# SOIL SERIES 87

## A REPORT ON FIELD RESEARCH IN SOILS

The 1971 edition of the "Bluebook" is a compilation of data collected and analyzed throughout Minnesota. Information was contributed by personnel of the Department of Soil Science, Extension Soil Specialists and Agronomists at St. Paul and at the branch stations of Crookston, Grand Rapids, Lamberton, Morris, Rosemount and Waseca; and Soils and Crops area agents. Other associate personnel contributing information included: Iron Range Resources and Rehabilitation; Minnesota Resources Commissions; Office of Water Resources Research, U.S. Department of the Interior; Soil Conservation Service; SWCRD-ARS-USDA; Tennessee Valley Authority; and the Weather Bureau.

Some of the results are from 1970 experiments only and should be regarded on this basis. Since considerable amounts of data includes only one year's study, it should not be considered as conclusive and not for further publication.

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# Some Climatological Notes, 1970

by Donald G. Baker

## A. Summary of the 1970 Soil Water Survey

The number of soil samples obtained this year were greatly reduced in number from previous years. As a result the information cannot be as detailed.

In every case where the amount of water apparently used by the crop during the 1970 season, column 9 in Table 1, exceeds about 22 inches the explanation rests in the precipitation characteristics. For example, at Kellogg in Wabasha county 9.54 inches were measured in May, 6.22 inches in June and 6.11 inches in October. All figures were well above average and undoubtedly much water was lost by runoff for which we have no measure. For this reason the apparent water use by the crop at Kellogg equalled 32.17 inches. In reality the amount consumed was probably some 10 inches less. The apparent water use amounts at Dodge Center and Milaca are probably several inches too high also. The amount used by the alfalfa at Crookston, 25.49 inches, seems a bit high, but it certainly compares favorably with the 19.07 inches used by the wheat and the 18.47 inches by the sugarbeets over the entire season. The Crookston and Lamberton data are discussed in greater detail later.

We are, of course, operating under two handicaps when viewing the data. One is that neither the runoff, nor the drainage through the soil profile was measured. The second point is that only at Crookston and Lamberton were the precipitation measurements made adjacent to the soil sample site; at most places we were forced to use the precipitation measurement made some distance away.

Table F 19 oil er ey lte The ls sam to Dep f 5 t.

| County | Nearby Town | Operator | Soil Type | Crop | Total Available Water Inches | Percent of Possible Water | Inches Difference Fall 70' - Fall 69' | Water Used in Season Inches |
|---|---|---|---|---|---|---|---|---|
| Dodge (Last sampled 11/25/70) | Dodge Center | Sutherland | Kasson si.l. | Corn | 8.91 | 84 | --- | 28.75 5/4-11/25 |
| Mille Lacs (Last sampled 10/26/70) | Milaca | Nichols | Mora si.l. | Oats | 8.47 | 88 | +4.32 | 25.35 4/21-10/26 |
| Polk (Last sampled 10/30/70) | Crookston | U of M | Hegne si.c.l. | Alfalfa (#1) | 2.43 | 14 | -8.9 | 25.49 5/13-10/30 |
| Polk (Only sample 11/4/70) | Crookston | U of M | Hegne si.c.l. | Sw. Cl. Fallow (#4) | 11.53 | 68 | - - - | - - |
| Polk (Last sampled 11/3/70) | Crookston | U of M | Hegne si.c.l. | Wheat (#6) | 2.77 | 16 | -2.3 | 19.07 5/18-11/3 |
| Polk (Last sampled 10/30/70) | Crookston | U of M | Hegne si.c.l. | Sugarbeets (#7) | 2.47 | 14 | - - - | 18.47 6/2-10/30 |
| Ramsey (Last sampled 11/6/70) | St. Paul | U of M | Waukegan si.l. | Sod | 16.92 | 206 | +15.5 | 16.80 5/6-11/6 |
| Ramsey (Last sampled 11/6/70 | St. Paul | U of M | Waukegan si.l. | Soybeans | 14.34 | 174 | +12.8 | 18.59 5/6-11/6 |
| Ramsey (Last sampled 11/12/70) | St. Paul | U of M si.l. | Waukegan | Bare soil | 12.14 | 147 | +11.0 | 22.72 5/6-11/12 |
| Redwood (Last sampled 10/16/70 | Lamberton | U of M | Nicollet c.l. | Corn | 3.26 | 33 | -1.6 | 20.61 4/27-10/16 |
| Sibley (Last sampled 10/29/70 | Winthrop | Woods | Nicollet c.l. | Corn | 10.36 | 88 | --- | 19.31 4/30-10/29 |
| Todd (Last sampled 11/5/70) | Bertha | Harting | Blowers l.f.s. | - | 4.03 | 47 | --- | 14.55 5/8-10/20 |
| Wabasha (Last sampled 11/5/70) | Kellogg | Zickrick | Fayette si.l. | Small grain | 13.43 | 86 | 0.0 | 32.17 4/23-11/5 |

The fact that runoff is not measured shows up in the St. Paul data. These data indicate that apparently the sod and soybeans consumed 16.80 and 18.59 inches, respectively, compared to 22.72 inches lost from the bare soil. Evapotranspiration losses from a bare soil are of necessity less than from a vegetated surface. Obviously the water use data show the best results in years of gentle rain and little runoff.

Figure 1 shows the departure from normal of the growing season precipitation. The greatest departure was in a large area in the northern and north-central parts of the state. The maximum departure was 8 inches below normal centering around northern Aitkin county.

Figure 2 shows the distribution of the above normal rainfalls of October and November. The greatest departure amounted to 350% above normal and occurred in the southeast. Except for the northwestern part of the state above normal rains fell in October and November throughout the state.

The above normal rains of late autumn are reflected only in the St. Paul soil water data, column 8 in Table 1. At the other locations the heavy rains generally fell after the samples were taken.

It would appear that the soil water is at or above normal in almost all parts of the state except in the northwest.

The change in the soil water reserves during the course of the 1970 season at Crookston and at Lamberton is shown in Figures 3 and 4, respectively. Figure 3 is of special interest becuase it shows how the crops differ in water use. At this point it is best to explain why and when differences between crops can occur, since in much irrigation scheduling it is usually assumed there is no difference between crops in water usage.

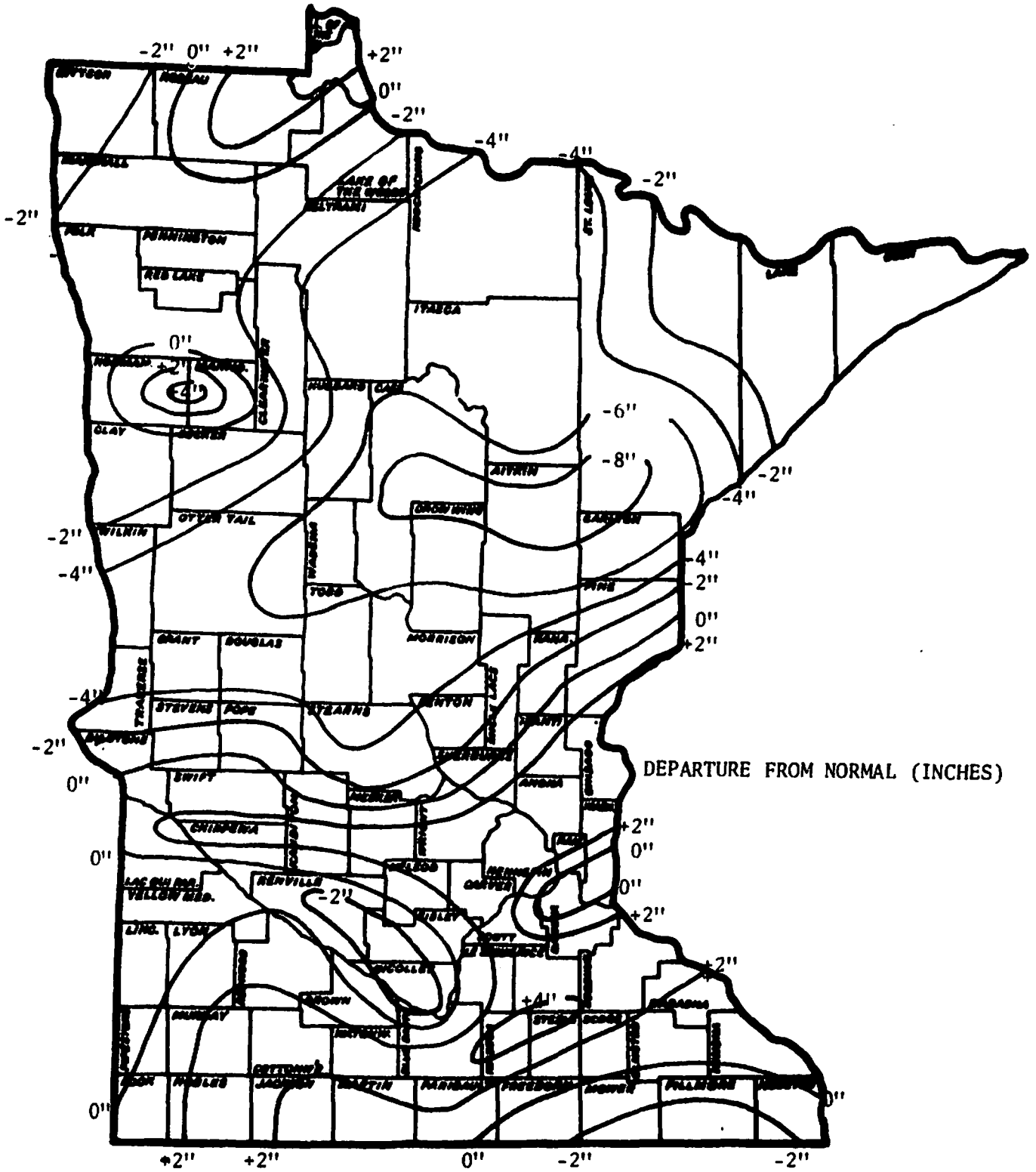


**Figure 1.** MINNESOTA PRECIPITATION APRIL THROUGH SEPTEMBER 1970

Earl L. Kuehnast
NOAA Climatologist for Minnesota
University of Minnesota
St Paul, Minnesota 55101

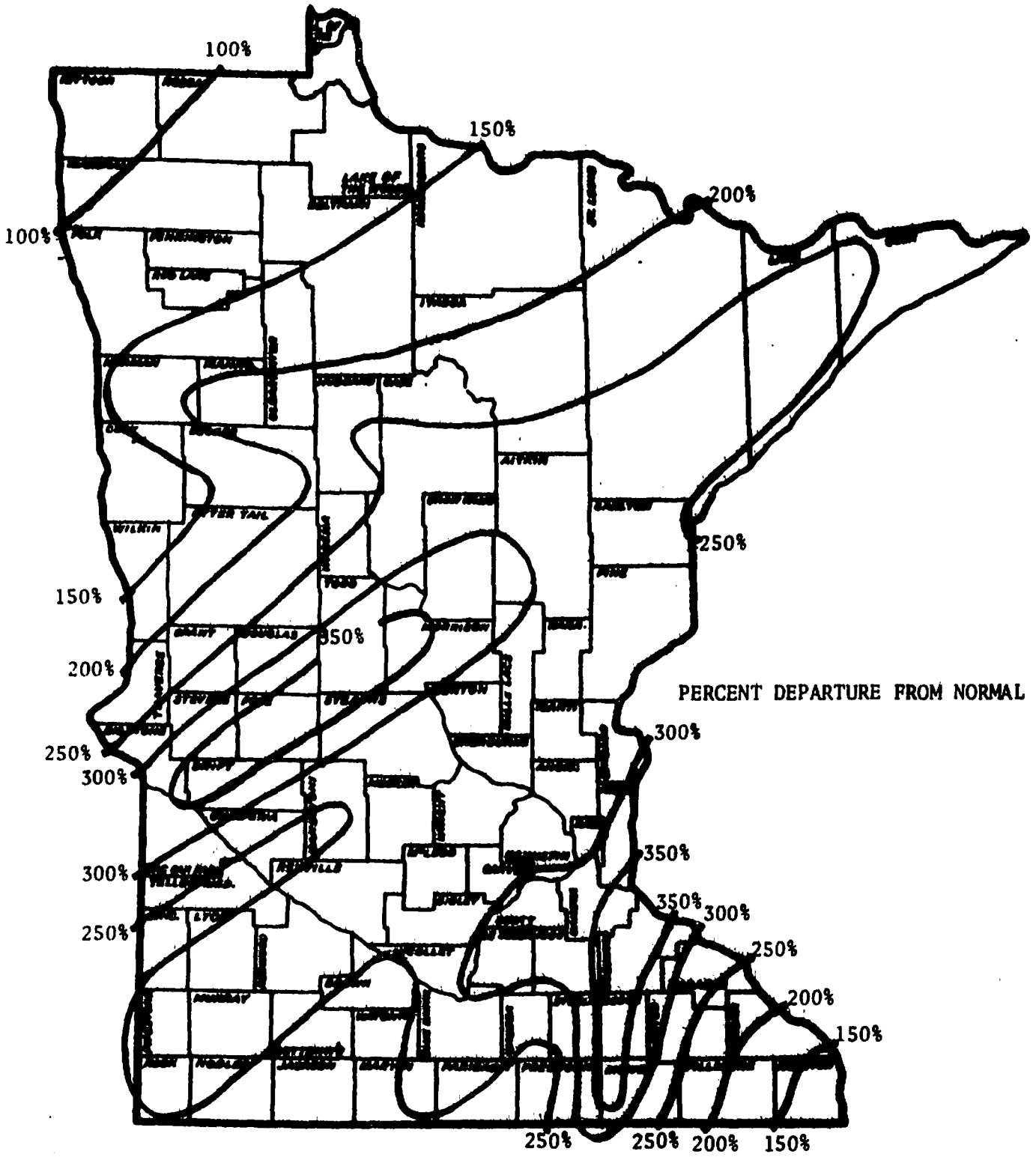


Figure 2. MINNESOTA PRECIPITATION DURING OCTOBER-NOVEMBER 1970

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The common agricultural crops do not show a difference in water use if (1) water is readily available, (2) the crop covers the ground completely or nearly so, and (3) the comparison is made over the same period of time.

At Crookston the three crops, wheat, sugar beets and alfalfa show differences for the reasons given above. That is, water became more and more critical as the season progressed which is apparent in Figure 3. In addition, in the early part of the season there was a great difference in the amount of ground covered by the three crops. The wheat was harvested in mid-season while the sugarbeets and alfalfa continued to grow and use water. As a result differences between the crops should be apparent.

Table 2 shows a striking difference in the water use of the three crops even when a (nearly) equal time period is considered. The differences, therefore, are mainly due to the relatively low soil water which brings out the difference in the crops' growth characteristics and ability to exploit the water in the soil.

Table 2. Variation in water useage of three crops under approximately equal time periods at Crookston, 1970

| Period | Number of Days | Crop | Total | Ave. per day |
|---|---|---|---|---|
| June 4 - Aug. 31 | 88 | Alfalfa | 16.72 in. | 0.190 in |
| June 2 - Aug. 31 | 90 | Sugarbeets | 14.85 | 0.165 |
| June 1 - Aug. 31 | 91 | Wheat | 13.04 | 0.143 |
| June 4 - Oct. 1 | 119 | Alfalfa | 19.92 | 0.167 |
| June 2 - Oct. 1 | 121 | Sugarbeets | 19.04 | 0.157 |
| June 1 - Oct. 1 | 122 | Wheat | 12.00 | 0.098 |

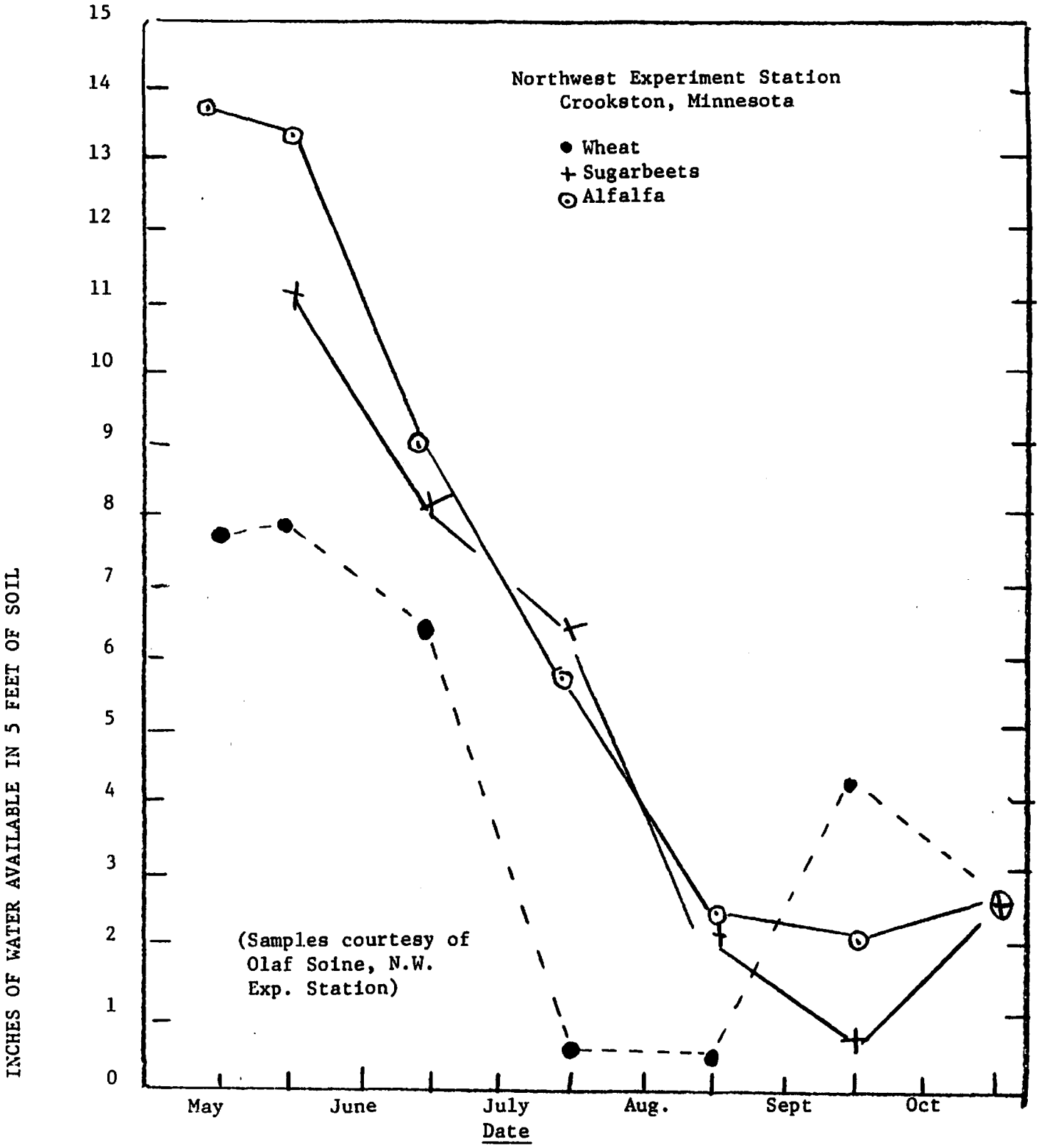


Figure 3. Change in the soil water reserves at Crookston during the 1970 season with three different crops.

Figure 4 shows both how the soil water changed at Lamberton during the 1970 season and also how that season compared with the 11-year average 1960-1970. By the end of the season the soil water was well below normal. However, it is believed that the late autumn rains brought the water up to nearly the normal amount before soil freezing took place.

B. Average Soil Water Conditions at Lamberton

On the average the soil water at Lamberton, Figure 4, was at a maximum in the week of May 31 - June 6 and was lowest in either the week of August 23-29 or August 30-September 5. The soil water profile at the time of the average maximum and minimum soil water content at the Southwest Experiment Station is shown in Figure 5. The picture shown in Figure 5 is idealized, since the soil is sampled at 6 inch increments down to 2 feet and in 12 inch increments down to 60 inches. The vertical bar for each depth increment represents the actual average amount of water found. The curved lines in turn represent the idealized soil water content profile.

C. Comparison Between Evapotranspiration and Pan Evaporation

Because irrigation is receiving increasing interest, Figure 6 may be of value. This figure shows how the ratio between "potential" evapotranspiration and pan evaporation varies during the course of an average season. During the heart of a growing season, June-August, the overall ratio is about 0.7. That is, the crop will consume about 70% as much water as that lost from an evaporation pan. Although it averages about 0.7, the ratio in these three months ranges between a minimum of 0.45 at the beginning of June to a peak of 0.78 in mid- to late July.

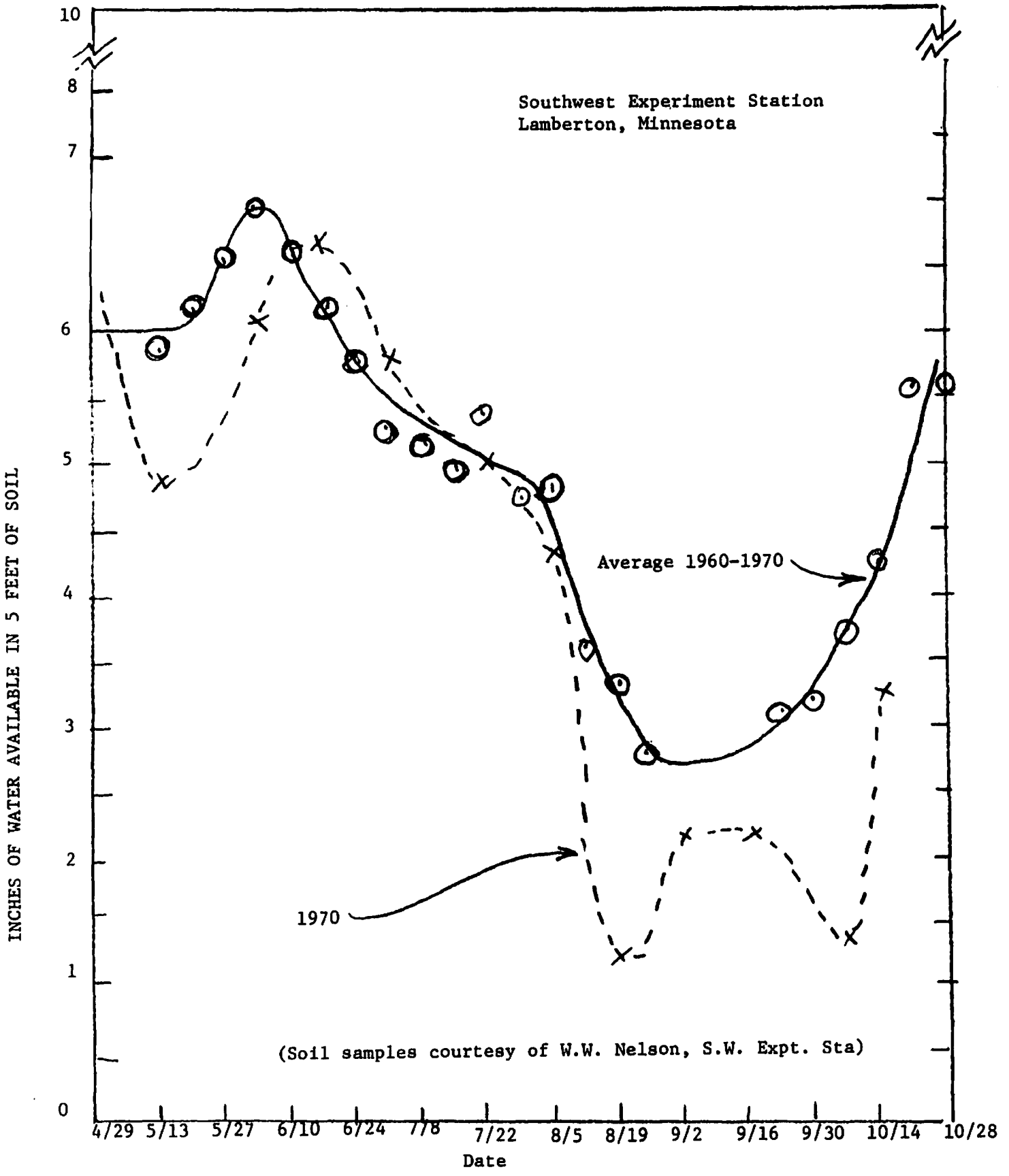


Figure 4 Comparison between the average (1960-1970) and the 1970 water content of the 5 foot soil profile under corn at Lamberton

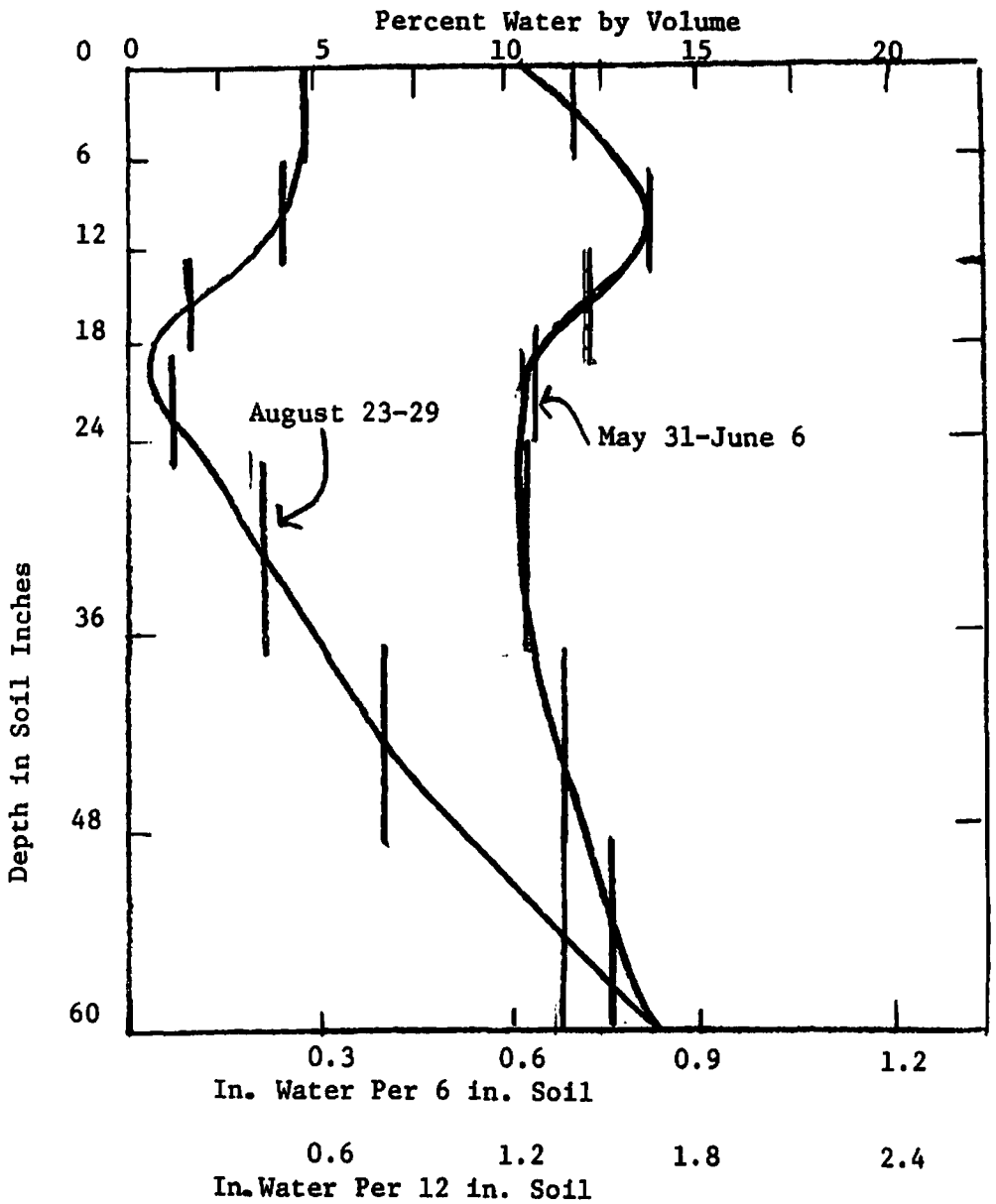


Figure 5. Average soil water content at the time of the mean maximum (May 31-June 6) and mean minimum (August 23-29) at Lamberton for the period 1960-1969

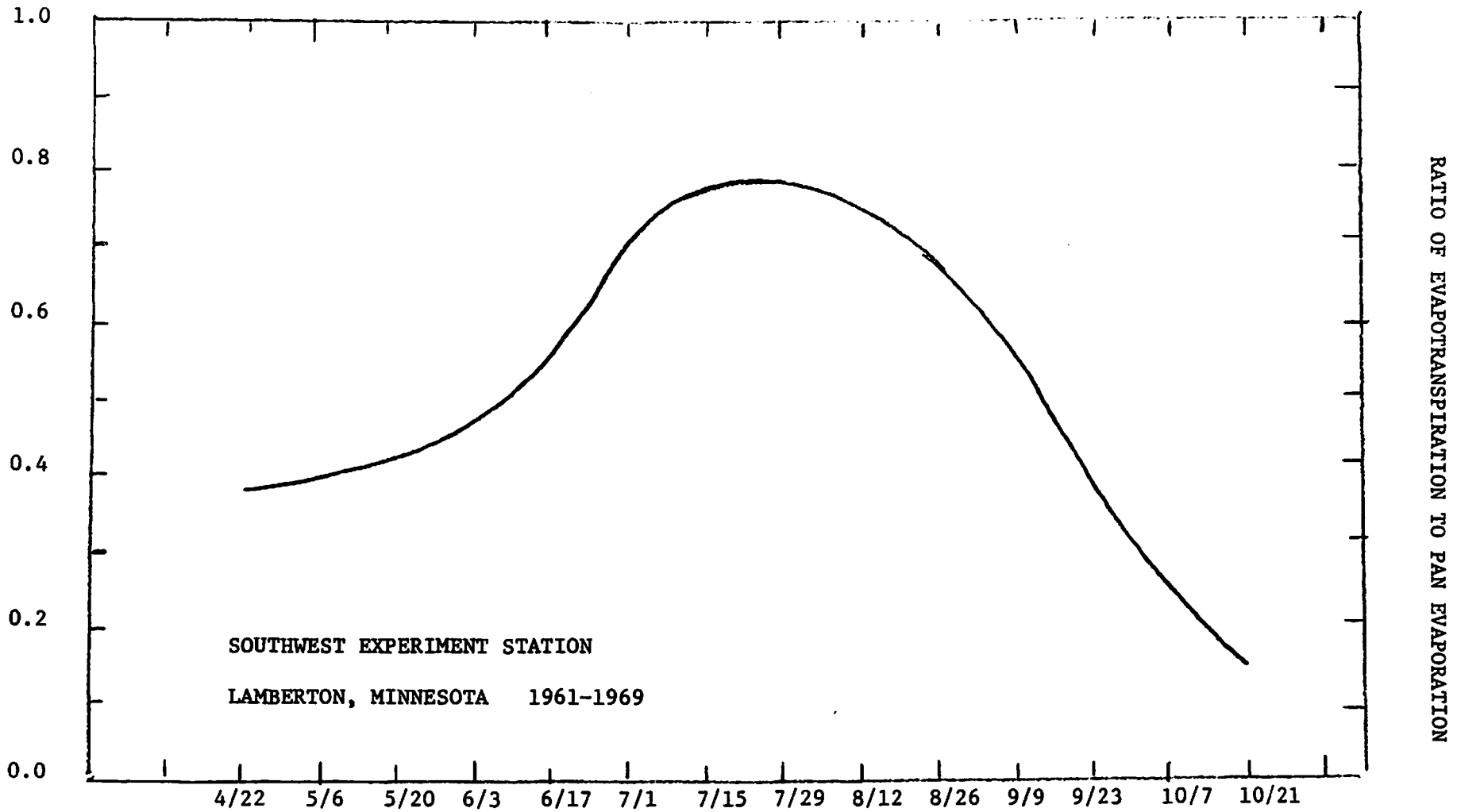


Figure 6. Ratio of "potential" evapotranspiration to pan evaporation at Lamberton for the period 1961-1969.

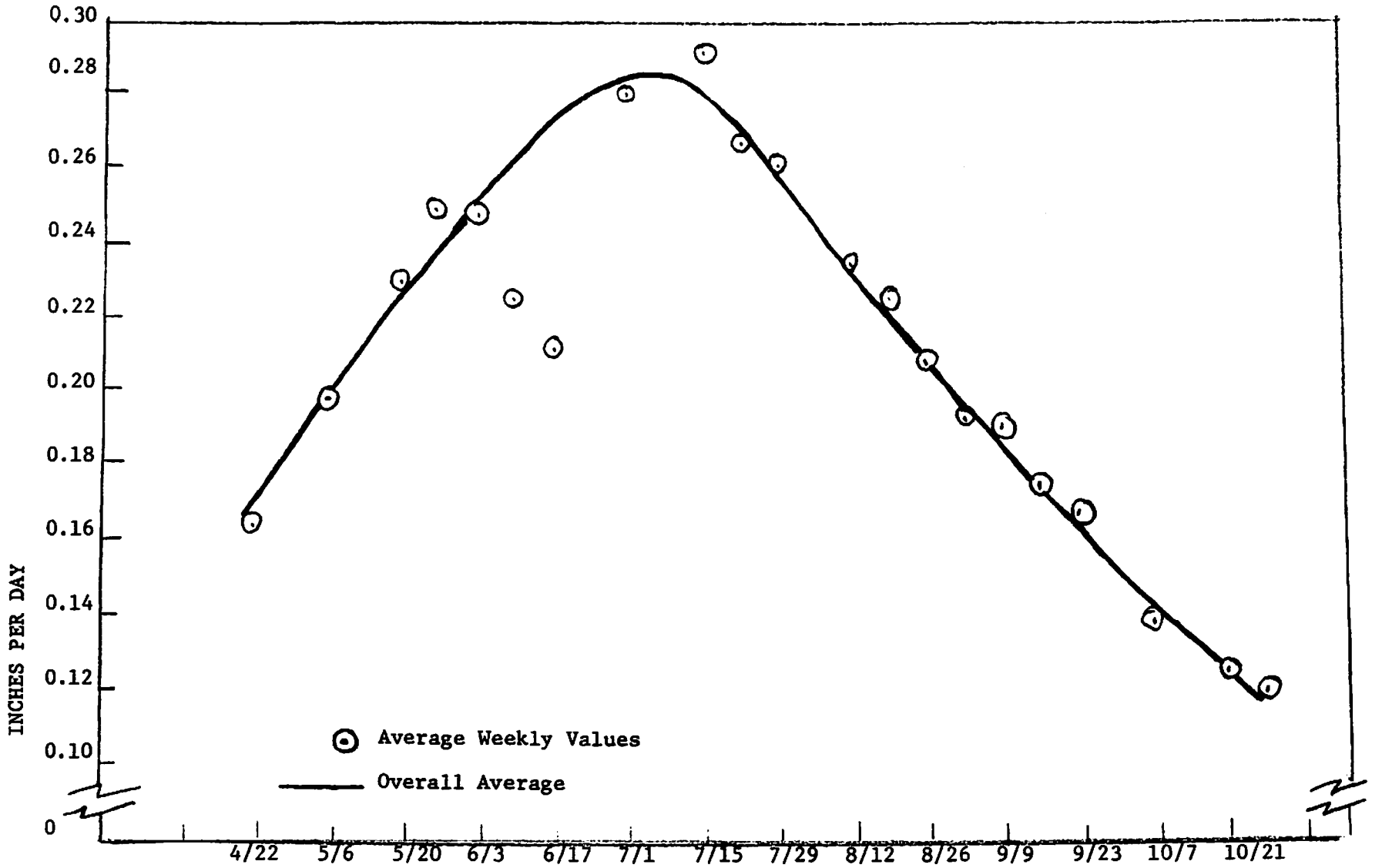


Figure 7. Average daily pan evaporation, Lamberton, 1961-1969

Use of the ratios in Figure 7 in combination with evaporation pan measurements will permit a ready estimation of the water consumed by a crop that is relatively well watered. This, of course, has direct application in irrigation scheduling. Since evaporation is a relatively conservative quantity (that is, it remains fairly constant over large areas) Figure 6 in combination with the data in Figure 7 can be applied over most of southern Minnesota.

The term "potential" evapotranspiration needs to be defined, for it is used here a bit differently from the usual definition. In this case it is considered as the amount of water consumed by an actively growing green crop (the data are based upon corn as the crop) when at least 50% of the available soil water is present. In making these calculations it was also assumed that 10% of the precipitation was lost as runoff and thus unavailable in adding to the soil water.

Those to whom I am indebted for obtaining the soil samples or supplying soil water data are the following:

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Dr. Olaf C. Soine, Northwest Experiment Station, U. of M. , Crookston

Dr. Wallace C. Nelson, Southwest Experiment Station, U.of M., Lamberton

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Mr. Roger Hoff, District Conservationist, S.C.S., U.S.D.A., Wabasha

Mr. Robert E. Krause, District Conservationist, S.C.S., U.S.D.A., Long Prairie

I also wish to thank the field aids who helped the above men obtain the soil samples. It is my hope that the notes prepared each year will be of particular value to those who helped with the samples and thus in a small measure repay their efforts. Several of the above have taken samples for 11 seasons now.

AVAILABLE SOIL MOISTURE SURVEY, 1970
Northwest Experiment Station
Crookston, Minnesota
Olaf C. Soine, Soil Scientist

Soil samples were collected from three different cropping systems during the growing season. The soil was sampled to a depth of 60 inches and 35 individual samples were taken from each site. Moisture determinations were made at this station on 735 samples of soil during the year. Because of the late spring, the first sampling was on May 13 on site 1. This area had a good snow cover and the frost didn't penetrate too deeply. On site 7, which was in legume fallow the previous year, the frost didn't disappear until June 2, because of high moisture content and poor over-winter cover.

The data in Tables 1, 2, 3, and 4 gives the sampling dates, the precipitation for each period, inches of available soil moisture for each depth, and the total for the season. Table 4 gives the results for November 4, 1969, as this field will be in sugarbeets in 1971. Each table gives the last sampling in the fall of 1969 so that the accumulated overwinter and early spring moisture can be determined.

Discussion: The total available soil moisture at the end of the 1969 growing season was above average at sites 1, 4, and 7. At site 6, table 3, the 1969 sugarbeet crop removed large amounts of water and the soil never did accumulate available moisture in comparison to the other sites.

The overwinter snowfall and early spring precipitation was normal, but May and June precipitation was above average. This resulted in a

good supply of available moisture and by July 1, the supply was very good.

July and August showed a 3.93 inch deficit in precipitation and negative available moisture readings appeared on August 1 at sites 6 and 7 to a depth of 24 inches. This condition continued through August, September, and October, and on November 1, deficit readings at 49-60 inch depth were present as shown in table 3.

The fall rains recharged the top two feet of soil except on site 6. Here the previous sugarbeet crop exhausted the soil moisture so that the reserve was low at the end of 1969.

The total available moisture for the 60-inch depth on October 30 and November 3 was very low at sites 1, 6, and 7. All three were in the 2.43 to 2.77 inch range. Compare this to 11.53 inches of available water on site 4, which was in legume fallow.

Table 1. Site 1 Alfalfa (Barley-1969) Available moisture in inches, 1970

| Sampling date | Precip. inches | Depth in inches 0-6 | 7-12 | 13-18 | 19-24 | 25-36 | 37-48 | 49-60 | Total |
|---|---|---|---|---|---|---|---|---|---|
| 10-31-69 | --- | 0.98 | 0.76 | 1.08 | 0.87 | 2.21 | 2.02 | 3.40 | 11.32 |
| 5-13-70 | 5.17 | 1.48 | 1.37 | 1.36 | 1.20 | 3.05 | 2.89 | 2.51 | 13.86 |
| 6-4-70 | 4.45 | 1.52 | 1.40 | 1.39 | 1.52 | 2.74 | 2.72 | 2.17 | 13.46 |
| 6-29-70 | 3.61 | 0.68 | 0.83 | 1.06 | 0.99 | 2.18 | 2.19 | 1.15 | 9.08 |
| 7-29-70 | 0.92 | 0.17 | 0.18 | 0.56 | 0.42 | 1.37 | 1.72 | 1.38 | 5.80 |
| 8-31-70 | 1.11 | 0.11 | 0.00 | 0.11 | -0.02 | 0.33 | 0.62 | 1.23 | 2.38 |
| 10-1-70 | 2.82 | 0.20 | 0.21 | 0.21 | -0.06 | -0.21 | 0.08 | 1.57 | 2.00 |
| 10-30-70 | 1.15 | 0.79 | 0.32 | 0.09 | -0.11 | -0.13 | -0.07 | 1.54 | 2.43 |
| Total precip. | 19.23 | | | | | | | | |

Table 2. Site 7 Sugarbeets (Sw.Cl.Fallow 1969) Available moisture in inches, 1970

| Sampling date | Precip. inches | Depth in inches 0-6 | 7-12 | 13-18 | 19-24 | 25-36 | 37-48 | 49-60 | Total |
|---|---|---|---|---|---|---|---|---|---|
| 11-4-69 | --- | 0.71 | 0.88 | 0.99 | 0.53 | 1.76 | 2.38 | 1.74 | 8.99 |
| 6-2-70 | 9.62 | 1.16 | 1.17 | 1.29 | 1.01 | 2.00 | 2.69 | 2.01 | 11.33 |
| 6-30-70 | 3.70 | 0.82 | 0.73 | 0.89 | 0.78 | 1.30 | 2.15 | 1.44 | 8.11 |
| 7-31-70 | 1.02 | 0.55 | 0.39 | 0.86 | 0.26 | 0.72 | 2.26 | 1.38 | 6.42 |
| 8-31-70 | 0.92 | -0.17 | -0.33 | 0.14 | -0.07 | 0.23 | 1.45 | 0.87 | 2.12 |
| 10-1-70 | 2.82 | 0.23 | 0.12 | -0.17 | -0.24 | -0.76 | 1.18 | 0.39 | 0.75 |
| 10-30-70 | 1.15 | 0.52 | 0.22 | 0.40 | -0.43 | -0.25 | 1.28 | 0.73 | 2.47 |
| Total precip. | 19.23 | | | | | | | | |

Table 3. Site 6 Wheat (Sugarbeets 1969) Available moisture in inches, 1970

| Sampling date | Precip. inches | Depth in inches 0-6 | 7-12 | 13-18 | 19-24 | 25-36 | 37-48 | 49-60 | Total |
|---|---|---|---|---|---|---|---|---|---|
| 10-31-69 | --- | 0.30 | 0.05 | 0.39 | 0.36 | 1.18 | 1.87 | 0.82 | 4.97 |
| 5-18-70 | 6.25 | 0.56 | 0.45 | 0.59 | 0.79 | 2.18 | 2.00 | 1.31 | 7.88 |
| 6-1-70 | 3.37 | 0.45 | 0.38 | 0.59 | 0.59 | 1.90 | 2.46 | 1.59 | 7.96 |
| 6-30-70 | 3.70 | 0.29 | 0.26 | 0.21 | 0.39 | 1.93 | 2.12 | 1.31 | 6.51 |
| 7-31-70 | 1.02 | -0.59 | -0.70 | -0.69 | -0.40 | 0.94 | 1.30 | 0.79 | 0.65 |
| 8-31-70 | 0.92 | -0.42 | -0.56 | -0.62 | -0.50 | 0.61 | 1.48 | 0.57 | 0.56 |
| 10-1-70 | 2.82 | -0.11 | -0.22 | 1.04 | -0.37 | 1.03 | 2.15 | 0.90 | 4.42 |
| 11-3-70 | 2.09 | 0.41 | 0.52 | 0.36 | 0.48 | 0.01 | 1.24 | -0.25 | 2.77 |
| Total precip. | 20.17 | | | | | | | | |

Table 4. Site 4 Sw. clover fallow, available moisture in inches, 1970

| Sampling date | Precip. inches | Depth in inches 0-6 | 7-12 | 13-18 | 19-24 | 25-36 | 37-48 | 49-60 | Total |
|---|---|---|---|---|---|---|---|---|---|
| 11-4-70 | --- | 0.87 | 0.99 | 0.86 | 0.88 | 2.76 | 3.02 | 2.15 | 11.53 |

# IRON AND ZINC TRIALS ON CORN AND FLAX - 1970

Northwest Experiment Station, Crookston
Olaf C. Soine, Soil Scientist

These trials were started in 1970 to determine if corn and flax would respond to an application of iron and zinc. Recent soil tests show that available zinc varies from 0.5 to 2.5 ppm in the Red River Basin. It has been difficult to find zinc deficiency symptoms in growing crops but iron chlorosis in flax is rather common.

Sequestrene 138 iron and sequestrene zinc chelate were broadcast, and double disked and harrowed before planting. Both materials were coated on 18-46-0 at 8 lb. per 100 lb. of fertilizer, which helped in obtaining a uniform application. A 85-day corn was drilled in 24-inch rows on June 3, and the plots were harvested on September 23.

Table 1 gives the yield of corn for the various treatments of iron and zinc. The heading "Fertilizer" in tables 1, 2, and 3 gives the amount of 18-46-0 that was applied to furnish the required amount of iron and zinc per acre.

Table 1. The effect of iron and zinc on the yield of corn, 1970

| Treatment | Rate lb/A | Fertilizer[1] lb/A | Yield 15.5% moisture bus/A |
|---|---|---|---|
| Check | -- | 63 | 102 ab[2] |
| Zinc | 0.36 | 32 | 106 a |
| Zinc | 0.72 | 63 | 97 ab |
| Iron | 0.30 | 63 | 90 b |
| Iron | 0.60 | 125 | 90 b |
| LSD | | | 15 |

[1] Zinc and iron chelates furnished by Giegy Chemical Company.

138 Iron contained 6% iron

Zinc ($Na_2Zn$) contained 14.2% zinc

[2] Any two averages followed by the same letter do not differ at the 5% level of significance according to Duncan's New Multiple Range Test.

| | | | |
|---|---|---|---|
| Soil test pH | 8.3 | P | 18 lb. |
| Zinc | 2.7 ppm | K | 310 lb. |

Treatment 0.36 lb/A of zinc was the only one that increased the yield of corn, but the increase was not significant. The yield from the 0.72 lb. rate of zinc was nine bushels less than the yield from the 0.36 lb. rate.

Both iron treatments produced identical yields, and were 12 bushels less than the check.

Summit and Nored were selected for this trial to determine if varietal differences are present in flax. The flax plots received the same fertilizer treatment and were handled in the same manner as the corn trials. The plots were sown on May 26. The emergence was very poor and the plots were reseeded on June 8. Summit was harvested on September 14 and Nored was harvested on September 30.

The effect of iron and zinc on Summit and Nored flax is given in Tables 2 and 3 respectively.

Table 2. The effect of iron and zinc on the yield, seed weight, oil content, and iodine value of Summit flax, 1970

| Treatment | Rate | Fertilizer | Yield | Seed Weight | Oil Content | Iodine value |
|---|---|---|---|---|---|---|
| | lb/A | lb/A | bu/A | g/1000[2] | % oven dry | no. |
| Check | - - | 63 | 19.1 [a1] | 5.6 | 40.1 | 190 |
| Zinc | 0.36 | 32 | 24.6 [bc] | 5.5 | 40.0 | 188 |
| Zinc | 0.72 | 63 | 23.1 [bc] | 5.6 | 39.5 | 185 |
| Iron | 0.30 | 63 | 20.1 [a] | 5.5 | 39.9 | 189 |
| Iron | 0.60 | 125 | 19.9 [a] | 5.5 | 39.0 | 187 |
| LSD | | | 2.4 | | | |

[1]Any two averages followed by the same letter do not differ at the 5% level of significance according to Duncan's New Multiple Range Test.

[2]Weight of 1000 seeds in grams.

Table 3. The effect of iron and zinc on yield, seed weight, oil content, and iodine value of Nored flax, 1970

| Treatment | Rate | Fertilizer | Yield | Seed Weight | Oil Content | Iodine value |
|---|---|---|---|---|---|---|
| | lb/A | lb/A | bu/A | g/1000[1] | % oven dry | No. |
| Check | -- | 63 | 14.6 | 5.4 | 41.2 | 192 |
| Zinc | 0.36 | 32 | 15.8 | 5.6 | 40.7 | 192 |
| Zinc | 0.72 | 63 | 15.3 | 5.5 | 41.0 | 192 |
| Iron | 0.30 | 63 | 14.5 | 5.3 | 40.8 | 192 |
| Iron | 0.60 | 125 | 16.5 | 5.3 | 40.7 | 193 |
| LSD | | | 7.1 | | | |

[1]Weight of 1000 seeds in grams.

Summit matured two weeks earlier and yielded more than Nored. Because of the late planting, Nored continued to bloom until late September and the plots were harvested after the first fall frost. The two zinc treatments gave the highest yield increases for both varieties. The iron treatments were not significantly different from the check for either variety. There were no significant differences in the seed weight or oil content for either variety.

Nored had a slightly higher iodine value than Summit, but the results were not significantly different for any treatment.

# SUGARBEET ROTATION STUDIES - 1970

Northwest Experiment Station, Crookston
Olaf C. Soine, Soil Scientist

This experiment, which consists of six 4-year rotations, was started in 1967, and data is now available for the 4-year period, with the exception of table 3. The rotations and average yields are given in table 1. Sugarbeets follow the last crop in each rotation (e.g., Rotation 1, beets follow legume fallow; Rotation 2, beets follow oats, etc.). Rotation 1 is the most common cropping system used in this area. In Rotation 4, the first crop of alfalfa is removed and the land is fallowed the remainder of that year. The black fallow in Rotation 5 is used for weed control, and sometimes the legume seeding may fail. This area is not too well adapted for soybeans, but the yields have been good, as shown in Rotation 6.

Table 1. Sugarbeet rotation - average yields, 1967-70

| | | | | |
|---|---|---|---|---|
| Rotation 1 | Beets<br>17.5 T | Wheat*<br>46.8 Bu. | Barley<br>76.4 Bu. | Legume Fallow<br>--------- |
| Rotation 2 | Beets<br>16.0 | Wheat<br>46.4 | Barley<br>74.4 | Oats<br>102.7 Bu. |
| Rotation 3 | Beets<br>17.0 | Potato**<br>266 | Wheat<br>46.0 | Barley<br>76.9 |
| Rotation 4 | Beets<br>17.1 | Wheat<br>45.8 | Barley<br>74.2 | Alfalfa fallow***<br>2185 |
| Rotation 5 | Beets<br>18.0 | Wheat<br>48.9 | Barley<br>77.1 | Black Fallow<br>-------- |
| Rotation 6 | Beets<br>16.9 | Wheat<br>46.8 | Barley<br>75.1 | Soybeans<br>27.5 |

* All grain yields on pure seed basis.
** No. 1 potato
*** 1st crop removed

The effect of the 1967-70 crop on the 4-year average yield of beets, percent sugar, impurity index, and pounds of sugar per acre is given in table 2. The yield of beets varied from 16 tons on Rotation 2 to 18 tons on Rotation 5, but the farmer is paid on the amount of sugar and this is based on percent sucrose. The other yields were similar and the results do not indicate any definite advantage for fallowing over continuous cropping.

There are some interesting variations in the percent sugar for the various rotations. The black, legume, and alfalfa fallow rotations have the lowest percent sugar, while Rotations 2 and 6 have the highest.

The impurity index gives some indication of the quality of beets and the lower this figure is the better the processing quality. The three fallow rotations have the highest impurity indexes while the oats and barley rotations, Rotations 2 and 3, have the lowest.

Differences in sugar yield were not significant between the various rotations, which indicates that fallowing does not pay for itself.

Table 2. Effect of 1967-70 crop on 1967-70 yield, percent sugar, impurity index, and yield of sugar

| Rotation | 1967-70 crop | Yield T/A | Sugar % | Impurity index | Sugar T/A |
|---|---|---|---|---|---|
| 1 | Legume fallow | 17.5 | 13.83 | 864 | 2.42 |
| 2 | Oats | 16.0 | 14.80 | 639 | 2.37 |
| 3 | Barley | 17.0 | 14.27 | 711 | 2.43 |
| 4 | Alf.hay fallow | 17.1 | 14.29 | 769 | 2.44 |
| 5 | Black fallow | 18.0 | 13.92 | 828 | 2.51 |
| 6 | Soybeans | 16.9 | 14.36 | 753 | 2.43 |

Table 3 gives the average net income for 1967-69. These figures include a land cost of $20.00 per acre and $5.00 per acre for taxes. If a grower owns his land, these costs would not be "out of pocket" costs.

The calculations for all crops and the rates for all farm operations are based on two publications[1] by the Extension Service, University of Minnesota, and North Dakota Crop and Livestock Reporting Service. The highest income came from Rotation 3 which included potatoes, while the lowest came from Rotations 1 and 4. The net returns from the three fallow rotations were the lowest.

Table 3. Average net income from six sugarbeet rotations 1967-69

| | | | | | |
|---|---|---|---|---|---|
| Rotation 1 | Beets | Wheat | Barley | Legume Fallow | Total |
| | $172 | $21 | $19 | $-45 | $167 |
| Rotation 2 | Beets | Wheat | Barley | Oats | |
| | $156 | $23 | $22 | $11 | $212 |
| Rotation 3 | Beets | Potato | Wheat | Barley | |
| | $162 | $266 | $19 | $20 | $467 |
| Rotation 4 | Beets | Wheat | Barley | A.Hay fallow | |
| | $160 | $21 | $21 | $-34 | $167 |
| Rotation 5 | Beets | Wheat | Barley | Bl.fallow | |
| | $184 | $25 | $22 | $-44 | $187 |
| Rotation 6 | Beets | Wheat | Barley | Soybeans | |
| | $161 | $23 | $18 | $11 | $213 |

[1] Custom Rates for Farm Operation. Extension Pamphlet 134 - Revised 1969 - Agricultural Extension Service, University of Minnesota.

Custom Farm Work Rates. Jan. 8, 1969. North Dakota Crop and Livestock Reporting Service, North Dakota State University, Fargo, North Dakota.

# WEATHER SUMMARY
## Northwest Experiment Station, Crookston
## 1970

Olaf C. Soine, Soil Scientist

The weather summary for 1970 is given in table 1 and includes precipitation, mean temperatures, and long-time averages. Table 2 gives the number of clear, partly cloudy, and cloudy days for the year.

Above average precipitation during the spring, drought during July and August, and above average precipitatioan during the last four months of the year characterized the weather during 1970. Seven months were above average in precipitation. June continued to have above normal rainfall for the seventh consecutive year. The growing season, April through September, registered 0.15 inches of precipitation above the long-time average. The total precipitation for the year was 20.84 inches — 0.64 inches above normal.

The drought during July and August was not too severe but this period showed a deficit of 3.93 inches of rainfall.

The snowfall for the calendar year measured 49 inches and contained 3.45 inches of water. From January through April, 25 inches of snow fell and this contained 2.08 inches of water.

The mean temperature for the year was 39.1° F. compared to 39.7°F., the long-time average. The first five months of 1970 were colder than normal. January was 5.2°F. and March 13.3°F. below normal. The summer and fall months were above average in temperature. The growing season, April-September, was 1.3° F. above the long-time average.

The coldest day of the year was on January 18 when the thermometer dropped to -38$^{o}$F. Two days, June 28 and July 26, had the highest temperatures with readings of 98$^{o}$F.

The last spring frost occurred on May 5 when the termperature dropped to 28$^{o}$F.; however, a 32$^{o}$F. temperature was recorded on May 26, but no frost damage was noted. The first fall frost occurred on September 27 when a temperature of 28$^{o}$F occurred.

The frost-free period of 125 days during 1970 was one day longer than average.

Table 1. Weather Summary for 1970 with averages for precipitation and mean temperatures for 1900-64.

| Month | Precipitation - inch: Snowfall Inches | Precipitation Inches | Rain | Total | 1900-64 Avg. | | Mean temperature degree 1970 | 1910-64 |
|---|---|---|---|---|---|---|---|---|
| January | 8.0 | 0.31 | 0 | 0.31 | 0.56 | | -0.3 | 4.9 |
| February | 3.0 | 0.23 | 0 | 0.23 | 0.61 | | 8.6 | 8.8 |
| March | 9.0 | 1.11 | 0.53 | 1.64 | 0.79 | | 13.0 | 26.6 |
| April | 5.0 | 0.43 | 0.96 | 1.39 | 1.51 | | 38.1 | 41.4 |
| May | 0 | 0 | 5.40 | 5.40 | 2.62 | | 52.7 | 54.6 |
| June | 0 | 0 | 3.70 | 3.70 | 3.36 | | 69.4 | 63.8 |
| July | 0 | 0 | 1.02 | 1.02 | 2.98 | | 72.8 | 69.7 |
| August | 0 | 0 | 0.92 | 0.92 | 2.89 | | 70.2 | 67.5 |
| September | 0 | 0 | 2.82 | 2.82 | 2.11 | | 60.0 | 57.2 |
| October | 3.0 | 0.15 | 1.40 | 1.55 | 1.34 | | 46.9 | 45.4 |
| November | 9.0 | 0.60 | 0.54 | 1.14 | 0.86 | | 27.3 | 27.2 |
| December | 12.0 | 0.62 | 0.10 | 0.72 | 0.59 | | 10.1 | 11.6 |
| TOTAL | 49.0 | 3.45 | 17.39 | 20.84 | 20.20 | Mean | 39.1° | 39.7° |

Table 2. Number of clear, partly cloudy, and cloudy days for 1970.

| | Jan. | Feb. | March | April | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Avg. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Clear | 11 | 9 | 14 | 3 | 5 | 9 | 17 | 17 | 10 | 11 | 8 | 14 | 10.7 |
| P. Cloudy | 9 | 10 | 8 | 6 | 9 | 13 | 10 | 9 | 8 | 7 | 3 | 9 | 8.4 |
| Cloudy | 11 | 9 | 9 | 21 | 17 | 8 | 4 | 5 | 12 | 13 | 19 | 8 | 11.3 |

# FIELD EXPERIMENTS WITH ASPHALT BARRIERS (AMB) ON SANDY SOILS IN SHERBURNE COUNTY

G. R. Blake, D. S. Fairchild, B. C. McCaslin

In the spring of 1968, a project was initiated on a Hubbard loamy course sand to study the potential benefits of an asphalt moisture barrier on:

1. Increased crop yields,
2. Conserving of irrigation water,
3. Prevention of excessive nutrient leaking, and
4. Improved crop quality.

The asphalt moisture barrier was layed at a 22 inch depth with a specially constructed machine that would lift the soil, spray the asphalt layer, and replace the soil with a minimum of soil disturbance. The barriers were installed with the cooperative efforts of American Oil Company and International Harvester.

Since the barriers are permeable to water, the logical question is, how does it save water? The barrier does this by interrupting the capillary conducting channels. Thus, moisture tension at the upper barrier surface is very low after leakage is complete. Instead of having an equilibrium "field capacity" at a pore pressure of minus 0.1 bar normal for sandy soil, we have a pseudo-field capacity at about 0.01 bar suction. This means that water under positive pressure drains readily but water content at equilibrium is much higher than if capillary connections were complete.

Three replications of 4 treatment combinations were applied as a split plot design. The treatment combinations included:

1. No barrier x no irrigation,
2. Barrier x no irrigation,
3. No barrier x irrigation, and
4. Barrier x irrigation.

The four crops (snap beans, sweet corn, potatoes, and onions) were superimposed over these basic treatments.

The 1970 growing season at Elk River was characterized by a relatively wet spring and early summer, a drier July and August, and a wet fall. A total of 25.19" of precipitation was recorded during the growing season (Table 1). Additional levels of irrigation water and dates applied are included in Tables 2 and 3.

Table 1. Climatological Notes, Elk River, 1970

| Month | Inches Precipitation |
|---|---|
| April | 3.35 |
| May | 4.11 |
| June | 5.16 |
| July | 2.46 |
| August | 2.97 |
| September | 2.59 |
| October | 4.55 |
| Total | 25.19 |

Table 2. Irrigation Dates, Elk River, 1970.

| Date | Inches of Water Added |
|---|---|
| 5/7/70 | 0.50 |
| 5/20/70 | 0.75 |
| 6/5/70 | 0.50 |
| 6/24/70 | 0.32 |
| 6/25/70 | 0.96 |
| 6/26/70 | 0.48 |
| 6/30/70 | 0.40 |
| 7/6/70 | 1.00 |
| 7/8/70 | 0.60 |
| 7/12/70 | 1.00 |
| 7/22/70 | 1.30 |
| 7/26/70 | 0.75 |
| 7/30/70 | 1.25 |
| 8/5/70 | 1.00 |
| 8/13/70 | 1.00 |
| 8/20/70 | 1.0 |
| 8/26/70 | 1.5 |
| Total | 14.31 |

Table 3. Irrigation levels, Elk River, 1970

| Crop | Inches of Water Added |
|---|---|
| Snap Beans | 5.61 |
| Sweet Corn | 7.66 |
| Potatoes | 14.41 |
| Onions | 14.41 |

Snap Beans

Fertilizer - Preplant:
(1) 46 + 91 + 91
(2) Gypsum - 300 lbs/A

Sidedressed: 40 lbs N/A

Herbicide - Preplant - 3 lbs/A EPTC

Table 4. Snap bean yields, Elk River, 1970

| | NO IRRIGATION | | IRRIGATION | | Statistical Significance | | |
|---|---|---|---|---|---|---|---|
| | No Barrier | Barrier | No Barrier | Barrier | I | Bar | IXB |
| | lbs/Acre | | | | | | |
| Size #1 | 208.3 | 457.3 | 216.6 | 244.3 | N.S. | N.S. | N.S. |
| Size #2 | 1900.8 | 2700.5 | 4521.5 | 3264.3 | * | N.S. | N.S. |
| Size #3 | 124.9 | 263.3 | 598.3 | 567.4 | * | N.S. | N.S. |
| Sizes #1+2 | 2109.1a | 31577a | 6687.3b | 5706.9b | * | N.S. | * |
| Total | 2232.2a | 3417.0a | 7279.3b | 6272.6b | * | N.S. | * |

I. Means in horizontal rows followed by different letters are significantly different at 5% level. (Duncan's New Multiple Range Test).

Sweet Corn

Fertilizer - Preplant:
(1) Gypsum - 300 lbs/A

Planting: (1) 26 + 51 + 51

Sidedressed:
(1) 6/12/70 - 83 lbs. N/A
(2) 6/24/70 - 83 lbs. N/A

Herbicide - 1 1/2 lbs/A Lasso - Preplant

Table 5 - Asphalt Barrier Study - Sweet Corn - Elk River 1970

| | NO IRRIGATION | | IRRIGATED | | Statistical |
|---|---|---|---|---|---|
| | No Barrier | Barrier | No Barrier | Barrier | Significance |
| | | | Number of Ears/Acre | | |
| Total | 12,584 | 12,955 | 29,056 | 29,282 | Irr.* |
| Smut | 273 | 187 | 2,417 | 2,120 | Irr.* |
| Marketable | 12,311 | 12,768 | 26,639 | 27,162 | Irr.* |
| Weights of Ears/Acre | | | lbs/acre | | |
| Total | 3,836 | 4,197 | 16,784 | 16,592 | Irr.* |
| Smut | 245 | 168 | 2,175 | 1,908 | Irr.* |
| Marketable | 3,590 | 4,029 | 14,609 | 14,684 | Irr.* |
| Quality Factor # | | | | | |
| Weight/Ear | 0.29 | 0.31 | 0.55 | 0.54 | Irr.* |
| Over-all Quality | 5.36 | 4.42 | 7.13 | 7.29 | Irr.* |
| Maturity | 5.33 | 4.74 | 5.71 | 5.62 | Irr.* |
| Filled ends and/or Missing rows | 4.06 | 3.31 | 7.09 | 7.48 | Irr.* |

*Classifications Maturity, Over-all quality, and filled ends and/or missing rows are based on the following weighted $\overline{X}$ with a scale of 0-10 points (10 being perfect) weighted $\overline{X}$ =

$$\frac{\text{Number of No. 1 Ears X 10 + Number of No. 2 Ears X 6 + Number of No. 3 Ears X 2}}{\text{Total No. of ears/plot}}$$

Potatoes

Variety - Russet Burbanks

Fertilizer - Preplant:
(1) 300 lbs/A Gyspum
(2) 0 + 0 + 48

Planting: (1) 79 + 79 + 79

Sidedressed: (1) 6/12/70 - 67 lbs. N/A
(2) 6/23/70 - 67 lbs. N/A

Herbicide - 6 lbs/A EPTC - Preplant

Table 6 - Asphalt Barrier Study Potatoes - Elk River 1970

| | NO IRRIGATION | | IRRIGATED | | Statistical |
|---|---|---|---|---|---|
| | No Barrier | Barrier | No Barrier | Barrier | Significance |
| | lb/A | | | | |
| No. 1's | 2,359 | 3,227 | 28,435 | 28,781 | Irr.* |
| No. 2's | 7,693 | 9,805 | 13,789 | 13,938 | Irr.* |
| Total 1 and 2 | 10,053 | 13,032 | 42,224 | 22,719 | Irr.* |

Onions

Fertilizer - Preplant:
(1) 46 + 91 + 91

Sidedressed: (1) 6/22/70 - 67 lbs. N/A
(2) 7/8/70 - 73 lbs. N/A

Herbicide - 6 lbs/A DCPA - Preplant

Table 7 - Asphalt Barrier Study Onions - Elk River 1970

| | NO IRRIGATION | | IRRIGATED | | Statistical Significance | | |
|---|---|---|---|---|---|---|---|
| | No Barrier | Barrier | No Barrier | Barrier | Irrig | Bar | IXB |
| | | | Number of Onions/A | | | | |
| Total | 55,370 | 60,113 | 52,756 | 50,578 | N.S. | N.S. | N.S. |
| No. 1 | 3,224a | 2,707a | 12,899b | 20,300c | * | N.S. | * |
| No. 2 | 47,970 | 51,783 | 36,182 | 27,973 | N.S. | N.S. | N.S. |
| No. 3 | 3,039 | 3,959 | 1,666 | 604 | * | N.S. | N.S. |
| Culls | 1,138 | 1,663 | 2,009 | 1,701 | N.S. | N.S. | N.S. |
| | | | Weights of Onions lbs/A | | | | |
| Total | 11,974 | 14,433 | 18,789 | 21,780 | N.S. | N.S. | N.S. |
| No. 1 | 1,496a | 1,269a | 7,696b | 11,601c | * | * | * |
| No. 2 | 10,100 | 12,225 | 10,071 | 9,619 | N.S. | N.S. | N.S. |
| No. 3 | 445 | 909 | 1,021 | 561 | N.S. | N.S. | N.S. |

# Means in horizontal rows followed by different letters are significantly different at 5% level.

An additional asphalt barrier study was initiated in 1968 on Zimmerman fine sand. This study has 4 replications, 4 treatments, and two crops. The treatments include:

1. No asphalt,
2. 1500 gallons asphalt/A
3. 950 gallons asphalt/A, and
4. 750 gallons asphalt/A.

Sweet corn and field corn are grown on these varying rates of asphalt with no irrigation.

Tables 8 and 9 give a summary of 1970 data collected. It is interesting to note the yield increases of the no asphalt treatments versus any of the differing rates of asphalt. The sweet corn yields were increased by approximately 2,000 lbs/A by any treatment of asphalt. The field corn yields were increased by 21 bu/A by 1500 gallons of asphalt/A. The yields of both crops are relatively good considering the water holding capcity of this soil combined with the low rainfall and high temperatures in late July and early August. Visual observations at this critical time showed leaves of the no asphalt plots curled and wilted compared to the asphalt treated plots that were more near normal.

Sweet Corn and Field Corn

| | |
|---|---|
| Fertilizer - Preplant: | (1) 0 + 0 + 108 |
| Planting: | (1) 25 + 50 + 50 |
| Sidedressed: | (1) 6/18/70 - 67 lbs N/A<br>(2) 6/30/70 - 67 lbs N/A |

Herbicide - 2 1/2 lbs/A Atrazine

Table 8 - Asphalt Barrier Study - Sweet Corn - Elk River Satellite, 1970

| | Gallons of Asphalt/Acre | | | |
|---|---|---|---|---|
| | 0 | 750 | 950 | 1,500 |
| Numbers of Ears/Acre | | | | |
| Total | 22,688 | 22,796 | 23,607 | 22,131 |
| Sucker | 7,925 | 7,082 | 7,118 | 5,171 |
| Smut | 197 | 0 | 176 | 0 |
| Marketable | 15,466 | 15,715 | 16,382 | 16,960 |
| Weights of Ears/Acre (lbs) | | | | |
| Total | 9,832a | 11,978b | 11,681b | 11,640b |
| Sucker | 1,144 | 1,009 | 1,008 | 747 |
| Marketable | 8,688a | 10,969b | 10,592b | 10,893b |
| Quality factors# | | | | |
| Maturity | 5.38 | 5.53 | 5.36 | 5.41 |
| Over-all Quality | 7.15 | 7.66 | 7.63 | 7.69 |
| Filled ends and/or Missing rows | 6.58 | 6.40 | 6.56 | 6.37 |

#Means in horizontal rows followed by a different letters are significantly different letters are significantly different at 5% level.

#Classifications maturity, overall quality and filled ends and/or missing rows are based on a weighted $\bar{X}$ with a scale of 0-10 points (10 being perfect)

Table 9 - Asphalt Barrier Study - Field Corn - Elk River Satellite, 1970

| | Gallons of Asphalt/Acre | | | |
|---|---|---|---|---|
| | 0 | 750 | 950 | 1,500 |
| Bu/Acre (15.5%) | 98 | 98 | 103 | 119 |

# FIELD EXPERIMENTS WITH SOIL MODIFICATION ON AN IRRIGATED HUBBARD LOAMY COARSE SAND

R. S. Farnham, D. S. Fairchild

In the spring of 1969, a project was initiated to study maximizing crop yields by modifying the soil root zone environment to assure optimum air, water and nutrients. The following materials were installed as detention layers:

1. Peats,
2. Wood products, (low grade pulp)
3. Composted garbage,
4. Manure,
5. Calcined clay, and
6. Vermiculite.

The layers were installed in a 18 inch band 18 inches deep directly beneath the crop row. A number of plots were installed with a 14 foot by 14 foot continuous layer. In both types of placement the detention layer was 1/2 to 1 inch thick.

There is no replication within the experiment and data should be considered accordingly.

Snap beans and field corn were grown in 1970.

## Field Corn

The 1970 growing season at Elk River was characterized by a relatively wet spring and early summer, but with a dry July and August.

A total of 25.0 inches of precipitation was recorded at the station. An additional 15 inches of water was added periodically by irrigation.

A 110 day corn variety was planted on May 8 at 29,000 plants per acre. The fertility program included:

1. Preplant - 300 lbs./A gypsum,
2. Preplant - 72 + 144 + 144,
3. Side dress (6/19/70) - 67 lbs. N/A, and
4. Side dress (6/29/70) - 83 lbs. N/A.

Total N + $P_2O_5$ + $K_2O$ fertilizer applied was 224 + 144 + 144. The frequency of nitrogen application being very important on these coarse textured irrigated soils. Corn yields were excellent in 1970 with a definite trend of a treatment response of the checks versus soil modification plots. (Table 1).

Table 1. Corn Yields with Soil Modification Treatments on a Hubbard Loamy Coarse Sand.

| Treatments | 1970 Bu./A 15.5% | |
|---|---|---|
| No Bands | | |
| Checks | 120 | |
| | 141 | Average |
| | 145 | 135 |
| Continuous Layers | | |
| Reed sedge peat | 134 | |
| Sphagnum peat | 184 | |
| Hydromulch (wood product) | 172 | |
| Row Bands | | |
| Hydromulch | 183 | |
| Composted garbage | 174 | |
| Reed - sedge peat | 171 | |
| Sphagnum peat | 180 | |
| Decomposed peat | 183 | |
| Vermiculite 1/2" | 201 | |
| Vermiculite 3/4" | 154 | |
| Vermiculite 1" | 166 | |
| Calcined clay | 174 | |

Snap Beans

Snap beans were planted on June 22. An additional 12.5 inches of water was added periodically by irrigation. The fertility program included:

1. Preplant - 300 lbs/A gypsum,
2. Preplant - 40 + 80 + 80,
3. Side dress (7/22/70) - 40 lbs. N/A, and
4. Side dress (8/6/70) - 42 lbs. N/A.

Total N + $P_2O_5$ + $K_2O$ fertilizer applied was 122 + 80 + 80.

The row band treatment yields responsed consistently above the checks and continuous layer treatments. (Table 2).

Table 2. Snap Bean Yields with Soil Modification Treatments on a Hubbard Loamy Coarse Sand.

| Treatments | lbs./A |
|---|---|
| No Bands | |
| Checks | 8,233 |
| | 9,264 |
| Continuous Layers | |
| Turface | 9,641 |
| Vermiculite | 7,158 |
| Vermiculite (roto-tilled) | 10,019 |
| Row Bands | |
| Metro organic 1/2" | 18,528 |
| Reed - sedge peat (field) | 14,317 |
| Reed - sedge peat (greenhouse) | 16,654 |
| Sphagnum peat | 17,322 |
| Vermiculite 1/2" | 14,128 |
| Vermiculite 3/4" | 12,603 |
| Vermiculite 1" | 17,192 |
| Calcined clay | 15,144 |

## Conclusion

Soil modification will become increasingly important because of:

1. Need to conserve water resources,
2. Reduce nitrogen and phosphorous groundwater pollution,
3. Alternative use for organic wastes,
4. Reduce pesticide leaching,
5. Reduce soil temperature, and
6. Greater higher economic returns.

# Elk River Plots 1970

C.J. Overdahl * and C.P. Klint

## Potatoes - 1970

Considerable stand variation was the chief problem in 1970. Even though plots showed growth and color difference due to treatment, very little difference was noted in yield. Variety 1968 - Burbank, 1969 and 1970 Norland. (Average of 4 replicates.)

Nitrogen effect -

| | Yield CWT/Acre | | |
|---|---|---|---|
| | 1968 | 1969 | 1970* |
| 75 + 150 + 500 | 139 | 251 | 84 |
| 150 + 150 + 500 | 204 | 270 | 233 |
| 300 + 150 + 500 | 216 | 285 | 187 |

*N rates were 75 and 225 lbs of N above previous treatments on the 150 300 pound treated plots.

Potash and magnesium effect -

| $N + P_2O_5 + Mg$ | Yield CWT/Acre | | |
|---|---|---|---|
| | 1968 | 1969 | 1970* |
| 200 + 150 + 0 + 0 | 158 | 270 | 267 |
| 200 + 150 + 150 + 0 | 170 | 288 | 268 |
| 200 + 150 + 500 + 0 | 189 | 286 | 287 |
| 200 + 150 + 0 + 50 | 195 | 286 | 237 |
| 200 + 150 + 150 + 50 | 199 | 327 | 294 |
| 200 + 150 + 500 + 50 | 183 | 305 | 263 |
| | N.S. | N.S. | N.S. |

| Average $K_2O$ Effect | | |
|---|---|---|
| 1968 | 1969 | 1970 |
| 176 | 278 | 252 |
| 185 | 306 | 281 |
| 186 | 297 | 275 |

| Average K Soil Test | | |
|---|---|---|
| 1968 | 1969 | 1970* |
| 280 | 221 | 182 |
| - | 292 | 295 |
| - | 519 | 408 |

* Efforts of Dean Fairchild and Bob McCaslin are greatfully acknowledged.

| | | |
|---|---|---|
| Avg. pH 5.3 | 5.2 | 5.5 |
| Avg. P 200+ | 200+ | 200+ |

| Average Mg lbs/A | Average Mg Effect 1968 | 1969 | 1970 | Average Mg in petiole 1968 | 1969 | 1970 |
|---|---|---|---|---|---|---|
| 0 | 172 | 282 | 274 | .25 | .18 | - |
| 50 | 192 | 304 | 265 | .28 | .24 | - |

Alfalfa 1970

Four cuttings on irrigated plots were taken of alfalfa in 1970, but yields were about equal to that of 1969 from 3 cuttings. Yields were nearly doubled by irrigation.

Yields according to potash treatment:

Irrigated plots

| $K_2O$ lbs/A Seeding 1968 | Topdressed Annually | Alfalfa yields Tons/A by cuttings 1 6/1 | 2 7/6 | 3 8/11 | 4 9/23 | 1970 Total |
|---|---|---|---|---|---|---|
| 0 | 0 | 1.74 | 1.59 | 1.30 | .58 | 5.21 |
| 0 | 240 | 1.99 | 1.79 | 1.56 | .78 | 6.12 |
| 480 | 0 | 1.75 | 1.68 | 1.47 | .75 | 5.65 |
| 480 | 240 | 1.86 | 2.00 | 1.63 | .82 | 6.21 |

Non-irrigated

| | | % K | | | | |
|---|---|---|---|---|---|---|
| 0 | 0 | 1.56 | 1.11 | - | - | 2.67 |
| 0 | 240 | 1.93 | 1.33 | - | - | 3.26 |
| 480 | 0 | 1.74 | 1.23 | - | - | 2.97 |
| 480 | 240 | 1.85 | 1.48 | - | - | 3.33 |

Tissue tests % K according to potash treatment:

Irrigated

| | | | | | |
|---|---|---|---|---|---|
| 0 | 0 | 1.65 | 1.66 | 1.19 | 1.24 |
| 0 | 240 | 2.35 | 2.37 | 1.71 | 1.82 |
| 480 | 0 | 2.15 | 2.40 | 1.65 | 1.83 |
| 480 | 240 | 2.40 | 2.56 | 2.03 | 2.19 |

| | | % K | | | |
|---|---|---|---|---|---|
| 0 | 0 | 1.78 | 1.45 | - | - |
| 0 | 240 | 2.30 | 2.20 | - | - |
| 480 | 0 | 2.25 | 2.34 | - | - |
| 480 | 240 | 2.58 | 2.82 | - | - |

Alfalfa yields by treatment by years

$K_2O$ lbs/A

| seeding 1968 | topdressed annually | 1969 irrigated | 1969 non-irrigated | 1970 irrigated | 1970 non-irrigated |
|---|---|---|---|---|---|
| 0 | 0 | 5.2 | 2.6 | 5.2 | 2.7 |
| 0 | 240 | 5.4 | 2.8 | 6.1 | 3.3 |
| 480 | 0 | 5.4 | 2.8 | 5.7 | 3.0 |
| 480 | 240 | 6.3 | 2.7 | 6.2 | 3.3 |

%K tissue tests first cutting by treatment by years

| | | | | | |
|---|---|---|---|---|---|
| 0 | 0 | 2.0 | 2.1 | 1.7 | 1.8 |
| 0 | 240 | - | - | 2.4 | 2.3 |
| 480 | 0 | - | - | 2.2 | 2.3 |
| 480 | 240 | 2.7 | 2.6 | 2.4 | 2.6 |

Soil test K lbs/acre by treatment by year (Sept. sampling)

| | | | | | |
|---|---|---|---|---|---|
| 0 | 0 | 150 | 150 | 95 | 135 |
| 0 | 240 | 272 | 272 | 340 | 475 |
| 480 | 0 | 277 | 242 | 158 | 192 |
| 480 | 240 | 480 | 367 | 415 | 458 |
| Average pH | | 6.0 | 5.4 | 6.8 | 6.0 |

8 tons of lime applied in spring of 1968, original pH = 5.4

pH rises more slowly on unirrigated plots

K test at beginning of experiment = 190. There was about a ton increase in alfalfa yield due to potash when irrigated in 1969 and 1970. The unirrigated showed a .6 and .8 increase, respectively, for these years.

# THE EFFECT OF NITROGEN AND POTASSIUM ON 1969 AND 1970 CORN YIELD ON AN IRRIGATED HUBBARD LOAMY COARSE SAND IN SHERBURNE COUNTY

J. M. MacGregor, D.S. Fairchild and B. D. McCaslin

A study was initiated in the spring of 1969 to learn the effect of varying rates of nitrogen and of potassium fertilization on the yield and composition of field corn. Nitrogen was applied at rates of 0, 100, 200 and 400 lbs/A as a total of 2 split applications in early and late June of 1969. In 1970, there was some residual effect of the 1969 N treatment at the 400 N/A rate until July and no 1970 treatment was applied. Since no residual effect of the 1969 N treatments at the 100 and 200 lb/A rates remained in 1970, an additional 100 lbs was applied on July 6, 1970 to those plots receiving that rate in the previous year and 200 lbs/A applied to plots receiving 200 lbs N/A in 1969--making a 2 year total N application at rates of 200, 400 and 400 lbs/A.

Phosphate was planter applied near the seed in 1969 only at the rate of 100 lbs of 0-43-0 per acre (43 lbs P/A). Potash was broadcast in 1969 at rates of 90, 180 and 360 lbs $K_2O$/A (75, 150 and 300 lbs K/A) in 1969 only.

Soil pH in 1969 varied from 5.0 to 5.1 with medium (M) organic matter, extractable P (Bray No. 1) was 200 lbs/A and exchangeable K from 210 to 320 lbs/A. Five replications were designed as a randomized block; each plot was 50 feet long and 15 feet in width. Minhybrid 5301 was planted on May 27, 1969 with a resulting population of 23,000. On April 29, 1970 corn hybrid Trojan TXS102 (110 day maturity) was planted, which resulted in slightly less than 30,000 plants per acre. Thirty-inch rows were used and the corn was irrigated immediately after

planting to ensure uniform germination. Lasso herbicide was applied on April 30 at the rate of 1.5 lbs/A and the corn was cultivated once on June 11, 1970. Natural rainfall from April 13 to November 2, 1970 totaled 25.87 inches and 14.05 inches of water was applied to the field by periodic supplemental irrigation. The corn was mature and harvested in early October. The 1969 and 1970 fertilizer treatments and the resulting corn yields are shown in the following table.

Table 1. The 1969 and 1970 Fertilizer Treatments and Subsequent Corn Yields on an Irrigated Hubbard Loamy Coarse Sand in Sherburne County (average of 5 replications).

| 1969 | | | | 1970 | | | | 1969+ 1970 |
|---|---|---|---|---|---|---|---|---|
| Soil treatment (lbs/A) | | | Corn yield (bu/A) | Soil treatment (lbs/A) | | | Corn yield (bu/A) | yield (bu/A) |
| N | P | K | | N | P | K | | |
| 0 | 43 | 0 | 19.9a[1] | 0 | 0 | 0 | 18.5a[1] | 38.4 |
| 0 | 43 | 75 | 25.4a | 0 | 0 | 0 | 24.5a | 49.9 |
| 0 | 43 | 150 | 37.9a | 0 | 0 | 0 | 39.7a | 77.6 |
| 100 | 43 | 0 | 90.5b | 100 | 0 | 0 | 99.8b | 190.3 |
| 100 | 43 | 150 | 98.3b | 100 | 0 | 0 | 110.7b | 209.0 |
| 100 | 43 | 75 | 98.9b | 100 | 0 | 0 | 120.5b | 219.4 |
| 200 | 43 | 150 | 104.5bc | 200 | 0 | 0 | 107.7b | 212.2 |
| 400 | 43 | 300 | 119.1cd | 0 | 0 | 0 | 39.3a | 158.4 |
| 200 | 43 | 0 | 121.8cd | 200 | 0 | 0 | 113.3b | 235.1 |
| 200 | 43 | 75 | 128.9d | 200 | 0 | 0 | 122.7b | 251.6 |

[1] Numbers followed by the same letter are not significantly different at the 5.0% level (Duncan's New Multiple Range Test).

The very large (but transient) response of corn yield to N fertilization was significant when applied at either 100 or 200 lbs per acre. The N was applied each year as a split treatment (at seeding and again in late June) and even greater yield increases might be obtained with equivalent amounts separated into lesser, but more frequent treatments. The corn plants in the 400 lb/A N treatment (200 lbs/A in 1969 at seeding and 200 lbs in late June of 1969) were burned by the late June treatment and even the 1969 yields were no greater than the 200 lb treatment. Apparently the applied excess N was rapidly leached beyond plant root depth and essentially lost to crop production.

The soil was initially medium to high in exchangeable potassium, and therefore the lack of a significant response to the 1969 potassium treatments in both 1969 and 1970 would be expected.

Frequent N fertilization at relatively low rates combined with frequent irrigation appear to be the major requirements for maximum corn production on these sandy soils. Potassium fertilization would be expected to be a necessity relatively soon although phosphate is apparently ample for some time.

The experiment will be repeated in 1971 with varying rates of N being applied at several times during the growing season.

# THE RELATIVE EFFECT OF SULFUR COATED UREA AND OTHER FORMS OF NITROGEN ON 1970 CORN YIELD AND COMPOSITION WHEN GROWN ON AN IRRIGATED HUBBARD LOAMY COARSE SAND IN SHERBURNE COUNTY

J. M. MacGregor, R. C. Munter, D. S. Fairchild and B. D. McCaslin

Since sulfur-coated urea developed by the Tennessee Valley Authority is designed to lengthen the period of N availability over longer periods, an experiment was designed to determine this effectiveness for corn production on this sandy soil in comparison to equivalent N fertilization as urea alone, urea + equivalent sulfur (as flowers) and as ammonium nitrate N.

Since the soil was very sandy and porous, the sulfur-coated urea having the slowest availability (3.2% in 3 days, 10.4% in 7 days or 1.8% daily) was selected. Corn had been grown in 1969 using only 43 lbs/A of planter applied P per acre with no additions of N or of K--with resultant 1969 corn yields of less than 20 bushels per acre. Soil pH varied from 5.0 to 5.1, organic matter medium (M), extractable P (Bray No. 1) was 200 lbs/A, with exchangeable K varying from 210 to 320 lbs/A. The corn hybrid grown in 1970 was Trojan TXS102 (110 day maturity) planted on April 29 in 30-inch rows with a population of nearly 30,000 plants per acre. Lasso herbicide was applied on the day following seeding at the rate of 1.5 lbs/A. Natural rainfall in the period April 13--November 2 totaled 25.87 inches and a total of 14.05 inches by sprinkler irrigation was also applied at suitable intervals. Five replications of 5 treatments were used in a randomized block design; each plot was 6 rows (15 feet) by 50 feet in length. All 4 treatments were broadcast on June 16 to supply N at the rate of 100 lbs/A. Five index leaves were sampled from each plot on July 28 and again on August

28 and analyzed for percentage N (by Kjeldahl) and for 12 other elements on an emission spectrograph (Jarrel Ash 1.5 meter Atom-Counter). The corn was mature and harvested in early October.

Results

It was evident within 10 days following the N sidedressing treatments that the sulfur-coated urea was releasing the N at a slower than desirable rate since corn growth during most of the growing season was only slightly better than corn growing with no N fertilization.

The analyses of the sixth corn leaf at the 2 sampling dates are shown in Table 1 and Table 2.

It is evident that the sulfur-coated urea was being released much too slowly in comparison to the 3 other N treatments. Marked differences in the other elements were evident, especially in the concentrations of the same elements at the 2 stages of growth. In general, the N fertilization appeared to increase concentrations of total N, K, Ca, Sr, Zn and Mn and to decrease P levels in the corn leaves. (See Table 2)

Ear corn yields, N content and N removal in corn grains per acre are shown in Table 3. (See Table 3)

It is evident that the slightly soluble sulfur-coated urea used in this experiment released N much too slowly for maximum corn production in comparison to yields of 3 other N treatments which received equivalent (but more soluble) amounts of N (100 lbs/A). It is possible that the S-coated urea would have been much more productive if applied 1 1/2 months earlier at the time of seeding. This will be studied in 1971 along with possible residual effects of the 1970 S-urea treatments.

The relative efficiency of the 3 soluble N fertilizers in corn production is excellent, since in most Minnesota soils 50% or even 40% removal of the amounts of N applied would be considered more normal.

This experiment will be modified and repeated in 1971, since it is evident that sulfur-coating of the urea delays solubility and probably increases the length of time that fertilizer N remains available to the corn plants. Residual effect of the 1970 S-coated urea and the application of more soluble forms of this fertilizer for corn will be studied on these sandy irrigated soils.

Table 1. Analyses of the Sixth Corn Leaves on N Treated Hubbard Loamy Coarse Sand. (1970)

| Treatments: | % N (Kjeldahl) | % P | % K | % Ca | PPM Sr | PPM Fe | % Mg | PPM Zn | PPM Cu | PPM Mo | PPM Mn | PPM B |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (Analyses of 6th corn leaves sampled July 28, 1970) | | | | | | | | | | | |
| CHECK | 1.17 | .408b | 1.75a | .335a | 9.64a | 45.6 | .136 | 13.3a | 7.60 | 3.46 | 37.4a | 5.80 |
| 100# N/A as S-Urea | 1.12 | .276a | 1.88ab | .506b | 15.2b | 41.5 | .144 | 13.7a | 9.14 | 3.12 | 41.9a | 5.18 |
| 100# N/A as Urea + S | 2.55 | .341ab | 2.11ab | .637b | 19.5c | 35.0 | .190 | 20.46 | 12.7 | 3.72 | 60.7b | 6.12 |
| 100# N/A as Urea | 2.48 | .289a | 2.03ab | .583b | 18.2bc | 35.0 | .156 | 18.9b | 9.96 | 2.74 | 53.0b | 5.92 |
| 100# N/A as $NH_4NO_3$ | 2.49 | .365ab | 2.30b | .713b | 20.6c | 39.6 | .235 | 22.66 | 13.6 | 4.38 | 59.3b | 7.46 |
| Significance | | * | * | ** | ** | NS | NS | * | NS | NS | ** | NS |
| Coefficient of Variation | | 18.7 | 13.1 | 21.3 | 14.6 | 17.2 | 49.1 | 25.5 | 44.5 | 44.5 | 14.3 | 30.7 |

Table 2 Analyses of the Sixth Corn Leaves on N Treated Hubbard Loamy Coarse Sand (1970)

| Treatments: | % P | % K | %Ca | PPM Sr | PPM Fe | % Mg | PPM Zn | PPM Cu | PPM Mo | PPM Mn | PPM B |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | (Analyses of 6th corn leaves sampled August 28th 1970) | | | | | | | | | | |
| CHECK | .592b | 1.74a | 1.12a | 30.7a | 140 | .422 | 19.2a | 3.90a | 11.0 | 135a | 21.5 |
| 100# N/A as S-Urea | .242a | 2.06a | 1.62b | 45.6b | 147 | .414 | 19.3a | 9.26b | 11.7 | 164ab | 25.5 |
| 100# N/A as Urea + S | .309a | 4.00b | 1.67b | 48.2b | 126 | .466 | 28.4b | 19.2c | 10.6 | 194b | 23.6 |
| 100# N/A as Urea | .235a | 3.75b | 1.64b | 48.9b | 129 | .404 | 23.9ab | 19.2c | 9.2 | 166ab | 22.4 |
| 100# N/A as $NH_4NO_3$ | .232a | 3.66b | 1.74b | 52.6b | 147 | .428 | 24.9ab | 18.0c | 9.3 | 155ab | 23.1 |
| Significance | ** | ** | ** | ** | NS | NS | * | ** | NS | * | NS |
| Coefficient of Variation | 32.8 | 22.4 | 10.7 | 9.03 | 18.4 | 18.3 | 20.5 | 26.5 | 17.4 | 16.6 | 10.5 |

Table 3 The 1970 Yield of Ear Corn Grown On Hubbard Loamy Coarse Sand in Sherburne County, Nitrogen Content of Grain, & N Removal per Acre

(Average of 5 replications)

| Soil Treatment | Bu corn/A | % N in grain | lbs N removed/A |
|---|---|---|---|
| None | 13.4 a | 1.08 | 6.9 |
| S-coated urea (100# N/A 1/ | 60.2 b | 0.98 | 27.9 |
| Urea + S (100# N/A) 2/ | 141.0 C | 1.18 | 78.7 |
| Urea (100# N/A) 2/ | 144.8 C | 1.10 | 75.3 |
| $NH_4$ $NO_3$ (100# N/A) 2/ | 150.0 C | 1.14 | 80.9 |

1/ Contains 90 lbs sulfur/A

2/ Flowers of sulfur applied at 90 lb/A rate.

# EXPERIMENTS WITH NITROGEN SOURCE, PLACEMENT AND TIME OF NITROGEN APPLICATION TO A WEBSTER-CLAY LOAM AT LAMBERTON FROM 1960 - THROUGH - 1970

John M. MacGregor, Wallace W. Nelson and Robert G. Munter

A field fertilizer experiment for continuous corn was commenced in the spring of 1960 to determine the relative effectiveness of annually applied N as either ammonium nitrate or as urea. The nitrogen was broadcast and plowed down or simply broadcast and left on the plowed surface over winter, or broadcast in the spring and worked in during the usual seedbed preparation, or broadcast as a sidedressing in late June. Four replications of 18 different annual treatments were applied as a randomized block, each plot being 20 feet wide and 77.5 feet long. A starter fertilizer such as 8-24-12 is applied over the entire field at planting at approximately 175 pounds per acre. The corn seed for several years was drilled lengthwise over each plot at a 40 inch row spacing to obtain about 18,000 - 20,000 plants per acre, but later the row direction was reversed with a 30 inch row spacing to supply the same population. Many different studies have been made during the ten years of continuous corn growing to N application of this experiment, with results reported each year in Soil Series 76-84. The entire field was tiled in 1963.

Total precipitation during 1970 was 25.3" which is approximately normal for the area. Less than an inch (0.91") of rain fell during the entire month of August but the corn crop weathered this minor drought well. Ear corn yields during the 11 year period are shown in Table 1.

Table 1. Eleven Year Yield of Ear Corn on a Tiled Webster Clay Loam Near Lamberton with Annual Applications of $NH_4NO_3$ or Urea Nitrogen at Different Rates, Times and Placement.

(Average of 4 Replications)

| N applied annually in lbs/A[1] | Years | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1960 | 1961 | 1962 | 1963 | 1964 | 1965 | 1966 | 1967 | 1968 | 1969 | 1970 | Average |
| | Ear corn yield in bushels per acre | | | | | | | | | | | |
| 1) Check | 49.5 | 88.2 | 26.1 | 132.6 | 72.9 | 33.1 | 11.1 | 53.4 | 102.4 | 92.8 | 85.7 | 68.0a |
| 2) 40 as $NH_4NO_3$ - fall plow down | 42.3 | 87.5 | 30.9 | 148.6 | 88.3 | 34.9 | 26.8 | 75.7 | 131.6 | 109.3 | 96.3 | 79.3b |
| 3) 40 " urea - " " " | 55.1 | 78.2 | 29.1 | 148.8 | 100.3 | 38.8 | 19.8 | 86.9 | 132.5 | 124.5 | 120.4 | 84.9bc |
| 4) 40 " $NH_4NO_3$- fall plow - surface | 49.0 | 96.7 | 29.6 | 140.1 | 101.5 | 45.6 | 24.3 | 75.1 | 135.2 | 124.6 | 122.5 | 85.9bcd |
| 5) 40 " urea - " " " | 62.3 | 101.3 | 37.0 | 140.7 | 84.1 | 57.4 | 30.9 | 87.2 | 134.0 | 136.1 | 121.2 | 90.2cde |
| 6) 80 " $NH_4NO_3$ = " " down | 67.4 | 97.9 | 43.6 | 149.6 | 100.8 | 63.4 | 47.3 | 114.8 | 131.2 | 146.8 | 134.7 | 99.8fgh |
| 7) 80 " urea " " " | 61.7 | 76.9 | 36.7 | 154.5 | 104.9 | 73.0 | 37.8 | 117.2 | 142.6 | 144.3 | 141.4 | 99.1fgh |
| 8) 160 as $NH_4NO_3$ " " " | 69.8 | 97.9 | 46.7 | 147.7 | 100.9 | 70.8 | 38.5 | 127.4 | 140.2 | 158.7 | 141.7 | 103.7gh |
| 9) 160 as urea - " " " | 79.4 | 112.5 | 43.5 | 152.8 | 112.4 | 73.5 | 37.7 | 121.3 | 149.9 | 161.0 | 140.4 | 107.6h |
| 10) 40 " $NH_4NO_3$ - spring topdress | 66.2 | 92.0 | 45.4 | 152.2 | 99.8 | 63.4 | 23.7 | 99.8 | 128.0 | 142.0 | 125.6 | 94.4def |
| 11) 40 " urea " " | 45.4 | 91.1 | 31.4 | 147.6 | 100.6 | 59.8 | 33.8 | 95.0 | 140.5 | 143.4 | 118.9 | 91.7cdef |
| 12) 80 " $NH_4NO_3$ " " | 59.3 | 90.0 | 32.7 | 149.2 | 112.5 | 74.2 | 49.0 | 128.3 | 144.7 | 159.5 | 140.4 | 103.6gh |
| 13) 80 " urea " " | 57.7 | 99.1 | 40.5 | 149.3 | 115.7 | 84.4 | 41.8 | 128.6 | 138.7 | 155.9 | 146.2 | 105.2gh |
| 14) 40 " $NH_4NO_3$ sidedress | 63.6 | 92.6 | 39.5 | 148.6 | 90.4 | 54.8 | 38.6 | 96.8 | 133.4 | 142.3 | 127.1 | 93.4cdef |
| 15) 40 " urea " | 57.7 | 95.6 | 24.9 | 142.3 | 94.1 | 48.4 | 50.4 | 86.1 | 132.2 | 143.3 | 117.7 | 90.3cde |
| 16) 80 " $NH_4NO_3$ " | 50.4 | 98.4 | 46.7 | 140.7 | 113.0 | 68.1 | 43.8 | 101.6 | 137.7 | 140.3 | 127.7 | 97.2efg |
| 17) 80 " urea " | 76.9 | 86.4 | 48.2 | 143.8 | 121.4 | 64.7 | 47.3 | 117.0 | 146.9 | 166.2 | 140.5 | 105.4gh |
| 18) 160 " $NH_4NO_3$ " | 40.7 | 97.4 | 77.7 | 151.7 | 109.5 | 77.6 | 51.4 | 120.2 | 141.5 | 148.3 | 136.9 | 104.8gh |
| Average annual corn yield in bu/A | 58.6 | 93.3 | 39.4 | 147.7 | 101.3 | 60.3 | 36.3 | 101.8 | 135.7 | 140.9 | 127.0 | |

[1]. The entire area received an additional 14 lbs N/A as starter fertilizer annually (8-24-12 @ 175 lbs/A)

All of the broadcast fertilizer N treatments have significantly increased the average 11 year yield of corn grain above the plots receiving only the 14 lbs N/A in the starter fertilizer. No significant differences in corn yield resulted following urea or ammonium nitrate application and yields show that these two forms of N are both effective and equivalent.

Plowing down 40 lbs of N/A each fall has produced corn yields which were not significantly different to fall broadcasting immediately following fall plowing and allowing the ammonium nitrate or urea to remain on the plowed soil surface overwinter. However, corn yields where 40 lbs N/A as ammonium nitrate was fall plowed down were significantly lower than where the same amount of urea N was fall applied and left on the plowed surface (79.3 bu compared to 90.2 bu). This indicates that laboratory experiments indicating substantial N losses to the atmosphere as ammonia from surface applied urea are apparently not valid under actual field conditions of corn production. One hazard of plowing fall applied N down is, in the event of heavy late fall and early spring rains, N removal downward by leaching may be substantial, before it can be utilized by the following corn crop. Surface applied N may be lost from urea to the air as ammonia, or from ammonium nitrate as $N_2$ or as the various N oxides. While plowing limited amounts of N under in the fall may increase crop residue decomposition, it is apparent that this theory is not entirely justified, and fall applied N fertilizers allowed to remain on plowed surfaces overwinter may produce larger corn yields than those plowed under at the same time. Apparently overwinter losses of N to the atmosphere may be comparatively less than overwinter and early spring losses downward by leaching. During the 11 year period of this experiment 40 lbs of N left on the surface overwinter has produced an annual average of 6 more bushels of corn per acre (88.1 versus 82.1).

Comparing 11 year corn yield averages where 40 lbs of N/A (in addition to the 14 lbs N/A in the starter) was applied in the fall, winter, or as a June sidedressing, the surface fall treatments averaged 88.1 bushels, those applied at seeding averaged 93.0 bushels whereas those broadcast as a late June sidedressing averaged 91.9 bushels/A. The maximum difference is less than 5 bu of corn per acre, which may not be mathematically significant, but over the 11 years this would mean more than a 50 bushel advantage for the N fertilization at seeding, compared to the fall spreading on plowed ground. Where compared to plow down N fall fertilization, the total 11 year difference in N at seeding yield would exceed 100 bushels of corn per acre.

Where 80 lbs of N were broadcast in the fall, spring, or as a June sidedressing. The 11 year corn yields averaged 99.5, 104.4, and 101.3 bushels respectively, or another 5 bushel advantage of the spring treatment over the fall fertilization.

The N fertilization at the 160 lb N/A rate in the fall averaged 105.7 bushel, whereas the June sidedressing produced an average of 104.8 bu/A. Apparently this heavy rate of N fertilization compensates for any overwinter losses of applied N.

When rate of N fertilization is considered, the 8 fall surface treatments of 40 lbs (+14 lbs N in starter) averaged 88.8 bu., and the six 80 lb rate treatments averaged 105 bu/A during the 11 year period. The first 40 lbs of N increased average corn production by 21 bushels; whereas doubling the rate of N produced a 34 bushel increase;the 174 lb rate of N application produced 37 bushels more corn per acre.

Nitrogen Removal in Corn Grain

The amount of nitrogen removed in the corn grain is of interest. In Table 1 it was shown that little increase in corn yield could be expected over several years where total applied N exceeded 94 pounds per acre. The 1970 yields and relative utilization of N at different fertilization rates is shown in Table 2.

Table 2. Yield of Dry Shelled Corn, Percentage Nitrogen and Nitrogen Removal in Corn Grain per acre from $NH_4NO_3$ - Urea Treated Continuous Corn on Webster Clay Loam at Lamberton in 1970.

| Treatment (lbs N/A)[1] | Yield in bu/A (15.5% moisture) | Dry shelled corn (lbs/A) | % N (in grain) | lbs N removed / A | Fertilizer N applied (lbs/A) | Soil N[2] status |
|---|---|---|---|---|---|---|
| 1) Check | 85.7 a | 4055 | 1.13a | 45.8 | 14 | -31.8 |
| 2) 40 as $NH_4NO_3$ - fall plow down | 96.3 a | 4557 | 1.17 ab | 53.3 | 54 | + 0.7 |
| 3) 40 " urea - " " " | 120.4 bcd | 5697 | 1.17 ab | 66.7 | 54 | -12.7 |
| 4) 40 " $NH_4NO_3$ - " " surface | 122.5 cde | 5797 | 1.18 ab | 68.4 | 54 | -14.4 |
| 5) 40 " urea - " " " | 121.2 cde | 5735 | 1.20 abc | 68.8 | 54 | -14.8 |
| 6) 80 " $NH_4NO_3$ - " " down | 134.7 cdef | 6374 | 1.22 abcd | 77.8 | 94 | +16.2 |
| 7) 80 " urea - " " " | 141.4 ef | 6691 | 1.22 abcd | 81.6 | 94 | +12.4 |
| 8) 160 " $NH_4NO_3$ - " " " | 141.7 ef | 6705 | 1.24 abcd | 83.1 | 174 | +90.9 |
| 9) 160 " urea - " " " | 140.3 def | 6639 | 1.24 abcd | 82.3 | 174 | +91.7 |
| 10) 40 " $NH_4NO_3$ - spring topdress | 125.6 ede | 5943 | 1.25 abcd | 74.3 | 54 | -20.3 |
| 11) 40 " urea - " " | 118.9 bc | 5626 | 1.28 bcde | 72.0 | 54 | -18.0 |
| 12) 80 " $NH_4NO_3$ - " " | 140.4 def | 6644 | 1.28 bcde | 85.0 | 94 | + 9.0 |
| 13) 80 " urea - " " | 146.2 f | 6918 | 1.29 bcdef | 89.2 | 94 | + 4.8 |
| 14) 40 " $NH_4NO_3$ - sidedress | 127.1 cdef | 6014 | 1.32 cdef | 79.4 | 54 | -25.4 |
| 15) 40 " urea " | 117.7 bc | 5570 | 1.34 def | 74.6 | 54 | -20.6 |
| 16) 80 " $NH_4NO_3$ - " | 127.7 cdef | 6043 | 1.33 ef | 83.4 | 54 | +10.6 |
| 17) 80 " urea - " | 140.5 def | 6649 | 1.39 ef | 92.4 | 94 | + 1.6 |
| 18) 160 " $NH_4NO_3$ - " | 136.9 cdef | 6478 | 1.41 f | 91.3 | 94<br>174 | +82.7 |

1. The entire area received an additional 14 lbs N/A annually as starter fertilizer (8-24-12 @ 175 lbs/A).
2. Fertilizer N minus N removal in corn grain in lbs/A.

It is evident that the heavier rates of N fertilization produced comparatively small increases in corn grain protein, the greatest increases in protein apparently taking place with the later N treatments. The N fertilization at planting time appears to result in the more efficient combination of corn yield and corn protein.

Nitrogen removal in the grain increases with rate of N application, but the heavier treatments result in a lowered uptake by the growing corn. Nitrogen removal in the corn grain shows a proportional decrease that applied as fertilizer N added as the rate increases. Nitrogen removal in the grain is efficient up to the 94 lb N rate, but above this it decreases rapidly at the higher rate, with nearly 100 lbs of N/A remaining where 174 lbs of N were applied per acre.

Analysis of Subsoil Waters of N Plots.

Several wells for the collection of free subsoil waters to a depth of 72 inches were located on several plots. Water was present in a few of these allowing a mid-June sampling. The analytical results were closely related to the rates of N fertilization and N removal in the corn grain. These are shown in Table 3.

Table 3. Analyses of Subsoil Free Water in a Webster Clay Loam Near Lamberton Under N Fertilized Continuous Corn Mid-June sampling 1970

| Plot Number | Treatment Number | Soil Treatment | Sample depth | $NO_3$-N | $NH_4$-N | $PO_4$-P | K | Cond. |
|---|---|---|---|---|---|---|---|---|
| 73 | 1 | Check (14# N/A) | 4' | 1.8 | 1.0 | 0.013 | 1.8 | 1.0 |
| 7 | 1 | " " " | 6' | 3.0 | 2.0 | - | - | 2.8 |
| 38 | 16 | 80 N sidedressed (+14# N/A) | 3' | 17.0 | 0.6 | 0.030 | 1.1 | 0.8 |
| 38 | 16 | " " " " " | 5' | 7.3 | 10.0 | 0.227 | 2.0 | 0.9 |
| 38 | 16 | " " " " " | 6' | 15.0 | 4.0 | 0.025 | 2.8 | 1.5 |
| 58 | 16 | " " " " " | 2' | 5.3 | 2.0 | 0.000 | 4.2 | 2.5 |
| 58 | 16 | " " " " " | 4' | 9.1 | 2.0 | 0.074 | 3.0 | 3.4 |
| 63 | 16 | " " " " " | 6' | 9.5 | 2.0 | 0.056 | 2.0 | 2.8 |
| 34 | 18 | 160 N sidedressed (14# N/A) | 4' | 49.0 | 2.0 | 0.155 | 2.5 | 1.7 |
| 34 | 18 | " " " " " | 5' | 9.9 | 4.0 | 0.080 | 3.1 | 1.1 |
| 34 | 18 | " " " " " | 6' | 39.0 | 10.0 | 0.050 | 4.7 | 1.9 |
| 68 | 18 | " " " " " | 5' | 22.0 | 8.0 | 0.116 | 4.9 | 2.7 |

Nitrogen Fertilization and Silking and Pollination of Corn.

It appeared that N fertilization had some effect on corn pollen shedding and silking. Data were collected and subjected to statistical analyses and found to be non-significant.

Analyses of the Sixth "Index" Corn Leaves

Leaf samples from all plots were taken at silking and analyzed using a Jarrel Ash 1.5 Meter Atom-Counter Emission Spectrograph. Since the differences occurring are complex and not entirely clear, these data will not be included in this report.

# LIME PLOTS, LAMBERTON, 1970

J. Grava, W. W. Nelson, D. S. Fairchild
and B. D. McCaslin

A field experiment was established in the fall of 1965 to study the effects of liming on crop yields, chemical composition of plant tissue, and chemical properties of soils. The crops grown were: (a) Vernal alfalfa in series 4, and (b) in series 5, corn (1966, 1968 and 1970) and Chippewa soybeans (1967) and Hark soybeans (1969) in a sequence. Data on crop yields, soil and plant analyses were reported in the "Bluebooks" of Feb. 1967, pp. 69-70; March 1968, pp. 38-41; March 1969, pp. 30-31; March 1970, pp. 66-69.

Since the initial lime treatments (3 and 6 tons per acre of Dolomitic limestone applied in the fall of 1965) had not raised the pH to the desired levels, additional amounts were applied in spring of 1968 and worked in soil by disking (corn-soybean series), or disking, plowing and disking (alfalfa series). Alfalfa was reseeded in 1968.

Soil samples were collected during the summer of 1969. Lime treatments had increased the soil pH in alfalfa series from 5.7 to 6.1 with the 4 ton rate, and to 6.8 with 10 tons per acre. In the corn-soybean series, the check plots had soil pH values of 6.1 while the pH was raised to 6.6 with the 3 ton treatment and to 6.9 with the application of 6 tons per acre of limestone. The subsoil is alkaline at a depth of 12 inches in the corn-soybean series and at 24 inches in the alfalfa series.

In 1970, corn received 180 lbs. / acre of 8-24-12 starter, plus 100 lbs. / acre of N (33.5-0-0) or a total of 114 + 43 + 22 lbs. / acre of plant nutrients, expressed as N. $P_2O_5$ and $K_2O$. Corn was grown in 30-inch rows. All plots received ramrod herbicide applied in rows at a rate of 5 lbs. / acre. Alfalfa series received a broadcast application of 0 + 60 + 30 in the fall of 1969.

Corn yield was not affected by lime treatments (Table 1).

Table 1. Yield of corn, Lamberton lime plots, 1970.

| Rate of Lime | Yield of Shelled Corn (15.5% Moisture) |
|---|---|
| tons / acre | bu. / acre |
| 0 | 112 |
| 3* | 120 |
| 6* | 116 |
| Significance | NS |
| CV % | 8 |

*3 or 6 tons/acre applied in the fall of 1965 and again in the spring of 1968.

Three cuttings of alfalfa were taken in 1970 yielding four tons of hay per acre (Table 2). Liming had no effect on the yield of alfalfa.

Table 2. Yield of alfalfa, Lamberton lime plots, 1970.

| Rate of Lime | 1st Cutting | 2nd Cutting | 3rd Cutting | Total |
|---|---|---|---|---|
| | | Hay, tons/acre | | |
| 0 | 2.2 | 1.1 | 0.6 | 3.9 |
| 4* | 2.3 | 1.1 | 0.7 | 4.1 |
| 10** | 2.3 | 1.1 | 0.6 | 4.0 |

* 3 tons/acre applied in fall of 1965 and 4 tons/acre applied in spring of 1968.

** 6 tons/acre applied in fall of 1965 and 10 tons/acre applied in spring of 1968.

Chemical composition was not affected by lime treatments (Table 3).

Table 3. Chemical composition of sixth corn leaf at silking, Lamberton lime plots, 1970.

| Lime Treatment | P | K | Ca | Mg | Zn | Cu | Mo | Mn | B | Fe | Sr |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TO./acre | Percent in dry matter | | | | Parts per million in dry matter | | | | | | |
| 0 | .25 | 1.46 | .55 | .50 | 17 | 7 | 1.3 | 35 | 12 | 115 | 21 |
| 3 | .26 | 1.31 | .55 | .57 | 18 | 9 | 2.0 | 33 | 13 | 123 | 23 |
| 6 | .27 | 1.39 | .55 | .58 | 18 | 9 | 2.0 | 32 | 13 | 119 | 23 |
| Significance | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| CV | 5 | 11 | 9 | 15 | 13 | 20 | 24 | 10 | 12 | 10 | 12 |

The chemical composition of alfalfa is given in Table 4. Manganese content of alfalfa was decreased by liming consistently in all cuttings. The concentrations of other nutrient elements were not affected by liming.

Table 4. Chemical composition of alfalfa, Lamberton lime plots, 1970.

| Lime Treatment | P | K | Ca | Mg | Zn | Cu | Mo | Mn | B | Fe | Sr |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Percent in dry matter | | | | Parts per million in dry matter | | | | | | |
| | | | | | (a) First Cutting | | | | | | |
| 0 | .23 | 1.15 | 1.35 | .37 | 19 | 7 | .97 | 24b | 38 | 74 | 67b |
| 4 | .23 | 1.15 | 1.26 | .37 | 18 | 7 | 1.22 | 16a | 34 | 66 | 60a |
| 10 | .22 | 1.06 | 1.43 | .41 | 18 | 9 | 1.09 | 18a | 37 | 71 | 65ab |
| Significance | NS | NS | NS | NS | NS | NS | NS | ** | NS | NS | * |
| CV | 13 | 6 | 9 | 9 | 9 | 38 | 16 | 12 | 8 | 8 | 5 |
| | | | | | (b) Second Cutting | | | | | | |
| 0 | .26 | 1.21 | 1.30 | .44 | 21 | 8 | 1.14 | 27b | 42 | 89 | 64 |
| 4 | .26 | 1.17 | 1.31 | .47 | 19 | 8 | 1.27 | 17a | 42 | 95 | 64 |
| 10 | .24 | 1.10 | 1.36 | .48 | 20 | 9 | 1.20 | 16a | 40 | 102 | 66 |
| Significance | NS | NS | NS | NS | NS | NS | NS | ** | NS | NS | NS |
| CV | 8 | 8 | 4 | 6 | 8 | 24 | 15 | 16 | 6 | 22 | 9 |
| | | | | | (c) Third Cutting | | | | | | |
| 0 | .20 | 1.33 | 1.31 | .47 | 21 | 8 | 1.07 | 31b | 50 | 103 | 71 |
| 4 | .21 | 1.29 | 1.29 | .48 | 20 | 7 | 1.14 | 20a | 49 | 111 | 69 |
| 10 | .21 | 1.30 | 1.38 | .48 | 21 | 8 | 1.12 | 19a | 48 | 112 | 71 |
| Significance | NS | NS | NS | NS | NS | NS | NS | ** | NS | NS | NS |
| CV | 5 | 9 | 9 | 6 | 12 | 15 | 14 | 13 | 9 | 17 | 11 |

## SMALL GRAIN FERTILIZATION

Southwest Experiment Station - Lamberton

W. W. Nelson and S. D. Evans

Field experiments were established on Nicollet clay loam in the spring of 1970 to study the response of wheat, oats, and barley to nitrogen fertilization. A second objective was to determine the need for starter fertilizer on these crops. Three varieties of each crop were grown at three applied nitrogen levels. The nitrate nitrogen level in the 0-24 inch soil zone was 101 lbs/acre as determined by the North Dakota Soil Testing Laboratory; P tested high, K very high.

A. Oats

Main plots - Varieties (1) Lodi (2) Otter (3) Diana

Sub plots - No starter vs. starter (100 lbs. 10-20-20)

Sub-sub plots - Nitrogen levels of 0, 30, 60, and 90 lbs. of actual nitrogen.

Seeding Date - April 27, 1970

Table 1. Yield of oats - Lamberton, 1970.

| Variety | Nitrogen Applied lbs/acre | No Starter | Starter | Average |
|---|---|---|---|---|
| | | - Bu/acre - | | |
| Lodi | 0 | 58.0 | 68.8 | 63.4 |
| | 30 | 56.8 | 65.4 | 61.1 |
| | 60 | 62.1 | 59.9 | 61.0 |
| | 90 | 62.7 | 58.2 | 60.5 |
| Variety Average | | 59.9 | 63.1 | 61.5 |
| Otter | 0 | 71.7 | 69.5 | 70.6 |
| | 30 | 65.6 | 66.6 | 67.8 |
| | 60 | 68.7 | 68.0 | 68.4 |
| | 90 | 72.2 | 64.5 | 68.3 |
| Variety Average | | 69.6 | 68.0 | 68.8 |
| Diana | 0 | 58.4 | 54.2 | 56.3 |
| | 30 | 62.1 | 64.2 | 63.2 |
| | 60 | 52.6 | 67.9 | 60.2 |
| | 90 | 55.3 | 54.9 | 55.1 |
| Variety Average | | 57.1 | 60.3 | 58.7 |
| Overall Average | | 62.2 | 63.8 | |

Table 2. Groat Percentage, Oat Fertility Study - Lamberton, 1970.

| Variety | Nitrogen Applied lbs/acre | No Starter | Starter | Average |
|---|---|---|---|---|
| | | - Groat % - | | |
| Lodi | 0 | 66.9 | 58.7 | 62.8 |
| | 30 | 67.6 | 66.0 | 66.8 |
| | 60 | 65.8 | 68.7 | 67.2 |
| | 90 | 69.6 | 66.9 | 68.2 |
| Variety Average | | 67.4 | 65.1 | 66.3 |
| Otter | 0 | 71.3 | 70.9 | 71.1 |
| | 30 | 69.5 | 66.0 | 68.1 |
| | 60 | 70.0 | 68.7 | 69.3 |
| | 90 | 69.8 | 64.0 | 66.9 |
| Variety Average | | 70.2 | 67.4 | 68.8 |
| Diana | 0 | 63.0 | 67.1 | 65.2 |
| | 30 | 64.5 | 62.6 | 63.6 |
| | 60 | 66.7 | 65.5 | 66.1 |
| | 90 | 67.5 | 67.1 | 67.3 |
| Variety Average | | 65.5 | 65.2 | 65.4 |
| Overall Average | | 67.7 | 65.9 | |

Table 3. Analysis of Variance, Yield of Oats.

| Source of Variation | Significance |
|---|---|
| Reps | * (5% level) |
| Varieties (V) | ** (1% level) |
| Starter (S) | NS |
| V x S | NS |
| Nitrogen (N) | NS |
| N x V | NS |
| N x S | NS |
| N x V x S | NS |

B. Barley

Main plots - Varieties (1) Dickson (2) Larker (3) 64-76

Sub plots - No starter vs. starter (100 lbs. 10-20-20)

Sub-sub plots - Nitrogen levels of 0, 30, 60, and 90 lbs. of actual nitrogen.

Seeding Date - April 27, 1970

Table 4. Yield of Barley - Lamberton, 1970.

| Variety | Nitrogen Applied lbs/acre | No Starter | Starter | Average |
|---|---|---|---|---|
| | | - Bu/acre - | | |
| Dickson | 0 | 48.8 | 46.0 | 47.4 |
| | 30 | 49.5 | 43.9 | 46.7 |
| | 60 | 44.2 | 46.8 | 45.5 |
| | 90 | 48.5 | 45.6 | 47.0 |
| Variety Average | | 47.7 | 45.6 | 46.7 |
| Larker | 0 | 56.9 | 58.5 | 57.7 |
| | 30 | 58.1 | 62.5 | 60.3 |
| | 60 | 57.1 | 56.1 | 56.6 |
| | 90 | 65.7 | 59.4 | 62.6 |
| Variety Average | | 59.5 | 59.1 | 59.3 |
| 64-76 | 0 | 50.0 | 52.3 | 51.1 |
| | 30 | 52.4 | 54.4 | 53.4 |
| | 60 | 49.7 | 49.1 | 49.4 |
| | 90 | 42.8 | 45.8 | 44.3 |
| Variety Average | | 48.7 | 50.4 | 49.6 |
| Overall Average | | 52.0 | 51.7 | |

Table 5. Analysis of Variance, Yield of Barley.

| Source of Variation | Significance |
|---|---|
| Reps | NS |
| Varieties (V) | ** (1% level) |
| Starter (S) | NS |
| N x S | NS |
| Nitrogen (N) | NS |
| N x V | + (10% level) |
| N x S | NS |
| N x V x S | NS |

C. Wheat - Data for wheat not completed as of 1/28/71.

This work was done in cooperation with the following staff of the Department of Agronomy and Plant Genetics:

Oats - D. D. Stuthman

Barley - D. C. Rasmusson

Wheat - R. F. Heinen

# WINTER VERSUS SPRING FERTILIZATION ON 1968, 1969 and 1970 CORN YIELDS AT LAMBERTON

W. W. Nelson and J. M. MacGregor

This experiment was conducted during the late winter, spring, and summer of 1968 and 1969 on two sloping fields (1% and 5%) on the Soils Unit of the Minnesota Agricultural Experiment Station near Rosemount, and on a nearly level, untiled Webster clay loam at the Southwest Experiment Station near Lamberton in 1968, 1969, and 1970. Four replications of randomized paired plots 50 ft. long and 20 ft. wide were broadcast fertilized in mid-January (on snow) or in early April, using N, $P_2O_5$ and $K_2O$ and combinations of these at Rosemount, but only N and $P_2O_5$ combinations near Lamberton.

Snow during the three winters was not sufficiently deep to prohibit the operation of large fertilizer spreading trucks. Although all of the fertilizer was broadcast by hand, the granules appeared to sink a short distance into the snow almost immediately with resultant little movement into adjoining areas.

## Results

Unfortunately, both of the sloping fields near Rosemount failed to show significant increases in corn yields from any of the fertilizer applications, making it impossible to determine the relative effects of winter or spring broadcasting of fertilizer. Since these yields have previously been reported in Soil Series 84 and 86, the results will not be included here.

Table 2 THE 1969 YIELD OF SILAGE CORN FROM WEBSTER SILTY CLAY LOAM NEAR LAMBERTON FOLLOWING FERTILIZATION IN JANUARY OR IN MAY

| Treatment (Lbs/A) | Time of Fertilization | Yield of silage corn (Tons/A) I | II | III | IV | AVERAGE |
|---|---|---|---|---|---|---|
| None | - | 8.09 | 8.24 | 8.67 | 6.55 | 7.89 ab |
| 40+0+0 | January | 10.88 | 8.79 | 10.59 | 7.57 | 9.46 bc |
| 40+0+0 | May | 10.85 | 12.76 | 13.40 | 7.74 | 11.17 c |
| 0+40+0 | January | 10.03 | 7.28 | 8.29 | 7.71 | 8.33 ab |
| 0+40+0 | May | 8.50 | 7.60 | 6.84 | 5.97 | 7.23 a |
| 40+40+0 | January | 9.98 | 11.14 | 8.70 | 8.32 | 9.54 bc |
| 40+40+0 | May | 9.98 | 11.02 | 7.48 | 8.35 | 9.19 b |

The 1969 silage yield results were rather inconclusive and it was decided to repeat the experiment in the following year. The 1970 yields of ear corn are shown in Table 3.

Table 3 THE YIELD OF 1970 EAR CORN AT LAMBERTON GROWN ON A WEBSTER SILTY CLAY LOAM FERTILIZED IN MID-JANUARY OR EARLY APRIL

| Treatment (Lbs/A) | Fertilizer broadcast in: | I | II | III | IV | AVERAGE | SIG. |
|---|---|---|---|---|---|---|---|
| None | - | 61.2 | 68.8 | 60.6 | 66.2 | 64.2 | a |
| 40+0+0 | January | 94.4 | 87.3 | 90.3 | 90.3 | 90.6 | b |
| 40+0+0 | April | 94.9 | 94.5 | 93.1 | 97.0 | 94.9 | b |
| 0+40+0 | January | 63.6 | 82.3 | 63.8 | 68.2 | 69.5 | a |
| 0+40+0 | April | 51.4 | 79.6 | 64.9 | 70.2 | 66.5 | a |
| 40+40+0 | January | 105.1 | 94.9 | 96.6 | 115.5 | 103.0 | c |
| 40+40+0 | April | 102.9 | 110.6 | 102.4 | 105.3 | 105.3 | c |

## Conclusions

From the results obtained during the 3 years of experiments on the relatively level Webster silty clay loam near Lamberton, the spreading of either nitrogen fertilizer alone or in combination with phosphate in mid-January on the snow results in essentially equivalent increases in corn yield to similar rates applied in the following May.

The relatively level Webster soil at Lamberton produced significantly more corn with fertilization and the results are shown in the three following tables.

Table 1. The Yield of 1968 Ear Corn at Lamberton on a Webster Silty Clay Loam When Fertilized in Mid-January or in Early April

| Treatment (lbs/A) | Time fertilizer broadcast | Bushels ear corn/A @15.5% moisture I | II | III | IV | Average | Sig. |
|---|---|---|---|---|---|---|---|
| None | | 105.1 | 104.1 | 99.1 | 67.0 | 93.8 | a |
| 40+0+0 | January 17 | 110.2 | 109.1 | 127.8 | 94.8 | 110.5 | b |
| 40+0+0 | April 2 | 114.4 | 117.9 | 113.1 | 121.5 | 116.7 | b |
| 0+40+0 | January 17 | 97.1 | 104.3 | 102.8 | 102.0 | 101.6 | ab |
| 0+40+0 | April 2 | 105.0 | 93.2 | 103.1 | 71.6 | 93.2 | a |
| 40+40+0 | January 17 | 110.2 | 118.0 | 118.1 | 112.4 | 114.7 | b |
| 40+40+0 | April 2 | 112.0 | 122.6 | 104.8 | 106.4 | 111.5 | b |

The N (40+0+0) and the NP (40+40+0) resulted in significant increases in 1968 corn yield, with no significant difference between the different times of fertilizer application.

The autumn of 1968 and spring of 1969 were extremely wet and it was not possible to plow this untiled silty clay loam until the end of May. The 1969 corn was planted so late that it was decided to base 1969 yields on silage corn rather than the usual corn grain and these are shown in Table 2.

# CONTINUOUS CORN SILAGE

West Central Experiment Station - Morris

Samuel D. Evans

In 1965 an experiment was initiated on McIntosh silt loam to determine the effect of removal of continuous corn silage and fertilizer application on corn grain and corn silage yields. Rates of fertilizer used were 74 + 48 + 48 and 148 + 96 + 96. All plots received a broadcast application of 10 lbs. of zinc as zinc sulfate in the fall of 1965.

| Silage Yields - Dry matter, tons/acre | 1970 | Average 1966-70 |
|---|---|---|
| On plots harvested as grain 1965-70: | | |
| Low fertility (74 + 48 + 48) | 5.58 | 5.32 |
| High fertility (148 + 96 + 96) | 4.92 | 5.48 |
| On plots harvested as silage 1965-70: | | |
| Low fertility (74 + 48 + 48) | 5.51 | 5.33 |
| High fertility (148 + 96 + 96) | 5.73 | 5.64 |

| Grain Yields - Bushels/acre @ 15.5% moisture | 1970 | Average 1966-70 |
|---|---|---|
| On plots harvested as grain 1965-70: | | |
| Low fertility (74 + 48 + 48) | 92.36 | 85.85 |
| High fertility (148 + 96 + 96) | 89.18 | 86.56 |

In addition an unfertilized, unreplicated check adjacent to the experimental area yielded as follows:

| | 1970 | Average 1966-70 |
|---|---|---|
| Grain (0 + 0 + 0) | 81.20 bushels/acre | 56.85 bushels/acre |
| Silage (0 + 0 + 0) | 4.84 tons/acre | 4.23 tons/acre |

There appears to be no reduction in corn yields after removing silage for 6 years. Higher fertility did not increase silage yields or grain yields.

Variety - Pioneer 3956 Planting date - May 13

Leaf samples were taken on all plots in 1970 when the plants were 50% silked. The average values for the various treatments are given in Table 1.

Table 1. Average Nutrient Content of Leaf Opposite and Below the Ear when the Plants were 50% Silked (average of 4 reps).

| | Continuous Silage Plots | | Continuous Grain Plots | |
|---|---|---|---|---|
| | Low Fertility | High Fertility | High Fertility | Low Fertility |
| P% | .24 | .29 | .24 | .29 |
| K% | 1.10 | 1.41 | 1.47 | 1.77 |
| Ca% | .64 | .56 | .50 | .52 |
| Fe ppm | 100 | 203 | 95 | 105 |
| Mg % | .84 | .73 | .68 | .69 |
| Zn ppm | 24.3 | 17.2 | 24.0 | 17.1 |
| Cu ppm | 13.7 | 10.2 | 12.0 | 10.1 |
| Mo ppm | 11.6 | 10.7 | 9.4 | 9.3 |
| Mn ppm | 86 | 94 | 68 | 91 |
| B ppm | 6.5 | 6.6 | 5.8 | 6.7 |

# CORN IRRIGATION EXPERIMENT

West Central Experiment Station - Morris

S.D. Evans, D.D. Warnes, L.K. Lindor, & R.E. Smith

This experiment was continued as reported in Soil Series 82 (March 1968 and March 1969). Variety - Pioneer 3956 was planted on May 9, 1970. Atrazine and Ramrod were applied preemergence. Eleven and one half inches of water was applied between June 23 and August 24. Rainfall from planting through August 31 was 9.94 inches. The corn was harvested on October 15.

Table 1. Irrigated corn at Morris - 1970 and 1967-70 average.

| | Yield (Bu/A) | |
|---|---|---|
| Population treatment | 1970 | 1967-70 |
| Low | 118 a | 108 |
| Med | 127 b | 116 |
| High | 113 a | 116 |
| Nitrogen treatment | | |
| 60 lbs. | 112 a | 110 |
| 120 lbs. | 121 b | 115 |
| 180 lbs. | 124 b | 115 |
| Pop. X Nit. Interaction | | |
| Low x 60 | 112 | 104 |
| Low x 120 | 120 | 111 |
| Low x 180 | 120 | 108 |
| Med x 60 | 118 | 112 |
| Med x 120 | 131 | 120 |
| Med x 180 | 134 | 119 |
| High x 60 | 106 | 114 |
| High x 120 | 113 | 115 |
| High x 180 | 119 | 118 |

Fertilizer applied before planting in the spring of 1970 consisted of 400 lbs. of 0-25-25 and 9 lbs. of zinc as zinc sulfate. Starter fertilizer in 1970 was 110 lbs. of 9-36-18.

Leaf samples were taken on selected plots when the plants were 50% silked and are presented in Table 2.

Table 2. Summary of 1970 Leaf Analysis on Corn Irrigation Plot.

| Element | Range of Values |
|---|---|
| N % | 1.95 - 2.79 |
| P % | 0.21 - 0.33 |
| K % | 1.55 - 2.63 |
| Ca % | 0.49 - 0.98 |
| Fe ppm | 92 - 183 |
| Mg % | 0.35 - 0.67 |
| Zn ppm | 7.3 - 15.8 |
| Cu ppm | 3.6 - 12.6 |
| Mo ppm | 5.0 - 12.3 |
| Mn ppm | 49 - 85 |
| B ppm | 4.6 - 8.7 |

# PHOSPHORUS AND POTASSIUM FERTILIZATION OF ALFALFA

West Central Experiment Station - Morris

Samuel D. Evans

In the fall of 1966 an alfalfa fertility experiment was established at the station on Forman clay loam (formerly Barnes). Three cuttings were made in 1970 and there was a significant effect of phsophorus on the first crop.

Table 1. First Cutting Yields - 1970

| $P_2O_5$ Applied (lbs./acre) | $K_2O$ Applied (lbs./acre) 0 | 60 | 120 | 240 | 480 | Average |
|---|---|---|---|---|---|---|
| | Tons alfalfa hay/A @ 15% moisture | | | | | |
| 0 | 1.6 | 1.8 | 1.8 | 1.9 | 1.8 | 1.8 |
| 57 | 2.0 | 2.1 | 2.0 | 2.1 | 2.0 | 2.0 |
| 114 | 2.2 | 2.2 | 2.1 | 2.2 | 2.0 | 2.2 |
| 229 | 1.9 | 2.2 | 2.4 | 2.2 | 2.4 | 2.2 |
| 458 | 2.1 | 2.0 | 2.0 | 2.2 | 2.1 | 2.1 |
| Average | 2.0 | 2.1 | 2.1 | 2.1 | 2.1 | |

Table 2. Total of 3 cuttings - 1970

| $P_2O_5$ Applied (lbs./acre) | $K_2O$ Applied (lbs./acre) 0 | 60 | 120 | 240 | 480 | Average |
|---|---|---|---|---|---|---|
| | Tons alfalfa hay/A @ 15% moisture | | | | | |
| 0 | 4.0 | 3.8 | 4.0 | 4.2 | 4.2 | 4.0 |
| 57 | 4.2 | 4.2 | 4.0 | 4.2 | 4.6 | 4.2 |
| 114 | 4.4 | 4.6 | 4.2 | 4.6 | 4.2 | 4.4 |
| 229 | 4.0 | 4.5 | 4.6 | 4.2 | 4.9 | 4.4 |
| 458 | 4.4 | 4.3 | 4.0 | 4.6 | 4.3 | 4.3 |
| Average | 4.2 | 4.3 | 4.2 | 4.4 | 4.4 | |

Table 3. Analysis of Variance - 1970 Yields

| | 1st Cutting | 2nd Cutting | 3rd Cutting | 1970 Total |
|---|---|---|---|---|
| Reps | NS | NS | NS | NS |
| Phosphorus rates | ** | NS | NS | * |
| Potassium rates | NS | NS | NS | NS |
| P x K interaction | NS | NS | NS | NS |

# PHOSPHORUS FERTILIZATION OF CONTINUOUS CORN

West Central Experiment Station - Morris

Samuel D. Evans

A phosphorus fertilization experiment on continuous corn was set up in 1965 on Forman clay loam to determine (1) the interaction of row and broadcast levels of phosphorus on corn yields and, (2) the effect of high rates of phosphorus on the zinc content of corn leaves and on corn yields.

All plots received a uniform row application of 10 + 0 + 20. Nitrogen was plowed down in the fall of 1969 at the rate of 220 lbs. of N per acre.

In 1970 there were no significant treatment effects.

1970 Variety - Pioneer 3956 Planting date - May 20, 1970

Table 1. 1970 yields in Bu/acre at 15.5% moisture.

| Broadcast P Treatment (lbs./acre) | Row Phosphorus Treatment (lbs./acre) | | | | | |
|---|---|---|---|---|---|---|
| | ck | 15P | 30P | 45P | 45P+10Zn | Average |
| ck | 76.0 | 82.1 | 81.8 | 76.3 | 84.0 | 80.0 |
| 45P | 84.1 | 81.1 | 76.5 | 73.5 | 88.4 | 80.7 |
| Average | 80.0 | 81.6 | 79.2 | 74.9 | 86.2 | |

Table 2. Average yield in bu/acre at 15.5% moisture for 1965-70.

| Broadcast P (lbs./acre) | Row Phosphorus Treatment (lbs./acre) | | | | | |
|---|---|---|---|---|---|---|
| | ck | 15P | 30P | 45P | 45P+10Zn | Average |
| ck | 75 | 74 | 75 | 74 | 78 | 75 |
| 45P | 78 | 77 | 73 | 72 | 78 | 76 |
| Average | 77 | 75 | 74 | 73 | 78 | |

# POTASSIUM FERTILIZATION OF CORN

## Walter Flowers Farm - Benson

S.D. Evans, J. Edman, O. Gunderson

A potassium experiment on corn was set up south of Benson in the spring of 1970. The initial soil test is given in Table 1. Rates of potassium in addition to combinations with nitrogen and phosphorus were used. Zinc sulfate was applied uniformly over the area.

Table 1. Soil Test Values on the Flower's Farm.

| pH | Organic Matter | P | K | Zn | S |
|---|---|---|---|---|---|
| 7.8 | H | 16 | 420 | 1.0 | 9 |

Fertilizer was spread on the field on May 7. The corn was planted and taken care of by the farmer. The farmer used a basic fertilizer treatment on the entire area. The plots were thinned to a uniform stand on June 23. Leaf samples were taken and the averages are shown in Table 2.

Table 2. Average Nutrient Content in Leaves when the Plants were 50% Silked.

| Treatment | | | (Average of 4 Reps) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | P | K | Ca | Fe | Mg | Zn | Cu | Mo | Mn | B |
| N | $P_2O_5$ | $K_2O$ | % | % | % | ppm | % | ppm | ppm | ppm | ppm | ppm |
| | lbs/acre | | | | | | | | | | | |
| 0 | 0 | 0 | .34 | 1.44 | .48 | 103 | .58 | 9.6 | 13.7 | 10.6 | 68 | 12.1 |
| 0 | 0 | 100 | .36 | 1.64 | .44 | 110 | .52 | 10.8 | 17.7 | 9.7 | 70 | 12.0 |
| 0 | 0 | 300 | .34 | 1.69 | .44 | 95 | .46 | 9.4 | 13.0 | 9.6 | 66 | 12.0 |
| 0 | 0 | 600 | .31 | 1.54 | .47 | 95 | .46 | 10.8 | 12.3 | 8.9 | 69 | 10.6 |
| 100 | 0 | 600 | .32 | 1.70 | .46 | 94 | .46 | 14.2 | 17.1 | 9.4 | 70 | 13.4 |
| 100 | 100 | 600 | .33 | 1.73 | .42 | 114 | .48 | 12.7 | 19.1 | 10.1 | 70 | 11.0 |

The plots became very weedy but yields were taken on October 1. The average yields are shown in Table 3. There were no significant statistical differences between treatments.

Table 3. Yields in Bu/Acre @ 15.5% moisture (Average of 4 reps).

| N | $P_2O_5$ | $K_2O$ | Yield |
|---|---|---|---|
| | lbs/acre | | |
| 0 | 0 | 0 | 102 |
| 0 | 0 | 100 | 114 |
| 0 | 0 | 300 | 113 |
| 0 | 0 | 600 | 109 |
| 100 | 0 | 600 | 109 |
| 100 | 100 | 600 | 111 |

# SMALL GRAIN FERTILIZATION

West Central Experiment Station - Morris

S. D. Evans

Field experiments were established on Forman clay loam in the spring of 1970 to study the response of wheat, oats, and barley to nitrogen fertilization and to study starter response on wheat and barley. The nitrate nitrogen level in the 0-24 inch soil zone was 48 lbs./acre as determined by the North Dakota Soil Testing Laboratory. Soil test levels of P and K were very high.

A. Oats

1. Nitrogen study

Main plots - Varieties (1) Lodi (2) Otter (3) Diana

Sub plots - Nitrogen levels of 0, 30, 60, and 90 lbs. of actual nitrogen.

A uniform starter application of 100 lbs. of 10-20-20 was used.

Seeding date - May 1, 1970

Table 1. Yield of Oats, Morris, 1970.

| Nitrogen | Variety | | | |
|---|---|---|---|---|
| Applied lbs/A | Lodi | Otter | Diana | Average |
| | | Bu/A | | |
| 0 | 67.5 | 68.3 | 54.6 | 63.5 |
| 30 | 78.9 | 77.5 | 81.2 | 79.2 |
| 60 | 81.9 | 79.9 | 86.5 | 82.7 |
| 90 | 94.6 | 100.8 | 92.8 | 96.1 |
| Average | 80.7 | 81.6 | 78.8 | |

Table 2. Analysis of Variance, Oat Yields

| Source of Variates | Significance |
|---|---|
| Reps | NS |
| Varieties | NS |
| Nitrogen | ** (1% level) |
| Varieties x Nitrogen | NS |

Table 3. Groat Percentage, Oat Fertility Study - Morris, 1970

| Nitrogen Applied lbs/A. | Variety Lodi | Otter | Diana | Average |
|---|---|---|---|---|
| | | Groat % | | |
| 0 | 62.4 | 67.8 | 63.8 | 64.7 |
| 30 | 61.1 | 67.7 | 62.4 | 63.8 |
| 60 | 63.1 | 66.0 | 62.7 | 63.9 |
| 90 | 62.0 | 66.9 | 62.0 | 63.6 |
| Average | 62.2 | 67.1 | 62.7 | |

Table 4. Chemical Analyses of Oat Leaves Samples at Heading (one sample per treatment)

| Variety | Nitrogen Applied lbs/A | N % | P % | K % | Ca % | Fe ppm | Mg % | Zn ppm | Cu ppm | Mo ppm | Mn ppm | B ppm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lodi | 0 | 2.49 | .25 | 3.38 | .63 | 104 | .24 | 10.8 | 4.3 | 4.1 | 15 | 9.4 |
| | 30 | 2.53 | .23 | 2.99 | .63 | 154 | .21 | 13.6 | 7.6 | 6.3 | 25 | 9.8 |
| | 60 | 2.91 | .21 | 2.78 | .63 | 94 | .23 | 12.9 | 5.0 | 4.3 | 24 | 10.1 |
| | 90 | 3.28 | .22 | 3.41 | .58 | 111 | .24 | 17.5 | 11.5 | 5.7 | 22 | 8.4 |
| Otter | 0 | 2.38 | .37 | 2.72 | .48 | 127 | .21 | 14.6 | 15.6 | 5.7 | 21 | 9.8 |
| | 30 | 3.57 | .25 | 3.05 | .70 | 107 | .30 | 14.6 | 5.8 | 4.3 | 32 | 11.0 |
| | 60 | 2.94 | .29 | 2.94 | .63 | 139 | .22 | 15.6 | 10.4 | 3.9 | 46 | 9.3 |
| | 90 | 3.32 | .31 | 3.05 | .63 | 140 | .22 | 18.1 | 7.9 | 4.7 | 36 | 10.7 |
| Diana | 0 | 2.07 | .29 | 2.66 | .56 | 76 | .19 | 10.9 | 5.4 | 3.5 | 18 | 8.8 |
| | 30 | 2.70 | .30 | 3.20 | .56 | 127 | .20 | 21.1 | 27.3 | 5.1 | 16 | 8.7 |
| | 60 | 3.12 | .27 | 3.13 | .63 | 147 | .21 | 15.6 | 8.1 | 3.9 | 16 | 8.3 |
| | 90 | 2.39 | .31 | 2.87 | .58 | 96 | .22 | 12.3 | 10.9 | 5.9 | 33 | 13.3 |

B. Barley

1. Nitrogen Study

Main plots - Varieties (1) Dickson (2) Larker (3) 64-76

Sub plots - Nitrogen levels of 0, 30, 60, and 90 lbs. of actual nitrogen

A uniform starter application of 100 lbs. of 10-20-20 was used.

Seeding date - May 1, 1970

Table 5. Yield of Barley in Response to Nitrogen - Morris, 1970

| Nitrogen Applied lbs/acre | Variety | | | Average |
|---|---|---|---|---|
| | Dickson | Larker | 64-76 | |
| | | Bu./Acre | | |
| 0 | 39.0 | 39.3 | 38.0 | 38.8 |
| 30 | 52.0 | 52.7 | 53.7 | 52.9 |
| 60 | 59.1 | 60.5 | 61.6 | 60.5 |
| 90 | 70.0 | 68.5 | 59.1 | 65.9 |
| Average | 55.1 | 55.3 | 53.1 | |

Table 6. Analysis of Variance, Yields on Barley Nitrogen Study

| Source of Variates | Significance |
|---|---|
| Reps | NS |
| Varieties | NS |
| Nitrogen | ** (1% level) |
| Nitrogen x Varieties | NS |

Table 7. Chemical Analyses of Barley Leaves Sampled at Heading (one sample per treatment)

| Variety | Nitrogen Applied lbs/Acre | N % | P % | K % | Ca % | Fe ppm | Mg % | Zn ppm | Ca ppm | Mo ppm | Mn ppm | B ppm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dickson | 0 | 2.79 | .40 | 1.76 | .52 | 67 | .21 | 22.7 | 6.3 | 6.7 | 19 | 7.8 |
| | 30 | 2.60 | .35 | 2.18 | .50 | 120 | .21 | 17.0 | 8.9 | 6.9 | 19 | 9.8 |
| | 60 | 2.83 | .36 | 2.47 | .61 | 92 | .23 | 16.4 | 6.8 | 7.1 | 22 | 7.2 |
| | 90 | 3.33 | .46 | 2.91 | .58 | 73 | .28 | 20.9 | 7.4 | 6.3 | 31 | 7.9 |
| Larker | 0 | 2.44 | .39 | 1.96 | .77 | 67 | .23 | 14.1 | 2.5 | 5.9 | 25 | 7.0 |
| | 30 | 2.37 | .38 | 2.03 | .83 | 69 | .25 | 15.3 | 8.1 | 7.5 | 23 | 9.7 |
| | 60 | 3.12 | .37 | 1.96 | 1.08 | 71 | .25 | 19.7 | 5.3 | 6.7 | 28 | 9.8 |
| | 90 | 3.84 | .41 | 2.07 | 1.24 | 87 | .27 | 23.0 | 5.3 | 7.3 | 34 | 9.3 |
| 64-76 | 0 | 2.65 | .38 | 2.06 | .47 | 52 | .28 | 18.6 | 3.6 | 5.7 | 22 | 6.2 |
| | 30 | 3.07 | .44 | 2.70 | .63 | 66 | .32 | 19.7 | 7.6 | 5.9 | 35 | 6.2 |
| | 60 | 2.97 | .34 | 1.33 | .76 | 73 | .24 | 22.5 | 9.1 | 10.1 | 27 | 10.2 |
| | 90 | 3.19 | .48 | 3.02 | .60 | 1775 | .29 | 23.8 | 43.1 | 10.1 | 57 | 8.8 |

2. Starter Fertilizer on Barley

Main plots - Nitrogen levels of 30 and 60 lbs. of nitrogen

Sub plots - Varieties (1) Larker (2) 64-76

Sub-sub plots - Starter treatments

Seeding date - May 1, 1970

Table 8. Yield of Barley on Response to Starter - Morris, 1970

| | 30 lbs.N/Acre | | 60 lbs.N/Acre | | |
|---|---|---|---|---|---|
| | Larker | 64-76 | Larker | 64-76 | Average |
| | Bu/Acre | | | | |
| 10 + 0 + 0 Bcst | 54.0 | 48.7 | 62.8 | 65.8 | 57.8 |
| 10 + 0 + 0 Row | 49.3 | 52.8 | 61.1 | 62.5 | 56.4 |
| 10 + 20 + 0 Row | 56.5 | 52.9 | 60.1 | 61.7 | 57.8 |
| 10 + 20 + 20 Row | 56.2 | 54.5 | 66.5 | 68.5 | 61.4 |
| Variety Average | 54.0 | 52.2 | 62.6 | 64.6 | |
| Nitrogen Average | 53.1 | | 63.6 | | |

Table 9. Analyses of Variance, Barley Starter Plots

| Source of Variates | Significance |
|---|---|
| Reps | NS |
| Nitrogen (N) | + (10% level) |
| Varieties (V) | NS |
| N x V | NS |
| Starter trts. (S) | + (10% level) |
| N x S | NS |
| V x S | NS |
| N x V x S | NS |

C. Wheat

1. Nitrogen Study

Main plots - Varieties (1) Ciano 67 (2) Chris (3) Era

Sub plots - Nitrogen levels of 0, 40, 80, and 120 lbs. of actual nitrogen

A uniform application of 100 lbs. of 10-20-20 was used

Seeding date - May 1, 1970

Table 10. Yield of Wheat on Response to Nitrogen - Morris, 1970

| Nitrogen Applied lbs/Acre | Variety | | | |
|---|---|---|---|---|
| | Ciano 67 | Chris | Era | Average |
| | Bu/Acre | | | |
| 0 | 19.2 | 19.4 | 21.7 | 20.2 |
| 40 | 29.0 | 26.3 | 37.4 | 30.9 |
| 80 | 31.6 | 30.6 | 40.3 | 34.2 |
| 120 | 31.0 | 29.8 | 39.1 | 33.4 |
| Average | 27.8 | 26.6 | 34.7 | |

Table 11. Analysis of Variance, Wheat Yields

| Source of Variates | Significance |
|---|---|
| Reps | NS |
| Varieties | * (5% level) |
| Nitrogen | ** (1% level) |
| Varieties x Nitrogen | NS |

Table 12. Protein Levels of Era Wheat

| Nitrogen Applied lbs/Acre | % Protein |
|---|---|
| 0 | 10.3 |
| 40 | 10.8 |
| 80 | 12.2 |
| 120 | 13.0 |

Table 13. Chemical Analysis of Wheat Leaves Samples at Heading (one sample per treatment)

| Variety | Nitrogen Applied lbs/Acre | N % | P % | K % | Ca % | Fe ppm | Mg % | Zn ppm | Cu ppm | Mo ppm | Mn ppm | B ppm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ciano 67 | 0 | 3.07 | .31 | 1.93 | .42 | 97 | .24 | 17.6 | 5.8 | 6.9 | 18 | 4.9 |
| | 40 | 3.09 | .31 | 2.07 | .52 | 108 | .24 | 22.0 | 10.2 | 7.3 | 22 | 5.7 |
| | 80 | 3.93 | .34 | 1.39 | .67 | 151 | .29 | 26.7 | 7.3 | 9.3 | 31 | 6.2 |
| | 120 | 4.28 | .31 | 1.63 | .73 | 136 | .34 | 27.3 | 10.1 | 6.9 | 37 | 5.4 |
| Chris | 0 | 2.93 | .29 | 1.51 | .34 | 95 | .18 | 23.1 | 9.9 | 7.7 | 25 | 4.2 |
| | 40 | 3.61 | .26 | 1.64 | .41 | 239 | .23 | 23.8 | 6.4 | 3.5 | 32 | 2.8 |
| | 80 | 4.12 | .32 | 1.61 | .54 | 101 | .25 | 22.4 | - - | 7.5 | 47 | 5.8 |
| | 120 | 4.16 | .32 | 1.69 | .58 | 167 | .24 | 25.5 | 4.0 | 5.9 | 51 | 5.8 |
| Era | 0 | 2.67 | .35 | 2.10 | .31 | 113 | .12 | 25.9 | 11.0 | 5.1 | 20 | 3.5 |
| | 40 | 3.39 | .32 | 1.99 | .40 | 93 | .16 | 27.9 | 7.4 | 7.1 | 27 | 4.9 |
| | 80 | 3.75 | .32 | 1.57 | .55 | 89 | .19 | 31.5 | 8.7 | 7.1 | 39 | 6.2 |
| | 120 | 3.96 | .33 | 1.69 | .63 | 105 | .21 | 29.1 | 4.5 | 7.5 | 42 | 5.9 |

2. Starter Fertilizer on Wheat

Main plots - Nitrogen levels of 40 and 80 lbs. of N

Sub plots - Varieties (1) Chris (2) Era

Sub sub plots - Starter treatments

Seeding date - May 2, 1970

Table 14. Yield of Wheat in Response to Starter - Morris, 1970.

| | 40 lbs. N/Acre | | 80 lbs. N/Acre | | |
|---|---|---|---|---|---|
| | Chris | Era | Chris | Era | Average |
| | | - Bu./Acre - | | | |
| 10 + 0 + 0 Bcst. | 37.0 | 40.7 | 42.1 | 50.1 | 42.5 |
| 10 + 0 + 0 Row | 36.2 | 45.6 | 44.3 | 52.5 | 44.7 |
| 10 + 20 + 0 Row | 39.1 | 46.7 | 45.5 | 49.8 | 45.3 |
| 10 + 20 + 20 Row | 32.9 | 45.4 | 42.2 | 52.7 | 43.4 |
| Variety Average | 36.4 | 44.6 | 43.6 | 51.3 | |
| Nitrogen Average | 40.5 | | 47.5 | | |

Table 15. Analysis of Variance, Wheat Starter Plots

| Source of Variates | Significance |
|---|---|
| Reps | NS |
| Nitrogen (N) | NS |
| Varieties (V) | * (5% level) |
| N x V | NS |
| Starter trts. (S) | NS |
| N x S | NS |
| V x S | NS |
| N x V x S | NS |

This work was done in cooperation with the following staff of the Department of Agronomy and Plant Genetics:

Oats - D. D. Stuthman

Barley - D. C. Rasmusson

Wheat - R. E. Heinen

# Weather Summary - 1970

## West Central Experiment Station - Morris

Samuel D. Evans

| Month | Period | PRECIPITATION 1970 | PRECIPITATION 84 yr Ave | Deviation from Ave | AIR TEMPERATURE 1970 | AIR TEMPERATURE 84 yr Ave | Deviation from Ave | SOIL Soil (10cm) Temp 1970 | 3 yr. Ave |
|---|---|---|---|---|---|---|---|---|---|
| Jan | 1-31 | .24 | .66 | -.42 | 0.4 | 8.6 | -8.2 | 28.0 | 22.2 |
| Feb | 1-28 | .35 | .65 | -.30 | 11.3 | 12.8 | -1.5 | 28.0 | 24.2 |
| March | 1-31 | 1.52 | 1.04 | +.48 | 21.2 | 26.8 | -5.6 | 28.0 | 2[illegible]3 |
| April | 1-10 | 16 | .60 | -.44 | 33.8 | 38.3 | -4.5 | 32.2 | 41.1 |
| | 11-20 | 2.58 | .63 | + 1.95 | 38.2 | 44.3 | -6.1 | 35.4 | |
| | 21-30 | 2.09 | 1.10 | +.99 | 47.9 | 48.4 | -0.5 | 43.1 | |
| | | | | | | 43.7 | -3.7 | 36.9 | |
| Total or Average | | 4.83 | 2.33 | + 2.50 | 40.0 | | | | 56.1 |
| May | 1-10 | .03 | .81 | -.78 | 51.3 | 52.1 | -0.8 | 54.8 | |
| | 11-20 | .30 | 1.01 | -.71 | 53.8 | 55.6 | -1.8 | 55.6 | |
| | 21-31 | 2.15 | 1.18 | +.97 | 57.6 | 60.0 | -2.4 | 58.6 | |
| Total or Average | | 2.48 | 3.00 | +.52 | 54.4 | 56.0 | -1.6 | 56.4 | 67.8 |
| June | 1-10 | .01 | 1.34 | - 1.33 | 68.5 | 62.9 | +5.6 | 71.0 | |
| | 11-20 | 3.02 | 1.16 | + 1.86 | 67.0 | 66.6 | +0.4 | 71.1 | |
| | 21-30 | .07 | 1.41 | - 1.34 | 69.0 | 68.2 | +0.8 | 73.8 | |
| Total or Average | | 3.10 | 3.91 | .81 | 68.4 | 65.9 | +2.5 | 72.0 | 76.1 |
| July | 1-10 | .00 | 1.57 | - 1.57 | 70.6 | 69.9 | +0.7 | 79.3 | |
| | 11-20 | .72 | 1.06 | -.34 | 73.7 | 71.4 | +2.3 | 80.0 | |
| | 21-31 | 3.42 | .94 | + 2.48 | 74.2 | 71.7 | +2.5 | 79.5 | |
| Total or Average | | 4.14 | 3.57 | +.57 | 72.9 | 71.0 | +1.9 | 79.6 | 75.3 |
| August | 1-10 | .11 | 1.10 | -.99 | 69.0 | 70.6 | -1.6 | 75.7 | 61.8 |
| | 11-20 | .05 | .91 | -.86 | 71.4 | 69.1 | +2.3 | 78.0 | 46.7 |
| | 21-31 | .09 | .96 | -.87 | 69.6 | 66.8 | +2.8 | 74.0 | 34.2 |
| Total or Average | | .25 | 2.97 | -2.72 | 70.0 | 68.8 | +1.2 | 75.8 | 75.8 |
| Sept. | 1-30 | 2.55 | 2.26 | +.29 | 58.9 | 59.3 | -0.4 | 61.8 | 61.8 |
| Oct. | 1-31 | 4.11 | 1.52 | + 2.59 | 45.9 | 47.5 | -1.6 | 47.1 | 46.[illegible] |
| Nov. | 1-30 | 3.66 | .88 | + 2.78 | 27.4 | 29.9 | -2.5 | 33.7 | 34.2 |
| Dec. | 1-31 | .10 | .69 | -.59 | 12.5 | 15.8 | -3.3 | 21.0 | 24.4 |
| April-Aug | Growing Season | 14.80 | 15.78 | -.98 | 70.4 | 68.6 | +1.8 | 64.1 | 63.[illegible] |
| Jan-Dec | Annual | 27.33 | 23.46 | + 3.87 | 40.3 | 42.2 | -1.9 | 47.4 | 46.6 |

# YIELDS OF FIELD CORN GROWN EACH OF FOURTEEN YEARS (1957-1970) WITH VARYING RATES OF NITROGEN FERTILIZER AT MORRIS

J.M. MacGregor, S. Evans and G.R. Blake

A continuous corn fertilizer experiment was commenced in 1957 on a non-tiled Barnes loam at the West Central Experiment Station at Morris. Adequate amounts of phosphate and potash were applied annually with four rates of N application. Although a plant population of 16-18,000 corn plants per acre was desired, this was not always obtained, since different methods of seedbed preparation were employed until 1968. For the past three cropping seasons, the seedbed has been prepared on all treatments by the method commonly used in the area - plowing and disking. All vegetative residues remained on the field, either being plowed down or worked into the surface. Ear corn yields and the average for the fourteen years are shown in Table 1. Soil moisture appears to frequently a limiting factor in corn production in this area.

During the fourteen years of continuous corn, it is evident that while the annual 40 pound per acre N fertilization rate increased ear corn yields approximately 10 bushels per acre, further increases in the rate of annual N fertilization rate failed to result in a further increase in corn yields. Soil analyses have shown some accumulation of nitrate nitrogen to a 24 foot depth, although the major portion is present in the upper 8 foot depth.

The sixth corn leaf on all plots were sampled in 1970 at silking and analyzed for nitrogen content. The ear corn yields over the fourteen year period and 1970 leaf nitrogen are shown in the following table.

It is evident that all N treatments increased the N content of the corn leaves, but the more economic rate of N fertilization for the immediate corn crop is apparently the 40 lb/A rate. Heavy rates of N fertilization were not effective for increasing yields and would not be recommended.

YIELD OF EARN CORN DURING FOURTEEN YEARS ( 1957 - 70 ) WHEN GROWN EVERY YEAR WITH DIFFERENT RATES OF NITROGEN FERTILIZATION

AND PERCENTAGE N IN "INDEX" LEAVES IN 1970

(Average of 15 replications)

| N Appl. (lbs/A) | (a) | Bushels of ear corn per acre at 15.5% moisture | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | YEAR | | | | | | | | | | | | | | | |
| | | 1957 | 1958 | 1959 | 1960 | 1961 | 1962 | 1963 | 1964 | 1965 | 1966 | 1967 | 1968 | 1969 | 1970 | 14 yr. Ave. | 1970 % leaf N |
| 0 | (S) | 65.2 | 73.2 | 36.1 | 53.3 | 32.3 | 38.1 | 62.7 | 33.2 | 50.4 | 49.0 | 66.8 | 64.1 | 47.4 | 59.2 | 52.2 a | 1.45 |
| 40 | (F) | 71.0 | 81.5 | 40.9 | 48.2 | 48.3 | 59.0 | 80.9 | 34.1 | 68.3 | 63.7 | 69.2 | 79.6 | 58.0 | 76.9 | 62.8 b | 1.95 |
| 40 | (S) | 69.4 | 81.0 | 41.5 | 55.0 | 47.6 | 62.0 | 83.5 | 29.6 | 75.3 | 66.3 | 71.2 | 70.2 | 60.2 | 70.2 | 63.8 b | 1.89 |
| 80 | (S) | 72.1 | 82.4 | 39.7 | 53.7 | 45.0 | 65.3 | 77.4 | 29.1 | 80.8 | 75.9 | 69.7 | 78.5 | 59.9 | 78.5 | 65.1 b | 2.31 |
| 240 | (S) | 71.3 | 80.3 | 36.8 | 52.5 | 46.1 | 67.1 | 79.5 | 24.7 | 82.8 | 33.1 | 71.3 | 76.0 | 58.7 | 76.0 | 61.4 b | 2.38 |

(a) 40 pounds of both phosphate and potash were applied annually to all plots at time of N application.
(S) = Spring
(F) = Fall

# ZINC FERTILIZATION OF CONTINUOUS CORN

West Central Experiment Station - Morris

Samuel D. Evans

In the spring of 1965 an experiment was initiated involving the use of zinc fertilizer on continuous corn. The plots were set up on Forman clay loam and corn grown previously on this soil had not shown zinc deficiency, even though leaf samples indicated the zinc content was below 20 ppm zinc.

Table 1. Yields for 1970 and 1965-70.

| Treatment (lbs./A) | When applied | Yield in bu/acre at 15.5% moisture 1970 | 1965-70 average |
|---|---|---|---|
| Check | - - | 90.3 ab* | 83 |
| 5 lbs zinc as zinc sulfate | 1965 | 94.3 ab | 82 |
| 10 lbs zinc as zinc sulfate | 1965 | 96.0 b | 82 |
| 10 lbs zinc as zinc sulfate | yearly | 97.4 b | 84 |
| 20 lbs zinc as zinc sulfate | 1965 | 99.9 b | 83 |
| 0.5 lbs zinc as Zn chel. | yearly | 85.9 ab | 79 |
| 45 lbs P broadcast | yearly | 80.9 a | 78 |
| 45 lbs P broadcast + 10 lbs zinc as zinc sulfate | yearly 1965 | 91.2 ab | 81 |

1970 Variety - Pioneer 3956 Date Planted - May 19, 1970

* Yields followed by different letters are significantly different at the 5.0% level population (Duncan's new multiple Range test).

1970 Corn Tillage Experiment - Waseca
Wm. Leuschen, R. Frazier, J. Swan, J. True

| Treatments | | Early Plant Growth Grams Dry Weight / 12 plants 6/8/70 | | | | | Corn Yield Bu/Acre 15.5% Moisture | | | | | Final Stand Plants Acre |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Primary tillage | Secondary tillage | Rep. 1 | Rep. 2 | Rep. 3 | Rep. 4 | Avg | Rep. 1 | Rep. 2 | Rep. 3 | Rep. 4 | Avg | |
| 1. Fall Plow | None | 26.0 | 24.8 | 33.7 | 20.1 | 26.2 | 173.4 | 166.6 | 157.2 | 161.4 | 164.7 | 21,100 |
| 2. Fall Plow | Conventional | 31.0 | 43.8 | 37.5 | 25.8 | 34.5 | 175.9 | 163.0 | 160.1 | 168.2 | 166.8 | 21,900 |
| 3. Fall Plow | field Cultivate | 29.0 | 30.3 | 29.2 | 25.7 | 28.6 | 168.9 | 167.6 | 161.5 | 156.9 | 163.7 | 21,900 |
| 4. Spring Plow | Conventional | 34.3 | 30.3 | 36.7 | 30.7 | 33.0 | 160.2 | 169.7 | 154.6 | 161.6 | 161.5 | 21,000 |
| 5. Fall Chisel | Conventional | 29.5 | 26.9 | 29.2 | 20.1 | 26.4 | 162.8 | 178.5 | 153.5 | 162.0 | 164.2 | 22,400 |
| 6. Fall Chisel | Field Cultivate | 29.0 | 27.8 | 19.5 | 28.3 | 26.2 | 165.8 | 152.4 | 154.9 | 153.6 | 156.7 | 21,600 |
| 7. Fall Chisel | Zero | 22.0 | 23.2 | 17.7 | 15.8 | 19.7 | 175.9 | 163.7 | 149.6 | 155.2 | 161.1 | 21,600 |
| 8. Spring Chisel | Conventional | 26.3 | 29.7 | 23.5 | 26.5 | 26.5 | 143.5 | 159.5 | 142.5 | 155.3 | 150.2 | 23,600 |
| 9. Spring Chisel | Disk | 23.6 | 27.9 | 29.4 | 18.4 | 24.8 | 168.5 | 158.6 | 149.0 | 161.9 | 159.5 | 22,300 |
| 10. None | None | 19.9 | 21.2 | 15.5 | 20.3 | 19.2 | 157.8 | 156.8 | 154.7 | 154.1 | 155.9 | 22,900 |
| 11. None | Disk | 24.6 | 27.2 | 25.2 | 22.1 | 24.8 | 158.9 | 155.6 | 156.9 | 160.0 | 157.9 | 24,000 |

4 Reps (30 feet wide by 125 feet long)

11 Treatments Randomized Complete Block

Hybrid Minhybrid 4201, Population 22,200 (Range 21,000-24,000)

Date Planted - April 29-30 on corn ground

Date of Spring Tillage - April 29

All planting done with Ac-No till planter

Fertilizer : 175 lbs/A N ($NH_4No_3$) + 100 lbs/A $P_2O_5$ +100 lbs/A $K_2O$

Insecticide : Furadan

Herbicide: Ramrod Pre-emergence + Atrazine and oil post

Coulters removed on 8 rows per plot on all plots except (10) zero primary - zero secondary where coulters were removed for 4 rows.

4-inch soil temperature measurements were made using thermocouples in all 4 reps of treatment

CORN YIELD ANOVA

| | dF | SS | MS | F |
|---|---|---|---|---|
| Rep | 3 | 732.3298 | 244.1099 | |
| Treatment | 10 | 937.8519 | 93.7852 | 2.74* sig. at 5% level |
| Error | 30 | 1025.1427 | 34.1714 | |
| Total | 43 | | | |

Coefficient of variation = 3.640 percent

LSD = 8.43 Bu/A
Duncans Multiple Range Test (for 10) = 9.85 Bu/A

Treatment Comparisons

None of the following factorial effects were significantly different at 5% level

| Primary Tillage | Means | Time of Primary Tillage | Means |
|---|---|---|---|
| Plow | 164 Bu/A | Fall | 163 Bu/A |
| Chisel | 158 | Spring | 157 |
| No Plow | 157 | | |

| Secondary Tillage | Means | Fall plow vs. everything | Means |
|---|---|---|---|
| No spring tillage | 161 Bu/A | Fall Plow | 165 Bu/A |
| Conventional | 161 | All other treatments | 158 |
| Field Cultivate | 160 | | |
| Disk | 159 | | |

Linear regression of yield and early growth was negative with an r value of 0.04 indicating little relationship between early growth and final yield.

Corn Early Growth ANOVA

| | DF | SS | MS | F |
|---|---|---|---|---|
| Total | 43 | 81,473 | 1,910.9 | |
| Treatment | 10 | 19,109 | 1,910.9 | 6.80 ** Sig. at 1% level |
| Reps | 3 | 53,936 | 17,978.7 | 64.0 ** |
| Error | 30 | 8,428 | 280.9 | |

CV = 63.62

Treatment Comparisons:

| Primary tillage | Means | Time of primary tillage | Means |
|---|---|---|---|
| Plow | 30.55 b gms/12 plants | Fall | 26.9 gms/12 plants |
| Chisel | 24.71 a | Spring | 28.1 |
| No Plow | 22.00 a | | N.S. |

| Secondary tillage | Means |
|---|---|
| No spring tillage | 21.68 a gms/12 plants |
| Conventional | 30.11 c |
| Field cultivate | 27.35 bc |
| Disk | 24.80 b |

| Fall plow vs. Everything | Means |
|---|---|
| Fall plow | 29.74 b gms/12 plants |
| All other treatments | 25.07 a |

In each comparison treatments means with the same letter are not significantly different at the 5 percent level by Duncan's Multiple Range Test.

CONCLUSIONS:

1. None of the factorial effects were significantly different concerning final corn yield. That is, there was no significant difference (at 5% level) in yield between any of the primary treatment group or any of the secondary treatment group. The comparison of fall plowing vs. all other treatments most closely approached significance at the 5% level.

2. The F test of all treatments showed that significant differences were present (at the 5% level). However, most of this difference can be attributed to the spring chisel + conventional treatment which had 5.7 Bu/acre lower yield than any other treatment. Since spring chisel-disk was almost identical with only a drag harrow operation left out, it is difficult to explain this result. More years of data are required before any stress can be placed on this observed difference.

3. The coefficient of variation was very low, 3.6.

4. Early growth differences were observed. These growth differences generally agreed with the growth differences one would expect based on soil temperature measurements. Soil temperature decreased as amount of mulch increased (see the figure). Treatments with lower soil temperatures generally had reduced early growth. The differences in early growth were not reflected in final yields.

5. Differences between treatments and between reps were significant at the 1 percent level.

   a. Primary tillage - plow treatments had significantly greater early growth than chisel and no-plow treatments.

   b. Secondary tillage - conventional tillage gave significantly greater early growth than disk or no spring tillage treatments. No spring tillage had significantly lower early growth than conventional, field cultivate, and disk treatments.

   c. Time of Primary Tillage - fall plowing was not significantly different from spring plowing.

   d. Fall plow vs. Everything - fall plowing had significantly greater early growth than the average of all other treatments.

# FERTILITY EXPERIMENTS WITH CORN ON HIGH FERTILITY SOILS (1970)[1]

C.J. Overdahl, W.E. Fenster, R.D. Frazier[2]

In the fall of 1969, we established plots at two locations to measure feasibility rates of N, P, and K on highly productive land. Tables 1 to 4 show the 1970 yields, soil tests and tissue tests, according to N,P,K treatments.

Table 1. 1970 corn yields at 2 locations according to nitrogen treatments (Adequate P, K, and Zn on all plots)

| N lbs/A | Martin County | Waseca County |
|---|---|---|
| | bu/Acre | |
| 0 | 120a | 82 a |
| 50 | 128 ab | 109 b |
| 100 | 140 c | 143 c |
| 150 | 132 bc | 153 cd |
| 200 | 131 abc | 163 d |
| 400 | 135 bc | 169 d |

Where letters differ at each location, yields are statistically different at 10% level.

Table 2. 1970 corn yields at 2 locations according to phosphate and potast broadcast treatments (all phosphate plots received a basic treatment of 200+0+200+20 Zn and all potash plots has 200+150+0+20 Zn)

| $P_2O_5$ lbs/A | Martin Co. | Waseca Co.* | $K_2O$ lbs./A | Martin Co. | Waseca Co* |
|---|---|---|---|---|---|
| | Yields bu./acre | | | yields bu./acre | |
| 0 | 155 | 133 | 0 | 156 | 134 |
| 50 | 151 | 136 | 50 | 147 | 129 |
| 100 | 162 | 132 | 100 | 152 | 139 |
| 150 | 146 | 136 | 200 | 147 | 132 |
| 200 | 145 | 138 | 400 | 160 | 134 |
| Avg. Starter increase | 4 | 13 | | 16 | 10 |

There were no significant differences in corn yields from any of the broadcast P and K treatments. Starter fertilizer response significant at all locations, but no significant interaction between broadcast rates and starter

* Research at Waseca under direction of Dr. R.D. Frazier.

(1) reprinted from Special Report no. 12. 1971 Minnesota Retail Dealer's conference handbook

(2) Efforts of Dean Fairchild on plot work and statistical analysis greatfully acknowledged.

Table 3. 1970 soil tests of P and K and corresponding treatment one year after application

| $P_2O_5$ LBS/A | Martin Co. LBS/ACRE P | Waseca Co. | $K_2O$ LBS/A | Martin Co. LBS/ACRE K | Waseca Co. |
|---|---|---|---|---|---|
| 0 | 46 | 34 | 0 | 202 | 260 |
| 50 | 36 | 31 | 50 | 212 | 275 |
| 100 | 56 | 31 | 100 | 222 | 260 |
| 150 | 65 | 40 | 200 | 270 | 262 |
| 200 | 64 | 53 | 400 | 243 | 312 |
| Avg. pH | 7.7 | 6.4 | | 6.4 | 6.4 |

Table 4. 1970 tissue tests (July) and relationship to P and K treatment

| $P_2O_5$ | Martin Co. | | Waseca Co. | | $K_2O$ | Martin Co. | | Waseca Co. | |
|---|---|---|---|---|---|---|---|---|---|
| LBS/A | S* | NS* | S | NS | lbs/A | S | NS | S | NS |
| | | | | | % | | | | |
| 0 | .26 | .27 | .31 | .30 | 0 | 1.8 | 1.6 | 1.6 | 1.5 |
| 50 | .26 | .24 | .30 | .31 | 50 | 1.8 | 1.6 | 1.7 | 1.6 |
| 100 | .27 | .26 | .38 | .26 | 100 | 1.6 | 1.6 | 1.6 | 1.7 |
| 150 | .28 | .26 | .29 | .29 | 200 | 1.7 | 1.7 | 1.7 | 1.8 |
| 200 | .28 | .25 | .29 | .31 | 400 | 1.7 | 1.7 | 2.2 | 2.1 |

* S= starter
NS= no starter

Significant yield increases from N, shown in table 1, indicate the importance of high yearly treatments even when past treatments of N have been very high. Results for one year are never conclusive, but the need for nitrogen is very apparent and the starter response as high as 16 bushels per acre demonstrates the need to continue this practice even on high testing soils. The plot work must continue for some time to best evaluate the need for large broadcast rates of P and K.

## SUMMARY

It has been our observation that most farmers when planning a higher fertility program, increase the nutrients N, P, K in about equal proportion. Yields, no doubt, have increased considerably. Evidence form earlier experiments in Minnesota and neighboring states indicates that the high corn yield increases are due primarily to nitrogen and starter fertilizer. Experiments where yields, tissue tests and soil tests are observed under intensive corn production will be continued to better understand P and K broadcast needs.

# IRRIGATED ALFALFA PRODUCTION

H. L. Meredith and J. O. Jacobson

In 1967 alfalfa plots were established on an Estherville sandy loam near Verndale to determine maximum alfalfa production under irrigation. The fertility treatment follows.

| Year | Treatment / acre |
|---|---|
| 1966 | 3 tons lime* |
| 1967 | 3 tons lime<br>70 + 280 + 605 + 50S + 2B |
| 1968 | 0 + 70 + 315 + 2B |
| 1969 | 30 + 150 + 410 + 40S + 2B |
| 1970 | 30 + 150 + 410 + 40S + 2B |

*Agricultural limestone, Bryant Quarry

Lime and 1000 pounds 7-14-29-5S were broadcast and incorporated prior to seeding. Fall 1967, 700 pounds of 0 - 10 - 45 + 2B was topdressed and topdressing accomplished in fall thereafter.

Vernal alfalfa at the rate of 16 pounds per acre and a companion nurse crop of oats at the seeding rate of one bushel per acre were seeded in late April, 1967.

Yield history of this plot is as follows:

| Date | Cutting | Yield Tons/acre** | Total yield - Tons/acre |
|---|---|---|---|
| 7/15/67 | 1 | 1.5 | |
| 9/3/67 | 2 | 1.5 | 3.0 |
| 6/20/68 | 1 | 2.0 | |
| 7/23/68 | 2 | 2.5 | |
| 8/23/68 | 3 | 1.4 | 5.9 |
| 5/29/69 | 1 | 1.5 | |
| 7/16/69 | 2 | 2.4 | |
| 8/19/69 | 3 | 1.2 | 5.0 |
| 6/17/70 | 1 | 3.2 | |
| 7/15/70 | 2 | 1.7 | |
| 8/10/70 | 3 | 1.2 | 6.1 |

**Alfalfa Hay @ 15% moisture, average of three yield checks per cutting. Total production of 4 years = 20.0 tons or an average production of 5.7 tons per year excluding the seeding year. Obviously, a production rate of this magnitude is impractical. Most well managed alfalfa fields with reasonable water holding capacities can produce a comparable yield without irrigation.

It becomes clear, therefore, that higher yields are paramount to justify the added cost of irrigation. A fourth cutting must be harvested. Trial-error methods have taught us that a second-year stand or later most often will not survive if cut after August 25 and before October 1. This is primarily due to regrowth and depletion of root sugars, lowering of root osmotic concentration and the consequent rupture of root cells due to formation of large ice crystals. Generally after October 1, in this area, growth ceases. The root reserves are not depleted by cutting alfalfa at this time and early growth in the spring is not hampered by the late cutting. Alfalfa growth continues at average temperatures above 40°F. Experience has shown that 1 1/2

to 2 tons of additional alfalfa could be produced after August 10-15 if harvested after October 1.

Insects are the primary deterrent to production of high quality hay at this time. Insects must be controlled through the use of chemical border treatment and/or periodic field application.

# Analyses of Tile and Open Ditch Drainage Waters in Several South Central Minnesota Counties (1968-70)

J. E. Ellis, L. D. Hanson, J. M. MacGregor, and R. Munter

Nitrate nitrogen is formed in soils as organic matter decomposes, and is an essential step in making soil nitrogen available for growing plants. Nitrogen fertilization also increases nitrate supply in soils. In mid-1968 it was decided to collect water samples from several farm drainage tile outlets and from open drainage ditches to provide information on losses of nitrates and phosphorus. Water samples were collected in Kandiyohi, Meeker, McLeod, Renville, Sibley and in Wright Counties, and analyzed for nitrate-nitrogen ($NO_3$-N). The primary objective was to establish the relative amounts of $NO_3$-N lost in drainage waters under differing soil fertility management practices-especially the time and rate of N fertilization. Since tile (or open ditch) flow is dependent on amount and distribution of precipitation, and also on stage of crop growth, it was not possible to sample each location on a uniform interval schedule. The present report is a brief summary of results obtained during the 30 month period in which the survey has been conducted.

Initially, the water analyses were limited to $NO_3$-N alone, but early in 1969 phosphorus as $PO_4$-P was included, along with nitrite nitrogen ($NO_2$-N), ammonium N ($NH_4$-N), potassium (K) and electrical conductivity (a measure of soluble salts). Sulfate ($SO_4$) and chloride (Cl) were also determined on a few samples. Since each of the 6

counties were represented by either 3 or 4 sampling locations, samples were obtained from a total of 22 or more comparatively small drainage systems. Soil management practices were recorded for all locations, and the soil management effect on crop nutrient losses in drainage waters is now being studied in depth. A brief summary of the nitrate nitrogen and orthophosphorus content of these drainage waters during the 30 month study is shown in the following table.

Nitrate Nitrogen and Phosphate Phosphorus Concentrations in Drainage Waters of Six South Central Minnesota Counties (K, M, Mc, R, S, W) in 1968-69-70

| $NO_3$-N | | | $PO_4$-P | | |
|---|---|---|---|---|---|
| ppm range | Number of samples | % | ppm range | Number of samples | % |
| 0 - 10 | 123 | 30 | 0.0 - 0.1 | 271 | 82 |
| 10 - 20 | 141 | 34 | 0.1 - 0.2 | 33 | 10 |
| 20 - 30 | 88 | 21 | 0.2 - 0.3 | 11 | 4 |
| 30 - 40 | 32 | 8 | 0.3 - 0.4 | 7 | 2 |
| 40 - 50 | 24 | 6 | 0.4 - 0.5 | 2 | 1 |
| 50 - 60 | 5 | 1 | 0.5 - 1.0 | 4 | 1 |
| 60 - 70 | 1 | --- | 1.0 + | 1 | --- |
| | 414 | 100 | | 329 | 100 |

While it was not possible to determine the total amounts of water passing through these drainage systems, some calculation as the importance of their $NO_3$-N or $PO_4$-P content is of interest.

One inch of water spread uniformly over an acre (one acre inch) contains 27,204 gallons weighing 113.4 tons or 226,800 pounds. An acre inch of water containing 10 ppm of $NO_3$-N would contain 2.268 lbs. of N. Therefore, every acre inch of drainage water in the 10 ppm $NO_3$-N level would mean that some 2 1/4 pounds of N was being lost in the drainage waters from this field. Similarly, in the case of phosphorus, the same amount of water containing 0.1 ppm $PO_4$-P would be removing 0.02668 pounds of this form of P.

Although 64% of the analyzed samples contained 20 ppm $NO_3$-N or less, it is evident that substantial amounts of N are being lost from some farm fields and these could increase pollution of our rivers to some extent. However, it is possible that much of this denitrifies and is lost to the air before entering the larger streams. Dilution with other waters also occurs and nitrates are quickly utilized by water plants during the growing season. There has been little increase in $NO_3$-N content of our major river waters during the last 50 years, but these must be closely monitored in the future with increasing amounts of $NO_3$-N of sewage and higher fertilization rates. An additional interest is the amounts which enter ground waters below that affected by drain tile and ditches.

Although the P level of the drainage water is much lower, this element is also a contributor to eutrification of lake or river waters and losses from soil should be maintained at the lowest possible level consistent with optimum crop production.

In final analysis, both $NO_3$-N and P are essential to both plant and animal life, and must be present for natural biological processes. Nitrogen and phosphate fertilization is a well recognized essential for optimum crop production. Increasing our knowledge of the fate of these elements will promote better soil management practices for optimum crop production and minimum pollution of the environment.

# 1970 METHOD OF CORN PLANTING STUDY

Lancaster, Wisconsin
University of Wisconsin, Lancaster Experiment Farm
William Paulson, Supt., A. Peterson, J. Swan

Soil: Fayette Silt Loam, 6 to 8% south slope

Previous crop: Corn

Planting date: May 6, Tillage May 5

Tillage Treatments: Planting method

Chisel: A C coulter planter

Spring plow: wheeltrack plant

None: A C coulter plant

Soil temperature was measured in 3 of the 6 reps of the corn on corn study and in 2 reps of the sod - wheeltrack study. Each plot had 4 couples arranged in parallel.

Weather summary: (Table 1).

Conclusions:

1. Very severe crusts of up to one-inch in thickness were created by heavy rains in the latter part of May. Plant stands were seriously reduced on all treatments; stands ranged from 6 to 9,000 plants per acre. This terminated the experiment for 1970. Assuming that crusting was at least partly the reason for the reduced stands, none of the treatments provided sufficient protection to prevent severe damage to stands by crusting.
2. Spring soil temperatures were measured during May.

   a. Corn on corn -

   PM Plow-wheeltrack soil temperature (4-inch depth) was warmer than the chisel and no-till treatments by as much as 2°F. AM soil temperature differences between treatments were generally less than

0.5°F.

b. Corn on alfalfa sod -

Both 1-inch and 4-inch soil temperatures were measured. Immediately after planting wheeltrack planting was much warmer. The PM 4-inch soil temperature for wheeltrack planting on the 8th of May was 6°F warmer than no-till and the 1-inch soil temperature was 10°F warmer. After this, the PM soil temperatures for wheeltrack planting were generally warmer by up to 2°F at the 4-inch depth and by up to 4°F at the 1-inch depth compared to no-till. AM soil temperature differences were generally small and at the 4-inch depth no-till was consistently warmer than wheeltrack plowing by up to 2°F. At the 1-inch depth, differences in AM temperature were not consistent.

TABLE 1

WEATHER SUMMARY - 1970 Growing Season
U.W. EXPERIMENTAL FARM - LANCASTER, WIS.

| Month | Temperature mean max. (Degree F) | mean min. | mean | departure 1/ from normal | Precipitation 1970 total (in) | departure 1/ from normal | Growing Degree Days Base 50° 1970 | departure 1/ 2/ from normal |
|---|---|---|---|---|---|---|---|---|
| April | 59.2 | 37.4 | 48.3 | .9 | 1.92 | -1.27 | - | - |
| May | 70.2 | 40.0 | 59.6 | 2.1 | 7.48 | 4.16 | 320 | 58 |
| June | 78.3 | 57.3 | 67.8 | .7 | 2.56 | -2.06 | 532 | 17 |
| July | 82.6 | 59.9 | 71.2 | .1 | 7.16 | 3.07 | 657 | - 7 |
| August | 80.8 | 58.5 | 69.7 | 1.1 | 2.57 | -.76 | 603 | 22 |
| September | 70.8 | 50.6 | 60.7 | .2 | 8.00 | 3.81 | 329 | 3 |
| October | 60.3 | 41.0 | 50.6 | -.3 | 2.16 | .29 | - | - |
| Total | | | | | 31.85 | 7.24 | 2441 | 97 |

1/ Departure from normal values determined from U.W. Exp. Farm Weather data accumulated since 1963 and by using the current seasons records in arriving at the long term mean values.

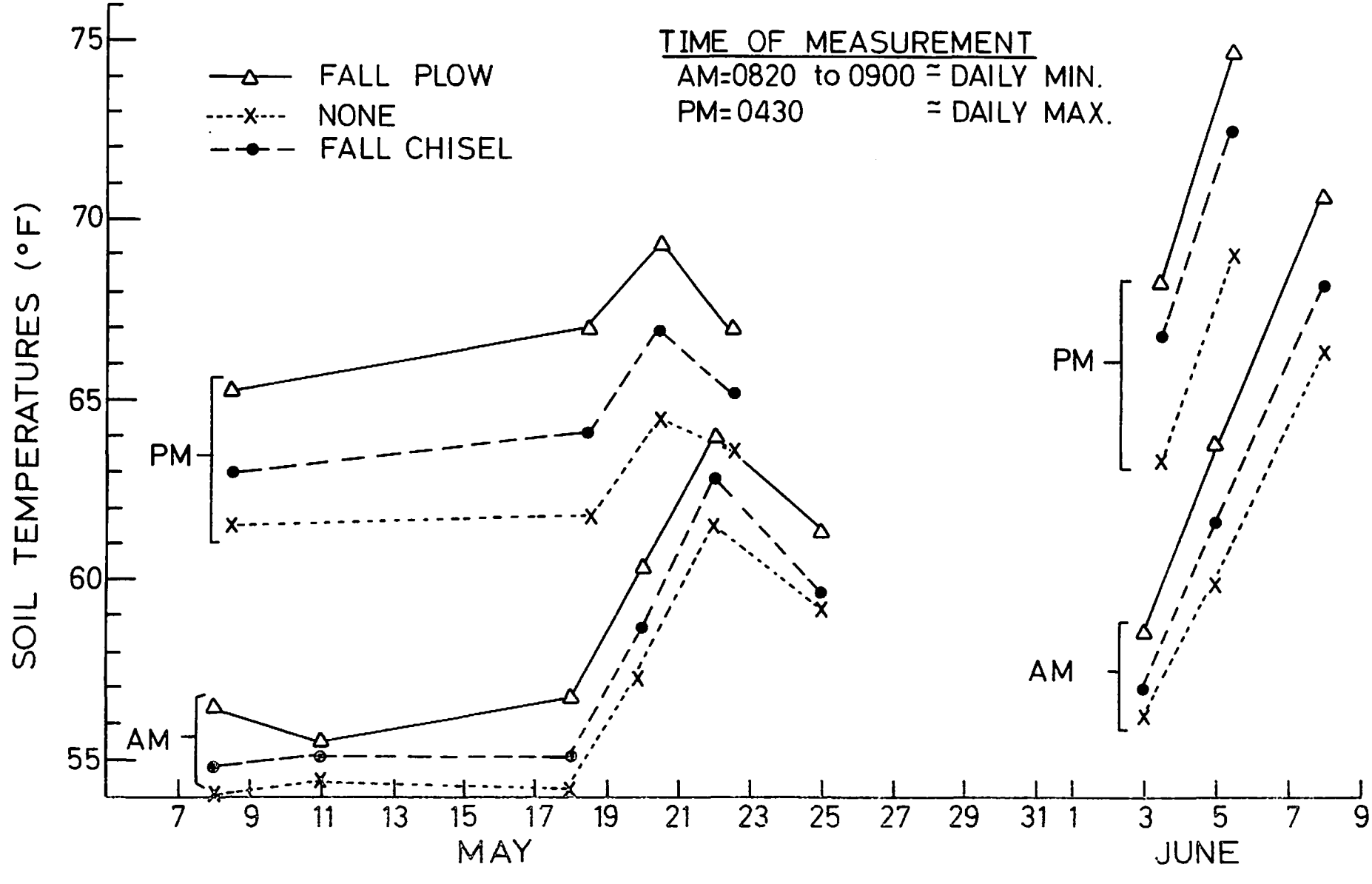
2/ Degree Days calculated using actual temperature values for the period and not ignoring values 50° or 86°, but including these in the determination of the daily mean temperature.

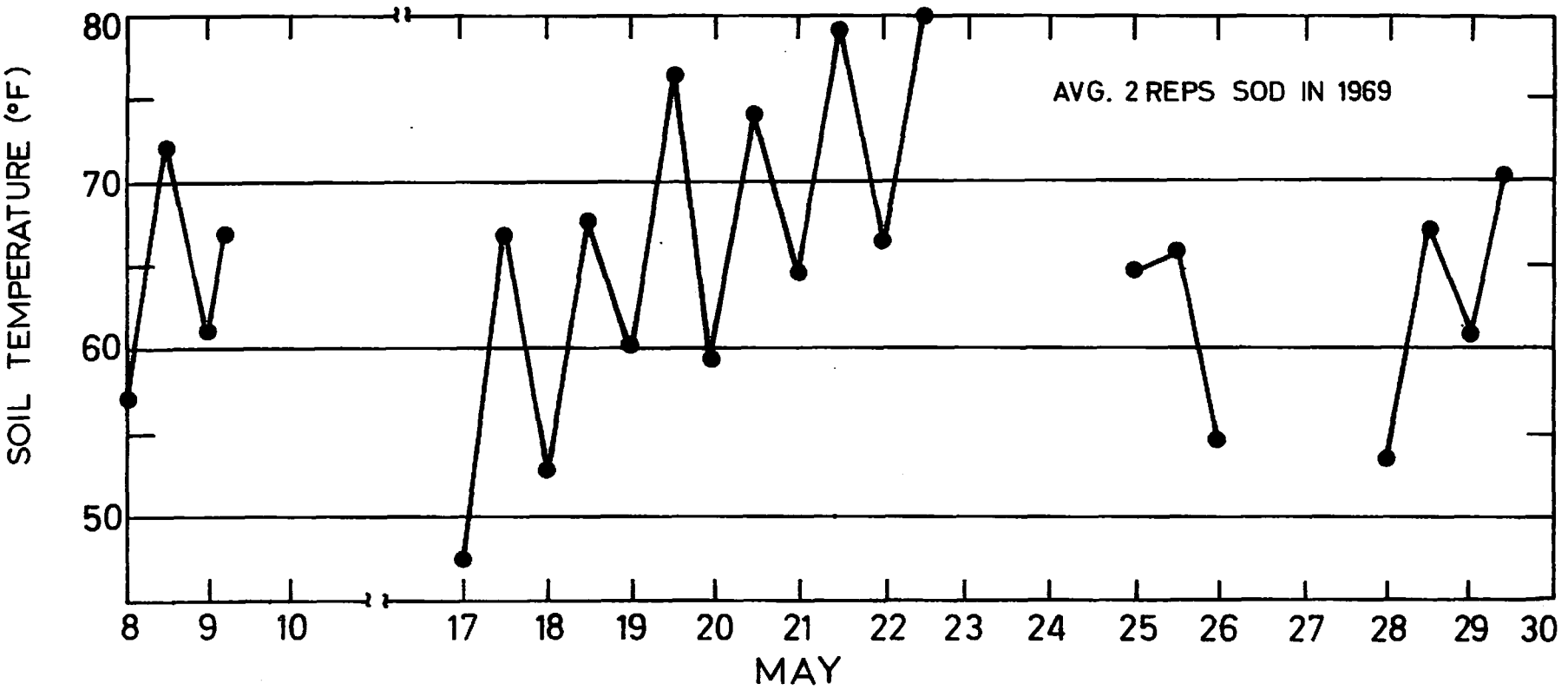
Last Day in Spring with Minimum Temperature - 32° or below : 5/2-20°
28° or below : 4/4-22°

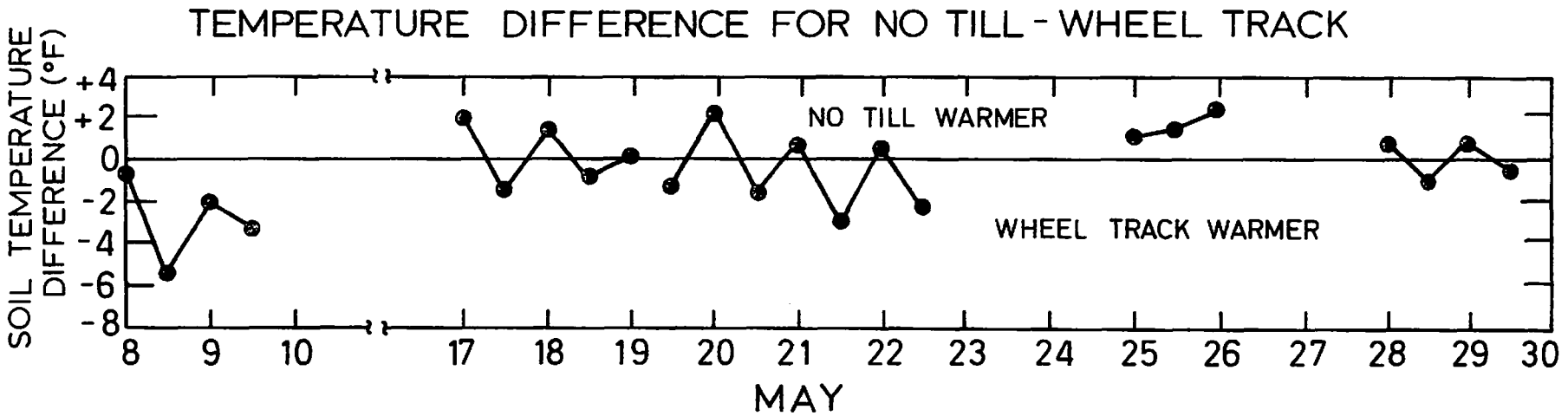
First Day in Fall with Minimum Temperature - 32° or below : 10/4-31°
28° or below : 10/16-25°

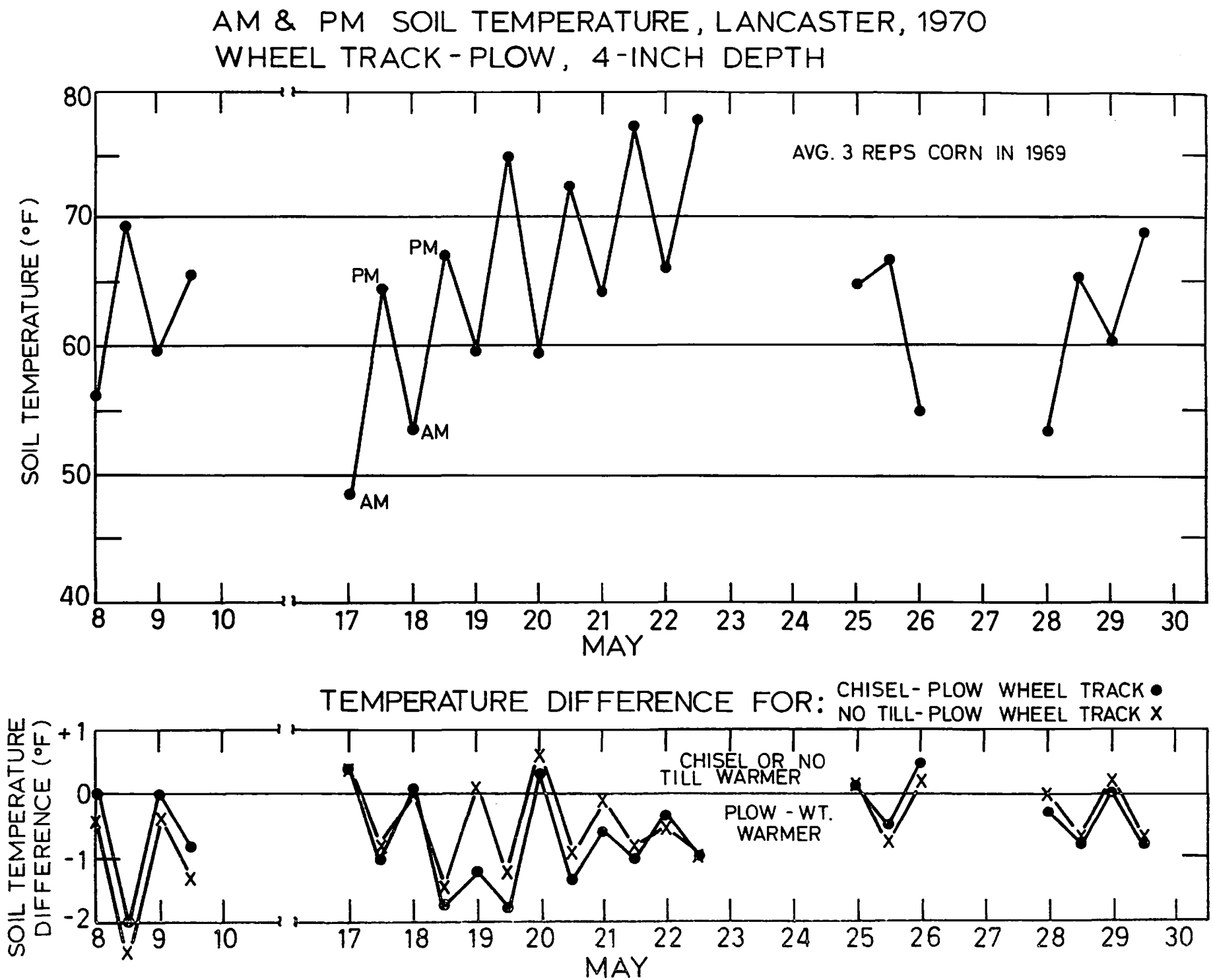
Growing Season above 32° : 155 days.

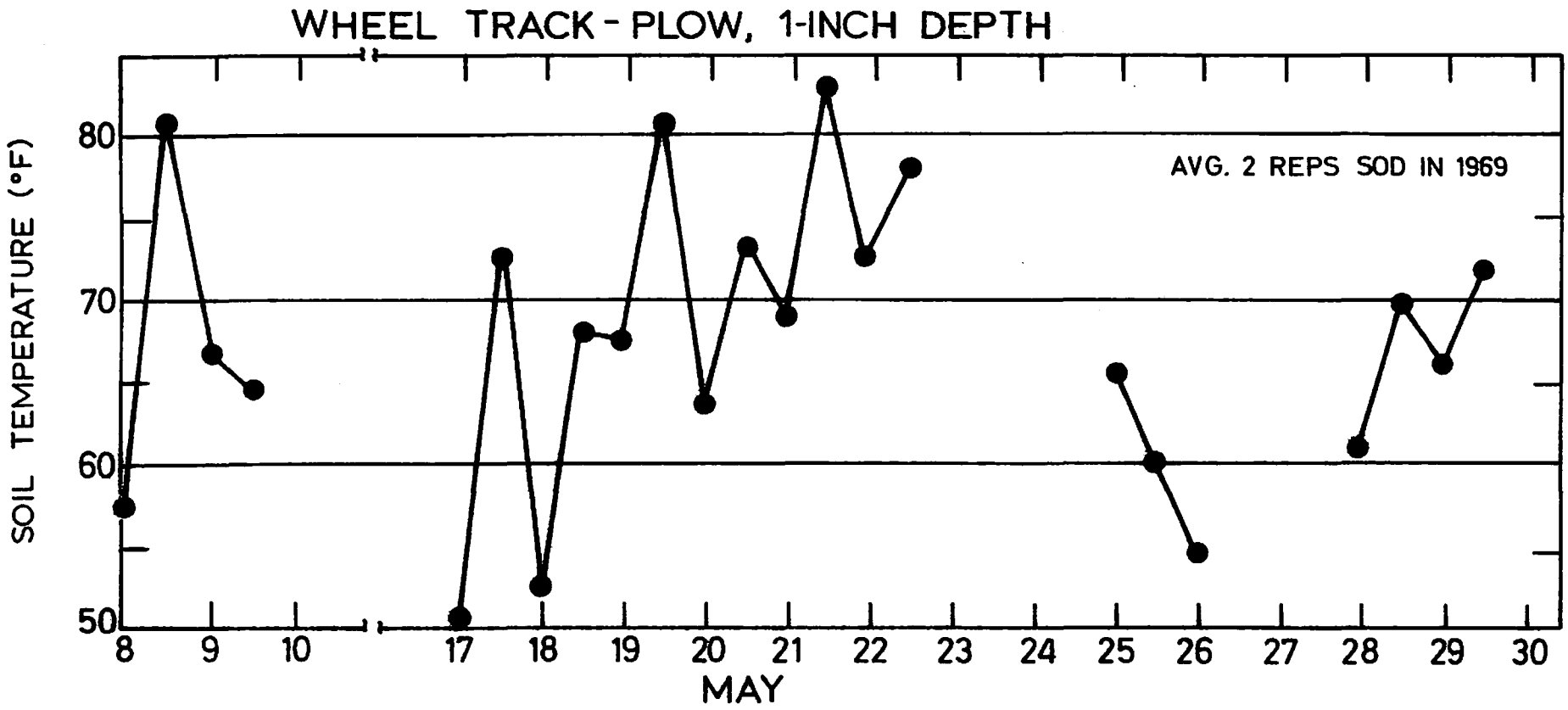
# 1970 TILLAGE EXPERIMENT
## WASECA 4-INCH SOIL TEMPERATURES

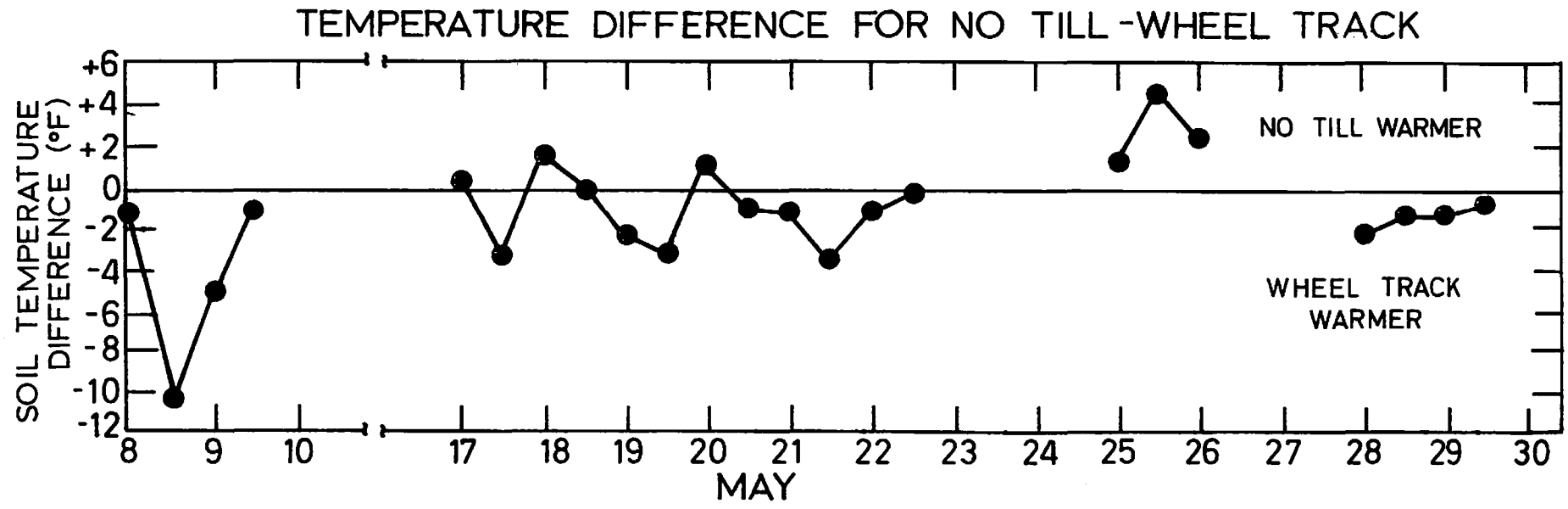



AM & PM SOIL TEMPERATURE, LANCASTER, 1970
WHEEL TRACK-PLOW, 4-INCH DEPTH
AVG. 2 REPS SOD IN 1969
SOIL TEMPERATURE (°F)
80
70
60
50
8
9
10
17
18
19
20
21
22
23
24
25
26
27
28
29
30
MAY


TEMPERATURE DIFFERENCE FOR NO TILL - WHEEL TRACK
SOIL TEMPERATURE DIFFERENCE (°F)
+4
+2
0
-2
-4
-6
-8
NO TILL WARMER
WHEEL TRACK WARMER
8
9
10
17
18
19
20
21
22
23
24
25
26
27
28
29
30
MAY


AM & PM SOIL TEMPERATURE, LANCASTER, 1970
WHEEL TRACK - PLOW, 4-INCH DEPTH
AVG. 3 REPS CORN IN 1969
SOIL TEMPERATURE (°F)
80
70
60
50
40
PM
AM
8 9 10 17 18 19 20 21 22 23 24 25 26 27 28 29 30
MAY
TEMPERATURE DIFFERENCE FOR: CHISEL-PLOW WHEEL TRACK ●
NO TILL-PLOW WHEEL TRACK X
SOIL TEMPERATURE DIFFERENCE (°F)
+1
0
-1
-2
CHISEL OR NO TILL WARMER
PLOW - WT. WARMER
8 9 10 17 18 19 20 21 22 23 24 25 26 27 28 29 30
MAY


WHEEL TRACK - PLOW, 1-INCH DEPTH
AVG. 2 REPS SOD IN 1969
SOIL TEMPERATURE (°F)
80
70
60
50
8
9
10
17
18
19
20
21
22
23
24
25
26
27
28
29
30
MAY


TEMPERATURE DIFFERENCE FOR NO TILL-WHEEL TRACK
NO TILL WARMER
WHEEL TRACK WARMER
SOIL TEMPERATURE DIFFERENCE (°F)
+6
+4
+2
0
-2
-4
-6
-8
-10
-12
8
9
10
17
18
19
20
21
22
23
24
25
26
27
28
29
30
MAY

# SULFUR FERTILIZATION OF KENTUCKY BLUEGRASS

John Grava, D. S. Fairchild, B. D. McCaslin and R. S. Farnham

In the spring of 1970 an experiment was initiated involving the use of sulfur fertilizer on Park Kentucky bluegrass grown for seed production. The plots were set up on Spooner very fine sandy loam located in Lake of the Woods County on E. Helmstetter farm. The soil contained 9 ppm of extractable sulfur (0-3 inch depth), indicating medium sulfur availability. The test is used by the University of Minnesota Soil Testing Laboratory and involves turbidimetric determination of soluble and adsorbed sulfate with barium chloride in monocalcium phosphate (500 ppm P) extracts.

The field had been renovated by plow-back in 1967 and had been burned in fall of 1969. All plots received a uniform application of 90 + 40 + 40 lbs./acre of plant nutrients, expressed as N, $P_2O_5$ and $K_2O$. A randomized block design was used with the two sulfur treatments (0, 20 lbs./acre S) replicated nine times. All fertilizer materials were top-dressed on May 5, 1970. The dimensions of individual plots were 10 by 20 feet. Plant tissue samples were collected at the beginning of the emergence of panicles. The sulfur content of tissue was determined in nitric and perchloric acid digests according to the method described by Blanchar et al.,1965, SSSA Proc. 29:71-72.

Seed yields of bluegrass were not significantly increased by applications of sulfur (table 1). However, the sulfur concentration in bluegrass was increased from 0.25 to 0.30% by the application of 20 lbs. per acre of sulfur. Both values were higher than the 0.23% S considered

to be the "critical level" for mixed perennial grasses (McNaught et al, 1961, New Zealand J. Agr. Research 4:177-196).

Table 1. Effect of sulfur treatment on seed yield and concentration of Kentucky bluegrass tissue, 1970.

| Treatment | Yield of Seed | Sulfur in Grass Tissue |
|---|---|---|
| | lbs./acre | Percent |
| None | 244 | 0.25a |
| 20 lbs./acre of S as $NaSO_4$ | 281 | 0.30b |
| Significance | NS | ** |
| CV | 23 | 8 |

# THE EFFECT OF NITROGEN FERTILIZATION ON SEED YIELD AND CHEMICAL COMPOSITION OF GRASSES WHEN APPLIED ALONE OR WITH PHOSPHORUS AND POTASSIUM 1970

JOHN GRAVA, D.S. FAIRCHILD, B.D. McCASLIN AND R.S. FARNHAM

Most grass seed production fields in northwestern Minnesota receive annual applications of commercial fertilizers. Nitrogen, where used at rates of 90 pounds per acre or less, seems to be used up during the growing season and no carry-over effects are evident in the following crop. However, there is some phosphorus and potassium carry-over as shown by the build-up of P and K soil test levels in the top three inches of soil from topdressed fertilizer.

The objective of this study was to find out whether nitrogen alone would insure high seed yields on soils in which P and K levels have been built up by past fertilization.

In the spring of 1970 two field experiments were established in Lake of Woods county. General information on the experimental sites is given in Table 1. Soil test results are shown in Tables 1 and 3.

TABLE 1 LOCATION, SOIL TYPE, AGE OF STAND AND OTHER INFORMATION CONCERNING THE EXPERIMENTS

| Field Number | Location | Soil Type | Species, Variety | Age of Stand | Burned |
|---|---|---|---|---|---|
| 4 | F. Baade L.O.W. County | Ulen Very fine sandy loam | Timothy, Climax | 4th seed year | May 5, 1970 |
| 5 | E. Helmstetter L.O.W. County | Spooner Very fine sandy loam | K. Bluegrass Park | 1967 plow-back | Fall, 1969 |

TABLE 2. PHOSPHORUS AND POTASSIUM SOIL TEST LEVELS, FIELD NO. 4.

| Depth of Sampling | Extractable P | Exchangeable K |
|---|---|---|
| INCHES | PP 2 M | PP 2 M |
| 0-3 | 24 | 90 |
| 3-6 | 6 | 60 |
| 6-12 | 6 | 50 |

TABLE 3. PHOSPHORUS AND POTASSIUM SOIL TEST LEVELS, FIELD NO. 5.

| Depth of Sampling | Extractable P | Exchangeable K |
|---|---|---|
| INCHES | PP 2 M | PP 2 M |
| 0-3 | 72 | 130 |
| 3-6 | 50 | 90 |
| 6-12 | 10 | 70 |

A randomized block design was used with six treatments replicated seven times. Individual plots were 10 feet wide and 20 feet long. The nitrogen treatments (60, 90, 120 lbs/acre N) were topdressed by hand. The P and K treatments (0+40+40 lbs/acre $P_2O_5$ and $K_2O$) were topdressed with a Gandy spreader. All of these fertilizer treatments were made on May 5, 1970. Plant tissue samples were collected at the beginning of the emergence of heads or panicles Total nitrogen in tissue was determined by the Micro-Kjeldahl method, and the other elements were determined in a multi-element emission spectrophotometer. A strip 17 feet long and 34 inches wide up the center was cut for seed yields.

Seed yields and the N, P, K concentrations in tissue of grasses are reported in Tables 4 and 5.

TABLE 4. THE EFFECT OF NITROGEN FERTILIZATION WHEN APPLIED ALONE OR WITH PHOSPHORUS AND POTASSIUM ON SEED YIELD AND CHEMICAL COMPOSITION OF CLIMAX TIMOTHY F. BAADE, L.O.W. COUNTY

| TREATMENT | | YIELD OF SEED | N | P | K |
|---|---|---|---|---|---|
| N | LBS/ACRE | LBS/ACRE | PERCENT IN DRY MATTER | | |
| | 60 | 288 a | 2.92 a | .35 | 2.45 |
| | 90 | 349 ab | 3.24 b | .37 | 2.42 |
| | 120 | 360 b | 3.34 b | .38 | 2.44 |
| Significance | | * | ** | NS | NS |
| PK | | | | | |
| | None | 338 | 3.31 b | .35 a | 2.31 a |
| | 0+40+40 | 327 | 3.05 a | .38 b | 2.55 b |
| Significance | | NS | * | * | ** |

The seed yield of timothy was increased significantly by increasing the N treatment from 60 to 120 lbs/acre. The N content of tissue from 90 lbs/acre treatment was significantly higher than that in tissue collected from the 60 lbs/acre treatment of nitrogen.

While the 0+40+40 fertilizer treatment did not affect the seed yield, it increased the P and K concentrations in tissue. The N content of tissue was significantly lowered by the PK treatment.

The N X PK interaction (not reported here) was nonsignificant. Thus, the effects of the nitrogen treatments on yield and chemical composition of grass tissue were the same with or without the PK treatment.

TABLE 5 THE EFFECT OF NITROGEN FERTILIZATION WHEN APPLIED ALONE OR WITH PHOSPHORUS AND POTASSIUM ON SEED YIELD AND CHEMICAL COMPOSITION OF PARK KENTUCKY BLUEGRASS. E. HELMSTETTER, L.O.W. COUNTY

| TREATMENT | | YIELD OF SEED | N | P | K |
|---|---|---|---|---|---|
| N | LBS/ACRE | LBS/ACRE | PERCENT IN DRY MATTER | | |
| | 60 | 146 a | 2.59 a | .39 a | 1.96 |
| | 90 | 189 ab | 2.99 b | .40 ab | 1.96 |
| | 120 | 203 b | 3.30 c | .42 b | 1.89 |
| Significance | | * | ** | ** | NS |
| PK | | | | | |
| | None | 170 | 2.92 | 0.39 a | 1.70 |
| | 0+40+40 | 189 | 3.00 | 0.42 b | 2.16 |
| Significance | | NS | NS | ** | NS |

The seed yield, and the N and P contents of bluegrass tissue were increased by increasing the N rate from 60 to 120 pounds per acre. The only effect the 0+40+40 fertilizer treatment had was an increased content of P in tissue.

The N X PK interaction was nonsignificant. Thus, the effects of the nitrogen treatments on yield and the N,P,K content of grass tissue were the same with or without the PK treatment.

# TRACE ELEMENT STUDY WITH KENTUCKY BLUEGRASS ON PEAT - 1970[1]

John Grava, D. S. Fairchild, B. D. McCaslin and R. S. Farnham

In 1968 an investigation was initiated to determine whether the seed yields of grasses can be increased by fertilization with trace elements. A second objective of this study was to determine what effect would trace element additions to various soils have on the chemical composition of grass tissue. There were three reasons for this:

1. Judging from the keen interest in trace element needs shown by farmers of other areas of the state, it was expected that sooner or later the grass seed producers of northwestern Minnesota would raise similar questions.
2. Previous investigations had shown that the copper content of grass tissue grown on peat was well below the critical concentration, and lower than the content in tissue from mineral soils.
3. Some beef producers in the area had expressed concern about the quality of forage, especially the trace element content of hay produced on peat soils.

In 1968, four field experiments were conducted in Roseau and Lake of the Woods counties. Boron (B), copper (Cu), manganese (Mn) and zinc (Zn) treatments were made to bluegrass and timothy on mineral

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[1] See"A Report on Field Research in Soils", Soil Series 84, March 1969, pp. 172-176, and Soil Series 86, March 1970, pp. 133-138 for results obtained from similar investigations conducted in 1968 and 1969.

and peat. No yield increases were obtained. In one trial on mineral soil boron decreased bluegrass seed yield by about 100 pounds per acre. The concentration of trace elements in tissue was not affected on some fields. Therefore, the rates of Mn and Zn were doubled in the 1969 and 1970 trials.

In 1969, seed yields of grasses were not affected by trace element treatments on mineral soils. On peat, however, the yield of bluegrass was increased by 124 pounds per acre with the combined treatment of all four trace elements. Copper alone increased the seed yield on this soil by 60 pounds per acre. The trace element contents in grasses were increased with the rates used on organic as well as on mineral soils. The copper content of bluegrass tissue on peat was increased to 8 ppm by an application of 50 lbs/acre of copper sulfate. Only 2 or 3 ppm of Cu were found in tissue without the copper treatment. According to studies conducted elsewhere, when the plant tissue contains less than 6 ppm Cu, responsive crops are likely to show copper deficiency.

Copper, when used in the sulfate form, is rather expensive. The cost of 50 lbs/acre of copper sulfate is about $17. Copper chelate treatments, if effective, would cost only about $6 per acre. For this reason the copper chelate as well as copper sulfate forms were used in the 1970 trials.

In 1970, three field experiments with Kentucky bluegrass and timothy were conducted to study the effects of trace element applications on seed yields and chemical composition of tissue. All materials were top-dressed on established stands of grasses on growers' fields. General information on the experimental sites is given in Table 1, and soil test results are shown in Table 2.

Table 1. Location, age of stand and other information concerning the experiments.

| Field No. | Location | K. Bluegrass variety | Age of Stand | Burned |
|---|---|---|---|---|
| 1. | Ed Baumgartner Roseau County | Park | 1968 seeding | Fall 1969 |
| 2. | C. Habstritt Roseau County | Park | 1968 seeding | No |
| 3. | Earl Swenson Clearwater County | Merion | 1968 seeding | No |

Table 2. Extractable copper and zinc in the top three inches of soil.

| Location | Copper* ppm | Zinc* ppm |
|---|---|---|
| Field 1 | 0.1 | 2.2 |
| Field 2 | 0.7 | 2.2 |
| Field 3 | 0.3 | 5.1 |

* Extracted with 0.01 M EDTA-1.0 M $(NH_4)_2CO_3$. This solution is used by the University of Minnesota Soil Testing Laboratory in the test for zinc. Extracts are analyzed on the atomic absorption spectrophotometer.

A randomized block design was used with six treatments replicated seven times.

Following amounts and sources of trace elements were used:

| Treatment | Rate and Material |
|---|---|
| 1. None | --- |
| 2. Copper sulfate | 50 lbs./acre $CuSO_4 \cdot 5H_2O$. |
| 3. Copper chelate | 1 or 2 lbs./acre of sequestrene copper chelate, 13% Cu.* |
| 4. Zinc sulfate | 50 lbs./acre $ZnSO_4 \cdot H_2O$ |
| 5. Copper sulfate + zinc sulfate | Same as above |
| 6. Copper chelate + zinc sulfate | Same as above |

* 1 lb/acre rate of Cu - chelate was used on fields 1 and 2; field 3 received 2 lbs/acre of Cu - chelate.
All trace elements were applied on May 5, 1970. The copper sulfate and zinc sulfate were spread by hand. The copper chelate was dissolved in water and applied with a funnel-top sprayer.

All treatments received a uniform application of the following plant nutrients, expressed as N, $P_2O_5$, $K_2O$ in lbs./acre: Field No. 1, 15 + 60 + 60 fall 1969; Field No. 2, 10 + 60 + 40, fall 1969; Field No. 3, 12 + 48 + 48, May 5, 1970.

The individual plots were 10 feet wide and 20 feet long. Plant tissue samples were collected at the beginning of the emergence of panicles. Contents of the four trace elements were determined in a multi-element emission spectrophotometer. A strip 17 feet long and 34 inches wide up the center was cut for seed yields.

Table 3. Effect of trace element applications on the seed yield of Kentucky bluegrass on peat, 1970.

| Treatments of trace elements | Field 1 Park (E.B.) | Field 2 Park (C.H.) | Field 3 Merion (E.S.) |
|---|---|---|---|
| | Yield of seed, lbs./acre | | |
| 1. None | 184 | 354 | 260 |
| 2. Copper sulfate | 180 | 397 | 285 |
| 3. Copper chelate | 179 | 326 | 314 |
| 4. Zinc sulfate | 176 | 346 | 294 |
| 5. Cu-sulfate + Zn-sulfate | 188 | 367 | 300 |
| 6. Cu-chelate + Zn-sulfate | 165 | 360 | 285 |
| Significance | N.S. | N.S. | N.S. |
| CV | 23 | 20 | 18 |

Table 4. Effect of trace element applications on the chemical composition of Kentucky bluegrass tissue grown on peat, 1970. Field 1, Park, E. B.

| Treatment | B | Cu | Mn | Zn |
|---|---|---|---|---|
| | Parts per million in dry matter | | | |
| 1. None | 10 | 2 | 45c | 27ab |
| 2. Cu-sulfate | 9 | 6 | 41ab | 26a |
| 3. Cu-chelate | 10 | 3 | 41ab | 29abc |
| 4. Zn-sulfate | 10 | 3 | 44bc | 31bc |
| 5. Cu-sulfate + Zn-sulfate | 10 | 5 | 41ab | 31bc |
| 6. Cu-chelate + Zn-sulfate | 9 | 4 | 39a | 32c |
| Significance | N.S. | N.S. | * | * |
| CV | 12 | 108 | 8 | 11 |

Table 5. Effect of trace element applications on the chemical composition of Kentucky bluegrass tissue grown on peat, 1970. Field 2, Park, C.H.

| Treatment | B | Cu | Mn | Zn |
|---|---|---|---|---|
| | Parts per million in dry matter | | | |
| 1. None | 12 | 1a | 79 | 31ab |
| 2. Cu-sulfate | 13 | 4bc | 76 | 30a |
| 3. Cu-chelate | 14 | 4bc | 82 | 31ab |
| 4. Zn-sulfate | 13 | 2ab | 73 | 33ab |
| 5. Cu-sulfate + Zn-sulfate | 12 | 5c | 65 | 34b |
| 6. Cu-chelate + Zn-sulfate | 12 | 5c | 73 | 37c |
| Significance | N.S. | ** | N.S. | ** |
| CV | 13 | 50 | 17 | 10 |

Table 6. Effect of trace element applications on the chemical composition of Kentucky bluegrass tissue grown on peat, 1970. Field 3, Merion, E.S.

| Treatment | B | Cu | Mn | Zn |
|---|---|---|---|---|
| | Parts per million in dry matter | | | |
| 1. None | 12 | 2a | 66 | 33a |
| 2. Cu-sulfate | 12 | 10bc | 63 | 33a |
| 3. Cu-chelate | 11 | 6ab | 59 | 33a |
| 4. Zn-sulfate | 12 | 2a | 60 | 43b |
| 5. Cu-sulfate + Zn-sulfate | 12 | 11c | 58 | 44b |
| 6. Cu-chelate + Zn-sulfate | 12 | 5a | 59 | 46b |
| Significance | N.S. | ** | N.S. | ** |
| CV | 12 | 67 | 10 | 10 |

Seed yields of bluegrass grown on peat were not affected by applications of copper sulfate, copper chelate or zinc sulfate (Table 3).

Effects of trace element treatments on the chemical composition of grass tissue are shown in Tables 3, 4 and 5.

Copper

On Field 1 (Table 4), the grass tissue had only 2 ppm of Cu. Copper treatments resulted in slight, but nonsignificant, increases in the concentration of copper.

On Field 2 (Table 5), the grass tissue from check plots contained only 1 ppm Cu. Copper content was increased to 4 or 5 ppm by the copper treatments. The application of 1 lb/acre of Cu-chelate was as effective as the 50 lbs./acre of Cu-sulfate treatment in affecting the copper concentration of Park K. bluegrass on this field.

On Field 3 (Table 6), the copper content of Merion K. bluegrass tissue was increased from 2 ppm to 10 or 11 ppm by application of 50 lbs./acre of Cu-sulfate. Cu-chelate, applied at 2 lbs./acre increased copper in tissue to 5 or 6 ppm.

Zinc

The concentration of zinc in bluegrass tissue was increased at all three locations with the application of 50 lbs./acre of zinc sulfate.

# THE COMPARATIVE EFFECT OF TWO NORTH DAKOTA LIGNITE BASE REINFORCED FERTILIZERS ON LAWN GRASS GROWTH IN 1970

J.M. MacGregor and B.D. McCaslin

The possible use of lignite extracted from North Dakota beds as a suitable organic material for the incorporation of additional fertilizer nutrients to be sold for lawn turf improvement was studied. Two grassed areas in the village of Falcon Heights were employed to compare available fertility present in these to similar amounts present in the usual mineral base fertilizers. Four replications of 11 fertility treatments were laid out in 10' x 15' plots on each of two fields with no supplemental sprinkling facilities. A comparable mix of ammonium nitrate (33-0-0), superphosphate (0-46-0) and nitrate of potash (0-0-60) to supply a 12-5-5 mineral fertilizer mixture was used for comparison. The three fertilizer materials were then broadcast to supply a total fertility equivalent of 24 lbs per 1000 sq. ft. of the 12-5-5 mineral mixture; of the lignite based 12-5-5, and of the 10-10-5 in either 1,2, or in 3 treatments (May,May and late June; May, late June, and mid-August.) In addition to these treatments, an extra heavy treatment was made of the 12-5-5 lignite base fertilizer was applied at the 24 pound rate in both the May and late June applications, making a total of 48 pounds per 1000 sq. ft. of lawn area. Each of the 11 treatments was replicated four times in a randomized block design on the two grassed areas. Clippings were harvested when appropriate and green weights were recorded.

The weights of grass clippings in pounds per plot are shown in Tables 1 & 2.

1.
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TABLE 1.

GREEN WEIGHTS OF LAWN GRASS CLIPPINGS DURING 1970 FOLLOWING FERTILIZATION WITH COMMERCIAL SPECIALTY FERTILIZER OR WITH ONE OF TWO NORTH DAKOTA LIGNITE BASE FERTILIZER MIXTURES. (average of 4 replications)

(U. Farm lawn - fertilized May 24th, June 28th, and August 22nd)

| Lbs per / 1000 sq. ft. per application | Fertilizer N $P_2O_5$ $K_2O$ | Date of Clipping 6/2 | 6/17 | 7/1 | 8/10 | 8/21 |
|---|---|---|---|---|---|---|
| | | pounds of green clippings per plot | | | | |
| None | None | 1.8 a | 2.7 a | 1.1 a | 3.2 a | 1.0 a |
| 8+8+8 | 12-5-5 (commercial) | 3.6 bc | 5.2 bc | 1.2 ab | 9.2 bc | 1.4 a |
| 8+8+8 | 12-5-5 (lignite base) | 3.7 bc | 5.3 bc | 1.2 ab | 8.5 bc | 1.4 a |
| 8+8+8 | 10-10-5 (lignite base) | 3.0 b | 4.9 b | 1.3 ab | 7.5 b | 1.2 a |
| 12+12 | 12-5-5 (commercial) | 3.5 bc | 7.4 c | 2.6 c | 12.8 d | 1.8 a |
| 12+12 | 12-5-5 (lignite base) | 4.0 cde | 6.3 bc | 1.7 abc | 12.4 d | 1.8 a |
| 12+12 | 10-10-5 (lignite base) | 3.7 bcd | 6.6 bc | 1.4 ab | 10.9 cd | 1.6 a |
| 24 | 12-5-5 (commercial) | 4.3 cde | 11.3 d | 2.6 e | 9.1 bc | 1.5 a |
| 24 | 12-5-5 (lignite base) | 4.1 cde | 11.7 d | 2.9 c | 8.4 bc | 1.3 a |
| 24 | 10-10-5 (lignite base) | 4.9 e | 11.1 d | 2.4 bc | 7.4 b | 1.4 a |
| 24+24 | 12-5-5 (lignite base) | 4.6 de | 11.2 d | 2.8 c | 21.5 e | 3.3 b |

Values (in vertical columns) followed by the same letters are not significantly different at the same level.

TABLE 2.

GREEN WEIGHTS OF LAWN GRASS CLIPPINGS DURING 1970, FOLLOWING FERTILIZATION WITH COMMERCIAL SPECIALTY FERTILIZER OR WITH ONE OF TWO NORTH DAKOTA LIGNITE BASE FERTILIZER MIXTURES ( average of 4 replications)

(MacGregor lawn - fertilized May 5th, June 29th, and August 21st)

| Lbs/1000 sq. ft. /application | Fertilizer N $P_2O_5$ $K_2O$ | DATE OF CLIPPING | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 5/3 | 5/19 | 5/28 | 6/2 | 6/16 | 7/1 | 7/30 | 8/14 | 9/4 |
| None | None | 3.4 N.S. | 2.6 a | 3.1 a | 1.4 a | 2.8 a | 1.5 a | 1.4 a | 1.7 a | 1.2 a |
| 8+8+8 | 12-5-5 (commercial) | 4.0 N.S. | 3.6 ab | 4.5 b | 2.3 b | 42 ab | 2.0 ab | 4.1 bcd | 3.8 cde | 2.0 ab |
| 8+8+8 | 12-5-5 (lignite base) | 3.5 N.S. | 3.4 ab | 4.7 bc | 2.3 b | 4.3 ab | 2.0 ab | 3.6 bc | 3.4 bcd | 1.5 ab |
| 8+8+8 | 10-10-5 (lignite base) | 3.4 N.S. | 3.5 ab | 4.7 bc | 2.2 b | 3.9 ab | 2.0 ab | 3.3 ab | 3.1 bc | 1.6 ab |
| 12+12 | 12-5-5 (commercial) | 3.8 N.S. | 3.6 ab | 5.4 bc | 3.0 c | 5.4 b | 2.y bc | 5.9 de | 5.0 e | 2.4 b |
| 12+12 | 12-5-5 (lignite base) | 03.8 N.S. | 4.0 ab | 5.6 bc | 2.9 bc | 4.7 ab | 2.0 ab | 4.3 bcd | 4.4 de | 1.9 ab |
| 12+12 | 10-10-5 (lignite base) | 04.1 N.S. | 4.0 ab | 5.9 c | 3.0 c | 5.3 b | 2.5 bc | 5.2 cde | 4.8 e | 2.1 ab |
| 24 | 12-5-5 (commercial) | 4.2 N.S. | 4.5 b | 7.3 d | 4.4 d | 8.3 cd | 4.0 e | 2.6 ab | 2.5 ab | 1.6 ab |
| 24 | 12-5-5 (lignite base) | 3.8 N.S. | 4.6 b | 7.4 d | 4.8 d | 8.3 ce | 3.5 de | 2.4 ab | 2.2 ab | 1.3 a |
| 24 | 10-5-5 (lignite base) | 3.1 N.S. | 4.0 ab | 7.3 d | 4.5 d | 7.0 c | 3.1 dd | 2.5 ab | 2.2 ab | 1.2 a |
| 24+24 | 12-5-5 (lignite base) | 4.3 N.S. | 4.8 b | 7.9 d | 5.0 d | 9.2 d | 4.0 e | 6.2 e | 7.3 f | 3.5 b |

NS - Not significant

Values (in vertical columns) followed by the same letters are not significantly different at the same level.

Green clipping weights showed that the two lignite base fertilizers were not superior to equivalent amounts of the same nutrients present in the commonly used mineral commercial lawn fertilizers. Therefore, they would be competitive with the present specialty lawn fertilizers only if they could be manufactured at the same or at lower cost and sold at approximately the same price.

The application of the large amounts of fertilizer at one time, or split into two or three treatments during the growing season produced much the same result with all three fertilizers. Where the 24 lb/1000 sq. ft. was applied all at one time initial grass growth was very rapid in comparison to that produced by the splitting the treatment for later application(s). However, by early September grass growth with all three methods of fertilization was not significantly different.

Growth on plots receiving the extra heavy lignite base fertilizer treatment (24 + 24 of 12-5-5) was significantly greater and remained at a significantly higher production level even at the close of the growing season.

# SOILS WITH FRAGIPANS IN WEST CENTRAL MINNESOTA

R. H. Rust, P. P. Antoine, and E. R. Gross

Field studies have been continued on plots established in 1966 at Sebeka in Wadena Co. located on Rockwood and Blowers sandy loams. (Typic and Aquic Fragiboralfs).

A satisfactory growth of alfalfa and bromegrass has been maintained for 4 years on this soil with a fragipan at about 26 inches. The 4 year average yield is 3.4 tons per acre (adjusted to 15% moisture). Plant analyses indicate that supplemental P (40 lbs/acre/yr) and K (120 lbs/acre/yr) has been sufficient to maintain P content of alfalfa at 0.24% and K at 2.0%. The supplemental (annual) P and K treatment produces an additional 1 T/A yield. However, plant analysis also indicated that the plant content of Ca, Fe, Mg, Zn, Cu, and B were lower-by-half than in previous years. Boron deficiency was evident in mature plants for the first time in 1970. Protein content (8.7%) compared to the previous year, was less-by-half.

One of the objectives of the study has been to ascertain the problems in establishing and maintaining satisfactory alfalfa, or alfalfa-brome, hay and pasture on soils with fragipan. It seems fairly evident that an initial high fertility input (lime + P + K + S) is necessary. Maintenance of quality stand over a 3-5 year period depends on annual increments of P and K and probably boron and sulphur. The early and rapid growth of an adequately fertilized legume-grass will remove the perched water table by May 15 in most years. The rooting zone of the alfalfa-brome mixture does not extend into the fragipan to any appreciable extent, so the "spreading-root" alfalfa varieties performed little or no better than the usual "tap-rooted"

varieties.

A preliminary experiment in flooding demonstrated that the soil could be saturated to the fragipan but, after 48 hours, the fragipan and the soil horizon below remained at less than field capacity.

Three years of continuous soil temperature monitoring were completed in May, 1970. Temperatures are measured at 6, 15, and 27 inches. Winter soil temperatures from December 15 - April 15 were nearly constant as a result of continuous snow cover and remained at about 34-37° F.

Mineralogical and micro-morphological studies of the fragipan lead to the conclusion that silicate clay is the principal bonding agent in the fragipan but that Al and Fe oxides as coatings on structural pieces also reinforce bridging between particles.

The nature of and depth to the fragipan as such preclude, at present, any economical amelioration. Calcareous soil materials are commonly below the fragipan in the Wadena drumlin areas and would be satisfactory materials in or near the rooting zones if economical mechanical means were available to incorporate them.

# IRRIGATED CORN FOLIAR LEAF ANALYSES

H. L. Meredith and J. O. Jacobson

Foliar analyses have been used to compare nutrient values in the vegetative tissue and hence have provided a limited knowledge of possible visibly observed differences. The studies discussed here will concern only corn. Typically, tissue values have been based on an optimal or minimal level at "silking". For numerous reasons, fields cannot be sampled exactly at silking. Droughty conditions at this critical time in the development of the corn plant often result in low tissue values, especially for those elements moving to the root surfaces by the diffusion mechanism, particularly P and K.

During the 1970 growing season, corn leaves were sampled at nine different dates from June 30 until September 17. The hybrid was a single cross 83-day relative maturity. Samples were taken from two locations. Planting date was May 2. No fewer than 10 samples made up the single composite sample at each location and date. Plant selection was taken from the "middle" of the plant at all sampling dates. This corresponded to the 6th leaf from the top or ultimately the ear leaf. Leaves were counted from the bottom and top to ensure the same corresponding leaf was sampled at different stages of development.

The data appear in Table 1. In general, the soil moisture levels were below "field capacity" and above the "wilting point" throughout the growing season. Sampling was accomplished following irrigation from one to five days. The temperature during the growing season was

much above seasonal normal. Even though soil moisture was adequate, the plants were under moisture stress as evidenced by cellular turgidity. Transpiration exceeded moisture uptake under these conditions due to high temperature.

The data indicate a seemingly broad plateau for those elements normally included in fertilizers. The fertility level at both locations was quite "average". The relatively high value for phosphorus is likely due to the higher diffusion rate occurring under warm-moist conditions, high native phosphorus levels and coarse textured soil.

Table 1. Foliar composition from an irrigated single-cross 83-day relative maturity hybrid sampled at nine sampling dates during the growing season. Verndale, Minnesota.

Corn Sampling
Ear Leaf
Irrigated Corn
Staples, Minn.

| 1970 | 6/30 | 7/7 | 7/15 | 7/21 | 7/30 | 8/14 | 8/18 | 9/3 | 9/17 |
|---|---|---|---|---|---|---|---|---|---|
| Element | | | | | | | | | |
| Phosphorus (P) | .46 | .35 | .36 | .36 | .39 | 40 | 42 | .26 | .19 |
| Potassium (K) | 3.4 | 2.9 | 2.0 | 2.2 | 2.1 | 1.8 | 2.1 | 1.9 | 1.3 |
| Calcium (Ca) | .34 | .39 | .43 | .42 | .52 | .50 | .85 | .90 | .78 |
| Magnesium (Mg) | .16 | .18 | .22 | .21 | .25 | .25 | .32 | .34 | .29 |
| Iron (Fe) | 176 | 236 | 191 | 201 | 237 | 233 | 325 | 425 | 500 |
| Zinc (Zn) | 22 | 29 | 32 | 22 | 23 | 24 | 19 | 25 | 12 |
| Copper (Cu) | 2.7 | 4.2 | 4.7 | 3.5 | 6.0 | 4.3 | 7.5 | 4.9 | 5.1 |
| Molybdenum (Mo) | 2.9 | 3.6 | 9 | 7 | 7.6 | 8.2 | 5 | 5 | 9.6 |
| Manganese (Mn) | 56 | 51 | 60 | 46 | 61 | 46 | 63 | 68 | 62 |
| Boron (B) | 19 | 9 | 16 | 14 | 9.3 | 14 | 11 | 8 | 10 |
| Nitrogen (N) | 3.74 | 3.58 | 3.07 | 2.91 | 2.72 | 2.79 | 2.77 | 1.36 | 1.22 |

The corresponding physical development to dates of sampling is as follows:

| Date | Physical Development | Date | Physical Development |
|---|---|---|---|
| 6/30 | 18" high* | 8/4 | 90% silk |
| 7/7 | 36" high | 8/18 | Late milk, early dough |
| 7/15 | Tasseled | 9/3 | Mature |
| 7/21 | 40% silk | 9/17 | Fully mature |
| 7/30 | 70% silk | | |

*Indicates average extension of all leaves of plant.

A second study involved sampling all leaves of the corn plant, same hybrid and growing condition as previously described.

This study was prompted by a September 10 sampling of a 95-day relative maturity hybrid in 1969. The values were interesting, Table 2.

Table 2. Foliar composition of a single-cross 95-day relative maturity hybrid grown under irrigated conditions, Verndale, Minnesota, 1969, fully dented and all leaves green and functioning.

| Leaf No.* | Percent | | | | | Parts Per Million | |
|---|---|---|---|---|---|---|---|
| | N | P | K | Ca | Mg | Zn | B |
| 1 | 2.2 | .23 | 1.1 | 1.2 | .22 | 56 | 11 |
| 2 | 2.2 | .30 | 1.5 | 1.1 | .27 | 59 | 9.0 |
| 3 | 2.5 | .34 | 1.6 | 1.0 | .31 | 52 | 8.4 |
| 4 | 3.0 | .49 | 1.6 | 1.0 | .37 | 49 | 7.9 |
| 5 | 3.0 | .50 | 1.8 | .86 | .36 | 41 | 6.6 |
| 6(ear leaf) | 2.7 | .43 | 2.0 | .84 | .34 | 27 | 5.0 |
| 7 | 2.7 | .39 | 2.4 | 1.0 | .42 | 24 | 5.5 |
| 8 | 3.0 | .43 | 2.3 | .93 | .39 | 28 | 5.2 |
| 9 | 2.6 | .32 | 2.4 | .84 | .39 | 18 | 4.2 |

*Counting from top to bottom of plant.

In 1970 corn tissue was sampled at four different dates at two locations from July 15 to August 20.

All of the leaves were sampled starting at the top of the plant, Table 3.

Table 3. Averaged irrigated corn leaf values, sampled at two locations and four sampling periods July 15-August 20, Verndale, Minnesota, 1970.

| | Percent | | | | | Parts Per Million | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Leaf No.** | N | P | K | Ca | Mg | Zn | Cu | Mo | Mn | B |
| 1 | 3.07 | .33 | 1.3 | .59 | .22 | 69 | 4.6 | 7.8 | 73 | 18 |
| 2 | 2.91 | .37 | 1.6 | .58 | .22 | 58 | 5.1 | 7.6 | 69 | 18 |
| 3 | 2.93 | .36 | 1.5 | .59 | .27 | 48 | 6.0 | 8.7 | 59 | 17 |
| 4 | 3.08 | .40 | 1.8 | .59 | .26 | 34 | 4.5 | 8.0 | 56 | 12 |
| 5 | 2.99 | .39 | 1.9 | .56 | .26 | 27 | 5.3 | 8.6 | 56 | 13 |
| 6 | 2.93 | .40 | 2.1 | .59 | .29 | 21 | 5.2 | 9.7 | 56 | 12 |
| 7 | 2.84 | .38 | 2.0 | .57 | .29 | 19 | 4.0 | 9.7 | 50 | 13 |
| 8 | 2.94 | .35 | 2.1 | .66 | .33 | 15 | 4.8 | 9.7 | 53 | 12 |
| 9 | 2.81 | .35 | 2.4 | .72 | .41 | 14 | 3.5 | 10 | 57 | 16 |
| 10 | 2.62 | .31 | 2.6 | .85 | .46 | 14 | 3.5 | 11 | 61 | 15 |

**Counting from top to bottom of plant.

Plant tissue analyses indicate neither the leaf selected nor the time of sampling is critical. One should use discretion when sampling corn tissue for foliar analyses. Selection of leaves near the middle of the plant regardless of maturity level will provide data of value.

# The Effect of Some Dry Ashing Factors on the Elemental Composition of Plant Tissue as Analyzed by Emission Spectroscopy

by

Robert C. Munter and Gary C. Halvorson

A review of the literature on method involving dry ashing shows a wide variety of recommended ashing temperatures (450° to 650°) and times (2 to 16 hours) for various elements. Acid pretreatments, including nitric acid treatments of ash have also been suggested. Sample weights and dilution of the sample ash must be sometimes be varied. Some samples have a high residual carbon remaining in the ash, and there is concern whether the oxidation was sufficient to release the elements sought.

This study is an attempt to measure some of these effects and also to arrive at some measure of variability that one can expect for the different elements. The primary objective was to establish the lowest temperature and shortest length of ashing time possible and yet obtain maximum elemental extraction form the ash. Parts of this study was carried out at different times so different samples were sometimes used to measure the different effects. Solutions of the sample ash were analyzed on a Jarrell Ash 1.5 meter spark emission, direct reading, spectrograph. The data was analyzed statistically by use of the computing centers SP33 analysis of variance program. Treatment means, overall means, coefficients of variability, and significance testing results are shown in tables 1 and 2.

## Effect of Temperature

Copper and Zn were the only elements to be affected to a significant degree as the maximum temperature of the muffle furnace was in-

creased from a low of 475° C to a high of 625° C. Throughout this range Cu decreased from 11.8 to 5.8 ppm due to volatilization as shown in Table 1 under "Effect of temperature". Line increased nearly 20% upon reaching 625° C. Because of this abrupt increase and some inconsistency among the means, this data should be viewed with caution. Although not significant, K, Ca, Mg, and B show a slight decrease with increasing temperature.

Effect of Nitric Acid Treatment of Ash

The ash from the corn leaf sample used in studying this effect contained a considerable amount of residual carbon even after ashing at 575° C for 10 hours. The ash was saturated with a few drops of concentrated nitric acid and heated on a hot plate to near dryness. The treated samples were again placed in the muffle furnace for 2 hours at 525° C. No residual carbon remained after this treatment. The results of the significance test in table 1 under "Effect of acid Treatment", show a significant increase in Al and a highly significant decrease in Cu and boron. The treatment means for Cu and B were reduced by two-thirds. For most of the other elements the means for the acid treatment are somewhat lower but not of significance.

Effect of Dilution

The treatment means in Table 1 under "Effect of Dilution" show a slight decrease in the concentration for all elements with the greater dilution of the ash. Aluminum and boron are the only elements that show a significant decrease. A large difference occurs between the means for Zn, but was not significant due to the large variability that occurred within the treatments. In general a greater dilution is expected to decrease spectrochemical interferences. The 5 and 10 fold dilutions consisted of the additional of 2.5 and 5.0 ml of 0.5% Li-Hcl solution to the ash from

0.5 g sample. Some of the variability may be due to the lower accurracy and precision in the semi-automatic pipetting of 2.5 ml as compared to 5 ml. The addition of 5 ml of 0.5% Li - HCl to the ash form a 0.5 g sample is preferred in our situation. The 0.5% Li - HCl solution used is a standard mixture used for all analysis by this spectrograph. The acidity is about 1.02 N.

Effect of Sample Weight

Table 1 under "Effect of sample Weight", shows no significant differences between the concentration of elements between ashing a 0.5 g or a 1.0 g sample. The whiter ash from a 0.5 sample did not result in higher values. The muffle furnace used has a capacity of 196 samples and because of the large amount of smoke generated, 0.5 g samples are preferred. The minimum weight of plant tissue that will yield a sufficient concentration for analysis would in general be about 0.1 g with the ash dissolved in 1 ml of acid solution. Sampling and contamination errors would be expected to increase with a decrease in sample size.

Effect of Ashing Time

Table 2 shows that there are no significant differences in concentration between ashing at maximum temperature for 3 or 10 hours, or 10 and 20 hours. The treatment mean for Cu at 20 hours is considerably lower than for 10 hours, but is not significant because of the high degree of variability. The c.v. for Cu is 18.6%. The shorter ashing time would therefore be recommended not only because of economics but would thus enable one to routinely ash samples during daily working hours. In the past samples were ashed only in the evening with a timer controlling the length of the ashing period.

Summary

Although this study was limited in several areas it provided some essential background information regarding the variables studied including some indication of variability. It must be kept in mind that the variability shown is partially the result of the different treatments. The variability actually occurring in a routine situation would be expected to be less. Following are some general conclusions arrived at.

1. Most elements were not significantly affected increasing the ashing temperature from 475° C to 625°C.
2. Copper decreased significantly with increased temp., highest values at 475 °C.
3. Recommended ashing temperature is 475 - 500°C
4. No difference found between 3 or 20 hours at maximum temperature.
5. Longer ashing times did not result in more complete oxidation of samples that have a high carbon residue in the ash.
6. No essential difference between sample weights and dilutions were found.
7. Aluminum increased, but Cu and B losses were great when the ash was treated with nitric acid and re-muffled.
8. Treating a dark colored ash with nitric acid and heating on a hot-plate, not re-muffled, did not result in an increase nor a decrease for any of the elements.
9. The order of variability giving the average of all coefficients of variability for all treatments is as follows:

Cu 10.5 > Zn 10.1 > Mo 8.7 > Sr 8.1 > Al 4.4 > Ca 4.3 > Mg 3.7 = K 3.7 > Mn 3.6 > P 3.3 = B 3.3

TABLE 1

Means, Coefficients of Variability, and Significance Test for 12 Elements in "Effect of Temperature, Acid treatment, and Dilution" in Dry Ashing Study.

| Treatments | % | | | | PPM | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | P | K | Ca | Mg | Al | Fe | Zn | Cu | Mo | Mn | B |
| **Effect of Temperature** | Means of treatments (3 reps) for corn leaf tissue (sample A) | | | | | | | | | | |
| 475°C | .262 | 1.49 | .687 | .398 | 35.7 | 111 | 24.7 | 11.8 | 6.5 | 55.8 | 9.8 |
| 525°C | .255 | 1.45 | .673 | .390 | - | 113 | 26.1 | 10.8 | 6.4 | 54.9 | 9.5 |
| 575°C | .261 | 1.41 | .676 | .389 | 37.5 | 116 | 25.0 | 9.3 | 6.3 | 55.4 | 9.6 |
| 625°C | .254 | 1.34 | 1.651 | .3.89 | 36.3 | 111 | 29.6 | 5.8 | 6.4 | 53.0 | 9.3 |
| Overall mean | .258 | 1.42 | .672 | .391 | 36.5 | 113 | 26.4 | 9.5 | 6.4 | 54.8 | 9.6 |
| % C.V. | 5.6 | 6.6 | 3.7 | 3.2 | 3.4 | 7.6 | 3.4 | 14.6 | 7.1 | 2.8 | 4.8 |
| Significance Test | NS | NS | NS | NS | NS | NS | ** | ** | NS | NS | NS |
| **Effect of Acid Treatment"** | Means of treatments (6 reps) for corn leaf tissue (sample B) | | | | | | | | | | |
| No acid | .271 | 1.69 | .587 | .373 | 43.3 | 113 | 18.2 | 10.2 | 7.2 | 44.7 | 6.1 |
| Acid | .272 | 1.63 | .571 | .362 | 49.6 | 110 | 14.4 | 4.0 | 7.4 | 41.9 | 2.1 |
| Overall mean | .271 | 1.66 | .579 | .367 | 46.5 | 112 | 16.3 | 7.1 | 7.3 | 43.3 | 4.0 |
| % C.V. | 2.4 | 3.8 | 4.5 | 3.7 | 5.9 | 71 | 15.6 | 12.2 | 3.7 | 5.1 | 2.5 |
| Significance Test | NS | NS | NS | NS | * | NS | NS | ** | NS | NS | ** |
| **Effect of Dilution** | Means of treatment (3 reps) for corn leaf tissue (sample B) | | | | | | | | | | |
| 5 fold | .277 | 1.74 | .597 | .378 | 46.4 | 119 | 20.9 | 10.9 | 7.3 | 45.7 | 6.0 |
| 10 fold | .265 | 1.68 | .594 | .361 | 40.6 | 110 | 16.5 | 9.6 | 6.9 | 45.0 | 5.7 |
| Overall mean | .271 | 1.71 | .585 | .370 | 43.5 | 114 | 18.7 | 10.3 | 7.1 | 45.4 | 5.9 |
| %C.V. | 1.2 | 3.7 | 2.1 | 3.7 | 2.9 | 9.1 | 19.0 | 8.8 | 4.5 | 1.8 | 1.2 |
| Significance test | NS | NS | NS | NS | * | NS | NS | NS | NS | NS | * |
| **Effect of Sample Weight** | Means of treatments (3 reps) for corn leaf tissue (sample B) | | | | | | | | | | |
| 0.52 | .265 | 1.68 | .574 | .361 | 40.6 | 110 | 16.5 | 9.6 | 6.9 | 45.0 | 5.7 |
| 1.02 | .264 | 1.67 | .582 | .368 | 41.2 | 107 | 16.7 | 8.9 | 6.8 | 45.7 | 5.7 |
| Overall mean | .265 | 1.68 | .578 | .365 | 40.9 | 109 | 16.6 | 9.3 | 6.9 | 45.4 | 5.7 |
| %C.V | 1.2 | 3.7 | 4.7 | 7.2 | 5.6 | 31 | 0.9 | 7.1 | 18.9 | 6.0 | 3.8 |
| Significance Test | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |

TABLE 2

Means, Coefficients of Variability, and Significance Test for 12 Elements in "Effect of Time at Maximum Temperature" in Dry Study.

| | % | | | | PPM | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | P | K | Ca | Mg | Sr | Al | Fe | Zn | Cu | Mo | Mn | B |
| | Means of treatments (3 reps) for a mixture of plant tissue (corn, alfalfa, oats) | | | | | | | | | | | |
| 3 hours at 485°C | .255 | 1.72 | .904 | .468 | 29.7 | - | 130 | 16.6 | 61.5 | 14.7 | 61.5 | 20.7 |
| 10 hours at 485°C | .244 | 1.69 | .915 | .466 | 30.6 | - | 127 | 15.7 | 63.3 | 12.1 | 61.8 | 20.1 |
| Overall mean | .250 | 1.71 | .910 | .467 | 30.1 | - | 128 | 16.2 | 62.4 | 13.3 | 61.6 | 20.4 |
| %C.V.4 | 2.4 | 3.3 | 2.4 | 1.1 | 4.0 | - | 1.5 | 11.4 | 1.9 | 15.9 | 0.9 | 1.8 |
| Significance test | NS | NS | NS | NS | NS | - | NS | NS | NS | NS | NS | NS |
| | Means of treatments (3 reps) for sugar beet leaf tissue | | | | | | | | | | | |
| 3 hours at 485°C | .255 | 2.07 | .561 | 1.05 | 3.27 | - | 132 | 164 | 12.5 | 22.4 | 58.8 | 46.0 |
| 10 hours at 485°C | .240 | 2.03 | .602 | 1.02 | 3.97 | - | 151 | 203 | 12.9 | 21.4 | 59.4 | 44.0 |
| Overall mean | .248 | 2.05 | .582 | 1.04 | .362 | - | 142 | 183 | 12.7 | 21.9 | 59.1 | 45.0 |
| % C.V. | 2.0 | 2.0 | 7.1 | 3.5 | 12.2 | - | 9.9 | 12.7 | - | 1.5 | 3.8 | 2.1 |
| Significance test | NS | NS | NS | NS | NS | - | NS | NS | NS | NS | NS | NS |
| | Mean of treatments (3 reps) for corn leaf tissue (sample A) | | | | | | | | | | | |
| 10 hours at 575°C | .261 | 1.41 | .676 | .389 | - | 37.5 | 116 | 25.0 | 9.3 | 6.4 | 55.4 | 9.6 |
| 20 hours at 575°C | .265 | 1.39 | .666 | .379 | - | 38.3 | 116 | 32.3 | 6.5 | 6.8 | 53.5 | 9.6 |
| Overall mean | .263 | 1.40 | .671 | .384 | - | 37.9 | 116 | 28.7 | 7.9 | 6.6 | 54.5 | 9.6 |
| % C.V. | 8.5 | 2.6 | 6.6 | 3.8 | - | 4.5 | 8.6 | 7.4 | 18.6 | 9.4 | 5.2 | 7.1 |
| Significance test | NS | NS | NS | NS | - | NS | NS | NS | NS | NS | NS | NS |

# Variability of Webster and Waukegan Soil Series for Some Soil Elements and Related Plant Composition

R. C. Munter and R. H. Rust

As a part of the 4 year (1965-69) study on Genetic Control of Physiological Processes, our field research effort had the following objectives:

1. To assess the soil variability in a field plot situation in respect to a number of essential mineral elements. The variability was measured in the surface (0-6 inches) and in the subsurface (6-12 inches).
2. To correlate the amounts of elements extracted by selected procedures with above ground plant uptake.
3. To evaluate time of soil sampling during the growing season as it might relate to plant uptake.

The following summary is not all-inclusive but is an indication of the nature of findings.

A. Relationship between ion availability and ion accumulation.

1. Using the 1966 data for Waukegan and Webster soils from barley plots where soil and plant samples were taken at 7-10 day intervals throughout the growing season a correlation matrix was constructed to examine the relationship between soil and, particularly whole plant values for the elements Ca, Mg, K, Sr, Cu, Zn, P, Fe, and Mn, Table 1. The extracting solutions were Bray's No. 1 for P, neutral 1 N $NH_4Ac$ for Ca, Mg, K, Sr, and Mn, and 0.1 N HCl for Zn, Cu and iron.

Examination of Table 1 shows that (1) in respect to correlation of a soil value of a particular element and the amount of the same element in the whole barley plant only P was correlated for the majority of sampling dates but (2) in respect to soil values of particular elements and other elements in the whole plant several correlations seem significant -

soil P with plant P, K, and Mn

soil Mg with plant K, P, Zn, and Mn

soil Ca with plant K, P, and Zn

soil Fe with plant Mn

soil K with plant Sr

The last noted was correlated significantly and negatively on 5 of 7 sampling dates, i.e., high soil K was associated with low Sr.

On the Waukegan soil, Mn is particularly well correlated with plant Mg and P and, to a lesser extent, with plant Ca, K, Sr, Fe and Zn. (First and last samplings are on Waukegan soil only.)

By sampling dates (or intervals) the number of significant soil to whole plant correlations for the 9 elements was as follows: 1st (15); 2nd (24); 3rd (38); 4th (5); 5th (22); 6th (16); 7th (20).

Thus soil samples taken at the third sampling date about the 4th week of barley growth, were found to have highest number of significant correlations with whole plant content. This may correspond to a time of maximum utilization, or

Table 1. Significant correlations between soil values and whole plant content of Ca, Mg, K, Sr, Cu, Zn, Fe, and Mn at 7 sampling dates for barley grown on Waukegan and Webster soils, 1966. Sampling interval was 7-10 days, with the 1st sampling at seeding and the 7th at harvest. Order of sampling is shown from left to right.

| Plant \ Soil | Ca | Mg | K | Sr | Cu | Zn | P | Fe | Mn |
|---|---|---|---|---|---|---|---|---|---|
| K | ° .75 -.62<br>.52 -.62 -.81<br>° | ° ° -.77<br>° -.56 -.67<br>° | ° .72 °<br>° ° °<br>° | ° ° °<br>-.66 °<br>° | ° .68 °<br>° ° °<br>° | ° .59 .80<br>° ° °<br>.66 | ° -.52 .67<br>° ° .50<br>.89 | ° .57 °<br>° -.51 °<br>° | ° .74°<br>.48 ° °<br>.67 |
| Ca | ° ° °<br>° ° °<br>° | ° ° °<br>° ° °<br>° | -.81 ° -.78<br>° ° °<br>° | ° ° °<br>° ° °<br>° | ° ° °<br>° ° °<br>° | ° .54 °<br>° ° °<br>° | ° ° .60<br>° ° °<br>.89 | ° ° -.73<br>° ° °<br>° | -.83 ° °<br>° ° °<br>° |
| Sr | ° ° °<br>° ° °<br>° | ° ° °<br>° ° °<br>° | -.79 -.52 -.84<br>° -.69 -.73<br>° | ° ° °<br>° ° °<br>° | ° ° °<br>° °-.54<br>° | ° ° °<br>° ° °<br>° | ° ° .61<br>° .50 °<br>° | ° -.49 -.79<br>° ° °<br>-.69 | -.82 -.49°<br>° ° °<br>° |
| Mg | ° ° -.79<br>°-.60 °<br>° | ° ° -.92<br>° -.63 °<br>-.75 | -.79 ° -.63<br>° ° °<br>° | ° ° °<br>°-.53 °<br>° | ° °-.58<br>° ° °<br>° | ° .52 .60<br>° ° °<br>° | ° ° .87<br>° ° °<br>.97 | ° ° -.69<br>° ° °<br>° | -.84 ° °<br>° ° °<br>.88 |
| Cu | ° ° -.64<br>°-.62 °<br>° | ° ° -.72<br>° ° °<br>° | ° ° °<br>° ° °<br>.70 | ° ° °<br>° ° °<br>° | ° ° °<br>° ° °<br>° | ° ° .74<br>° ° °<br>.92 | ° ° .59<br>° ° °<br>° | ° ° °<br>° ° °<br>-.70 | ° .60°<br>° ° °<br>° |
| P | ° ° -.64<br>°-.51 -.48<br>° | ° ° -.78<br>° -.58 -.62<br>-.81 | .74 ° °<br>° ° °<br>° | ° °-.49<br>°-.53 °<br>° | ° ° °<br>°-.53 °<br>° | ° ° .72<br>° ° °<br>° | ° ° .64<br>° .48 .53<br>.91 | .73 ° °<br>° ° °<br>° | .85 ° °<br>° ° °<br>.93 |
| Fe | -.73 .61 °<br>° ° °<br>° | ° ° -.56<br>° ° °<br>-.81 | ° .54 °<br>° °<br>° | ° ° °<br>° ° .60<br>° | ° .60 °<br>° ° °<br>° | ° .65 .77<br>° ° -.61<br>° | ° ° °<br>° ° °<br>.87 | .76 ° °<br>° ° °<br>° | ° .56°<br>° ° °<br>.97 |
| Zn | ° .49 -.60<br>°-.60 -.48<br>° | -.68 ° -.71<br>° -.56 -.54<br>-.80 | ° .55 °<br>° ° °<br>° | ° ° °<br>°-.54 °<br>° | ° ° °<br>°-.54 °<br>° | ° ° .72<br>° ° °<br>° | ° ° .55<br>° ° °<br>.92 | .93 .48 °<br>° ° °<br>° | ° .70°<br>° ° °<br>.94 |
| Mn | ° ° -.75<br>°-.56 -.65<br>° | ° ° -.91<br>° -.66 -.78<br>-.79 | .78 ° -.61<br>° ° °<br>° | ° ° °<br>°-.48 °<br>° | ° ° -.54<br>° ° °<br>° | ° ° °<br>-.82° -.64<br>° | ° -.84 -.84<br>-.83 -.81 -.79<br>° | -.73 .76 .81<br>.83 ° °<br>° | ° .79°<br>° ° °<br>° |

°no significance

uptake, of most of the elements studied.

Of the 9 elements studied soil values for "available" Mg and P were found to be more often correlated with whole plant content of the 9 elements; however, soil values for Mg were not correlated, on any sampling date, with Ca or Sr in the plant.

In order of decreasing number of significant correlations for soil values were: Mg = P > Ca > K > Fe = Mn > Zn > Cu > Sr. This order is in reasonable agreement with the amount of these elements found in the barley plant. Sr is not considered to be an essential element. Any correlation between soil Sr and plant content of the 9 elements studied would probably derive from complementary ion relationships, or the possible substitution of Sr for Ca or Mg. The content of Mn in the whole barley plant was particularly correlated with soil Mg and P. The significant correlations were all negative, that is, high soil values for Mg and P were associated with low plant Mn.

With respect to the various plant parts sampled, stem, selected leaves, grain, and whole plant, the most significant correlations were with whole plant content; next, with stem.

B. Relationships and variability between extractable soil ions.

1. A study of the relationships between the soil extractable ions of Ca, Mg, Sr, K, P, Cu, Fe, Zn and Mn as measured at 7-10 day sampling intervals was made on the 1966 barley variability plots on the Waukegan and Webster soils.

Table 2. Significant correlations between soil values for nine elements by sampling intervals, Waukegan and Webster series, 1966. Barley plots.

| Soil \ Soil | Ca | | | Mg | | | K | | | Sr | | | Cu | | | Zn | | | P | | | Fe | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mg | .89 | .84 | .86 | | | | | | | | | | | | | | | | | | | | | |
| | .71 | .77 | .85 | | | | | | | | | | | | | | | | | | | | | |
| | .69 | | | | | | | | | | | | | | | | | | | | | | | |
| K | ° | .91 | .73 | ° | .86 | .78 | | | | | | | | | | | | | | | | | | |
| | .71 | .59 | .77 | .89 | .72 | .82 | | | | | | | | | | | | | | | | | | |
| | ° | | | ° | | | | | | | | | | | | | | | | | | | | |
| Sr | .74 | ° | ° | .51 | ° | ° | ° | ° | ° | | | | | | | | | | | | | | | |
| | ° | .54 | ° | ° | .48 | ° | ° | ° | ° | | | | | | | | | | | | | | | |
| | .70 | | | ° | | | ° | | | | | | | | | | | | | | | | | |
| Cu | .67 | .77 | .68 | .84 | .66 | .62 | -.60 | .83 | .52 | ° | ° | ° | | | | | | | | | | | | |
| | .75 | ° | ° | .60 | .58 | ° | .78 | .86 | ° | ° | ° | ° | | | | | | | | | | | | |
| | ° | | | ° | | | ° | | | ° | | | | | | | | | | | | | | |
| Zn | -.58 | ° | ° | -.77 | ° | -.54 | .61 | ° | ° | ° | ° | ° | -.88 | .52 | ° | | | | | | | | | |
| | -.61 | ° | -.49 | -.75 | ° | -.61 | -.90 | -.55 | -.80 | ° | ° | ° | -.78 | -.52 | ° | | | | | | | | | |
| | ° | | | ° | | | ° | | | ° | | | ° | | | | | | | | | | | |
| P | -.65 | -.78 | -.70 | -.87 | -.83 | -.83 | .64 | -.83 | -.86 | ° | ° | ° | -.92 | -.85 | -.55 | .86 | ° | ° | | | | | | |
| | -.59 | ° | -.59 | -.83 | -.71 | -.83 | -.88 | -.81 | -.76 | ° | ° | ° | -.65 | -.79 | ° | .68 | ° | .62 | | | | | | |
| | ° | | | ° | | | ° | | | ° | | | ° | | | ° | | | | | | | | |
| Fe | .75 | .72 | .74 | .89 | .78 | .62 | -.51 | .84 | .96 | ° | ° | ° | .97 | .92 | .60 | -.87 | ° | ° | -.91 | -.85 | -.90 | | | |
| | .68 | ° | ° | .81 | ° | ° | .94 | ° | .62 | ° | ° | ° | .87 | ° | .63 | -.92 | ° | -.60 | -.76 | ° | -.50 | | | |
| | ° | | | ° | | | ° | | | ° | | | ° | | | -.59 | | | ° | | | | | |
| Mn | .90 | .85 | ° | .79 | .70 | ° | ° | .79 | ° | .70 | ° | ° | .64 | .55 | ° | -.51 | ° | ° | -.50 | -.56 | ° | .72 | .57 | ° |
| | .87 | .55 | ° | .57 | ° | ° | .59 | ° | ° | ° | ° | ° | .63 | ° | ° | -.59 | ° | ° | ° | ° | ° | .56 | ° | ° |
| | ° | | | -.73 | | | ° | | | ° | | | ° | | | .48 | | | .86 | | | ° | | |

° Non-significant correlation

Correlations made between the soil extraction values for nine elements as determined by N $NH_4Ac$ or 0.1 N HCl, Table 2.

The number of significant correlations between elements was in the order, Mg > Ca > P > K > Cu > Zn = Fe > Mn > Sr. By far the least number was with Sr, suggesting that soil Sr would be poorly predicted by other elements, save possibly by Ca.

Zn and P, for the most part, were negatively correlated with the other elements (except positively with each other). Ca and Mg were positively correlated at all sampling intervals.

In many instances, last sampling date correlations are lower than initial sampling equivalent (true for 25 out of 36 pairings). This may be a reflection on the extraction procedures, e.g., initially the extraction would be expected to draw first, leaving other less-readily available forms, which the N $NH_4Ac$ or the 0.1 N HCl extraction removes with varying efficiencies for each ion.

2. Study of soil variability between initial and final sampling on 1967 soil sampling on Waukegan soil.

In 1967 initial samplings were made on the Waukegan soil at about seeding time and final samplings at plant harvesting. Samples were taken from the barley, wheat, and soybean screening areas at a sampling intensity of about 1 sample per 50 $ft^2$.

The results are given in Tables 3, 4, and 5.

Table 3. Measures of extractable ions and pH, and summary of significance tests for soil samples taken from barley screening area, 0-6 inches, 1967.
N = 144

| | Sampling Time | |
|---|---|---|
| | Initial (Seeding) | Final (Harvest) |
| Ca | 2468 | 2575** |
| Mg | 498 | 513* |
| K | 242* | 216 |
| Sr | 12 | 12 |
| Cu | 1.6** | 1.4 |
| Zn | 4.0 | 4.4** |
| P | 49* | 46 |
| Fe | 21 | 23* |
| Mn | 12** | 4 |
| pH | 6.3** | 6.0 |

Values in ppm except pH.
**.01 significance level
*.05 significance level

Table 4. Measures of extractable ions and pH and summary of significance tests for soil samples taken from wheat screening areas, 0-6 inches, 1967.
N = 96

| | Sampling Time | |
|---|---|---|
| | Initial (Seeding) | Final (Harvest) |
| Ca | 2484 | 2516 |
| Mg | 503 | 487 |
| K | 214 | 204 |
| Sr | 12 | 14* |
| Cu | 1.3 | 1.4* |
| Zn | 4.7 | 4.7 |
| P | 48 | 47 |
| Fe | 24 | 24 |
| Mn | 11** | 4 |
| pH | 6.3* | 6.2 |

Values in ppm except pH.
**.01 significance level.
*.05 significance level.

Table 5. Measures of extractable ions and pH and summary of significance tests for soil samples taken from soybean screening area, 0-6 inches, 1967. N = 160

| | Sampling Time | |
|---|---|---|
| | Initial (Seeding) | Final (Harvest) |
| Ca | 2585 | 2721** |
| Mg | 413 | 446** |
| K | 125 | 130 |
| Sr | 12 | 15** |
| Cu | 1.4** | 1.2 |
| Zn | 3.8 | 3.8 |
| P | 28** | 21 |
| Fe | 33** | 27 |
| Mn | 9.8** | 3.1 |
| pH | 6.5 | 6.5 |

Values in ppm except pH.
** .01 significance level.

Measured values of soil Ca, Mg, and Sr are almost always significantly higher at final sampling time. In general, values for Cu, P, Mn and pH are significantly higher at initial sampling. Most striking is the change in Mn. Values at final sampling are about half the initial values.

# THE 1970 YIELDS OF TWELVE FIELDS OF SMALL GRAINS IN THE RED RIVER VALLEY BASIN FOLLOWING FERTILIZATION WITH MAJOR, SECONDARY AND MICRONUTRIENT ELEMENTS

John M. MacGregor[1]

For several years there has been an increasing interest in possible increases in small grain yields if fertilized with additional potash (K), sulfur (S), zinc (Zn), manganese (Mn), boron (B), copper (Cu), or a combination of all these elements on some soils of the Red River Valley Basin. Early in 1970, interested county agricultural agents in seven counties located 14 farmer-cooperators in their respective counties and a total of 7 experiments on oats, 2 on barley and 5 on wheat were initiated, extending from Wilkin County in the south to Kittson County in the north. Two fields of oats were not harvested due to excessive soil moisture and to other causes.

A randomized block design with 5 replications of the following 9 treatments was used on each field. Each of the 45 plots was 10' x 15', the total experimental area in each field being 75' x 90' (6750 sq. ft. or 0.15 acre). The following treatments were broadcast and worked in before seeding.

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[1]This investigation was made possible only with the cooperation of many others including the respective farm operators, the county agricultural agents, the area soil specialists, personnel at the Northwest Experiment Station and several members of the Department of Soil Science at St. Paul.

| | | Nutrients/A | | |
|---|---|---|---|---|
| | | N | $P_2O_5$ | $K_2O$ |
| 1. | Check | None (farmers' starter fertilizer only) | | |
| 2. | $N_1P_1K_1$ | 40 + | 40 + | 40 |
| 3. | $N_1P_1K_5$ | 40 + | 40 + | 200 |
| 4. | $N_1P_1K_1$ + Zn | 40 + | 40 + | 40 + 10 #/A zinc |
| 5. | $N_1P_1K_1$ + Mn | 40 + | 40 + | 40 + 10 #/A manganese |
| 6. | $N_1P_1K_1$ + B | 40 + | 40 + | 40 + 2 #/A boron |
| 7. | $N_1P_1K_1$ + Cu | 40 + | 40 + | 40 + 10 #/A copper |
| 8. | $N_1P_1K_1$ + S | 40 + | 40 + | 40 + 20 #/A sulfur |
| 9. | $N_1P_1K_1$ + Zn, Mn, B, Cu, S | 40 + | 40 + | 40 + all above elements |

All treatments were broadcast before seeding the small grains and disked in, the farmer seeded over the fertilized areas using the starter fertilizer of his choice. The $N_1$ $P_1$ $K_1$ and the $N_1$ $P_1$ $K_5$ represented the total N, $P_2O_5$, and $K_2O$ applied rate per acre, including that applied by the farm operator in his starter application. In short, the 40 + 40 + 40 or the 40 + 40 + 200 was the total N, $P_2O_5$ + $K_2O$ applied to each soil in 1970. The sulfur and micronutrient plots (and the total) all received the 40 + 40 + 40 basic treatment as well.

Excessive rains fell during the planting season particularly to the north of U. S. Highway 10 and continued until mid-June. Many farm fields were too wet to plant, or were planted much later than normal. The latter part of the growing season was very dry, and small grain yields were adversely affected. The following table shows the different locations, cooperating farm operator, soil analyses and 1970 small grain yields

obtained with the different fertility treatments.

It is evident that there was no significant yield increase from applications of additional potash (40+40+200), or from the zinc, manganese, boron, copper, or sulfur, either alone or when all were applied as a combination treatment. The only significant yield response was on a barley field in Wilkin County, and this resulted from the basic 40+40+40 treatment. In all probability the first two nutrients (N & P) were mainly responsible for this lone response and this effect was evident during much of the growing season. This was not true in the 11 other locations.

## Conclusions

The results obtained by fertilizing small grains in the unfavorable weather during the growing season of 1970 should not be considered as conclusive, but they suggest that the inclusion of such elements in fertilizers for small grains should probably not be emphasized at this time. These experiments will be repeated in 1971 and again in 1972 to further establish the value of these elements in present small grain production in northwestern Minnesota.

1970 Soil Analysis and Small Grain Yields on Fertilized Plots in Northwestern Minnesota

| County | Farm Operator | Soil Analyses: Texture | pH | OM | P (lbs/A) | K (lbs/A) | Zn (ppm) | S (ppm) | Cond. mmhos/cm | 1970 broadcast soil treatments (lbs/A): Checks | 40+40+40 | 40+40+200 | 40+40+40 + 10 Zn | 40+40+40 + 10 Mn | 40+40+40 + 2 B | 40+40+40 +10 Cu | 40+40+40 + 20 S | 40+40+40 + S + Micro + | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | Grain yields in bushels per acre | | | | | | | | | |
| **Oats** | | | | | | | | | | | | | | | | | | | |
| Wilkin | R. Bellmore | C.L. | 7.0 | H | 26 | 600+ | 1.9 | 1 | 0.4 | 65.8 | 56.3 | 57.1 | 55.8 | 60.6 | 58.5 | 66.2 | 65.2 | 63.7 | N.S. |
| Clay | D. Atherton | Si.CL | 7.0 | M | 95 | 600+ | 2.4 | 12 | 0.8 | 67.1 | 61.5 | 66.0 | 64.0 | 63.4 | 66.5 | 66.1 | 62.8 | 65.1 | N.S. |
| Becker | J. Matter | Si.CL | 8.0 | H | 35 | 510 | 1.6 | 8 | 0.6 | 72.3 | 74.1 | 67.3 | 80.4 | 73.0 | 74.3 | 78.2 | 69.6 | 73.0 | N.S. |
| Becker | D. Anderson | S.L. | 6.6 | M | 17 | 110 | 3.1 | 4 | 0.5 | 34.0 | 35.6 | 37.7 | 34.1 | 35.1 | 35.8 | 34.8 | 34.7 | 39.1 | N.S. |
| Pennington | D. Knutson | L.S. | 8.0 | H | 5 | 50 | 0.5 | 6 | 0.6 | 49.2 | 59.2 | 64.4 | 66.3 | 68.2 | 61.3 | 65.3 | 60.5 | 64.7 | N.S. |
| **Barley** | | | | | | | | | | | | | | | | | | | |
| Wilkin | W. Fredericks | C.L. | 8.2 | H | 20 | 370 | 2.2 | 39 | 0.8 | 44.0a | 66.8 | 70.0b | 62.4b | 60.8 | 59.4b | 61.7b | 62.2b | 60.8b | Sig. |
| Clay | L. Anderson | Si.CL | 8.1 | H | 17 | 430 | 1.3 | 1 | 0.5 | 41.9 | 45.5 | 46.4 | 53.3 | 51.0 | 50.7 | 46.4 | 52.6 | 52.8 | N.S. |
| **Wheat** | | | | | | | | | | | | | | | | | | | |
| Wilkin | R. Hoveland | C.L. | 7.8 | H | 8 | 420 | 1.5 | 9 | 0.4 | 48.1 | 49.1 | 46.4 | 50.5 | 49.8 | 49.0 | 48.9 | 47.2 | 50.4 | N.S. |
| Clay | D. Sellers | Si.CL | 8.0 | H | 7 | 370 | 1.0 | 40+ | 1.7 | 30.5 | 31.8 | 32.2 | 31.2 | 28.1 | 30.2 | 30.8 | 31.8 | 32.0 | N.S. |
| Polk | G. Meyer | Si.L | 8.0 | M | 43 | 520 | 2.6 | 9 | 0.8 | 14.4 | 13.5 | 14.8 | 16.6 | 14.8 | 16.3 | 12.0 | 15.2 | 16.0 | N.S. |
| Polk | N.W. Station | Si.L | 8.3 | H | 18 | 310 | 2.7 | 9 | 1.1 | 36.6 | 39.4 | 41.6 | 41.9 | 40.2 | 41.6 | 41.2 | 45.0 | 40.0 | N.S. |
| Kittson | O. Langen | Si.CL | 7.2 | M | 81 | 600+ | 1.2 | 6 | 1.6 | 48.7 | 53.1 | 50.3 | 45.9 | 51.2 | 48.4 | 53.4 | 48.3 | 40.9 | N.S. |

*N.S. - not significant

## Effect of Micronutrients on Soybean Seed Yields

G. E. Ham and R. D. Frazier

Micronutrients were applied to Chippewa 64 soybeans grown at Waseca. The soil treatment consisted of 10 pounds per acre sulfate source (elemental basis) and 3 pounds per acre chelate and silviplex sources broadcast and disced-in before planting. Foliar treatments consisted of 3 pounds per acre sulfate source and 0.6 pounds per acre chelate and silviplex sources applied as a foliar spray when the plants were beginning to flower.

No significant yield increases were obtained from the various treatments (Table 1). The leaf Cu and Zn levels were increased significantly by foliar applications of sulfate and silviplex sources (Table 2). In addition the sulfate source of Zn applied as a soil treatment significantly increased the Zn level of the leaf. Mn silviplex increased the Mn content of the leaf significantly.

Table 1. Effect on soybean seed yield when different micronutrients were applied to Chippewa 64 soybeans grown at Waseca, Minnesota in 1970.

| Treatment | Foliar bu/acre | Soil bu/acre |
|---|---|---|
| Check | ---------32.3---------- | |
| Fe-chelate | 30.2 | 32.0 |
| Fe-silviplex | 28.1 | |
| Fe-sulfate | 32.0 | 31.8 |
| Mn-chelate | 31.4 | 30.6 |
| Mn-silviplex | 28.9 | |
| Mn-sulfate | 30.5 | 30.0 |
| Cu-chelate | 32.0 | 32.1 |
| Cu-silviplex | 29.8 | |
| Cu-sulfate | 30.1 | 35.8 |
| Zn-cheltate | 32.5 | 32.4 |
| Zn-silviplex | 29.9 | |
| Zn-sulfate | 28.5 | 30.2 |

Table 2

Influence of micronutrients added as soil and foliar treatments to Chippewa 64 soybeans grown at Waseca, Minnesota during 1970

| Element applied | Nutrient content of last fully matured trifoliate | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | % P | % K | % Ca | ppm Sr | ppm Fe | % Mg | ppm Zn | ppm Cu | ppm Mo | ppm Mn | ppm B |
| Check | .372 | 1.50 | 1.44 | 28.9 | 105 | .525 | 50.5 | 9.4 | 6.0 | 49.9 | 58.6 |
| Fe chelate-soil | .370 | 1.50 | 1.33 | 26.7 | 104 | .517 | 49.2 | 10.5 | 7.6 | 48.6 | 59.3 |
| Fe sulfate-soil | .387 | 1.52 | 1.41 | 29.9 | 105 | .523 | 52.3 | 11.5 | 6.3 | 55.8 | 59.3 |
| Fe chelate-foliar | .375 | 1.45 | 1.48 | 32.2 | 119 | .538 | 51.4 | 6.0 | 6.6 | 45.2 | 59.2 |
| Fe sulfate-foliar | .381 | 1.41 | 1.49 | 30.0 | 135 | .544 | 49.9 | 7.7 | 8.4 | 57.5 | 58.4 |
| Fe silviplex-foliar | .361 | 1.38 | 1.45 | 31.7 | 130 | .569 | 51.6 | 9.1 | 7.1 | 47.7 | 58.8 |
| Mn chelate-soil | .367 | 1.50 | 1.53 | 32.2 | 115 | .572 | 46.4 | 7.9 | 8.2 | 43.8 | 59.4 |
| Mn sulfate-soil | .366 | 1.44 | 1.45 | 31.4 | 120 | .567 | 50.5 | 8.0 | 7.0 | 49.8 | 58.5 |
| Mn chelate-foliar | .368 | 1.46 | 1.53 | 34.3 | 116 | .560 | 51.8 | 9.9 | 7.5 | 51.9 | 56.9 |
| Mn sulfate-foliar | .366 | 1.48 | 1.53 | 34.0 | 102 | .554 | 49.5 | 10.1 | 6.3 | 63.9 | 57.1 |
| Mn silviplex-foliar | .387 | 1.47 | 1.46 | 31.3 | 116 | .518 | 49.8 | 9.4 | 7.2 | 78.2** | 60.5 |
| Cu chelate-soil | .368 | 1.52 | 1.48 | 29.7 | 113 | .550 | 49.6 | 8.2 | 6.1 | 42.8 | 58.2 |
| Cu sulfate-soil | .383 | 1.64 | 1.47 | 31.1 | 113 | .524 | 49.7 | 8.9 | 6.3 | 56.9 | 56.8 |
| Cu chelate-foliar | .347 | 1.46 | 1.51 | 33.5 | 119 | .542 | 46.2 | 10.8 | 7.6 | 51.5 | 54.8 |
| Cu sulfate-foliar | .375 | 1.50 | 1.51 | 32.8 | 112 | .550 | 51.7 | 19.3** | 7.9 | 55.0 | 59.5 |
| Cu silviplex-foliar | .351 | 1.37 | 1.52 | 33.2 | 111 | .587 | 51.1 | 20.3** | 7.8 | 61.0 | 59.7 |
| Zn chelate-soil | .362 | 1.54 | 1.49 | 32.1 | 117 | .536 | 46.1 | 8.4 | 6.8 | 46.7 | 57.8 |
| Zn sulfate-soil | .346 | 1.41 | 1.43 | 31.1 | 115 | .533 | 63.7** | 12.1 | 4.9 | 51.8 | 60.9 |
| Zn chelate-foliar | .395 | 1.51 | 1.60 | 36.4 | 110 | .558 | 51.3 | 6.4 | 6.9 | 52.1 | 55.6 |
| Zn sulfate-foliar | .367 | 1.46 | 1.37 | 28.2 | 103 | .514 | 64.9** | 8.8 | 7.1 | 48.2 | 56.7 |
| Zn silviplex-foliar | .380 | 1.55 | 1.46 | 30.9 | 101 | .522 | 69.9** | 7.6 | 6.4 | 50.8 | 57.0 |
| CV (%) | 9.7 | 12.2 | 8.4 | 16.2 | 89.2 | 11.0 | 9.9 | 42.8 | 30.5 | 21.9 | 6.4 |

** Significantly greater than the check at the .01 level

# EFFECT OF RESIDUAL POTASSIUM FERTILIZER SOURCES AND RATES ON SOYBEAN YIELD

G. E. Ham

The plots were located on the University of Minnesota Sand Plain Experimental Field near Elk River on a Hubbard loamy coarse sand soil with 0-2% slope. Fertilizer and lime treatments were applied in the spring of 1968 and plowed down. The soil test values for P and K were very high and medium, respectively before treatments were applied. The treatments applied are shown in Table 1. No further treatments were appplied since 1968. Soybean seed yields were increased significantly in many cases in 1970 as shown in Table 1. At the 200 pounds $K_2O$ per acre rate, $KNO_3$ produced a significantly greater seed yield than $KCl + NH_4NO_3$ with the same rates of K and N. The $KNO_3$ treatment increased the yield significantly at all rates.

Table 1. Effect on 1970 soybean seed yield at Elk River, Minnesota when different rates and sources of potassium fertilizer were applied in spring of 1968.

| Potassium sources | Pounds $K_2O$/acre | | | | |
|---|---|---|---|---|---|
| | 100 | 200 | 400 | 800 | 1600 |
| $K_2HPO_4$ | 37.8 | 38.6 | 39.4 | 39.9 | -- |
| $K_2SO_4$ | 37.7 | 38.4 | 41.7* | 40.0 | -- |
| $K_2CO_3$ | 39.0 | 43.7* | 36.6 | 42.5* | -- |
| $K_2SO_4 \cdot MgSO_4$ | 37.7 | 39.8 | 39.7 | 37.6 | -- |
| $KNO_3$ | 42.5* | 41.9* | 40.7* | 40.7* | -- |
| KCl | 40.3 | 42.1* | 38.7 | 38.1 | 42.8* |
| KCl + P | | 37.7 | | | |
| KCl + N | | 37.5 | | | |
| KCl + S | | 39.1 | | | |
| KCl + S + Mg | | 37.1 | | | |
| Check | 37.3 | | | | |

*Significantly greater than check yield at .05 level

# Soybean Chlorosis Studies

G.E. Ham, W.W. Nelson, S.D. Evans, G.O. Holcomb and O.M. Gunderson

Nitrogen and sulfur at the rate of 125 and 250 pounds per acre were applied to two sites at Morris and one site at Lamberton which had prevously grown chlorotic soybeans. In addition, various seed treatments were grown at these locations. Treatments, soybean varieties and seed yields are shown in Tables 1 - 4. None of the treatments consistently reduced the presence of chlorosis, increased seed yield or influenced nutrient composition of leaf samples. At Lamberton seed yields of Chippewa 64 was increased by nitrogen and sulfur. Chippewa 64 showed little or no chlorosis. The seed yield of Anoka and Hark which are very susceptible to chlorosis was not increased by nitrogen or sulfur. At Morris, the results were similar.

Table 1. Effect of seed treatments on Traverse soybeans at Morris in 1970

| Treatment | Seed yield Site 1 bu/acre | Seed yield Site 2 bu/acre |
|---|---|---|
| Check | 23.5 | 28.8 |
| $FeSO_4$ | 24.0 | 26.8 |
| $CuSO_4$ | 24.7 | 28.8 |
| $ZnSO_4$ | 22.9 | 26.8 |
| $MnSO_4$ | 23.6 | 22.5 |
| $K_2Cr_2O_7$ | 24.6 | 25.0 |
| $CoCl_2 .6H_2O$ | 22.4 | 26.3 |
| $MoO_3$ | 22.9 | 19.6 |
| Serine | 24.1 | 26.8 |
| Quercetin | 24.6 | 27.5 |
| B-naphthoxy acetic acid | 21.4 | ---- |
| Colchicine | 23.5 | 22.9 |
| Thiouracil | 24.0 | 25.3 |
| D-leucine | 24.2 | 25.0 |
| Kinetin | 23.7 | 28.5 |
| Gibberellic acid | 25.1 | 27.7 |
| N-6 benzyl adenine | 23.6 | 25.5 |

Table 2. Effect of nitrogen and sulfur fertilizer treatments on soybean seed yields at Morris in 1970.

Site 1: Bruer Farm

| Fertilizer treatment lbs/acre | Chippewa 64 bu/acre | Anoka bu/acre | Traverse bu/acre |
|---|---|---|---|
| Check | 20.1 | 22.3 | 21.6 |
| 125 lbs N | 23.4 | 23.7 | 23.4 |
| 250 lbs N | 21.2 | 21.6 | 21.3 |
| 125 lbs S | 21.7 | 24.2 | 22.8 |
| 250 lbs S | 23.8 | 21.8 | 24.4 |

Site 2: Hoslin Farm

| | | | |
|---|---|---|---|
| Check | 16.4 | ---- | 21.0 |
| 125 lbs N | 17.1 | ---- | 19.9 |
| 250 lbs N | 18.2 | ---- | 22.8 |
| 125 lbs S | 18.1 | ---- | 23.5 |
| 250 lbs S | 16.2 | ---- | 26.5 |

Table 3. Effect of seed treatments on Hark soybean seed yield at Lamberton

| Treatment | Seed yield bu/acre |
|---|---|
| Check | 30.5 |
| $FeSO_4$ | 27.0 |
| $CuSO_4$ | 33.9 |
| $ZnSO_4$ | 26.3 |
| $MnSO_4$ | 29.6 |
| $K_2Cr_2O_7$ | 35.8 |
| $C_0Cl_2 \cdot 6H_2O$ | 30.7 |
| MaO3 | 26.7 |
| Serine | 25.0 |
| Quercetin | 29.4 |
| B-naphthoxy acetic acid | 32.2 |
| Colchicine | 32.6 |
| Thiouracil | 28.8 |
| D-leucine | 23.4 |
| Kinetin | 35.3 |
| Gibberellic acid | 23.3 |
| N-6 benzyl adenine | 28.7 |

Table 4. Effect of nitrogen and sulfur fertilizer treatments on soybean seed yields at Lamberton, Minnesota in 1970

| Fertilizer Treatment lbs/acre | Soybean variety | | |
|---|---|---|---|
| | Chippewa 64 | Anoka | Hark |
| Check | 32.8 | 18.5 | 16.0 |
| 125 N | 35.4 | 18.0 | 17.9 |
| 250 N | 34.2 | 19.5 | 17.8 |
| 125 S | 36.2 | 19.4 | 16.3 |
| 250 S | 32.7 | 18.2 | 16.4 |

# SOYBEAN FERTILIZER PLACEMENT STUDY

G. E. Ham, R. D. Frazier, S. D. Evans and W. W. Nelson

Different fertilizer rates and placements were studied in a factorial experiment. Main plots were broadcast P and K which were split into three nitrogen rates. Each nitrogen rate was divided into row fertilizer placements (check, seed placement, 2 x 2 band and a combination of band and seed placement). Treatments, fertilizer rates, soybean variety and yields are shown in Tables 1, 2 and 3. The response to nitrogen was not significant at any location. The largest yield responses at Lamberton and Morris associated with P increases in the plant. The largest response was obtained from broadcast fertilizer applications. Starter or row fertilizer had less effects on seed yield either with or without broadcast fertilizer even though both starter and row fertilizer were significant.

Table 1. Effect on soybean seed yield when different fertilizer placements were applied to Corsoy soybeans grown at Lamberton, Minnesota in 1970.

| Starter fertilizer | Nitrogen Fertilizer Applied | | | | | |
|---|---|---|---|---|---|---|
| | 0 | | 50 lbs/acre | | 100 lbs/acre | |
| | No Bdcst bu/acre | Bdcst bu/acre | No Bdcst bu/acre | Bdcst bu/acre | No Bdcst bu/acre | Bdcst bu/acre |
| Check | 30.0 | 35.0 | 29.7 | 35.0 | 30.7 | 36.9 |
| Seed placement | 32.1 | 35.8 | 35.7 | 35.9 | 31.8 | 37.8 |
| Band | 32.7 | 36.8 | 32.5 | 36.3 | 32.6 | 35.3 |
| Seed placement + Band | 32.6 | 32.5 | 34.4 | 35.8 | 33.6 | 35.1 |

| | | |
|---|---|---|
| Fertilizer rates: | Band | 15 + 20 + 18 |
| | Seed placement | 5 + 7 + 6 |
| | Broadcast | 0 + 60 + 30 |

Soil test values: pH 5.7

P 10 lbs/acre (low)

K 290 lbs/acre (high)

Table 2. Effect on soybean seed yield when different fertilizer placements were applied to Corsoy soybeans grown at Waseca, Minnesota in 1970.

| Starter fertilizer | Nitrogen Fertilizer Applied | | | | | |
|---|---|---|---|---|---|---|
| | 0 | | 50 | | 100 | |
| | No Bdcst bu/acre | Bdcst bu/acre | No Bdcst bu/acre | Bdcst bu/acre | No Bdcst bu/acre | Bdcst bu/acre |
| Check | 52.8 | 53.0 | 56.5 | 52.5 | 55.3 | 54.1 |
| Seed placement | 59.0 | 52.3 | 54.3 | 47.1 | 51.3 | 43.5 |
| Band | 57.6 | 54.8 | 56.5 | 51.7 | 51.3 | 49.7 |
| Seed placement + Band | 56.7 | 54.8 | 56.1 | 43.6 | 47.3 | 46.9 |

Fertilizer rates: Band 14 + 35 + 45

Seed placement 4 + 10 + 14

Broadcast 0 + 100 + 150

Soil test values: pH 6.8

P 40 lbs/acre (very high)

K 265 lbs/acre (high)

Table 3. Effect on soybean seed yield when different fertilizer placements were applied to Clay soybeans grown at Morris, Minnesota in 1970.

| Starter fertilizer | Nitrogen Fertilizer Applied | | | | | |
|---|---|---|---|---|---|---|
| | 0 | | 50 | | 100 | |
| | No Bdcst bu/acre | Bdcst bu/acre | No Bdcst bu/acre | Bdcst bu/acre | No Bdcst bu/acre | Bdcst bu/acre |
| Check | 23.7 | 31.3 | 24.4 | 31.5 | 27.5 | 32.0 |
| Seed placement | 25.7 | 28.9 | 33.4 | 32.7 | 32.6 | 30.9 |
| Band | 26.4 | 30.0 | 31.0 | 32.0 | 33.8 | 32.6 |
| Band + Zn | 27.4 | 31.8 | 29.4 | 30.8 | 31.8 | 33.1 |

| | | |
|---|---|---|
| Fertilizer rates: | Band | 10 + 20 + 10 |
| | Seed placement | 4 + 8 + 4 |
| | Broadcast | 0 + 60 + 30 |
| | Zn ($ZnSO_4$) | 10 |
| Soil test values: | pH 7.7 | |
| | P 7 lbs/acre (low) | |
| | K 3000 lbs/acre (high) | |

# SOYBEAN NITROGEN FERTILIZER STUDIES

G. E. Ham, W. W. Nelson, R. D. Frazier and S. D. Evans

Ammonium nitrate at the rate of 0, 5, 10 and 15 pounds N per acre was applied to soybeans grown at Lamberton, Morris and Waseca. Soybean varieties and seed yields are shown in Table 1. Nitrogen fertilizer did not increase or decrease seed yield significantly. At Morris yields were generally decreased by nitrogen fertilizer due to the extremely dry weather during the growing season. At Waseca yields were increased by the fertilizer though the increases were not significant. At Lamberton yields were decreased by the 10 and 15 pound rates. At Waseca, nodulation was increased by the 5 and 10 pound rates on both varieties. At Lamberton nodulation was increased only by the 5 pound rate of nitrogen and at Morris, nodulation was decreased by all rates of nitrogen.

Table 1 : Effect of nitrogen fertilizer placed in the seed zone on soybean seed yields in 1970

| Row fertilizer nitrogen | Morris | | | Waseca | | | Lamberton | | |
|---|---|---|---|---|---|---|---|---|---|
| | Soybean variety | | | Soybean variety | | | Soybean variety | | |
| | Chippewa 64 bu/acre | Clay bu/acre | Average bu/acre | Chippewa 64 bu/acre | Corsoy bu/acre | Average bu/acre | Chippewa 64 bu/acre | Corsoy bu/acre | Average bu/acre |
| 0 | 24.5 | 34.4 | 29.4 | 30.4 | 38.4 | 34.4 | 35.5 | 43.2 | 39.4 |
| 5 | 21.7 | 32.8 | 26.4 | 32.2 | 40.5 | 36.3 | 34.8 | 44.9 | 39.8 |
| 10 | 22.4 | 32.9 | 27.7 | 33.1 | 39.1 | 36.1 | 34.4 | 42.4 | 38.4 |
| 15 | 22.5 | 32.1 | 27.6 | 34.0 | 37.1 | 35.5 | 32.0 | 42.8 | 37.4 |
| Average | 22.8a | 32.8b | | 32.4a | 38.8b | | 34.2a | 43.3b | |
| Coefficient of Variation % | 8.3 | | | 11.0 | | | 5.7 | | |

# THE EFFECTS OF SULFUR APPLIED ON A HIGH pH SOIL[1]

W. E. Fenster, O. M. Gunderson, R. J. Larson, D. S. Fairchild

Questions frequently asked in western Minnesota are, how can we lower soil pH? Since sulfur is acidic in reaction, how much sulfur must be applied to change the soil pH? If liming acid soils is a feasible practice, can we spend an equal amount to lower soil pH? In an attempt to answer these questions a research experiment was established in Chippewa County in the spring of 1969.

The soil selected was typical of large acreages in the area. The soil type of the plot site was a Vallers silty clay loam with a high pH. There was adequate surface drainage on the plot area.

Sulfur rates of 30, 500, 1,000 and 2,000 pounds / acre of elemental S were used in a series of plots randomized and replicated four times. The sulfur (18 - 32 mesh) was broadcast and disked into the soil. The cost of this product was 6 cents per pound. Corn was grown on the field in 1969 and soybeans in 1970.

Soil samples of the plow layer were tested from each plot in the spring, summer, and fall of each year. The results are shown in Tables 1, 2, and 3. No yield data was collected in 1969 because of the poor corn stand and apparent nitrogen deficiency in the field. In 1970 tissue and yield analyses of soybeans were determined.

The high rates of sulfur had the immediate effect of lowering the soil pH (Table 1). From the time of application in May to July 1969,

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[1]Revision of an article written by Orville Gunderson, Area Extension Soils Agent, 1970.

the soil pH was lowered from 7.9 to 6.7 by the 2,000 lbs. per acre rate of sulfur. Rates of 500 and 1,000 lbs. per acre of sulfur had similar effects. This was just a temporary effect on soil pH as is shown by subsequent testing. The pH on all treatments increased in the fall of 1969 and were lower again in the spring of 1970. In the fall of 1970 soil pH had returned to the original level.

Table 1: The effects of varying sulfur treatments on soil pH.

| Sulfur Treatments lbs. S/A | Date of Sampling | | | | | |
|---|---|---|---|---|---|---|
| | 5/9/69 | 7/8/69 | 10/23/69 | 6/1/70 | 7/15/70 | 10/15/70 |
| 0 | 7.8 | 7.8 | 8.0 | 7.7 | 7.8 | 8.0 |
| 30 - annually | 7.8 | 7.6 | 7.8 | 7.7 | 7.7 | 7.8 |
| 500 - 1969 | 7.7 | 7.0 | 7.7 | 7.2 | 7.4 | 7.6 |
| 1000 - 1969 | 7.8 | 6.9 | 7.6 | 7.0 | 7.3 | 7.7 |
| 2000 - 1969 | 7.9 | 6.7 | 7.2 | 6.7 | 7.2 | 7.9 |

Another effect of applying high rates of sulfur to the soil was the change in the soluble salts contents (Table 2). The initial average soluble salt content was 0.5 mmhos.. Soluble salts were increased with increasing rates of applied sulfur. In the fall of 1969 and spring of 1970 the rate of 2,000 lbs. per acre of sulfur increased the soluble salt content to 2.8 mmhos.. This is in the range where salt sensitive crops could be affected. There were no visual differences, however, on the soybeans during the growing season. The increase in soluble salts was a temporary effect. By the fall of 1970 all of the treatments had returned to their normal levels.

Table 2: The effects of varying sulfur treatments on soil soluble salts.

| Sulfur Treatments lbs. S/A | Date of Sampling | | | | |
|---|---|---|---|---|---|
| | 5/9/69 | 10/23/69 | 6/1/70 | 7/15/70 | 10/15/70 |
| | mmhos | | | | |
| 0 | 0.5 | 0.6 | 0.6 | 0.5 | 0.4 |
| 30 - annual | --- | 0.7 | 0.5 | 0.7 | 0.4 |
| 500 - 1969 | --- | 1.3 | 1.3 | 0.9 | 0.5 |
| 1,000 - 1969 | --- | 2.0 | 1.6 | 1.3 | 0.4 |
| 2,000 - 1969 | --- | 2.8 | 2.8 | 2.0 | 0.4 |

There were no yield differences from any of the sulfur treatments (Table 3). There also were no differences in nutrient uptake of corn and soybean plant tissue.

Table 3: The effect of varying sulfur treatments on soybean yields, 1970

| Sulfur Treatments lbs. S/As | Bu./A |
|---|---|
| 0 | 24 |
| 30 - annual | 23 |
| 500 - 1969 | 24 |
| 1,000 - 1969 | 24 |
| 2,000 - 1969 | 24 |

The only visual evidence of the sulfur treatments was in the spring of 1970 prior to field tillage. At that time there was a white crust on the surface of the plots on which the sulfur has been broadcast a year previously.

In the fall of 1970 the plots were split and additional sulfur was applied to half of the plots. On two replications the treatments with 1,000 and 2,000 lbs. of sulfur / acre were treated with an additional 1,000 and 2,000 lbs., respectively. Future plans are to continue soil testing three times a year for two more years.

A similar sulfur plot was established in Swift County in the spring of 1970. The same rates of sulfur treatments were used but with a different form of sulfur. A product called Agri-Sul (90%-S) was used at this site. There was no change in either soil pH or soluble salts on this plot. This would indicate, perhaps, that since this soil has a very high pH, 8.0, the acid produced through oxidation of the elemental sulfur may have been neutralized immediately by the free carbonates. It is also possible that the sulfur product used (Agri-Sul) may not have oxidized in sufficient quantities to effectively lower the pH. Poor moisture conditions may also have contributed to the sulfur product not oxidizing. This plot will also be monitored for a number of years.

In summary, it has been shown that under favorable conditions a soil pH can <u>temporarily</u> be lowered with high rates of sulfur. It should be noted, however, that no yield responses were realized by lowering the soil pH.

# SULFUR FERTILIZATION OF CORN IN SOUTHERN MINNESOTA[1]

D. S. Fairchild, W. W. Nelson, R. D. Frazier

In the spring of 1970, a project was initiated to determine if corn will respond to additional treatments of sulfur in Southern Minnesota on soils which are high in organic matter and low to medium in available sulfur.

Two field experiments were conducted in 1970. General information on the experimental sites is given in Table 1 and Table 2.

Table 1. Location and soil type of experimental sites.

| Location | Soil Type |
|---|---|
| Southwest Experiment Station<br>Redwood Co. | Webster clay loam |
| Lawrence Suppalla<br>Waseca Co. | Nicollet clay loam |

Table 2. Soil test levels of experimental sites.

| Location | P | K | S | Zn | pH | O.M. |
|---|---|---|---|---|---|---|
| | ----lbs/A---- | | P.P.M. | P.P.M | | |
| Redwood Co. | | | | | | |
| 0-3" | 28 | 240 | 11 | 2.7 | 5.9 | H |
| 3-6" | 27 | 235 | 12 | 2.8 | 6.0 | H |
| 6-12" | 11 | 195 | 13 | 1.7 | 6.2 | H |
| Waseca Co. | | | | | | |
| 0-3" | 143 | 473 | 24 | 4.6 | 6.1 | H |
| 3-6" | 103 | 437 | 27 | 4.6 | 6.2 | H |
| 6-12" | 33 | 233 | 22 | 2.8 | 6.2 | H |

[1]Appreciation is expressed to Bonewitz Laboratories, Inc. and Custom Farm Service, Inc. for their assistance.

Sulfur rates of 0, 20, and 100 lbs./A of actual S were used in a series of plot randomized and replicated nine times. The sulfur was applied in the elemental form.

Redwood County Site

The fertility program of the experimental site included: (1) starter-14 + 43 + 22, and (2) sidedress - 100 lbs./A N. The sulfur treatments were broadcast in early spring before tillage.

No significant yield responses resulted with the addition of increased rates of sulfur (Table 3). Table 4 indicates that there was no significant change in plant tissue contents with increasing sulfur rates. The sixth leaf tissue has not been analyzed as of this date.

There is indicates that elemental sulfur is not effective the year of application. To look at this possibility a residual study will be continued on this plot site in 1971.

Table 3. Sulfur treatments and corresponding 1970 corn yields Lamberton.

| Fertilizer Treatment lbs/S/A | 1970 Yield bu/A |
|---|---|
| 0 | 155a * |
| 20 | 157a |
| 100 | 154a |

*Numbers followed by the same letter are not significantly different at the 5.0% level population. (Duncan's New Multiple Range Test)

Table 4. Plant analyses of corn 10" tall under variable sulfur treatments. Lamberton, 1970

| Fertilizer Treatments | % | | | | | | P.P.M. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | P | K | Ca | Mg | S | Fe | Zn | Cu | Mo | Mn | B |
| lbs/S/A | | | | | | | | | | | | |
| 0 | 3.40 | 0.42 | 2.96 | 0.48 | 0.43 | 0.29 | 509.6 | 24.2 | 9.20 | 12.1 | 41.0 | 6.9 |
| 20 | 3.42 | 0.45 | 3.05 | 0.48 | 0.46 | 0.28 | 514.6 | 25.1 | 11.44 | 12.2 | 43.9 | 7.2 |
| 100 | 3.40 | 0.45 | 2.96 | 0.47 | 0.44 | 0.29 | 506.2 | 23.4 | 9.61 | 12.0 | 42.4 | 7.9 |
| Signif-icance | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. |
| F-value | 0.10 | 2.37 | 1.35 | 0.04 | 1.37 | 1.16 | 0.03 | 1.20 | 1.12 | 0.05 | 0.77 | 1.10 |
| C.V. | 3.3 | 8.3 | 4.5 | 11.2 | 8.6 | 7.8 | 14.1 | 9.8 | 33.5 | 14.8 | 11.8 | 20.1 |

Waseca County Site

The fertility program included 202 lbs/A N + 90 lbs/A $P_2O_5$ + 110 lbs/A $K_2O$ + 10 lbs/A $ZnSo_4$. It was learned after plot establishment that the nitrogen was applied in the ammonium sulphate form. This accounted for 90 lbs/A sulfate. As evidenced from Tables 5 and 6 there was no significant differences in plant tissue contents. S levels are adequate with the reported critical level of 0.20%. No yield measurements were taken because of the amounts of sulphates previously applied.

1971 Experiments

Sulfur fertilization will be looked at more extensively in 1971. The experiment established at Lamberton in 1970 will be continued as a residual study. Seven additional sites on corn and alfalfa have been established across Southern Minnesota. These experiments will have sulfur treatments from 0-100 lbs/A sulfur applied as two products: (1) $K_2So_4$, and (2) Sol - U - Sul.

Table 5. Plant analyses of corn 10" tall under variable sulfur treatments. Waseca, 1970

| Fertilizer Treatments | % | | | | | | P.P.M. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | P | K | Ca | Mg | S | Fe | Zn | Cu | Mo | Mn | B |
| lbs/S/A | | | | | | | | | | | | |
| 0 | 3.13 | 0.58 | 3.38 | 0.39 | 0.21 | 0.272 | 187.0 | 28.8 | 6.08 | 4.39 | 47.1 | 7.0 |
| 20 | 3.24 | 0.57 | 3.24 | 0.40 | 0.23 | 0.279 | 186.8 | 30.6 | 7.88 | 4.82 | 43.1 | 7.0 |
| 100 | 3.17 | 0.55 | 3.20 | 0.38 | 0.22 | 0.272 | 179.7 | 39.0 | 6.20 | 4.33 | 52.9 | 6.68 |
| Significance | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. |
| F. Value | 0.87 | 0.57 | 0.39 | 0.48 | 0.28 | 0.59 | 0.96 | 1.17 | 0.54 | 0.54 | 1.89 | 1.07 |
| C.V. | 5.5 | 11.8 | 13.8 | 13.2 | 24.6 | 4.7 | 15.2 | 46.2 | 24.0 | 24.0 | 22.6 | 8.3 |

Table 6. Plant analyses of sixth leaf under variable sulfur treatments. Waseca, 1970

| Fertilizer Treatments | % | | | | | | P.P.M. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | P | K | Ca | Mg | S | Fe | Zn | Cu | Mo | Mn | B |
| lbs/S/A | | | | | | | | | | | | |
| 0 | 2.49 | 0.28 | 2.25 | 0.81 | 0.29 | 0.216#a | 111.2 | 17.1 | 6.99 | 5.56 | 37.5 | 7.7 |
| 20 | 2.56 | 0.27 | 2.11 | 0.82 | 0.32 | 0.227b | 1112.4 | 16.8 | 7.93 | 6.39 | 33.1 | 7.7 |
| 100 | 2.53 | 0.27 | 2.19 | 0.81 | 0.32 | 0.227b | 188.3 | 18.1 | 5.63 | 6.20 | 37.4 | 7.7 |
| Significance | N.S. | N.S | N.S. | N.S. | N.S. | * | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. |
| F. Value | 0.54 | 0.55 | 0.41 | 0.06 | 0.35 | 3.77 | 0.90 | 0.78 | 1.11 | 0.92 | 0.64 | 0.02 |
| C.V. | 5.6 | 9.8 | 15.5 | 9.9 | 30.3 | 4.5 | 102 | 13.1 | 48.0 | 22.6 | 26.0 | 9.3 |

# Numbers followed by different letters are significantly different at 5.0% level. (Duncan's New Multiple Range Test)

# SOIL TESTING

John Grava

Currently the University of Minnesota soil testing laboratory processes nearly twenty-two thousand samples annually. The following data show the number of various types of samples analyzed in 1970.

| | | |
|---|---|---|
| Regular farm, garden and lawn samples | | 16,441 |
| Florist (greenhouse) samples | | 2,284 |
| Specials: | Sulfur | 1,241 |
| | Zinc | 809 |
| | Soluble salts | 487 |
| | pH | 526 |
| | Organic matter | 102 |
| | Departmental research | 91 |
| | Total | 21,981 |

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 1970.

| Month | Number of Samples |
|---|---|
| January | 387 |
| February | 595 |
| March | 1090 |
| April | 3177 |
| May | 1780 |
| June | 668 |
| July | 893 |
| August | 1178 |
| September | 2002 |
| October | 2273 |
| November | 1611 |
| December | 787 |

# FIVE YEARS (1966-1970) OF EXPERIMENTS WITH DIFFERENT ZINC FERTILIZER SOURCES AND PHOSPHATE FOR CONTINUOUS CORN ON A ZINC DEFICIENT HAMERLY LOAM NEAR BENSON, MINNESOTA

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

An investigation of commercial sources of zinc and the effect of heavy phosphate fertilization was commenced with field corn in the spring of 1966 with two main objectives:

(1) To determine the relative effectiveness of several commercially available zinc compounds on corn growth, yield and composition.

(2) The comparative effect of heavy phosphate fertilization on zinc availability to growing field corn and eventual grain yields.

A zinc deficient calcareous loam had been previously observed on the Richard Mikkelson farm at the junction of Highways 22 and 29 in Swift County and 5 year lease arrangements on a 7 acre tract were completed with the owner. Two randomized block experiments were established about the middle of May, 1966, each with 7 different treatments in quadruplicate. Three rates of granular zinc sulfate ($ZnSO_4.7\ H_2O$ to supply 10, 20 and 40 pounds of zinc per acre, granular ZnMNS to supply 10 pounds of zinc per acre, and the solid granular chelated zinc (Zn45) to supply 2.5 lbs of zinc per acre, were broadcast and plowed down in 1966 and again in 1967. The seventh treatment consisted of 0.5 lbs of chelated zinc per acre as Zn 45 applied in the granular form along the corn row in each of the first 3 years, and as a liquid application along each row in 1969 and 1970.

The phosphate interaction experiment was located a few hundred feet distant, being of the same size and design with annual phosphate treatments being plowed down in each of the first four years and zinc as the granular $ZnSO_4\ .7\ H_2O$ during each of the first 2 years. The farm operator also applied a total of 100+40+40 per acre in 1966 over the entire area.

Adequate N, $P_2O_5$+ $K_2O$ fertilizer was applied in succeeding years.

Zinc deficient soils in Minnesota are usually low-lying calcareous areas, subject to poor water drainage and retain excessive moisture in the spring. Late corn planting generally is the rule. These low-lying areas are also subject to relatively poor air drainage, and to early fall frosts. This necessitates the planting of early maturing corn (and even this often fails to mature). The extreme variability in zinc supplying power of such soils, even in limited areas is well known, making adequate treatment replication extremely difficult and often unsatisfactory.

The soil of each plot was sampled each fall and analyzed for available zinc, phosphorus and additional constituents, the results have been reported in previous Soil Series. Severity of visual zinc deficiencies shown by growing plants, zinc, and phosphorus analyses of the sixth corn leaf were determined, and ear corn yield have been obtained in each of the five years and the major results are shown in the following tables.
Table 1 shows the severity of zinc deficiency by actual appearance of the corn plants in mid-August of each year.

Table 1. Visual Zinc Deficiency Symptoms of Corn Plants Growing in a Zinc Deficient Loam near Benson Minnesota (Swift County) with Different Zinc and Phosphate Fertilization (1966-70).

| | Years | | | | | |
|---|---|---|---|---|---|---|
| | 1966 | 1967 | 1968 | 1969 | 1970 | 5 year average |
| **Zinc Source Experiment** | Visual Rating (0 = severe and 10 = normal zinc deficiency) | | | | | |
| No Zinc | 5.1 | 3.2 | 3.0 | 6.8 | 9.5 | 5.5 |
| 10 as $ZnSO_4$ (P.D.) | 7.9 | 7.1 | 6.5 | 8.2 | 9.6 | 7.9 |
| 20 " " " | 8.1 | 8.6 | 8.7 | 9.2 | 9.6 | 8.8 |
| 40 " " " | 9.0 | 8.5 | 9.0 | 10.0 | 9.9 | 9.3 |
| 10 as ZnMNS (PD) | 8.7 | 8.0 | 7.5 | 8.5 | 9.8 | 8.5 |
| 0.5 Zn as Zn 45 (annually row) | 2.6 | 6.4 | 6.0 | 8.0 | 9.8 | 6.6 |
| 2.5 Zn as Zn 45 (bdct. & P.D. in "66 & '67) | 6.0 | 3.9 | 3.0 | 4.5 | 8.4 | 5.2 |
| **$P_2O_5$ - Zn Interaction Experiment** | | | | | | |
| (lbs $P_2O_5$/A in 1966, '67, '68 and '69) | | | | | | |
| 40 " " (PD) | 7.0 | 7.5 | 7.0 | 6.8 | 9.9 | 7.6 |
| 80 " " " | 7.0 | 7.0 | 5.7 | 7.3 | 9.6 | 7.3 |
| 160 " " " | 5.7 | 8.0 | 6.2 | 6.8 | 9.5 | 7.2 |
| 320 " " " | 3.9 | 5.0 | 3.2 | 4.8 | 9.1 | 5.2 |
| 640 " " " | 2.7 | 3.5 | 2.5 | 2.5 | 6.3 | 3.5 |
| 320 " " " + 10 Zn as $ZnSO_4$ ('66 & '67) | 8.5 | 8.4 | 8.7 | 9.8 | 9.9 | 9.0 |
| 640 $P_2O_5$ annual PD + 10 Zn as $ZnSO_4$ ('66 & '67) | 7.9 | 8.5 | 8.2 | 8.3 | 9.9 | 8.6 |

PD = Plowed down.

It is evident that by the fifth year of the experiment (1970), considerable mixing of the applied zinc had occurred and even the corn plants of the originally no zinc treated plots were obtaining sufficient zinc for apparently near normal growth. However, four years of fertilizing with $P_2O_5$ at the rate of 640 lbs resulted in corn plants visually deficient in zinc.

Table 2 shows the actual zinc content of the sixth corn leaves at silking.

Table 2. Zinc Concentrations in the Sixth (Index) Corn Leaves Growing on a Zinc Deficient Loam near Benson, Minnesota (Swift County) with Different Zinc and Phosphate Fertilization (1966-70).

| | Years | | | | | |
|---|---|---|---|---|---|---|
| | 1966 | 1967 | 1968 | 1969 | 1970 | 5 year average |
| Zinc Source Experiment | Leaf zinc in parts per million | | | | | |
| No Zinc | 7.2 | 9.2 | 14.8 | 13.8 | 7.1 | 10.4 |
| 10 as $ZnSO_4$ (PD) | 11.7 | 13.8 | 16.4 | 17.6 | 10.4 | 14.0 |
| 20 " " " | 14.0 | 18.2 | 23.4 | 28.0 | 12.1 | 19.1 |
| 40 " " " | 18.0 | 26.5 | 29.4 | 42.6 | 22.0 | 27.7 |
| 10 " ZnMNS (PD) | 9.3 | 12.8 | 15.3 | 18.2 | 9.4 | 13.0 |
| 0.5 Zn as Zn 45 (annually row) | 8.6 | 11.8 | 12.1 | 15.6 | 12.5 | 11.4 |
| 2.5 Zn as Zn 45 (bdct. & PD in '66 & '67) | 8.3 | 11.5 | 12.7 | 14.9 | 8.9 | 12.0 |
| $P_2O_5$ - Zn Interaction Experiment (lbs $P_2O_5$/A in 1966, '67, '68 and '69) | | | | | | |
| 40 " " (PD) " | 10.0 | 10.2 | 13.3 | 17.1 | 16.6 | 13.4 |
| 80 " " " " | 10.2 | 12.5 | 16.1 | 18.4 | 10.0 | 13.4 |
| 160 " " " " | 8.4 | 10.5 | 13.1 | 15.1 | 8.8 | 11.2 |
| 320 " " " " | 7.5 | 9.0 | 12.7 | 14.2 | 8.6 | 10.4 |
| 640 " " " " | 7.3 | 8.2 | 9.3 | 13.4 | 8.4 | 9.3 |
| 320 " " " " + 10 Zn as $ZnSO_4$ in ('66 & '67) | 12.4 | 13.2 | 14.4 | 28.4 | 16.6 | 17.0 |
| 640 $P_2O_5$ annual PD + 10 Zn as $ZnSO_4$ in ('66 & '67) | 11.0 | 12.0 | 17.3 | 27.1 | 12.6 | 16.0 |

PD = Plowed down.

The relative availability of zinc from the different sources is evident in the amount of this element present in the corn leaves growing on the variously treated soils. The effect of heavy phosphate applications to this soil during the first four years on zinc concentrations in the corn leaves is also evident, as well as the corrective effect of 10 lbs. of Zn/A plowed down in the sulfate form.

Table 3 presents the phosphorus content of the sixth corn leaves at silking.

Table 3. Phosphorus Concentrations in the Sixth (Index) Corn Leaves Growing on a Zinc Deficient Loam near Benson, Minnesota (Swift County) with Different Zinc and Phosphate Fertilization (1966-70).

| | Years | | | | | |
|---|---|---|---|---|---|---|
| | 1966 | 1967 | 1968 | 1969 | 1970 | 5 year average |
| Zinc Source Experiment | Percentage leaf P | | | | | |
| No Zinc | 0.400 | 0.367 | 0.410 | 0.339 | 0.254 | 0.354 |
| 10 as $ZnSO_4$ (PD) | 0.297 | 0.304 | 0.338 | 0.272 | 0.236 | 0.289 |
| 20 " " " | 0.259 | 0.273 | 0.462 | 0.265 | 0.230 | 0.298 |
| 40 " " " | 0.259 | 0.281 | 0.511 | 0.302 | 0.202 | 0.311 |
| 10 " ZnMNS | 0.326 | 0.285 | 0.630 | 0.284 | 0.234 | 0.352 |
| 0.5 Zn as Zn 45 (annually row) | 0.394 | 0.331 | 0.351 | 0.382 | 0.237 | 0.339 |
| 2.5 Zn as Zn 45 (bdct. & PD in '66 & '67) | 0.372 | 0.323 | 0.458 | 0.325 | 0.295 | 0.355 |
| $P_2O_5$ - Zn Interaction Experiment (lbs $P_2O_5$/A in 1966, '67, '68 and '69) | | | | | | |
| 40 " " " (PD) | 0.351 | 0.317 | 0.410 | 0.362 | 0.268 | 0.342 |
| 80 " " " " | 0.313 | 0.312 | 0.338 | 0.350 | 0.264 | 0.315 |
| 160 " " " " | 0.359 | 0.323 | 0.462 | 0.385 | 0.280 | 0.362 |
| 320 " " " " | 0.400 | 0.436 | 0.510 | 0.410 | 0.337 | 0.419 |
| 640 " " " " | 0.486 | 0.570 | 0.630 | 0.600 | 0.482 | 0.554 |
| 320 " " " " + 10 Zn as $ZnSO_4$ ('66 & '67) | 0.325 | 0.308 | 0.351 | 0.321 | 0.258 | 0.313 |
| 640 $P_2O_5$ annual PD + 10 Zn and $ZnSO_4$ in ('66 & '67) | 0.304 | 0.310 | 0.458 | 0.289 | 0.238 | 0.320 |

PD = plowed down

The P content of the leaves was depressed where larger amounts of zinc were available in the soil resulting in higher leaf Zn. Phosphate fertilization was reflected in leaf P, and 1970 corn leaves were lower in P than in the preceding four years, this being a probable relecteion of omitting the 1970 $P_2O_5$ fertilization.

Yields of corn grain during the five years are shown in Table 4.

Table 4. Yields of Corn Grain Grown on a Zinc Deficient Loam near Benson, Minnesota (Swift County) with Different Zinc and Phosphate Fertilization (1966-70).

| | Years | | | | | |
|---|---|---|---|---|---|---|
| | 1966 | 1967 | 1968 | 1969 | 1970 | 5 year average |
| Zinc Source Experiment | Bushels per acre at 15% moisture | | | | | |
| No Zinc | 92.0 | 56.1 | 71.3 | 90.8 | 81.1 | 78.3 |
| 10 as $ZnSO_4$ (PD) | 115.4 | 77.5 | 92.4 | 96.1 | 85.7 | 93.4 |
| 20 " " " | 111.8 | 75.6 | 94.8 | 97.3 | 84.1 | 92.7 |
| 40 " " " | 109.3 | 81.7 | 88.8 | 90.1 | 85.8 | 91.1 |
| 10 " ZnMNS | 103.8 | 79.2 | 86.9 | 94.7 | 87.1 | 90.3 |
| 0.5 Zn as Zn 45 (annually row | 85.5 | 69.7 | 93.4 | 83.3 | 78.7 | 82.1 |
| 2.5 Zn as Zn 45 (bdct. & PD in '66 & '67) | 93.3 | 58.4 | 79.0 | 81.0 | 79.6 | 78.3 |
| $P_2O_5$ - Zn Interaction Experiment (lbs $P_2O_5$/A in 1966, '67, '68 and '69) | | | | | | |
| 40 " " " " | 98.4 | 68.5 | 86.9 | 96.8 | 108.7 | 91.9 |
| 80 " " " " | 96.9 | 65.8 | 94.5 | 104.2 | 93.9 | 91.1 |
| 160 " " " " | 96.3 | 60.8 | 100.0 | 94.4 | 98.7 | 90.0 |
| 320 " " " " | 96.8 | 50.2 | 81.4 | 89.7 | 100.9 | 83.8 |
| 640 " " " " | 83.4 | 34.3 | 72.0 | 82.2 | 90.1 | 72.4 |
| 320 " " " " + 10 Zn as $ZnSO_4$ ('66 & '67) | 113.6 | 74.8 | 92.6 | 110.6 | 106.5 | 99.6 |
| 640 $P_2O_5$ annual PD + 10 Zn and $ZnSO_4$ in ('66 & '67) | 107.6 | 74.7 | 100.6 | 117.2 | 102.0 | 100.4 |

PD = plowed down

During the five years of the experiment, the plots to which the more effective forms of zinc was applied and plowed down produced more than 10% additional corn. Heavy phosphate fertilization at rates of 320 or 640 pounds of $P_2O_5$ per acre depressed corn grain production, with marked improvement when $ZnSO_4 \cdot 7H_2O$ was plowed down to supply zinc at the 10 pound per acre rate.

# STUDIES ON CAUSES OF VARIATIONS IN ZINC AVAILABILITY TO CORN IN A CALCAREOUS KANDIYOHI COUNTY SOIL

Adisak Sajjapongse and J.M. MacGregor

Zinc deficiency in corn growing on certain high lime mineral or organic soils in western Minnesota has been recognized since 1961. The apparent extreme variability in zinc availability has been frequently observed to occur in problem fields within relatively short distances, with no know reason. In a zinc deficient field in southeastern Kandiyohi county, 5 year average corn yields on a soil receiving no added zinc, ranged from 28 to 52 bushels per acre on areas only 100 feet apart, with no obvious soil differences. Zinc as zinc sulfate applied at rates from 5 to 40 lbs/A resulted in markedly increased yields over the 5 year period of the field study.

These soils were sampled in 1969 to a 48 inch depth, and soil temperatures and moisture content were found to be essentially equivalent at the four depth levels of all 36 plots of the study. The samples were analyzed and little or no differenc was found in soil pH or in soluble salt content. However, there were marked differences in extractable zinc, extractable P, calcium carbonate equivalent and exchangeable K and these appeared to be associated with lower or higher corn yields. Corn yields during the 5 year field study were larger with higher extractable soil zinc, lower extractable soil P and higher exchangeable K. Higher calcium carbonate equivalent seemed to counteract the undesirable affects of high soil P levels.

Greenhouse studies on the four depths of all 36 plots (3 replications of 12 treatments) showed no additional corn growth from the 1962 zinc treatments, but where zinc had been added 8 years previously, the greenhouse corn plants contained more zinc. However, corn plants from even the untreated soils all exceeded the minimum "critical" levels of

15 ppm zinc when grown in the greenhouse. However, corn plants grown on surface soils took up much more zinc than plants grown on soils from the second and third foot depths, while plants growing on the fourth foot depth were intermediate in zinc concentration. This is explainable, in probably being due to zinc extraction by plant roots and subsequent deposition at the surface in decaying plant organic matter for many years. Apparently plant roots seldom penetrated below the 3 feet level in these heavy, cold, and wet soils, and essentially all of the original soil zinc still remains at the fourth foot depth.

Studies with radiozinc ($Zn^{65}$) indicated the major zinc uptake by the corn plants to be from the soil, this being especially marked where the larger amounts of zinc were applied to the surface soil in 1962.

There was essentially no penetration of the fertilizer zinc beyond the 12 inch soil depth 8 years after application.

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