Table 3. The following soil test is given for both locations.

Location	Texture	PH	Organic Matter		Ex. Phosphorus		Ex. Potassium	
			Per Cent	R. Level	Lbs./A.	R. Level	Lbs./A.	R. Level
Field 17 0-6"	Si Clay	7.5	5.2	M	55	VH	260	H
" 17 6-12"	Clay	7.9	4.2	L	13	M	160	M
Field 40 0-6"	Loam	7.9	4.4	M	20	M	150	M
" 40 6-12"	Loam	8.1	3.5	M	4	VL	100	M

PHOSPHORUS FERTILIZATION OF CONTINUOUS CORN

West Central Experiment Station

Samuel D. Evans

In 1965 a phosphorus experiment was set up to determine (1) the effect of broadcast phosphorus on corn yields and soil test levels, (2) the effect of row phosphorus at two soil test levels, and (3) the effect of high phosphorus applications on the zinc content of corn leaves and on corn yields.

Yield - Bushels/Acre @ 15.5% Moisture

Row Treatment lbs./A / Broadcast Treatment lbs./A	0 P	15 P	30 P	45 P	45 P + 10 Zinc	Average
0 P	94.91	94.91	95.45	97.02	95.78	95.55
45 P	95.42	94.08	94.18	91.31	98.40	94.71
Average	94.68	94.50	94.82	94.16	97.09	

LSD (5%) Average of 2 broadcast fertilizer treatments - - - - - 5.32 Bu./A

LSD (5%) Average of 2 row fertilizer treatments - - - - - - - - 6.27 Bu./A

LSD (5%) Between 2 row means at one broadcast level - - - - - 7.45 Bu./A

LSD (5%) Between 2 broadcast means at one row level - - - - - - 9.19 Bu./A

Coefficient of variation (a) 8.42%

Coefficient of variation (b) 7.37%.

Initial soil tests (Barnes silty clay loam)

PH - 6.6 Organic Matter - 6.7%

Extractable phosphorus - 19 Exchangeable potassium - 353

Comparison of Phosphorus Sources

A. C. Caldwell, E. C. Seim, G. W. Rehm

A phosphorus source experiment was established at Rosemount in 1951. Twelve treatments of various phosphate materials were replicated four times across a regular rotation of corn, soybeans, wheat, and alfalfa. Potassium has been applied as required according to soil test. Lime applications were made on two replicates in the fall of 1961.

A prolonged drought in the summer of 1964 eradicated the alfalfa stands so no hay yields were obtained in 1965. To compensate for the poor alfalfa growth in 1964, the 1965 corn was given a sidedressed application of 60 lbs. of N/acre. The 1965 corn yields are reported in the following table.

The effect of various phosphate fertilizers on yield of corn, wheat, and soybeans.

(Port Byron silt loam - Rosemount-1965)

Treatments	Rate	Corn	Wheat	Soybeans
	lbs. P_2O_5/A/Yr.	Bu./A.	Bu./A.	Bu./A.
None	0	111.1	12.3	16.8
Ord. Superphosphate	40	125.4	19.8	15.7
Conc. Superphosphate	40	125.2	23.3	16.3
Calcium metaphosphate	40	129.4	18.0	18.6
Phosphoric Acid	40	124.7	19.4	20.1
Fuzed Tricalcium phosphate	40	127.5	17.6	18.4
Florida Rock and ord. Super.	20 + 20	128.8	20.1	21.1
Florida Rock	100	118.9	16.5	18.1
	lbs. P_2O_5/A./4 yrs.			
Fl. Rock Phosphate	1000	130.4	18.3	18.9
Western Rock Phos.	1000	123.9	17.4	20.3
Colloidal clay rock phos.	1000	121.0	12.4	18.3
Tunisian rock phos.	1000	121.8	18.0	16.7

Corn yields were increased by all phosphate treatments. Increases ranged from 7.8 bushels per acre for Florida rock phosphate applied at the rate of 100 lbs. of P_2O_5/acre annually to 19.4 bushels when the Florida rock was applied every 4 years at the 1000 lbs. P_2O_5 per acre rate. The last heavy rock phosphate applications were made in 1963. The last heavy applications at Tunisian rock phosphate occurred in 1962.

Wheat yields, although adversely affected by climatic conditions and rust infections, were increased from 0.1 to 10.9 bushels per acre by phosphate treatments. Poorest response was obtained from colloidal clay rock phosphates. Best response was obtained from concentrated superphosphate. Generally the more readily available phosphates gave the best response.

Soybean yields were generally low due to the poor growing conditions early and late in the season. Many pods did not mature completely before frost. No pattern of phosphate response is evident in the 1965 yields.

In past years all phosphate treatments have produced yield increases in alfalfa. Wheat yields have been increased in some years. Corn yields have also shown increase in past years but no particular treatment has been consistently superior to the others. In 1963 and 1964 soybean yields showed small but consistent increases due to the phosphate treatments.

The effect of lime and molybdenum on the yield of alfalfa, oats, corn, and soybeans.

A. C. Caldwell, E. C. Seim, G. W. Rehm

The purpose of this experiment, started in the fall of 1951, is to study the long time effects of lime on (1) the yields of some common crops, and (2) on the physical and chemical properties of the soil. Treatments of 0, 3, 6, 12, and 24 tons of dolomitic lime per acre were applied on 4 replications in 1951. A rotation of corn, oats, and 2 years of alfalfa was established. Each year corn and oats have received 200 lbs. of 5-20-20 per acre. The alfalfa has received P and K as needed according to soil test. Since 1959 soybeans have replaced one year of alfalfa in the rotation. The beans receive 100 lbs. of 5-20-20 starter fertilizer per acre.

In 1960, molybdenum as $(NH_4)_2 MoO_4$ was applied at the rate of 8.7 ounces per acre on one of the check plots in each replicate.

In 1965 yields were obtained for corn, oats and soybeans. Alfalfa yields were not taken as most of the stand was lost during the 1964 drought. The 1965 yields are reported in the accompanying table.

Effect of lime and molybdenum on yields of corn, oats, and soybeans.

(Port Byron silt loam - Rosemount, 1965).

Lime Treatment	Corn		Oats		Soybeans	
Tons/A.	Bu./A.	Diff.	Bu./A.	Diff.	Bu/A.	Diff.
0	125.0	-	92.5	-	18.8	-
3	134.5	+9.5	82.5	-10.0	17.5	-1.3
6	126.7	+1.7	89.9	- 2.6	17.3	-1.5
12	133.8	+8.8	92.9	+ 0.4	17.2	-1.6
24	130.7	+5.7	95.8	+ 3.3	19.4	+0.6
0 + 8.7 oz. Mo/acre	127.8	+2.8	93.2	+0.7	16.8	-2.0
		N.S.		N.S.		N.S.

All treatments gave increases in corn yield but these were not significant at the 5% probability level. Oat yields were good but there was an excessive amount of plot variation due to lodging on some reps. No significant differences in soybean yield were recorded.

In past years the major effect of liming has been on the yield of alfalfa which has been doubled by the lime treatments. The molybdenum treatment has also produced yield increases in the alfalfa.

Sulfur Investigations on Soils and Crops

Report No. 7.

A. C. Caldwell, J. Grava, E. C. Seim, G. W. Rehm, Chih-ning Sun,

R. S. Adams, and W. P. Martin

Department of Soil Science

University of Minnesota

The current research on sulfur had its beginning in 1962. Since that time major investigations have included studies on the oxidation of elemental sulfur in soil, effects of rates and kinds of sulfur-bearing materials on field crops, the movement of sulfur in soil, the measurement of sulfur in the atmosphere and rainfall, development of a satisfactory method for the determination of sulfur in plant tissue, an examination of the S-bearing compounds present during oxidation of elemental sulfur in soil, studies on the effects of soil type characteristics on sulfur oxidation, and an evaluation of the S-supplying power of some of the major soil types of Minnesota.

This report includes primarily the results of the field trials at the Park Rapids experimental site, for 1965, and other information gathered since June 1965.

Appreciation is expressed to the Sulphur Institute and the Tennessee Valley Authority for help in the financing of these studies.

Field Research

E. C. Seim

In 1965 studies on sulfur were carried on at the Park Rapids, Minnesota sulfur experimental field. Experiments begun in previous years on alfalfa, corn, soybeans, and sunflowers were continued in 1965. In addition new experiments on potatoes, corn and small grains were initiated. Supplemental irrigation facilities became available in 1965. The potatoes were irrigated on a regular schedule and other crops on a supplemental basis only.

Alfalfa

Two studies with several rates and types of sulfur on alfalfa were established in 1962. One study measures the effect of the various materials applied annually. The other study measures the residual effect of the 1962 sulfur treatments. The experiments compare the effects of three rates of elemental sulfur (25, 50, 100 lbs. S/acre) and a 50 lb. S/acre application of gypsum with a control (0 lbs. S/acre). An additional heavy gypsum application (1000 lbs. S/acre) was included in the residual study. All plots received complete applications of phosphorus and potassium according to soil tests at the beginning of the experiment. Borax (20 lbs/acre) was applied after the 1st cutting in 1962. Additional potassium has been topdressed as needed. The results of previous years have been presented in reports 1-6.

In 1965 three cuttings of alfalfa were taken. The 1965 yield results for the annually applied S treatments are reported in Table 1. Table 2 contains the 1965 yield results for the residual treatments.

The difference between the controls and the treated plots increased with each successive cutting. For the first cutting the yields of the treated plots

Table 1. Effect of annual applications of sulfur-bearing materials on the yield of alfalfa (1965).

Material	Rate lbs.S/acre	Yield 1st cut tons/acre	2nd cut tons/acre	3rd cut tons/acre	Total tons/acre
None	0	1.31	0.56	0.25	2.11
Sulfur	25	2.35	1.55	0.91	4.81
Sulfur	50	2.40	1.72	0.83	4.94
Sulfur	100	2.49	1.46	0.74	4.68
Gypsum	50	2.59	1.63	0.87	5.09
lsd (.05)		.35	.32	.19	.62
(.01)		.48	.43	.26	.84
hsd (.05)		.51	.46	.27	.88
(.01)		.64	.57	.34	1.11

Table 2. Residual effect of sulfur-bearing materials on the yield of alfalfa. (1965)

Material	Rate lbs. S/acre *	Yield 1st cut tons/acre	2nd cut tons/acre	3rd cut tons/acre	Total tons/acre
None	0	1.33	0.54	0.33	2.19
Sulfur	25	2.16	0.96	0.65	3.78
Sulfur	50	2.24	1.35	0.71	4.30
Sulfur	100	2.51	1.57	0.84	4.92
Gypsum	50	2.18	1.20	0.70	4.08
Gypsum	1000	2.46	1.36	0.86	4.67
lsd (.05)		.41	.34	.22	.64
(.01)		.55	.45	.30	.87
hsd (.05)		.58	.48	.32	.91
(.01)		.72	.59	.40	1.13

* applied in 1962.

were at least 1.8 times larger than the checks. For the second cutting they were 2.6 times larger and for the third cutting they were more than 2.9 times larger than the checks. The comparable figures for the residual study are 1.6, 1.7, 1.9. The figures therefore indicate that sulfur from natural sources (atmospheric and soil) are rapidly exhausted by the first cutting. As a consequence of the exhaustion of sulfur supply and possibly also because of enzyme and protein deficiencies present in the untreated plants, recovery of the alfalfa on the check plots following the first cutting was much slower than recovery of the treated alfalfa.

The highest yielding annual treatment was 50 lbs. of sulfur per acre as gypsum but there was no significant difference between the yields of the treated plots. The highest yielding residual treatment was 100 lbs. of sulfur per acre from elemental sulfur.

The residual data in 1965 indicate that although the 25 lbs. per acre elemental sulfur treatment is still producing 1.7 times more hay than the checks they are not producing the maximum yield possible when sulfur is non-limiting. The yields from plots treated with 50 lbs. of sulfur as gypsum also show some evidence that they are beginning to tail off.

The total sulfur content of the alfalfa tissue was determined for each cutting by the nitric perchloric acid digestion method developed by Rehm and Blanchar. The results are shown in table 3 for the annually treated plots and in Table 4 for the residual study. As in previous years all sulfur treatments significantly increased the sulfur content of the alfalfa. The sulfur level of the untreated alfalfa is in the critical range for the 1st and 2nd cuttings. All of the percentages for the third cutting are somewhat higher.

Table 3. Effect of annual applications of sulfur-bearing materials on the sulfur content of alfalfa (1965).

Material	Rate lbs. S/acre	Sulfur content of tissue (%) 1st cut	2nd cut	3rd cut
None	0	0.175	0.145	0.221
Sulfur	25	0.291	0.267	0.392
Sulfur	50	0.304	0.312	0.422
Sulfur	100	0.363	0.366	0.520
Gypsum	50	0.271	0.307	0.421
lsd (.05)		.054	.032	.055
(.01)		.073	.043	.072
hsd (.05)		.077	.045	.079
(.01)		.096	.056	.098

Table 4. Residual effect of sulfur-bearing materials on the sulfur content of alfalfa (1965).

Material	Rate lbs. S/acre	Sulfur content of tissue (%) 1st cut	2nd cut	3rd cut
None	0	0.151	0.136	0.222
Sulfur	25	0.176	0.146	0.213
Sulfur	50	0.216	0.173	0.288
Sulfur	100	0.260	0.212	0.316
Gypsum	50	0.179	0.147	0.223
Gypsum	1000	0.326	0.268	0.413
lsd (.05)		.026	.042	.052
(.01)		.035	.057	.071
hsd (.05)		.037	.060	.074
(.01)		.045	.074	.092

This is probably due to the third cutting being taken at a less mature stage than the 1st and 2nd cuttings in order to allow time for recovery before frost.

In the annually treated plots 100 lbs. S/acre as elemental sulfur produced the hay with the highest sulfur content. On the residual study, the heavy gypsum application (1000 lbs. S/acre in 1962) has produced hay with the highest percent of sulfur. The sulfur contents of the 25 lb. per acre elemental sulfur treatments and the 50 lbs. S per acre gypsum treatments also give indications that effects of these two treatments are beginning to diminish.

Alfalfa following corn

Alfalfa was seeded in 1963 to an area which had been in corn in 1962. Treatments were modified to include a check; the residual effect of elemental sulfur applied in 1962 at the rate of 25, 50 and 100 lbs. of S per acre; gypsum at 60 lbs. S per acre; the residual effect of 10 lbs. of S per acre as K_2SO_4 and 16-20-0-S applied to the corn; and a sulfur plus trace element treatment that supplied a total of 25 lbs. of sulfur per acre. No additional sulfur was applied in 1964 or 1965. In 1964 only the second cutting was taken for yield as the 1st cutting was severely hit by drought. In 1965 supplemental irrigations made it possible to obtain three cuttings. The yield data are reported in Table 5. Yields up to 4.8 tons per acre were obtained on the gypsum treated plots. The total yield for the check plots averaged 2.0 tons/acre.

In 1964 the plots which had received trace elements plus sulfur produced the top yields (but differences between treatments were slight). In 1965 the yields of the trace element plus sulfur plots were clearly below the yields of

Table 5. Effect of sulfur-bearing materials on theyield of alfalfa following corn. (1965)

Material	Rate lbs. S/acre	Date of Application	Yield (tons/acre) 1st cut	2nd cut	3rd cut	Total
None	0		1.03	0.51	0.45	2.00
Sulfur	25	1962	1.88	1.24	0.84	3.62
Sulfur	50	1962	2.14	1.34	1.03	4.51
Sulfur	100	1962	2.21	1.39	0.93	4.53
Gypsum	60	10 lb. S. in 1962 50 lb. S. in 1963	2.36	1.44	1.04	4.83
K_2SO_4	10	1962	1.57	0.90	0.65	3.12
16-20-0-S	10	1962	1.35	0.62	0.50	2.48
Trace + S	25	10 lb. S/acre as Zn-Mn-N-S 1962 15 lbs. S/acre as trace element mixture in 1963	2.11	1.29	0.81	4.22
lsd (.05)			.28	.43	.17	.66
(.01)			.37	.58	.23	.88
hsd (.05)			.44	.69	.28	1.05
(.01)			.54	.83	.33	1.27

the gypsum or heavier elemental sulfur treatments. Although the different levels and times of sulfur application make comparisins between treatments difficult, it appears that there has been no beneficial effect of the trace-elements in raising the yield above what might have been expected from an equal application of readily soluble sulfate sulfur.

The sulfur content of the alfalfa tissue is reported in Table 6. The data indicated that sulfur has reached a limiting level on the NPS and K_2SO_4 treated plots, and near-limiting on those which received 25 lbs. per acre as elemental sulfur. Despite the low levels of sulfur in the tissue on these plots yield increases were still obtained.

Small Grain

In 1965 the effects of sulfur-treatments on the yield of small grain were conducted using Traill Barley, Lodi Oats, and Chris Wheat. All plots received a broadcast application of 30 lbs. of N per acre, 35 lbs. of P per acre, and 249 lbs. of K per acre and100 lbs. per acre of sulfur free 12-32-16 starter applied in the row at planting time. Treatments consisted of 10 lbs. of sulfur per acre as elemental sulfur, gypsum or sodium sulfate applied in the row at planting. Treatments were replicated five times for each small grain.

The results of the sulfur treatments on the yield on the sulfur content of the whole plant at the time of heading out and on the sulfur content of the grain are shown in Table 7 for barley, Table 8 for oats, and Table 9 for wheat.

Barley yields ranged from 38.1 to 46.5 bushels per acre. There were no significant differences in yield between treatments. Gypsum and sodium

Table 6. Effect of sulfur-bearing materials on the sulfur content of alfalfa following corn. (1965)

Material	Rate lbs. S/acre	Date of Application	Sulfur Content of Tissue (%) 1st cut	2nd cut	3rd cut
None	0		0.144	0.134	0.232
Sulfur	25	1962	0.171	0.147	0.255
Sulfur	50	1962	0.211	0.163	0.315
Sulfur	100	1962	0.249	0.233	0.318
Gypsum	60	10 lbs. S in 1962 50 lbs. S in 1963	0.244	0.207	0.300
K_2SO_4	10	1962	0.153	0.133	0.194
16-20-0-S	10	1962	0.187	0.133	0.219
Trace + S	25	10 lbs. S/acre as Zn-Ma-N-S in 1962 15 lbs. S/acre as Trace Elem mix in 1963	0.189	0.166	0.240
lsd (.05)			.042	.029	.055
(.01)			.057	.040	.074
hsd (.05)			.068	.48	.089
(.01)			.081	.057	.106

Table 7. Effect of sulfur-bearing materials on the yield and sulfur content of Barley. (1965)

Material	Rate lbs. S/acre	Yield bu/A	Sulfur Content whole plant %	grain %
None	0	39.9	0.124	0.116
Gypsum	10	43.1	0.164	0.124
Elem. Sulfur	10	38.1	0.180	0.133
Na_2SO_4	10	46.5	0.171	0.132
lsd (.05)		N.S.	N.S.	.009
(.01)				.013
hsd (.05)				.012
(.01)				.016

Table 8. Effect of sulfur-bearing materials on the yield and sulfur content of oats. (1965)

Material	Rate lbs. S/acre	Yield bu/A	Sulfur Content whole plant %	grain %
None	0	55.9	0.160	0.139
Gypsum	10	55.8	0.159	0.142
Elem. Sulfur	10	49.4	0.181	0.155
Na_2SO_4	10	56.0	0.185	0.156
lsd (.05)		N.S.	N.S.	.109
(.01)				.153
hsd (.05)				.149
(.01)				.195

sulfate had a tendency to increase the yield from 3 to 6 bushels. Elemental sulfur had a negligible or slightly negative effect on the yield.

Sulfur content of the whole plants was increased by treatment but due to a wide variation these differences were not significant. The sulfur content of the grain did show a significant increase although the magnitude of the increase was not large.

Table 9. Effect of sulfur-bearing materials on the yield and sulfur content of wheat. (1965)

Materials	Rate lbs/A	Yield bu/A	Sulfur Content whole plant %	grain %
None	0	19.6	0.166	0.159
Gypsum	10	21.8	0.174	0.163
Elem. Sulfur	10	20.8	0.219	0.187
Na_2SO_4	10	21.9	0.208	0.178
lsd (.05)		N.S.	.011	.015
(.01)			.015	.021
hsd (.05)			.015	.020
(.01)			.020	.026

Oat yields ranged from 49.4 to 56.0 bushels per acre. The interpretation of the data is similar to that for barley. There were no significant differences in yield but elemental sulfur had a slight tendency to decrease yield. The sulfur content of the grain was significantly increased by all of the sulfur treatments.

Wheat yields ranged from 19.6 to 21.9 bushels per acre. No significant differences in the yields were observed. There were significant increases, however, in the sulfur content of the whole plant and in the sulfur content of the grain.

Corn

In 1965 the effect of sulfur on corn was studied in two experiments. The first was a continuation of the continuous corn study established in 1963. As the corn was still immature when the first fall frosts threatened silage yields were taken. Two weeks later the corn had matured sufficiently to make ear corn yields meaningful. The corn still showed considerable variation in maturity and moisture content. The 1965 yields are reported in Table 10. The sulfur contents of the 6th leaf samples taken at the time of silking are included in Table 10 and seem to indicate that all of the sulfur applied in 1963 has been removed by the three corn crops or has otherwise become unavailable to the plant roots due to position or form. There were no significant differences in yield.

The second study involving sulfur fertilization of corn was placed on a new area which was plowed out of sod in the fall of 1964. The data of previous years indicated that a sulfur deficiency on corn would be most likely to occur on corn following sod in a cold wet year. Under these conditions the oxidation of the sulfur from the organic matter would be retarded and no buildup of available sulfur due to cultivation would have had a chance to occur. Only one sulfur treatment was used, 10 lbs. of sulfur per acre as Na_2SO_4. The corn received a basic fertilizer application of 150# N/acre as ammonium nitrate; 25# P/acre as 0-54-0; and 200# K/acre as 0-0-62. A sulfur-free starter (5-10-30) was used at the rate of 300 lbs. /acre. The corn was thinned to a final population of 18, 300 plants per acre. Supplemental irrigation was applied as needed.

Within two weeks from the time of planting the corn on the untreated plots was showing chlorosis and veination. Within another week the deficiency

symptoms were general on the untreated plots giving the experimental area a checkerboard effect. In addition to the deficiency symptoms which generally follow the pattern for sulfur deficiency described by Fox et al. (1961),* the untreated corn averaged from 6 to 12 inches shorter than the treated corn. At this time the corn was side dressed with 60# N. From this point on the deficient corn began to outgrow the deficiency.

Samples of the deficient and normal corn plants were taken for sulfur analysis on a weekly basis from the onset of the deficiency until the corn was knee high, and again at silking time. The early samples consisted of whole plants. At silking time the 6th corn leaf was sampled. In addition samples were taken of the corn grain at harvest. The results are reported in Table 12.

The silage yields, percent moisture in ears at harvest and the ear corn yields are reported in Table 11. The untreated corn had outgrown the deficiency by late July and consequently no differences were observed in the silage yield. The treated corn was more mature, 4% drier, and produced 9.1 bushels more ear corn than the untreated corn.

Sulfur deficiency symptoms were observed in several other fields in Hubbard County and in a TVA cooperator's field in Todd County. Samples from the Voghtman field in Hubbard County were the most striking in the development of the symptoms. The corn never outgrew the stunting because of a severe summer drought. The sulfur content of a sample of the deficient plants was 0.165%.

Near Batavia, Minnesota, in Todd County, deficiency symptoms similar to those observed at Park Rapids were observed in a TVA-cooperators field. Corn which had received the 8-16-32 starter fertilizer was deficient and stunted. The sulfur content of the tissue was 0.228%. In the same field corn

which had received 5-20-20 starter fertilizer was healthy and the sulfur content of the tissue was 0.270%.

Table 10. Effect of sulfur on the yield and sulfur content of 3rd year corn.

Material	Rate lbs. S/acre (applied in 1963)	Silage yield Tons/acre	Ear corn yield Bu/acre	Sulfur content 6th leaf %
None	0	5.31	75.7	.197
Na_2SO_4	5	5.59	71.0	.195
"	15	5.29	75.8	.199
"	25	5.41	75.9	.207
		N.S.	N.S.	N.S.

Table 11. Effect of sulfur on the silage and ear corn yield of corn after sod. (1965)

Treatment	Rate lbs. S/acre	Silage yield	Ear Corn Moisture %	Ear Corn Yield Bu/acre
None	0	6.04	50.6	73.8
Sulfur (Na_2SO_4)	10	6.20	46.0	82.9

Table 12. Effect of sulfur on the sulfur content of corn after sod. (1965)

Treatment	Rate lbs. S/acre	Sulfur Content of Tissue Sampling			
		6-23-65	6-30-65	7-8-65	6th Leaf
None	0	.225	.235	.242	.200
Sulfur (Na_2SO_4)	10	.356	.280	.260	.238

Sunflowers

The study on the effect of sulfur on the yield of sunflower seed was continued in 1965. No additional applications of sulfur were made in 1965. All plots received 80 lbs. of P_2O_5/acre as 20-52-0 and 300 lbs. of K_2O/acre as 0-0-62. The 1965 yields are reported in Table 13. No effects of sulfur on the yield of sunflower seed were observed in 1964 or 1965. In 1965 yields ranged from 440 lbs. to 1090 lbs. /acre. Plots in the interior of the field produced less seed than the exterior plots regardless of treatment.

Table 13. Effect of sulfur on the yield of sunflower seed.

Treatment	Rate lbs. S/acre	Yield lbs. /acre
None	0	777.4
Gypsum	50	678.7 N.S.

Soybeans

The soybean study initiated in 1963 was continued in 1965. No additional applications of sulfur were applied. All plots received applications of P (100# P/acre as 0-54-0) and K (150# K/acre as 0-0-62) before planting in 1965.

The 1965 soybean yields are reported in Table 14. The maturity of the beans was delayed by the cool season but advanced sufficiently to make a harvest possible. Increases in yield up to 2.9 bu/acre due to the residual sulfur treatments were recorded. The statistical analysis of the data is not yet complete, however, and it is not known how significant these increases will be. In previous years there have been no significant differences in yields due to sulfur.

Table 14. Effect of sulfur-bearing materials on the yield of soybeans (1965).

Treatment	Rate lb. S/acre (applied in 1963)	Yield bu/acre
None	0	14.9
Sulfur	25	16.2
Sulfur	50	17.6
Gypsum	50	17.8

Red-Clover-Brome

In 1965 no yields were taken from the newly seeded red clover-brome plots. The plots were clipped to a height of 6 to 8 inches in late August to control weeds. Visible color differences were noticed between the checks and treated plots before frosts in the fall.

Potatoes

In 1965 the availability of irrigation made it possible to conduct a study on potatoes at yield levels for which sulfur might become limiting. Two sulfur-bearing materials (elemental sulfur and gypsum) at the rate of 50 lbs. of S/acre were compared with a control. Basic applications of 500# K/acre, as 0-0-62, 200# N/acre as 33-0-0, and 50# P/acre as 0-54-0 were applied before planting. Plots were replicated six times. The variety Bounty was chosen because of its ability to outyield other varieties under irrigation. Irrigation was begun when the plants were about 12" tall and continued on a regular schedule until late August. Plant petioles and leaves were analyzed for sulfur. Yields were recorded, and the quality of potatoes was checked by running specific gravity on representative samples from each plot.

Yields, percent total solids, and percent total sulfur in the petioles are reported in Table 15. The differences in yield are not significant. Potato quality as measured by specific gravity test and converted to total solids was also unaffected by the sulfur treatments. There were large differences in the sulfur content of the potato petioles taken at midseason.

Table 15. Effect of Elemental Sulfur and Gypsum on the Yield, Total Solids, and Sulfur Content of Irrigated "Bounty" potaotes.

Treatment	Rates lbs. S/acre	Yield bu/acre	Total Solids %	Total Sulfur in petioles %
None	0	645	20.8	.199
Sulfur	50	647	21.1	.318
Gypsum	50	668	21.2	.344

Sulfur in the Atmosphere

The collection and analysis of rainwater for sulfur and the measurement of the SO_2 content of the atmosphere by the lead peroxide "candle" method has continued. The data recorded for the months of May 1965 to August 1965 are reported in Table 16. Previous monthly data has been reported in reports 1-6.

Work in Progress

The collection and analysis of rain and snowfall and the analysis of SO_2 in the atmosphere by means of lead peroxide coated "candles" is continuing.

Additional tissue analyses are being completed on potatoes, corn and soybeans. Where applicable samples are being checked for interactions with N, P and K.

Table 16. Sulfur in the atmosphere and sulfur in precipitation at four locations in Minnesota from May 1965 to August 1965.

Period	Rainfall (inches)	S in Rainfall (lbs/A)	SO_2 in atmosphere (lbs S/A)
	St. Paul		
May	3.29	1.97	2.47
June	5.36	1.01	1.44
July	3.75	.81	2.09
August	3.59	1.17	1.44
	Park Rapids		
May	3.50	.79	1.31
June	5.59	.66	.64
July	1.60	.43	.85
August	2.61	.28	.69
	Duluth		
May	2.93	1.16	1.85
June	3.53	1.45	.89
July	3.57	1.09	.98
August	3.90	--	.65
	Lamberton		
May	7.33	1.50	1.91
June	2.60	.64	.59
July	2.55	.82	.69
August	1.69	.37	.98

Leaching of Sulfate Sulfur

A leaching study was established in the spring of 1964. Sulfur treated plots received 200 lbs. of sulfur per acre as gypsum. Sweet corn was grown on both treated and untreated plots. In 1965 one half of the plots were irrigated on a schedule to provide 1 inch of water every ten days. Soil samples were taken at 6 inch intervals to a depth of 36 inches at the close of the 1964 growing season (Sept. 26) and in the spring and fall of 1965. (May 8th and Sept. 24, 1965)

Sulfate sulfur in the core samples was extracted with .15% of $CaCl_2$ and measured turbidimetrically as $BaSO_4$.

The detailed results of the fall 1964 sampling were given in the previous report (Report No. 6).

The results of the 1965 spring sampling are shown in Table 18. Table 17 presents the results of the fall 1965 sampling.

The results are presented graphically in Figures 1 and 2.

There was no difference in sulfate in the profile of the untreated plots between the spring and fall samples. On the treated plots there was a significant decrease in the sulfur content of the profile between the spring of 1965 and fall 1965. The peak S content was still found in the 12-18 samples but had decreased from about 20 ppm to 9.6 ppm.

A comparison of the treated plot data for the spring of 1965 with the results of the previous fall (1964) indicates that there was little change in the sulfate content of the upper profile during the winter. Below 18 inches the average sulfate content did decrease by about 5 ppm during the winter months.

Table 17. Sulfate sulfur in the profile of a Dorset sandy loam on September 24, 1965.

Treatment	Core	Plot	Depth of Sample (inches) 0-6	6-12	12-18	18-24	24-30	30-36	Total Sulfate Sulfur 0-36"
			ppm S.						lbs S/acre
Unirrigated	1	1	6.8	5.0	5.8	5.0	5.0	5.0	
			7.5	4.8	5.8	5.0	5.0	5.0	
No. S.	2	"	2.5	2.3	3.3	1.5	1.5	1.5	
			2.5	7.0	3.0	1.5	1.5	2.0	
	3	"	2.0	2.0	2.3	2.3	2.3	2.5	
			2.0	2.0	2.3	2.3	2.5	2.5	
	Average		3.9	3.2	3.8	2.9	3.0	3.1	39.8
Irrigated	7	3	4.8	4.0	4.8	2.5	2.8	2.5	
			4.8	4.8	4.8	2.8	2.8	2.8	
No. S.	8	"	4.0	3.3	2.8	3.3	2.8	2.5	
			4.0	2.8	3.3	3.3	3.3	2.5	
	9	"	2.8	2.3	2.8	1.8	1.5	1.5	
			2.5	2.3	2.8	2.8	1.5	1.5	
	Average		3.8	3.3	3.6	2.8	2.5	2.2	36.4
Unirrigated	4	2	4.0	9.8	14.3	8.8	9.5	5.8	
			4.0	9.5	15.0	8.8	9.5	6.3	
Gypsum @ 200 lb. S/acre in 1964	5	"	4.8	3.0	6.0	3.5	3.5	3.5	
			5.0	3.0	6.0	3.5	3.5	3.5	
	6	"	9.8	7.8	8.0	9.5	7.8	7.5	
			9.8	7.8	8.3	9.5	7.5	8.0	
	Average		6.2	6.8	9.6	7.3	6.9	5.7	85.0

Table 18. Sulfate sulfur in the profile of a Dorset sandy loam on May 8, 1965.

Treatment	Core	Plot	Depth of sample (inches) 0-6	6-12	12-18	18-24	24-30	30-36	Total Sulfate Sulfur 0-36"
			ppm S.						lbs S/acre
No. S.	1	1	3.5	2.5	3.0	1.5	2.5	2.0	
			3.5	3.8	2.5	2.5	2.5	1.5	
	2	"	5.3	4.5	5.3	7.0	3.8	4.3	
			6.0	4.3	6.3	5.3	4.3	5.0	
	3	"	4.0	2.8	3.0	2.0	2.0	1.5	
			4.0	2.8	3.0	2.5	2.0	3.0	
	7	3	4.5	2.5	2.8	2.8	2.3	3.0	
			4.0	4.0	2.0	2.8	2.8	3.0	
	8	"	4.8	1.8	3.3	3.0	2.5	2.8	
			5.0	2.5	3.0	2.8	2.5	2.8	
	9	"	6.3	3.5	3.0	2.5	2.5	2.5	
			6.3	3.5	3.3	2.5	2.5	2.5	
	Average		4.7	3.2	3.4	3.1	2.7	2.8	39.8
Gypsum @ 200 lbs S/acre	4	2	9.5	16.5	23.8	7.5	2.5	2.5	
			9.0	15.0	23.8	7.5	2.5	2.5	
in Spring 1964	5	"	7.3	19.5	18.8	4.5	3.5	3.0	
			7.3	19.5	19.0	4.5	3.5	2.5	
	6	"	9.0	37.5	23.8	5.0	1.5	1.5	
			9.0	37.5	23.8	5.0	1.5	1.5	
	10	4	11.3	23.0	19.8	8.3	2.8	3.8	
			11.3	23.0	17.8	8.3	2.8	3.8	
	11	"	9.8	20.0	21.5	9.8	8.8	11.5	
			10.0	20.3	22.0	9.8	7.5	9.8	
	12	"	16.3	13.3	16.5	11.3	9.0	6.5	
			15.5	15.8	17.5	11.3	9.0	6.5	
	Average		11.4	21.7	20.8	7.7	4.6	4.6	141.6

Figure 1
Sulfate sulfur in the profile of a Dorset sandy loam.

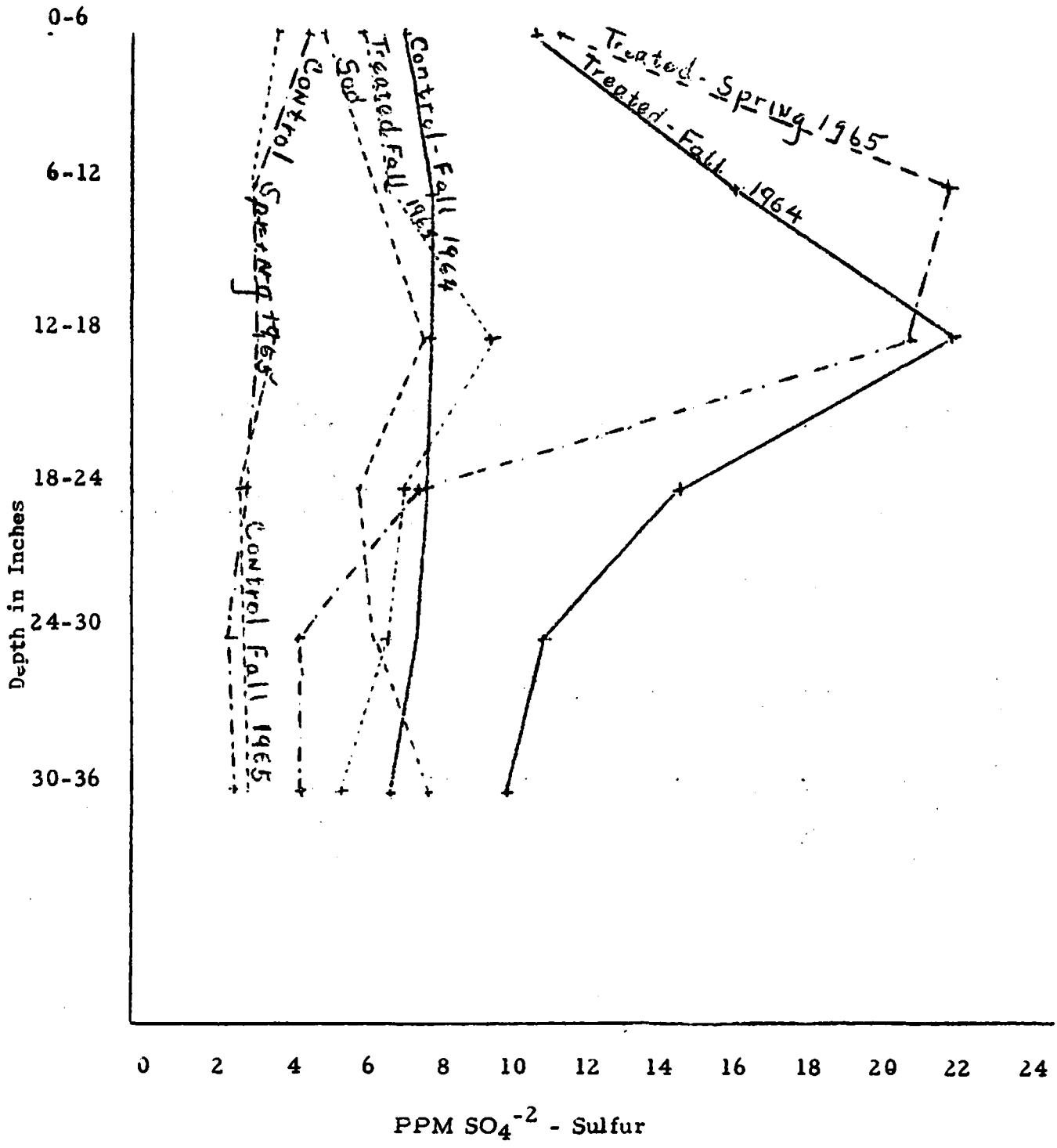
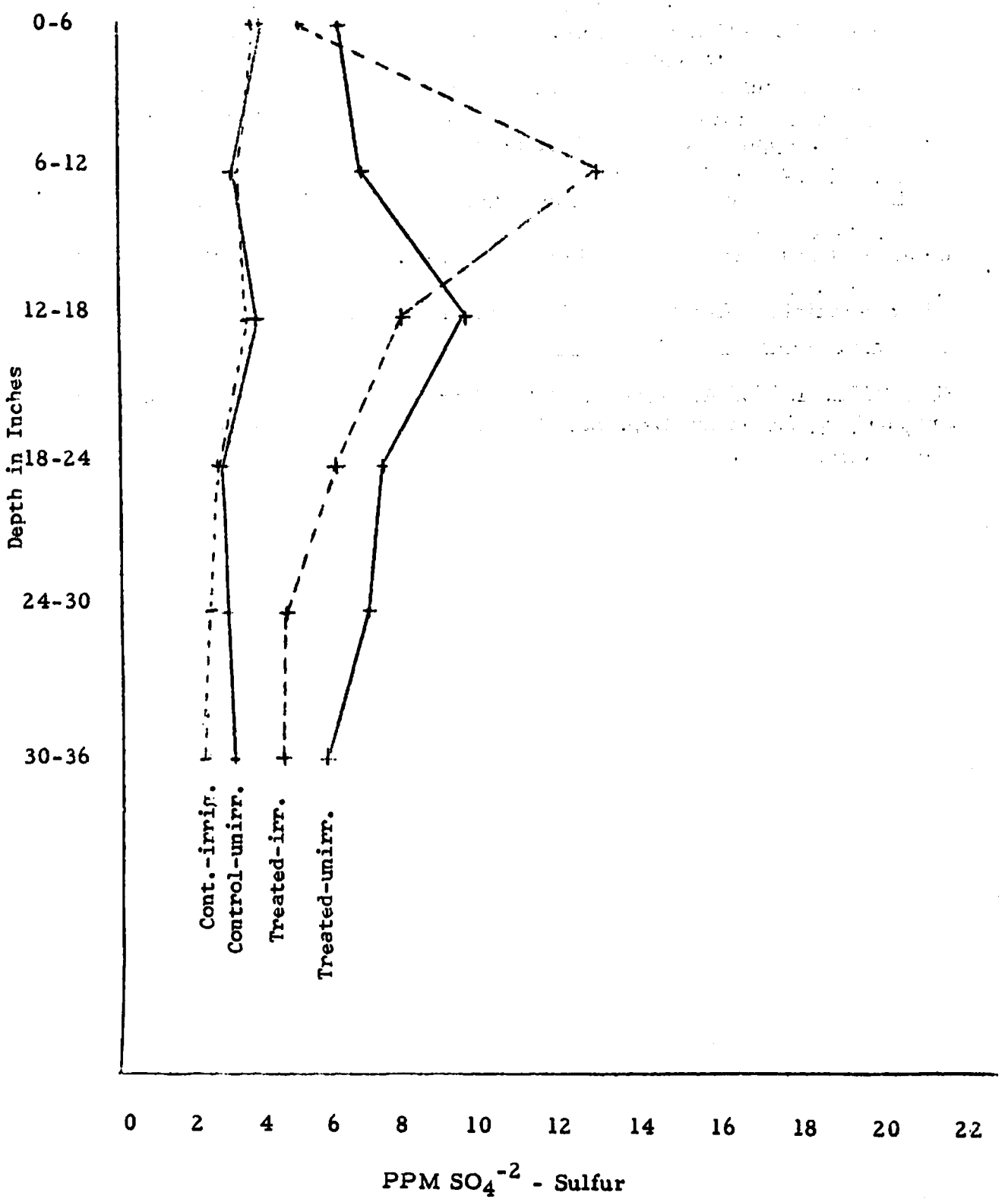


Figure 2
The effect of irrigation on the Sulfate sulfur in the profile of a Dorset sandy loam.



Irrigation caused no change in the sulfur content of the profile samples of the untreated plots. The sulfur content of the irrigated plot samples which had received the sulfur applications in 1964 averaged about 1 ppm less than the unirrigated treated plot samples. The one exception to this was observed in the 6-12 inch sample. If the one core sample which was very high in sulfate sulfur at this level is not used in calculating the averages, a value of 7. 4 ppm is obtained instead of 13. 3 ppm.

If the amount of sulfate sulfur in the control profile is subtracted from the amount in the treated profile we obtain 45. 2 lbs. or 22. 6% the applied sulfur remaining after two growing seasons and one winter.

Fox, R. L. and C. A. Hoover; Sulfur Fertilizers aid Corn and Soybean Production. Nebraska Exp. Sta. Quart. Winter 1961.

Sulfur Investigations on Soils and Crops
(Summary)

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A program of sulfur research on soils and crops in Minnesota was begun in 1962. Financial assistance was provided by the Sulphur Institute and the Tennessee Valley Authority. Studies have been conducted in the field, greenhouse and laboratory. Major investigations have included effects of rates and kinds of sulfur-bearing materials on the yield and sulfur content of field crops, (2) the movement of sulfur through the soil, (3) sulfur in the atmosphere and precipitation, (4) oxidation of elemental sulfur in the soil, (5) evaluation of sulfur supplying power of various soils. Field work is conducted in northcentral Minnesota at the sulfur experimental field, Park Rapids.

Most striking and consistent yield responses to sulfur treatments have been obtained with alfalfa. Sulfur, applied either as gypsum or as elemental-S has been an important factor in the establishment and maintenance of alfalfa. Sulfur treatments have more than doubled forage yields, and increased the S content of alfalfa.

Discoloration was observed in corn (after sod) on plots without S treatments in the early stages of growth. Corn receiving 10 lbs./acre of S had normal appearance. The discoloration in corn gradually disappeared after the application of sidedressed nitrogen and as the season progressed. Sulfur content in the tissues from normal and abnormal plants seem to indicate that this discoloration in corn was indicative of S deficiency.

Sulfur treatments have increased S content in the tissue of small grains, soybeans, sunflowers and potatoes. However, additions of S have not resulted in significant yield increases in these crops.

Results of the sulfur status study with 79 soils indicated that the soils of northcentral and northeastern Minnesota are relatively low in S supplying power. Soils of southern and western Minnesota have a relatively high S supplying power.

Leaching studies have shown that sulfate-S movement from top-dressed gypsum is greater in cultivated soil than in soil under a sod crop. Irrigation also increased the downward movement of sulfate-S.

The greatest amounts of S in precipitation and in the atmosphere were recorded at St. Paul, close to the industrial Twin City area, and the lowest amounts were found at Park Rapids. Intermediate amounts of S were recorded at Duluth in northeastern Minnesota and at Lamberton in southwest Minnesota

Publications, Reports.

Sulfur investigations on Soils and Crops. Department of Soil Science, University of Minnesota.

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Report No. 3. January 1964
Report No. 4. June 1964
Report No. 5. December 1964
Report No. 6. June 1965
Report No. 7. January 1966

Oxidation of elemental sulfur in soil. Paulina Wang Li, M. S. Thesis. University of Minnesota, 1964.

Sulfur in plant materials by digestion with nitric and perchloric acid. R. W. Blanchar, G. W. Rehm, and A. C. Caldwell. Soil Sci. Soc. of Amer. Proc. 29:71-72. 1965.

Sulfur oxidation and supplying power of some Minnesota soils. G. W. Rehm, M. S. Thesis, University of Minnesota, 1965.

Sulfur for Minnesota soils. C. J. Overdahl, A. C. Caldwell and J. Grava. Soils Fact Sheet No. 5, Agric. Ext. Service, University of Minnesota, October 1965.

The Effect of Boron, Phosphorus and Potassium on the Yield of Five Legume - Grass Hay Fields and the Boron Composition of the Aflalfa in Carlton County in 1965

J. M. MacGregor, P. Borich & G. Randall*

In July, 1964, following the removal of first cutting of hay, experimental plots were established on four Carlton County farms to determine the effect of boron alone and in addition to phosphorus - potassium on the yield and composition the mixed legume-grass hays grown in the area. A 6 x 6 Latin square design was used. Symptoms of boron deficiency of legumes were evident on the second cutting of two of the four fields in August, 1964. While the boron applications at rates of 1 or 2 pounds per acre reduced teh severity of the B deficiency symptoms, these treatments did not significantly increase 1964 second cutting hay yields. Boron with phosphorus - potassium improved growth, but there again was no significant increase in hay yield of the second cutting on any of the four fields in a relatively dry midsummer growing period.

In the spring of 1965, an additional 1 and 2 pounds of boron per acre were applied to the four 1964 fields, and a fifth field was added. First and second cuttings were harvested and the alfalfa plants of each field were analyzed for boron content. The first cutting of 1965 was very heavy and lodging on the PK plots was a problem, with no visible growth difference on any treatment. The second cutting growth was reasonably good and the yield was much heavier than in 1964, with untreated and PK treated plots on three of the five fields exhibiting boron deficiency. As in 1964, the boron treatments appeared to relieve the deficiency symptoms of the alfalfa to some extent, but even the plots receiving 4 pounds of boron (nearly 40 pounds of borax) per acre still showed some of the characteristic symptoms of boron deficiency.

Hay yields (at 15% moisture) and boron content of alfalfa for the two 1965 cuttings were as follows:

The Boron Content of Alfalfa and Grass Legume Hay Yields on Five Carlton County Farms in 1965

Field 1. George Oraskovich Farm - Carlton Vilas sandy loam
Soil test pH 7.2, Organic matter 5.4%(H) P 180(VH) Ex.K 420(VH)

Fert.Treatment (lbs/A)	Hay Yield in tons/acre at 15% moisture			Boron content of aflalfa ppm	
	1st cutting	2nd cutting	Total(1965)	1st cutting	2nd cutting
none	1.80	0.65	2.45	80 a	60 a
0-60-180	1.69	0.93	2.62	69 a	42 a
0-60-180 + 1B	1.73	1.05	2.78	92 a	97 b
0-60-180 + 2B	1.82	0.85	2.67	95 a	106 b
0-60-180 + 2B[1]	2.02	0.86	2.88	100 a	122 b
0-60-180 + 4B[2]	1.57	1.12	2.69	113 a	167 c

According to Duncan's multiple Range test, those with different letters are significantly different from each other.

None of the yield increases of either the first or second cutting or total yield were mathematically significant. Boron content of oven-dried first cutting alfalfa was not significantly affected by mineral treatment, but the lower yielding second cutting under drier soil conditions was affected by increasing amounts of boron applie

*The cooperation of SCS personnel in classifying these soils is gratefully acknowledge

[1]One pound of boron applied annually in spring of 1964 and in 1965

[2]Two pounds " " " " " " " " " " "

Field 2. Marvin Benson Farm-Mahtowa-Vilas sandy loam (near woods)
Soil test --pH 6.9, organic matter 2.8 (L), Avail P 70(VH),Ex.K-100(M)

Fert.Treatment (lbs/A)	Hay Yield in tons/acre at 15% moisture 1st cutting	2nd cutting	Total(1965)	Boron content of alfalfa ppm 1st cutting	2nd cutting
none	2.86 a	1.15 a	4.01 a	65 a	34 a
0-60-180	3.51 b	1.61 b	5.12 b	72 ab	36 a
0-60-180 + 1B	3.49 b	1.72 b	5.21 b	92 bc	70 b
0-60-180 + 2B	3.56 b	1.52 b	5.08 b	112 cd	85 bc
0-60-180 + 2B[1]	3.36 b	1.48 ab	4.83 b	112 cd	85 bc
0-60-180 + 4B[2]	3.46 b	1.43 ab	4.89 b	126 e	104 c

The fertilizer treatments increased the second cutting yield significantly (5% level), whereas the first and total cuttings produced highly significant increases (1% level). There were no increase for PK&B over the PK alone treatment. There were marked B deficiency symptoms in the second cutting alfalfa of this field especially on the 0-60-180 treatment with no B. The addition of boron decreased the symptoms, but failed to completely remove the rosetting as well as the red and yellow leaf coloration.

Boron concentrations in the alfalfa of both cuttings were significantly increased by the boron treatments to the soil the larger increases occurring at the higher application rates.

[1]one pound of boron applied annually in spring of 1964 and in 1965
[2]two pounds " " " " " " " " " " "

Field 3. Marvin Benson Farm (near building) Mahtowa, Vilas sandy loam
Soil test --pH 7.3, organic matter 4.1 (M),Avail P 190(VH),Ex.K-320(VH)

Fert.Treatment (lbs/A)	Hay Yield in tons/acre at 15% moisture 1st cutting	2nd cutting	Total 1965	Boron content of alfalfa ppm 1st cutting	2nd cutting
none	1.74	1.19	2.93	70 a	60 a
0-60-180	1.80	1.05	2.85	64 a	53 a
0-60-180 + 1B	1.81	1.20	3.01	84 b	97 b
0-60-180 + 2B	1.77	1.12	2.89	86 b	102 b
0-60-180 + 2B[1]	1.78	1.23	3.01	82 b	112 b
0-60-180 + 4B[2]	1.73	1.19	2.92	96 c	127 c

None of the fertilizer treatments significantly increased first or second cutting or total yields on this field. Second cutting alfalfa growing on two of the six 0-60-180 plots showed a marked boron deficiency, and it is probably that since this experiment was located near a former poultry house, there may have been substantial applications of poultry manure made some years ago and this would supply some boron to the soil. Boron applications again significantly increased the boron content of the alfalfa hay, whereas the PK alone treatment tended to produce larger hay yields, the alfalfa having no more or possibly lower boron concentrations than the unfertilized hay.

[1]one pound of boron applied annually in spring of 1964 and in 1965
[2]two pounds " " " " " " " " " " "

Field 4. Lauri Waisanen farm, -Kettle River - Unnamed sandy loam
Soil test --pH 6.3, organic matter 4.5%(M) Avail p.18(M),Ex.K. 120(M)

Fert.Treatment (lbs/A)	Hay yield in tons/acre at 15% moisture			Boron content of alfalfa ppm	
	1st cutting	2nd cutting	Total 1965	1st cutting	2nd cutting
none	2.32 a	1.40 a	3.72 a	83 a	38 a
0-60-180	2.64 ab	1.94 b	4.58 b	55 a	36 a
0-60-180 + 1B	2.71 ab	1.97 b	4.68 b	125 b	76 b
0-60-180 + 2B	2.89 b	2.01 b	4.90 b	129 b	92 c
0-60-180 + 2B[1]	2.75 b	2.05 b	4.80 b	126 b	88 c
0-60-180 + 4B[2]	2.73 b	1.94 b	4.67 b	128 b	112 d

The first cutting hay yield was significantly (5% level) increased by all fertilizer treatments, with the second cutting and total hay yield increases being highly significant (1% level), although none of the latter fertilizer yields were significantly different from each other. The PK treatment appears to produce the significant effect rather than the boron. Plant growth on the untreated plots was shorter than on the five treated plots, with boron deficiency symptoms being most evident on the PK plots. Boron treatments did not entirely remove these symptoms, although the B treated alfalfa plants contained significantly more boron than those plants grown where no boron was applied.

[1]one pound of boron applied annually in spring of 1964 and in 1965
[2]two pounds " " " " " " " " " " "

Field 5. Gerald Mower Farm-Cromwell-Vilas loamy sand
Soil test--pH 7.1-organic matter 3.6% (M) avail p.200+(VH)Ex.K 510 (VH)

Fert.Treatment (lbs/A)	Hay yield in tons/acre at 15% moisture			Boron content of alfalfa ppm	
	1st cutting	2nd cutting	Total 1965	1st cutting	2nd cutting
none	2.08	0.82	2.90	75 a	42 a
0-60-180	2.45	0.96	3.41	72 a	40 a
0-60-180 + 1B	2.32	1.00	3.32	100 bc	77 b
0-60-180 + 2B	2.44	0.98	3.42	111 bc	103 c
0-60-180 + 2B[1]	2.48	1.02	3.50	90 ab	77 b
0-60-180 + 4B[2]	2.28	0.92	3.20	116 c	93 c

The fertilizer treatments were applied to this field in May of 1965, with double application of boron on the two heavier treatments. None of the treatments significantly increased hay yields and no boron deficiency symptoms were noted on the legumes of either the first or the second cutting although such symptoms were common a short distance away in the same field.

Boron applications significantly increased boron uptake by the alfalfa plants, however.

[1]two pounds of boron applied in spring of 1965
[2]four " " " " " " " "

Present Conclusions of this Study

1. Whereas the phosphate-potash (0-60-180) treatment has significantly increased some hay yields on two of the experimental fields, the boron treatment has failed to increase crop yield on any cutting of the five fields. (All fields were originally limed and well PK fertilized by the farm operator.)

2. Boron deficiency symptoms were observed on the second cutting alfalfa plants of three of the fields. Symptoms were most severe on PK treated plots, with the untreated plots exhibiting the symptoms to a lesser degree.

3. The boron treatments decreased the severity of the alfalfa boron deficiency symptoms to a certain extent, but failed to completely remove the stunting, rosetting, reddening, and yellowing of the plants.

4. All boron treatments materially increased the boron uptake by plants on both cuttings of all five experimental fields. However, the boron content of alfalfa from even the PK plots apparently was not at critically low levels essential for normal plant growth.

5. The results of this study during 1964 and 1965 have shown little encouragement for the economic application of boron for the purpose of controlling alfalfa yellowing on the soils of this region. The symptoms attributed to boron deficiency are more probably induced by other soil factors, of which limited soil water may be one important contributor.

Direct and Residual Effect of Zinc Fertilization of Corn on a Zinc Deficient Silty Clay Loam in Southern Kandiyohi County

J. M. MacGregor and O. M. Gunderson

During the 1961 growing season, zinc deficiency was observed on some corn plants on the C. H. Litch farm at Lake Lillian. With the cooperation of the farm owner and Dr. R. R. Allmaras of the A.R.S. Soil and Water Research Station at Morris, a field experiment of zinc application for corn was initiated in May of 1962. Soybeans were seeded in 1963 but died out because of residue remaining from a 1962 application of atrazine. Corn was grown in 1964 and in 1965. Leaves were sampled (6th leaf from the ground) in each of the three years and were analyzed by the X-ray fluorescence procedure. The average zinc content of the leaves and yield of ear corn per acre for the three years are shown in the following table.

The Effect of 1962 Zinc Fertilization of a Zinc Deficient Silty Clay Loam in Southern Kandiyohi County on Zinc Concentrations in Corn Leaves and Corn Yields in 1962, 1964 and 1965.

1962 Treatment (lbs./A)	Leaf zinc in ppm			Yield of ear corn in bu./A		
	1962	1964	1965	1962	1964	1965
No zinc	9	19	8	43	40	38
Zinc broadcast and plowed under in spring						
15 zinc sulfate	13	19	12	69	58	59
30 " "	19	20	20	66	56	58
60 " "	27	27	25	76	56	69
120 " "	29	28	31	67	50	69
Zinc sulfate and/or nitrogen applied as a band starter						
20 nitrogen (N) alone	9	-	11	61	41	47
30 zinc sulfate	10	-	13	59	53	55
15 zinc sulfate + 20 N	10	-	14	63	58	56
30 " " " " "	11	-	13	64	65	65
60 " " " " "	12	-	20	63	62	59
Zinc chelate coated on seed corn ($7\frac{1}{2}$ oz. $Na_2ZnEDTA$ per bu.)						
Seed treatment alone	9	-	8	55	51	48
" " + 30 zinc sulfate plowed down	22	-	17	74	67	67

Comparatively good agreement was evident between the amounts of zinc applied in 1962 and subsequent concentrations in the corn leaves. Earlier investigators in other sections of the United States have shown that the critical level of leaf zinc for normal corn growth to be approximately 15 to 20 parts per million. In general, the band applied zinc appears to be much less available to the corn plants than equal amounts broadcast and plowed under in 1962, even four cropping seasons later.

The zinc treatments produced substantial increases in corn yield with banding being only slightly less productive than plowing down, even though the corn leaves growing on the banded zinc plots contained considerably less zinc in each of the three growing seasons.

Although zinc chelate coatings on the seed increased corn yield in each of the three years, the zinc content of these leaves was extremely low, which might be expected from the amount of zinc initially applied (less than 1 oz. of the chelate per acre) and the corn yields were considerably less than any of the zinc sulfate treatments.

Nitrogen applications, either alone or in combination with zinc, had little appreciable effect on corn yields.

It is apparent that where zinc deficient soils do occur in Minnesota, the application of zinc sulfate, either plowed down or as a band application, will be an economic practice for corn production.

ZINC FERTILIZATION OF CONTINUOUS CORN

West Central Experiment Station

Samuel D. Evans

Two zinc experiments were set up at the West Central Experiment Station in 1965. The first was an experiment comparing rates and sources of zinc on a soil which had not shown any zinc deficiency symptoms. The second was a demonstration on a field which exhibited zinc deficiency in 1964.

1. Zinc Experiment

Treatment	Yield - Bu./A @ 15.5%
Check	97.80
5 lbs. zinc as zinc sulfate	98.93
10 lbs. zinc as zinc sulfate	96.63
20 lbs. zinc as zinc sulfate	98.93
45 lbs. phosphorus	99.54
45 lbs. phosphorus + 10 lbs. zinc as zinc sulfate	96.45
8 lbs. zinc 45 chelate	97.47
LSD (5%)	5.14

Coefficient of Variation - 4.48%

Initial soil test (Barnes silty clay loam)

PH - 6.6 Organic Matter - 6.7%

Extractable phosphorus - 19 Exchangeable potassium - 353

2. Zinc Demonstration

Treatment	Yield - Bu./A @ 15.5%
125 lbs. of 8-32-16	74.1
100 lbs. of 8-32-16 + 10 lbs. zinc as zinc sulfate	82.0

Initial soil test (Barnes loam) - This field is extremely variable

PH - 7.2 to 8.2 Organic Matter - 2.8 to 5.0%

Extractable phosphours - 40 to 75 Exchangeable potassium 130 to 400

EXTENSION DEMONSTRATION ON CORN FERTILIZATION 1965

C. J. Overdahl

County agents in several counties established fertilizer trials to observe the effect of starter, nitrogen sidedressing, and zinc treatments. They also included any fertilizer material or method in question where more information was desired. The latter involved ground soybeans, certain low-analysis material sold as specialty goods or soil conditioners, and pop-up fertilizers. Plots were replicated twice.

Corn yields in bushels per acre at 15.5 percent moisture are shown in the following tables.

Table 1. Watonwan County, John Ankeny, County Agent; Lemuel Swanson, Cooperator

Fertilizer Treatment in the Row	Sidedressed Nitrogen: None	Sidedressed Nitrogen: 70 Pounds
	Yield, bu./acre	
None	83	89
16+64+32	92	99
+ 5 lb. zinc	91	98
Ground Soybeans	84	91

Soil Test:	pH	OM%	P	K	Soil Texture
	7.7	5.0 M	30 H	290 VH	Clay Loam

- Final stand averaged about 18,000 plants per acre.
- Ground soybeans were applied at 125 pounds per acre.
- Preceding crop was corn
- Corn moisture percentage at time of harvest varied from 22.8 where 8-32-16 at 200 pounds per acre was used to 25.7 where ground soybeans were used as starter.

Ground soybeans appear to have no effect on yield or in reducing moisture content. There is no evidence of zinc response even though it might have been expected where the soil pH is high and row phosphorus applications and phosphorus soil test is high. There is an average increase of about seven bushels from the nitrogen treatments and about ten bushels from the 8-32-16 starter fertilizer.

Table 2. Big Stone County, Curtis Churness, County Agent; Dale Blum, Cooperator

Fertilizer Treatment in the Row	Sidedressed Nitrogen: None	Sidedressed Nitrogen: 70 Pounds
	Yield Bu./Acre	
None	24	35
9+28+9	41	45
+ 5 lb. zinc	44	50
0+0+75	20	37

Moisture content at harvest time (Oct. 25) was extremely high, varying from 42 percent on the plots receiving starter to 48 percent on untreated plots. Nitrogen response averaged about 10 bushels, starter increased yield by 13 bushels, and zinc appeared to increase yield about 4 bushels, although such small increases are questionable since greater variation within identical treatments occurred.

Table 3. Nobles County, Francis Januschka, County Agent; Earl Newburn, Cooperator

Fertilizer Treatment in the Row	Sidedressed Nitrogen None	Sidedressed Nitrogen 70 Pounds
	Yield, Bu./Acre	
None	104	116
9+36+18	111	120
+ 5 lb. zinc	113	120
+ pop-up	114	121

Soil Test:	pH	OM%	P	K	Soil Texture
	6.0	6.0 VH	20 M	310 VH	Loam

There was a 9-bushel increase from nitrogen, but little increase, if any, from zinc or "pop-up" fertilizer. Pop-up fertilizer is a small amount of mixed fertilizer applied in direct contact with the seed, for quick starter effect, in addition to the regular starter placed 2 inches to the side of and below the seed. Starter effect was also small. Medium-textured soils, such as a loam, usually do not show as large a starter effect as do finer textured soils unless the P and K tests are lower than in this demonstration.

Moisture at harvest time varied from 33 percent on untreated plots to 28 percent where starter and nitrogen were applied.

Corn was planted in 30-inch rows. The stand at harvest time was 23,500 plants per acre. Atrazine was used to control weeds and parathion was applied to control rootworms.

Table 4. Nobles County, Francis Januschka, County Agent; Lenz Bros., Cooperators

Fertilizer Treatment in the Row	Sidedressed Nitrogen None	Sidedressed Nitrogen 70 Pounds
	Yield Bu./Acre	
None	80	95
10+40+20	87	100
+ 5 lb. zinc	80	99
+ 50 lb. pop-up	84	93

Soil Test:	pH	OM%	P	K	Soil Texture
	7.0	5.5 M	62 VH	450 VH	Silty Clay Loam

Apparently with P and K tests as high as shown here, there are small needs for these nutrients under any weather conditions. The wet soils and cold temperatures, such as experienced this year, generally are expected to create a need for starter.

Corn was planted with a till planter on unplowed soil. Atrazine was used to control weeds, and diazinon was applied to control corn rootworms.

Table 5. Sibley County, John Peterson, County Agent; Russell Carlson, Cooperator

Fertilizer Treatment in the Row	Sidedressed Nitrogen	
	None	70 Pounds
	Yield, bu./Acre	
None	66	71
175# 5-20-20	68	84
+ 5 lb. zinc	63	74
175# soil conditioner	70	70

There is about an 8-bushel increase from nitrogen. The preceding crop was alfalfa. There appears to be a good yield increase from starter where nitrogen was used, but little if any response from 175 pounds per acre of soil conditioner and either no response or possibly a slight decrease from zinc. Ear moisture content was lowest (35 percent) at harvest time (October 16), with starter or starter plus nitrogen, and highest, (38 percent), on the plot with soil conditioner plus nitrogen and on the untreated plots. Corn was planted June 9.

Table 6. Sibley County, John Peterson, County Agent; David Battcher, Cooperator

Fertilizer Treatment in the Row	Sidedressed Nitrogen	
	None	70 Pounds
	Yield bu./Acre	
None	87	92
175# 5-20-20	110	112
175# inert sand	82	85
175# soil conditioner	91	100

This was a somewhat poorly drained Webster clay loam. The nearly inert sand was added with the prospect of maintaining better air and moisture relationships near the seed, but it appears to have had an adverse effect, if any. There is response of about 22 bushels from starter and very little nitrogen response. The soil conditioner used was a mineral material with very little nutrient value as demonstrated by its small yield increase compared to equal amounts of 5-20-20.

Ear moisture on the harvest date, October 30, was 26 percent where starter or starter plus nitrogen was used and from 32 to 34 percent on the other treatments. Corn was planted May 19.

A Survey of Grass Seed Production Fields in Northwestern Minnesota - 1965

John Grava, D. M. Larsen, G. W. Randall, R. S. Farnham,
W. P. Martin, and J. M. MacGregor

Previous investigations on the grass seed production project have dealt mainly with the effects of fertilization with primary nutrients, N, P and K on the yield of grass seed. Rates and time of application have been studied on mineral and organic soils in northwestern Minnesota (see "The Blue Books" of 1961, 1962, 1963 and 1964). The findings of these studies have been helpful in advising growers on the use of commercial fertilizers.

An exploratory survey of 12 grass seed production fields was conducted in 1964. Soils were classified and chemical analyses made on soil and plant tissue samples (see "The Blue Book" of Feb. 1965, pp. 113-126).

A similar survey was conducted during the summer of 1965. A total of 25 Timothy and 21 Park Kentucky Blue grass seed production fields were investigated in Clearwater, Roseau and Lake of the Woods Counties. Fifteen Timothy fields were on peat and ten on mineral soils. Six bluegrass fields were on peat and 15 on mineral soils. Five of the Timothy stands were one year old, 16 were two or three years old and four were six to seven years old. Three of the bluegrass fields had one year old stands, 13 stands were two to three years old and five had four to five years old stands.

Plant tissue samples were collected from representative areas about the time when grasses headed out. The samples have been submitted for spectrographic analysis. Soil samples were collected from the same areas from which the plant samples had been obtained. Soils were classified as to the soil type. Chemical analyses of the samples are nearly completed.

Grass seed yields were determined by harvesting mature plants from three - one square yard areas from the same spots where tissue and soil samples had been collected.

Based on information provided by growers and on actual determinations of seed yields, the average production field in the three county area received following amounts of plant nutrients, and produced seed yield as indicated in table 1.

Table 1. Average Amounts of Plant Nutrients Used, Fertilizer Costs and Seed Yields of Timothy and Park Kentucky Blue Grass in Northwestern Minnesota - 1965

Species, Soils	Plant Nutrients Used N	P_2O_5	K_2O	Fertilizer Cost*	Average Seed Yield
	lbs./acre			$/acre	lbs./acre
(1) Timothy					
On mineral soils	58 +	21 +	18	10.74	201
On peat	25 +	32 +	32	8.02	310
All Timothy fields	36 +	28 +	27	8.90	272
(2) Park Kentucky Blue grass					
On mineral soils	51 +	29 +	9	10.20	469
On peat	21 +	43 +	43	9.08	289
All Blue grass Fields	43 +	33 +	18	9.92	418

*Fertilizer costs per pound of nutrient:
N, 13.5 cents; P_2O_5, 10 cents; K_2O, 4.5 cents.

Generally, grass fields on mineral soils receive twice as much nitrogen as those on peat soils. Most commonly used commercial fertilizers on peat soils have ratios of 1:2:2 or 1:4:4 on mineral soils the fertilizers may have ratios of 1:1:0, 2:1:0 or 2:1:1.

Seed producers in the three county area considered the season of 1965 as one of the best in recent years and consequently obtained relatively high seed yields, especially of certified Park Kentucky Bluegrass. This may have been due to favorable weather conditions during the growing season. Cool season grasses such as Timothy and Kentucky Bluegrass prefer somewhat cool and moist weather. Following are climatological data as measured at the weather station, Roseau power plant from April 1 to July 31, 1965 (from climatological data,

Minnesota, Vol. 71, 1965, U. S. Weather Bureau).

Precipitation (inches)		Temperature (°F)		Growing Degree Days $T_b = 40°F$
Total	Departure from normal	Average	Departure from normal	
21.8	+2.1	33.1	-4.4	1817

Slow-release nitrogen studies on Turf Grass-1965

R. S. Farnham

Studies of slow-release turf fertilizers were continued in 1965 on plots located on the St. Paul Campus. The comparisons did not include periodic clippings as in previous years but instead nitrogen analyses of dry grass clippings was determined near the end of the growing season (October 1, 1965) and visual ratings for color and thickness were made. These data were obtained to determine the long-lasting effectiveness of various slow-release turf fertilizers.

Materials and Methods

The slow-release fertilizers included in this study were resin-coated 16-8-8, 20-10-5, and ammonium nitrate furnished by Archer-Daniels Midland; Uramite (urea formaldehyde), American Humates organic fertilizer produced from weathered lignite mined in Wyoming; and two new organic materials (treatment no's 7 and 8) using peat as the organic filler. The resin-coated fertilizers have proven very effective as to their slow-release characteristic over the past few years of experimentation and thus were good materials to use to compare the effectiveness of the other fertilizers used.

Plots were located between Agronomy and Plant Pathology buildings and the size of each was 5' by 20'. Color and thickness ratings were made on Oct. 1, 1965 and nitrogen analyses were determined on clippings collected at this time. Plots were watered as needed.

Results

Data in table 1 show the results of visual observation and nitrogen analyses at end of growing season for bluegrass. The treatments can be compared to two checks which received no fertilizer.

Observations periodically during the growing season showed little difference in the fertilizer materials as to thickness and color of the grass. The data on nitrogen analyses at the end of the season does not differ significantly with different fertilizer treatments but does show great differences when compared to the check receiving no fertilizer.

The extremely slow release organic material from sewage sludge (milorganite) was superior to all others in nitrogen content color and thickness at the end of the season but were no better than the others during the growing season.

The low rating on color and thickness of grass and very low nitrogen level of the two check plots is noteworthy.

It can be concluded from this experiment that several slow-release nitrogen fertilizers prepared especially for turf grass are suitable for application in the spring as a single application. Further evaluations need to be made on basis of cost per pound of nitrogen as many of these slow-release forms vary considerably in price.

Table 1. 1965 TURF PLOTS - ANALYSES AT END OF SEASON*

Treatment	N Rate lbs/1000 sq ft	Color and Thickness Ave. Rating**	Nitrogen as % Dry Matter
1. 16-8-8 (coated)	8	6.0	3.17
2. 20-10-5 (coated)	8	6.1	3.47
3. NH_4NO_3 (coated)	8	7.5	3.11
4. Uramite (U-F)	8	7.2	3.06
5. American Humates(ORG.)	8	6.5	2.99
6. Milorganite (Sewage Sludge)	8	8.0	3.33
7. Batch "I" (Organic)	8	5.0	2.98
8. 53026 (Organic)	8	6.2	3.26
9. Check I (No fertilizer)	0	2.0	2.70
10. Check II (No fertilizer)	0	1.0	1.90

*Sampled Oct. 1, 1965.

**Color and thickness rating made on Oct. 1, 1965 ranges from 8 as best appearance to 1 as poorest. All analyses are averages of two replicates.

SOIL TESTING DURING 1965

John Grava

Currently the University of Minnesota Soil Testing Laboratory processes more than thirty thousand samples annually. The following data show the number of various types of samples analyzed in 1965:

Regular farm, garden and lawn samples	27,313
Florist (greenhouse)	1,268
Limestone and marl	62
Departmental research samples	2,000
Total	30,643

The number of regular soil samples processed by the laboratory was considerably below that of previous years. In 1964, for example, over 33,000 samples were received for routine tests. It seems that sample collection was hindered by unfavorable weather conditions during 1965. Sample collection in some areas was almost impossible due to heavy snow cover, floods and excessive soil moisture during spring and an extremely wet fall. On the other hand, the influx of samples during November and December was very heavy. About 12,500 samples, or 45 percent of the total number of samples were received during the last two months of the year. 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 1965

Month	Number of Samples
January	1947
February	987
March	840
April	1506
May	1132
June	524
July	675
August	1621
September	2648
October	2905
November	6315
December	6111

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Such contributions to further both field and laboratory research on Minnesota soils are hereby gratefully acknowledged.