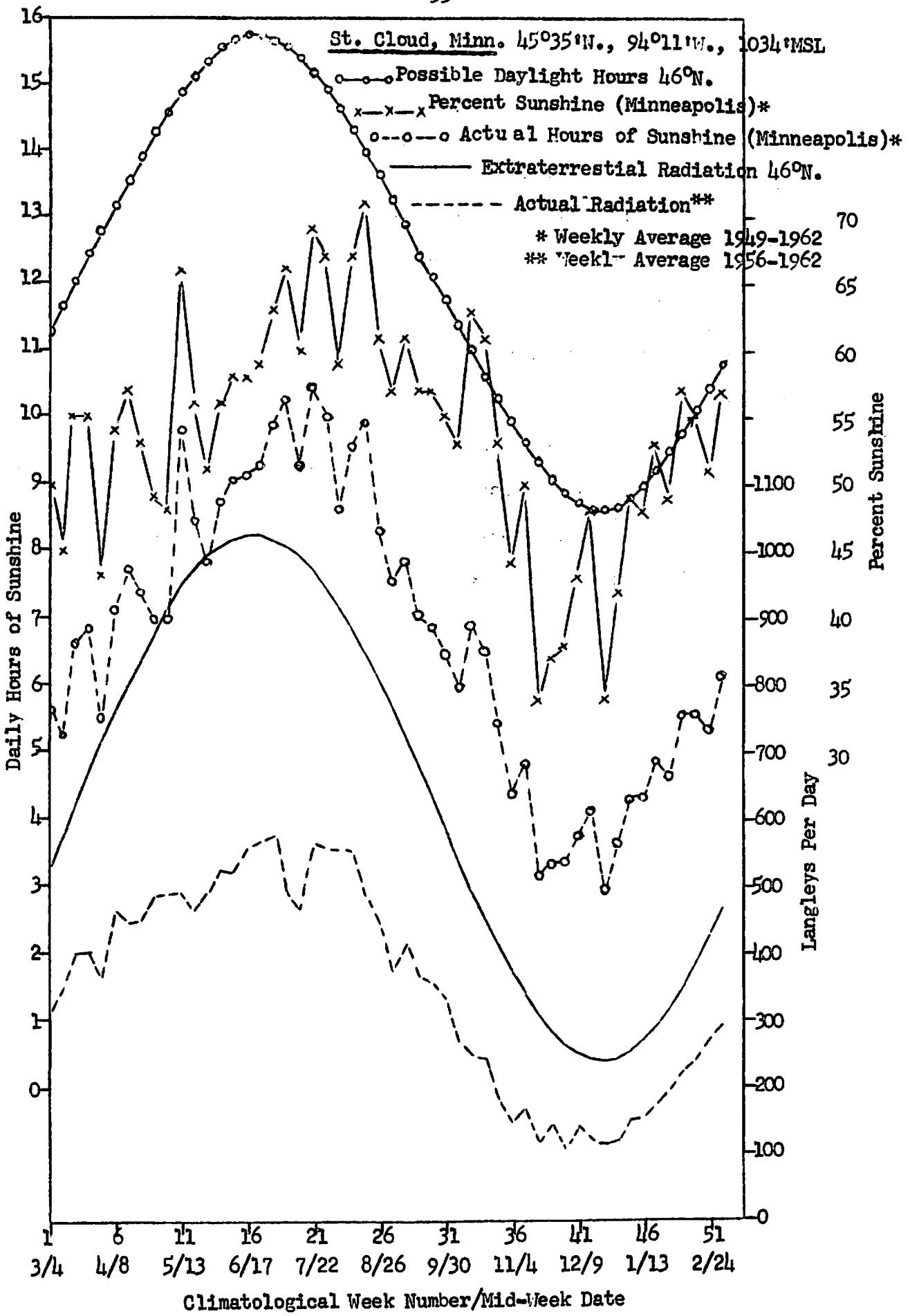
Radiation

On a continual recording basis both solar radiation and net radiation are obtained at the Soils Department Weather Station. Detailed studies using these data are being made. Of a more general nature is a pilot study into the correlation between sunshine duration and solar radiation reception, as well as the distribution of each based upon climatological records.

The results obtained, though of preliminary nature, are interesting. The only item of this study to be presented here, however, is the following figure which shows the average weekly sunshine received at Minneapolis and the average weekly radiation received at St. Cloud. Incidentally, until a year ago these were the only stations in the state recording such data.


St. Cloud, Minn. 45°35'N., 94°11'W., 1034'MSL
Possible Daylight Hours 46°N.
Percent Sunshine (Minneapolis)*
Actual Hours of Sunshine (Minneapolis)*
Extraterrestial Radiation 46°N.
Actual Radiation**
* Weekly Average 1949-1962
** Weekly Average 1956-1962
Daily Hours of Sunshine
Percent Sunshine
Langleys Per Day
Climatological Week Number/Mid-Week Date
1 6 11 16 21 26 31 36 41 46 51
3/4 4/8 5/13 6/17 7/22 8/26 9/30 11/4 12/9 1/13 2/24

The Weather of 1963

The following summary was kindly provided by Mr. Joseph H. Strub, Jr., for inclusion in this outline.

Although January began quite warm, severe cold moved into the northern third of the State on the 10th and the rest of the State on the 11th. Daily minimum temperatures registered 0° F. or colder from then through January 31. Throughout February daily minimum temperatures were recorded 0° F. or colder for at least half of the month, but their occurrence was not consecutive as in January. Except for long-term mean precipitation over the southwest division during January and along the Canadian Border during February, January and February precipitation was much below the long-term mean. With the extended cold of January and February, and the lack of snowfall, frost penetration was much deeper this year compared to last year.

March temperatures were 4° to 9° above the long-term mean. Precipitation was near the mean. Although snowfall was near the mean, the above 32° F. temperatures the last 10 days of the month coupled with nighttime readings below 32° F. released the snow melt slowly so that there was no flood problem. Frost penetration came out rapidly. Record breaking temperatures in the sixties and seventies occurred the last 4 days of March. The last occurrence of 0° F. or colder occurred on March 22 at Gunflint Lake.

April temperatures continued warm with precipitation above the mean. Field work started throughout most of the State by mid-April. Seeding was well underway in the central and southern half of the State. Mississippi River navigation opened at Minneapolis-St. Paul on April 1 after a channel was made through Lake Pepin ice on March 31. The year's first storm of 3/4 inch hail occurred on April 1 in the Paynesville area.

What looked like the start of earlier-than-usual and an excellent agriculture season darkened somewhat as May turned out cool and wet. Western and southern Minnesota were hit hard by a freeze during the early morning hours of the 21st, 22nd, and 23rd as temperatures as low as 21° in some areas damaged soybeans, corn, peas, garden crops, and fruit trees. Greatest damage was sustained the morning of the 22nd. For many areas the temperature recorded was the coldest temperature of record for so late in the season. Regardless, planting and seeding were completed in most areas by May 31.

With the return of warm temperatures in June severe weather began to occur throughout the State. The season's first damaging windstorm covered southeastern Minnesota on June 8. The first 1963 tornado was observed at Janesville on June 9. The first occurrence of a temperature of 100° F. or more was recorded at Canby on June 29, 101°F.

June temperatures were below the long term mean with precipitation also below the mean with the exception of the southwest, south central, and parts of the north central and northeast divisions, where it was above. For all of the State there was little or no rainfall from June 10 through 27. This lack of rainfall aggravated by temperatures generally in the upper eighties and nineties the last 9 days of the month dried the State out. Although agricultural interests had sufficient moisture to continue growth, urban areas such as Minneapolis-St. Paul were suffering moisture to continue growth, urban areas such as Minneapolis-St. Paul were suffering as supplement watering was needed to sustain grass, shrubbery, ornamental trees, and truck gardens. Watering bans were in effect throughout many suburban areas by the end of the month.

The first eleven days of July were void of effective rainfall except for the southwestern and south central divisions. July rainfall ranged from 0.97 inch at Duluth to 13.61 inches at Canby. This July rainfall at Canby was more than the total seven month precipitation at Minneapolis-St. Paul, 12.62 inches. For the most part rainfall was heavy over the southern third of the State.

August rainfall was below the long-term mean but what fell was timely. September precipitation was above except for the northern third of the state and the southeast division. The remaining four months of the year were below the long-term monthly mean.

July temperatures were near the long-term mean with August below. September returned to above the long-term mean with October and November much above. The October-November months combined were the second warmest such period of record for many locations. Surprisingly, the warmest October-November for much of the state was that of 1953. Although a temperature of 32° or colder was reported in numerous areas in September, it wasn't until October 29 when temperatures were lower than 32° F. statewide that the growing season ended.

December ended 1963 the way it began in January with temperatures much below the long-term mean and precipitation also below except for north central Minnesota and along the Canadian border where it was above the long-term mean. For most of the state December was the fourth coldest of record. There were at least twelve consecutive days with a minimum temperature 0° F. or colder. On the 15th-16th and again for the period of the 19th through the 21st, the maximum, as well as the minimum temperatures, did not go higher than 0° F.

There was no snow in October except for a trace at Babbitt. November snowfall was light with the first measurable amounts falling on the 11th. Minneapolis-St. Paul had only a trace of snow during November. This had only happened once before in 1928. Winter came to Minnesota in a hurry on December 8-9 as 3 to 9 inches of snow fell throughout the state followed by sub-zero temperatures on the 11th. The first occurrence of -10° or colder was on December 11; of -20° or colder on December 15; and of -30° or colder on December 16.

With the snow and cold arriving in December as it did, winter agricultural routine and sporting activities went into high gear. Ice fisherman were on the lakes by the 10th as lakes over most of the state were ice covered by December 1. The sub-zero temperatures broke on the 22nd allowing Christmas shoppers to complete their buying.

The Mississippi River navigation season ended at Minneapolis-St. Paul on December 9 and at La Crescent-La Crosse on December 14. Lake Superior navigation terminated at Duluth on December 14.

The Effect of Nitrogen Source, Placement and Time of Application on the Yield and Composition of Continuous Corn on Webster Clay Loam at Lamberton

J. M. MacGregor, W. W. Nelson, and R. G. Hanson

The effect urea and ammonium nitrate as sources of nitrogen on the yield and composition of corn is being studied. The nitrogen materials are being plowed down and surface applied. The plowed down treatments are fall applications. The surface treatments were applied in fall, spring and a late sidedressing. This study was started in 1960.

Each experimental plot is 77.5 feet long and six corn rows wide. Each treatment is replicated four times. Sufficient phosphorus and potassium is applied as broadcast and starter applications. A plant population of 18,000 plants per acre is established. The primary objectives of this field project is to investigate:

1) The relative effectiveness of equal amounts of nitrogen as urea or as ammonium when applied to this soil at different rates.
2) The relative efficiency of such nitrogen forms when they are applied in the late fall, in the spring at time of planting, or as late sidedressing in late June or in early July.
3) The relative values of fall plowing down of two sources in comparison to overwintering of the nitrogen fertilizer on the surface of the fall plowed soil.
4) To find if there was any possible fertilizer nitrogen accumulation in the soil, the relative amounts removed by the corn crop and losses sustained through leaching, losses to the air, or losses by soil erosion.

For the first few years, all data was obtained by harvesting and analyzing the corn plants, and computing the nitrogen removal and relative efficiency based on amounts actually present in the corn plants. The plant parts were divided into ears, leaves, upper stalk and lower stalk. Soil samples were collected from some treatments during 1962 and 1963. The depths sampled were 0-6", 6-12" and 12-24".

The yield of corn in 1960 was quite low for all treatments. The 1961 yields were much higher than the 1960 yields and could be related to amount of applied nitrogen. In 1962 the weather was cold and wet and only sidedress applications indicate strong response to application of nitrogen.

The effect of nitrogen source, rate and time of application of urea and ammonium nitrate on the yield of continuous corn is presented for the 4 years (1960-63) in Table 1.

Table 1. The Effect of Nitrogen Source, Rate and Time of Application on the Yield of Continuous Corn at Lamberton from 1960-63.

(Ranked according to 1963 yield - average of 4 replicates)

Rank	Treatment (Lbs. N Per Acre)	Yield of Ear Corn (Bu./acre) 1960	1961	1962	1963*
1	80 as Urea plowed under fall	61.7	76.9	36.7	154.5
2	160 " Urea " " "	79.4	112.5	43.5	152.8
3	40 " NH_4NO_3 at planting	66.2	92.0	45.4	152.2
4	160 " NH_4NO_3 late sidedressing	40.7	97.4	77.7	151.7
5	80 " NH_4NO_3 plowed under fall	67.4	97.9	43.6	149.6
6	80 " Urea at planting	57.7	99.1	40.5	149.3
7	80 " NH_4NO_3 " "	59.3	90.0	32.7	149.2
8	40 " Urea plowed under fall	55.1	78.2	29.1	148.8
9	40 " NH_4NO_3 late sidedressing	63.6	92.6	39.5	148.6
10	40 " NH_4NO_3 plowed under fall	42.3	87.5	30.9	148.6
11	160 " NH_4NO_3 " " "	69.8	97.9	46.7	147.7
12	40 " Urea at planting	45.4	91.1	31.4	147.6
13	80 " Urea late sidedressing	76.9	86.4	48.2	143.8
14	40 " Urea " "	57.7	95.6	24.9	142.3
15	80 " NH_4NO_3 " "	50.4	98.4	46.7	140.7
16	40 " Urea left on plowed surface	62.3	101.3	37.0	140.7
17	40 " NH_4NO_3 " " " "	49.0	96.7	29.6	140.1
18	Check	49.5	88.2	26.1	132.6

* Duncan's New Multiple Range test = 0.05

The yields in table 1 are ranked according to the results obtained in 1963. These yields would not be ranked the same each year. The 1963 yields were not significantly different from each other as is drawn by Duncan's multiple rank test. However many treatments are significantly higher in yield than the check. The check as expected was the lowest yielding plot.

The total yield obtained over the 4 years of this field experiment, the total increase in yield and the calculated pounds of nitrogen applied per increase in yield of continuous corn as influenced by nitrogen source, rate and time of application is presented in Table 2.

Table 2. The Total Yield of 4 Years, Increase and Pounds of Nitrogen Applied Per Bushel Yield Increase of Continuous Corn as Influenced by Nitrogen Source, Rate & Time of Application at Lamberton (1960-63)

(Ranked according to 4 year total - average of 4 replicates)

Rank	Treatment (Lbs. N. per acre)	Total 4 yr. Yield	4 yr. Increase in Yield	Nitrogen Applied 4 yr.	Nitrogen Applied Per Increase Yield
		Bu/A.	Bu/A.	lbs./A.	lbs./bu.
1	160 as Urea plowed under fall	388.8	92.4	800	8.7
2	160 " NH_4NO_3 late sidedressing	367.5	71.1	800	11.3
3	160 " NH_4NO_3 plowed under fall	362.1	65.7	800	12.2
4	80 " NH_4NO_3 " " "	358.5	62.1	320	5.1
5	40 " NH_4NO_3 at planting	355.8	59.4	120	2.0
6	80 " Urea late sidedressing	355.3	58.9	320	9.0
7	80 " Urea at planting	346.6	50.2	320	6.4
8	40 " NH_4NO_3 late sidedressing	344.3	47.9	120	2.5
9	40 " Urea left on plowed surface	341.3	44.9	120	2.7
10	80 " NH_4NO_3 late sidedressing	336.2	39.8	320	8.0
11	80 " NH_4NO_3 at planting	331.2	34.8	320	9.2
12	80 " Urea plowed under fall	329.8	33.4	320	9.6
13	40 " Urea late sidedressing	320.5	24.1	120	5.0
14	40 " Urea at planting	315.5	19.1	120	6.3
15	40 " NH_4NO_3 left on plowed surface	315.4	19.0	120	6.3
16	40 " Urea plowed under fall	311.2	14.8	120	8.1
17	40 " NH_4NO_3 " " "	309.3	12.9	120	9.3
18	Check	296.4	----	----	----

The highest total yields were obtained on plots receiving 160 pounds of nitrogen and is independent of source, placement and time. The rank of total yields appear to very closely follow rate of nitrogen application. The late sidedressing and at planting time applications appear to be ranked higher for all of the increments of nitrogen that were applied. Generally the 40 pounds of nitrogen per acre application showed the least nitrogen required for increased yield of corn. These results indicate the 160 pounds of nitrogen per acre would be the least economic production in relation to nitrogen required for bushel increase in yield.

The effect of nitrogen source, rate and time of application on the total nitrogen content of 1963 continuous corn plots is presented in Table 3.

Table 3. The Effect of Nitrogen Source, Rate and Time of Application on the Total Nitrogen Content of 1963 Corn of the Continuous Corn Plots at Lamberton

(Total above ground plant parts - average of 4 replicates)

Treatment (lbs. N. Per acre)	Nitrogen in Plant Parts					Inc. in Nit.
	Leaves lbs N/A	Ears lbs N/A	Upper Stalks lbs N/A	Lower Stalk lbs N/A	Total Nit. lbs N/A	lbs/A
Check	18.9	76.1	4.1	2.2	101.3	----
40 as NH_4NO_3 plowed down fall	24.9	71.3	4.9	3.7	104.8	3.5
40 " Urea " " "	23.7	92.3	5.4	4.9	126.0	24.7
40 " NH_4NO_3 left on surface fall	25.0	78.1	5.1	4.0	112.2	10.9
40 " Urea " " " "	22.7	87.0	4.6	4.4	118.7	17.4
80 " NH_4NO_3 plowed down fall	21.9	82.3	5.1	5.5	114.8	13.5
80 " Urea " " "	28.1	81.3	4.4	5.3	119.1	17.8
160 " NH_4NO_3 " " "	24.8	90.9	4.6	4.5	124.8	23.5
160 " Urea " " "	20.0	77.2	4.4	5.0	106.6	5.3
40 " NH_4NO_3 at planting	21.1	79.6	4.7	5.3	110.7	9.4
40 " Urea " "	23.5	61.6	4.2	3.8	93.1	-8.2
80 " NH_4NO_3 " "	18.6	74.5	3.7	5.8	102.6	1.3
80 " Urea " "	26.6	73.8	4.1	3.4	107.9	6.6
40 " NH_4NO_3 late sidedressing	20.5	71.8	4.1	4.0	100.4	-0.9
40 " Urea " "	29.7	70.2	4.4	3.8	108.1	6.8
80 " NH_4NO_3 " "	24.5	67.0	4.1	4.0	99.6	-1.7
80 " Urea " "	28.3	80.1	6.1	5.9	120.4	19.1
160 " NH_4NO_3 " "	20.0	80.1	6.1	5.9	114.3	13.0

The highest quantity of nitrogen in the above ground plant parts is generally from the plots where nitrogen was plowed down in the fall. The nitrogen yield did not appear to follow the rate of application or does it appear to be related to source of nitrogen. During the four years of this experiment the increase of nitrogen yield over the check was the lowest during 1963. Since all but ears are returned to the soil it would be anticipated that an increase in nitrogen yields would increase rather than decrease for the higher nitrogen rates. With adverse conditions for corn growth in 1963 the organic nitrogen may have been held and then released by the very favorable conditions existing in 1963. The analysis of soil from some of fertilized plots indicated exchangeable ammonia to be high in fall after treatment and nitrates to be high the following spring. Spring and sidedress plots were low in exchangeable ammonia and nitrates during entire growing season. The fall treatments were again low in exchangeable ammonia and nitrate by early summer and remained low all season. This would indicate available nitrogen was being utilized by the corn.

The Effect of Five Nitrogen Sources on the Yield of Corn at Lamberton

J. M. MacGregor, W. W. Nelson and R. G. Hanson

The influence of five nitrogen sources on the production of corn growing on Webster clay loam was investigated at Lamberton. Two fields were used in this experiment. These fields had corn following corn and corn following alfalfa. 175 lbs./acre of 8-24-12 was applied as a starter fertilizer.

The nitrogen sources, yields and yield increases is presented in Table 1.

Table 1. The effect of nitrogen source on yield of corn where corn follows corn and corn follows alfalfa on Webster clay at Lamberton

(Average of 4 replicates - 50 lbs. nitrogen/per acre applied)

Source of nitrogen	Corn following corn		Corn following alfalfa	
	Yield of corn	Increase over check	Yield of corn	Increase over check
	Bu/A	Bu/A	Bu/A	Bu/A
Check	63.7	--	88.5	--
33.5 - 0 - 0	81.0	17.3**	81.3	-7.2
Urea	82.3	18.6**	78.8	-9.7
Anhydrous	81.3	17.6**	80.7	-7.8
Liquid 20.5%	83.6	19.9**	87.1	-1.4
Liquid 37%	78.8	15.1*	80.7	-7.8

175 lbs/acre 8-24-12 starter fertilizer

* Significant 5% L.S.D.
** Significant 1% L.S.D.

All the sources of nitrogen significantly increased the yield of corn for the field where corn followed corn. There was a nonsignificant decrease in yield with nitrogen application for the field where corn followed alfalfa.

The Effect of High Rates of Phosphorus Application on the Growth and Composition of Corn and Soybeans

A. C. Caldwell and W. W. Nelson

In 1962 an experimental plot was established at Lamberton to study the effects of extremely high rates of phosphorus application on the yield and chemical composition of crops. Concentrated superphosphate was applied by broadcast application at rates up to 800 pounds of P per acre. In 1962 corn was grown on all of these plots. The treatments consisted of rates of broadcast phosphorus from 0 to 800 pounds per acre P with and without an additional starter fertilizer application of 40 pounds of P per acre. Corn was grown on these same treatments in 1963 and the results of both years shown in table 1. In 1963 soybeans were grown on those plots which received starter phosphorus in 1962.

In general, the data in table 1 indicate that the yield of corn was increased by the first increment of phosphorus added and no further increases found with increasing rate of application.

The phosphorus content of 6th leaf of untreated corn was below the critical level, but after application of 100 pounds per acre P the phosphorus content was above the critical level. The data also indicate that the manganese content was increased at higher levels of phosphorus application.

Data in table 2 show that the yield of soybeans was increased slightly due to the residual effect of phosphorus application. Phosphorus content of the soybean tissue increased with increasing rate of phosphorus application to the soil. Both zinc and aluminum contents of the plants were reduced by the application of high rates of phosphorus the previous year.

Table 1. Effect of phosphorus on the yield and nutrient composition of corn at Lamberton.

Broadcast fertilizer		Starter fertilizer	Shelled corn yield		Nutrient content of 1962 6th leaf samples[1]					
			1962	1963	P	Ca	Mg	Mn	Zn	Al
pp2m P	pp2m K	pp2m P	bu./acre		--------%------			-----ppm------		
0	0	0	53	138	.25	.24	.29	34	25	76
0	0	40	60	152	.26	.28	.33	46	27	88
50	0	0	58	144						
50	0	40	65	147						
100	0	0	60	148	.29	.29	.34	44	27	105
100	0	40	62	147	.31	.29	.33	47	34	128
100	100	0	70	148						
100	100	40	72	150						
200	0	0	72	142						
200	0	40	77	144						
200	200	0	67	155	.36	.27	.27	48	26	77
200	200	40	73	149	.31	.23	.23	45	24	71
400	0	0	56	148	.40	.30	.34	47	25	84
400	0	40	65	145	.38	.32	.36	61	40	133
800	0	0	74	147	.51	.30	.31	56	27	83
800	0	40	69	153	.60	.37	.38	71	24	87
L.S.D. (.05)			6	11						

[1]All analytic data analyzed from a composite sample analyzed by Ohio State University Spectrographic Laboratory.

Table 2. Yield and composition of soybeans as effected by phosphorus fertilization at Lamberton in 1963.

Fertilizer broadcast in 1962[1]		Yield of soybeans	Nutrient content of soybean tissue[2]					
			P	Ca	Mg	Mn	Zn	Al
pp2m P	pp2m K	bu./acre	--------%---------			-------ppm--------		
0	0	29	.24	1.55	.69	39	123	180
50	0	32						
100	0	33	.33	1.60	.77	39	83	148
100	100	32						
200	0	33						
200	200	32	.32	1.50	.57	37	54	120
400	0	32	.38	1.60	.77	39	72	110
800	0	31	.52	1.65	.80	39	65	115
L.S.D. (.05)		2.2						

[1]Also 40 pp2m P was applied to all plots as starter fertilizer in 1962.

[2]Chemical analysis run by the Ohio State University Spectrographic Laboratory.

Comparison of Phosphorus Sources

A. C. Caldwell and E. C. Seim

A phosphorus source experiment was established at Rosemount in 1951. Twelve treatments of various phosphate materials were replicated 4 times across a regular rotation of corn, wheat, and 2 years of alfalfa. In 1959 the rotation was changed to corn, soybeans, wheat, and alfalfa. Potassium has been applied as required according to soil test. Lime was applied to 2 replicates in the fall of 1961. Corn yields were significantly increased by phosphate treatments over the check but the differences between sources were not substantial and do not follow a consistent pattern over the years. Soybean yields in 1963 showed small but consistent increases to the phosphate treatments. No specific phosphate treatment has been consistently better over the years. Wheat yields were disappointingly low in 1963 because of late planting and dry weather immediately thereafter. As in past years large increases in the yield of alfalfa resulted from all sources whether or not the phosphorus was readily available.

Effect of various phosphate fertilizers on yield of corn, soybeans, wheat, and alfalfa.

(Rosemount, 1963)

Treatments	P_2O_5/A/Yr. Lbs.	Corn Bu/A	Soybeans Bu/A.	Wheat Bu/A.	*Alfalfa Tons/A.
None		94.4	26.8	11.5	1.42
Ord Super	40	119.3	26.7	13.5	2.50
Conc Super	40	108.7	27.6	15.4	2.50
Cal Meta	40	122.9	28.4	12.4	2.68
Phos. Acid	40	112.8	27.9	13.1	2.32
Fused trical. Phos	40	112.3	30.1	16.3	3.05
Fl. Rock & Ord. Super	20+20	115.2	29.4	14.7	2.60
Fl. Rock	100	109.1	27.2	13.6	2.04

(Cont.)

Effect of various phosphate fertilizers .... (Cont.)

Treatments	P_2O_5/A/4 Yr.	Corn	Soybeans	Wheat	*Alfalfa
Fl. Rock	1000	117.7	28.3	15.6	2.03
Western Rock	1000	115.7	29.3	14.7	1.90
Cal. Clay Rock	1000	99.0	27.6	13.6	2.19
Tunis. Rock	1000	120.6	29.0	11.4	2.19
* Only two replications					
Std error		3.3	1.7	2.1	.43
Lsd (.05)		9.5	NS	NS	NS
Hsd (.05)		16.7	NS	NS	NS

Yield and potassium content of alfalfa as affected by potassium applications

(Northeast Experiment Station)

H. J. Hopen, R. S. Grant and A. C. Caldwell

The residual effects of potassium applied in 1961 were still evident on the yield and potassium content of alfalfa in 1963. This soil is classed as one very low in exchangeable potassium. Levels of potassium in plants below 1.5% are considered deficient. Stand counts showed over twice as many alfalfa plants on the heavily fertilized plots.

Table 1. Yield and potassium content of alfalfa

Treatment lbs. K_2O/A	1st Harvest Yield tons/A.	1st Harvest K %	2nd Harvest Yield tons/A.	2nd Harvest K %
None	1.8	1.27	0.6	1.34
100	2.2	1.39	0.9	1.33
200	2.6	1.68	1.1	1.46
400	2.7	2.33	1.2	1.87
800	3.0	2.97	1.3	2.59

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

A. C. Caldwell and E. C. Seim

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 were 0, 3, 6, 12, and 24 tons of dolomitic lime per acre, replicated 4 times. A rotation of corn, oats, and 2 years of alfalfa was set up. Each year corn and oats have received 200 pounds of 5-20-20 per acre. The alfalfa has received P and K as needed according to soil tests. Since 1959 soybeans have replaced one year of alfalfa in the rotation. The beans receive 100 pounds of 5-20-20 per acre as a starter fertilizer.

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.

Effect of the different treatments on yields are shown in the Table. Alfalfa yields have been most affected by lime, as has been the case in the past. Six tons of lime gave the greatest yield but 3 tons were nearly as effective as six tons in increasing the yield. Molybdenum was also effective in increasing alfalfa yields in 1963 as it was in 1962.

Oat yields were increased by all treatments, significantly so by 3 tons of lime and by the Mo treatment. This is what has been found in most other years except 1962 when the yields were erratic.

Increases in corn yields were not significant in 1963. In past years all treatments have generally increased corn yields. The diminished response to lime and molybdenum in 1963 may be attributed to the lower yields which reflect the effect of a period of drougth in midsummer.

There were no major effects of lime on soybeans.

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

(Rosemount 1963)

Lime Treatment Tons/A.	Alfalfa (2 cuttings) Tons/A.	diff	Oats Bu/A.	diff	Corn Bu/A.	diff	Soybeans Bu/A.	diff
0	0.95	--	38.5	--	109.0	--	26.1	--
3	2.11	+1.16	48.2	+9.7	104.0	-5.0	27.7	+1.6
6	2.62	+1.67	40.1	+1.6	111.0	+2.0	26.7	+0.6
12	2.43	+1.48	40.4	+1.9	113.7	+4.7	27.2	+1.1
24	2.46	+1.51	39.8	+1.3	117.1	+8.1	26.8	+0.7
0 + 8.7 oz. Mo/A.	1.91	+0.96	44.2	+5.7	106.2	-2.8	26.1	--
Standard error		1.25		4.16		5.1		
Hsd (.05)		.55		N.S.		22.3		N.S.
Hsd .01		.70		N.S.		28.7		N.S.

Sulfur Investigations on Soils and Crops

A. C. Caldwell, Paulina Li, E. C. Seim,
George Rehm and W. P. Martin

Department of Soil Science
University of Minnesota

An active research program on sulfur has been conducted in Minnesota in 1963. Studies have been made in the field and laboratory. Major investigations have included effects of rates and kinds of sulfur - bearing materials on field crops, sulfur in the atmosphere, oxidation of elemental sulfur in the soil, and development of a satisfactory method of determining total sulfur in plants. Some of the results of these investigations are given below.

Field Research

One of the major areas of investigation of sulfur in soil was the field research conducted on an experimental area near Park Rapids. Alfalfa planted in 1962 received various rates of elemental sulfur and gypsum. About 1/2 of the plots were to receive no more sulfur and would serve as a measure of the residual effects of sulfur treatments; additional sulfur was added in 1963 to the remaining plots. All alfalfa plots were sampled for yield and tissue collected for analysis. Stand counts were made also. The plot area that had been in corn in 1962 was planted to alfalfa in 1963. Additional sulfur was applied to all plots except the control and two other sets that had gotten sulfur in 1962. Barley was planted and sulfur as elemental sulfur, gypsum and potassium sulfate was applied with the seed at planting time. Sulfur as sodium sulfate was broadcast for corn at rates of 5, 15 and 25 pounds of sulfur per acre. Treatments on soybeans consisted of broadcast applications of elemental sulfur at 25 and 50 pounds per acre and gypsum at the rate of 50 pounds of sulfur per acre. Barley, corn and soybeans were sampled for yield and tissue samples collected for analysis.

Yields of alfalfa on the Park Rapids sulfur experimental field showed no difference between plots which had gotten sulfur in 1962 and 1963, and those which had treatment only in 1963. Yields were greatly increased over the control by sulfur

treatments however (table 1). There were no significant differences between the effects of elemental sulfur or gypsum. Generally elemental sulfur at 25 pounds of sulfur per acre was not as effective as 50 and 100 pounds. A spring plant count showed over twice as many plants on the sulfur treated plots as on the controls.

A nitric-perchloric digestion of alfalfa tissue collected in 1962 showed recovery of about 35% more sulfur than a dry combustion method previously used. Plants from control plots, for example, increased from .117 to .179% S (young plants). All sulfur treatments resulted in a large increase in the sulfur content of young and mature alfalfa plants. Gypsum was a more efficient form of sulfur in this respect than elemental sulfur.

Drouth hurt barley yields badly, differences between treatments were small, so no significant effects from sulfur were apparent. Applications of sulfur did result in increased sulfur in the plants however. Gypsum and potassium sulfate were more efficient in getting sulfur into the plant than was elemental sulfur. There were no significant effects of sulfur treatments on corn or soybeans.

Spectroscopic analysis of alfalfa, oat and corn tissue (1962 samples), showed no effects of sulfur on the content of other elements measured, including K, P, Ca, Mg, SiO_2, Mn, Fe, B, Cu, Zn, Al, Sr, Na and Ba.

Sulfur in the Atmosphere

Sulfur in the rainfall and SO_2 in the atmosphere were determined at 4 major sites, St. Paul, Duluth, Park Rapids and Lamberton. These sites are at the corners of a square approximately 200 miles on each side in an area of central Minnesota. Collections were made once a month and samples analyzed for total sulfur.

Estimates of sulfur as SO_2 and that in precipitation showed much greater amounts of both at St. Paul than any other station (table 2). At St. Paul the amount of sulfur in precipitation was 13.3 pounds per acre compared to 3.1 pounds at Park Rapids. Also there was 5 times more SO_2 in the atmosphere at St. Paul than in the air at Park Rapids.

Oxidation of Elemental Sulfur in Soils

Work was continued in 1963 on the oxidation of elemental sulfur in soils. Under investigation was the effect of particle size, rate of application, length of time of incubation, and temperature on sulfur oxidation. The effects of rate, particle size and time on the oxidation of elemental sulfur incorporated into 3 fertilizer materials were also studied.

Data on the oxidation of elemental sulfur showed that the amount of sulfur oxidized increased with decrease in particle size. Greatest oxidation occurred with particle sizes of less than 100 mesh. Oxidation reached a peak at 60 days of incubation time. The amount of sulfur applied to the soil did not seem to affect the fraction oxidized. Little sulfur was oxidized at 4° C., some at 10° C. (graph). Temperatures of 30° C. and 40° C. were more effective than 23° C. and lower. In studies with sulfur-fertilizer mixtures it was shown that maximum oxidation of fine and medium particle sizes (-10+30 and -30 mesh) occurred after 60 days of incubation, after which the amount oxidized declined (table 3). With larger particle sizes sulfur oxidation kept increasing slightly with time. Sulfur was oxidized to a greater extent in the nitric phosphates and diammonium phosphates than in the triple superphosphates.

The addition of sulfur to fertilizers did not affect water soluble or Bray No. 1 available phosphorus in triple superphosphate or diammonium phosphate. Sulfur did reduce both kinds of phosphorus in the nitric phosphates.

Determination of Sulfur in Plant Material by Nitric-Perchloric Digestion

A major effort was made to fashion a more satisfactory method for determining the sulfur content of plant tissue. Particular attention was given to the initial step of oxidizing plant material to see that complete oxidation of difficultly oxidizable sulfur compounds occurred, and to see that sulfur was not lost in some gaseous form. To check on completeness of oxidation, methionine (a difficultly oxidizable

material) was digested. A major shift in method was going to a nitric-perchloric digestion rather than furnace combustion of a salt-organic material mixture.

It is our belief that we have now developed a satisfactory method of determining total sulfur in plant tissue. It was reported above that the amount of sulfur recovered in alfalfa by a nitric-perchloric digestion was up to 35% greater than a dry combustion procedure. Studies with methionine indicated an average of 98% recapture of this difficultly oxidizable material.

Table 1. Effect of sulfur bearing materials on stand and yield of alfalfa.

Material	Rate lbs. S/ac.	Stand plants per sq. ft.	Yield[1] S app'd. '62 only tons/ac.	Yield[1] S app'd. '62 & '63 tons/ac.
None	0	7	.46	.53
Sulfur	25	15	1.04	1.03
"	50	15	1.08	1.23
"	100	18	1.27	1.29
Gypsum	50	19	1.18	1.10
"	1000	14	1.04	
L.S.D.			.24	.25

[1] Two cuttings

Table 2. Sulfur dioxide in the atmosphere and sulfur in precipitation at four locations in Minnesota from Oct. '62 to Oct. '63.

Location	SO_2 lbs. S/ac.*	S in precip. lbs. S/ac.	Precip. inches
St. Paul	33.8	13.3	20.7
Duluth	9.3	6.9	19.2
Park Rapids	6.5	3.1	19.7
Lamberton	5.6	6.4	26.6

* Per acre of exposed surface of PbO_2 coated fabric.

Table 3. Oxidation of elemental sulfur in granulated fertilizers

Base Material	%S	Particle Size	Incubation Time, Days 10	60	120
			S oxidized, ppm		
14-14-14	5	-10 +20	9	16	27
14-14-14	6	-35	45	76	62
0-42-0	15	-10 +20	5	12	10
0-42-0	17	-35	21	56	34
18-45-0	13	-10 +20	10	42	26
18-45-0	18	-35	25	61	30

L.S.D., 0.05 = 10

* Added to soil at rate of 100 ppm S

Table 4. Sulfur recovery of thiourea and methionine by digestion with nitric-perchloric acids.

Thiourea		Methionine	
Added ppm S	Recov'd. %	Added ppm S	Recov'd %
40	94	40	98
"	96	"	98
"	96	"	98
"	96	"	94
"	98	"	96

FOLIAR, SOIL AND SEED TREATMENTS WITH IRON ON SOYBEANS IN 1963

by

J. M. MacGregor

Soybeans growing on some calcareous soils developed a yellowed leaf condition caused by a deficiency of iron inducing insufficient chlorophyll development. This yellowed condition of soybeans usually occurs in more or less scattered areas in the affected fields, and seldom is an entire soybean field affected. Some soybean varieties are more seriously affected than others, and cool, moist growing seasons favor the condition. In serious cases, soybean yellowing may be apparent from the time of plant emergence late in May or early June, but it usually becomes more noticeable in mid-June. Since mineral soils usually contain at least 1% iron (which would mean some 10 tons of iron per acre six inches of soil) and plants need only 1 or 2 pounds of iron per acre to grow a crop, it is obvious that any iron deficiency of plants must be due to limited iron availability rather than total supply present in the soil.

Research on the problem has shown that the yellowing of plants condition is the result of many interacting soil factors, of which the presence of free lime in the soil is probably the most important. Since it is economically impractical to remove the free lime from calcareous agricultural soils, the problem becomes one of increasing iron availability. Iron occurs in soils in two forms, the proportion of each depending upon the relative soil acidity and alkalinity.

1. Ferric iron which is relatively insoluble in water (FeO or iron rust is an example) and becomes even more so as the pH passes neutrality and becomes alkaline. In alkaline soils, essentially all solid iron occurs in the ferric (unavailable) form.

2. Ferrous iron, which is soluble in water and may become so abundant in strongly acid soils as to create toxic conditions for plant root growth. Soil acids dissolve iron bearing minerals at a relatively rapid rate to produce a soil water solution relatively high in ferrous (available) iron, and this soluble iron excess also tends to limit phosphorus availability. However, strongly acid soils high in quartz sand may actually be deficient in total iron.

Mineral soils which are approximately neutral in reaction usually contain relatively small amounts of ferrous iron, but since most plants require only one or two pounds of iron per acre for normal growth, iron availability is seldom a problem. As soil pH rises, and eventually free lime is present, more and more of the ferrous iron is oxidized to the ferric form, until some plant species are unable to obtain sufficient soluble iron to support normal chlorophyll formation. One can lime an acid soil to improve soil reaction, but it is impractical to attempt to remove excess free lime from a soil by any chemical means now available. The problem of correcting iron chlorosis of plants becomes one of either adding iron to the soil or plant in a form which will remain available for much of the growing season, or adding some substance which will render the unavailable soil iron more available.

A. 1963 Seed or Soil Treatments

Field experiments in which various iron compounds have been banded along the soybean row near the yellowed seedlings have been carried on for several years with generally

unsatisfactory results. The only treatment which corrected the soybean chlorosis in every trial, was the banded application of Chelate-138 HFe (HFe EDDHA) when banded at the rate of 100 pounds per acre. Since the cost of such a treatment would approach three hundred dollars per acre, this is obviously an impractical corrective treatment for field crops such as soybeans.

In 1963, several possible available iron containing materials were either stuck to the soybean seed coat, or were applied in the row at planting time in contact with the seed. This was done on two farm soybean fields known to have a chlorotic soybean problem, using two soybean varieties, Lindarin and Chippewa. One field was located near Gaylord in Sibley County, while the second was planted much later in Kandiyohi County near Pennock. The Pennock field was not harvested because of an uneven stand and serious weed competition. Each of four replicates consisted of three rows 20 feet in length, of which 15 feet of the center row was harvested in October to determine yield and treatment effect.

Growth observations were made each week on both fields, but at no time was there significant difference in the degree of chlorosis on the different treatments. The yields obtained on the Sibley County field are shown in Table 1.

Table 1. The Effect of Iron Treatments on Seed or to a Calcareous Soil on the 1963 Soybean Yield at Gaylord (Harpster clay loam-pH of 8.0)

No.	Iron Treatment	Lindarin	Chippewa
		(Bushels per acre)	
1	None	11.6	12.7
		Yield increase for iron treatment	
2	Kalo seed treatment	-2.6	1.9
3	Fe Chelate 138@1#/A (0.06#Fe/A)	-4.4	-3.0
4	Fe " " @20#/A (1.2#Fe/A)	1.1	----
5	Chelate 138@20#/A (no Fe)	-3.4	----
6	" " on vermiculite 2.5#/A or 0.06#Fe	-1.8	----
7	Versenol Fe on vermiculite @1#/A or 0.06#Fe	-3.6	----
8	Grace 7-35-0 (Fe amm. phos) 78#Fe/A	-1.5	-0.4
9	ADM Chelate 138Fe + $FeSO_4$ (21.2%Fe) @0.954#/A	-3.7	0.2
10	ADM coated $FeSO_4$ (21.2%Fe) @0.954#/A	1.9	1.4
	Significant (5%)	3.8 bu.	5.5 bu.

It is obvious that none of the nine treatments had a favorable effect on the yield of either soybean variety. Treatment 5 was the only one which contained no iron with the intention that some of the soil iron might be made available to the growing soybeans.

B. 1963 Iron Spraying of Chlorotic Soybeans

Since calcarious soils quickly oxidize the available ferrous iron to the unavailable ferric iron, many investigators have recommended the spraying of chlorotic soybean plants with ferrous iron compounds, based on the theory that the iron would be absorbed into the leaves and never come into contact with the soil. In 1948, the Iowa Agricultural Extension Service recommended the spraying of chlorotic soybeans with ferrous sulfate at the rate 10 pounds per acre after dissolving in 50 gallons of water. This would have a material cost of some 40 cents per acre. Some Minnesota county agents have investigated this treatment with generally unsatisfactory results.

The Tennessee Corporation of Atlanta, Georgia manufactures a compound "Nu-Iron" containing 30% iron readily absorbable by plants.

In the latter part of June, three chlorotic soybean field areas were selected for iron spray treatments -- the first field being located one mile west of Lake Lillian on Highway 7 in Kandiyohi County, the second approximately midway between Willmar and Raymond on Highway 23 in Kandiyohi County, and the third field was 8 miles east of Montevideo on Highway 7 in Chippewa County. Each treatment was replicated four times on the three fields, with one row plots 20 feet in length.

Since the sprays were to be applied by hand, it was considered that this would be more efficiently applied than with power spraying equipment, so both the recommended treatment rate and one-tenth the recommended treatment rate were applied on June 21, and a second application was sprayed on as a second treatment on half the plots eleven days later (July 2).

The chlorotic plants on the differently sprayed treatments were observed at weekly intervals, and while some leaf scorching was noted on the heavier (recommended) rate treatments, considerable leaf greening occurred during early July. The entire chlorotic area of the Chippewa county field recovered its green color at this time, but this recovery was irrespective of any spray treatment. Soybean plants on both of the Kandiyohi field areas remained largely chlorotic, and eventually the plants on several feet of both sprayed or unsprayed soybean rows died completely, and only stubs of the soybean stems remained. The three fields were harvested in early October, and the calculated yields are shown in Table 2. (Next page)

Calcareous soils on which soybean chlorosis occurs are extremely variable, and relatively large increases or decreases in yield are necessary for mathematical significance effect. None of the increases or decreases shown in Table 2 are consistent or are sufficiently large to attribute as due to iron spray effect alone.

Conclusions

None of the 1963 seed coating, soil, or spraying treatments with iron compounds to correct iron chlorosis were effective for improving soybean chlorosis or yield, and hence cannot be recommended for farm use.

Table 2. The Effect of Spraying Chlorotic Soybeans with Ferrous Sulfate and Nu-Iron on 1963 Yield

Location Soybean variety	Lake Lillian Chippewa	Raymond Chippewa	Montevideo Harmon	Ave.
Treatment	Yield in bushels per acre			
None	13.5	14.8	27.4	18.6
	Yield increase for iron spray			
$FeSO_4$ 1#/A June	2.3	0.6	1.8	1.6
$FeSO_4$ 1#/A June + July	2.5	1.7	-0.5	1.2
$FeSO_4$ 10#/A June	4.0	4.3	-3.0	1.6
$FeSO_4$ 10#/A June + July	5.3	4.8	-1.2	3.0
Nu-Iron (1/10 rec. rate) - June	5.1	-1.7	-1.7	0.6
Nu-Iron (1/10 rec. rate) - June + July	2.4	0.1	-1.5	0.3
Nu-Iron (rec. rate) - June	-3.0	1.8	-3.3	-1.5
Nu-Iron (rec. rate) - June + July	-1.0	6.0	-3.8	0.4
Significant (5%)	8.0 bu.	7.4 bu.	5.7 bu.	

State Survey of Zinc in Corn

D. F. Bezdicek and John MacGregor*

Zinc deficiency in corn was first reported from central Minnesota in 1961. Soils in this area are believed to contain adequate total zinc, but conditions brought about by high soil pH and high lime reduce the amount available for normal plant growth.

A state survey of corn conducted in 1962 showed that zinc deficiency occurred in Meeker, Swift, and Kandiyohi Counties.

A more thorough survey was conducted in 1963 to study the relationship between leaf zinc concentration and observed deficiency symptoms, soil pH, and soil type. Results from 100 samplings showed a probable zinc deficiency in twelve Minnesota counties. A general relationship between leaf zinc concentration and the degree of observed zinc deficiency was found. Visual deficiency symptoms began to appear when the leaf zinc concentration fell below 15 to 17 parts per million (ppm). This value is near the minimum critical level of leaf zinc reported by other investigators.

Table 1 shows the relationship between leaf zinc coneentration and great soil group and soil series. Some of the soils of the Calcium Carbonate Solonchak, Chernozem, and Humic Gley are at a critical minimum available zinc level based on leaf zinc concentration.

Several soils were further classified as being available zinc deficients on the basis that the leaf samples taken contained less than 15 ppm zinc and that zinc deficiency symptoms were observed. These appear in Table 2.

Corn grown on these soils may not necessarily respond to zinc fertilization. However, there is a greater probability of zinc response to corn on these soils and also to other high lime soils not included in the survey.

* The cooperation of the Soil Conservation Service personnel for their assistance in the soil classification is hereby acknowledged.

Table 1. The average Zn content of "index leaf" samples taken from corn growing on various soil series of great soil groups included in 1963 Minnesota zinc survey.

Great soil group and series	Average "index leaf" Zn content ppm		Number of fields sampled	
Gray-Brown Podzolic	20.9		3	
Hayden		19.3		1
Seaton		21.1		1
Fayette		22.4		1
Gray-Brown Podzolic-Brunizem	26.9		7	
Lester		16.6		2
Downs		21.2		1
Racine		29.6		2
Kasson		33.6		1
Mt Carroll		33.9		1
Brunizem	21.9		6	
Waukegan		12.8		1
Kingston		12.3		1
Kenyon		18.1		1
Nicollet		20.3		1
Port Byron		31.8		1
Ostrander		36.0		1
Humic Gley	20.6		15	
Parnell		9.6		1
Harpster		15.2		1
Lura		15.4		1
Marna		16.5		1
Webster		16.9		2
Flom		18.0		3
Hatfield		19.5		2
Floyd		20.7		1
Glencoe		22.8		1
Lamoure		33.8		1
Blue Earth		37.9		1
Chernozem	17.5		11	
Kranzburg		13.6		1
Barnes		15.6		4
Brookings		16.6		1
Aastad		17.9		4
Estelline		24.0		1

(Cont.)

Table 1. (Cont.)

Great soil group and series	Average "index leaf" Zn content ppm		Number of fields sampled	
Calcium Carbonate Solonchak	15.0		31	
Ulen		10.7		1
Borup		11.8		1
Colvin		14.3		14
Bearden		14.8		4
Vallers		18.3		9
Hamerly		20.3		2

Table 2. Predicted "available zinc deficient" soil series of the 1963 survey on the basis that leaf samples taken form the soil sampling area exhibited both zinc deficiency symptoms and contained 15 ppm Zn or less in the "index leaf" at silking.

1. Aastad	7. Colvin	13. Ulen
2. Barnes	8. Hamerly	14. Vallers
3. Bearden	9. Harpster	15. Webster calcareous variant
4. Beauford	10. Kranzburg	16. 36-H*
5. Borup	11. Lura	*Swift County Soil Conservation Service
6. Buse	12. Parnell	

Fertilizer Rotation Experiment

West Central Experiment Station

S. D. Evans and A. C. Caldwell

An NPK factorial experiment involving the three nutrients alone and in all combinations applied across a 5 year rotation and continuous corn has been in existence for 8 years. The 5 year rotation crops are flax, alfalfa, corn, corn and soybeans. Treatments and rates are as given in the tables.

The experiments were started by Soil Science personnel but are handled now by help at the station led by Dr. Evans.

N-P-K EXPERIMENT - 1963

Table 1. Yield of Continuous Corn

Treatment	$N-P_2O_5-K_2O$ Lbs/A	Average Yield Bu/A	Diff. from Untreated	Treatment Effect
None	0+0+0	46.62	- -	- -
N	160+0+0	57.91	+11.29	+20.87*
P	0+140+0	45.28	- 1.34	- 4.32
K	0+0+40	51.02	+ 4.40	- 3.11
NP	144+140+0	70.93	+24.31	+ 6.93
NK	160+0+40	67.61	+20.99	+ 2.41
PK	0+140+40	29.85	-16.77	-10.16
NPK	144+140+40	59.83	+13.21	- 0.24
NPK+	304+320+80	59.83	+13.21	- -

Table 2. Yield of First Year Corn

Treatment	$N-P_2O_5-K_2O$ Lbs/A.	Average Yield Bu/A.	Diff. From Untreated	Treatment Effect
None	0+0+0	88.28	- -	- -
N	60+0+0	76.16	-12.12	- 5.45
P	0+20+0	94.52	+ 6.24	+12.91*
K	0+0+40	78.58	- 9.70	+ 0.16
NP	44+20+0	88.53	+ 0.35	+ 0.42
NK	60+0+40	78.96	- 9.32	+ 3.60
PK	0+20+40	97.33	+ 9.05	- 3.60
NPK	44+20+40	93.25	+ 4.97	- 2.65
NPK+	84+100+80	84.70	- 3.58	- -

Table 3. Yield of Second Year Corn

Treatment	Lbs/A $N-P_2O_5-K_2O$	Bu/A Average Yield	Diff. From Untreated	Treatment Effect
None	0+0+0	64.42	- -	- -
N	80+0+0	67.73	+ 3.31	+ 6.43
P	0+60+0	70.16	+ 5.74	+14.05**
K	0+0+40	55.87	- 8.55	- 3.42
NP	64+60+0	81.01	+16.59	+ 2.60
NK	80+0+40	60.21	- 4.21	- 0.65
PK	0+60+40	73.03	- 8.61	- 4.54
NPK	64+60+40	80.24	-15.82	- 1.16
NPK+	104+100+80	90.19	+25.77	- -

Table 4. Yield of Soybeans

Treatment	Lbs/A $N-P_2O_5-K_2O$	Bu/A Average Yield	Diff. From Untreated	Treatment Effect
None	0+0+0	32.02	- -	- -
N	20+0+0	33.95	+ 1.93	+ 0.21
P	0+40+0	31.56	- 0.46	- 0.81
K	0+0+40	31.76	- 0.26	- 0.63
NP	20+40+0	32.59	+ 0.57	- 1.26
NK	20+0+40	31.50	- 0.52	- 1.27
PK	0+40+40	31.84	- 0.18	+ 0.09
NPK	20+40+40	29.98	- 2.04	- 0.17
NPK+	40+80+80	33.01	+ 0.99	- -

Table 5. Yield of Flax

Treatment	Lbs/A $N-P_2O_5-K_2O$	Bu/A Average Yield	Diff. From Untreated	Treatment Effect
None	0+0+0	27.88	- -	- -
N	60+0+0	26.71	- 1.17	- 0.82
P	0+40+0	28.87	+ 0.99	+ 0.65
K	0+0+20	24.42	- 3.46	- 0.63
NP	60+40+0	25.54	- 2.34	- 1.65
NK	60+0+20	27.41	- 0.47	+ 1.43
PK	0+40+20	28.20	+ 0.32	+ 0.74
NPK	60+40+20	26.43	- 1.45	- 0.57
NPK+	120+80+40	26.39	- 1.49	- -

Table 6. Yield of Alfalfa

Treatment	Lbs/A $N-P_2O_5-K_2O$	Tons/A Average Yield	Diff. From Untreated	Treatment Effect
None	0+0+0	3.32	- -	- -
N	20+0+0	3.23	- 0.09	+ 0.25
P	0+80+0	5.19	+ 1.87	+ 1.92**
K	0+0+40	2.59	- 0.73	- 0.31
NP	20+80+0	4.75	+ 1.43	+ 0.15
NK	20+0+40	3.80	+ 0.48	+ 0.51
PK	0+80+40	5.19	+ 1.87	+ 0.23
NPK	20+80+40	5.51	+ 2.19	- 0.13
NPK+	20+160+80	4.71	+ 1.39	- -

THE NICOLLET COUNTY PLOTS: Webster soils of southern Minnesota

W. P. Martin, Fred Wetherill and H. W. Kramer

Yield Results 1963

See 1962 results, p. 34 in Soil Fertility "blue book."

CONTINUOUS CORN: Rate and time of application (Started 1954)

Nitrogen treatments:		Yield results:	
Total	Time*	Starter only**	+PK broadcast***
None	0-0-0	107 bu./acre	95 bu./acre
40 lbs.	1-0-0	152	144
80	1-1-0	147	159
120	1-1-1	151	156
80	1-0-1	154	161
80	0-1-1	147	153
40	0-0-1	145	149
40	0-1-0	143	148
80	2-0-0	151	141
120	3-0-0	156	154

* Refers to time of application as between planting time-first cultivation-second cultivation; example: 1-0-0 means 40 lbs. N at planting time.
** 200 lbs. 6-24-12 in the row at planting time.
*** Starter plus 300 lbs. 0-20-20 broadcast.

CORN-OATS, with and without legume green manure (Started 1948)

	Corn:	(with legume)	Oats:	(with legume)
1. Check	75 bu/ac.	69 bu/ac.	45 bu/ac.	59 bu/ac.
2. N on oats	98	81	77	82
3. NP on oats	129	98	84	85
4. NPK on oats	129	101	97	99
5. P plowdown	136	96	56	70
6. NPK in hill	114	99	43	74
7. N plowdown	81*	100*	60*	56*
8. N sidedress	136*	115*	67*	67*

* One replication only vs three.

NICOLLET COUNTY PLOTS CONTINUED

CORN-SOYBEANS-CORN-OATS-HAY (with regular and extra-heavy fertilization treatments)
(Started 1948 as 4-year rotation; soybeans added in 1958)

Standard Treatment	Corn	(*)	Soybeans	(*)	Corn	(*)	Oats	(*)	Hay	(*)
	bu./ac.		bu./ac.		bu./ac.		bu./ac.		tons/ac.**	
6. Check	122	147	43	44	114	148	83	93	1.4	2.1
1. P on oats	130	132	42	41	109	122	82	95	1.7	2.1
2. PK on oats	148	144	44	43	116	130	92	97	2.2	2.5
7. NP on oats	129	142	43	45	126	123	98	100	1.9	1.8
3. NPK on oats	139	145	48	40	129	128	98	94	1.5	2.0
10. P on oats & corn	128	144	41	41	127	128	84	95	1.7	2.1
4. Manure on corn	144	141	45	46	144	157	82	92	1.8	2.3
8. Manure & P on corn	150	144	43	47	140	157	88	96	1.9	2.2
5. Manure & NPK on corn	148	142	44	48	141	153	90	98	2.0	2.2

(*) Denotes extra-heavy fertilizer treatments.
** Only one hay cut salvaged because of wet weather.