or combination treatments. However, the highest plant weight and yield, and the lowest moistures were obtained with the combination treatment.

Small plant weight was also significantly increased with the broadcast treatment of 0+60+30. Although the height and yield were greater and the moisture was less from the broadcast treatment, these differences were not significant.

June 1 planting

Even at this late date of planting, the small plant weight, height, yield, and moisture content were all significantly affected by the row treatments. Again, the corn fertilized with pop-up, 2 x 2 band, or combination treatment showed a significant increase in weight, height, and yield and a significant decrease in moisture over the no row (check) treatment. In all cases there were no significant differences among the pop-up, 2 x 2 band or combination treatments.

The broadcast treatment of 0+60+30 significantly increased the small plant weight and height, but did not significantly increase the yield or decrease the moisture.

Comparing the planting dates, lower yields (74.9 vs 78.5) and higher moisture contents (29.2 vs 17.8) were obtained with the June 1 planting.

Polyphosphate Investigations

A. C. Caldwell
and
Richard C. Leslie

Field trials comparing polyphosphates and orthophosphates were run at Lamberton and Rosemount Experiment Stations. Three different phosphate treatments at two rates were employed at both stations, as shown in Table 1. One yield row and two border rows were planted for each plot.

Table 1. Phosphorus treatments.

No.	Phosphate Material	Rate #/Acre	Application
1	Check		
2	Ortho. Dry 11-14-0	62.5	2 x 2
3	Ortho. Dry 11-14-0	62.5	Pop-up
4	Ortho. Liq. 8-24-0	125.0	2 x 2
5	Ortho. Liq. 8-24-0	125.0	Pop-up
6	Poly. Liq. 11-37-0	81.1	2 x 2
7	Poly. Liq. 11-37-0	81.1	Pop-up

At Rosemount, treatments were replicated five times, using Chippewa soybeans. At Lamberton, treatments were replicated four times using Merit soybeans. In addition to the phosphate treatments at Lamberton, three nitrogen treatments, at 200#/Acre, were applied by three different means, (1) broadcast before planting as processed feathers and disced in, (2) broadcast as 33.5-0-0 in a single application and disced in before planting, (3) broadcast as 33.5-0-0 in split applications, 100# before planting and 100# in early July.

The plants in the non-nitrogen fertilized plots were randomly sampled at three different growth stages, whole plants 4 to 6 inches high, and the uppermost fully matured trifoliate leaves at the flower and pod stage.

Total dry matter was determined for the first sampling only. Elemental analyses were run on the check, liquid orthophosphate 2 x 2, and liquid polyphosphate 2 x 2 plants from the first and third samplings. Yields were determined on all plots including the nitrogen fertilized.

RESULTS

Yields

The yields at Lamberton are presented in Table 2.

Table 2. Effect of Phosphate Fertilizers on Soybean Yields at Lamberton

	Treatments						
	Check	Ortho Dry 2 x 2	Ortho Dry Pop-up	Ortho Liq 2 x 2	Ortho Liq. Pop-up	Poly Liq. 2 x 2	Poly Liq. Pop-up
	Bu/Acre						
No Nitrogen	18.1	21.5	21.2	20.9	19.9	21.4	22.3
200 lbs. Nitrogen as Feathers	22.8	27.4	25.5	25.7	25.8	28.2	23.7
200 lbs. Nitrogen as 33.5-0-0 single appl.	26.3	28.1	28.9	29.1	27.7	28.4	24.6
200 lbs. Nitrogen as 33.5-0-0 split appl.	24.3	25.1	24.5	26.8	26.3	26.8	25.6

The soybean yields were adversely affected by a lack of optimum moisture throughout the growing season. The yield data shows polyphosphate fertilizer to be an adequate source of phosphorus. The addition of 200 lbs. of nitrogen produced an increase in yields of all treatments.

The effect of Boron, Phosphorus & Potassium on Soluble Soil Boron & Yield of Grass-Legume Hay on a Vilas Loamy Sand in Carlton County 1965-66-67 (Gerald Mower Farm - Cromwell)

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

In July of 1964 following the removal of first cutting hay, experimental plots were established on four Carlton County farms to determine the effect of phosphorus and potassium alone and with different rates of boron application to soils on grass-legume hay fields common in this area. A 6 X 6 Latin square design was used with plots of one square rod. The major results have already been reported in previous "Bluebooks" of 1965, 1966, and 1967. (Soil Series 79, 80, and 81).

Early in 1965 a fifth field was established on a one-year-old legume-grass stand on a Vilas loamy sand, approximately 2 miles southeast of Cromwell. Two cuttings were made in each of the three years. In October of 1967, soils of three of the six replications were sampled to a 24 inch depth and three sample depths from each plot were analyzed for soluble boron content.

During the first cutting year (1965) there was a growth difference in the appearance of the alfalfa on the phosphate-potash treatments, but little effect of boron. During the second year (1966) the phosphate-potash only plots and those receiving only one pound of boron per acre showed some indications of leaf yellowing and slight rosetting. During the third year, the symptoms of boron deficiency on the no boron, or on the one or two pound plots became more pronounced.

The following table shows the hay yields obtained in 1967 and the total yield for the three year period, based on 15% moisture of the two annual cuttings.

Table 1. The Effect of Phosphate-Potash and of Boron Fertilization on the Three Year Yield of a Grass-Legume Hay on a Vilas loamy sand.

	Tons hay per acre at 15% Moisture			
	1967			1965-67 total
Treatment (lbs/A)	1st. cutting	2nd. cutting	total	
Check	2.17a	0.43a	2.60a	9.83a
0 + 60 + 180	2.26ab	0.64b	2.90abc	10.69b
0 + 60 + 180 + 1B(1965)	2.57c	0.58b	3.17bc	11.02bc
0 + 60 + 180 + 2B(1965)	2.58c	0.65b	3.23c	11.51c
0 + 60 + 180 (+ 1B in 1965, 1966, 1967)	2.50bc	0.53ab	3.03bc	11.56c
0 + 60 + 180 (+ 2B in 1965, 1966, 1967)	2.30abc	0.53ab	2.83ab	10.56ab

The terms a,b,c refer to significant differences in yield.

It is apparent that alfalfa on this field which showed boron deficiency symptoms, the total application of boron at rates 1, 2 and 3 pounds per acre during the three growing seasons resulted in a significant yield increase in 1967 and for the total three year period (1965-67). During the first two years of the experiment (1965 & 1966) there was no clearly established yield increase due to the application of boron. It is probable that such a treatment becomes more effective as the stand becomes older on this sandy soil. Phosphate-potash treatment, however effectively increased hay yields in the first year (1965). Therefore, phosphate-potash fertilization was initially effective for increasing hay yields on this sandy soil, but boron treatments were needed in the third cropping season.

Soils of three replications were sampled in October 1967 and the soluble boron content of three depths are shown in the following table.

Table 2. Soluble Boron Content of Vilas Loamy Sand in October 1967.

Soil Treatment (lbs/A)	Soil Depth (Average of 3 replications) 0 - 6"	6" - 12"	12" - 24"
	Boron in parts per million		
Check.	0.81	0.78	0.79
0 + 60 + 180	0.87	0.77	0.70
0 + 60 + 180 + 1B(1965)	0.95	0.90	0.91
0 + 60 + 180 + 2B(1965)	0.79	0.77	0.76
0 + 60 + 180(+ 1B in 1965, 1966, 1967)	1.25	1.07	1.03
0 + 60 + 180(+ 1B in 1965, 1966, 1967)	1.50	1.62	1.05

The 1965 applications of boron at rates of 1 or 2 pounds per acre had largely disappeared by late in 1967. Where the same amounts were applied annually increases in soluble boron evident, illustrating the comparatively rapid loss of this element from this soil.

Experiments with Zinc for Corn in Southeastern Kandiyohi County (1962 - 67)

John M. MacGregor, Orville Gunderson and Gyles Randall

In 1962, an experiment was commenced (with the cooperation of personnel of the U.S.D.A. Soil and Water Research Station at Morris) on the effect of form, placement and rate of zinc application to an unnamed calcareous silty clay loam about two miles northwest of the village of Lake Lillian for corn production. Powdered zinc sulfate at four rates was broadcast and plowed down in May, similar rates were applied as a starter band 2 inches to one side and 2 inches below the seed, both alone and with ammonium nitrate nitrogen at the rate of 20 pounds of N per acre. One treatment of chelated zinc was included where the seed was dusted with Na_2Zn zinc chelate at the rate of 8 ounces per bushel of seed. Corn was grown in 1962, 1964, 1965, 1966 and 1967. Soybeans were planted in 1963, but were killed by the residual effect of a heavy dosage of atrazine in 1962 to control quack grass as much as possible on the experimental area. The experimental design was a randomized block having three replications.

The sixth (index) leaf was sampled each year in late July and these were analyzed for zinc content. Observation has generally indicated that the critical zinc level in leaves at this time is approximately 15 parts per million (ppm). Ear corn yields were also obtained and both leaf zinc and yields for the five years are shown in the following table.

The Effect of a 1962 Zinc Treatment to an Unnamed Calcareous Silty Clay Loam in Southeastern Kandiyohi County on Succeeding Yields of Ear Corn
(Averages of three replications)

1962 Trt. lbs/A	Leaf zinc in ppm					Yield of ear corn in bu/A (15.5% moisture)						
	1962	1964	1965	1966	1967	1962	1964	1965	1966	1967	Total	Average
No zinc	9	19	8	10	13	43	40	38	41	36	198	39.6 a
Zinc broadcast and plowed under in spring of 1962												
15 $ZnSO_4$	13	19	12	10	14	69	58	59	54	43	283	56.6 de
30 "	19	20	20	14	13	66	56	58	51	47	278	55.6 cde
60 "	27	27	25	15	19	76	56	69	56	43	300	60.0 e
120 "	29	28	31	25	21	67	50	69	52	41	279	47.6 b
Zinc sulfate and/or nitrogen applied as a band starter												
20 N alone	9	--	11	11	12	61	41	47	45	44	238	47.6 b
20 N + 15$ZnSO_4$	10	--	13	12	13	59	53	55	51	36	254	50.8 bcd
20 N + 30$ZnSO_4$	10	--	14	11	14	63	58	56	61	52	290	58.0 de
20 N + 60$ZnSO_4$	11	--	13	16	18	64	65	65	60	35	289	57.8 de
30$ZnSO_4$	12	--	20	12	14	63	62	59	51	49	284	56.8 de
Zinc chelate coated on 1962 seed corn (7½ oz. NaZnEDTA per bu.)												
Seed trt alone	9	--	8	9	11	55	51	48	48	42	244	48.8 bc
Seed trt +30$ZnSO_4$P.U.	22	--	17	13	16	74	67	67	64	43	315	63.0 e

P.U.=Plowed under

Both sources of inorganic zinc were apparently more efficient for increasing both corn leaf zinc and ear corn yield, but since an extremely small amount of the chelated zinc (NaZnEDTA) was applied to the seed in 1962, the results could hardly be considered to be representative of the effectiveness of this zinc source.

Several conclusions may be made from this 65 month study:

1. One treatment of zinc sulfate effectively increased corn yield for several years.

2. Zinc as the sulfate when broadcast and plowed down was found at greater concentrations in the corn leaves than where similar rates of application were banded two inches below and two inches to one side of the seed, with

or without ammonium nitrate nitrogen.

3. Although the zinc sulfate appeared to be somewhat more effective than banding along the row during the first year, there were no significant placement yield differences for the total five year yield.
4. The banded N applications increased corn yields in the first year only.
5. Zinc sulfate at rates of 15 and 30 pounds per acre maintained leaf zinc concentrations at satisfactory levels for three crops before dropping below the so-called "critical" levels in the fourth and fifth year. Corn yields decreased more gradually.
6. During the entire study, limited plant populations apparently lowered possible higher yields, since seed germination on this fine textured, calcareous and cold soil was relatively poor each year.
7. A residual corn yield effect of zinc is evident after several years of cropping to corn, especially where rates in excess of 30 pounds of $ZnSO_4$ were applied.

The 1966-67 Results of a Zinc Source and a Zinc-Phosphate Interaction Effect on Leaf Composition and Corn Yield on a Calcareous Loam in Swift County

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

In the spring of 1966, a project was commenced to study:

1. The effect of several commercial zinc fertilizer materials, and
2. The effect of increasing amounts of phosphate fertilization on the zinc and phosphorus content of the sixth corn leaf and on the resulting ear corn yield.

Two randomized block experimental areas were established in mid-May of 1966 on the Richard Mikkelson farm some 2 to 3 miles north of Benson in Swift County. Each experiment consisted of 7 treatments replicated 4 times. All zinc treatments except one chelated zinc source (which was row applied each year) and all P treatments were broadcast and then plowed down. The farm operator also applied a total of 100 + 40 + 40 per acre as a blanket broadcast application before plowing. In 1966 the spring was late, so 90 day maturity corn was planted. Atrazine was applied on June 1st and leaf samples were taken in early September. In 1967, the planting season was earlier and a 100 day corn maturity was used. A mid-September frost materially decreased the 1967 ear corn yield. The soil pH was 8.2.

One of the problems in field experiments with zinc fertilization is the extreme variability of soils in their response to zinc applications. For this reason, large apparent differences may not be statistically significant.

The zinc and phosphorus content of the sixth (index) corn leaf collected in August of 1967 is shown in Table 1.

Table 1. Zinc and Phosphorus Content of the Sixth Corn Leaf Growing with Various Zinc Applications to the Soil.

Zn Treatment (lbs/A)	Leaf Zn in ppm 1966	Leaf Zn in ppm 1967	Leaf P - % 1966	Leaf P - % 1967
1. None	7.2c	9.2d	0.400a	0.367a
2. 10 as $ZnSO_4$-plowed down-1966	11.7bc	13.8c	0.297bc	0.304bc
3. 20 " " " " "	14.0b	18.2b	0.259c	0.273c
4. 40 " " " " "	18.0a	26.5a	0.259c	0.281bc
5. 10 as ZnMNS " " "	9.3bc	12.8cd	0.326abc	0.285bc
6. 0.5 as Na_2Zn-row-1966 & 1967	8.6c	11.8cd	0.394a	0.331ab
7. 2.5 " " -plowed down-1966	8.3c	11.5cd	0.372ab	0.323abc

The 20 and 40 pound rates of zinc as the sulfate significantly increased leaf zinc in both years, while the 10 pound rate as sulfate or as ZnMNS gave a lesser and non-significant increase. Both chelate applications were least effective in raising leaf zinc concentrations.

As rates of zinc fertilization increase, phosphorus decreases in corn leaves, with the heavier $ZnSO_4$ treatments producing a significant depression with chelated zinc having the least effect on leaf P.

Zinc is applied to soils primarily to increase corn yields and these are shown in Table 2.

Table 2. The Effect of Zinc Applications on the Yield of Field Corn in 1966 and 1967.

Zn Treatment (lbs/A)	Ear Corn @ 15.5% moisture - bu/A 1966	Ear Corn @ 15.5% moisture - bu/A 1967
1. No zinc	92.0bc	56.1
2. 10 as $ZnSO_4$-plowed down-1966	115.4a	77.5
3. 20 " " " " "	111.8a	75.6
4. 40 " " " " "	109.3a	81.7
5. 10 as ZnMNS-" " "	103.8ab	79.2
6. 0.5 of Na_2Zn-in row-1966 & 1967	85.5c	69.7
7. 2.5 " " -plowed down-1966	93.3bc	58.4
		N.S.

The more mature crop of 1966 showed significant yield increases with the three rates of $ZnSO_4$ application, with the ZnMNS effect being less clear cut. The two chelated zinc treatments failed to significantly increase yields.

As mentioned previously, a mid-September frost in 1967 materially lowered yields. The variability in yields amongst the four replicates was large, resulting in no significant effect of the zinc treatments.

The second portion of this experiment was to determine the effect of applied phosphate zinc and phosphorus content of corn leaves and on eventual corn yield. The effect of increasing rates of phosphate fertilization on leaf Zn and P are shown in Table 3.

Table 3. The Effect of Phosphate Fertilization on Zinc and Phosphorus Concentrations of the Sixth Corn Leaf.

	Leaf Zn in ppm		Leaf P - %	
1966 Soil Treatment (lbs/A)	1966	1967	1966	1967
1. 40 P_2O_5	10.0ab	10.2abc	0.351bc	0.317c
2. 80 "	10.2ab	12.5ab	0.313bc	0.312c
3. 160 "	8.4bc	10.5abc	0.359bc	0.323c
4. 320 "	7.5c	9.0bc	0.400b	0.436b
5. 640 "	7.3c	8.2c	0.486a	0.570a
6. 320 " + 10 Zn as $ZnSO_4$	12.4a	13.2a	0.325bc	0.308c
7. 640 " " " "	11.0a	12.0ab	0.304c	0.310c

It is evident that the higher rates of phosphate fertilization have significantly decreased the zinc content of the leaves and the application of 10 pounds of Zn per acre as the sulfate results in a sharp increase in leaf zinc levels. Increasing P_2O_5 fertilization increases leaf P and $ZnSO_4$ soil treatments repress P levels.

The 1966 and 1967 ear corn yields of the zinc-P experiment are shown in Table 4.

Table 4. The Effect of Phosphate and of Zinc Sulfate Fertilization on Ear Corn Yield in 1966 and 1967.

1966 Soil Treat (lbs/A)	Ear Corn Yield @ 15.5% moisture (bu/A)	
	1966	1967
1. 40 P_2O_5	98.4ab	68.5a
2. 80 "	96.9ab	65.8a
3. 160 "	96.3ab	60.8a
4. 320 "	96.8ab	50.2a
5. 640 "	83.4b	34.3a
6. 320 " + 10 Zn as $ZnSO_4$	113.6a	74.8a
7. 640 " " " "	107.6a	74.7a

Since zinc deficiency in corn is more likely to occur on the more calcareous soils, most of severely deficient areas occur on relatively low lying lands which are subject to wet soil conditions in the spring and this often delays planting and maturity. In 1966, the corn was relatively mature when frost ended the growing season and the 640 pound P_2O_5 treatment produced the lowest corn yield. Applying 10 pounds of zinc per acre to the two higher P_2O_5 treatments resulted in significantly increasing these yields.

In 1967, the harvested corn was immature, and though the yield trend was similar to that of 1966, none of the differences were significant. Corn maturity is essential for maximum zinc or phosphate effect on yields. Zinc uptake by the corn plants in August of both years is much the same (Table 3) and it would be logical to believe substantial differences in ear corn yield would result if the corn matured. When early frost terminates corn growth, variability is marked and yield differences do not reach mathematical significance.

Conclusions

1. Heavy P fertilization of calcareous soils represses leaf zinc and corn yield while increasing P content of the leaves.
2. Applying zinc sulfate corrects this situation.
3. $ZnSO_4$ remains available to corn plants for at least two years.
4. Immature corn results in lower yields and increases yield variation, thereby significance due to zinc fertilization.

Micronutrient Uptake by Soybeans

V. D. Krentos and R. H. Rust

The supply potential of surface horizons from 11 Minnesota soils for copper, molybdenum, and zinc was investigated in a controlled environment study. The soils used in the study were Aastad, Bearden, Fayette, Hegne, Kranzburg, Lester, Milaca, Nicollet, Ulen, Webster, and Zimmerman- soils which occur in the existing and expanding soybean growing areas. Cu, Mo, and Zn uptake in relation to certain Rhizobia strains was also studied. Plants of the Chippewa 64 variety were grown to 35 days in a 16-hour light and 8-hour dark cycle at 70° F.

Zinc applied at a rate of 5 ppm generally decreased phosphorus content in plants grown on either calcareous (Hegne, Blue Earth) or non-calcareous (Webster) surface materials (0 - 6"). On the other hand, applications of phosphorus increased dry matter yields on these three soils with a possible optimum between the 60 and 120 ppm P rates.

Zinc content in the soybean tops was higher, by a factor of 4, on the more acid soils such as Fayette and Milaca as compared to the alkaline soils such as Bearden, Hegne, and Ulen. Zn concentration ranged from 50 - 70 ppm in plants grown on the Fayette and Milaca to 10 - 20 ppm on Bearden and Ulen soils.

Neither copper content nor concentration in the plants were significantly different as grown on the 11 soils. Copper concentration was 5 - 6 ppm in the 35 day old soybean tops.

Molybdenum content was about two times higher in plants grown on the calcareous Bearden and Hegne compared to the somewhat acid Fayette, Lester,

or Milaca soils. Mo concentrations ranged from 0.7 ppm in plants grown on Zimmerman to about 2 ppm on Ulen.

Additions of zinc and molybdenum at the rates of 5 ppm and 0.25 ppm, respectively, resulted in increased uptake on all soils but the increase for added Zn was highest on the somewhat acid soils and for added Mo, on the calcareous soils.

Nitrogen content and concentration were increased on most soils when seeds were inoculated with an effective Rhizobia strain although certain indigenous strains were as "effective" as the introduced. Content of N and yield of N were increased by added Zn, Cu, and Mo, particularly when added in combination at the rates of 5 ppm Zn, 1 ppm Cu, and 0.25 ppm Mo. Statistical analyses suggested that the addition of Mo was more effective in increasing N content and concentration than Cu or Zn.

The establishment of Rhizobia, as indicated by the character of nodulation, seemed to be favored most in Aastad, Kranzburg, and Webster soils and least in Zimmerman and the calcareous soils, especially Hegne. It should be noted, though, that only one effective strain was used for inoculation. In most of the soils indigenous strains of Rhizobia apparently were as effective in increasing N as the introduced strains.

While increases in N content and concentration and in P and Zn content were associated with "effective" Rhizobia, no significant differences were observed with boron, calcium, copper, iron, magnesium, or potassium uptake as related to inoculation treatment.

SULFUR INVESTIGATIONS ON SOILS AND CROPS

A. C. Caldwell, E. C. Seim, G. W. Rehm, and H. Feilinger

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.

An experimental field was established near Park Rapids, Minnesota in the spring of 1962. Over the years tests have been conducted on alfalfa, corn, soybeans, potatoes, sunflowers, barley, oats, wheat and red clover-brome. An overhead irrigation system was established in 1965 to provide supplemental irrigation for the sulfur experiments. Additional experiments utilizing new sulfur bearing materials are in effect this year. New studies also include soil and air temperature and soil water measurements.

This report includes 1967 yield data and analytical studies completed or summarized since December 1966.

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

Alfalfa

A rate and form of sulfur study in alfalfa was established in 1962. First cutting alfalfa yields for 1967 and the sulfur content of the tissue sampled at that time are reported in Tables 1 and 2. Annual

applications of sulfur about doubled the yield over the unsulfured plot. All rates and forms of sulfur supplied adequate amounts of sulfur to the plants when they were applied annually. Sulfur and gypsum treatment applied in 1962, however, are no longer supplying sulfur at an adequate rate for maximum production. The 100 lbs. of elemental sulfur per acre treatment and the heavy gypsum treatment (1000#s/acre) continue to produce significant yield increases over the check but sulfur content has fallen below .3%.

Table 1. Effects of annual applications of S on yields of alfalfa and on % S in tissue.

Material	Rate # S/Acre	Yield (1st. cutting) tons/Acre	S in tissue (1st. cutting) % S
0	0	.63	.193
Sulfur	25	1.42	.350
Sulfur	50	1.15	.353
Sulfur	100	1.10	.360
Gypsum	50	1.12	.371
lsd (.01)		.28	.045
hsd (.01)		.37	.059

Table 2. Effects of residual applications of S on yield of alfalfa and on % S in tissue.

Material	Rate # S/Acre	Yield (1st. cutting) tons/Acre	S in tissue (1st. (cutting) % S
	0	.35	.170
sulfur	25	.53	.176
sulfur	50	.79	.204
sulfur	100	1.18	.230
gypsum	50	.48	.169
gypsum	1000	1.23	.284
lsd (.01)		.22	.032
hsd (.01)		.29	.044

On another established alfalfa field, nitrogen was supplied to some plots to determine whether cold weather might be limiting nitrification and nitrogen fixation. Thirty lbs. of sulfur and 32 lbs. of nitrogen were applied to plots whose previous history indicated all effects of

of sulfur materials applied in 1962 had been dissipated. The results are shown in Table 3. Nitrogen increased yields of the first cutting from .6 to 1.9 ton. All of the increased tonnage was not alfalfa however, as the nitrogen greatly stimulated the growth of grass and other weeds. There are indications that ammonium nitrogen increased the uptake of sulfur relative to the same amount of sulfur supplied with nitrate nitrogen or without nitrogen.

Table 3. Effects of sulfur and nitrogen materials on yield of alfalfa and on % S in tissue.

Material	#S/Acre	Date of application	1967 fertilization N	P	K	Comments	Yield 1st. cut ton/acre	S in tissue % S
None	0#	-----		18	90		.40	.199
Sulfur	25# 30#	1962 1967	#32	18	90	NO_3-N	1.02	.331
Sulfur	50#	1962		18	90		.73	.237
Sulfur	100#	1962		18	90		.89	.240
Gypsum	60#	10# (1962) 50# (1963)		18	90		.66	.248
K_2SO_4	10# 30#	1962 1967		18	90	N-check	.62	.348
16-20-0+S	10# 30#	1962 1967	#32	18	90	NH_4-N	1.08	.395
Trace Elements 25 +S		1962 10# S as Zn-Mn-N-S						
		15#S as Trace Element Mixture 1963		18	90		.36	.214
lsd (.01)							.31	.084
hsd (.01)							.45	.121

Small Grain

In 1967 sulfur treatments gave early indications of increasing growth and vigor in barley, wheat and oats. Sulfur produced only small or insignificant increases in yields of grain however. No sulfur-bearing material was consistently better than the others. The yields, sulfur content of the whole plants at the boot stage and the sulfur content of the grain are reported in Table 4.

Table 4. Effect of sulfur-bearing materials on yield and sulfur content of small grain.

Small Grain	Material	# S/Acre	%S-Boot Stage	%S-Grain	Yield bu/acre
Wheat	none	0	.171	.193	15.2
Wheat	Elem. S	10	.186	.224	16.1
Wheat	Gypsum	10	.187	.215	14.8
Wheat	Na_2SO_4	10	.170	.195	13.9
			N.S.	N.S.	N.S.
Oats	none	0	.163	.207	51.9
Oats	Elem. S	10	.178	.232	51.3
Oats	Gypsum	10	.175	.226	54.9
Oats	Na_2SO_4	10	.179	.224	53.7
			lsd(.05).012	lsd(.05).013	N.S.
			hsd(.05).017	.018	
Barley	None	0	.210	.151	43.6
Barley	Elem. S	10	.236	.165	44.3
Barley	Gypsum	10	.215	.162	47.8
Barley	Na_2SO_4	10	.207	.149	46.0
			lsd(.05).018	N.S.	N.S.
			hsd(.05).025)		

CORN

Although the corn exhibited sulfur deficiencies early in the season, 10 lbs. of sulfur as Na_2SO_4 broadcast and disked in before planting did not significantly increase the yield of corn. Corn which did not receive sulfur produced 90.3 bushels per acre, sulfur-treated corn produced 91.9 bushels per acre. Sulfur treatments increased the sulfur content of

the 6th leaf from .261 to .282%.

Table 5. Effect of sulfur on the yield and sulfur content of corn. (Minn. 806 - irrigated).

Treatment	%S 6th leaf	Yield bu/Acre
Check-No Sulfur	.261	90.3
10# S/acre as Na_2SO_4	.282	91.9
	N.S.	N.S.

POTATOES

Yields of irrigated Burbank Russet potatoes ranged from 432.0 bushels (259 cwt) per acre to 625.4 bushels (375 cwt) per acre. Sulfur treatments did not consistently affect the yield or quality of the potatoes as indicated by specific gravity, but both gypsum and elemental sulfur treatments (50# S/acre) significantly increased the sulfur content of the potato petioles. The sulfur content of the petioles from untreated plants averaged .192% sulfur while those receiving 50 lbs. of sulfur per acre as elemental sulfur or gypsum averaged .295 and .282% S respectively.

Table 6. Effect of sulfur on yield of irrigated Burbank Russet potatoes.

Treatment	Rate #S/acre	Yield bu/acre	Yield cwt/acre	S in petioles % S	Specific gravity
None	0	521.5	312.9	.192	1.098
Elem. S	50	570.4	347.2	.295	1.090
Gypsum	50	502.9	301.8	.282	1.092
		N.S.	N.S.	lsd (.01) .055 hsd (.01) .065	N.S.

SOYBEANS

Yields of soybeans ranged from 26 to 30 bushels per acre but treatment differences due to applications of elemental sulfur and gypsum were not significant (Table 7).

Table 7. Effect of sulfur on the yield of soybeans
Park Rapids, Minnesota - 1967

Treatment	#S/Acre	Yield bu/Acre	% of S-Grain
Check	0	28.27	.364
Sulfur	25	26.86	.355
Sulfur	50	28.74	.348
Gypsum	50	30.21	.366
		N.S.	N.S.

Effects of Sulfur Treatments on pH of Surface Soil

A survey of the pH of the surface soil of alfalfa plots treated with annual applications of sulfur and gypsum indicated that the sulfur applications were lowering the ph of the surface. Consequently a more extensive sampling was made in the spring before the 1967 treatments were applied. Samples were taken by one inch increments to three inches and another from 3 to 6 inches. Each plot sample was a composite of five cores taken at random within each plot. The data presented in Table 8 are the averages of six plots.

Table 8. Effect of S treatments on the pH of the surface of a Dorset sandy loam.

Treatment	Rate	pH			
	lbs.S/acre/yr.	0 - 1"	1 - 2"	2 - 3"	3 - 6"
None	0	6.67	6.53	6.28	6.52
Elemental S	25	5.90	5.75	5.87	6.20
Elemental S	50	5.65	5.82	5.92	6.32
Elemental S	100	5.07	5.42	5.77	6.25
Gypsum	50	6.53	6.15	6.12	6.37
lsd (.01)		.32	.32	.25	N.S.
hsd (.01)		.42	.43	.33	N.S.

SULFATE LEACHING

A study was established in the spring of 1964 to trace the movement of sulfate sulfur in the profile under field conditions. Sulfur treated plots received 200 lbs. of sulfur per acre as gypsum. Sweet corn was grown on both treated and untreated plots. Periodically, soil samples were taken from these plots at 6 inch intervals to a depth of 36 inches. Sulfate sulfur in these samples was extracted with a .15% $CaCl_2$ solution and measured turbidimetrically as $BaSO_4$.

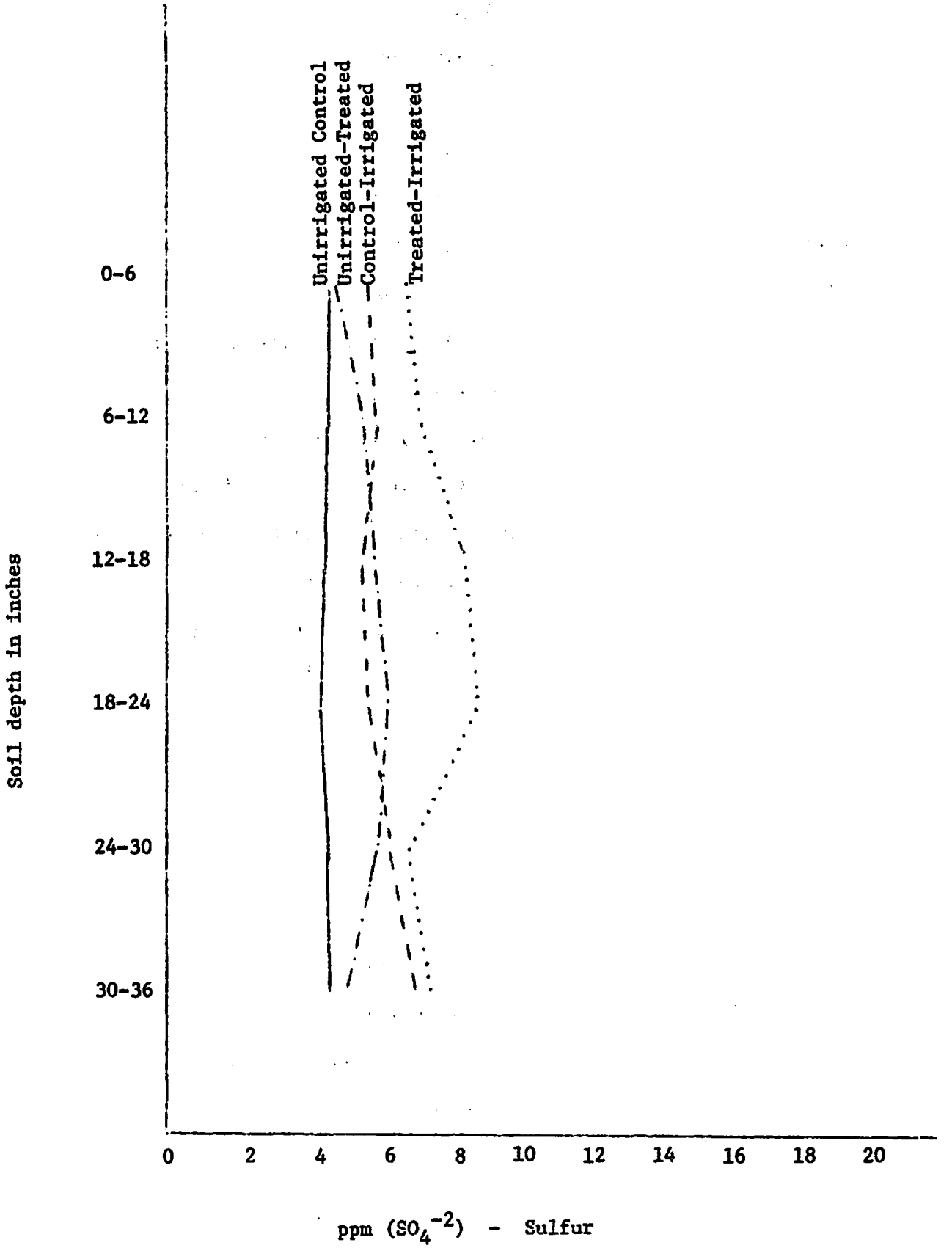
The detailed results of previous samplings were given in previous reports (Sulfur Investigations on Soils and Crops. Reports 6,7,and 9).

The results of the sampling made October 1, 1966 are reported in Table 9 and depicted graphically in Figure 2.

Table 9. Sulfate sulfur in the profile of a Dorset sandy loam on October 1, 1966.

Treatment	Core	Plot	Depth of Sample (inches) 0-6	6-12	12-18	18-24	24-30	30-36
Unirrigated No S	1	1	6.8	6.8	6.0	5.8	4.5	5.3
			6.0	6.3	6.8	5.3	5.0	5.0
	2	1	5.0	5.0	4.5	5.0	6.5	5.8
			5.0	5.0	5.0	5.3	5.8	5.3
	3	1	2.8	2.5	2.3	2.5	2.5	3.3
			2.8	2.3	2.5	2.3	2.3	3.3
	Average		4.7	4.6	4.5	4.4	4.6	4.7
Irrigated No S	7	3	5.0	4.5	4.5	5.8	5.0	5.3
			5.0	4.5	5.3	5.3	5.0	5.8
	8	3	6.0	7.8	6.0	6.0	6.0	5.8
			6.0	7.3	6.0	6.0	6.0	6.0
	9	3	6.3	6.3	6.3	5.0	8.0	7.0
			6.3	6.3	5.3	6.8	8.0	7.0
	Average		5.8	6.1	5.6	5.8	6.4	6.1
Unirrigated Gypsum @ 200 lbs. S/acre in 1964	4	2	4.0	7.0	7.3	7.0	6.3	4.3
			4.3	6.8	7.8	6.3	6.0	4.3
	5	2	6.5	5.0	5.5	5.3	5.3	5.3
			6.3	5.0	5.3	5.5	6.3	5.8
	6	2	4.3	5.5	5.3	6.8	6.0	6.0
			3.5	4.3	5.0	6.8	6.3	6.0
	Average		4.8	5.7	6.0	6.3	6.0	5.2
Irrigated Gypsum @ 200 lbs. S/acre in 1964	10	4	5.8	6.8	6.0	10.3	6.0	7.3
			5.8	6.0	8.5	8.0	6.0	7.3
	11	4	6.7	8.8	9.5	10.5	7.8	7.8
			8.0	8.0	10.3	8.7	7.8	8.0
	12	4	8.0	7.0	8.0	7.8	7.0	7.8
			7.0	7.0	8.5	7.8	7.0	7.0
	Average		6.9	7.3	8.6	8.9	6.9	7.5

Sulfate sulfur in the profile of a Dorset sandy loam
(200 lbs. S/acre as Gypsum applied in Spring 1964)
Fall "66"



Soybean Inoculation Studies

George E. Ham

Six strains of Rhizobium japonicum (soybean rhizobia) obtained from the USDA, Beltsville collection were used to inoculate three different varieties of soybeans at Grand Rapids in 1967. The peat-based inoculants were applied to the seed the night before planting and kept refrigerated until planted. Three replications with three-row plots were utilized with the center row of each plot inoculated. Inoculation increased the seed yield of both Portage and CMI by 8 bushels per acre (Table 1). Few or no nodules were present on the roots of the uninoculated plants.

Nitrogen fertilizer (ammonium nitrate) was added at planting time at the rate of 50, 100, and 200 pounds of nitrogen per acre in order to determine the amount required to produce a seed yield equal to the inoculated plants. No inoculum was applied to the seed. In no case did the addition of nitrogen fertilizer increase yields as much as inoculation with the best nitrogen fixing rhizobia (Table 2). The heavier rates of nitrogen reduced the stand and shortened the plants.

Inoculation experiments at Waseca, Lamberton and Big Lake showed no yield increase for inoculation when rhizobia were already present in the soil. Samples of soybeans that had been preinoculated with liquid and peat-based cultures and samples hand inoculated immediately before planting were compared to the uninoculated check. Paired samples taken before and after inoculation were grown in adjacent three-row plots in order to remove any variation due to seed source. Nodulating and non-nodulating soybean isolines of Chippewa maturity produced seed yields of 36 and 26 bushels per acre, respectively, at Rosemount during 1967.

Table 1. Influence of different strains of Rhizobium japonicum on soybean seed yields on a rhizobia-free soil at Grand Rapids in 1967.

Rhizobium strain	Soybean variety		
	Portage	CMI	55-14
	Seed yield bu/A	Seed yield bu/A	Seed yield bu/A
0	25	24	26
38	27	25	28
110	30	26	27
122	28	28	29
123	26	28	28
135	27	25	28
138	33	27	28
Mixture *	26	32	28

* Mixture is a composite of the six different strains
lsd (.05) = 3 bu/ acre
lsd (.01) = 4 bu/ acre

Table 2. Influence of nitrogen fertilizer on soybean seed yields at Grand Rapids in 1967.

Nitrogen fertilizer rate	Soybean variety		
	Portage	CMI	55-14
lb/A	bu/A	bu/A	bu/A
0	26	25	30
50	28	24	29
100	28	26	27
200	27	24	26

Sugarbeet Rotation Study - 1967
Northwest Experiment Station, Crookston
Olaf C. Soine, Soil Scientist

Sugarbeet production in the Red River Valley is a highly specialized enterprise with a large investment in land, machinery, and high production costs. Most growers use a 4-year rotation which includes 1 year of legume or black fallow. This gives the grower 3 cash crops in a 4-year period. This sugarbeet rotation study was initiated in the spring of 1967 to appraise the economic return from various systems of cropping.

The crop yields for the 6 rotations are as follows for 1967.

Rotation 1	Beets	Wheat	Barley	Sw. cl. fallow
	13.11 T.	55.7 bus.	101.2 bus.	_____
Rotation 2	Beets	Wheat	Barley	Oats
	13.72 T.	55.6 bus.	100.9 bus.	136.7 bus.
Rotation 3	Beets	Potato	Wheat	Barley
	13.13 T.	195 bus.	52.2 bus.	91.5 bus.
Rotation 4	Beets	Wheat	Barley	Alf-hay-fallow
	12.02 T.	49.7 bus.	105.6 bus.	_____
Rotation 5	Beets	Wheat	Barley	bl. fallow
	13.33 T.	60.1 bus.	100.4 bus.	_____
Rotation 6	Beets	Wheat	Barley	Soybeans
	13.40 T.	57.5 bus.	91.1 bus.	33.6 bus.

Chris wheat sown May 20 - harvested August 24, 1967.

Larker barley sown May 20 - harvested August 15, 1967.

Norland potato planted May 22 - harvested August 31, 1967.

Merit soybeans planted May 22 - harvested October 2, 1967.

Sugarbeets planted May 20 - harvested September 22, 1967.

POTATO FERTILIZATION ON SANDY LOAMS

Curtis J. Overdahl
Extension Specialist in Soils

Potato experiments under irrigation were conducted in 1966 and 1967 near Osseo in Hennepin County and Clear Lake in Sherburne County. The objective was to determine the fertilizer need on soils that had been fertilized intensively for several years and soil tests having been built to very high levels. Also of interest was the effect of high potassium fertilization on magnesium availability. Two farms were selected where a contrast was possible between a very high build-up of fertility over several years, and one which had not had the benefit of this nutrient build up. The latter farm was recently purchased and put under irrigation and intensive potato production.

Yields and related factors were as follows:

Potassium Experiments:

Soil tests at beginning of experiment were as follows:

Tessman Farm, Hennepin County P=200+, K=600+, pH=5.4, sandy loam

Gray Farm, Sherburne County P=17 lbs., K=130, pH=5.4, sandy loam

1966 Results

	Yield* CWT/Acre		Petiole Analysis			
			Tessman		Gray	
Fertilizer Treatments	Tessman	Gray	%K	%Mg	%K	%Mg
100 + 100 + 0	332	207	11.6	.14	-	-
100 + 100 + 50	315	-	12.0	.17	-	-
100 + 100 + 100	293	232	12.3	.09	8.3	.55
100 + 100 + 250	356	313	13+	.15	10.0	.38
100 + 100 + 500	277	338	12.8	.14	11.8	.31
100 + 100 + 1000	-	341	-	-	11.3	.37

* Norland variety

1967 Results

Fertilizer Treatments	Yield* CWT/Acre Tessman	Yield* CWT/Acre Gray **	Petiole Analysis Tessman %K	Petiole Analysis Tessman %Mg	Petiole Analysis Gray %K	Petiole Analysis Gray %Mg
150 + 150 + 0	206	111	8.0	.22	4.5	.49
150 + 150 + 100	-	194	-	-	7.6	.22
150 + 150 + 150	225	-	8.0	.20	-	-
150 + 150 + 250	-	198	-	-	9.0	.15
150 + 150 + 500	222	199	7.9	.20	9.0	.13
150 + 150 + 1000	-	203	-	-	9.0	.15

* Average of two varieties
**This plot had severe hail June 30, but the moderately late bounty variety recovered quite well, while the somewhat earlier Norland yielded considerably less.

Where the potassium (K) test was 600+ at Tessman's, there was no K response in 1966. In 1967, there was considerable yield variation and no apparent response. Tissue analysis for K showed little treatment effect. Magnesium (Mg) content tested low for all treatments of K.

At Gray's Farm near Clear Lake in 1966, potato yields increased directly with K treatments, K in the petiole also increased directly with treatments and magnesium content was correspondingly decreased but not nearly to such a low level as at Tessman's. In 1967, the results may not be as meaningful because of severe hail damage. The first 100 pounds of K_2O gave the only important yield increase, but hail apparently reduced chances of the potatoes being able to capitalize on any high K treatments. Magnesium content was reduced seriously as K content was increased due to K treatment.

Changes in soil test due to K treatment are also of interest, particularly on the Clear Lake Farm where we started from a relatively low level. This land is usually plowed about seven or eight inches deep.

Potassium Treatment K_2O lbs/acre	K Soil Test After 1966 Crop 0 - 6"	6 - 12"	After 1967 Crop 0 - 6"	6 - 12"
0	130	50	150	70
100	150	50	170	75
250	180	100	180	105
500	200	250	345	330
1000	230	400	340	365

MAGNESIUM EXPERIMENTS

In 1967, a magnesium experiment was established on the Tessman farm. There was no significant yield response to magnesium or effect on the magnesium content in the petioles. Results with the bounty variety were as follows:

	Magnesium Treatment lbs/acre 0	25	50	75	300
Yield CWT	339	328	341	344	322
% Mg in petioles	.22	.23	.26	.25	.23

Magnesium was applied as magnesium sulfate. All material was applied in the row except 225 pounds of the 300 pound treatment. The NPK rates were 150 + 150 + 500. This plot was adjacent to the other experiments but was in rye for soil improvement in 1966.

Two years results with magnesium containing dolomitic limestone on nearby plots gave no yield increase with four varieties and little, if any, effect on magnesium petiole content. Magnesium in the petioles in 1967 ranged from .19 to .25. Limestone rates ranged from 0 to 8000 pounds per acre.

PHOSPHORUS STUDIES

There was no apparent phosphorus response in 1966 at Osseo where the P test was 200+, but in 1967 there was an obvious starter P response. Where the P soil test was only 17 pounds per acre at Clear Lake, results were as follows:

1966 Treatment	CWT*/A	%P	1967 Treatment	CWT*/A	%P
100 + 0 + 500	255	.29	150 + 0 + 500	98	.16
100 + 100 + 500	325	.26	150 + 150 + 500	233	.43

* 1966 Norland Variety, 1967 Average of Bounty and Norland Varieties.

The P soil test after one year was raised from 17 to 26 and after two years was raised to 40 pounds of absorbed P per acre.

NITROGEN STUDIES

Response to nitrogen at Tessman's indicated that 200 pounds per acre was superior to 100 pounds, while at Gray's there was a good response from 100, but 200 pounds in 1966 yielded no better. In 1967, the 200 pound treatment looked best but hail kept these plots from producing very well and conclusions on nitrogen could not be drawn.

Funds for this project were supplied by the American Potash Institute. Efforts in plot work leadership by G. W. Randall, C. P. Klint, as well as county agents, George Roadfeldt, Enoch Bjuge, Horticulture specialist, O. C. Turnquist, and TVA specialist, Harvey Meredith, are gratefully acknowledged. The excellent cooperation of Howard Gray and Eldon Tessman in the use of their machinery, as well as their land, is much appreciated.

FERTILIZER TRIALS ON OIL CROPS

Northwest Experiment Station
Crookston, Minnesota - 1967

Olaf C. Soine, Soil Scientist

Sunflowers: The yield data for sunflowers for 1967 and the 1966-67 averages are given in Table 1. The yields were lower in 1967 than in 1966 due in part to the summer drought. The 20-40-0 treatment gave the best yield response in 1967 and also for the 2-year average. There was very little variance in the bushel weights.

Tame Mustard: The yield data for tame mustard is given in Table 2. The yields in 1967 were low, due in part to the summer drought. Six treatments were above the check plot, and 7 were below. The *10-40-0 treatment gave the highest yield response in 1967, and the *20-40-0 gave the best response in the 2-year data.

Table 1. The effect of fertilizer on the yield and bushel weight of sunflowers.
Northwest Experiment Station, 1967 and 1966-1967 average.

Treatment lbs./acre	Yield lbs./acre		Bus. wt.	
$N - P_2O_5 - K_2O$	1967	Av. 1966-67	1967	Av. 1966-67
20-40-0	2205	1894	28	28
40-80-0	2094	1882	28	29
20-40-20	1971	1749	28	28
40-80-40	1711	1688	28	29
0-0-20	1791	1671	27	28
0-40-20	1754	1630	28	28
0-80-0	1680	1565	28	28
20-0-0	1626	1546	28	28
0-80-40	1638	1525	28	29
0-0-0	1578	1488	28	29
40-0-0	1319	1470	28	28
0-40-0	1393	1454	28	29
80-160-80	1390	1390*	27	27
0-0-40	1290	1289	28	28

Table 2. The effect of fertilizer on the yield of tame mustard. Northwest Experiment Station, 1967 and 1966-67 average.

Treatment lbs./acre $N - P_2O_5 - K_2O$	Yield-1967 lbs./acre	Av. Yield 1966-1967 lbs./acre
**20-40-0	820	1093
*10-40-0	918	1073
**30-40-0	905	1017
*30-40-20	818	1009
20-40-20	861	990
0-40-0	860	978
**20-0-0	735	953
10-40-0	835	946
0-0-0	852	940
*10-0-0	814	922
*20-40-0	809	899
**60-80-40	---	1266+
40-80-40	852	852++
**40-40-20	840	840++
80-160-80	791	791++

\+ 1966 data
++ 1967 data
Treatments *10-0-0 and **20-0-0 broadcast before seeding.
Remaining treatments applied alone and in combinations with broadcast treatments in a band at seeding time (e.g. **20-40-0---**20-0-0 broadcast + 0-40-0 with drill).
Sown May 6, 1967 -- Harvested August 3, 1967

1967 Sunflower Fertility Experiment

A. Heikkila, H. Shurson, F. Jorgenson, and G. Randall

An experiment was established in the spring of 1967 in Clearwater County to determine the effect of differnet fertility treatments on the seed yield of sunflowers. The variety Arrowhead was used. All treatments were replicated three times.

Experimental Field Soil Test Values

Sample No.	pH	O.M. %	P lbs/A	K lbs/A	Texture
1.	7.5	8.5+ Vh	16 M	240 H	Silt loam
2.	6.9	8.5 Vh	27 H	310 Vh	Silt loam

Table 1. The Effect of the Fertilizer Treatment on Number of Harvested Heads and Seed Yield.

Treat No.	Treatment lbs N + P_2O_5 + K_2O	Number Heads	(DMRT)*	Yield lbs/A	(DMRT)
1	0 + 0 + 0	51	a	728	bc
2	0 + 0 + 30	45	a	610	c
3	0 + 30 + 0	38	a	795	bc
4	0 + 30 + 30	41	a	549	c
5	30 + 0 + 0	54	a	1166	a
6	30 + 0 + 30	51	a	1012	ab
7	30 + 30 + 0	43	a	766	bc
8	30 + 30 + 30	49	a	784	bc
9	30 + 30 + 60	47	a	970	ab
10	30 + 60 + 30	46	a	869	abc
11	60 + 30 + 30	47	a	1036	ab
12	60 + 60 + 60	52	a	998	ab

*Duncan's Multiple Range Test; those numbers followed by the same letter are not significantly different at the .05 level.

Results showed no significant differences among the treatments regarding the number of heads harvested, but significant yield responses were observed. The addition of 30# N gave a 262 pound seed yield increase, even on these soils high in organic matter. Phosphate and potash treatments did not increase sunflower seed yields. High and very high P and K soil test levels showed little possibility of response for adding these elements. Increasing the fertility rates up to 60#/A did not significantly increase the yields above the 30 + 0 + 0 treatment.

AGRONOMIC STUDIES WITH SUGAR CORN AND SORGHUM

Russell D. Frazier, Waseca

Interest developed in 1967 for agronomic studies on sugar corn and sorghum due to the introduction of a new industry in southcentral Minnesota. The acreage in 1967 was some 11,000 acres. The entire above-ground portion of the crop is harvested, the juice is extracted and refined as liquid sugar. While the potential of the industry to southern Minnesota is clearly apparent, the agronomic factors involved have not been well studied. Northland Research entered into an agreement with the University to conduct research, particularly in the areas of the effects of soil fertility conditions on the production, extraction and refining of sugar. Plant content of nitrogen and potassium at harvest time was thought to affect the sugar extraction processes used. The objective of the initial study was to study the effect of the amount and placement of nitrogen and potassium fertilizer on early seedling vigor and other agronomic variables in both high sugar corn and sorghum. To our knowledge, there have been no previous studies in this country of the effects of soil fertility on the sugar content of high sugar corn. An N-K factorial experiment was initiated using N at the 70, 140 and 200 lb. levels with K_2O at 0, 200 and 400 lb. per acre rates. Four replicates were provided; P_2O_5 treatment was uniform at 100 lbs. per acre, as was a starter fertilizer of 175 lb. of 6-24-24. Each plot was split with and without a "pop-up" application of 50 lb. of 15-39-9.

Percent sugar and pounds per acre production of sugar were calculated using a hand refractometer reading directly in percent sugar. Readings were taken on the expressed sap from six plants harvested per plot. In calculating sugar yield, the assumption was made that the sugar content of the entire plant was represented by this sap. While the data thus obtained do represent the sugar content of the stalks, the leaves, ears, and tassels of the plant contain

a lesser content of sugar and thus the data tend to over-estimate the sugar concentrations and the sugar production per acre. Fresh and dry weights were obtained on samples from each plot and pounds per acre sugar production as well as total dry matter calculated on this basis. Plant population was a uniform 25,000 plants per acre. Soil tests for P and K are in the high range.

Table 1. Percent Sugar in Stalks, Sugar Corn Research, 1967, Southern Experiment Station, Waseca. (One year's data, not for publication.)

	Fertilizer nutrients applied					
	K_2O 0		K_2O 200		K_2O 400	
(% sugar)	Starter	Band	Starter	Band	Starter	Band
August 22-25			Percentage sugar			
N_{70}	9.0	9.6	9.3	9.4	9.2	9.0
N_{140}	9.0	9.3	9.1	9.1	9.2	9.2
N_{210}	8.8	9.1	8.8	9.2	9.3	9.2
September 14						
N_{70}	13.0	14.0	13.0	13.9	12.9	13.5
N_{140}	13.0	13.0	13.1	13.3	13.6	13.5
N_{210}	13.3	13.8	12.8	13.3	13.3	13.5
October 2						
N_{70}	11.1	11.2	12.5	12.3	12.5	11.6
N_{140}	11.9	11.0	12.7	12.6	13.0	11.9
N_{210}	12.4	12.1	11.3	12.0	11.7	12.2

Table 2. Pounds per acre sugar production, sugar corn research, 1967; Southern Experiment Station, Waseca, Minnesota 1967.

	Fertilizer nutrients applied					
	K_2O 0		K_2O 200		K_2O 400	
	Starter	Band	Starter	Band	Starter	Band
August 22-25			Percentage sugar			
N_{70}	5054	5779	6514	6825	6594	6726
N_{140}	5996	6284	5808	6333	6219	6494
N_{210}	6018	6067	6447	6374	6829	5646
September 14						
N_{70}	8248	8478	8805	9235	9294	9624
N_{140}	8321	7817	8705	8716	9662	10157
N_{210}	9549	8856	9434	9123	9472	9449
October 2						
N_{70}	3665	3585	8257	7978	4769	4609
N_{140}	4252	3887	4744	4792	4895	4985
N_{210}	7318	7367	4283	4501	4960	4632

This data is incomplete and not for publication. Pounds per acre sugar is subject to the sampling methods used, and probably over-estimates true production.

Table 3. Dry Matter Pounds Per Acre, Southern Experiment Station, Waseca, Minnesota, 1967.

	Fertilizer nutrients applied					
	K_2O 0		K_2O 200		K_2O 400	
	Starter	Band	Starter	Band	Starter	Band
August 22-25			Percentage sugar			
N_{70}	20,833	16,874	20,417	19,791	16,562	17,708
N_{140}	17,500	18,125	24,479	18,541	18,437	18,125
N_{210}	17,916	17,604	20,104	17,187	16,145	15,520
September 14						
N_{70}	18,183	16,595	17,940	17,994	18,667	19,063
N_{140}	17,771	16,529	17,295	17,015	18,917	19,177
N_{210}	19,498	18,033	17,505	20,334	18,514	20,322
October 2						
N_{70}	17,050	16,832	18,265	17,381	18,340	19,788
N_{140}	16,729	16,934	17,443	18,792	16,696	18,618
N_{210}	18,477	16,588	17,923	19,298	20,289	19,277

This data is incomplete and not for publication.

FERTILIZING ALFALFA IN MORRISON COUNTY MINNESOTA

Curtis J. Overdahl
Extension Specialist in Soils

Limited experiments and field demonstrations indicate that high yielding, high quality alfalfa can be grown if details of fertilization, liming, variety, and proper cutting times are observed.

Alfalfa is seldom grown successfully on sandy textured soils that test low in potassium or have pH values below 6.3.

These conditions generally prevail in soil areas of Minnesota approximately north and east of a line from the Twin Cities to Alexandria, Minnesota to the Canadian border. There are, of course, many exceptions to such a general description. Although many of these soils are not sandy textured, the nutrient deficiencies are often similar.

Experimental plots on alfalfa were established at Pierz in Morrison County in the fall of 1962 on non-irrigated land. These plots were established to determine needed rates of potassium, lime, and phosphorus, but sulfur and boron were applied to be sure a deficiency of these elements didn't limit growth.

Results definitely show that high rates of potassium, both at seeding time and topdressed later, are necessary for most economical production. There is a lime response even with initial pH levels of 6.2 or 6.3. Alfalfa winter killed in 1966 hence no data are available for that year.

Table 1. Alfalfa yields in tons per acre and related profits according to varying 1963 treatments of potash and 1964, 1965, and 1967 yields.

Year	Cuttings	1963 Seeding time rates of K_2O, pounds per acre				
		0	60	120	180	240
1964	2	2.31	2.40	2.60	2.70	3.00
1965	3	4.02	4.16	4.50	5.08	5.36
1967	3	1.32	1.23	1.32	1.70	1.71
3-year yield total		7.65	7.79	8.42	9.48	10.07
Potash cost/acre		0	3.00	6.00	9.00	12.00
3-year increase tons/acre		0	.14	.77	1.83	2.42
Value of increase at $18/ton		0	$2.52	$13.86	$32.94	$43.56
Hay value increase less potash cost (three year total)		0	$-.48	$ 7.86	$23.94	$31.56

In Table 1, it can be seen that the effect of the 1963 potash treatments has about disappeared after three crop years. All plots fertilized in 1963 were split three ways in the fall of 1964 and were topdressed annually at 0, 120, and 240 pounds of K_2O. Each year all plots received 60 lbs/acre of P_2O_5. Borated gypsum at the rate of 300 lbs/acre supplying 50 pounds of actual sulfur and 4 1/2 lbs/acre of boron was applied in 1963 and 1967 over all plots.

Soil samples were taken in May 1967, tissue tests were made at the time of the first cutting. Yields were taken June 13, July 26, and August 31.

Table 2. Soil treatments of K_2O and its relationship to 1967 soil tests, tissue analysis and alfalfa yields. Only two replicates are involved in this sampling.

K_2O Treatment						
	annually	Soil Test			Tissue	1967 Yield
1963	1964, 65, 66	pH	P	K	% K	tons/acre
0	0	6.9	21 high	30 V. low	0.7	0.8
60	0	6.3	42 V. high	40 V. low	0.7	0.9
120	0	6.6	40 V. high	40 V. low	1.0	1.0
180	0	6.9	33 V. high	50 V. low	1.3	1.9
240	0	7.1	21 high	40 V. low	0.9	1.7
0	120	6.8	18 med.	150 med.	1.8	2.5
60	120	7.0	18 med.	100 med.	1.9	4.5
120	120	6.9	20 M. high	130 med.	2.1	4.3
180	120	6.8	23 high	190 med.	2.0	3.5
240	120	6.7	21 high	150 med.	1.9	3.9
0	240	6.5	28 high	390 V. high	2.2	4.1
60	240	6.8	28 high	350 V. high	2.3	4.9
120	240	6.9	19 M. high	340 V. high	2.3	4.1
180	240	6.3	28 high	250 high	2.2	3.6
240	240	6.8	16 med.	380 V. high	2.4	5.2

In the soil tests above, with only a few exceptions, we are quite certain the pH is at an adequate level after five years with five tons of lime. Phosphorus levels appear quite adequate, but P_2O_5 levels have been increased to 120 pounds for 1968.

Table 3. 1967 Averages from 20 replications of alfalfa.

	K_2O Annual Treatments after 1963		
	0	120	240
Yield 1967 tons/acre	1.52	4.14	4.51
% K in tissue	.93	1.96	2.25
Soil test, K	42 V. low	173 med.	325 V. high

Table 4. Lime Results. Alfalfa yields increases in tons/acre from 1962 lime treatments. Adequate P, K, S, and B added regularly.

	Tons per acre of lime*	
	2.5	5
1964 (2 cuts)	.24	.39
1965 (3 cuts)	.14	.41
1967 (3 cuts)	.60	.88
Total increase to date	.98	1.68
pH (6.3 initially) 1967	6.7	7.0

* Calcium carbonate equivalent of the lime was 93%, 31% of the lime passes a 60 mesh screen and 94% passes an 8 mesh screen. Lime is from Bryan's Quarry at Shakopee.

Table 5. Phosphorus Results. Increase in alfalfa yields in tons/acre and related soil test and tissue test. Adequate lime, K, S, and B added.

	Annual Treatment P_2O_5	
	30	60
1964 (2 cuts)	.30	.45
1965 (3 cuts)	.74	1.03
1967 (3 cuts)	1.37	1.86
Annual average increases	.80	1.11
% P tissue*	.22	.28
Soil test P* lbs/acre 1967	18	27

* With no phosphorus tissue contained .19% P, and soil tested 10 lbs/acre.

Acknowledgement is due the American Potash Institute for financial support of this project, to L. D. Hanson in assisting the establishment of the project, to Gyles Randall assisting in plot work and statistical analysis, and to Roderick Boser for excellent cooperation with field work and use of his land.

Grass Seed Production and Fertilizer Needs

John Grava, D. M. Larsen, G. W. Randall, and R. S. Farnham

Seed production of turf and forage grasses is a very important farm enterprise in northwestern Minnesota. Nearly one million dollars in cash sales are realized annually by seed producers in Roseau, Clearwater, Lake of the Woods and East Polk Counties. Cleaning plants at Roseau and Gully processed 1.5 million pounds of Kentucky bluegrass and 4.5 million pounds of timothy seed in 1965.

Optimum yields of high-quality seed require sufficient supply of plant nutrients. This is well recognized by the growers. They invest from seven to thirteen dollars per acre each year for commercial fertilizers. Generally, about one-third of the total production costs is spent on fertilization. Thus, soil fertility problems, proper fertilization, and diagnostic techniques used in the evaluation of plant nutrient needs are of utmost interest to the producers of grass seed.

Fertilization studies with Kentucky bluegrass and timothy have been conducted by several staff members of the Department of Soil Science since 1959. Information has been obtained on optimum rates of N, P, and K, on effects of time of fertilization, chemical properties of soils, soil tests, and plant analysis.

During the 1966/67 growing season, 8 field experiments were conducted on growers'fields in northwestern Minnesota. The investigations consisted of: (a) Date of fertilization, 3 trials with K. bluegrass and 2 trials with timothy, (b) Fertilization of 6 to 9 year old timothy stands, three trials. The determinations included the measurement of seed yield, determination of 16 chemical elements in grass tissue, and climatological measurements at selected sites.

Since the experimental data on timothy will be used by D.M. Larsen for

his M.S. thesis problem, data from K. bluegrass plots only is given in this report.

Cool season grasses, such as K. bluegrass and timothy prefer somewhat cool and moist weather. The 1966/67 season, as shown in Table 1, was characterized by slightly less than normal precipitation during fall and winter, and above normal rainfall during the spring of 1967. The average temperature at the Roseau weather station was about normal in the fall of 1966, and below normal during winter and spring seasons.

Fertilization of production fields in the prime of their productivity can double or triple the seed yields of K. bluegrass. This was the case with Field No. 1 on a Bearden sicl soil (Table 2). The field was renovated in the fall of 1965 and yielded about 100 lbs./Acre of seed in 1966. The dried-up vegetative growth was burned off in spring of 1967. Fertilization increased seed yields by 400 lbs./Acre.

The productivity of K. bluegrass fields seems to be affected by a number of factors. Age of stand may be one such factor. Field No. 2 on peat, was seeded in spring of 1963 and yielded, by grower's estimate, more than 600 lbs./Acre of seed in 1966. The field was burned in summer of 1966, after seed harvest. Fertilization with 20+40+40 increased seed yield from 136 to 247 lbs./Acre. Apparently the field was past its prime and the grower had planned to renovate it in the fall of 1967.

The removal of old straw and dried up vegetation by burning, clipping or grazing often is related with high seed yields of K. bluegrass. Non-removal of such residue then would be expected to have a certain depressive effect on seed yields. This may have been the case with Field No. 3 on a Rocksbury loam, Lake of the Woods County. The field was seeded in spring of 1964 and yielded, by grower's estimate, about 600 lbs./Acre of seed. The grower does not burn his fields but utilizes the vegetative growth after

seed harvest by grazing and occasional clipping. The plot area was fenced in to protect it from grazing animals. In the spring the plot area had a relatively thick mat of dried-up vegetation which was not removed. The application of 60+46+46 lbs./Acre of plant nutrients increased the seed yield from 76 to 199 lbs./Acre.

Field trials on the effect of time of fertilization--- fall, winter, or spring---have not shown any consistent differences in favor of either application time. The results of the 1967 experiments, however, indicated that fertilization during late summer (Aug. 25) or late spring (May 20) resulted in lower seed yields when compared with the other dates of fertilization (Table 3). Growers are encouraged to apply fertilizers in the fall, from the middle of September on.

Table 1. Climatological Data as Measured at Roseau U.S. Weather Station

PERIOD	PRECIPITATION (INCHES) TOTAL	DEPARTURE FROM NORMAL	TEMPERATURE (°F.) AVE.	DEPARTURE FROM NORMAL	GDD T_b = 40° F.
1966/67					
Aug. - Oct.	5.46	-1.46	54.5	-0.4	1335
Nov. - Mar.	4.43	-1.11	9.1	-3.4	---
Apr. - July	10.96	1.48	52.0	-3.6	1592
Total	20.85	1.14			2927
Average			34.8	-2.9	

Table 2. Effect of Fertilization on the Seed Yield of Park Kentucky Bluegrass 1967.

PLANT NUTRIENTS APPLIED N P_2O_5 K_2O LBS./ACRE	FIELD 1. E.B. ROSEAU CO. BEARDEN SICL	FIELD 2. E.B. ROSEAU CO. PEAT	FIELD 3. L. O. W. CO. ROCKSBURY L.
	YIELD OF SEED LBS./ACRE		
None	163	136	76
40+46+46	339	---	---
60+46+46	567	---	199
60+92+46	---	---	184
10+40+40	---	245	---
15+40+40	---	224	---
20+40+40	---	247	---

Table 3. Effect of Date of Fertilization on the Seed Yield of Park Kentucky Bluegrass.

DATE OF FERTILIZATION	FIELD 1. BEARDEN SICL	FIELD 2. PEAT	FIELD 3. ROCKSBURY L.
	YIELD OF SEED, LBS. /ACRE		
1966 Aug. 25	497	210	137
Sept. 15	567	247	199
Oct. 15	531	251	237
1967 May 1	421	266	168
May 20	295	235	147
SPLIT (1/2 on Sept. 15, 1/2 on May 1.)	567	266	202

Soil Testing in Minnesota during 1967

John Grava

Currently the University of Minnesota Soil Testing Laboratory processes nearly thirty five thousand samples annually. The following data show the number of various types of samples analyzed in 1967:

Regular farm, garden and lawm samples	31,384
Florist (Greenhouse) samples	2,244
Limestone	67
Departmental research samples	764
Total	34,459

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 1967.

Month	Number of Samples
January	1650
February	1544
March	1860
April	3997
May	1476
June	1307
July	840
August	1525
September	3480
October	4520
November	4798
December	4387