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Sugar Beet Nutrition Studies in Southern and West Central Minnesota

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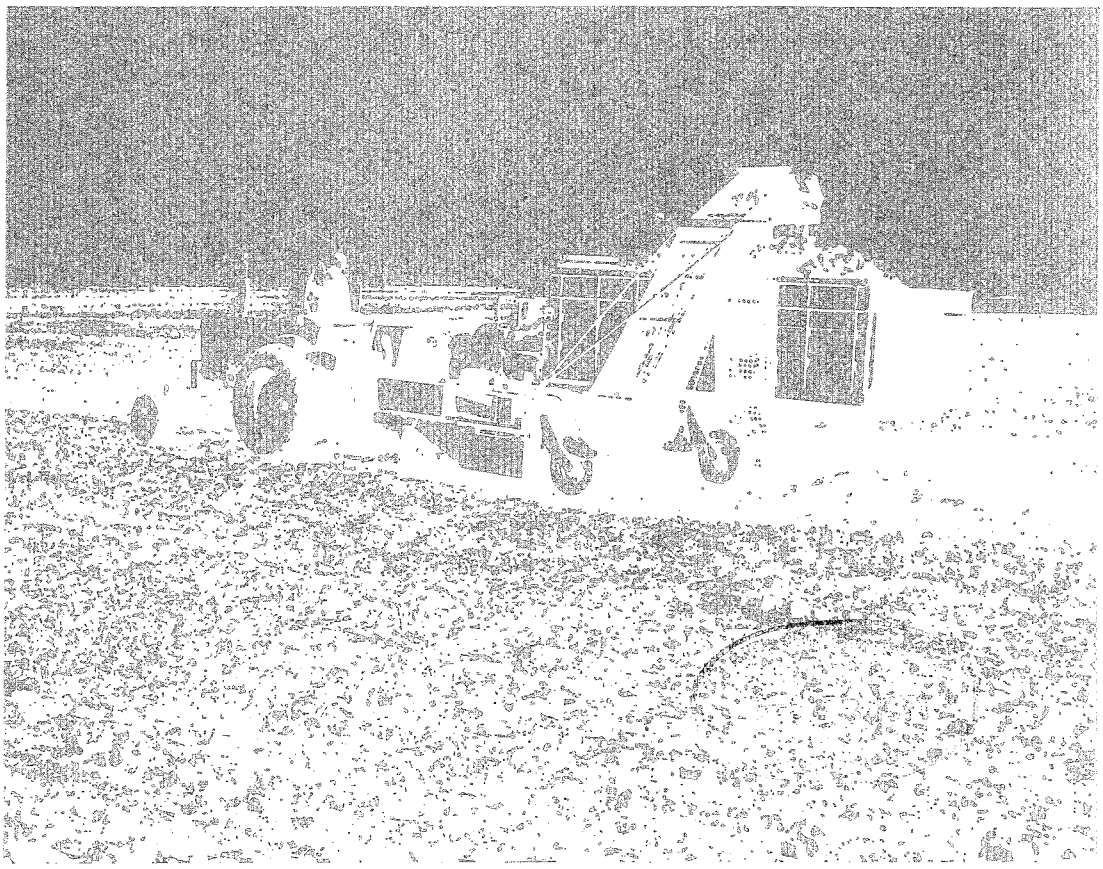

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RECOGNITION

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INTRODUCTION

Growers in southern and west-central Minnesota have expressed a need for detailed information on the effects of lime and fertilizer on sugar beets. The crop is grown without resorting to summer-fallowing in this area of the state, contrary to the general practice used in the Red River Valley area. Climate, soil types, and acidity levels in this area are considerably different from those in northwestern Minnesota. For these reasons, liming and fertilization studies were begun in 1965 under the direction of the University of Minnesota soil scientists at the Southern and West-Central Experiment Stations. The work was supported in part by growers' associations in the areas studied. Micronutrient studies were included as a part of the research in some instances.

HISTORICAL

Minnesota's sugar beet industry began in the southern part of the state in 1898 when the Minnesota Sugar Company built a sugar beet processing plant at St. Louis Park. This plant, not entirely successful, was destroyed by fire in 1905.[1] The second plant in Minnesota, today's oldest operating plant in the state, was built at Chaska by the Carver County Sugar Company in 1906. It was purchased by the American Crystal Sugar Company in 1925.[2] In 1917 the American Crystal Sugar Company built its Mason City, Iowa, plant. These two plants receive sugar beets from Minnesota Crop Reporting Districts 4, 5, 7, 8, and 9 which include sugar beets grown near Appleton, Clara City, Redwood Falls, and the areas of Blue Earth and other parts of south-central Minnesota. The Mason City plant also receives sugar beets grown in northern Iowa and extreme northeastern Nebraska.

The Minnesota Crop and Livestock Reporting Service indicates a steady increase in the acreages and tonnages of sugar beets over the years since the early 1900's.[3] In 1920 Minnesota growers produced sugar beets on only 7,031 acres; by 1958 the state acreage was 72,900. In 1967, Minnesota growers produced sugar beets on more than 126,700 acres. The south and west-central areas of Minnesota produced 12,500 acres by 1958 and by 1967 this figure was up to 34,500 acres.

[1] From "Facts about Beet Sugar in Minnesota, North Dakota, and Iowa." Publication of the Amercan Crystal Sugar Company, Denver, Colorado.

[2] Ibid.

[3] From "Minnesota Agricultural Statistics Yearbooks." Crop and Livestock Reporting Service, USDA and Minnesota Department of Agriculture.

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SUGAR BEET FERTILIZATION RESEARCH IN MINNESOTA—HISTORICAL

Research on sugar beet fertilization in southern Minnesota has been very limited. Some work in the Red River Valley in Minnesota has been reported in mimeographed form by the Department of Soil Science, University of Minnesota. Rost[4] reported that sugar beets grown on fine-textured soils of the Valley responded to potassium more than potatoes. The common practice, he reported in 1953, was to use straight phosphorus on sugar beets. Soine, of the Northwest Experiment Station at Crookston, reported some fertilizer trials on sugar beets.[5] His summary included the following statements:

1. Sugar beets on legume fallow average one ton per acre more than those grown with a black fallow.
2. The sugar content averaged 0.71 percent higher on the legume fallow treatment than from the black fallow.
3. The three highest nitrogen rates, which in this study were 30, 40, and 50 pounds of N applied, increased the yield 0.12 to 0.66 tons per acre on the legume fallow while increases were limited to 0.24 to 0.38 tons per acre on the black fallow.
4. Using nitrogen fertilizer lowered the percent sugar content below the check on all treatments except 10 pounds per acre of N used on black fallow land.

In the mimeographed 1969 Soils Series publication Soine reported on a sugar beet experiment with fertilizers containing zinc. In this work, root yield and sucrose content were increased by adding from 10 to 40 pounds of zinc either in band or broadcast applications before planting. Heavy applications of zinc sulfate increased yield and sucrose content and lowered the impurity index, which indicates easier processing of the beet roots by the sugar manufacturer.

STUDIES IN SOUTHERN AND WEST-CENTRAL MINNESOTA

This research was initiated to clarify results which might be expected in southern and west-central Minnesota.

Studies began in 1964 and 1965 and included:

1. The effect of limestone on the yield, nutrient content, and sugar content of sugar beets.
2. Nitrogen fertilization of sugar beets in southern and west-central Minnesota.
3. Nitrogen, phosphorus, and potassium fertilization of sugar beets in southern and west-central Minnesota.
4. Micronutrient fertilization of sugar beets in southern Minnesota.

[4] Rost, C. O. "A Report on Field Research in Soils." Soils Series No. 4, Department of Soil Science, University of Minnesota, January 1943.

[5] Soine, Olaf C. "A Report on Field Research in Soils." Soils Series No. 74, Department of Soil Science, University of Minnesota, 1960.

Limestone as well as nitrogen, phosphorus, and potassium carriers were applied in replicated soil treatments. Micronutrient carriers were applied as soil and foliar treatments. Data presented include soil chemical tests, nutrient composition of dried petioles of the beet plants, as well as yield of the sugar beet roots for the crop immediately following the treatment. Laboratory analyses of the beet roots were made by the American Crystal Sugar Company. These determinations included sucrose content, chemical purity, and content of nitrogen, potassium, and sodium. The research results of the three studies are presented in this order: limestone, N-P-K, micronutrients. Table 1 shows the soil test values for the various studies included in this report. Analysis was done at the University of Minnesota Soil Testing Laboratory.

Table 1. Initial soil test values at several locations

Location	Soil* texture	pH	Organic matter	P**		K**	
				lb/acre			
C. Hoehn, Waseca, Lime plots	SiCL	5.8	H	63	VH	440	VH
S. Reippel, Holloway, N, 1965	SiCL	7.6	H	16	M	430	VH
Morris, N-P-K, 1966	CL	7.7	H	4	VL	410	VH
Louter, Hollandale, N-P-K, 1966	CL	7.5	H	114	VH	310	VH
Waseca, N-P-K, 1967	L	6.2	H	57	VH	370	VH
DeBoer, Hollandale, N-P-K, 1967	SiL	7.1	H	179	VH	430	VH
Waseca, N-P-K, 1968	CL	6.2	H	60	VH	330	VH
DeBoer, Hollandale, N-P-K, 1968	SiL	7.1	H	108	VH	500	VH
C. Hoehn, Waseca, foliar 1967	SiCL	5.4	H	90	VH	410	VH
T. Hoehn, Waseca, foliar 1968	CL	6.1	H	56	VH	370	VH
DeBoer, Hollandale, foliar 1968	SiL	7.4	H	117	VH	580	VH

* SiCL = silty clay loam; CL = clay loam; SiL = silt loam; L = loam

** Soil test values give extractable P and exchangeable K.

STUDY 1. LIMESTONE

The limestone study began in 1964 when different rates of ground agricultural limestone were applied on replicated plots in a cooperating farmer's field near Waseca. The soil type was Marna silty clay loam. Beets were grown on the area in 1965 and again in 1968. Table 2 gives the results from the limestone treatments. Percent purity is reported for 1965 and the impurity index is used for the 1968 data because of a change in laboratory methods.

In the following text and tables a single asterisk is used to denote statistical significance at the 95 percent confidence level. A double asterisk indicates highly significant differences at the 99 percent level. The 95 percent confidence level means that 5 times in 100 the results could happen by chance. The 99 percent level means that only 1 time in 100 could the results be caused by chance.

Firm conclusions on the effectiveness of limestone cannot be drawn from this information. Statistically significant differences were found in root production in 1965 and in impurity indexes in 1968. The heavier

Table 2. Yield and purity of sugar beet roots after limestone soil treatments near Waseca

Limestone treatment	Sucrose		Yield		Purity	Impurity index
	1965	1968	1965	1968	1965	1968
T/acre	lb/acre		T/acre		%	
0	5,520	5,218	17.6	17.9	90.3	648
4	5,096	5,345	15.5	19.0	90.9	781
6	5,936	5,081	18.8	19.3	90.5	759
8	5,921	5,010	17.8	18.9	90.6	727
Significance	ns	ns	*	ns	ns	*

* = statistically significant differences exist
ns = values are not significantly different

rates of limestone appear to have improved crop yield without drastically decreasing quality or increasing impurity. The 1968 data do not show significant differences in root production due to treatment; however, there seems to be a trend in favor of heavier limestone applications.

Table 3 shows petiole nutrient contents found three years after various limestone treatments. Limestone has not had a marked effect on petiole content of nutrient elements.

Table 3. Nutrient composition of sugar beet petioles after limestone soil treatments near Waseca

Limestone treatment	Nutrient									
	N	P	K	Ca	Mg	Fe	Zn	Cu	Mn	B
T/acre	%	%	%	%	%	ppm	ppm	ppm	ppm	ppm
0	2.01	.20	3.03	.73	.60	209	32.5	5.72	176	34.1
4	2.06	.21	2.82	.66	.57	154	27.3	4.99	197	33.6
6	2.25	.19	3.18	.79	.79	182	30.7	5.43	121	33.9
8	2.10	.19	1.81	.71	.67	175	29.2	4.52	177	28.5

STUDY 2. N

In 1965 replicated broadcast nitrogen rate studies were established on four cooperating farmers' fields in south-central and west-central Minnesota. In some cases the micronutrients zinc and boron were added along with the heavier nitrogen treatments.

Nitrogen rate varied with location and farmer practice. Generally, from 0 to 100 pounds of N per acre were added in 30-pound increments. In one instance rates were from 120 to 250 pounds of N per acre.

Table 4 indicates that nitrogen fertilizer did not significantly increase or decrease root tonnage. In general, nitrogen decreased sucrose content and purity. Where over 30 pounds per acre of nitrogen was used, N content of the beet root was increased. These results agree with results from nitrogen studies reported by other sugar beet producing states.

STUDY 3. N-P-K
1966

A broadcast fertilizer experiment using N, P, and K as variables was begun in 1966. This experiment was continued for 3 years at locations near Hollandale, Waseca, and Morris. The treatments used are shown in Table 5.

The results of the first year of these studies are summarized in table 6, 1966 N-P-K results.

Table 4. Yield and purity of sugar beet roots following nitrogen soil treatments in 1965 at several locations

Sheldon Reippel Farm, Holloway

Nitrogen treatment	Sucrose	Yield	Sucrose	Purity	Total nitrogen
lb/acre	lb/acre	T/acre	%	%	%
0	5,309	15.3	17.47	86.8	.782
35	5,324	15.6	17.10	89.4	.760
70	5,714	16.3	17.47	89.6	.720
105	5,367	15.8	17.02	87.0	.964
140	5,480	16.1	17.08	88.1	.758
Average of N	5,439	15.8	17.22	88.2	.797
105 + 10 lb Zn	5,116	15.3	16.90	87.5	.813
Significance	ns	ns	ns	ns	ns

Donald Neubaurer Farm—Bird Island

Nitrogen treatment	Sucrose	Yield	Sucrose	Roots 100′	Purity	Total nitrogen
lb/acre	lb/acre	T/acre	%	number	%	%
0	5,523	16.2	17.09	63.3	91.2	.62
30	5,712	16.7	17.17	64.0	92.6	.76
60	5,467	16.3	16.80	67.8	90.9	.77
90	5,786	17.5	16.47	70.7	90.2	.82
Average of N	5,622	16.6	16.88	66.5	91.2	.74
60 + 10 lb Zn	6,331	18.6	17.02	70.7	90.8	.78
60 + 10 lb B	5,674	16.5	17.25	67.0	91.6	.81
Significance	ns	ns	*	ns	*	*

George Byron, New Richland

Nitrogen treatment	Sucrose	Yield	Sucrose	Roots 100′	Purity	Total nitrogen
lb/acre	lb/acre	T/acre	%	number	%	%
0	6,459	19.9	16.26	99.4	90.0	.69
30	6,061	19.1	15.86	99.2	89.4	.63
60	6,136	19.4	15.80	93.6	90.3	.79
90	6,232	20.3	15.36	99.0	88.9	.74
120	5,680	18.7	15.22	94.6	89.4	.95
150	5,870	19.3	15.16	97.6	88.1	.99
Average of N	6,073	19.5	15.61	97.2	89.3	.80
No micronutrient	5,877	19.0	15.44	93.7	89.1	.83
10 lb B	5,768	18.6	15.50	93.4	89.6	.82
10 lb Zn	5,823	19.0	15.32	96.2	88.8	.81
Significance	ns	ns	ns	ns	ns	ns

* = statistically significant differences exist
ns = values are not significantly different

The Tilney Farms—Lewisville

Nitrogen treatment	Sucrose	Yield	Sucrose	Roots 100′	Purity	Total nitrogen
lb/acre	lb/acre	T/acre	%	number	%	%
100	4,064	14.1	14.45	64.3	86.3	.92
130	4,266	14.7	14.52	75.2	87.1	1.00
160	4,335	14.8	14.65	75.0	87.2	1.08
190	4,306	15.3	14.09	67.8	87.0	1.01
220	4,214	14.9	14.24	62.2	85.0	1.07
250	4,486	15.9	14.10	71.5	85.8	1.10
Average	4,277	14.9	14.34	69.3	86.4	1.03
Significance	ns	ns	ns	ns	*	ns

* = statistically significant differences exist
ns = values are not significantly different

Table 5. N-P-K treatments studied, 1966-1968 at Morris, Waseca, and Hollandale

Morris Nutrient		Rates applied 1966 through 1968	
		lb/acre	
N	0	70	140
P_2O_5	0	57	114
K_2O	0	30	60
Waseca and Hollandale Nutrient		**Rates applied 1966 through 1967**	
		lb/acre	
N	0	70	140
P_2O_5	0	57	114
K_2O	0	30	60

Waseca and Hollandale Nutrient		Rates applied 1968	
		lb/acre	
N	0	70	140
P_2O_5	0	92	140
K_2O	0	96	192

Fertilizer benefits were inconsistent. Heavier nitrogen rates increased sugar production at Morris but not at Waseca and Lamberton. Sugar content decreased at all locations; but at Morris the tonnage increase more than offset the lower content. Purity decreased significantly at Waseca and Hollandale.

Phosphorus treatment increased both root production and total sugar production per acre at Waseca.

Potassium caused no significant response at any location.

Representative petiole content values from the three study locations and from The Tilney Farms, Lewisville, are shown in table 7. Ranges of accepted critical values for nutrient composition in sugar beet petioles are also shown. It is interesting to note that petiole contents at Waseca were in the low range for phosphorus and and that sugar content and yield responded to higher phosphorus rates (table 6).

1967

The N-P-K studies begun in 1966 were repeated in replicated plots in 1967 and 1968 at Morris, Waseca, and Hollandale. Only the Hollandale plots were harvested in 1967 and 1968 because of drought, wind dam-

Table 6. Yield and purity of sugar beet roots following 1966 N-P-K soil treatments at Morris, Waseca, and Hollandale

Location	Fertilizer applied	Sucrose	Yield	Sucrose	Purity	Elemental petiole content, July 23
	lb/acre	lb/acre	T/acre	%	%	%
Morris						
	0 N	4,492	15.72	17.51		
	70 N	5,967	17.40 *	17.13		
	140 N	6,127	18.23	16.81		
	0 P_2O_5	5,973	17.36	17.20		
	57 P_2O_5	5,758	16.84	17.12		
	114 P_2O_5	5,872	17.16	17.12		
	0 K_2O	5,825	16.86	17.27		
	30 K_2O	5,913	17.28	17.14		
	60 K_2O	5,865	17.21	17.04		
Waseca						
	0 N	4,317	14.92	14.49	89.38	
	70 N	4,119	14.59	14.18 *	88.01 *	
	140 N	3,882	14.48	13.40	87.45	
	0 P_2O_5	3,892	13.97	13.97	88.32	
	57 P_2O_5	4,148 *	14.59 *	14.21	88.27	.152
	114 P_2O_5	4,279	15.43	13.88	88.25	.227
	0 K_2O	4,020	14.32	14.07	88.51	6.74
	30 K_2O	4,024	14.52	13.88	87.68	6.08
	60 K_2O	4,275	15.15	14.11	88.66	6.98
Hollandale						
	0 N	5,080	17.57	14.47	87.72	
	70 N	4,716	16.64	14.19	86.73 *	
	140 N	4,927	17.60	14.00	85.52	
	0 P_2O_5	4,859	16.84	14.43	86.64	.352
	57 P_2O_5	5,020	17.48	14.39	86.68	.367
	114 P_2O_5	4,844	17.49	13.83	86.65	.352
	0 K_2O	4,937	17.21	14.38	86.88	5.49
	30 K_2O	4,874	17.10	14.24	86.56	5.90
	60 K_2O	4,911	17.50	14.05	86.53	5.29

* Bracketed values contain significant increases or decreases.

age, disease, and drainage problems at the other locations.

Table 8 indicates that only nitrogen gave statistically significant effects at Hollandale in 1967. These effects (no significant increases in either root or sugar yield and striking increases in impurities) are considered negative. Phosphorus and potassium treatments showed no significant effects.

1968

In 1968 fertilizer rates were increased at Waseca and Hollandale (table 5). Unfortunately, bad weather at Waseca and Morris again damaged stands so that research results were not meaningful. Production at Hollandale was much lower in 1968 than in 1967, but it was felt the data would be valuable. Results from N-P-K fertilization were inconclusive in 1968. Statistical significance was not estimated for the 1968 Hollandale data because of analytical difficulties in the laboratory (see table 9).

Table 7. Representative nutrient composition of sugar beet petioles following 1966 N-P-K treatments at several locations

Location	N	P	K	Ca	Mg	Mn	Fe	B	Ca	Zn	Al	Sr	Mo	Co
	%	%	%	%	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Morris		.37	5.3	.47	.41	21.7	201.6	21.9	7.7	14.9	33.6	27.1	1.75	2.34
Waseca		.25	5.2	.84	.72	38.7	129.	34.7	8.5	24.8	204.	38.4	3.36	3.09
Hollandale		.30	4.2	.74	.56	67.5	120.	33.2	9.4	24.2	111.	42.4	2.60	2.57
Lewisville		.21	4.0	.83	.78	73.0	63.8	24.6	8.2	13.0	44.4	35.5	3.22	2.27
Low	3.0	.14-.25	.61-1.00		.05	11-25		9-15	3-5	9-15				

Table 8. Yield and purity of sugar beet roots following 1967 soil treatments at Hollandale

Fertilizer applied	Sucrose	Yield	Sucrose	K in root	Amino N in root		Sodium in root		Impurity index	
lb/acre	lb/acre	T/acre	%	ppm	ppm		ppm			
0 N	6,752	20.2	16.7	2,450	188		265		523	
70 N	6,701	20.0	16.9	2,420	224	**	306	**	545	**
140 N	6,951	21.1	16.5	2,420	267		360		590	
0 P_2O_5	6,851	20.7	16.6	2,410	213		298		544	
57 P_2O_5	6,608	19.8	16.7	2,500	245		337		577	
114 P_2O_5	6,946	20.8	16.7	2,380	220		296		538	
0 K_2O	6,733	20.1	16.8	2,350	212		297		527	
30 K_2O	7,056	21.3	16.6	2,450	242		329		572	
60 K_2O	6,616	19.9	16.7	2,490	225		304		559	

** values bracketed contain highly significant increases.

Table 9. Yield and purity of sugar beet roots following 1968 N-P-K soil treatments at Hollandale

Fertilizer applied	Sucrose	Yield	Sucrose	K in root	Amino N in root	Sodium in root	Impurity index
lb/acre	lb/acre	T/acre	%	ppm	ppm	ppm	
0 N	2,595	12.6	11.0	2,386	518	803	1,437
70 N	2,201	10.7	10.5	2,044	553	881	1,325
140 N	2,550	12.2	11.0	2,189	595	836	1,316
0 P_2O_5	2,346	10.9	10.8	2,265	553	847	1,303
92 P_2O_5	2,448	12.1	10.9	2,162	552	819	1,338
184 P_2O_5	2,554	11.6	11.0	2,253	535	816	1,285
0 K_2O	2,397	11.1	11.0	2,134	539	844	1,296
96 K_2O	2,404	11.1	10.9	2,253	565	850	1,877
192 K_2O	2,579	12.5	10.9	2,283	542	793	1,216

Very few statistically significant changes occurred in sugar beet root yields, sucrose content, or root purity following N, P, or K fertilization. There have been increases at some locations in some years in connection with some treatments, but by and large, N-P-K fertilization at the rates used in these studies has been inconsistent in modifying production. It should be noted that P and K soil test levels of most locations were very high at the outset of the fertilizer studies.

STUDY 4. MICRONUTRIENTS

Zinc and boron were applied to the soil at 10 pounds per acre in connection with certain of the nitrogen studies in 1965. There were no significant responses to either of these micronutrients at any of the three locations in 1965 (see tables 4a, c, and d).

Soil-applied zinc sulfate was added to the N-P-K experiments at Morris and Waseca in 1966. Zinc, boron, and manganese were added as separate treatments at Hollandale. Only slight effects were seen for zinc at Morris and Waseca, while some increases were evident for all three micronutrients at Hollandale (see table 10).

Table 10. Yield and purity of sugar beet roots following 1966 soil-applied micronutrients at Morris, Waseca, and Hollandale

Location	Sucrose	Yield	Sucrose	Purity
	lb/acre	T/acre	%	%
Morris				
N-P-K	6,348	17.88	17.75	——
N-P-K + Zn	6,173	17.84	17.30	——
Waseca				
N-P-K	3,702	13.50	13.78	86.78
N-P-K + Zn	3,798	13.78	13.78	86.92
Hollandale				
N-P-K	4,644	16.17	14.35	85.38
N-P-K + Zn	4,639	16.87	13.75	86.68
N-P-K + B	5,279	17.74	14.88	87.38
N-P-K + Mn	5,246	17.94	14.62	87.52

Soil Application of Micronutrients

Expanded treatments of both soil- and foliar-applied micronutrients were tried near Waseca, Hollandale, and Lewisville in 1967 and 1968. The micronutrient fertilizers were broadcast and worked into the soil in addition to N-P_2O_5-K_2O applications at all locations. Micronutrients used were sulfates of copper, zinc, and manganese plus a soluble source of sodium borate. Slight but inconsistent results are shown in table 11. Foliar nutrient composition from these same treatments is shown in appendix table 1.

Foliar Application of Micronutrients

Micronutrients were applied to foliage in three areas during 1967 and 1968. The yield results are shown in table 12 and foliar nutrient compositions are given in appendix table 2. Foliar fertilizers included sodium borate as a source of boron, a zinc-containing fungicide, sulfates of iron, copper, zinc, and manganese plus a mixture of three chelates. None of the foliar treatments gave a consistent nor a statistically significant crop yield increase. Table 1 shows that the soil tests for P and K were in the very high range where foliar treatments were used. Soil pH ranged from 7.1 to 7.5 at all foliar locations except at Waseca, where it was 5.9.

Table 11. Yield of sugar beet roots following 1967 and 1968 soil-applied micronutrients at Hollandale

Treatment	Yield	
	1967	1968
	T/acre	T/acre
Check	21.6	11.5
Sodium borate	22.7	10.7
Copper sulfate	21.7	10.9
Zinc sulfate	21.7	12.5*
Manganese sulfate	19.8	11.7

* statistically significant

Table 12. Yield of sugar beet roots following 1967 and 1968 foliar applied micronutrients at several locations

Treatment	Waseca		Lewisville		Hollandale	Average
	1967	1968	1967	1968	1968	
	T/acre		T/acre		T/acre	T/acre
Check	12.4		20.2			16.3
Sodium borate	14.6	16.4	20.5	15.8	9.0	15.3
Manganese chelate	14.0	15.7	16.5	17.9	11.2	15.1
Manganese sulfate	11.9	13.4	14.8	20.0	10.7	14.2
Zinc fungicide	14.1	13.9	13.9	18.7	9.6	14.0
Zinc chelate	11.8	15.2	14.9	16.8	10.6	13.9
Zinc sulfate	11.5	15.1	13.9	17.6	9.5	13.5
Iron chelate	11.4	13.7	18.0	18.2	9.7	14.2
Iron sulfate	10.9		15.5			13.2
Copper sulfate	9.0	12.7	15.6	16.3	9.6	12.6
Fe 138 + Mn + Zn Chelate		16.6		20.0	10.9	15.8

In four seasons, thirteen micronutrient experiments gave significant increases in sugar beet production in only one case, with slight increases apparent in others. From these data we concluded that, at present, micronutrient fertilization is not generally important in the sugar beet producing areas of southern and west-central Minnesota.

SUMMARY AND CONCLUSIONS

Sugar beet yields and nutrient composition of petioles were studied in southern and west-central Minnesota. Experiments in various locations and seasons included rates of limestone, N-P-K, and micronutrient fertilization. Little response was found where soil test levels were in the high or very high range or where past fertilization with the major elements was heavy.

The data do not support the use of limestone on these southern Minnesota soils, although there was a favorable production trend following its use.

Sugar beet growers who have been using heavy fertilization in the past probably could use less fertilizer in the future because of soil build-up. Additional amounts of fertilizer may be profitable where current soil tests are not high.

Micronutrient fertilization did not affect yield or sugar content in these experiments. Perhaps if sugar beets are grown on other soils and different conditions micronutrients may be beneficial.

Appendix Table 1. Nutrient composition of sugar beet petioles following 1967 and 1968 soil-applied micronutrient fertilizer at Hollandale

1967 treatment	P	K	Ca	Mg	Fe	Zn	Cu	Mn	B
	%	%	%	%	ppm	ppm	ppm	ppm	ppm
Check	.16	4.92	.52	.51	44.3	23.7	6.02	19.7	16.2
Sodium borate	.16	4.83	.52	.50	49.3	22.3	5.53	19.1	18.2
Copper sulfate	.16	4.89	.53	.51	56.9	23.6	6.93	14.0	18.0
Zinc sulfate	.15	4.79	.55	.54	59.2	23.0	5.77	20.2	18.4
Manganese sulfate	.15	4.89	.54	.49	49.7	23.7	5.38	18.4	18.3
(Date of Sampling: August 8, 1967)									
1968 treatment	P	K	Ca	Mg	Fe	Zn	Cu	Mn	B
	%	%	%	%	ppm	ppm	ppm	ppm	ppm
Check	.19	2.98	.75	.77	85.6	17.9	4.57	44.4	24.2
Sodium borate	.18	2.97	.74	.78	79.2	17.6	5.65	44.2	26.5
Copper sulfate	.17	2.63	.79	.82	84.5	16.8	4.43	47.9	25.5
Zinc sulfate	.21	2.98	.73	.79	66.1	18.6	4.73	39.9	25.4
Manganese sulfate	.21	2.67	.72	.73	112.6	19.7	5.56	28.6	24.5
(Date of Sampling: August 21, 1968)									

Appendix Table 2. Nutrient composition of sugar beet petioles following 1967 and 1968 foliar-applied micronutrient fertilizer at several locations

Waseca, 1967

Treatment	P	K	Ca	Mg	Fe	Zn	Cu	Mn	B
	%	%	%	%	ppm	ppm	ppm	ppm	ppm
Check	.26	5.01	.54	.56	45.6	16.5	5.86	46.7	25.9
Sodium borate	.21	4.35	.54	.60	42.9	17.0	4.78	32.8	23.8
Manganese chelate	.21	3.86	.52	.55	40.7	16.7	4.37	28.9	24.4
Manganese sulfate	.23	4.78	.60	.59	71.8	15.8	4.75	43.8	25.6
Zinc fungicide	.24	4.40	.57	.55	61.4	15.9	4.22	32.0	25.4
Zinc chelate	.22	4.33	.62	.58	79.8	15.7	4.55	31.3	25.9
Zinc sulfate	.24	4.76	.53	.50	63.7	18.8	5.95	38.1	25.9
Iron chelate	.24	5.04	.57	.55	60.2	16.4	5.44	34.4	25.8
Iron sulfate	.21	4.46	.51	.55	64.5	16.7	5.14	33.9	25.2
Copper sulfate	.22	5.19	.56	.57	.60.9	18.1	6.04	35.6	25.7

(Date of Sampling: August 16, 1967)

Lewisville, 1967

Treatment	P	K	Ca	Mg	Fe	Zn	Cu	Mn	B
	%	%	%	%	ppm	ppm	ppm	ppm	ppm
Check	.21	3.49	.35	.52	30.3	13.4	5.59	16.5	16.4
Copper sulfate	.25	3.63	.42	.43	701.8	52.2	5.83	29.5	19.8
Zinc sulfate	.22	3.55	.38	.54	90.8	18.2	5.34	21.5	17.3
Zinc chelate	.25	3.60	.35	.46	429.4	35.2	5.59	22.7	18.1
Iron chelate	.23	3.33	.38	.45	79.6	11.7	5.49	25.5	17.9
Manganese sulfate	.30	4.57	.47	.56	334.7	26.1	8.35	35.7	24.4
Manganese chelate	.27	3.77	.37	.33	95.8	15.1	7.23	32.5	19.3
Sodium borate	.22	3.57	.34	.49	13.7	30.5	5.82	18.4	17.1
Zinc fungicide	.23	3.60	.40	.53	454.1	39.0	6.31	18.4	13.3
Iron sulfate	.26	3.89	.35	.41	63.3	13.2	6.21	29.3	19.8

(Date of Sampling: August 16, 1967)

Hollandale, 1968

Treatment	P	K	Ca	Mg	Fe	Zn	Cu	Mn	B
	%	%	%	%	ppm	ppm	ppm	ppm	ppm
Copper sulfate	.17	3.64	.78	.58	84.6	15.5	14.5	40.0	25.6
Zinc sulfate	.15	3.53	.71	.51	81.1	63.1	4.85	50.4	25.7
Zinc chelate	.16	3.32	.70	.53	70.8	18.8	5.60	45.3	24.9
Iron chelate	.17	3.59	.71	.52	85.1	15.9	5.22	31.6	25.2
Manganese sulfate	.17	3.35	.71	.54	79.2	18.4	5.70	51.5	25.0
Manganese chelate	.17	3.38	.74	.51	96.0	17.7	5.30	53.7	24.2
Sodium borate	.17	3.55	.75	.56	116.0	16.6	5.19	38.6	25.9
Zinc fungicide	.17	3.67	.71	.49	77.1	15.5	5.26	35.0	24.3
Fe 138 + Mn + Zn Chelate	.19	3.82	.77	.58	83.8	18.6	5.46	41.5	26.1

(Date of Sampling: August 21, 1968)

Waseca, 1968 Treatment	N	P	K	Ca	Mg	Fe	Zn	Cu	Mn	B
	%	%	%	%	%	ppm	ppm	ppm	ppm	ppm
Copper sulfate	2.33	.24	3.16	.64	.50	72.52	31.20	18.80	181.22	34.7
Zinc sulfate	2.06	.23	3.22	.65	.49	97.28	101.44	5.77	186.70	36.2
Zinc chelate	2.17	.23	3.08	.66	.49	95.14	43.49	6.19	151.06	35.3
Iron chelate	2.03	.19	2.71	.63	.49	114.21	28.77	4.88	170.18	35.5
Manganese sulfate	1.91	.21	2.99	.68	.49	91.07	34.02	5.35	261.76	36.5
Manganese chelate	2.11	.22	2.90	.70	.50	137.88	33.98	5.28	202.03	36.5
Sodium borate	2.16	.23	3.34	.69	.50	74.99	32.57	6.53	192.57	35.8
Zinc fungicide	1.87	.20	3.07	.74	.55	98.34	38.72	5.32	196.99	33.7
Fe 138 + Mn + Zn Chelate	1.84	.21	3.10	.67	.54	121.93	51.79	5.26	197.15	37.4

(Date of Sampling: August 23, 1968)

Lewisville, 1968 Treatment	N	P	K	Ca	Mg	Fe	Zn	Cu	Mn	B
	%	%	%	%	%	ppm	ppm	ppm	ppm	ppm
Copper sulfate	3.30	.23	2.68	.78	.86	114.61	22.16	65.60	103.55	28.9
Zinc sulfate	3.25	.23	2.48	.71	.79	89.79	152.88	7.79	82.81	27.2
Zinc chelate	3.29	.22	2.43	.87	.93	131.90	55.92	6.54	127.21	27.7
Iron chelate	3.11	.21	2.58	.94	.81	125.31	21.04	6.89	97.24	28.8
Manganese sulfate	3.24	.23	2.50	.77	.82	116.35	21.40	7.54	258.37	30.0
Manganese chelate	3.20	.20	2.46	.82	.87	137.10	21.84	7.03	128.84	27.6
Sodium borate	3.33	.22	2.31	.83	.85	110.95	21.13	7.64	106.59	28.8
Zinc fungicide	3.36	.22	2.32	.77	.85	106.14	48.20	7.82	97.88	29.4
Fe 138 + Mn + Zn Chelate	3.28	.22	2.51	.78	.89	144.91	33.51	6.44	116.36	28.9

(Date of Sampling: August 22, 1968)