from each

Table 1. Average soil test values for individual fields, sunflower sulfur and micronutrient study Oakes, 1981.

Depth	Soil Tests											
	pH	NO_3-N	P	K	E.C.	O.M.	SO_4-S	Zn	Fe	Mn	Cu	B
In	lb/acre			##	%				ppm			
					Hecla Irrigated							
0-6	7.2	16	13.0	255	.083	1.95	10.5	0.7	15.2	12.2	0.8	2.5
6-12	7.3	12	6.0	174	.085	---	11.5	---	---	---	---	---
12-24	7.4	26	5.0	221	.085	---	16.7	---	---	---	---	---
					Hecla Dryland							
0-6	6.0	13	13.5	216	.055	1.65	5.0	0.4#	26.9	16.0	0.8	1.2
6-12	6.3	15	11.1	153	.063	---	9.3	---	---	---	---	---
12-24	6.3	31	8.8	165	.062	---	4.0	---	---	---	---	---
					Ulen Dryland							
0-6	8.4	13	3.6	307	.107	2.12	20.5	0.3#	6.2	5.4	1.2	2.6
6-12	8.4	9	2.0	164	.102	---	33.2	---	---	---	---	---
12-24	8.4	8	2.0	120	.095	---	19.8	---	---	---	---	---
					Serden Irrigated							
0-6	6.2	8	23.8	141	.050	1.60	9.2	1.1	19.1	4.3	0.6	0.9
6-12	6.0	8	13.5	107	.048	---	4.8	---	---	---	---	---
12-24	6.1	11	7.7	73	.043	---	5.5	---	---	---	---	---

#Low soil test value for zinc sensitive crops.
##mmhos/cm.
All soil test values were determined by the North Dakota Soil Testing Lab except boron which was determined by the University of Wisconsin Soil Testing Lab.

plot were collected at the 12-leaf stage for plant analysis. When sunflower reached anthesis, an additional plant sample was taken using the uppermost mature leaf of 25 sunflower plants from each plot. Twenty feet of the inner two rows was harvested by hand for seed yield data. Selection of the harvested area was based on uniformity of stand. Care was taken to avoid diseased areas, insect-damaged areas, saline areas, and discontinuities.

Plant Analysis Results

Three of the four experimental sites produced large, vigorous sunflower plants. Seed yield was high from these three fields. Due to nitrogen deficiency, the irrigated Serden field did not produce vigorous growth. Excessive leaching and poor commercial application of nitrogen seem to be responsible for the occurrence of nitrogen deficiency. In this field, nitrogen content of plants was low, plants were small, and yield was low.

Table 2. Summary of micronutrient and extraneous micronutrient fertilizers applied to each field, sunflower sulfur and micronutrient study Oakes, ND, 1981.

Site	Fertilizer Summary
Hecla Irr.	100 lb/acre N as 82-0-0 (anhydrous ammonia) was applied several weeks before planting. 25 lb/acre P_2O as 0-46-0 (concentrated superphosphate) was broadcast and incorporated into the soil several weeks before planting.
Hecla Dry.	100 lb/acre N as 82-0-0 (anhydrous ammonia) was applied several weeks before planting
Serden Irr.	80 lb/acre N, 5.0 lb/acre Zn and 1.0 lb/acre Cu were applied commercially several weeks before planting. 15 lb/acre N as 33-0-0 (ammonium nitrate) was applied July 9, 1981 to correct nitrogen deficiency symptoms.
Ulen Dry.	100 lb/acre N as 33-0-0 (ammonium nitrate) and 55 lb/acre P_2O as 0-46-0 (concentrated superphosphate) were broadcast and incorporated into the soil several weeks before planting.

Table 3. List of treatments used in sunflower sulfur and micronutrient study, 1981.

Trt. Number	Check##	Nutrient Added# Sulfur	Zinc	Iron	Copper	Manganese	Boron
		lb/acre					
1	check						
2		20					
3		20	4.5				
4		20	4.5	0.27			
5		20	4.5	0.27	2.7		
6		20	4.5	0.27	2.7	4.5	
7		20	4.5	0.27	2.7	4.5	0.9

#The nutrients were added in the following materials: sulfur as ammonium sulfate and sulfur; zinc as zinc sulfate; iron as iron EDDHA (Diethylenetriaminepentaacetic acid); copper as copper sulfate; manganese as manganese sulfate; boron as borox.

##Check treatments were fertilized with ammonium nitrate to equal nitrogen supplied by ammonium sulfate.

Plant analysis results are presented in Table 4. Plant sulfur data were considered unreliable due to difficulties in the sulfur analysis procedure and are therefore not presented.

Table 4. Sunflower plant analysis data, sunflower sulfur and micronutrient study Oakes, ND 1981.

Fert.	Growth stage	Field				
		Hecla Irr.	Hecla Dry.	Ulen Dry.	Serden Irr.	Average
				Zinc, ppm		
check	12-leaf	42	39	22	56	40
Zn	12-leaf	54*	48*	24	67*	48*
check	anthesis	37	27	15	30	27
Zn	anthesis	37	30*	16	33	29
				Iron, ppm		
check	12-leaf	172	193	145	240	188
Fe	12-leaf	194	181	145	202*	181
check	anthesis	168	74	70	278	148
Fe	anthesis	175	72	69	281	150
				Copper, ppm		
check	12-leaf	9.8	8.8	18.2	8.8	11.5
Cu	12-leaf	10.5	8.8	17.9	8.0	11.3
check	anthesis	12.4	9.3	20.7	10.1	13.2
Cu	anthesis	13.2	8.6	20.0	9.9	13.0
				Manganese, ppm		
check	12-leaf	190	261	85	167	182
Mn	12-leaf	235*	282	81	231*	207*
check	anthesis	99	141	68	172	121
Mn	anthesis	101	135	68	199	125
				Boron, ppm		
check	12-leaf	92	91	99	102	96
B	12-leaf	101	99	116*	108	106*
check	anthesis	104	96	97	97	98
B	anthesis	105	94	99	104	100
				Nitrogen, %		
check	12-leaf	4.15	4.22	3.63	3.57	3.89
check	anthesis	3.79	3.60	3.07	2.11	3.14

[a]Significant compared to check using ANOVA procedure F test (.05).

Sunflower in both irrigated fields exhibited increased zinc and manganese uptake in the 12-leaf stage as a result of fertilization with these micronutrients. The Ulen dryland plot showed increased boron uptake in the 12-leaf stage as a result of boron fertilization. The Hecla dryland plot showed increased zinc uptake due to zinc fertilization at the 12-leaf stage and at anthesis.

When data from all fields were combined and averaged, significant uptake of zinc at both the 12-leaf stage and at anthesis was observed from zinc fertilization. Significant plant uptake of boron and manganese at the 12-leaf stage resulted from fertilization with these elements. Part of the difference between uptake in fertilized plots and check plots of some elements may be attributed to the cool early sumemr of southeastern North Dakota. Lack of root extension and transpiration are common causes of inadequate nutrient uptake (4). This may be why manganese uptake was significantly higher due to fertilization only at the 12-leaf stage and not at anthesis. As the sunflower roots extended, sufficient uptake of manganese occurred from soil sources and was independent of fertilization. Zinc, however, showed significantly increased uptake at both stages of growth due to zinc fertilization.

Iron fertilization decreased iron uptake at the Serden irrigated plot at the 12-leaf stage. No explanation can be given for this decreased uptake of iron due to iron fertilization.

Soil tests indicated that the soil at all sites contained sufficient amounts of all nutrients except possibly zinc at both dryland sites. The North Dakota State University Soil Testing Laboratory cites 0.50 ppm DTPA soil-extractable zincas the critical level for sensitive crops. However, no interpretation of the DTPA zinc test exists for sunflower. Although the soil test levels of zinc were below 0.50 ppm, sunflower yield did not increase with zinc application. However, plant uptake of zinc did increase due to zinc fertilization (it appears that enough zinc was present in the soil for high yields and that some luxury consumption of zinc occurred as a result of zinc fertilization). Research has shown that sunflower has an iron stress-response mechanism in which roots are able to acidify the root environment, solubilizing iron (5). Other cations such as zinc and manganese may also be solubilized.

Yield Results

Yield data are presented in Table 5. Applications of sulfur and micronutrients did not significantly increase sunflower seed yields. Sulfur and micronutrients were of no value as a starter fertilizer for sunflower under given experimental conditions even though some early uptake of boron, manganese, and zinc was demonstrated.

The boron treatment (treatment 7) gave the lowest average seed yields in three out of four sites, but was statistically significant only at one location. Average yield of the boron treatment over all locations was significantly lower than yield of the iron treatment (treatment 4) and the sulfur treatment (treatment 2). Plant boron concentrations in the 12-leaf stage at the Ulen dryland plot were inversely correlated to seed yield. The sunflower boron content at anthesis showed no correlation to sunflower seed yield. Even though increased boron uptake was not generally evident, boron toxicity may have resulted from fertilization with boron.

Dryland plots outyielded irrigated plots. Most of the lower yields of the irrigated fields resulted from insufficient nitrogen on the Serden irrigated field. Head rot (*Sclerotinia sclerotiorum*) was responsible for decreased yield on the Hecla irrigated field. The average yield of irrigated sunflower was only 1835 pounds per acre compared to 2457 pounds per acre for dryland sunflower.

Summary

The use of sulfur and micronutrients produced no significant seed yield increases by sunflower. Average seed yield of sunflower treated with boron was significantly lower than sunflower treated with sulfur and iron, but not significantly lower than the check treatment.

Table 5. Mean seed yields for individual fields, sunflower sulfur and mitronutrient study Oakes, ND 1981.

Treatment	Mean seed yield lb/A	Grouping#
Hecla irrigated		
3) S+Zn	2519	A
2) S	2504	A
4) S+Zn+Fe	2457	A
6) S+Zn+Fe+Cu+Mn	2432	A
1) Check	2406	A
7) S+Zn+Fe+Cu+Mn+B	2320	A
5) S+Zn+Fe+Cu	2295	A
Hecla dryland		
Treatment	**Mean seed yield lb/a**	**Grouping#**
2) S	2865	A
1) Check	2766	A
4) S+Zn+Fe	2730	A
6) S+Zn+Fe+Cu+Mn	2678	A
5) S+Zn+Fe+Cu	2654	A
3) S+Zn	2554	A
7) S+Zn+Fe+Cu+Mn+B	2275	A
Ulen dryland		
Treatment	**Mean seed yield lb/a**	**Grouping#**
2) S	2361	A
4) S+Zn+Fe	2309	AB
5) S+Zn+Fe+Cu	2303	AB
3) S+Zn	2283	AB
1) Check	2202	AB
6) S+Zn+Fe+Cu+Mn	2202	AB
7) S+Zn+Fe+Cu+Mn+B	2024	B
Serden irrigated		
Treatment	**Mean seed yield bu/a**	**Grouping#**
4) S+Zn+Fe	1406	A
1) Check	1287	A
3) S+Zn	1258	A
6) S+Zn+Fe+Cu+Mn	1245	A
2) S	1217	A
5) S+Zn+Fe+Cu	1193	A
7) S+Zn+Fe+Cu+Mn+B	1155	A
Average		
Treatment	**Mean seed yield lb/a**	**Grouping#**
2) S	2237	A
4) S+Zn+Fe	2226	A
1) Check	2165	AB
3) S+Zn	2154	AB
6) S+Zn+Fe+Cu+Mn	2139	AB
5) S+Zn+Fe+Cu	2111	AB
7) S+Zn+Fe+Cu+Mn+B	1993	B

#Means with the same grouping letters are not significantly different using D.M.R. (.05).

Though yield did not increase, sunflower demonstrated increased nutrient uptake of several micronutrients as a result of micronutrient fertilizers. As an average for all fields, sunflower at the 12-leaf stage showed increased boron, zinc, and manganese uptake form the fertilization of these elements. The plant samples taken at anthesis showed increased zinc uptake from zinc fertilizer. Zinc tested below 0.50 ppm DTPA soil-extractable zinc in the Hecla and the Ulen dryland sites, but increased yield was not obtained from applied zinc at either site. Apparently sunflower is not a zinc sensitive crop. No nutrient deficiencies were predicted by soil test rsults. Soil test results indicated high to very high soil boron values. Applied boron on these high boron soils may have decreased sunflower seed yield.

Farming practices that include sulfur and micronutrient fertilization without regard for soil tests and plant analysis represent poor management. Boron in this experiment may have decreased yields from excessive fertilization of boron. Manganese and copper are other elements which may also decreased yields if improperly used. Even if yields are not affected, it is not economical to buy costly fertilizers when the soil can supply all of the sulfur or micronutrient needs of sunflower. The experiment also shows no evidence that starter fertilizers containing sulfur and/or micronutrients are beneficial to sunflower when soil tests indicate adequate amounts of these nutrients.

"Better safe than sorry" is not a good way to manage sulfur and micronutrient fertilization of sunflower. While soil testing and plant analysis are the best ways to determine the need for sulfur and micronutrients of many crops, research is needed to determine soil test levels that would require additional sulfur and micronutrients to produce increased sunflower yields.

REFERENCES CITED

1. Blamey, F. P. C., D. Mould and K. Nathanson. 1978. **Relationships between B deficiency symptoms in sunflowers and the B Ca/B status of plant tissues.** Agron. J. 70:376-380.

2. Dahnke, W. C. (ed). 1975. **Recommended chemical soil test procedures for the North Central Region.** North Dakota Agr. Exp. Sta. Bull. 499, Fargo, ND.

3. Dranichnikova, T. D. 1978. **Effect of trace elements on physiological processes and productivity of sunflower.** Soils and Fertilizers 1979 (42):4175.

4. Lucas, R. E. and B. D. Knezek. 1972. **Climate and soil conditions promoting micronutrient deficiencies in plants.** p. 265-283. In J. J. Mortvedt (ed). Micronutrients in agriculture. Soil Sci. Soc. Am., Madison, WI.

5. Olsen, R. A., R. B. Clark and J. H. Bennett. 1981. **The enhancement of soil fertility by plant roots.** Am. Scient. 69:378-384.