SOIL SERIES 88

A REPORT ON FIELD RESEARCH IN SOILS

The 1972 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 1971 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.

Sincere appreciation is expressed for materials and/or financial assistance or program support from several organizations including: Amchem Products; American Potash Institute; American Oil Company; Bonewitz Laboratories, Inc.; Chevron Chemical Compaay; CIC Biometerology Graduate Program; College of Environmental Sciences, University of Wisconsin; Conwed Corporation; Custom Farm Services; DuPont Chemical Company; Eagle-Picher Company; Elanco Products Company; Farmers Union Central Exchange; Geigy Agricultural Chemical Corporation; Gulf Oil Company; Green Giant Company; International Harvester Company; International Minerals and Chemical Corporation; Jacques Seed Company;

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Note: Molybdenum values obtained with the Multi-Element Emmission Spectrophotometer are questionable due to analytical inference.

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CLIMATOLOGICAL NOTES OF 1971

D. G. Baker

A. Review of the Weather (based on notes prepared by Earl L. Kuehnast, State Climatologist, National Weather Service)

1971 began with a winter snowfall generally 125-175% of normal everywhere except in the west where it was about normal. In April to mid-May it was quite dry, but the weather became wet and cold for the remainder of May. June was warm, wet and stormy. There was a total of 11 days of hail with two very severe storms; one in the Rochester area on the 24th and the other south of Bird Island in Renville County where nearly 12 inches of rain fell. This was the greatest ever documented in the state. There were also 11 separate hail days in July which was on the whole a sunny but cool month averaging about 5° F below normal. August was sunny and cool with precipitation about 33% of normal in the south and 66% of normal in the north. The main feature of September was the below normal precipitation in the south and above normal in the north. Fig. 1 shows the growing season (May-September) precipitation. In parts of south-central Minnesota rainfall was about 6 inches below normal.

October was an exceptional month. It was in fact, the wettest October in history, for precipitation averaged nearly 350% above normal. In the area from Ada to Fosston in the northwestern part of the state it was 650% above normal! A map of the distribution of the October rainfall is shown in Fig. 2.

November served as the transition month as usual with the introduction of snow and cool temperatures in the latter part of the month. Snow cover of at least one inch in depth was about three weeks early since it occurred on November 23 rather than about December 15. During December temperatures were about normal and precipitation somewhat below normal.

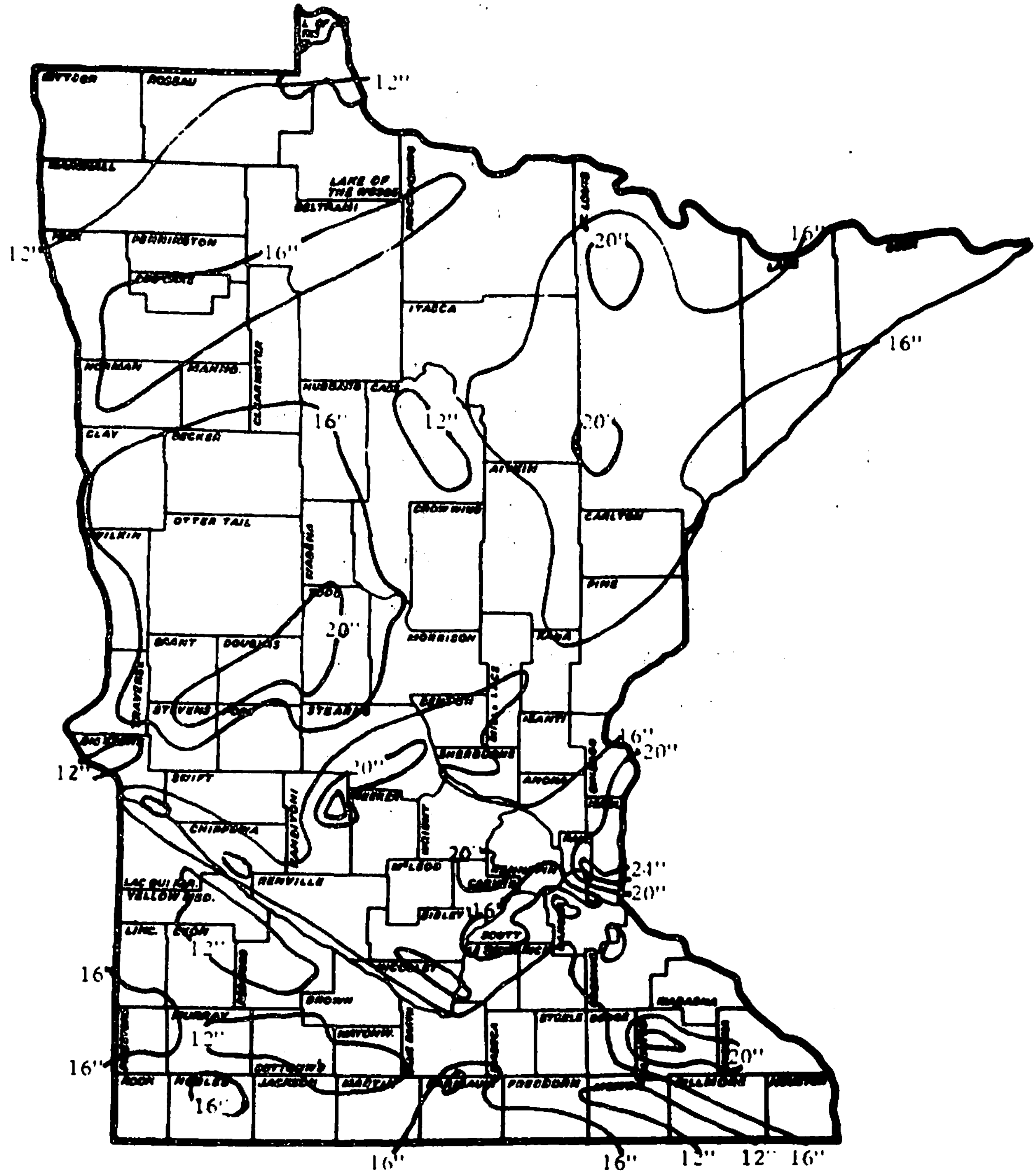

Figure 1. MINNESOTA 1971 GROWING SEASON RAINFALL (May-September)

Earl L. Kuehnast
State Climatologist
National Weather Service

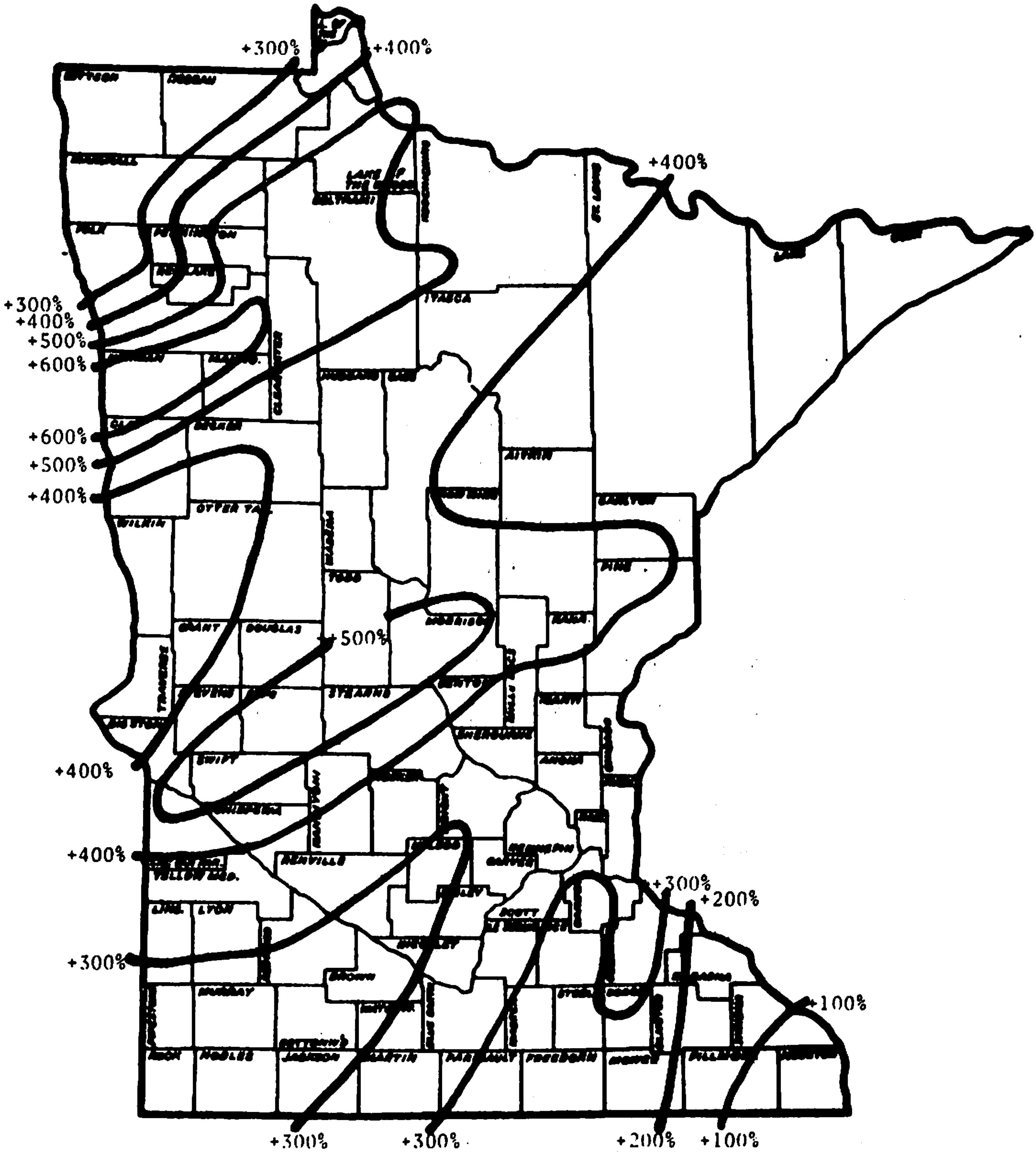

Figure 2. MINNESOTA PRECIPITATION-DEPARTURE FROM NORMAL-OCTOBER 1971

Earl L. Kuehnast
State Climatologist
National Weather Service

B. Soil Moisture

Through some very simple measurements* we are able to gain information about not only the soil moisture reserves but also how much water the crops consume. These measurements are made by gravimetric samples of the soil down to 5 feet at a minimum of 3 sites in a field. The data obtained from these samples plus the measured precipitation permit an estimate of the water consumption of crops. It ia apparent that without a measure of both surface runoff and drainage through the soil beyond the 5 foot depth water use by the crop can only be an estimate. Table 1 shows the results obtained in this year's survey.

The Sibley, Todd, and Wabasha County results all show higher than usual water use figures. Apparently, there was an unusual amount of surface runoff or drainage through the profile which, because neither is measured, makes the crop water use figure high.

All stations except Lamberton (Redwood County) show moderate to high soil moisture reserves in the autumn of 1971. Both the Lamberton and Crookston (Polk County) reserves are probably much higher now for their last sampling dates largely preceded the above normal rains of October.

It would seem, therefore, that the soil moisture reserves throughout the state must be normal to well above normal. The crops for the 1972 season should, therefore, if given the opportunity to establish adequate root systems, be able to survive any but the most severe drought. If rains are above normal in 1972, then there may well be problems of excessive soil moisture in the '72 season.

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*Simple though these measurements are, they are nevertheless time consuming, backbreaking and may in some cases represent a physical hardship. This last is particularly true of those samples taken at the beginning and end of the season when temperatures may be low and winds strong.

The individuals and agencies responsible for the soil moisture samples are listed in Table 1.

The frequent samples taken through the season at both the Northwest (Crookston) and Southwest (Lamberton) Agricultural Experiment Stations permit a view of more than just the seasonal fluctuations of soil moisture. These changes are shown in Fig. 3 and Fig. 4.

The 11 years of soil moisture data at the Southwest Experiment Station (Fig. 4) give us a general view of the course of fluctuation of soil moisture that is available at only a few stations in the United States. Of particular interest is the time when moisture reserves are at a maximum (about June 1-7) and at a minimum (about September 1-12). A curious "hump" occurs in the drawdown curve at about July 15-29. This seems to coincide with the time when tasseling and silking occur in corn. If this "hump" is real it may indicate not that plants' consumption of water is less, but that the water which falls is more efficiently used. It is to be remembered that not long before this about 100% plant cover is reached. There is the possibility (assuming the "hump" in the drawdown curve is real) that the plants may temporarily use less water at this time, although work by other investigaors would seem to rule this possibility out.

The Crookston data in Fig. 3 indicate the importance of the crop factor when soil moisture is considered. The crop of the previous year is very important in those areas where the autumn and spring soil moisture recharge is unable to bring the soil up to field capacity. For example, at Crookston the alfalfa (1971) plot was also in alfalfa in 1970. Since alfalfa is an actively transpiring green crop for a longer period than either sugarbeets or wheat, its consumption of water is greater. Thus at the beginning of the 1971 season the spring water content was lower than for the other two plots.

Table 1. Soil moisture survey of 1971[a].

County and Nearby Town	Sampled By	Agency	Soil Type	Crop	Soil Moisture[b] Date & Sample	Precipitation[c]	Water Use
Dodge Co., Dodge Center	S.F. Crull	S.C.S., U.S.D.A.	Kasson silt loam	Corn	5/11= 7.47 in. 12/6 = 7.29	19.32 in.	19.50 in.
Mille Lacs Co., Milaca	W. M. Kalton	S.C.S., U.S.D.A.	Mora silt loam	Hay	5/4 = 9.13 11/2 =12.02	23.70	20.81
Polk Co., Crookston	O.C. Soine	N.W.Exp.Sta., U. of M.	Hegne Si.C.L.	Alfalfa	4/30= 4.49 10/4 = 6.12	20.13	18.50
Polk Co., Crookston	O.C. Soine	N.W.Exp.Sta., U. of M.	Hegne Si.C.L.	Wheat	5/7 = 1.83 10/4 = 8.30	20.02	13.55
Polk Co., Crookston	O.C. Soine	N.W.Exp.Sta., U. of M.	Hegne Si.C.L.	Beets	4/30= 9.38 10/4 = 5/61	20.13	23.90
Ramsey Co., St. Paul	D.G. Baker	Exp.Sta., U. of M.	Waukegan Si.L.	Sod	5/2 =18.05[d] 10/25=14.65[d]	21.72	25.12
Ramsey Co., St. Paul	D.G. Baker	Exp.Sta., U. of M.	Waukegan Si.L.	Bare	5/29=14.20[d] 9/15=12.79[d]	13.30	14.71
Ramsey Co., St. Paul	D.G. Baker	Exp.Sta., U. of M.	Waukegan Si.L.	Soybeans	5/29=16.26[d] 9/15=13.94[d]	13.30	15.62
Redwood Co., Lamberton	W.W. Nelson	S.W.Exp.Sta., U. of M.	Nicollet C.L.	Corn	5/5 = 6.77 10/7 = 2.79	13.70	17.68
Sibley Co., Gaylord	D.T. Goerend	S.C.S., U.S.D.A.	Nicollet clay loam	Corn	4/22= 9.35 11/8 = 9.78	27.44	27.01
Todd Co., Long Prairie	R.E. Krause	S.C.S., U.S.D.A.	Blowers loamy fine sand	Alfalfa	5/21=13.77 10/28= 7.56	23.07	29.28

Table 1. (Continued)

County and Nearby Town	Sampled By	Agency	Soil Type	Crop	Soil Moisture[b] Date & Sample	Precipitation	Water Use
Wabasha Co., Wabasha	R.W. Hoff	S.C.S., U.S.D.A.	Fayette silt loam	Corn	4/20=12.79 11/2 =10.24	23.62 in.	26.17 in.

[a]Through an error on my part no fall soil moisture sampling kit was sent to P. N. Kennedy, St. James, Watonwan Co., who has been a faithful cooperator for a number of years.

[b]The date of the spring and fall soil sample and total plant available water in a 5 foot column of soil (with exception at St. Paul, Ramsey Co., See footnote d).

[c]Measured precipitation between soil sample periods. All measurements made in or near the towns named except Owatonna was substituted for Dodge Center precipitation.

[d]These figures are for total water present rather than available water.

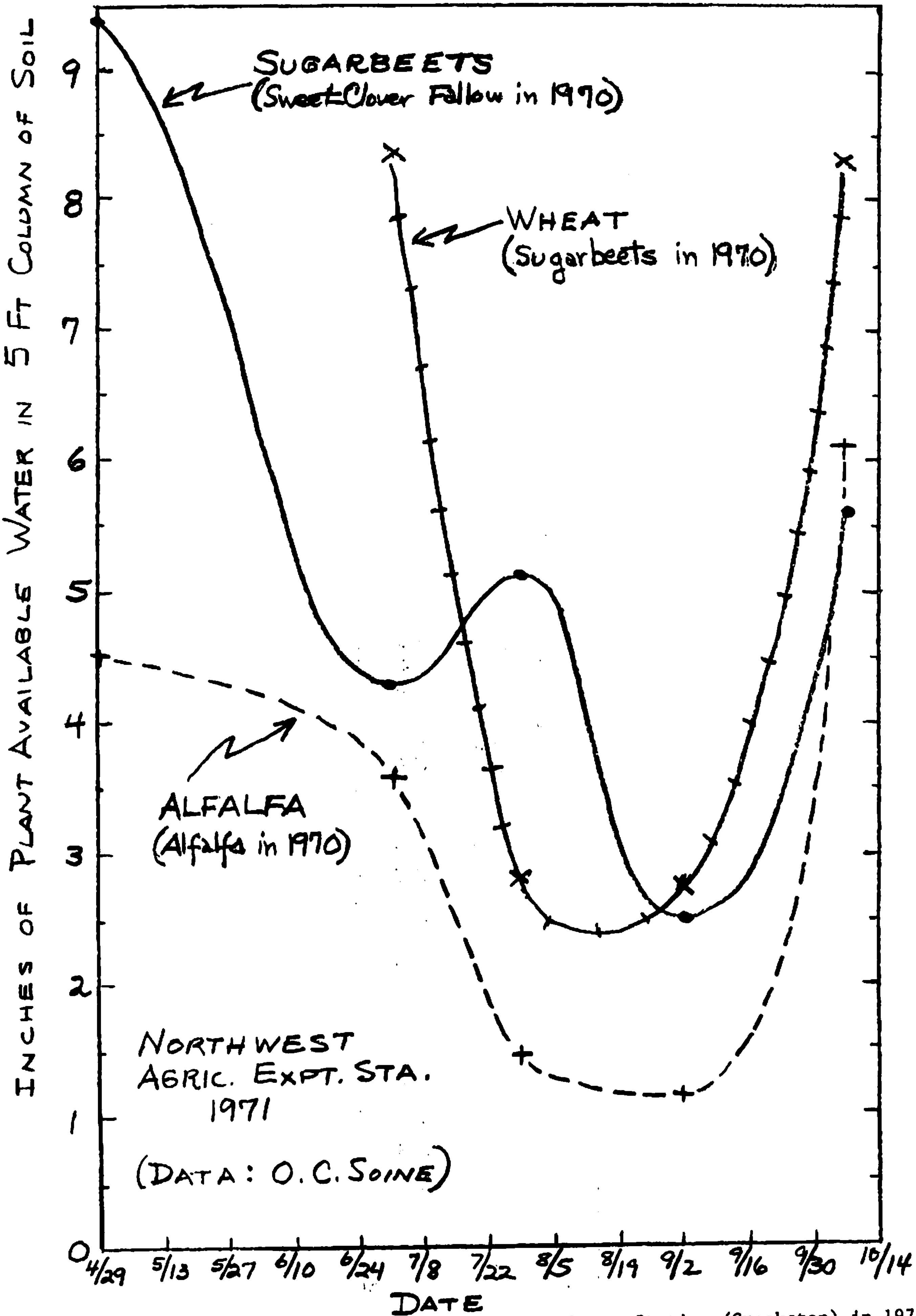

Figure 3. Soil moisture under 3 crops at the Northwest Station (Crookston) in 1971.

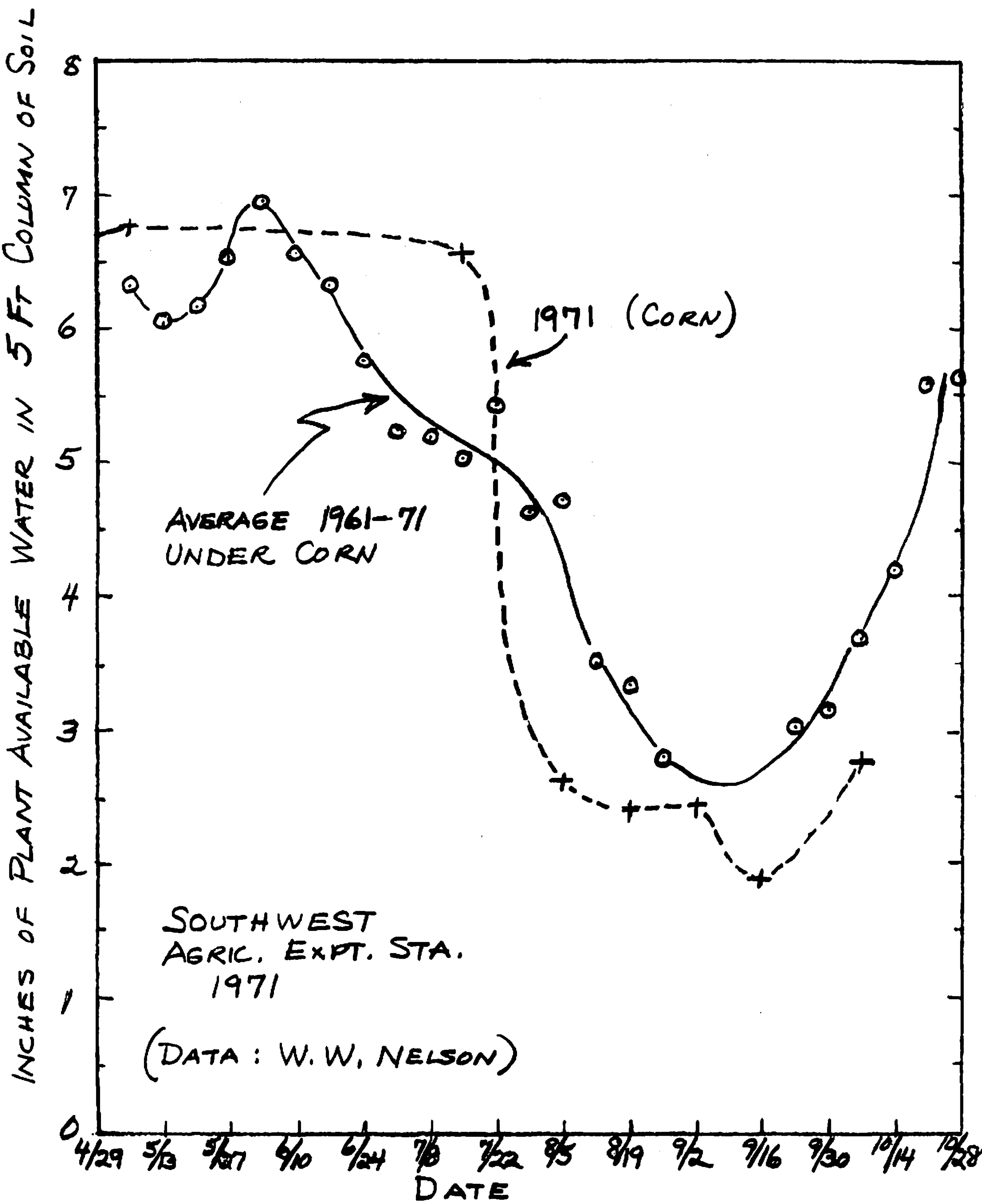

Figure 4. Soil moisture under corn at the Southwest Station (Lamberton) in 1971. The average soil moisture curve for the 11 year period 1961-71 is also shown.

C. Fall Soil Temperatures

The temperature of the soil should remain of interest to us even when the growing season is over and the crops are in. For example, when soil temperatures reach 50°F or lower the activity of soil microorganisms virtually ceases. This has a direct bearing on fall fertilizer applications, for there is little likelihood at that point of the nitrogen in the NH_3 type fertilizers being converted to the NO_3 form. The latter is a form that is readily lost from soil. fig. 5 shows the average date on which 50° F or lower occurs at the 2-inch depth of agricultural soils.

The date when soils begin to freeze also of interest for it represents the time when the bearing strength and trafficability of the soil changes greatly. Fig. 6 shows the mean date when a temperature of 32° F may be expected at the 2-inch depth of agricultural soils.

It should be obvious that only the most general sort of map is presented and that due to type of cover, slope, soil and other factors there may be appreciable local differences from the dates shown in Fig. 5 and 6.

The reader should know how the dates in Fig. 5 and 6 were obtained so that an undue degree of confidence is not placed upon them. The soil temperatures available for study come form 6 sites: Fairmont (9 years of data), Faribault (5 years of data), Lamberton (10 years of data), Morris (3 years of data), St. Paul (9 years of data), and Waseca (7 years of data). The average date when 50°F and 32°F last occurred at the 2-inch soil depth was determined. The dates at the two stations for which only a 3-inch depth temperature was available. The dates at the two stations for which only 3-inch depth was measured were corrected by substracting two days from the average occurrence date. Because the 6 stations are too few upon which to base any kind of a statewide map the occurrence dates of various autumn air temperatures, for which a great number of stations are available, were studied for similarity. It was found that the mean date of the first occurrence of the 24° F air temperature (Minn. Agr. Expt. Sta. Tech. Bull. 243, 1963) in the fall averaged only 3 days after the 50° F 2-inch soil temperature. With some slight modifications then the state map was drawn based on the numerous stations for which the air temperature occurrence dates are available. The 32° F map was drawn using as a guide the average dates when both 20° F and 25° F air temperatures occur in the fall. This map was modified slightly to conform to the general configuration obtained in Fig. 5.

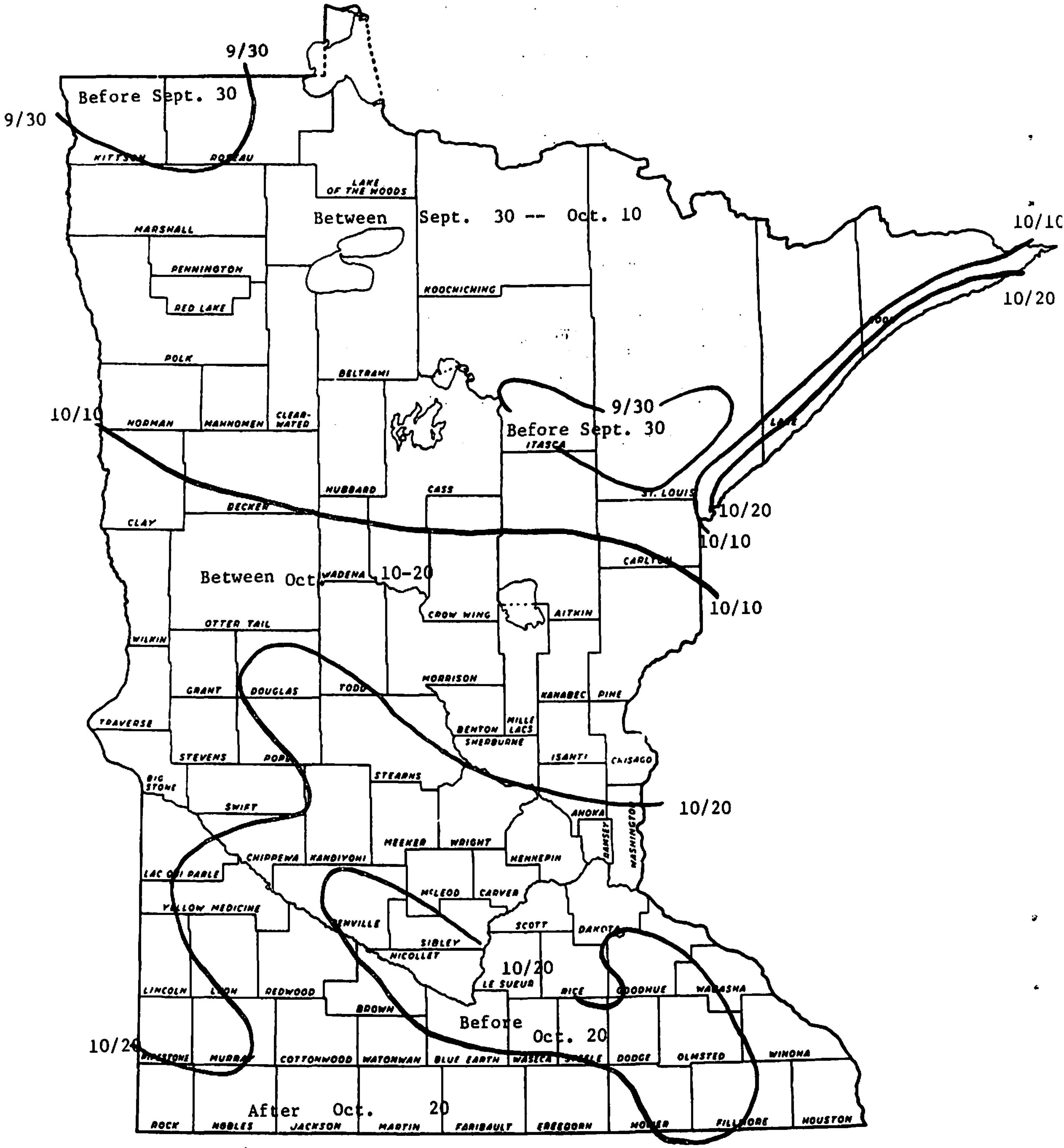

Figure 5. Average date of last occurrence of 50° F or higher in soil at 2 inch depth.

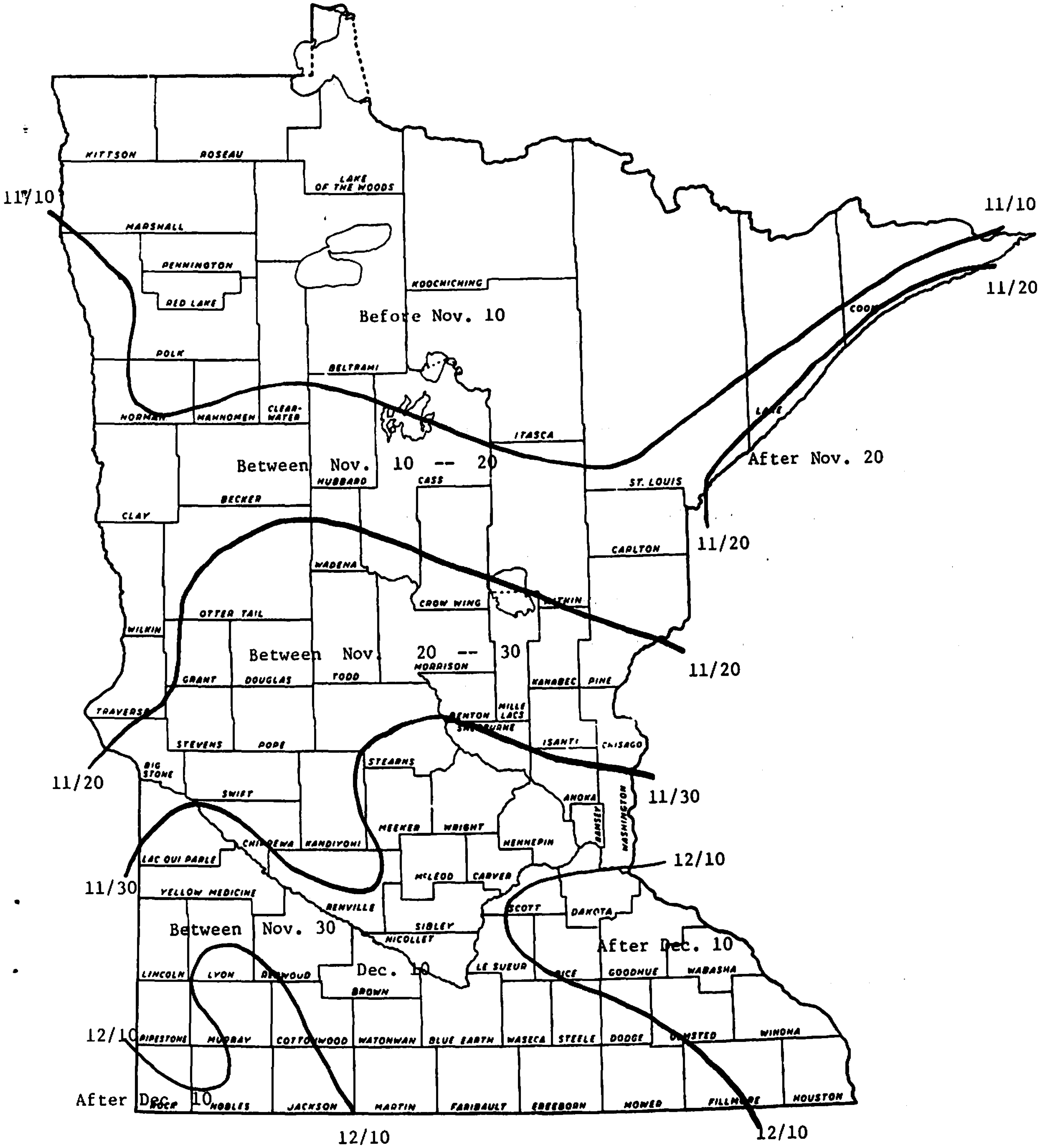

Figure 6. Average date when soil temperature (at 2 inch depth) reaches 32° F or lower.

D. Phenological Observations

The Future Farmers of America in the state of Minnesota have entered into a project (Operation Rain Gage) of recording precipitation. Some members are also taking phenological observations of their crops along with the precipitation measurements. Fig. 7 is derived from some of the data supplied by the young people in the F.F.A. This figure shows why cumulative growing degree days are a tempting means of predicting the growth of plants. In this case a comparison is made between the height of corn and growing degree days. The agreement is all the more remarkable when it is realized that the comparison is between corn at 6 different counties and the growing degree days were calculated based only upon the average temperature at Waseca -- not even the 1971 temperature.

Another interesting feature is the growth of the plant versus the number of days after planting. For example, on the average the corn plant reached 36 inches by about June 30 or 54 days after planting.

There is some additional information which has been gleaned from the F.F.A. "Operation Rain Gage". Fig. 8 shows data obtained from southeastern Minnesota. Data from other parts of the state were obtained, but it is unnecessary to show more since the results are similar. The point on interest and concern is that as presently grown tasseling and silking in corn and flowering in soybeans occur when the growing season probability of precipitation is least. This is a serious matter because the water requirement of corn and soybean is most critical at this time with respect to plant yield.

That this critical stage of growth occurs when it does suggests that the stage of growth be advanced if possible. It would appear that even a week advance would greatly benefit Minnesota agriculture.

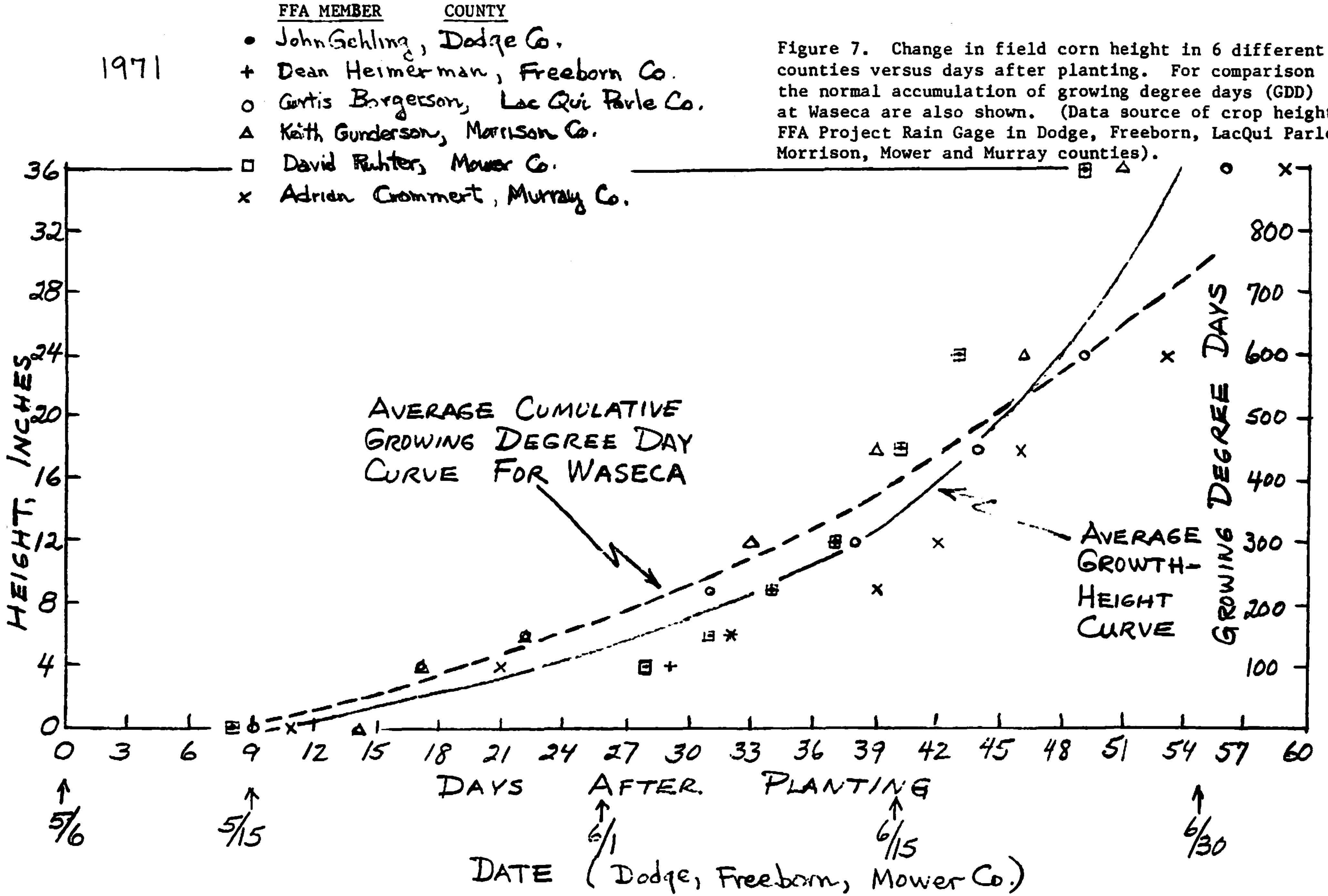

Figure 7. Change in field corn height in 6 different counties versus days after planting. For comparison the normal accumulation of growing degree days (GDD) at Waseca are also shown. (Data source of crop height FFA Project Rain Gage in Dodge, Freeborn, LacQui Parle Morrison, Mower and Murray counties).

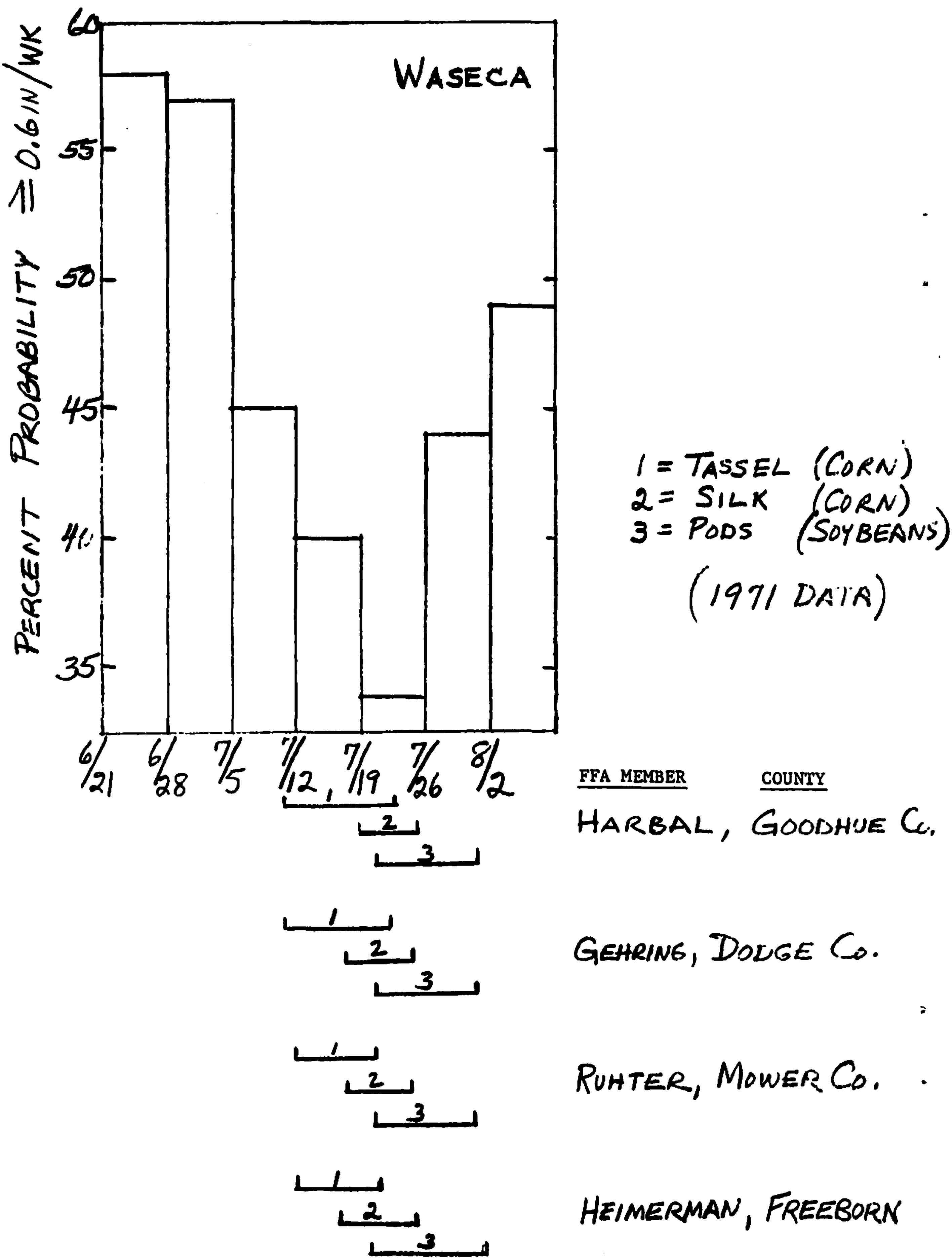

Figure 8. The probability of that weekly total precipitation at Waseca will equal or exceed 0.60 inches. Also shown at base of the chast in the interval in days when tasseling and silking in corn and pods in soybeans occurred in 4 neighboring counties.

E. Net Radiation and Evapotranspiration

Net radiation is the difference between the incoming radiation of all wavelengths (that is, both the shortwave solar and the longwave atmospheric radiation) and the outgoing radiation of all wavelengths (reflected shortwave and longwave from the earth). When there is more incoming than outgoing, common in the daytime and in summer, the excess is consumed in evapotranspiration; heating the air, soil and crop; and in photosynthesis. When soil moisture is readily available the greater share of the surplus energy is used in evapotranspiration.

As shown in fig. 9 the ratio between net radiation and incoming solar radiation is on the average about 0.50 (or 50%) during the heart of the growing season at St. Paul. This is fortuitous, since it permits an approximation of the net radiation to be made from the solar radiation measurements. (For the advantage of the reader it should be pointed out that there is no regular network of net radiation stations while there is one of solar radiation of many years standing maintained by the National Weather Service.)

Fig. 10 shows why net radiation is of importance in our climatic area. The net radiation (when converted into the inches of water that could be evaporated by the energy available) agrees very closely to the average measured daily water loss (evapotranspiration) at Lamberton.

The point to this whole section is that where soil moisture is by and large readily available to a coop the average daily consumption of water through evapotranspiration may be estimated as follows: During May-July the net radiation equals about 50% of the measured solar radiation, and about 100% of the net radiation will be consumed in evapotranspiration.

Thus the measured quantity solar radiation can be used to estimate two quantities, net radiation and evapotranspiration, which normally are not measured or, if measured, then only at a few experimental sites.

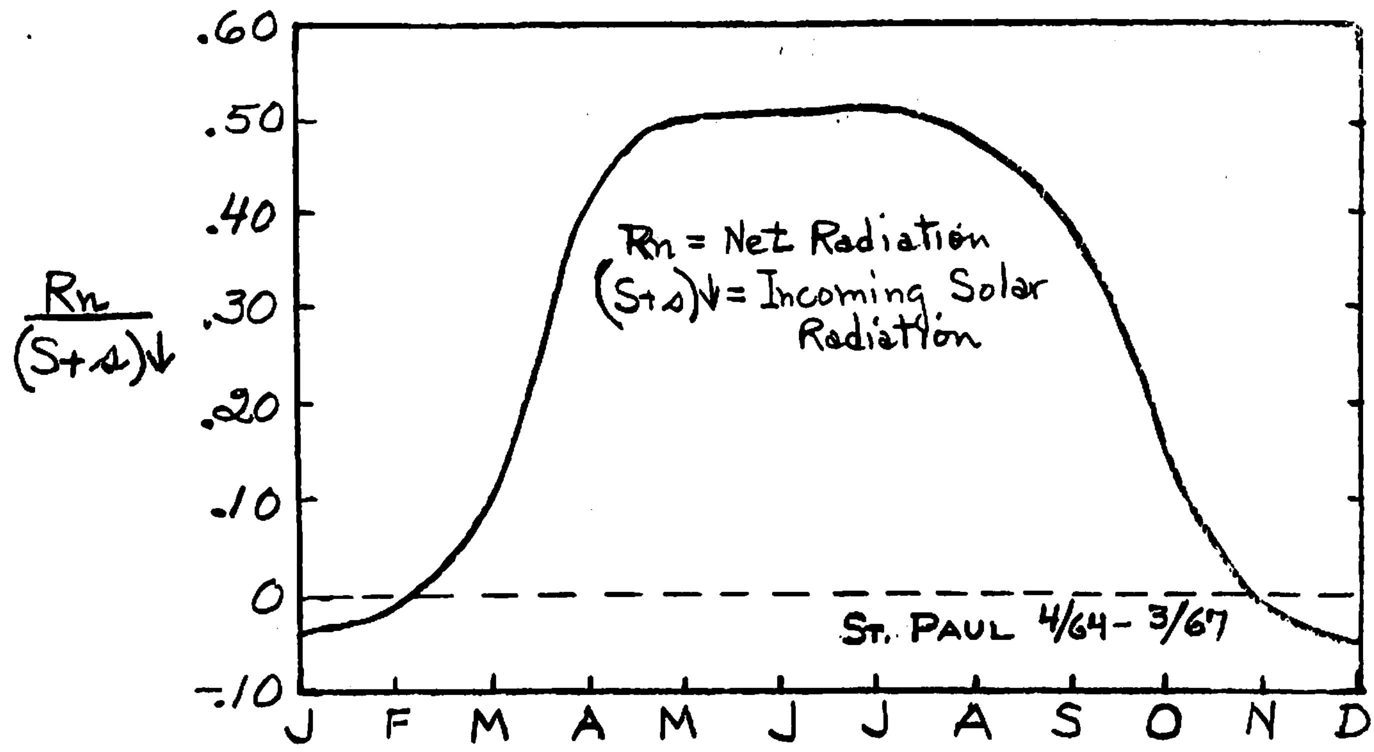

Figure 9. Average ratio of net radiation (Rn) to the incoming solar radiation (Sts)↓ for a 3 year period at St. Paul.

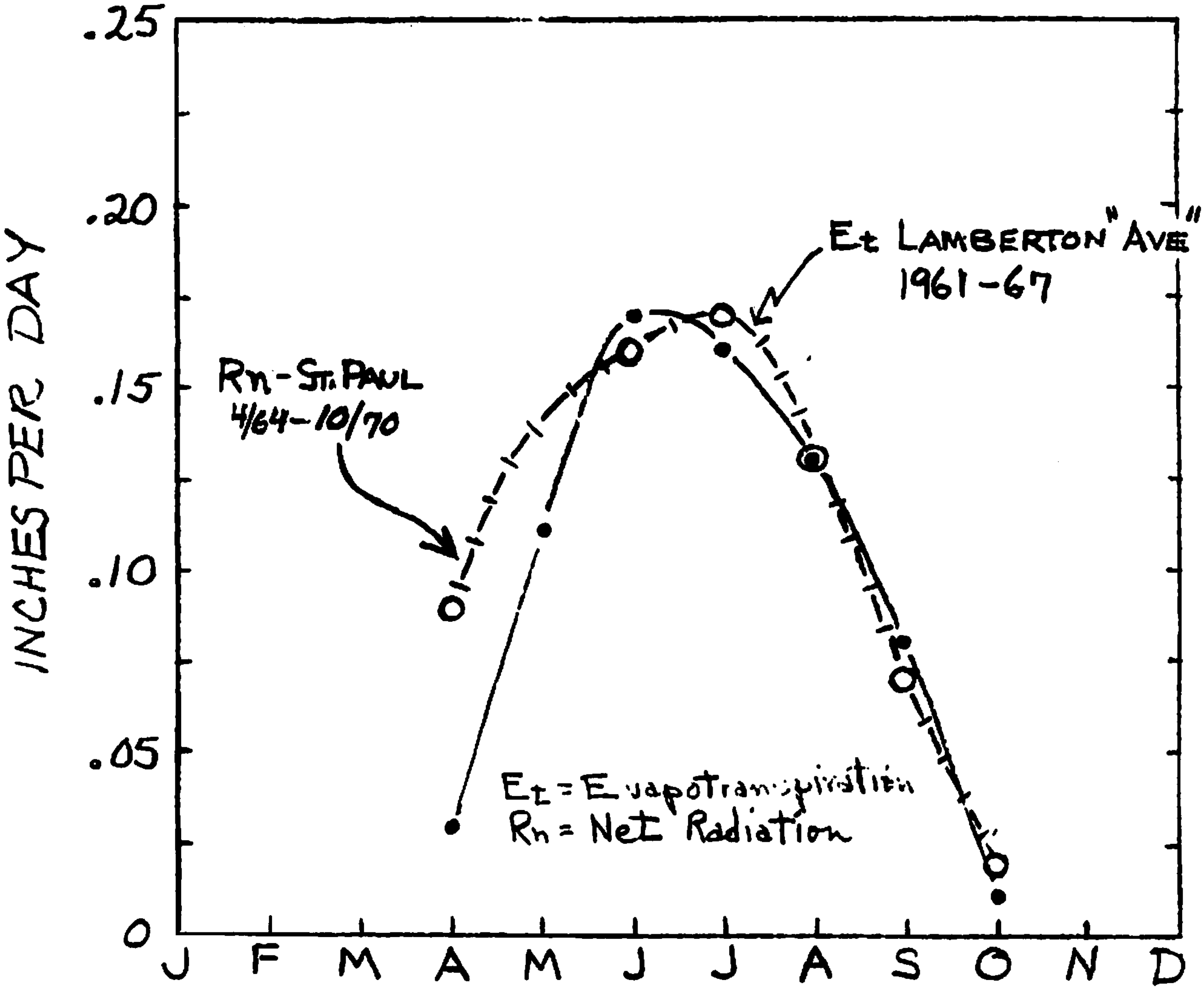

Figure 10. Comparison between measured evapotranspiration at Lamberton with measured net radiation at St. Paul.

F. Reflection (Albedo) and Cover

The solar radiation received at the earth's surface is not all absorbed by the earth and the vegetation. A certain fraction of it is reflected back and this is known as the albedo. Natural objects on the earth's surface differ in the amount of radiation that is reflected. We are aware of this when comparing, for example, two extremes such as snow cover and a moist bare soil.

As may be expected, the albedo varies throughout the growing season, and it is largely a matter of how much soil the crop covers. Fig. 11 shows how the albedo varies with the change in crop cover which in this case is soybeans in 20 inch rows. It is to be noted that the albedo of bare soil is about 12%, and as the vegetative cover increases so does the albedo. With full cover the albedo reaches a maximum of about 26%. The equation predicts that for each 10% change in plant cover the albedo will change 1.3%.

It is evident from Fig. 11 that the albedo ordinarily changes in such a regular fashion with the increasing plant cover that the albedo can be readily predicted, if the cover is known.

The data upon which Fig. 11 is based are total daily values of the albedo. The albedo varies considerably during the day as the angle of the sun's rays on the earth's surface changes. However, these changes are not shown here but are a part of the total daily values. The fact that the albedo was measured over soybeans does not negate the application of the equation to other kinds of plant cover, although there will be slight differences to be sure. The albedo of erect standing vegetation, such as wheat, oats or corn, probably does not vary appreciably from that of soybeans for the same amount of soil that is covered. This will hold true as long as the plant is actively transpiring and green.

Two years of continuous recording of reflected radiation along with the incoming solar radiation showed the annual average albedo at St. Paul to be 31%. For the growing season, May-September it was 20%, and for the winter months of December-February, it was 78%. The high value of winter resulted from the snow cover. So in effect the albedo of an area changes greatly only with the presence or absence of snow. The vegetative cover and kind of vegetation is of relatively slight importance.

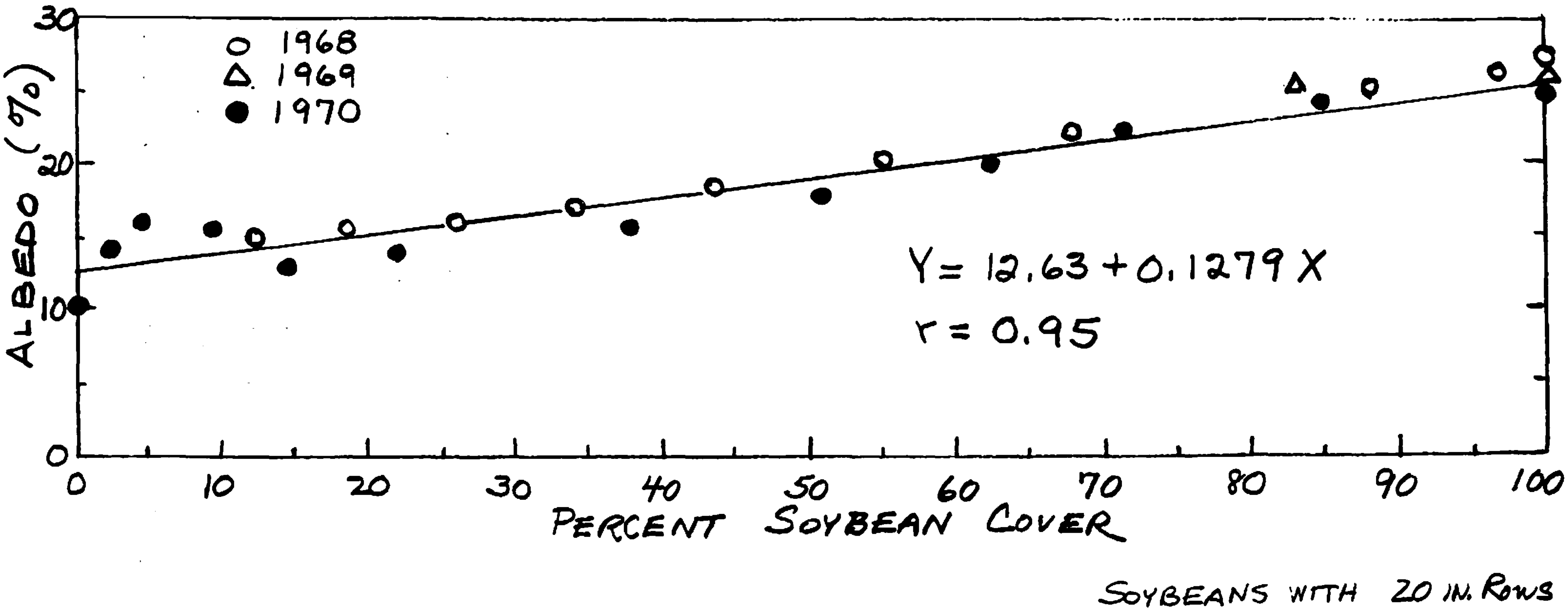

Figure 11. Relationship between plant cover (expressed in percent of soil covered) and albedo. The measurements were made over soybeans in 20 inch rows at St. Paul.

WEATHER SUMMARY
Northwest Experiment Station, Crookston
1971

Olaf C. Soine, Soil Scientist

Record breaking rainfall in September and October were highlights of the 1971 weather at the Northwest Experiment Station. The total precipitation for the year was six inches above normal, and for the growing season, April-September, it was four inches.

The weather summary for 1971, which is given in Table 1, includes precipitation, mean temperature, and long-time averages. Table 2 gives the number of clear, partly cloudy, and cloudy days for the year.

The precipitation for September and October which was 10.67 inches, was over half of the total for the year, and completely saturated the top five feet of soil. Of the total precipitation, 23.35 inches fell as rain, the remaining 2.83 inches came as snow.

The snowfall for the calendar year measured 41 inches, and for the winter 1970-71 it was 52 inches. The moisture content per inch of snow for 1971 was .069 inches and for the winter 1970-1971 it was .061 inches.

Mean temperature for the year was 40.3° compared to 39.7° F., the long-time average. The spring months of April, May, and June were warmer than normal. The fall months of September, October, and November were slightly above average. January, with a mean temperature of -3.9° was the coldest month of the year and was 8.8° below normal. August was the warmest summer month with a mean temperature of 69.2°.

January 15 was the coldest day with a reading of -39°, while August 9 had the highest temperature of 97°.

The last spring frost occurred on May 11 when the temperature dropped to 28°. The first fall frost occurred on September 18 when the temperature was 29°. A killing frost came on October 28.

The frost-free period of 129 days during 1971 was four days longer than average.

Table 1. Weather Summary for 1971 with averages for precipitation and mean temperatures for 1900-64

Month	Precipitation - inch: Snowfall Inches	Precipitation - inch: Snowfall Precipitation (inches)	Precipitation - inch: Rain	Precipitation - inch: Total	Precipitation - inch: 1900-64 Avg.		Mean temperature (degrees): 1971	Mean temperature (degrees): 1910-64
January	14.5	.63	0	.63	.56		-3.9	4.9
February	3.0	.25	0	.25	.61		11.3	8.8
March	8.0	.69	Tr	.69	.79		25.1	26.6
April	2.5	.21	.41	.62	1.51		44.0	41.4
May	0	0	2.99	2.99	2.62		55.9	54.8
June	0	0	3.06	3.06	3.36		67.8	63.8
July	0	0	4.16	4.16	2.98		65.9	69.7
August	0	0	2.36	2.36	2.89		69.2	67.5
September	0	0	5.88	5.88	2.11		59.7	57.2
October	2	.30	4.49	4.79	1.34		48.3	45.4
November	3	.42	Tr	.42	.86		28.5	27.2
December	8	.33	Tr	.33	.59		11.3	11.6
Total	41	2.83	23.35	26.18	20.20	Mean	40.3	39.7

Table 2. Number of clear, partly cloudy, and cloudy days for 1971

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Avg.
Clear	14	13	7	12	17	9	8	16	5	8	6	5	10.0
P. Cloudy	6	7	7	6	6	9	14	11	14	7	8	9	8.7
Cloudy	11	8	17	12	8	12	9	4	11	16	16	17	11.8

AVAILABLE SOIL MOISTURE SURVEY, 1971

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

Soil samples were collected from three different cropping systems during the growing season. Available soil moisture determinations were made at this station on 735 samples of soil during the year. The first samples were taken on April 30 on sites 1 and 4. On site 7, which was in sugarbeets in 1970, subsoil frost disappeared by May 7, 1971, and the first soil samples were taken.

The data in tables 1, 2, 3, and 4 give the sampling dates, the precipitation for each period, inches of available soil moisture for each depth, and the total for the season. Each table gives the last sampling in the fall of 1970 so that the accumulated overwinter and early spring moisture can be determined. Site 8 was in black fallow in 1971 and the results in table 4 are for the last sampling of the year.

Discussion:

The soil was rather dry at the end of the 1970 cropping season and the total available moisture at sites 1 and 7 was low. The 19-48 inch depth was extremely dry, as indicated by the negative readings. Site 4 was fallowed in 1970 and on November 4 the total available moisture was 11.53 inches compared to 2.43 and 2.47 inches on sites 1 and 7.

The spring and summer rainfall was above normal and helped to recharge the upper soil profile. July and August were below normal and moisture deficiencies began to appear in 7-36 inch depth. Above normal rainfall during the fall helped to recharge the top and subsoils and by the end of the season the total available moisture supply was good. At sites 7 and 8 subsoil water was encountered at 36 inches, which made it difficult to sample.

Table 1. Site 1. Alfalfa (Alfalfa 1970) Available moisture in inches, 1971

Sampling date	Precip. (inches)	Depth in inches							
		0-6	7-12	13-18	19-24	25-36	37-48	49-60	Total
10-30-70	----	.79	.32	.09	-.11	-.13	-.07	1.54	2.43
4-30-71	4.06	.85	1.02	.88	.49	.47	.44	.34	4.49
6-1-71	2.99	.56	.79	.84	.53	.92	.42	.36	4.42
6-30-71	3.03	.52	.31	.53	.34	.79	.64	.46	3.59
7-29-71	4.19	.83	.38	.31	.14	.42	.09	-.72	1.45
9-1-71	2.40	.11	-.19	-.05	-.17	-.13	.20	1.38	1.15
10-4-71	7.71	.95	.79	.87	.71	1.04	1.16	.60	6.12
10-29-71	1.75	.80	.84	.93	.59	1.32	1.11	.84	6.43
Total	26.13								

Table 2. Site 7. Wheat (Sugarbeets 1970) Available moisture in inches, 1971

Sampling date	Precip. (inches)	Depth in inches							
		0-6	7-12	13-18	19-24	25-36	37-48	49-60	Total
10-30-70	----	.52	.22	.40	-.43	-.25	1.28	.73	2.47
5-7-71	4.13	.34	.29	.37	-.17	-.41	.98	.43	1.83
6-1-71	2.92	.45	.47	.81	.85	-.29	.57	1.19	4.05
6-30-71	3.03	.71	.66	.35	.46	1.84	2.39	1.91	8.32
7-29-71	4.19	.30	.02	.19	.59	-.22	1.25	.71	2.84
9-1-71	2.40	.14	-.09	.34	.05	-.07	1.47	.94	2.78
10-4-71	7.71	.78	.94	1.13	.86	1.13	2.04	1.42	8.30
10-29-71	1.75	.56	.98	1.99	2.12	5.21	5.62	5.92	22.40
Total	26.13								

Table 3. Site 4 Sugarbeets (Sw.cl. fallow 1970) 1971

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	----	.87	.99	.86	.88	2.76	3.02	2.15	11.53
4-30-71	3.52	.74	.78	.75	.64	2.63	2.30	1.54	9.38
6-1-71	2.99	.53	.71	.64	.61	1.82	2.28	1.58	8.17
6-30-71	3.03	.02	.02	.69	.37	.53	1.47	1.23	4.33
7-29-71	4.19	.61	.26	.18	.48	2.08	-.27	1.79	5.13
9-1-71	2.40	.23	-.05	-.32	-.69	.53	1.42	1.40	2.52
10-4-71	7.71	.81	.35	.13	-.04	1.24	1.84	1.28	5.61
10-29-71	1.75	.54	.94	1.18	1.28	2.31	2.11	1.55	9.91
Total	25.59								

Table 4. Site 8 Black fallow (Oats 1970) Available moisture in inches 1971

Sampling date	Precip. (inches)	Depth in inches							
		0-6	7-12	13-18	19-24	25-36	37-48	49-60	Total
10-29-71	----	1.08	1.12	1.08	1.03	2.55	2.46	1.78	11.10

COMPARISON OF FALL AND SPRING APPLIED NITROGEN ON THE YIELD AND NUTRIENT UPTAKE OF ERA WHEAT

Charles Simkins, Olaf Soine and Paul Groneberg

Semi-dwarf wheat varieties have demonstrated their ability to produce high yields in many countries of the world. These short-statured varieties with the capability of utilizing large amounts of N without lodging have greatly enhanced the importance of wheat as a food and feed grain.

The semi-dwarf wheat varieties are relatively new to Minnesota, but have yielded well under conditions of high soil fertility, good weed control and sufficient available moisture.

Nitrogen rate trials conducted during the 1970 crop year produced significant increases in the yield of semi-dwarf wheat varieties when nitrogen fertilizer materials were applied as a topdressing at or shortly after seeding of grain. Yields of Era wheat exceeded 70 bushels per acre near Alvarado, Minnesota where the growing crop received sufficient moisture for good crop growth.

Farmers of the Red River Basin are interested in the possibility of applying nitrogen fertilizer in the fall if the efficiency and response to the fall applied material is similar to that obtained from spring applications. The interest in fall application of nitrogen stems from lower nitrogen prices, better distribution of labor and the problems concerned with applying 80 to 100 pounds of nitrogen at planting time.

Due to the particularly great difference in soil moisture conditions likely to be encountered during the fall, winter and spring in the Red River Basin, studies on the efficiency of spring and fall applied nitrogen must be conducted for several years. This study was initiated with the hope that it could be continued in some form for the next 5 years.

The study would simply involve the application of a recommended rate of nitrogen as determined by a NO_3N test on soil samples taken to a depth of 24 inches.

The study would involve a determination not only of yield, but also the total nitrogen taken up by the wheat plant. It would also involve the determination of the efficiency of the fertilizer applied as well as the nitrogen uptake from the soil.

Methods and Materials

A site was selected on the Crookston Experiment Station which had been previously cropped to sugar beets. The nitrate nitrogen test to a depth of 3 feet indicated a level of 60 pounds per acre. The phosphorus and potassium levels were relatively high - 30 pounds P and 420 pounds K per acre, respectively. Soil tests indicated a low zinc availability.

The seedbed was prepared by disking twice in the fall. Ammonium nitrate fertilizer material was applied at the rate of 100 pounds of N per acre on October 21, 1970. 1.5 percent of the applied nitrogen was in the N15 form. The soil temperature at a 3 inch depth at the time of the fall application was 52°F. The nitrogen fertilizer materials were dissolved in water and sprinkled on the appropriate plot areas. Each plot consisted of an area 3 feet by 6 feet. On April 20, 1971, the spring applications of nitrogen were made to adjacent plots and each plot, including a check plot, was seeded to Era wheat. A seeding rate of 120 pounds per acre was used. The spacing between rows was 6 inches. In addition to the 100 pound N rate applied as broadcast treatment, an equivalent of 12 pounds of nitrogen and 100 pounds per acre of P_2O_5 was applied with the seed at planting time. The plots were periodically weeded by hand.

At planting time, there was approximately 1 inch of available moisture in the top 3 feet of soil. During the germination period, some difficulty was experienced with emergence. Later, however, there were rather ideal conditions for growing and development. The rainfall recorded was: April - .62 inches, May - 2.99 inches, June - 3.06 inches, July - 4.16 inches, August - 2.16 inches. On July 15, plant samples were taken from each plot. This included the whole plant-head, stems and as much root as possible. The wheat plants were in the early stages of grain formation. The total yield of vegetation per acre was determined on an oven dried basis. The samples were later analyzed for total nitrogen. It is anticipated the samples will also be analyzed for N15 nitrogen. Each plot was sampled to a 3 foot depth at harvest time (August 12, 1971). If possible, these samples will also be subjected to N15 analysis. Yields of grain and straw were determined by harvesting and threshing on August 12, 1971.

Results - Yield

The grain yields for the fall and spring applied nitrogen is compared with the no treated plots in Table 1.

Table 1. Yields of Era wheat - fall vs. spring application of nitrogen - 1971. (Average of 3 replications.)

	Grain bu/acre	Straw lbs/acre
Check	37 a	3,848 a
100 lbs. N/acre-fall	90 b	10,080 b
100 lbs. N/acre-spring	95 b	11,490 b

The grain and straw yields were substantially increased by the 100 pound nitrogen application. There was, however, no significant difference in yield between the fall and spring applications.

Results - Uptake of Nutrients

The amount of nitrogen in the whole plant at the July 15 sampling date is shown in Table 2.

Table 2. Nutrient status of Era wheat - whole plant analyses - early seed stage - July 15, 1971 - Crookston Station.

Treatment lbs/acre	% N	% P	% K	% Ca	% Mg
Check	.84 a	.236	.783 a	.164	.190
100 N-Fall	1.17 b	.229	.927 b	.173	.251
100 N-Spring	1.20 b	.238	.956 b	.190	.243
Treat. Sig.	**	N.S.	*	N.S.	N.S.

Fall and spring application of nitrogen at the 100 pound per acre rate increased the nitrogen in the whole wheat plant. It also resulted in a significant uptake of potassium. Phosphorus, calcium and magnesium in the plant were not significantly altered by nitrogen applications. The level of several elements including zinc, copper, manganese and boron in the whole wheat plant are shown in Table 3.

Table 3. Nutrient level of several micro-elements in wheat plant, July 15, 1971. Crookston Station.

Treatment lbs/acre	ppm* Zn	Cu	Mn	B
Check	14.4 b	1.43	62.9	2.47
100 N-Fall	10.5 a	1.50	47.0	2.43
100 N-Spring	11.3 a	1.80	52.6	2.40

Of the micro-nutrients examined only the level of zinc in the wheat plant was altered by the application of nitrogen.

The levels as shown here are above the critical levels generally accepted for good growth of wheat. Studies in the Crookston area have indicated zinc response to sugar beets under similar conditions.

Results - Uptake of Nitrogen

A calculation of the total nitrogen in the wheat plant was made.

It was based on the nitrogen in the plant at the July 15 sampling and the oven dry weight of the vegetative plant harvested (roots and above ground portion of wheat plant). The total nitrogen for each treatment is shown in Table 4.

Table 4. Nitrogen uptake by Era wheat - whole plant - July 15, 1971. Crookston Experiment Station.

Treatment lbs/acre	N in Wheat Plant lbs/acre	% of Applied Nitrogen
Check	68	
100 N - Fall	142	74
100 N - Spring	144	76

The above calculated nitrogen values would indicate that the nitrogen requirement for this semi-dwarf variety grown under conditions similar to these trials would require from 1.8 to 1.5 pounds of nitrogen per bushel of grain and straw, or 3 pounds nitrogen per 100 pounds of grain and straw.

The total straw produced per bushel of grain was not significantly different than that obtained in normal height varieties. Data collected as a result of many trials has indicated that with normal height wheat varieties, a straw yield of 100 pounds for each bushel or 60 pounds of grain produced.

The efficiency of applied nitrogen fertilizer cannot be calculated until N15 analysis have been made. The quantity of nitrogen in the fertilized wheat plants minus the nitrogen in the unfertilized wheat plants gives some measure of nitrogen uptake from the fertilizer. There is, however, the possibility that those plants fertilized with nitrogen may develop stronger plants, better root systems and thus be able to extract more nitrogen from the soil.

NITROGEN TRIALS ON SEMIDWARF VARIETIES OF WHEAT, BARLEY, AND OATS IN 1971

This was a cooperative trial at Crookston, Lamberton, and Morris to determine the amount of nitrogen fertilizer semidwarf varieties of small grains require. Two semidwarfs - Ciano 67 and Era - were compared to Chris, a tall variety of wheat. Barley semidwarf 64-76 was included with Dickson and Larker. Otter and Diana, two semidwarf oat varieties were compared with Lodi.

Four rates of ammonium nitrate were broadcast and incorporated into the soil before planting. In order to provide an adequate supply of phosphate and potash, 150 lb of 0-20-10 was drill applied. Wheat and oats emerged on May 3 and barley on May 7. Broadleaf weeds were controlled with 2,4-D.

Ciano-67 was harvested on July 26 and all plots ripened uniformly. Era and Chris were 4-8 days later in maturity. The 80 and 120 lb rates produced slight to moderate lodging of Chris. These higher rates delayed the maturity of Chris and Era 1-2 weeks.

Harvesting of Larker barley started on July 20, Dickson on July 26, and 64-76 on July 30. The higher rates caused some slight delay in maturity but no definite trend or pattern was visible.

Diana was harvested on July 21, Otter on July 28 and Lodi on July 30.

The plot area was in sugarbeets in 1970. The past fertilization was 250 lb 0-46-0 in 1969 and 100 lb 6-42-0 per acre in 1970.

Table 1 gives the soil analysis for the plot area. Available phosphate and extractable potash were very high. The amount of sulfur was adequate. Nitrate-nitrogen on the wheat plot area was low but on the other two plots it was high.

Table 1. Soil analysis of plot area

	O. Matter	pH	P	K	S	NO3-N*
			---lb/A---		PPM	lb/A
Wheat plot	H	8.1	100	470	30	60
Barley plot	H	8.1	165	600	40	123
Oats plot	H	8.1	200	600	21	122

*NO_3-N 0-24 inch depth

The spring was dry and field work started early. Seeding started on April 16. The first rain, which measured 2.76 inches, came on May 22-25. The precipitation during the remainder of the growing season was adequate and well distributed.

Table 2 gives the yield and bushel weights of the wheat, barley and oat varieties. All nitrogen treatments gave significant yield increases of wheat compared to the check. The 80 and 120 lb rates produced significantly higher yields of Era as compared to the 40 lb rate.

Table 2. Effect of four nitrogen treatments on yield and bushel weights of three wheat, barley, and oat varieties in 1971.

Treatment	Ciano	Chris	Era	Ciano	Chris	Era
	---------bu/A---------			---------bu wt-------		
Check	37.7	44.7	47.2	63	60	60
40 lb	50.1	59.4	69.7	62	61	61
80 lb	53.4	56.8	80.8	62	60	61
120 lb	57.9	61.5	78.7	63	59	61
LSD 5%	7.7	8.9	6.5	--	--	--
Treatment	Dickson	Larker	64-76	Dickson	Larker	64-76
	----------bu/A----------			---------bu wt---------		
Check	83.2	69.4	81.6	48	47	47
30 lb	90.8	69.0	64.4	47	47	44
60 lb	94.7	64.1	87.7	48	47	44
90 lb	86.1	72.7	79.0	47	46	45
LSD 5%	10.1	13.5	21.4	--	--	--
Treatment	Otter	Lodi	Diana	Otter	Lodi	Diana
	---------bu/A---------			---------bu wt---------		
Check	82.3	84.0	63.8	37	35	38
30 lb	75.3	77.2	70.0	36	35	37
60 lb	93.9	89.8	71.6	36	35	37
90 lb	75.8	87.2	92.6	36	35	37
LSD 5%	16.0	9.5	26.1	--	--	--

Barley yields were variable and no definite pattern appeared. The only significant yield increase came from the 60 lb rate on Dickson.

The yield response of oats to nitrogen fertilization was variable. The 30 lb rate lowered the yield of Otter and Lodi. Although there were no significant yield differences of Otter and Lodi, the 60 lb rate gave the best increase. The 90 lb rate gave a significant increase of Diana.

There were no essential differences in bushel weights of wheat, barley, or oats.

The nitrogen content of the flag leaf is given in table 3. The samples were collected on June 30 and sent to the Soils Department at St. Paul for analysis.

Nitrogen content of the flag leaves from the treated plots was higher than the untreated check, except the 30 lb rate on Lodi. In general, the 80 lb rate gave the best response on wheat. The 90 lb rate gave the best response on barley and oats.

Table 3. Percent nitrogen in flag leaf of three wheat, barley and oat varieties, 1971.

Treatment	Ciano	Chris	Era
	percent nitrogen		
Check	3.34	3.35	3.09
40 lb	4.10	3.88	3.69
80 lb	4.55	4.20	4.03
120 lb	4.48	4.04	4.31
Treatment	**Dickson**	**Larker**	**64-76**
	percent nitrogen		
Check	4.03	3.88	4.04
30 lb	4.26	4.33	4.28
60 lb	4.32	4.20	4.60
90 lb	4.30	4.36	4.66
Treatment	**Otter**	**Diana**	**Lodi**
	percent nitrogen		
Check	3.74	3.46	4.03
30 lb	4.07	4.30	3.96
60 lb	4.03	4.40	4.64
90 lb	4.28	4.56	4.41

MICRONUTRIENT STUDIES ON SUGARBEETS AT NORTHWEST EXPERIMENT STATION AND GLYNDON, 1971

There is considerable interest in the effect of certain micronutrients on the yield and quality of sugarbeets in this general area. Fertilizer companies in the Red River Valley have been "pushing" the sale of zinc, iron, manganese, and boron, and including them in their sugarbeet fertilizers. Previous research has shown that the Valley soils contain sufficient zinc for beet production.

An experiment was undertaken to determine the effect of the above micronutrient on the yield and quality of sugarbeets at Crookston and Glyndon. Six treatments were used and the materials were broadcast and mixed with the soil by roto-tilling. Sulfur was included as a treatment because of local interest. The iron, manganese, boron, and sulfur treatments were mixed together and applied as a treatment labeled "Blast."

The previous fertilizer program on these plot areas was as follows:

Crookston: 0-46-0 @ 250 lb/A broadcast previous fall
6-42-0 @ 100 lb/A row application at planting time
Previous crop: Sweet clover fallow
Glyndon: 5-25-5 @ 400 lb/A broadcast
Previous crop: Sweet clover fallow

Soil information is given in table 1 for both locations.

Table 1. Analyses of soils at Crookston and Glyndon, 1971

	pH	O. Matter	Ext.P	Exc.K	S	B	Mn	Zn
			lbs/A					
Crookston	7.9	H	97	420	54	2.8	1	1
	lb NO_3-N	0-24 inches	170					
Glyndon	7.9	H	14	185	80	2.5	1	1
	lb NO_3-N	0-24 inches	151					

Samples of the leaf, blade, and petioles were taken in mid-July and August at both locations for analysis.

Discussion: The nutrient levels of the sugarbeet blades at both locations for July 19 and August 19, 1971, are given in table 2. None of the nutrient levels in table 2 are in the deficiency range. They are intermediate to high for the major elements like P, K, Na and Mg. The addition of the treatments did not greatly influence the uptake of other elements. For example, the Blast treatment did not increase the uptake of phosphorus, potash, sodium or magnesium, or any of the micronutrients when compared to check.

The addition of iron did not increase the uptake of this element by the leaf blade. The iron content of the blades was lower at the August sampling at Crookston.

Although zinc was not added, the levels were well above the 20 ppm which are considered adequate for growth.

The manganese treatment did not increase the uptake of this element by the beet plant. The boron and manganese treatments increased the phosphorus and calcium content of the blade when compared to the check plot, but had very little effect on the other elements.

The addition of sulfur had no essential effect on the results.

Table 3 gives the nutrient levels for the petioles at the two sampling dates and locations.

There was no essential increase in the micronutrient content of the petioles from any treatment at either sampling date or location.

Table 2. Nutrient levels of sugarbeet leaf blades at Northwest Experiment Station, Crookston and Glyndon, 1971.

Crookston - Sampled July 19, 1971

Treatment	Rate lbs/A	P	K	Ca	Na	Mg	Fe	Zn	Mn	B	Mo
		--------Percent------------					------PPM-------				
Check	----	.409	1.84	.432	2.62	.844	80	37	93	45	18
Blast	*	.417	1.78	.479	2.27	.806	79	38	89	45	18
Boron	2	.459	1.87	.441	2.17	.721	81	35	71	45	16
Manganese	10	.438	1.90	.471	2.44	.776	79	38	87	46	16
Sulfur	20	.418	1.85	.455	2.54	.796	78	38	91	48	17
Iron	0.3	.405	1.83	.433	2.49	.721	74	39	106	46	17

* Combined boron, manganese, sulfur and iron into one treatment.

Table 2. Continued

Treatment	P	K	Ca	Na	Mg	Fe	Zn	Mn	B	Mo	S
	-----------Percent----------					---------PPM-------------					
Crookston - Sampled August 18, 1971											
Check	.250	3.38	.640	3.34	.839	64	26	95	63	18	
Blast	.242	3.46	.6681	3.07	.851	62	24	100	66	19	
Boron	.262	3.58	.681	3.05	.873	63	23	98	71	19	
Manganese	.253	3.37	.608	3.15	.797	63	25	87	68	18	
Sulfur	.267	3.44	.588	3.20	.770	60	26	101	68	17	
Iron	.241	3.54	.599	3.54	.852	55	25	98	68	19	
Glyndon - Sampled July 22, 1971											
Check	.326	1.48	.515	4.13	.904	84	35	49	37	20	
Blast	.312	1.75	.428	4.13	.904	85	44	45	35	16	
Boron	.308	1.17	.548	4.32	.939	82	33	50	36	19	
Manganese	.390	1.69	.433	3.87	.798	97	43	46	31	18	
Sulfur	.339	1.57	.476	4.14	.820	88	34	49	36	18	
Iron	.392	1.76	.425	3.75	.767	90	42	37	36	17	
Glyndon - Sampled August 19, 1971											
Check	.145	2.37	.506	4.82	.785	89	29	38	54	16	
Blast	.165	2.37	.539	4.91	.788	87	27	40	56	17	
Boron	.165	2.33	.440	4.84	.755	83	26	39	54	17	
Manganese	.168	2.27	.532	4.91	.780	85	26	43	58	17	
Sulfur	.170	2.30	.533	4.72	.786	83	27	43	55	17	
Iron	.145	2.25	.503	4.86	.821	85	28	43	55	18	

Table 3. Nutrient levels of sugarbeet petioles at the Northwest Experiment Station, Crookston and Glyndon, 1971.

Treatment	P	K	Ca	Na	Mg	Fe	Zn	Mn	B	Mo	S
	-----------	Percent	-----------			---------	PPM	-------------			
Crookston - Sampled July 19, 1971.											
Check	.264	2.15	.135	2.47	.139	13	2	17	21	5	
Blast	.257	2.05	.140	2.08	.154	13	3	17	21	5	
Boron	.272	2.09	.128	1.83	.127	13	4	13	20	4	
Manganese	.262	2.10	.132	2.15	.144	14	3	17	22	5	
Sulfur	.275	2.09	.116	2.31	.119	11	3	17	21	4	
Iron	.266	2.05	.113	2.25	.107	11	3	17	23	4	
Crookston - Sampled August 18, 1971											
Check	.149	2.63	.155	2.81	.128	13	2	15	25	5	
Blast	.156	2.71	.155	2.56	.125	13	4	16	27	5	
Boron	.143	2.50	.162	2.44	.134	13	2	14	25	5	
Manganese	.163	2.55	.150	2.45	.120	13	3	15	25	5	
Sulfur	.167	2.40	.136	2.37	.111	12	4	14	25	4	
Iron .141	.141	2.46	.136	2.69	.109	11	4	14	25	4	
Glyndon - Sampled July 22, 1971											
Check	.182	1.84	.145	3.96	.217	21	7	12	21	6	
Blast	.218	1.85	.117	3.37	.182	20	7	12	19	5	
Boron	.174	1.66	.147	3.97	.228	18	7	12	21	5	
Manganese	.192	1.91	.123	3.71	.189	21	8	12	20	5	
Sulfur	.188	1.79	.142	3.79	.208	22	7	13	20	5	
Iron	.213	1.58	.125	3.68	.192	22	7	11	19	5	
Glyndon - Sampled August 19, 1971											
Check	.081	1.27	.106	4.17	.048	13	**	5	24	3	
Blast	.080	1.01	.110	4.09	.049	12	**	4	26	***	
Boron	.087	1.28	.115	4.24	.058	15	**	5	27	3	
Manganese	.091	1.31	.115	4.49	.069	15	**	6	28	3	
Sulfur	.083	1.31	.117	4.23	.062	15	**	6	26	3	
Iron	.097	1.28	.115	4.32	.077	16	**	6	26	4	

** Less than 1.0
***Less than 3.0

The yields, percent sugar, impurity index and sugar yields for both locations are given in table 4. Adding micronutrients did not produce any significant yield increases at Crookston. The sulfur and iron treatments increased the yield 0.4 and 0.6 tons per acre when compared to the check plots. At Glyndon the check plot had the highest yield.

There were no significant differences in percent sugar, impurity indexes or sugar yield at either location.

This one-year study indicates that the supply of micronutrients in the soil is adequate for sugarbeet production.

Table 4. Effect of six treatments on yield, percent sugar, impurity index, and sugar yield at the Northwest Experiment Station, Crookston and Glyndon, 1971.

Treatment	Rate	Yield of beets	Sugar	Impurity	Sugar
Crookston	lb/A	T/A	%	index	T/A
Check	--	22.7	15.23	573	3.46
Blast	(1)	22.4	15.15	566	3.39
Boron	2	22.7	15.08	595	3.42
Manganese	10	22.7	15.25	592	3.46
Sulfur	20	23.1	15.58	581	3.60
Iron	0.3	23.3	15.25	560	3.55
LSD 5%		2.0			

(1) Combined last 4 treatments

Glyndon					
Check	--	20.1	15.7	618	3.16
Blast	(1)	18.9	15.9	583	3.01
Boron	2	19.9	15.9	605	3.16
Manganese	10	19.9	15.3	652	3.05
Sulfur	20	18.9	15.8	635	2.99
Iron	0.3	19.2	15.4	666	2.96
LSD 5%		1.5			

(1) Combined last 4 treatments

ALFALFA REMOVAL VS. PLOW-DOWN FOR SUGARBEETS

In this study, alfalfa production fields were used to study the effect of removing the first crop for hay versus plowing down the first crop for beet production. In 1967, the first crop of alfalfa was cut and removed on June 29. These plots and the plots with alfalfa were plowed and fallowed the remainder of that year. Beets were planted on these plots in 1968. In 1970, the alfalfa was cut and removed on June 17, but the plots weren't plowed until July 8 because of excessive rainfall. These plots were planted to beets in 1971.

Fertilizer 0-46-0 at 250 lbs per acre was broadcast the previous fall and 6-42-0 at 100 lbs per acre was drill applied at seeding time. The beet field in 1968 was mechanically thinned and weeded and no hand labor was used.

The beets were harvested on September 20, 1968, and October 11, 1971.

The experimental data is given in table 1 for 1968 and 1971.

Table 1. Effect of alfalfa removal vs. plow-down on yield, percent sugar, impurity index and sugar yield, 1968 and 1971.

Year	Treatment	Yield T/A	Sugar %	Impurity index	Sugar Yield T/A
	-				
1968	Alf. removal	15.45	12.72	766	1.97
	Alf. plow-down	15.90	12.24	864	1.95
1971	Alf. removal	15.23	14.6	852	2.22
	Alf. plow-down	14.84	14.3	899	2.12

In 1968, the beets on the plow-down plots yielded .45 tons more than the alfalfa removal plots. In 1971, the opposite was true--the alfalfa removal plots yielded .39 tons more than the plow-down. The alfalfa removal plots had higher percent sugar and lower impurity indexes. The sugar yield was very similar for both treatments.

Table 2 gives information about the yield and value of the alfalfa hay. The alfalfa was weighed and calculated to 15.5% moisture basis and is reported on this basis in table 2. The yield in 1970 was very good and the price was $20.00 compared to $18.00 per ton in 1968. The growers in the Crookston area have a market for this crop, which is as asset for this type of sugarbeet production.

Table 2. Yield and value of alfalfa hay removed, 1968 and 1971.

Year	Yield T/A	Value per A
1968	1.10	$19.80
1969	2.43	$48.60

SUGARBEET ROTATION STUDIES - 1971
Northwest Experiment Station

Olaf C. Soine, Soil Scientist

The first four-year cycle of this experiment was completed in 1970, and the data will be summarized. The fertilizer plan for beets was changed in 1971 to utilize soil nitrate-nitrogen tests to determine nitrogen rates. One-hundred-fifty pounds of total nitrogen per acre was the desired rate, and if needed, ammonium nitrate was added to the amount of soil nitrate-nitrogen in the 0-24 inch depth to reach this rate. The cropping plan of the original six 4-year rotations was continued.

Table 1 gives the average amount of soil nitrate-nitrogen (NO_3-N) for the six rotations, amount of ammonium nitrate (NH_4NO_3) added, and total nitrogen. Soil samples were taken October 1970 from 0-24 inch depth and the replications were averaged. Beets always follow the last crop in the 4-year rotation as given in table 1.

Table 1. Nitrate-nitrogen in 0-24 inch depth, amount of ammonium nitrate added, and total nitrogen per acre, 1971.

Rotation*	Nitrate-nitrogen in soil	Amm. Nitrate added	Total Nitrogen
	lbs per acre		
Bl. fallow	174	13	187
Leg. fallow	197	none	197
Alf. fallow	164	19**	183
Barley	56	94	150
Soybeans	58	92	150
Oats	52	98	150

* Beets on these plots in 1971.

** Three replications were used, and one plot in each rotation was below 150 lbs of nitrogen per acre.

The three different fallow rotations had a large supply of nitrate-nitrogen in the soil 0-24 inch depth, ranging from 164 to 197 lb per acre. On the legume fallow plots, green material equal to 2,126 lb of dry matter per acre was plowed under about the last part of June. The first crop of hay on the alfalfa fallow plots, which average 2,140 lb per acre, was removed and the stubble was plowed under. These plots were fallowed the remainder of the year.

The amount of nitrate-nitrogen in the 0-24 inch depth on the three non-fallow plots were similar and about what could be expected after four years of cropping.

In the spring of 1971, the sugarbeet plots were divided and ammonium nitrate was added to one-half of the plots which were below 150 lb per acre of nitrogen. The other half of the plots received the same fertilizer treatment that was used during the past four years. This yield, percent sugar, and impurity index are given in table 2.

Table 2. Yield of beets, percent sugar, and impurity index with no nitrogen and added nitrogen fertilizer, 1971.

Rotation*	Yield 1971		Sugar		Impurity Index	
	No-N	Plus N	No-N	Plus N	No-N	Plus N
	T/A		%			
Bl. fallow	20.20	20.50	16.1	15.9	465	485
Leg. Fallow	20.74	20.74	15.8	15.8	551	551
Alf. hay	22.60	22.80	15.7	15.5	540	567
Barley	19.51	21.89	16.2	15.6	440	550
Soybeans	17.96	20.11	16.4	16.7	416	402
Oats	17.54	21.29	15.9	15.9	417	535

* Beets always follow these crops.

The addition of nitrogen increased the yield of beets on the three non-fallow plots. The largest increase of 3.75 tons of beets per acre was following oats.

There were no essential differences in percent sugars from the added nitrogen compared to no nitrogen.

The beets from the three non-fallow plots had the lowest impurity indexes.

The 1971 crop yields for all six rotations are given in table 3. The yields of wheat, barley and oats are good and above average. Potatoes and soybeans were above average in yield.

Table 3 gives the beet yields for each rotation without and with added nitrogen.

Table 3. Crop yields for six sugarbeet rotations, 1971.

Beets	Wheat (1)	Barley	Black fallow
20.20 T	45.8 Bu.	62.6 Bu.	--------
20.50 (13 lb amm. nitrate added)			
Beets	Wheat	Barley	Legume fallow (2)
20.70	56.4	55.0	2436 lb
Beets	Wheat	Barley	Alfalfa fallow (3)
22.60	59.8	62.5	3500
22.80 (19 lb amm. nitrate added)			
Beets	Potato (4)	Wheat	Barley
19.51	356 bu	59.4	54.8
21.89 94 lb amm. nitrate added)			
Beets	Wheat	Barley	Soybeans
17.96	46.0	60.6	32.8
20.11 (92 lb amm. nitrate added)			
Beets	Wheat	Barley	Oats
17.54	46.5	62.1	105.4
21.29 (98 lb amm. nitrate added)			

(1) All grain yields on pure seed basis
(2) Dry matter basis
(3) Alf. hay at 15.5% moisture
(4) Yield of No. 1 potatoes

ZINC AND IRON TRIALS ON FLAX - 1971
Northwest Experiment Station, Crookston
Olaf C. Soine, Soil Scientist

This trial was started in 1970 to determine if flax would respond to zinc and iron fertilization. Sequestrene 138 iron and sequestrene zinc chelates were broadcast before planting and rotovated into the soil. In order to eliminate any soil nitrogen deficiency in the plot area, 120 lb per acre of ammonium nitrate were broadcast and rotovated into the soil before planting. Soil analysis is given at the bottom of table 1. Summit at 40 and Nored at 30 lb per acre were sown on May 3 and emerged May 12. The plots were harvested on September 14.

The results of zinc and iron on Summit and Nored Flax are given in table 1.

Table 1. Effect of zinc and iron on yield, oil content, and iodine value of Summit and Nored flax, 1971.

Treatment	Rate lb/A	Fertilizer lb/A	Yield bu/A	Oil content % oven dry	Iodine value No.
Summit					
Check	0	63	21.8	38.9	194
Check	0	125	22.4	38.5	193
Zinc	0.36	32	18.8	39.1	192
Zinc	0.72	63	21.7	38.1	192
Iron	0.30	63	20.2	38.2	192
Iron	0.60	125	21.0	37.6	192
LSD 5%			13.5		
Nored					
Check	0	63	20.7	40.5	191
Check	0	125	18.5	39.9	189
Zinc	0.36	32	18.1	38.8	189
Zinc	0.72	63	21.3	38.6	189
Iron	0.30	63	22.4	39.3	189
Iron	0.60	125	20.0	38.8	190
LSD 5%			11.4		

Soil test: pH 8.3 P 160 lb/A
zinc 1.5 ppm K 550 lb/A

Both materials were coated on 18-46-0 at 8 lb per 100 lb of fertilizer. The heading "Fertilizer" in table 1 gives the amount of 18-46-0 that was applied to furnish the required amount of zinc and iron per treatment. The two check plots received 63 and 125 lb of 18-46-0 so that treatments could be compared.

The stands were poor and variable and this is reflected in the high LSD values. The additon of zinc and iron did not increase the yield of Summit flax, or affect the oil content or iodine value. The two check plots had the highest yields, which might suggest that fertilizer was more important than the zinc and iron treatments.

Two treatments - zinc at 0.72 and iron at 0.30 lb - increased the yields of Nored flax, but the results were not significant. There was no essential effect on the oil content or iodine value of Nored Flax.

Table 2 gives the average results for 1970 and 1971. Two-year data show that Summit was the best yielder. The check with 125 lb fertilizer had the highest 2-year average yield. The additon of zinc and iron did not significantly increase the yield, oil content or iodine value of either flax variety.

Table 2. Effect of zinc and iron on yield, oil content, and iodine value of Summit and Nored flax, 1970-71

Treatment	Rate lb/A	Fertilizer LB/A	Yield bu/A	Oil content % oven dry	Iodine value No.
Summit					
Check	0	63	20.5	39.5	192
Check	0	125	22.4*	38.5*	193*
Zinc	0.36	32	21.7	39.6	190
Zinc	0.72	63	22.4	38.8	189
Iron	0.30	63	20.2	39.1	191
Iron	0.60	125	20.5	38.3	190

* 1971 Data

Continued

Table 2. Continued

Treatment	Rate lb/A	Fertilizer lb/A	Yield bu/A	Oil content % oven dry	Iodine value No.
Nored					
Check	0	63	17.7	40.9	192
Check	0	125	18.5**	39.9	189**
Zinc	0.36	32	17.0	39.8	191
Zinc	0.72	63	18.3	39.8	191
Iron	0.30	63	18.5	40.1	191
Iron	0.60	125	18.3	39.8	192

**1971 Data

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1971 FERTIGATION OF CORN ON A HUBBARD LOAMY COARSE SAND IN SHERBURNE COUNTY

John MacGregor, Dean Fairchild and Robert Munter

Nearly 15 percent of potential agricultural soils in Minnesota are comparatively sandy in texture. The hazard of drouth, combined with low native fertility, has resulted in minimal use of such areas for crop production purposes. Many less sandy soil areas also have less than optimum crop production in years when soil moisture becomes inadequate following insufficient or uneven precipitation distribution. Supplemental irrigation by various types of sprinkling systems has now become quite commonplace, especially with improved equipment and the discovery that many such drouthy soil areas are underlain by ample water suitable for irrigation purposes. Since all of the nutrient elements essential for plant growth can be obtained in water soluble forms, and fed to plants during the growing season, the question arises as to how much and how often fertilizer materials should be added in the irrigation water. Publications on the equipment necessary for this fertigation are available from the Department of Agricultural Engineering on the St. Paul Campus.

While phosphorus, potassium, and other nutrient elements may be necessary at times, the relatively low organic matter content of sandy soils means low available soil nitrogen levels. Since fertilizer nitrogen is relatively inexpensive, very soluble, and is readily transported in soil moisture, the high porosity and downward movement of excess moisture in such soils of low water holding capacity raises the question of how much fertilizer nitrogen could a crop of corn grown each year profitably use. In addition to the financial loss of applying nitrogen not used by the growing corn, the unused nitrogen is readily leached beyond the reach of corn roots, and can be one source of pollution to adjoining water supplies.

The initiation of the irrigated field research station near Elk River earlier in 1968 provided an excellent opportunity to study the fertilization of corn grown each year under irrigation of the Hubbard loamy coarse sand. The soil had a pH of 5.0 to 5.4, organic matter was medium, the extractable phosphorus was very high at 200 lbs/A, with a medium potassium level of 210 lbs/A. Soil sulfur was low at 5 lbs/A and zinc was high at 2.3 lbs.

Since the experimental area soil was extremely variable in soil organic matter and the previous fertility treatments were unknown, corn was planted in 1968 with no fertility treatments to observe variability in corn growth. Observations confirmed considerable variation in corn growth and yield, and it was decided that six replications of each fertility treatment would be necessary. All nitrogen and potassium treatments were broadcast in dry form by hand, rather than by injection into the irrigation water.

<u>1969 Study</u>

No lime was applied, the land being plowed in mid-May and planted on May 27 to provide 23,000 plants per acre. Fertilizer phosphorus was row applied over the entire area, using the planter attachment to supply 43 lbs of P/A (100 lbs P_2O_5.) Potassium was broadcast (as KCl) to supply 0, 75, 150 and 300 lbs of K/A (0, 125, 250 and 500 lbs K_2O/A.) The nitrogen was applied as split broadcast treatments of ammonium nitrate, half at planting and the remainder one month later to supply 0, 100, 200, and 400 pounds of N per acre. Considerable vegetative burning damage resulted where the 400 lbs rate of N was broadcast late in June, which probably decreased the ear corn yields on this treatment. Rainfall during the growing season totalled 11.5 inches, with a total of 14.75 inches being applied in weekly irrigations. The following corn yields were obtained:

Table 1. 1969 Corn yields with varying rates of nitrogen and potassium fertilization on a Hubbard loamy coarse sand in Sherburne County. (Average of 6 replications.)

Fertilizer Treatments*	1969 Yield 15.5%
	bu/A
0 + 43 + 0	19.9 a**
0 + 43 + 75	25.4 a
0 + 43 + 150	37.9 a
100 + 43 + 0	90.5 b
100 + 43 + 150	98.3 b
100 + 43 + 75	98.9 b
200 + 43 + 150	104.5 bc
400 + 43 + 300	119.1 cd
200 + 43 + 0	121.8 cd
200 + 43 + 75	128.9 d

* Pounds per acre of N + P + K. Applied in 1969.

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

There were no significant yield differences due to potassium applications, whereas the nitrogen increased yields from 4.5 to 6.5 times that of the no-nitrogen treatments.

Plans had been made to sample soils from each plot to a depth of 20 feet each fall, to study applied nutrient movement and concentration, but the extreme stoniness at a 12" depth made soil sampling essentially impossible and this phase of the study was abandoned.

1970 Study

Since the deep soil sampling late in 1969 was not accomplished, and only the N treatment had increased corn yields, the 1970 corn was planted with no initial fertility treatments to determine if a residual effect from any of the 1969 N treatments would be evident in 1970 corn growth with a population of 30,000 plants per acre. Growing season (4/13 to 11/21) rainfall totalled 25.87" and this was supplemented by 14.05" of irrigation water applied as needed. There was no apparent residual effect on corn growth where 100 or 200 lbs N/A had been broadcast one year previously, but some increased growth was evident until late in June where the 400 lbs N/A rate had been broadcast in mid 1969. Since the 1970 corn growing on the 100 and 200 lbs N/A 1969 treated areas showed no residual N to be available, the same N treatments (as those of 1969) were then applied in late June of 1970. No N was applied in 1970 to those plots where N had been applied in 1969 at the 400 lb/A rate. Both 1969 and 1970 fertility treatments and resulting corn yields are shown in Table 2.

Table 2. The 1969 and 1970 fertilizer treatments and subsequent corn yields on an irrigated Hubbard loamy coarse sand in Sherburne County. (Average of 6 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	209.8
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.)

It is evident that the nitrogen fertilization at the 400 lb/A rate applied one year previously had some residual yield effect and doubled the 1970 corn yields over corn plots having no N fertilization. However, the total two year yield was considerably less than with annual treatments of nitrogen at the 100 or 200 pounds per acre.

1971 Study

Since heavy N fertilization (400 lbs/A) showed only minor increases in corn yield the following year, it was possible that a further splitting of the N treatments over the entire growing season might be more effective. Since the maximum rate of nitrogen fertilization was only 200 lbs per acre in 1970, there would be little or no residual N remaining for the 1971 corn growth. Therefore, three rates of N fertilization were studied (100, 200, and 300 lbs/A): (1) all being broadcast at planting time, or (2) split into 4 applications made at intervals of one month, (3) split into 8 applications made at bimonthly intervals. The split applications could be easily made in the irrigation water. No other fertilizer was applied and the 1971 corn population was approximately 30,000 plants per acre.

The 1971 growing season was ideal, rainfall during the growing season totalling 15.5", and this was supplemented with 15.0" of irrigation water applied as needed. Corn yields are shown in Table 3.

Table 3. The 1971 yields and N content of corn grain and of corn leaves grown on irrigated Hubbard loamy coarse sand near Elk River with different rates and times of N fertilization. (Average of 6 replications.)

Total N Applied lbs/A	Time(s) of N application	lbs N/A application	% N in leaves	Bu corn /A @15.5% moisture	Corn Grain %N	Corn Grain lbs/A
None	-------	----	0.61	43 a[1]	0.92	19
100	5/11 (at planting)	100	1.19	92 b	0.82	28
100	5/11, 6/11, 7/11, 8/11	25	1.42	154 cd	1.06	77
100	5/11 and 26, 6/11 and 26, 7/11 and 26, 8/11 and 26	12.5	1.53	136 c	1.02	66
200	5/11 (at planting)	200	1.11	158 cde	0.99	74
200	5/11, 6/11, 7/11, 8/11	50	1.89	185 def	1.15	101
200	5/11 and 26, 6/11 and 26, 7/11 and 26, 8/11 and 26	25	2.10	192 f	1.23	112
300	5/11 (at planting)	300	1.15	173 def	1.02	84
300	5/11, 6/11, 7/11, 8/11	75	2.05	195 f	1.33	122
300	5/11 and 26, 6/11 and 26, 7/11 and 26, 8/11 and 26	37.5	2.43	189 ef	1.36	121

[1] Numbers followed by the same letter are not significantly different at the 5% level. (Duncan's New Multiple Range Test.)

It is evident that using limited amounts of nitrogen, (100 lbs/A) split applications are significantly more effective for increasing corn yields instead of a single time of planting application. While monthly fertilizer treatments resulted in higher corn yields, than from the eight treatments applied at fortnightly intervals, yield differences between the two split treatments were not of significance. Nitrogen removal was greatest with the monthly treatments.

Doubling the rate of nitrogen application to 200 lbs/A resulted in somewhat higher corn yields. Monthly treatments were not significantly greater yielding than the single treatment at planting, although splitting the treatments into eight 15 day periods produced significantly more corn than the single heavy fertilization at planting. The single, or four monthly applications at 200 lbs failed to significantly increase yields over the 100 lb N rate were split into 4 monthly applications. Nitrogen removal in corn grain increased with fertilization frequency.

As expected, the use of 300 pounds of nitrogen per acre resulted in much the same corn yield, whether applied at planting, at monthly periods, or when split amounts were applied twice in each of the four months. At this heavy N fertilization rate, N in the corn grain increased with monthly treatments but not with further splits.

A general conclusion might be drawn that a single nitrogen application at planting time to sandy, irrigated soils is inefficient and wasteful of fertility. The use of N at higher rates decreases the relative importance of split treatments. Monthly N fertilization supplying a total of 100 lbs/ N/A produced about 150 bushels of corn, doubling the monthly rate produced about 185 bushels whereas the monthly 75 lb N rate per acre resulted in 195 bushels of corn per acre. It would appear that the most economic rate would be 200 lbs N/A applied in monthly or even more frequent intervals, thus maximizing N uptake and use by the growing corn, and minimizing N leaching losses and pollution of subsoil waters. The apparent maximum efficiency of the N fertilization, based on N removal in the corn grain was approximately 50% of the fertilizer N applied.

FIELD EXPERIMENTS WITH SOIL MODIFICATION ON AN IRRIGATED HUBBARD LOAMY COARSE SAND -- ELK RIVER STATION 1969-71

R. S. Farnham, D. S. Fairchild

In the spring of 1969, a project was initiated to study the possibilities of increasing 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. Peat
2. Wood products (low grade pulp)
3. Composted garbage
4. Manure
5. Calcined clay
6. Vermiculite

The layers were installed in two ways. One, an 18 inch band, 18 inches deep directly beneath the row and two, square plots were installed with a 14 foot by 14 foot continuous layer at 18 inches below the surface. In both types of placement the detention layer was 1/2 to 1 inch thick.

There is little replication within the experiment and data should be considered accordingly.

Snap beans and field corn were crops grown in 1970 and 1971.

<u>Field Corn</u> - 1970

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 102 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 with soil modification versus the checks.

Table 1. Corn Yields with Soil Modification Treatments on a Hubbard Loamy Coarse Sand (1970).

Treatments	1970 Bu./A 15.5% H_2O	
No Bands		
Checks	120	
	141	Average
	145	135
Continuous Layers (Square 14' X 14' Plots)		
Reed sedge peat	134	
Sphagnum peat	184	
Hydromulch (wood product)	172	
Row Bands (18" wide)		
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 - 1970

Snap beans were planted on June 22, 1970. A total of 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 responded consistently above the checks and continuous layer treatments. (Table 2). Row spacing was 18 inches.

Table 2. Snap Bean Yields with Soil Modification Treatments on a Hubbard Loamy Coarse Sand -- 1970 data.

Treatments	Total Yield lbs./A
No Bands	
Checks	8,233
	9,264
Continuous Layers (14' X 14' Square)	
Surface	9,641
Vermiculite	7,158
Vermiculite (roto-tilled)	10,019
Row Bands (18" wide)	
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

Field Corn - 1971

In 1971 the same 102 day corn variety was planted with a population of 29,000 plants per acre. Fertilizer preplant and side dress nitrogen applications were the same as in 1970

Table 3 shows the yields of corn from these experiments. The highest yield (204 bushels per acre) was obtained using fresh reed-sedge peat. This yield was slightly higher than the highest 1970 yield (201 bushels). However, the 1971 data shows some rather erratic responses due to differential herbicide injury and spotty corn borer damage. The check plots were extremely variable ranging from a low yield of 144 to a high of 184.

All plots received about 1 inch of irrigation per week in addition to the rainfall.

The results of the past two years experiments are very encouraging despite the erratic 1971 yields and future investigations will deal with possibilities of reducing irrigation frequency and amounts. The detention layers obviously are contributing to higher yields of field corn.

Table 3. Field Corn Yields with Soil Modification Treatments. 1971 season.

Treatments	1971 Bu/Acre 15.5% H_2O
No Bands (check plots)	Ave. 160 Range 144 to 184
A. Square Plots (14' X 14' Layers)	156
Reed sedge peat	144
Sphagnum peat	188
Calcined clay	166
Vermiculite	154
B. Row Plots (18" bands)	
Hydromulch	146
Composted garbage	143
Reed-sedge peat (fresh)	204
Reed-sedge peat (composted)	146
Decomposed peat	148
Vermiculite 1/2"	136
Vermiculite 1"	144
Sphagnum peat	161
Calcined clay	142

Snap Beans - 1971

Several organic and inorganic detention layers were installed during early summer of 1971 and placed at only 12 inches below the surface of the soil instead of 18 inches as in previous studies. Snap beans were planted July 17th and yields taken on September 23rd.

The data in Table 4 shows the yields obtained with the different treatments. Spacings were 30 inches because of the location of detention layers instead of 18" as in 1970 studies. Yields in 1971 for these late planted beans were considerably lower than those in 1970 because of the wider spacings. Some increases were noticeable, though, due to detention layers and in most cases the beans were of much better quality where detention layers were used. This was particularly true where Sphagnum peat and manure were used. A higher percent of total yields were grades 1 and 2 fresh beans.

Table 4. Snap Bean Yields with New Detention Layers at Shallow Depths (12 inches). 1971 data

	Treatments	Yields lbs/acre GRADES			
		Size 1 (large)	2	3(small)	Total
1A	Reed-sedge peat	2875	1864	960	5699
1B	Reed-sedge peat	2948	1676	1411	6035
2A	Vermiculite	2823	2787	2161	7771
2B	Vermiculite	4427	366	767	5560
3A	Sphagnum peat	4792	3417	990	9199
3B	Sphagnum peat	2587	2756	2063	7406
4A	Check (disturbed)*	3203	2736	1496	7435
4B	Check (disturbed)*	1860	2544	1407	7221
5A	Manure	4389	2333	871	7593
5B	Manure	4844	1851	871	7566
6A	Sphagnum peat sheet	2525	2370	667	5612
6B	Sphagnum peat sheet	3502	2215	1411	7128
7	Composted garbage	3859	2239	697	6795
8A	Check (undisturbed)**	2718	2492	1716	6926
8B	Check (undisturbed)**	2866	2270	1460	6596

* Check (disturbed) - Soil removed and replaced.
** Check (undisturbed) - Regular field soil.

SUMMARY of Results to Date

Several organic and inorganic detention layers have been evaluated for two years at the Elk River irrigation station in an attempt to increase the yield and quality of crop plants by soil modification. Many of these materials look promising and continued research is planned to evaluate their economic potential and effectiveness as a management practice.

In the future soil modification practices may become increasingly more important for the following reasons:

1. Need for conserving water resources.
2. Reduce leaching losses of nitrogen and phosphorous and they reduce pollution of waters.
3. Alternative use for organic wastes.
4. Increase in economic returns through higher yields and improved quality of agricultural products.

1971 Frequency of Irrigation Study - Elk River

C. Klint, J. Swan, C. Turnquist, R. Machmeier, G. Titrud

Both Russett Burbank and Norland potatoes were grown. Potatoes were planted May 5 and harvested September 30.

Plowed	4/17
Disked	5/1
Herbicide	5/3 - 3 lbs/A (a.1) EPTC in 70 gal/A spray and disked immediately
Fertilizer	5/5 - 1000 lbs/A (8-16-16) banded at planting
Planted	5/5 - 36 inch rows x 11 inches spacing
Dragged	5/21
Sidedressed	6/8
	6/23 - 150 lbs/A (34-0-0) Norland
	300 lbs/A (34-0-0) Russett

Regular spray program followed.

Tensiometer readings were taken in two reps (2 1/3 and 3 1/2 day frequency) on each variety at approximately the 6 inch and 10-12 inch depth. Differences between treatments were small and recorded suction never exceeded 0.3 bar. The low suctions measured and slow response of the instruments may have been partly due to contact problems in the loamy coarse sand soil.

Two irrigation frequencies were compared on potatoes:

1. 1.25 inches of water every 3 1/2 days (2/week)
2. 0.90 inches of water every 2 1/3 days (3/week)

The irrigation frequencies were replicated 8 times.

Irrigation began June 15 and ended September 8.

Irrigation Dates and Amounts

Date	Pan Evaporation Since Last Irrigation	Rainfall Since Last Irrigation	2 1/3 Day Frequency	3 1/2 Day Frequency
June 15	--	--	1.0 inches	1.0 inches
22	--	--	1.0 inches	1.0
July 9	--	--	0.9	1.25
12	--	--	0.9	1.25
14	--	--	0.9	--
16	0.53	0.14	0.9	1.25
19	0.73	0.30	0.9	1.25
21	0.44	0.16	0.9	--
23	0.35	0	0.9	1.25
26	0.73	0	0.9	1.25
28	0.33	0	0.6	--
30	0.36	0.24	0.75	1.1
Aug. 2	0.66	0.10	0.9	1.25
4	0.28	0	0.9	--
6	0.41	0	0.9	1.25
9	0.58	0	0.9	1.25
11	0.56	0.04	0.9	--
13	0.54	0	0.9	1.25
16	0.73	0.02	0.9	1.25
18	0.53	0	0.7	--
23	0.95	1.75	0.9	1.25
25	0.36	0	0.9	--
27	0.37	0	0.9	1.25
30	0.69	0	0.9	1.25
Sept. 3	0.92	1.64	0.9	1.25
8	1.15	1.52	0.9	--
Total			23 inches	21.9 inches

1971 Yield and Specific Gravity - One Year's Data Only

Russett Burbank

Irrigation Frequency	Total Yield CWT/A	U.S. No. 1's CWT/A	Pickouts CWT/A	Undersize CWT/A	Specific Gravity	Total Solid Percent
3 1/2 day	478	446	14.6	18.0	1.080	19.7
2 1/3 day	491	453	22.7	15.4	1.081	19.9
Avg.	484	450	18.7	16.7	1.081	19.9

Norland

Irrigation Frequency	Total Yield CWT/A	U.S. No. 1's CWT/A	Pickouts CWT/A	Undersize CWT/A	Specific Gravity	Total Solids Percent
3 1/2 day	510	490	3.3	16.8	1.067	16.9
2 1/3 day	514	492	5.4	16.9	1.067	16.9
Avg.	512	491	4.3	16.8	1.067	16.9

ANOVA

	DF	Number 1's F	Total Weight F	Pickouts
Reps	7	4.07 * Sig at 5% level	3.23 N.S.	1.40 N.S.
Irrigation tmts.	1	0.15 N.S.	0.51 N.Ss	2.35 N.S.
Error A	7	--	--	
Variety	1	11.75 ** Sig at 1% level	5.68 * Sig at 1% level	14.64 * Sig at 1% level
Interaction	1	0.04 N.S.	0.15 N.S.	0.64 N.S.
Error B	14	--	--	
	CV=	7.26%	6.59%	92.4%

No significant differences were found in amount of undersized potatoes produced. CV = 22.9%

Conclusions:

For 1971, there was no significant differences in total yield, U.S. No. 1's undersized, pickouts or specific gravity for the two irrigation treatments. For the weather conditions present in 1971, the longer 3 1/2 day irrigation cycle gave results equal to the shorter 2 1/3 day cycle.

There was no significant difference in the weight of undersized or pickouts produced by the two irrigation frequencies.

The amount of No. 1 potatoes produced on the different replicates were significantly different (5% level). The effect of reps on total weight and amount undersized approached significance. Even though the plot area was only 160 x 160 feet square, the differences in soil and/or microclimate were apparently sufficient to cause measurable yield differences.

Norland outyielded Russett Burbank in both total weight and number 1's and had significantly fewer pickouts.

THE RELATIVE EFFECT OF THREE TVA SULFUR COATED UREAS IN COMPARISON TO AMMONIUM NITRATE ON CORN YIELD AND COMPOSITION GROWN ON AN IRRIGATED HUBBARD LOAMY COARSE SAND IN SHERBURNE COUNTY

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

An initial experiment on the relative availability of N from a low solubility sulfur coated urea fertilizer produced by the Tennessee Valley Authority for corn on an irrigated sandy soil was conducted in 1970. This low solubility form having 3.2% N available in 3 days, 10.4% in 7 days, or 1.8% daily was selected since soluble N loss would be nearing a maximum under the irrigated sandy soil condition and all of the applied N should be available in 48 days. All 1970 N treatments were made at the 100 lb N/A rate. The results (pp. 50-55, Soil Series 87) showed that N availability in this experimental fertilizer under field conditions was not sufficient for optimum corn growth, the grain yield being only 60.2 bushels per acre, compared to 13.4 for the check, urea + sulfur yielded 141.0 bushels, urea alone yield 144.8 bushels, and NH_4NO_3 produced 150.0 bushels. Nitrogen present in the corn grain was only 27.9 lbs/A with the S urea, whereas other N fertilizers removed from 75 to 81 lbs N/A. This low N utilization indicated a possible residual N effect in 1971 where the S urea had been applied in 1970.

Corn (TXS 102 F_6) was then planted in 30" rows on May 10, 1971 for a 30,000 plant population per acre. Herbicide consisting of 2 lbs. of atrazine and 1 lbs. of Lasso per acre was applied in a 70 gallon per acre spray. No phosphorus or potassium fertilizer was applied since adequate residual amounts remained from the application of these elements in 1969.

One half of each of the 1970 plots received no fertilizer in 1971, to determine any possible residual effect remaining from the 1970 N treatments. The remaining half of each broadcast treatments at the uniform rate of 100 lbs. of N per acre as follows:

(1) Class "C" sulfur coated urea (9.5% available in 7 days).

(2) Class "D" sulfur coated urea (18.2% available in 7 days).

(3) Class "F" sulfur coated urea (26.4% available in 7 days).

(4) Urea + sulfur (equivalent amounts as in S coated urea).

(5) NH_4NO_3 only.

There were five replications of each treatment as in 1970.

The 1971 growing season was relatively ideal for corn growth, the total May-September (inclusive) rainfall being 15.5" and this was regularly supplemented with one inch increments of sprinkler irrigation water totaling 15.0". The corn was harvested in late October, dried, and grain yields determined. These and the yields from the residual N (1970 fertilization) are reported in the following table.

The Effect of Different Nitrogen Fertilizers on Corn Yield, N Uptake and Removal from an Irrigated Hubbard Loamy Coarse Sand.

1970		1971			
N Applied (lbs/A)	Corn Yield (bu/A)	N Applied (lbs/A)	Corn Yield (bu/A)	N in Corn Grain %	N Removed (lbs/A)
----	13.4 a	----	7.3 a	1.20	4.47
----	13.4 a	S urea (C) (100N)	58.1 b	0.88	24.67
urea 100N	144.8 c	----	16.0 a	0.87	6.59
----	144.8 c	S urea (D) (100N)	102.4 c	0.90	41.56
NH_4NO_3 100N	150.0 c	----	22.9 a	0.95	10.09
----	150.0 c	S urea (F) (100N)	119.8 cd	0.89	51.39
S urea 100N	60.2 b	----	16.9 a	1.30	9.17
----	60.2 b	Urea + A (100N)	121.7 cd	0.93	52.67
Urea + S 100N	141.0 c	----	16.2 a	0.93	7.42
----	141.0 c	NH_4NO_3 (100N)	132.6 d	0.85	52.28

Although all of the 1970 N treatments doubled 1971 corn yield over the average check yield where no N was applied in either year, none of these increases were significant, and apparently very minor amounts of N remained in these sandy soils for the following 1971 corn crop. Yields improved with the sulfur coated urea from Class C (58.1 bu/A and significant yield increase) through Class D to Class F, with the latter producing approximately the same corn yield as the urea and sulfur applied separately, or the 1971 NH_4NO_3 fertilization.

Nitrogen analyses of the corn grain (the only crop actually removed from the field), show that sulfur coated urea (C) supplied about 20 pounds (20% of the N applied) to the corn grain. The (D) sulfur-urea resulted in 35 pounds (35%) more N in the corn grain per acre. The (F) sulfur urea application resulted in about 40 pounds more N in the corn grain (40% of that applied) in comparison to the 43% and 45% removed in the grain of the urea plus sulfur, and the NH_4NO_3 alone treatment respectively.

In conclusion, it is evident that the N availability to corn varies with the different S coated urea products studied (Classes C, D, and F) and this may be of economic importance in corn production under non-irrigated conditions.

LIME PLOTS, LAMBERTON, 1971

J. Grava, W. W. Nelson, D. S. Fairchild, 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), Hark soybeans (1969) and Corsoy soybeans (1971) in a sequence. Data on crop yields, soil and plant analyses were reported in the departmental "Bluebooks"[1].

Since the initial treatments (3 and 6 tons per acre of dolomitic limestone applied in fall of 1965) had not raised the pH to the desired levels (6.5, 6.9), additional amounts were applied in the spring of 1968 and worked in the soil by disking (corn-soybean series), or by disking, plowing and disking (alfalfa series). Alfalfa was reseeded in 1968.

Soil samples were collected during summer of 1969. Lime treatments had increased the soil pH in alfalfa series from 5.7 to 6.1 with the lower (3 + 4 tons/A) lime rate, and to 6.8 with the higher rate (6 + 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 lower (3 + 3 tons/A) rate and to 6.9 with the higher (6 + 6 tons/A) rate of dolomitic limestone. The subsoil is alkaline at a depth of 24 inches in the alfalfa series and at 12 inches in the corn-soybean series.

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1)See "A Report on Field Research in Soils", Feb. 1967, pp. 69-70; Soil Series 82, March 1968, pp. 38-41; Soil Series 84, March 1969, pp. 30-31; Soil Series 86, March 1970, pp. 66-69; Soil Series 87, March 1971, pp. 64-67 for results obtained in previous years.

In 1971, alfalfa received no fertilizer. Soybeans were not fertilized but all plots received 3/4 lb/A Treflan and 2 lb/A Amiben.

Alfalfa yields were not affected by liming in 1971 (Table 1). Liming, in general, did not affect chemical composition of first cutting alfalfa tissue (Table 2).

Soybean yields were not affected by lime treatments (Table 3). Chemical composition of soybean seeds is shown in Table 4.

Table 1. Yield of alfalfa, Lamberton lime plots, 1971.

Rate of Lime	First Cutting	Second Cutting	Total
Tons/Acre		Hay -- Tons/Acre	
0	2.3	1.0	3.3
7*	2.4	1.0	3.4
16**	2.3	1.0	3.3
Significance	NS***	NS	NS
CV%	6	20	6

*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.

***N.S. -- Treatment means not significantly different at the 5.0% level.

Table 2. Chemical composition of alfalfa, Lamberton lime plots, 1971.

Lime Treatment	P	K	Ca	Mg	Zn	Cu	Mo	Mn	B	Fe	Al
Tons/Acre	-- Percent in dry matter --				------- Parts per million in dry matter ---------						
					FIRST CUTTING						
0	.25ab[1]	1.31c	1.31	.35	19	6	11	25	42	79	40
7	.24a	1.24a	1.28	.34	20	5	11	19	38	79	41
16	.26b	1.23b	1.35	.37	20	5	12	20	40	83	41
Significance	*	**	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV%	5	2	9	9	7	30	9	18	6	9	14

[1]Treatment means followed by different letters are significantly different at the 5.0% level.

Table 3. Yield of soybeans, Lamberton lime plots, 1971

Rate of Lime	Yield
Tons/Acre	Bu/Acre
0	31
6*	33
12*	31
Significance	NS**
CV%	6

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

**N.S. -- Treatment means not significantly different at the 5.0% level.

Table 4. Chemical composition of soybean seed, Lamberton lime plots, 1971.

Lime Treatment	P	K	Ca	Mg	Zn	Cu	Mo	Mn	B	Fe
Tons/Acre	-- Percent in dry matter --				---- Parts per million in dry matter ----					
0	.46	1.41	.16	.20	40	12	8	18	29	65
6	.46	1.39	.16	.20	39	11	10	18	30	83
12	.46	1.43	.16	.20	39	10	10	17	29	70

SOIL FERTILITY MATERIALS PLOTS

G. D. Holcomb, W. W. Nelson, C. J. Overdahl

Quite frequently, University personnel are asked for an opinion about various products claimed to be superior in value to commonly available fertilizer material. Claims may be made for one or more benefits such as increased yield, higher protein content of grain, improved soil tilth, lower moisture content at harvest time, less problems with disease and insects, etc.

In the spring of 1971, field trials were established at the Southwest Experiment Station, Lamberton, to compare some of the products with a conventional fertilizer program. Because it is not feasible to test all products which may be purchased as fertilizers or related materials, a soil conditioner, an organic soil builder and a liquid fertilizer (advertised for both foliar and soil applications) were selected.

TABLE 1. TREATMENTS (Acre basis rate)

1. Check (0+0+0 total applied)
2. Liquid 10-20-10: Seed plus foliar. (52+20+10 total applied).
   4 gal. with seed plus 4 gal. on foliage (2 applications at 2 gal. rate)
   200 lbs. 21-0-0 broadcast and worked in.
3. Liquid 10-20-10: Seed (47+10+5 total applied)
   Same as treatment 2 except no foliage applications.
4. Soil Conditioner: (0+0+0 total applied)
   250 lbs. broadcast and worked in.
5. Organic Soil Builder: (30+10+5 total applied)
   300 lbs. broadcast and worked in.
   200 lbs. to the side and below seed.
6. Conventional Fertilizer: (114+43+22 total applied)
   300 lbs. 33.5-0-0 broadcast and worked in.
   180 lbs. 8-24-12 to the side and below seed.

All treatments were replicated four times with and four times without broadcast applications of phosphate and potash. The purpose of the broadcast application is to have comparisons under medium to high fertility soil conditions as well as under low fertility soil conditions. The rate applied was 0-90-45. Those receiving broadcast phosphate and potash were referred to as medium + fertility trials; those not receiving it are the low fertility trials.

Weed and insect control: Except for treatments 4 and 5, all plots received a herbicide (Ramrod) and an insecticide (Bux). All plots were cultivated two times. There was no lodging. However, weeds were a slight problem in treatment 6 in the low fertility trials and a moderate problem in the medium + fertility trials. Weeds were a moderate problem in treatments 4 and 5 in the low fertility trails and severe in the medium + fertility trials.

Table 2. Initial Soil Test Values

Sample	pH	Buffer Index	Organic Matter	P (lbs/A)	K (lbs/A)
Rep 1	5.6	6.6	M	7	250
Rep 2	5.6	6.6	M	10	250
Rep 3	5.5.	6.5	M	8	210
Rep 4	5.6	6.6	M	5	170

The corn, Pioneer 3784, was planted May 21. Final plant population was approximately 19,000 per acre. Foliar applications were made June 22 and July 6.

RESULTS

Statistical analyses are not available at the time this summarization is being prepared.

Data in Table 3 shows the conventional fertilizer treatment producing the highest yield under both low and medium + fertility conditions Following in decreasing yield were the liquid fertilizer treatments, check, organic soil builder and soil condtioner. There was no yield increase from the foliar applications of liquid fertilizer. The yield advantage of the check treatment over the organic soil builder and the soil conditioner treatments was due to weed control.

Moisture content of the gratin at harvest was lowest from the conventional fertilizer followed by the liquid treatments. Grain moisture content was highest with the soil conditioner, organic soil builder and check treatments, with little difference among the three.

Protein conent was highest in the grain from the conventional fertilizer treatment. This was followed in order by treatment 2, 3, 1, 4, and 5. There was little difference in the last three treatments, however.

There was less problem with corn borers on the soil conditioner (treatment 4) plots. Apparently due to short growth and low preference by the corn borer moth.

In mid-June there was a height advantage and the corn was darker green on the conventional and liquid treatment plots. Tasseling under these treatments was 3 to 7 days ahead of that for the other treatments.

Mineral analyses of leaf samples taken at tasseling have not been completed.

TABLE 3. MEASUREMENTS - FERTILITY MATERIALS PLOTS, LAMBERTON, 1971

Low Fertility Trials (No P & K broadcast)

Treatment	Ext. Leaf Hgt. on June 21	Date 50% Tasseled	% Stalks w/ borers Aug. 3	% Barren Stalks	% Moist. at Harv.	Shelling %	% Protein in Grain	Yield Bu/A
1	17.5	7-31	25	2.3	41.0	79.7	7.4	64
2	21.8	7-27	26	2.3	38.7	81.0	9.3	76
3	21.3	7-27	40	4.3	39.6	80.3	9.1	79
4	17.3	8-2	3	13.3	41.6	79.8	7.8	49
5	18.0	8-1	19	4.5	42.9	77.9	7.6	53
6	24.0	7-27	18	7.5	37.7	81.2	10.1	83

Medium + Fertility Trials (0+90+45 broadcast)

Treatment	Ext. Leaf Hgt. on June 21	Date 50% Tasseled	% Stalks w/ borers Aug. 3	% Barren Stalks	% Moist. at Harv.	Shelling %	% Protein in Grain	Yield Bu/A
1	21.0	7-28	31	5.3	38.5	80.6	7.6	71
2	23.8	7-24	56	8.5	36.4	83.0	8.6	79
3	25.0	7-25	58	14.5	36.6	79.1	8.3	78
4	20.8	8-1	26	21.5	39.9	77.1	6.7	39
5	22.5	7-28	41	12.0	38.3	75.8	6.6	45
6	24.3	7-24	33	12.3	35.2	82.4	10.1	93

TWELVE YEARS OF FIELD EXPERIMENTS WITH NITROGEN SOURCE, PLACEMENT AND TIME OF NITROGEN APPLICATION TO A WEBSTER-CLAY LOAM AT LAMBERTON FROM 1960 THROUGH 1971

John M. MacGregor, Wallace W. Nelson and Robert C. 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 in a randomized block, each plot being 20 feet wide and 77.5 feet long. A starter fertilizer such as 8-24-12 is applied annually with the planter fertilizer attachment over the entire field at planting at approximately 175 pounds per acre (14+42+21). The corn seed for several years was drilled lengthwise over each plot in a 40 inch row spacing to obtain about 18,000-20,000 plants per acre, but the row direction was later reversed and a 30 inch row spacing supplied the same population. Many different studies have been made during the 12 years of continuous corn growing on the effect of N application in this experiment, with results reported each year in Soil Series 76-87. The entire field was tiled in 1963. Soil pH is approximately 6.6

Total precipitation during 1971 was 24.7", which is approximately normal for the area. June rainfall totaled 7.11" with a total of only 4.24" in the 3 month period following. The relatively dry July through September growing season resulted in decreased corn production. Fall frost was not a problem in 1971. Ear corn yields during the entire 12 year period are shown in Table 1.

All of the broadcast N treatments have significantly increased the 12 year average corn yields over the four plot average where only the starter fertilizer (containing 14 lbs N/A) was annually applied. Although the N-urea treated plots produced an average of 2.3 bushels more corn than where NH_4NO_3-N was applied, none of the individual treatments were significantly larger, illustrating that the two N sources are equally effective for increasing corn production in this soil.

Effect of Time of N Fertilizer Application

Fourteen pounds of N per acre in the annual starter fertilizer (175 lbs of 8-24-12) has resulted in average corn yields over the 12 year period of 65.7 bushels. Applying 40 lbs N/A in the fall increased yields nearly 20 bushels (85.3); the same rate at time of planting produced 26.6 bushels more corn (92.3 bu/A);whereas sidedressing N treatments produced corn yields averaging 92.7 bushels with the minimal N fertilization rate (totaling 54 lbs N/A).

Eighty pounds of N/A applied late each fall resulted in average corn yields of 100.2 bushels; N at time of planting corn yields averaged 105.7 bushels; and as a sidedressing, 102.1 bushels.

Fertilizing in the fall at the rate of 160 lbs of N/A with 14 lbs more in spring starter (total of 174 lbs N/A) produced an average of 106.5 bushels; and 104.8 bushels where a similar sidedressed rate of N was made in the following June.

It is apparent that N fertilization at such minimal rates of 54 pounds per acre is more effectively applied either at spring planting, or as a June sidedressing. When heavier rates of N are applied, corn yields were less affected by time of N fertilization.

Fall Plowdown N Versus Fall Surface N

This is most effectively shown by comparing the two sets of fall 40 lb N treatments (treatments 2 and 3, with 4 and 5). The fall plowed down N averaged 83.2 bushels, whereas the 8 plots with the 2 nitrogen fertilizers (NH_4NO_3 and urea) left over winter on the plowed surface soil have averaged 87.5 bushels. While not mathematically significant, this would mean about 50 bushels more per acre over the entire 12 year period for the N left over winter on the plowed surface. No comparison is available for the two heavier N treatments, since these were both plowed down each fall.

Rate of N Application Effect

The 8 treatments with 40 pounds of N per acre in addition to the starter fertilizer N (an average of 32 plots) has averaged 89.0 bushels of corn per acre over the 12 year period, which is 23.3 bushels above the starter fertilized only corn yield. The six treatments (24 plot average) with 80 lbs N/A, (94 lb total) has averaged 101.7 bushels or 36 bushels more for 80 lbs N/A. The three 160 lb/A N treatments (totaling 174 lbs N/A on 12 plots) has produced a 12 year average of 105.9 bu/A, or 40.2 bushels more corn annually than with the starter N alone. It is apparent that the 80 pounds of additional N per acre over the 14 pounds of starter has probably been the most practical in the experimental area for continuous corn.

Nitrogen Content of Corn Leaves and N Removal in Corn Grain

The effect of fertilization on the N content of the "index" or sixth leaf from the ground, and the amount actually removed in the corn grain is important. The relative concentrations of N in the leaves is an indication of amounts of N returned to the soil in plant tissues, whereas the N in the grain is removed. The 1971 grain yields, leaf and grain N are shown in Table 2.

Nitrogen in the sixth leaf is increased from about 2% to a maximum of approximately 2.5% in the heaviest N fertilization. Nitrogen in grain increased from 1.10% to 1.67%, but the large yield increase quadrupled total N per acre removal in the grain. In general the 94 lb/A rate (80+14) of N application approximately equalled the amount of N removed in grain, with lesser N fertilization rates removing more N than that supplied in the fertilizer. It is obvious that the 174 lb N/A rate is not providing an economic increase in corn yield and that the excess beyond that removed by the corn grain may be contributing to undesirable amounts of N in drainage and/or subterranean waters.

<u>Analyses of Subsoil Waters of N Plots</u>

An extremely dry July, August, and September resulted in very dry subsoil conditions, and no subsoil water samples were collected or analyzed in 1971.

Table 1. Yields of ear corn during 12 years 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]	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	12 Year Average
	Ear corn yield in bushels per acre												
Check	49.5	88.2	26.1	132.6	72.9	33.1	11.1	53.4	102.4	92.8	85.7	40.8	65.7a
40 as NH_4NO_3 - fpd[2]	42.3	87.5	30.9	148.6	88.3	34.9	26.8	75.7	131.6	109.3	96.3	88.7	80.1b
40 as urea - fpd	55.1	78.2	29.1	148.8	100.3	38.8	19.8	86.9	132.5	124.5	120.4	100.7	86.2bcd
40 as NH_4NO_3 - fps[3]	49.0	96.7	29.6	140.1	101.5	45.6	24.3	75.1	135.2	124.6	122.5	81.5	85.5bc
40 as urea - fps	62.3	101.3	37.0	140.7	84.1	57.4	30.9	87.2	134.0	136.1	121.2	82.4	89.5cde
80 as NH_4NO_3 - fpd	67.4	97.9	43.6	149.6	100.8	63.4	47.3	114.8	131.2	146.8	134.7	108.0	100.5ghi
80 as urea - fpd	61.7	76.9	36.7	154.5	104.9	73.0	37.8	117.2	142.6	144.3	141.4	107.8	99.9fghi
160 as NH_4NO_3 - fpd	69.8	97.9	46.7	147.7	100.9	70.8	38.5	127.4	140.2	158.7	141.7	120.2	105.1hi
160 as urea - fpd	79.4	112.5	43.5	152.8	112.4	73.5	37.7	121.3	149.9	161.0	140.4	110.6	107.9i
40 as NH_4NO_3 - std[4]	66.2	92.0	45.4	152.2	99.8	63.4	23.7	99.8	128.0	142.0	125.6	84.0	93.5cdefg
40 as urea - std	45.4	91.1	31.4	147.6	100.6	59.8	33.8	95.0	140.5	143.4	118.9	94.6	91.9cdef
80 as NH_4NO_3 - std	59.3	90.0	32.7	149.2	112.5	74.2	49.0	128.3	144.7	159.5	140.4	122.7	105.2hi
80 as urea - std	57.7	99.1	40.5	149.3	115.7	84.4	41.8	128.6	138.7	155.9	146.2	116.0	106.1i
40 as NH_4NO_3 - sd[5]	63.6	92.6	39.5	148.6	90.4	54.8	38.6	96.8	133.4	142.3	127.1	104.5	94.3defg
40 as urea - sd	57.7	95.6	24.9	142.3	94.1	48.4	50.4	86.1	132.2	143.3	117.7	100.5	91.1cde
80 as NH_4NO_3 - sd	50.4	98.4	46.7	140.7	113.0	68.1	43.8	101.6	137.7	140.3	127.7	97.6	97.2efgh
80 as urea - sd	76.9	86.4	48.2	143.8	121.4	64.7	47.3	117.0	146.9	166.2	140.5	124.4	107.0i
160 as NH_4NO_3 - sd	40.7	97.4	77.7	151.7	109.5	77.6	51.4	120.2	141.5	148.3	136.9	104.2	104.8hi
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	99.4	

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

[2]fpd -- fall plow down

[3]fps -- fall plow-surface

[4]std -- spring topdress

[5]sd -- sidedress

Table 2. Percentage N in sixth leaf, 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 1971.

Treatment (lbs N/A)[1]	% N in sixth leaf[2]	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 status[3]
Check	1.97	41a	2382	1.10a	24a	14	-10.2
40# N/A stalks, fall	2.10	89bcd	5185	1.31bcde	67bc	54	-13.4
40# urea stalks, fall	2.22	101bcdeg	5904	1.33bcdeg	78c	54	-24.3
40# N/A plow, fall	2.23	82b	4765	1.24ab	60b	54	- 5.9
40# urea plow, fall	2.13	82b	4817	1.47cdefg	60b	54	- 5.6
80# N/A stalks, fall	2.31	108defg	5531	1.51fgh	94de	94	- 0.1
80# urea stalks, fall	2.28	108defg	6298	1.50efgh	94de	94	- 0.1
160# N/A stalks, fall	2.39	120fg	7026	1.62gh	114g	174	+60.8
160# urea stalks, fall	2.50	111defg	6466	1.62gh	104efg	174	+69.8
40# N/A before spr. plt.	2.16	84bc	4909	1.22ab	60b	54	- 5.5
40# urea before spr. plt.	2.22	95bcde	5517	1.30bcd	72bc	54	-18.1
80# N/A before spr. plt.	2.78	122fg	7170	1.35bcdef	97def	94	- 2.6
80# urea before spr. plt.	2.34	116efg	6780	1.41bcdef	96def	94	- 1.5
40# N/A sidedress	2.01	105cdefg	6108	1.33bcdef	81cd	54	-27.0
40# urea sidedress	2.29	100bcdef	5873	1.29abc	74bc	54	-20.1
80# N/A sidedress	2.31	98bcde	5705	1.47cdefg	84cd	94	+10.4
80# urea sidedress	2.10	124g	7271	1.49defgh	109fg	94	-14.5
160# N/A sidedress	2.50	104cdefg	6093	1.67h	101efg	174	+73.2
Significance							
Rep		N.S.		N.S.	N.S.		
Treatment		**		**	**		
C.V.		13.33		8.70	12.47		

[1]The entire area received an additional 14 lbs N/A annually as starter fertilizer (8-24-12 @ 175 lbs/A).
[2]None of these values were significantly different (N.S.).
[3]Fertilizer N minus N removal in corn grain in lbs/A.

WINTER VERSUS SPRING FERTILIZATION ON 1968, 1969, 1970, and 1971 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, 1970, and in 1971. Four replications of randomized paired plots 50 ft. long and 20 ft. wide were broadcast fertilized in mid-January (on snow) or in 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 four winters was not sufficiently deep to prohibit the operation of large fertilizer spreading trucks. Although all of the fertilizer was broadcast by hand, on each of four replications the granules appeared to sink a short distance into the snow almost immediately, with little resultant lateral movement into adjoining areas.

Results

Both of the sloping fields near Rosemount unfortunately failed to show significant increases in corn yield from any of the fertilizer applications, making it impossible to determine the relative effects of winter or of spring broadcasting fertilizer. Since these yields have previously been reported in Soil Series 84, 86, and 87 the results will not be included here.

The relatively level Webster silty clay loam at Lamberton produced significantly more corn with fertilization and the results are shown in the four following tables. The same plot areas were re-used in each of the four years.

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

Treatment (lbs/A)	Time fertilizer broadcast	I	II	III	IV	Average
		Bushels ear corn/A @ 15.5% moisture				
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) produced significant increases in 1968 corn yield, with no significant difference for different times of fertilizer application.

The autumn of 1968 and the spring of 1969 were extremely wet, and it was not possible to plow this untiled silty clay loam until the end of May of 1969. This resulted in such late planting that it was necessary to base 1969 yields on silage corn, rather than the usual corn grain. Silage corn yields are shown in Table 2.

Table 2. The Yield of Silage Corn in 1969 From Webster Silty Clay Loam Near Lamberton Following Fertilization in January or May,1969.

Treatment (lbs/A)	Time of Fertilization	I	II	III	IV	Average
		Yield of silage corn (tons/A)				
None		8.09	8.09	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 extend the experiment for several more growing seasons. The 1970 yields of ear corn are shown in Table 3.

Table 3. Yield of Ear Corn Grown in 1970 on a Webster Silty Clay Loam Near Lamberton Following Fertilization in Mid-January or Early April, 1970.

Treatment (lbs/A)	Fertilizer broadcast in:	I	II	III	IV	Average
		Ear corn yield in bu/A @ 15.5% moisture				
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 1b
0+40+0	January	63.6	82.3	62.8	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

Corn yields from either winter or spring fertilization were not significantly different in the preceding 3 growing seasons (1968-69-70), but in 1971 there was evidently some fertilizer N loss where applied in January as compared to the later application. Although 1971 annual precipitation was nearly normal (24.70"), distribution was extremely variable with a total of 16.25" falling in only 4 months (2.10" in February, 7.11" in June, 4.41" in October, and 2.63" in November). The remaining months were comparatively dry, and this resulted in much lower corn yields than those of the preceding years. Ear corn yields, average N present in grain, and N removed per acre in the grain are shown in the following Table.

Table 4. Ear Corn Yield, Percentage N in Grain and N Removal Per Acre in 1971 From a Webster Silty Clay Loam Near Lamberton When Fertilized in January or in April.

Fert. Trt. (lbs/A)	Fert. broadcast in:	I	II	III	IV	Yield	Average Grain %N	Average Grain lbsN/A
		Bu/A ear corn @ 15.5% Moisture						
None		36.7	26.3	32.2	12.0	26.8 ab	1.03	16.6
40+0+0	January	52.3	72.7	50.7	32.5	52.1 c	1.03	32.2
40+0+0	April	55.8	72.2	74.5	61.3	66.0 de	1.08	42.1
0+40+0	January	33.6	44.4	37.7	35.1	37.7 b	0.98	21.8
0+40+0	April	10.4	29.8	37.8	12.1	22.5 a	0.98	12.9
40+40+0	January	50.5	49.5	62.3	55.1	54.4 cd	1.05	33.8
40+40+0	April	71.8	75.8	83.1	61.2	73.0 e	1.10	47.5

Although the first three years of this field experiment indicated no significant loss of either N or of NP applied in January, the relatively dry growing season of 1971 indicate a significant advantage for the spring application of either N or of NP. The relatively low N content of the grain, and low grain yields in comparison to previous years, indicate the apparent low fertility level of the experimental area. The higher yield with the winter applied P is not readily explainable.

Conclusions

It is evident that broadcasting of N fertilizers in January, even on the relatively level Webster soil at Lamberton is sometimes less effective for corn production than similar treatments broadcast a few months later. The 1971 corn yields and grain composition indicate that larger amounts of the spring applied N remain available, at least in some growing seasons.

WEST CENTRAL EXPERIMENT STATION - MORRIS

WEATHER SUMMARY - 1971

		Preceipitation			Air Temperature			Soil (10cm) Temperature	
Month	Period	1971	84 yr. Av.	Dev from Av.	1971	84 yr. Av.	Dev. from Av.	1971	4 yr.Av.
January	1-31	1.18	.66	+.52	2.6	8.6	-6.0	19.0	21.4
February	1-28	1.63	.65	+.98	12.2	12.8	-0.6	24.6	24.3
March	1-31	.31	1.04	-.73	26.4	26.8	-0.4	27.6	28.9
April	1-10	.09	.60	-.51	37.2	38.3	-1.1	34.3	
	11-20	.35	.63	-.28	51.4	44.3	+7.1	41.6	
	21.30	1.17	1.10	+.07	45.7	48.4	-2.7	46.3	
Total or Average		1.61	2.33	-.72	44.8	43.7	+1.1	40.7	41.0
May	1-10	0	.81	-.81	50.7	52.1	-1.4	50.4	
	11-20	.59	1.01	-.42	55.3	55.6	-0.3	57.8	
	21-31	1.59	1.18	+.41	54.8	60.0	-5.2	53.0	
Total or Average		2.18	3.00	-.82	53.7	56.0	-2.3	53.7	55.5
June	1-10	2.15	1.34	+.81	63.8	62.9	+0.9	63.1	
	11-21	3.67	1.16	+2.51	73.1	66.6	+6.5	74.9	
	21-30	1.80	1.41	+.39	69.4	68.2	+1.2	71.2	
Total or Average		7.62	3.91	+3.71	68.8	65.9	+2.9	69.7	68.3
July	1-10	1.51	1.57	-.06	68.8	69.9	-1.1	71.6	
	11-20	.44	1.06	-.62	66.9	71.4	-4.5	73.0	
	21-31	.14	.94	-.80	62.2	71.7	-9.5	69.8	
Total or Average		2.09	3.57	-1.48	65.9	71.0	-5.1	71.4	75.0
August	1-10	Trace	1.10	-1.10	66.0	70.6	-4.6	71.4	
	11-20	.27	.91	-.64	71.5	69.1	+2.4	75.8	
	21-31	4.27	.96	+3.31	67.4	66.8	+0.6	72.1	
Total or Average		4.54	2.97	+1.57	68.3	68.8	-0.5	73.0	74.8
September	1-30	2.05	2.20	-.21	58.4	59.3	-0.9	61.5	61.8
October	1-31	7.11	1.52	+5.59	49.0	47.5	+1.5	49.4	47.4
November	1-30	2.52	0.88	+1.64	29.2	29.9	+0.7	34.8	34.4
December	1-31	.32	0.19	-.37	12.0	15.8	-3.8	33.0	25.1
April - August	Growing Season	18.04	15.78	+2.26	60.3	61.2	-0.9	61.7	62.9
January-December	Annual	33.16	23.47	+9.69	41.1	42.2	-1.1	46.5	46.5

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 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.

1971 Silage Yields and Grain Percentage

Dry Matter, tons/acre

	Total Yield	% Grain
On plots harvested as grain 1965-71:		
Low fertility (74 + 48 + 48)	6.30	50
High fertility (148 + 96 + 96)	6.81	48
On plots harvested as silage 1965-71:		
Low fertility (74 + 48 + 48)	6.15	50
High fertility (148 + 96 + 96)	7.19	49

1971 Grain Yields

Bushels/acre @ 15.5% Moisture

On plots harvested as grain 1965-71:	
Low fertility (74 + 48 + 48)	100.57
High fertility (148 + 96 + 96)	119.07

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

Grain (0 + 0 + 0)	63.42 bu/acre
Silage (0 + 0 + 0)	3.79 tons/acre

There is still no reduction in yields after growing 7 years of continuous corn silage. Higher fertility increased both silage and grain yields in 1971.

Variety - Pioneer 3935 Plant date - May 7.

FERTILIZER MATERIAL PLOTS

West Central Experiment Station - Morris

S. D. Evans, O. Gunderson, G. Holcomb, and C. Overdahl

An investigation of the effect of soil conditioners, organic fertilizers, and liquid fertilizers was commenced on field corn in the spring of 1971 at Morris. The experiment was set up on a site consisting of Tara and McIntosh silt loams. The initial soil tests are given in table 1.

Table 1. Initial soil test values on Morris Fertilizer Materials Plot.

Sample	pH	Organic Matter	P	K	Zn
			---lbs/A------		ppm
Rep 1	7.8	M	8	370	3.0
Rep 2	7.9	M	5	240	2.7
Rep 3	7.5	M	8	240	3.3
Rep 4	7.4	M	17	220	1.4

The experiment was set up in a split block design of 4 replications. Main blocks were (1) no broadcast fertilizer and (2) 80 lbs. P_2O_5 broadcast. Ten individual fertilizer treatments were superimposed across each main block pair. The individual treatments are described in table 2.

As can be seen in table 3, there was no significant effect of the broadcast phosphorus. Comparison of the standard fertilizer material (H) with the other materials (table 4) shows no advantage for the other materials. In all measurements listed in table 4, treatment H is equal to or better than any of the other treatments.

Table 2. 1971 Morris Fertilizer Materials Trial.

Treatment Letter	Treatment Description	Herbicide	Insecticide
A	Check	Yes	Yes
B	200 lbs/A of ammonium sulfate (21-0-0) broadcast before planting + 5 gal/A of 10-20-10 with seed at planting + 2 foliar applications of 2 gal/A each on 6-21 and 7-20	Yes	Yes
C	Same as B but without foliar treatments	Yes	Yes
D	Wonderlife (0-0-0), a soil conditioner, at 250 lbs/A broadcast before planting	No	No
E	Same as D	Yes	Yes
F	Shurgro (6-2-1), an organic fertilizer, at 300 lbs/A broadcast before planting + 200 lbs/A with planter	No	No
G	Same as F	Yes	Yes
H	105 lbs/A of N as 33 1/2-0-0 broadcast before planting + 190 lbs/A of 8-32-16 at planting	Yes	Yes
J	Same as H but with an additional 100 lbs/A of N as 33 1/2-0-0 and 100 lbs/A of K_2O as 0-0-60 broadcast before planting	Yes	Yes
K	Same as H but with an additional 5 gal/A of liquid 7-21-7 with seed at planting	Yes	Yes

Leaf samples were taken in all plots at silking. The leaf used was the one opposite and below the top ear. Chemical analysis of the leaves (table 5) shows significant changes in % N, % P, % Ca, % Mg ppm Zn, ppm Cu, ppm Mn, and ppm B. There was no treatment effect on % K, ppm Fe, or ppm Mo. There was no effect of broadcast phosphorus on the leaf content of any of the elements measured.

Conclusion

From one year's results the standard fertilizer materials at recommended rates give the highest yield at the most economical cost.

The hybrid used was Pioneer 3956A(N) planted on May 14. Furadan at 10 lbs/A was applied to all treatments but D and F. Lasso at 2 1/2 lbs/A was broadcast on all treatments but D and F on May 17.

Table 3. Effect of Broadcast Phosphorus on Plant Measurements.

	No P	80 lbs/A of P_2O_5
Extended leaf		
Height on June 22	15.1 inches	15.6 inches
Date 50% silked	Aug. 2	Aug. 2
Date 50% of plants shedding pollen	Aug. 7	Aug. 7
No. of plants/acre at Harvest	20,059	20,005
% broken stalks	0.7%	0.9%
% root lodged	35.7%	35.9%
% ears normal in size and/or shape	74%	76%
% ear moisture at harvest	33.86%	33.61%
% protein in grain	8.6%	8.2%
Yield @ 15.5% moisture	63 bu/A	64 bu/A

Table 4. Effect of Fertilizer Materials on Plant Measurements*

Treatment Letter	Ext. Leaf Ht. on June 22	Date 50% Silked	Date 50% of Plants Shedding Pollen	No. of Plants per Acre at Harvest	% Broken Stalks	% Root Lodged	% Ears Normal in Size and/or Shape	% Ear Moisture at Harvest	% Protein in Grain	Yield Bu/A
A	12.4 AB	8-5 DE	8-10 D	19675 A	0.3 A	20.3 A	73 B	34.41 C	7.7 CD	40 D
B	16.8 CD	7-31 AB	8-5 BC	20979 ABC	0.8 A	20.8 A	89 C	30.64 DE	8.5 BC	78 B
C	15.6 BCD	8-2 C	8-7 C	21319 BC	0.8 A	21.0 A	89 C	32.78 CDE	8.8 AB	72 BC
D	12.4 AB	8-6 E	8-12 E	20412 AB	0.3 A	95.8 B	21 A	39.83 A	7.6 CD	20 E
E	12.0 A	8-5 DE	8-9 D	20752 ABC	0.3 A	17.1 A	75 B	34.49 C	7.5 D	47 D
F	14.4 ABC	8-4 D	8-10 DE	19618 A	0.0 A	94.9 B	28 A	37.51 B	7.4 D	24 E
G	15.8 CD	7-31 BC	8-5 BC	21376 BC	0.8 A	19.1 A	91 C	32.56 CDE	7.8 CD	65 C
H	17.8 DE	7-31 AB	8-5 AB	21830 C	1.5 A	27.3 A	95 C	31.79 DE	9.6 A	94 A
J	16.6 CD	7-30 AB	8-5 B	21716 BC	2.2 A	20.8 A	95 C	33.08 CD	9.5 A	94 A
K	19.8 E	7-29 A	8-3 A	20922 ABC	1.1 A	20.8 A	95 C	30.28 E	9.6 A	92 A

* Values followed by different letters in the same column are significantly different at the 5% level.

Table 5. Effect of Fertilizer Materials on Leaf Analysis (Leaves Sampled at Silking)*

Treatment Letter	N %	P %	Ca %	Mg %	Zn ppm	Cu ppm	Mn ppm	B ppm
A	1.42 ABC	.14 BCD	.54 A	.63 AB	9.1 AB	4.2 AB	69 AB	13 B
B	2.19 DE	.17 CD	.61 AB	.63 AB	9.1 AB	8.1 C	90 CD	10 A
C	2.00 CDE	.16 CD	.63 AB	.64 AB	8.8 AB	8.6 C	94 D	11 A
D	.88 A	.11 A	.55 A	.57 A	7.4 A	2.2 A	61 A	13 B
E	1.50 BC	.14 ABC	.60 AB	.66 AB	13.0 B	5.0 B	75 BC	12 AB
F	1.30 AB	.12 AB	.61 AB	.67 AB	7.8 AB	2.9 AB	61 A	13 B
G	1.84 BCD	.18 DE	.66 B	.64 AB	11.7 AB	7.8 C	81 BCD	10 A
H	2.49 E	.21 EF	.63 AB	.76 B	8.8 AB	11.7 D	118 E	10 A
J	2.51 E	.21 EF	.60 AB	.71 AB	9.3 AB	11.2 D	117 E	10 A
K	2.51 E	.24 F	.67 B	.71 AB	9.4 AB	12.6 D	122 E	10 A

* Values in the same column followed by different letters are significantly different at the 5% level.

YIELDS OF FIELD CORN GROWN EACH OF FIFTEEN YEARS (1957-1971) 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 four cropping seasons, the seedbed of the entire experimental area has been prepared on all treatments by the method commonly used in the area - fall plowing and disking. All vegetative residues remained on the field, either being plowed down or worked into the surface. Residues have been fall plowed down over the entire experimental plot since late 1967. Ear corn yields and the average for the fifteen years are shown in Table 1. Relatively dry soil conditions have frequently limited corn yields during the years of this study.

It is evident that the annual 40 pound per acre N fertilization rate increased average corn yields approximately 10 bushels per acre and also that further increases in annual N fertilization rate failed to further increase corn yields. Soil analyses have shown some accumulation of nitrate nitrogen to a 24 foot depth, although major concentrations occur in the upper 8 foot depth.

Corn grain from all plots was sampled in 1971 and analyzed for nitrogen content. The ear corn yields over the fifteen year period and 1971 N content and removal are shown in the following table.

It is evident that during the 15 year period, the 40 pound rate of fertilizer N application has increased average corn yields by approximately 10 bushels per acre, with no additional increase with increased rates of N fertilization.

Assuming that the N content of the grain has been relatively constant during the 15 year period, total N removal and balance in the soil is also shown, with little utilization where heavy N fertilization occurred.

YIELD OF EAR CORN DURING FIFTEEN YEARS (1957-71) WITH DIFFERENT RATES OF ANNUALLY APPLIED NITROGEN, WITH N CONCENTRATIONS AND REMOVAL IN THE CORN GRAIN
(average of 15 replications)

	Annual fertilization rate in lbs/A				
	0+40+40(S)	40+40+40(F)	40+40+40(S)	80+40+40(S)	240+40+40(S)
Year	(Bushels of corn per acre @ 15.5% moisture)				
1957	65.2	71.0	69.4	72.1	71.3
1958	73.2	81.5	81.0	82.4	80.3
1959	36.1	40.9	41.5	39.7	36.8
1960	53.3	48.2	55.0	53.7	52.5
1961	32.3	48.3	47.6	45.0	46.1
1962	38.1	59.0	62.0	65.3	67.1
1963	62.7	80.9	83.5	77.4	79.5
1964	33.2	34.1	29.6	29.1	24.7
1965	50.4	68.3	75.3	80.8	82.8
1966	49.0	63.7	66.3	75.9	33.1
1967	66.8	69.2	71.2	69.7	71.3
1968	64.1	79.6	70.2	78.5	76.0
1969	76.4	58.0	60.2	59.9	58.7
1970	59.2	66.9	70.2	78.5	76.0
1971	64.2	79.9	82.6	83.6	85.4
15 Year Average (bu/A)	54.3	64.0	64.8	66.1	62.8
%N in 1971 corn grain	1.15	1.32	1.47	1.60	1.81
Pounds N/A in 1971 grain	32.8	50.9	60.0	67.0	75.7
N applied in 15 years (lbs/A)	--	600	600	1200	3600
Approx. N removed grain (lbs/A)	444	599	671	751	807
N balance in soil	-444	-599	-671	+449	+2793

(S) - Fertilizer broadcast in spring
(F) - Fertilizer broadcast in fall

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 1970 at the rate of 120 lbs. of N per acre. Reps 3 and 4 were severely damaged by standing water in late June.

1971 Variety - Pioneer 3956   Planting date - May 5, 1971

Table 1. 1971 yields in Bu/acre at 15.5% moisture (Reps 1, 2, 5 and 6 only)

Broadcast P Treatment (lbs/acre)	Row Phosphorus Treatments (lbs/acre)					
	Ck	15 P	30 P	45 P	45 P + 10 Zn	Average
0	97.3	98.4	100.0	105.1	108.9	102.0
45 P	110.6	100.4	96.9	91.9	105.4	101.0
Average	104.0	99.4	98.5	98.5	107.2	

Table 2. Average yield in bu/acre at 15.5% moisture for 1965-71.

Broadcast P Treatment (lbs/acre)	Ck	15 P	30 P	45 P	45 P + 10 Zn	Average
0	78.0	77.4	79.0	78.5	82.5	79.1
45 P	82.6	79.4	76.4	74.3	82.4	79.1
Average	80.3	78.4	77.7	76.4	82.4	79.0

As shown in Table 1, yields were reduced slightly by very high rates of phosphorus. This depression in yield is less than in some previous years. This may be due to the fact that the growing season was favorable and yields were higher than in any year of this experiment. At the higher yield level there is probably a need for more phosphorus. As in past years, the addition of 10 lbs. of zinc at the highest phosphorus level increased yields.

In Table 2 are the 7-year average yields. Statistical analysis has not been done over years but it again appears that there is a slight reduction in yield at very high phosphorus rates; i.e., 30 P and 45 P in the row at the 45 P broadcast level. There is also a significant increase in yield from the addition of zinc at the 45 P row rate.

POTASSIUM FERTILIZATION OF CORN

Walt Heideman Farm - Benson

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

A potassium experiment on corn was set up southeast of Benson in the spring of 1971. The initial soil tests are given in Table 1. Rates of potassium in addition to combinations with nitrogen and phosphorus were used.

Table 1. Soil test values on the Heideman farm, Spring 1971.

Section of plot area	Soil Texture	pH	Organic Matter	Phosphorus (lbs/A.)	Potassium (lbs/A.)	Zinc (ppm)
Northeast	silt loam	7.9	High	9	250	2.9
Southeast	silt loam	8.1	High	5	280	3.2
Southwest	silt loam	8.0	High	4	240	3.5
Northwest	silt loam	7.7	High	5	260	3.3

The field was in alfalfa in 1970 and was fall plowed. Treatments were applied on May 3 and the corn was planted and taken care of by the farmer. A starter fertilizer of 100 lbs/acre of 8-32-16 was used. Leaf samples were taken on July 30 and the results are shown in Table 2. The only nutrients which were significantly different between treatments were manganese and boron. Potash appeared to lower the leaf manganese. The addition of nitrogen or nitrogen and phosphorus at the high potassium level raised the leaf manganese. The variation in leaf boron did not appear to be related to treatment. At no time during the summer was there a visual difference between treatments.

Table 2. Nutrient content of leaves at silking.

Treatment N (lbs/A)	Treatment P_2O_5 (lbs/A)	Treatment K_2O (lbs/A)	P %	K %	Ca %	Al ppm	Fe ppm	Mg %	Zn ppm	Cu ppm	Mo ppm	Mn[a] ppm	B[a] ppm
0	0	0	.26	1.37	.58	60	179	.54	23	10.0	18.4	85bc	9.7bc
0	0	100	.27	1.43	.57	62	182	.53	18	9.8	17.3	78ab	7.1a
0	0	300	.26	1.43	.55	56	173	.54	18	8.9	18.0	77ab	8.6abc
0	0	600	.26	1.54	.54	60	174	.46	20	10.0	16.3	76a	9.2bc
100	0	600	.26	1.52	.60	61	175	.48	19	10.6	15.7	83abc	8.4ab
100	100	600	.26	1.50	.54	48	159	.49	18	9.4	17.3	88c	10.2c
Treatment Significance			NS	NS	NS	NS	NS	NS	NS	NS	NS	*	*

[a] Treatments followed by the same letter are not significantly different at the 5% level.

The plots were harvested on October 7 and the harvest data is given in Table 3. There were no significant effects of any of the treatments.

Table 3. Harvest data on Potash Plots at Benson

N	P_2O_5	K_2O	Yield Bu/A @ 15.5% M	Number of ears harvested on an acre basis	Ear moisture at harvest %
	(lbs/A)				
0	0	0	111.5	22,500	30.1
0	0	100	109.1	22,600	31.0
0	0	300	107.6	22,300	32.0
0	0	600	111.1	22,100	31.8
100	0	600	105.9	22,500	32.6
100	100	600	109.2	22,400	31.2
Treatment Significance			NS	NS	NS

Statistical Analysis done by Dean Fairchild.

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 1971 and 1965-71.

Treatment* (lbs/acre)	When Applied	Yield in bu/acre at 15.5% moisture 1971**	Average 1965-71
Check	- -	121.9	88.3
5 lbs. zinc as zinc sulfate	1965	114.0	86.3
10 lbs. zinc as zinc sulfate	1965	118.6	86.7
10 lbs. zinc as zinc sulfate	yearly	118.2	89.0
20 lbs. zinc as zinc sulfate	1965	118.5	88.2
0.5 lbs. zinc as Zn chel.	yearly	118.7	84.5
45 lbs. P broadcast	yearly	120.4	84.2
45 lbs. P broadcast +	yearly		
10 lbs. zinc as zinc sulfate	1965	112.0	85.2

* All plots received a uniform application of 120 lbs. of N in the fall of 1970 and 125 lbs. of 8-32-16 starter.

**Reps 1, 2, 3, and 6 only.

Yields (Table 1) in 1971 were very high. The highest yielding treatment was the check at 121.9 bu/acre. All other treatments were lower with 5 lbs. zinc as zinc sulfate and the 45 P + 10 zinc treatments being substantially lower. The 7-year average yields show no differences between zinc treatments and the check. The treatments with phosphorus are slightly lower.

NPK FERTILIZATION OF SOYBEANS

West Central Experiment Station - Morris

S. D. Evans and G. E. Ham

A series of plots was established on Forman clay loam in the fall of 1967 to determine the optimum fertilization rates for sugar beets. The project was discontinued after one cropping year, so these plots were put in soybeans in 1969, 1970, and 1971. Yields were taken in 1969 and 1971. Fertilizer rates used are given in table 1.

Table 1. Fertilizer rates used in the experiment (rates are lbs/acre in the elemental form).

Nitrogen	Phosphorus	Potassium
N_0 - 0	P_0 - 0	K_0 - 0
N_1 - 70	P_1 - 25	K_1 - 25
N_2 - 140	P_2 - 50	K_2 - 50

Two separate experiments were carried out each year. On one experiment fertilizer was applied the fall before yields were measured (direct fertilization). On the other experiment there was no fertilizer applied in the fall immediately before yields were measured (residual fertilization). The elements were applied in all combinations of a 3 x 3 x 3 factorial of 2 replications. Chippewa 64 soybeans were used in 1969 and Clay soybeans in 1971. The initial soil tests are given in table 2.

Table 2. Initial soil test values - Fall 1967.

Sample No.	pH	O.M.	P	K
1	7.0	5.7	24	370
2	6.7	6.0	26	370

In 1969 yields averaged about 30 bushels per acre (table 3). In 1971 with more moisture, yields averaged about 37 bushels per acre (table 4). The summary of the statistical analysis of the data (table 5) shows very little effect of any treatments. In the 1971 data phosphorus and potassium have a slight effect on yield. This shows up as a quadratic effect with both elements reaching a maximum yield at the middle level of each; i.e., P_1 or K_1. The effect is very small, however, with $P_1 - P_0 = 1.1$ bushels per acre and $K_1 - K_0 = 2.2$ bushels per acre.

A 10-lb. zinc treatment with zinc supplied in zinc sulfate was included as an extra treatment each year. In no case (table 6) was there a significant positive effect of the zinc application.

Table 3. 1969 soybean yields on NPK factorial experiment.

Bushels/Acre

Residual Fertilization (Fertilizer applied in fall of 1967)

	N_0	N_1	N_2	Aver.		N_0	N_1	N_2	Aver.		P_0	P_1	P_2	Aver.
P_0	30.8	31.5	31.7	31.3	K_0	29.2	30.6	30.3	30.0	K_0	30.4	28.7	31.0	30.0
P_1	28.6	30.7	32.2	30.5	K_1	30.1	31.2	32.5	31.3	K_1	31.8	32.2	29.9	31.3
P_2	31.3	30.2	30.2	30.6	K_2	31.5	30.7	31.4	31.2	K_2	31.9	30.8	30.8	31.2
Aver.	30.3	30.8	31.4	--	Aver.	30.3	30.8	31.4	--	Aver.	31.3	30.5	30.6	--

Direct Fertilization (Fertilizer applied in fall of 1968)

	N_0	N_1	N_2	Aver.		N_0	N_1	N_2	Aver.		P_0	P_1	P_2	Aver.
P_0	30.3	30.6	30.4	30.4	K_0	27.5	30.0	29.2	28.9	K_0	30.6	28.2	27.8	28.9
P_1	29.8	30.0	30.0	30.0	K_1	31.4	31.0	30.7	31.0	K_1	31.8	30.5	30.8	31.0
P_2	27.7	31.0	30.4	29.7	K_2	29.0	30.6	30.8	30.2	K_2	28.8	31.3	30.5	30.2
Aver.	29.3	30.6	30.3	--	Aver.	29.3	30.6	30.3	--	Aver.	30.4	30.0	29.7	--

Table 4. 1971 soybean yields on NPK factorial experiment.

Bushels/Acre

Residual Fertilization (Fertilizer applied in fall of 1969)

	N_0	N_1	N_2	Aver.		N_0	N_1	N_2	Aver.		P_0	P_1	P_2	Aver.
P_0	39.6	37.6	37.1	38.1	K_0	37.3	36.0	37.2	36.8	K_0	38.4	35.5	36.6	36.8
P_1	35.1	36.6	38.8	36.8	K_1	37.3	37.7	38.4	37.8	K_1	38.4	38.9	36.2	37.8
P_2	35.5	36.6	36.2	36.1	K_2	35.6	37.1	36.5	36.4	K_2	37.6	36.0	35.6	36.4
Aver.	36.7	36.9	37.4	--	Aver.	36.7	36.9	37.4	--	Aver.	38.1	36.8	36.1	--

Direct Fertilization (Fertilizer applied in fall of 1970)

	N_0	N_1	N_2	Aver.		N_0	N_1	N_2	Aver.		P_0	P_1	P_2	Aver.
P_0	35.4	38.2	37.0	36.9	K_0	35.8	36.0	37.6	36.5	K_0	35.6	38.2	35.6	36.5
P_1	38.1	37.4	38.4	38.0	K_1	37.6	38.8	38.4	38.3	K_1	37.8	39.2	37.8	38.3
P_2	35.2	35.7	36.8	35.9	K_2	35.3	36.4	36.2	36.0	K_2	37.2	36.5	34.2	36.0
Aver.	36.2	37.1	37.4	--	Aver.	36.2	37.1	37.4	--	Aver.	36.9	38.0	35.9	--

Table 5. Summary of ANOVA on 1969 and 1971 soybean yields.

Source of Variation	Degrees of Freedom	1969 Residual	1969 Direct	1971 Residual	1971 Direct
N	2	NS	NS	NS	NS
Linear	1	NS	NS	NS	NS
Quadratic	1	NS	NS	NS	NS
P	2	NS	NS	NS	NS
Linear	1	NS	NS	NS	NS
Quadratic	1	NS	NS	NS	+
K	2	NS	NS	NS	+
Linear	[illegible]	NS	NS	NS	NS
Quadratic	1				
NP	4	NS	NS	NS	NS
L x L	1	NS	NS	NS	NS
Rest	3	NS	NS	NS	NS
NK	4	NS	NS	NS	NS
L x L	1	NS	NS	NS	NS
REST	3	NS	NS	NS	NS
PK	4	NS	NS	NS	NS
L x L	1	NS	NS	NS	NS
REST	3	NS	NS	NS	NS

Note: NS - Non significant, + - significant at the 10% level,
* - significant at the 5% level.

Table 6. Effect of 10 lbs. zinc on soybean yields.

Treatment	1969 Residual	1969 Direct	1971 Residual	1971 Direct
		Bushels/acre		
N_1 P_1 K_1	31.8	30.8	38.6	39.6
N_1 P_1 K_1 + 10 Zn	25.4	28.8	38.8	39.6

SMALL GRAIN FERTILIZATION

West Central Experiment Station - Morris

S. D. Evans

Field experiments were carried out on Tara silt loam in 1971 to study the response of wheat, oats, and barley to nitrogen fertilization. The nitrate nitrogen level in the 0-24 inch soil zone was 70 lbs/acre as determined by the University of Minnesota 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 - April 7, 1971

Table 1. Yield of Oats, Morris, 1971.

Nitrogen Applied lbs/A	Variety: Lodi	Otter	Diana	Average
		Bu/A		
0	46.6	69.3	76.6	64.2
30	109.5	108.2	92.5	103.4
60	106.2	115.3	108.8	110.1
90	73.0	109.3	119.7	100.7
Average	83.8	100.5	99.4	

Table 2. Lodging Score, Oats, Morris, 1971.

Nitrogen Applied lbs/A	Variety: Lodi	Otter	Diana	Average
		Lodging[a]		
0	1.0	1.0	1.0	1.0
30	2.0	2.0	1.7	1.9
60	2.3	2.0	2.0	2.1
90	2.7	2.0	2.3	2.3
Average	2.0	1.8	1.8	

[a] 1-Erect, 9-Flat

Table 3. Groat Percentage, Oat Fertility Study - Morris, 1971

Nitrogen Applied lbs/A	Lodi	Otter	Diana	Average
		Groat %		
0	73.3	74.0	72.0	73.1
30	74.7	75.0	72.3	74.0
60	75.0	75.7	73.3	74.7
90	75.0	76.3	73.0	74.8
Average	74.5	75.2	72.7	

Table 4. Analysis of Variance

Source of Variation	Yield	Heading Date	Pl.Ht.	Lodging	Groat %
	Significance				
Varieties	NS	**	**	NS	NS
Nitrogen	**	NS	**	**	**
Varieties x Nitrogen	NS	NS	NS	NS	NS

Table 5. Chemical Analyses of Oat Leaves Samples at Heading (Reps combined).

Variety	Nitrogen Applied lbs/A	N %	P %	K %	Ca %	Fe ppm	Mg %	Zn ppm	Cu ppm	Mo ppm	Mn ppm	B ppm
Lodi	0	3.10	.22	1.57	.46	75	.23	8.1	1.5	7.8	35	3.6
	30	2.58	.22	1.76	.38	60	.24	7.4	1.8	7.9	28	3.9
	60	4.11	.25	1.30	.52	92	.26	11.1	1.7	8.2	48	5.1
	90	3.16	.22	1.66	.45	74	.22	9.0	2.0	7.6	37	4.0
Otter	0	2.84	.24	1.69	.42	61	.20	7.8	1.8	6.9	28	3.2
	30	4.12	.28	1.42	.54	82	.24	12.1	1.6	7.9	32	4.5
	60	3.41	.26	1.66	.40	77	.23	8.5	1.3	7.5	27	4.8
	90	3.99	.26	1.60	.46	77	.24	10.3	1.3	7.8	26	5.0
Diana	0	3.67	.22	1.38	.52	79	.23	12.6	1.0	7.5	34	7.5
	30	3.29	.22	1.51	.45	70	.25	9.7	0.7	8.1	25	6.8
	60	2.98	.20	1.59	.42	59	.26	9.4	1.0	7.3	24	8.2
	90	3.99	.23	1.37	.55	95	.24	13.4	1.1	8.4	36	8.8

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 actuan nitrogen.

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

Seeding date - April 7, 1971

Table 6. Yield of Barley - Morris, 1971

Nitrogen Applied lbs/Acre	Variety Dickson	Larker	64-76	Average
	Bu/Acre			
0	43.4	35.7	46.7	41.9
30	62.7	49.7	58.5	57.0
60	70.1	54.5	65.7	63.4
90	63.7	54.1	69.4	62.4
Average	60.0	48.5	60.1	

Table 7. Lodging Score, Barley - Morris, 1971

Nitrogen Applied lbs/Acre	Variety Dickson	Larker	64-76	Average
	Lodging[a]			
0	2.0	5.0	1.7	2.9
30	3.0	6.3	2.0	3.8
60	2.7	6.0	2.0	3.6
90	5.0	7.3	2.0	4.8
Average	3.2	6.2	1.9	

[a]1-Erect, 9-Flat

Table 8. Analysis of Variance.

Source of Variation	Significance Yield	Heading Date	Pl. Ht.	Lodging
Varieties	NS	**	**	**
Nitrogen	*	NS	**	**
Nitrogen x Varieties	NS	NS	*	NS

Table 9. Chemical Analyses of Barley Leaves Sampled at Heading (Reps combined)

Variety	Nitrogen Applied lbs/Acre	N %	P %	K %	Ca %	Fe ppm	Mg %	Zn ppm	Ca ppm	Mo ppm	Mn ppm	B ppm
Dickson	0	2.70	.26	.77	.69	51	.35	13.5	4.0	9.6	51	6.4
	30	3.12	.27	.85	.85	57	.37	16.4	4.1	10.6	54	6.2
	60	2.98	.27	.82	.83	89	.36	15.6	4.0	10.4	50	6.0
	90	3.81	.28	.87	.99	60	.37	20.3	4.7	10.3	66	6.6
Larker	0	3.42	.28	.66	1.50	63	.43	19.4	3.6	12.0	61	7.5
	30	3.43	.27	.74	1.39	62	.39	21.1	3.3	11.3	53	7.5
	60	2.51	.28	.70	1.05	57	.36	13.4	3.8	9.5	60	7.6
	90	3.51	.29	1.02	.96	58	.42	22.8	5.0	11.0	76	6.1
64-76	0	3.28	.30	.86	.57	50	.32	19.5	4.4	11.2	51	7.5
	30	3.85	.29	1.00	.84	56	.39	28.2	5.4	10.4	73	5.0
	60	3.37	.28	.94	.75	51	.36	22.4	4.6	10.3	55	5.5
	90	3.26	.26	.93	.69	61	.36	21.8	4.5	10.3	60	5.1

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 - April 7, 1971

Table 10. Yield of Wheat - Morris, 1971

Nitrogen Applied lbs/Acre	Variety Ciano 67	Chris	Era	Average
		Bu/Acre		
0	44.9	35.0	34.5	38.1
40	47.2	41.3	46.0	44.8
80	46.2	42.7	43.6	44.2
120	47.1	34.3	47.2	42.9
Average	46.4	38.3	42.8	

Table 11. Lodging Score, Wheat - Morris, 1971

Nitrogen Applied lbs/Acre	Variety Ciano 67	Chris	Era	Average
		Lodging[a]		
0	1.0	1.3	1.0	1.1
30	1.0	2.7	1.3	1.7
60	1.0	5.0	2.0	2.7
90	1.0	7.0	2.3	3.4
Average	1.0	4.0	1.7	

[a] 1-Erect, 9-Flat

Table 12. Analysis of Variance

Source of Variation	Significance			
	Yield	Heading Date	Pl. Ht.	Lodging
Varieties	NS	**	**	**
Nitrogen	*	NS	**	**
Nitrogen x Varieties	NS	NS	**	**

Table 13. Chemical Analysis of Wheat Leaves Sampled at Heading (Reps Combined)

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	3.35	.24	1.00	.40	69	.32	12.9	1.6	10.6	37	3.0
	40	3.64	.25	1.16	.49	72	.34	15.0	1.5	11.3	39	3.0
	80	3.92	.28	1.07	.57	76	.39	16.8	1.5	13.2	51	3.2
	120	3.20	.25	1.07	.37	68	.33	12.0	1.5	10.0	39	4.0
Chris	0	2.97	.24	1.05	.30	62	.27	13.9	2.3	8.9	42	2.3
	40	3.63	.25	1.01	.42	77	.30	15.8	2.3	10.7	52	3.0
	80	3.94	.25	1.02	.45	74	.33	17.0	2.1	10.3	58	2.7
	120	3.39	.24	.95	.34	66	.28	15.3	2.2	11.5	49	3.3
Era	0	3.20	.28	1.20	.29	62	.25	20.4	2.0	9.8	42	2.1
	40	3.56	.27	1.07	.31	59	.26	21.0	1.9	9.2	44	2.2
	80	2.81	.27	1.20	.25	54	.19	17.4	1.8	8.6	27	1.6
	120		.27	1.20	.36	66	.25	22.1	2.2	8.4	45	1.3

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

Statistical analysis was done by Dean Fairchild, Department of Soil Science.

THE EFFECT OF HEAVY APPLICATIONS OF ANIMAL MANURES ON BOTH THE CROP (CORN) AND THE SOIL
1970 and 1971

West Central Experiment Station - Morris
Samuel D. Evans, J. M. MacGregor, R. C. Hunter, and P. R. Goodrich

Experimental Design

Main treatments arranged in three replications of a complete randomized block design. Each plot is split into two parts for sub-plot treatments.

Treatments

Main plots:

1. No manure or fertilizer.
2. Recommended amounts of inorganic fertilizer.
3. Solid manure from a conventional beef feeding facility (manure + straw).
4. Liquid beef manure from a slatted floor feeding barn.
5. Liquid hog manure from a slatted floor hog finishing barn.

Sub-plots:

A. Corn treated at planting with insecticide for corn rootworm control.

B. No rootworm control.

Main Plot Size

60 feet wide by 120 feet long.

Soil Type

Tara and Doland silt loams.

Initial Soil Sampling

Dates - September 25, 28, and 29, 1970.

Soil samples frozen immediately and then transferred to St. Paul.

Initial Tillage

Ran field cultivator over plots to receive liquid manure.

Initial Manure Application

Treatment 3 - September 30

Treatment 4 - September 30, October 1

Treatment 5 - October 2

Plowing

October 5 at a depth of 4-5 inches.

Second Manure Application

Treatment 3 - October 8

Treatment 4 - October 7

Treatment 5 - October 6

Plowing

All plots plowed 8-10 inches deep on October 16.

Total Manure Application (Fall 1970)

Treatment 3 - 100 tons/acre

Treatment 4 - 284 tons/acre (2 1/2 acre inches)

Treatment 5 - 284 tons/acre (2 1/2 acre inches)

Table 1. Manure Analyses (Fall 1970)

	Solid Beef	Liquid Beef	Liquid Hog
Total Solids	31.35%	10.82%	1.24%
Total Volatile Solids (from total solids)	78.30%	8.43%	99.51%
B.O.D.	4,066 mg/l	124,800 mg/l	11,340 mg/l
C.O.D.	46,695 mg/l	62,960 mg/l	26,400 mg/l
Total N	11,200 ppm	2,018,470 ppm	2,335,920 ppm
NO_3-N	2,819 ppm	156,000 ppm	135,600 ppm
PO_4	2,880 ppm	633,000 ppm	125,500 ppm

May 6 - Sampled plots which were to receive inorganic fertilizer.

Table 2. Soil Test Results

Sample	pH	Organic Matter	P	K	Zinc
Rep 1	7.1	M	19	200	1.9
Rep 2	7.2	M	21	240	1.7
Rep 3	7.4	M	17	230	3.7

May 6 - Applied 109 lbs/A of actual N as ammonium nitrate to treatment 2 plots.

May 7 - Planted plots in 30-inch rows with Pioneer 3956A(N) @ 20,000 seed/acre. Four rows in each plot were left without insecticide. Remaining 16 rows received 10 lbs/A of Furadan (10% granule). Plots of treatment 2 received 154 lbs/A or 7-26-26 as a starter (11 + 40 + 40). None of the other treatments received any fertilizer.

May 10 - Sprayed all plots with 2 1/2 lbs/A of Lasso broadcast.

May 24 - Corn just emerging. No apparent differences between treatments.

June 15 - Cultivated all plots.

June 17 - Observed wilting in liquid beef plots.

June 28 - Cultivated all plots.

July 6 - Took 3 soil samples to an 8-inch depth for conductivity measurements.

Area in Rep 1 Only	Electrical conductivity on a saturations extract mmhos/cm
Liquid beef plot where corn was stunted and wilted	6.5
Liquid beef plot where corn was normal	1.3
Check plot	0.2

July 22 thru July 31 - Took notes on pollen shed and silking. On the day following silking took leaf samples in the A parts of all main plots.

There were significant changes in all elements except nitrogen. (Table 3). Manure treatments increased P and K and lowered Ca and Mg. Liquid beef manure drastically increased Zn, Mn, and B in the leaves.

August 4 - Pulled 5 plants in each plot, made a visual rating of rootworm damage, and took pictures of roots. (Dallas Rasmusson, Department of Entomology, Fisheries and Wildlife).

September 15 - Sampled main plots; collected ear, plant, and root samples.

The dry matter production per acre is given in Table 4. The liquid beef plots were highest in above ground D.M. production, while the liquid hog plots were highest in total D.M. production. Chemical analyses of the fodder, grain, and roots is given in Table 5.

September 16 - Took soil samples in plot area to investigate arthropod population. (John Mihm, Department of Entomology, Fisheries, and Wildlife).

September 21 - Took plant counts and lodging notes.

September 23 - Took silage and grain yields and fodder and grain samples.

Harvest data is given in Table 6.

Plants per acre at harvest varied from 18,500 to 21,500. Plants root lodged were quite high in the check and fertilized plots without insecticide. Lodging in all other plots was below 10%. Grain yields ran from 83.52 bu/A on the fertilized plot without insecticide to 116.63 bu/A on the liquid beef plot with insecticide. There was no significant difference between main plot treatments, but there was a significant increase in yield from using insecticide. There was a significant effect of main plot treatments on silage yield, but no effect of insecticide. Nitrogen analyses of the fodder and grain is given in Table 7.

October 4 - Harvested the bulk of the experimental area as shelled corn.

October 9 and 11 - Sampled all plots to a 4-foot depth (3 sub-samples per plot).

A summary of the soil sample analyses is given in Table 8. Nitrate-nitrogen increased in all plots receiving manure. The biggest change occurred with liquid beef manure. In the 3- to 4-foot zone all plots are quite similar in nitrate-nitrogen content.

The treatments receiving either solid or liquid beef manure show chloride levels much above those a year earlier. Liquid hog manure shows an increase in chloride but the increase is less than with the beef manures.

Electrical conductivity measured on a soil filtrate is higher on all plots receiving manure. Again there is a bigger increase with the beef manures than with the hog manure.

October 13 and 14 - Installed permanent neutron access tubes to an 8-foot depth in all plots in rep 1 (3 tubes per lot).

October 14 and 15 - Spread 100 tons/acre of solid beef manure on appropriate plots.

October 15 - Plowed solid beef plots to a 10-inch depth. Had difficulty plowing area in that coulters would not cut thru the material and it would pile up in front of plow. Finally removed coulters and this worked better. There was still some manure left on the surface.

October 15 - Spread 30 lbs. zinc sulfate on fertilized plots.

October 21 - Ran field cultivator thru all plots to receive liquid manure.

October 21 - Applied 1 1/4" hog manure.

October 25 - Applied 1 1/4" liquid beef manure.

Plowed liquid hog manure plots.

Applied 1 1/4" liquid hog manure.

November 3 - Plowed all but solid beef plots.

Applied 1 1/4" liquid beef manure.

November 10 - Plowed east 1/2 of liquid beef manure plot, rep 1. Still too wet, surface soil frozen, wheels slip on a layer about 10 inches deep.

November 12 - Finished plowing liquid beef plots.

November 23 and 24 - Took neutron probe readings in rep 1.

February 9 and 10 - Took neutron probe readings in rep 1.

Table 3. Summary of Leaf Analysis of Corn Leaves (Sampled at Silking)

Treatment	N %	P %	K %	Ca %	Mg %	Al ppm	Fe ppm	Zn ppm	Cu ppm	Mn ppm	B ppm
Check	2.84	.25	1.40	.66	.45	165	152	13.2	10.3	87	4.2
Fertilized	2.70	.36	1.81	.71	.55	174	186	12.2	11.6	107	4.5
S. Beef	2.95	.40	2.43	.52	.24	131	149	13.4	8.8	87	5.6
L. Beef	2.99	.36	2.04	.73	.23	115	127	27.3	7.0	258	13.0
L. Hog	3.10	.34	2.38	.63	.27	154	154	15.4	9.0	102	6.3
LSD (5%)	----	.08	.48	.12	.09	13	25	5.1	3.0	36	6.6
Significance[a]	NS	*	**	*	**	*	*	**	*	**	**

[a] NS is non-significant, + is significant at the 10% level, * is significant at the 5% level, **is significant at the 1% level.

Table 4. Dry Matter Production (Sampled September 15)

Treatment	Forage Lbs/A of Dry Matter	Forage Roots* Lbs/A of Dry Matter
Check	6,742	15,365
Fertilized	7,550	16,192
S. Beef	6,948	18,171
L. Beef	7,863	17,954
L. Hog	7.472	18,629

*Assuming only 42% of roots harvested on all plots.

Table 5. Chemical Analysis of the Samples Collected on September 15.

Treatment	Cl ppm	N %	P %	K %	Ca %	Mg %	Al ppm	Fe ppm	Zn ppm	Cu ppm	Mn ppm	B ppm
FODDER												
Check	1795	.63	.11	.93	.34	.40	49	287	7.2	5.5	53	11.3
Fertilized	2785	.76	.13	1.03	.34	.43	43	126	6.2	6.2	50	18.5
S. Beef	5397	.80	.22	1.74	.25	.25	42	113	6.4	5.3	46	5.4
L. Beef	5508	1.07	.28	1.99	.48	.28	49	140	8.6	5.2	142	6.2
L. Hog	2591	.87	.14	1.83	.31	.24	40	110	7.0	4.2	50	4.4
GRAIN												
Check		1.48	.47	.52	Less	.20	14	36	24.9	2.4	7	3.4
Fertilized		1.56	.50	.56	than	.22	7	41	27.4	1.9	10	8.1
S. Beef		1.70	.64	.63	.02%	.24	12	47	34.6	1.7	13	6.5
L. Beef		1.75	.63	.59		.25	4	36	33.0	1.0	15	5.1
L. Hog		1.73	.57	.55		.23	5	33	37.3	3.7	12	7.6
ROOTS												
Check		.71	.17	.63	.23	.21	2024	2322	12.9	6.4	70	3.8
Fertilized		.63	.15	.71	.21	.24	1559	1797	10.2	4.7	56	3.1
S. Beef		.87	.17	1.37	.26	.20	1791	1930	10.6	7.0	60	2.9
L. Beef		.92	.17	1.48	.31	.25	1361	1523	9.8	3.8	61	2.6
L. Hog		.91	.23	1.18	.31	.24	2414	2675	13.5	5.1	85	4.3

Table 6. Harvest Data.

Treatment	Insecticide	Plants per Acre	Root Lodged 30° or more %	Broken Above Ear %	Broken Below Ear %	Broken if Pushed to Arms Length %	Grain: No. of Ears per Acre	Grain: Nubbins %	Grain: % Ear Moisture at Harvest	Grain: Grain Yield Bu/Ac @ 15.5% Mois.	Silage: Lbs/Ac on Dry Matter Basis	Silage: Ears as a % of the Total	Silage: Dry Matter at Harvest %
Check	W	19500	4.0	13.1	2.5	17.1	19500	4.5	38.2	96.88	11700	59.2	54.6
	W/O	18500	56.2	11.5	1.2	3.3	18800	7.0	38.8	92.86	11200	58.7	54.2
Fertilized	W	20700	1.4	18.1	3.5	20.1	19900	6.8	38.2	110.72	13900	54.7	51.3
	W/O	19400	41.8	25.5	2.7	9.4	19700	5.6	36.7	83.52	12100	53.4	57.9
S. Beef	W	21000	0.2	32.5	4.4	19.4	19300	5.0	36.4	103.60	13700	54.9	49.2
	W/O	19300	5.5	28.8	3.0	21.1	18200	9.2	35.9	98.78	13000	54.0	50.9
L. Beef	W	21500	1.8	20.9	4.0	11.9	20400	7.6	38.4	116.63	14300	53.4	45.6
	W/O	21500	3.4	22.1	4.5	11.5	20000	8.2	39.6	102.78	13400	49.5	47.7
L. Hog	W	20300	0.7	23.5	9.6	17.7	19800	8.1	32.5	101.71	14700	55.4	55.4
	W/O	19200	8.6	34.1	1.7	14.3	18900	7.9	35.2	97.54	13400	52.9	54.4

Table 7. Nitrogen in the Fodder and Grain at Final Harvest on September 23.

Treatment	Insecticide	Fodder N %	Grain N %
Check	W	.56	1.41
	W/O	.64	1.43
Fertilized	W	.71	1.65
	W/O	.70	1.62
S. Beef	W	.74	1.72
	W/O	.82	1.85
L. Beef	W	1.04	1.80
	W/O	1.07	1.85
L. Hog	W	.92	1.70
	W/O	.91	1.91

Table 8. Analyses of Soil Samples Taken in Morris Animal Manure Plots.

Nitrate (NO_3-N)
ppm in Soil

Depth (ft.)	Check A	Check B	Fertilized A	Fertilized B	Solid Beef A	Solid Beef B	Liquid Beef A	Liquid Beef B	Liquid Hog A	Liquid Hog B
0-1/2	12	10	12	10	16	44	18	100	13	22
1/2-1	12	6	18	9	15	56	14	165	21	71
1-2	13	4	13	11	15	41	12	196	14	106
2-3	11	16	14	31	15	37	14	63	10	62
3-4	4	21	5	22	8	25	7	20	5	25

Chloride
ppm in Soil

Depth (ft.)	Check A	Check B	Fertilized A	Fertilized B	Solid Beef A	Solid Beef B	Liquid Beef A	Liquid Beef B	Liquid Hog A	Liquid Hog B
0-1/2	22	10	11	8	13	15	9	30	7	8
1/2-1	12	5	6	6	9	18	5	41	6	6
1-2	13	4	6	3	8	82	8	104	7	18
2-3	15	10	15	15	15	155	17	168	11	81
3-4	12	23	13	18	16	76	13	58	10	30

Electrical Conductivity on Soil Filtrate
(20 g. air dried soil + 50 ml. H_2O mmhos/cm)

Depth (ft.)	Check A	Check B	Fertilized A	Fertilized B	Solid Beef A	Solid Beef B	Liquid Beef A	Liquid Beef B	Liquid Hog A	Liquid Hog B
0-1/2	.17	.14	.17	.13	.23	.30	.18	.41	.16	.16
1/2-1	.15	.13	.16	.13	.10	.24	.14	.50	.16	.31
1-2	.18	.12	.16	.17	.20	.29	.17	.60	.15	.40
2-3	.19	.17	.21	.26	.20	.34	.19	.44	.18	.40
3-4	.17	.20	.18	.24	.19	.24	.18	.21	.16	.22

Note: A - Readings on Soil Samples taken in fall of 1970 before manure application.
B - Readings on Soil Samples taken in fall of 1971 before manure application.

1971 Corn Tillage Experiment - Waseca

Wm. Lueschen, J. Swan, J. True

Tillage Treatments		Early Plant Growth Grams Dry Weight/10 plants					Final Stand 1000 plants/acre
Primary	Secondary	Rep 1	Rep 2	Rep 3	Rep 4	Avg.	
1. Spring Plow	None	51	47	34	40	43 d	20.8
2. Spring Plow	Conventional	39	32	32	29	44 d	23.5
3. Spring Plow	Field Cultivate	37	38	41	39	39 cd	22.3
4. Spring Plow	Conventional	66	55	57	46	--	21.4
5. Spring Chisel	Conventional	36	43	22	21	31 bc	23.6
6. Spring Chisel	Field Cultivate	29	33	29	17	27 ab	22.1
7. Spring Chisel	Zero	20	27	19	16	21 a	21.5
8. Spring Chisel	Conventional	49	24	38	18	--	21.6
9. Spring Chisel	Disk	35	31	39	19	31 bc	21.8
10. None	None	22	17	19	17	19 a	22.1
11. None	Disk	48	40	49	24	40 d	21.5

4 reps (30 feet x 125 feet)

11 treatments - Randomized complete block

Hybrid - Funks 4444

Date Planted and Secondary Tillage-5/4/71

Date of Spring Primary Tillage-4/23-26

All planting done with AC-No Till planter

Bdcst fertilizer-175 lbs/A N (NH_4NO_3) + 50 lbs/A P_2O_5 + 50 lbs/A K_2O

Insecticide: Furadan 1 lb. banded

Herbicide: Ramrod pre-emergence + Atrazine and oil post

Coulters removed on 8 rows/plot on all plots except 10 zero primary and zero secondary where coulters removed for 4 rows.

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

In 1970, no fall tillage was done for the 1971 season due to tiling operations.

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

Plots were in corn in 1970 and received the same tillage treatments except that in 1971 spring primary tillage replaced fall primary tillage.

1971 Corn Tillage Experiment - Waseca

Tillage Treatments: Primary	Secondary	Corn Yield Bu/Acre 15.5% Moisture: Rep 1 Conv.	Rep 1 Flute	Rep 2 Conv.	Rep 2 Flute	Rep 3 Conv.	Rep 3 Flute	Rep 4 Conv.	Rep 4 Flute	Avg. Conv.	Avg. Flute	Average F & C
1. Spring Plow	None	123.1	123.5	104.5	125.1	92.4	101.6	127.3	121.1	111.8	117.8	114.8 b
2. Spring Plow	Conv.	100.9	108.0	114.7	110.5	99.8	92.3	103.5	107.9	104.7	104.7	102.6 ab
3. Spring Plow	Field Cult.	103.0	95.5	99.0	104.6	96.6	93.8	104.4	125.5	100.8	104.9	102.8 ab
4. Spring Plow	Conv.	97.1	99.2	99.2	87.7	104.9	100.3	112.3	104.0	103.4	97.8	--
5. Spring Chisel	Conv.	100.4	111.0	94.2	98.6	97.5	115.1	114.8	121.0	101.7	111.4	103.3 ab
6. Spring Chisel	Field Cult.	112.4	103.9	93.9	107.3	112.5	121.4	109.8	122.9	107.2	113.9	110.5 ab
7. Spring Chisel	Zero	114.4	122.2	111.6	107.3	118.7	131.8	114.3	109.5	114.6	117.7	116.2 b
8. Spring Chisel	Conv.	90.7	94.4	103.8	110.8	76.0	87.4	117.7	120.2	97.1	103.2	--
9. Spring Chisel	Disk	123.6	123.8	107.2	121.1	100.2	95.3	97.0	113.8	107.0	113.5	110.3 ab
10. None	None	88.7	93.3	90.8	87.2	91.3	100.7	107.4	109.9	94.6	97.8	96.2 a
11. None	Disk	108.8	100.0	103.5	111.8	82.7	99.5	113.6	112.7	102.2	106.0	104.1 ab
								Average		104.1	108.6	106.7

1971 Mulch Rates Tons/Acre

Treatment	Rep 1	Rep 2	Rep 3	Rep 4	Avg.
Plow	Trace	Trace	Trace	Trace	Trace
Chisel	1.56	1.41	1.48	1.31	1.44
Zero	2.55	3.03	3.65	2.80	3.01

Measurements made just after planting.

Corn Tillage - Waseca, 1971

Treatments		Reps 1	2	3	4	Days to 50% Emergence Total	X̄
Fall Plow	Zero	16	17	16	16	65	16
Fall Plow	Conv.	15	16	15	16	62	16
Fall Plow	Field Cult.	16	16	16	16	64	16
Spring Plow	Conv.	15	15	15	15	60	15
Fall Chisel	Conv.	17	16	17	19	69	17
Fall Chisel	Field Cult.	18	18	17	19	72	18
Fall Chisel	None	19	19	19	19	76	19
Spring Chisel	Conv.	16	18	16	17	67	17
Spring Chisel	Disk	17	17	16	19	69	17
Zero Tillage	Zero	19	20	19	19	77	19
Zero	Disk	16	18	16	18	68	17
	Total	184	190	182	193	749	187
	X̄	17	17	17	18	68	17

1971 Corn Yield - ANOVA

	dF	MS	F
Rep	3	461.2770	11.99*
Fluting	1	329.3889	8.56 N.S.
Error	3	38.47185	--
Tillage	8	344.9869	3.92**
Interaction	8	20.13983	0.23 N.S.
Error	48	87.94476	--
Total	71		

Coefficient of variation = 8.78 percent

Treatment Comparisons (Array test)

Primary tillage		Secondary tillage	
Plow	106.8 ab	No Spring Tillage	109.0 N.S.
Chisel	110.0 b	Conventional	103.0
No Plow	100.1 a	Field Cultivate	106.7
		Disk	107.2

Linear regression of yield and early growth had an r value of 0.003 indicating little relationship between early growth and final yield.

Corn Early Growth - ANOVA

	dF	MS	F
Rep	3	238.6944	8.20 **
Tillage	8	354.5486	12.20 **
Error	24	29.04861	
Total	35		

C.V. = 16.48 percent

Primary tillage		Secondary tillage	
Plow	41.9 b	No Spring tillage	27.4 a
Chisel	27.4 a	Conventional	37.5 b
No plow	29.5 a	Field Cultivate	32.9 ab
		Disk	35.6 ab

Population - ANOVA

	dF	MS	F
Reps	3	27.03065	10.88 **
Tillage	8	1.930069	0.78 N.S.
Error	24	2.484606	
Total	35		

CV = 7.28 percent

RELATIVE EARLY CORN GROWTH

Waseca Tillage Trials

Primary Tillage	Secondary Tillage	Time of Primary Tillage	Percent of Highest Treatment 1970	1971
Plow	Conv.	Fall	100	--
		Spring	94	100
	Zero	Fall	74	--
		Spring	--	98
	Field Cultivate	Fall	83	--
		Spring	--	89
Chisel	Conv.	Fall	74	--
		Spring	77	71
	Zero	Fall	57	--
		Spring	--	48
	Field Cultivate	Fall	74	--
		Spring	--	61
	Disk	Spring	71	71
No tillage	Disk	--	71	91
	Zero	--	54	43

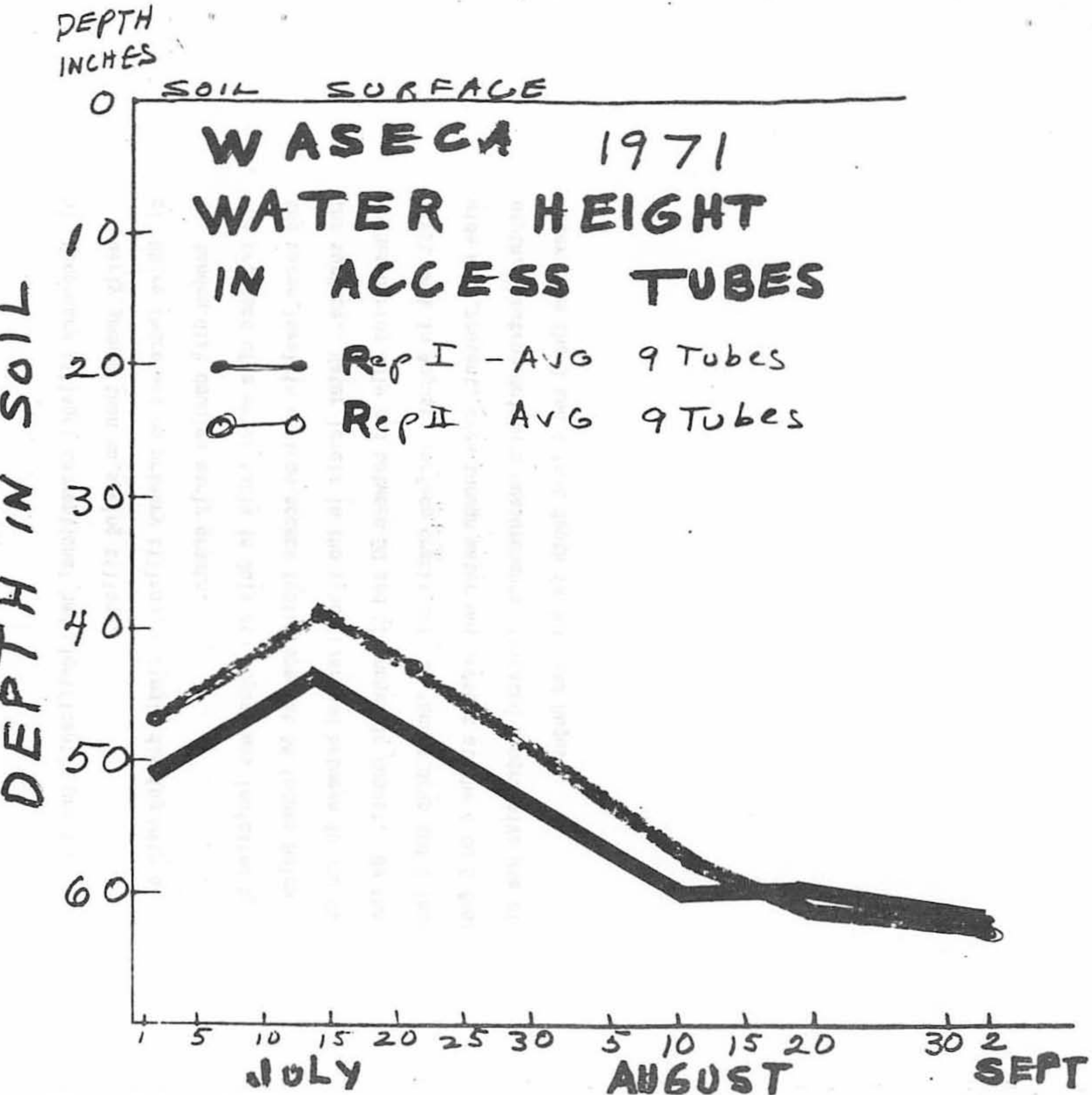
Conclusions:

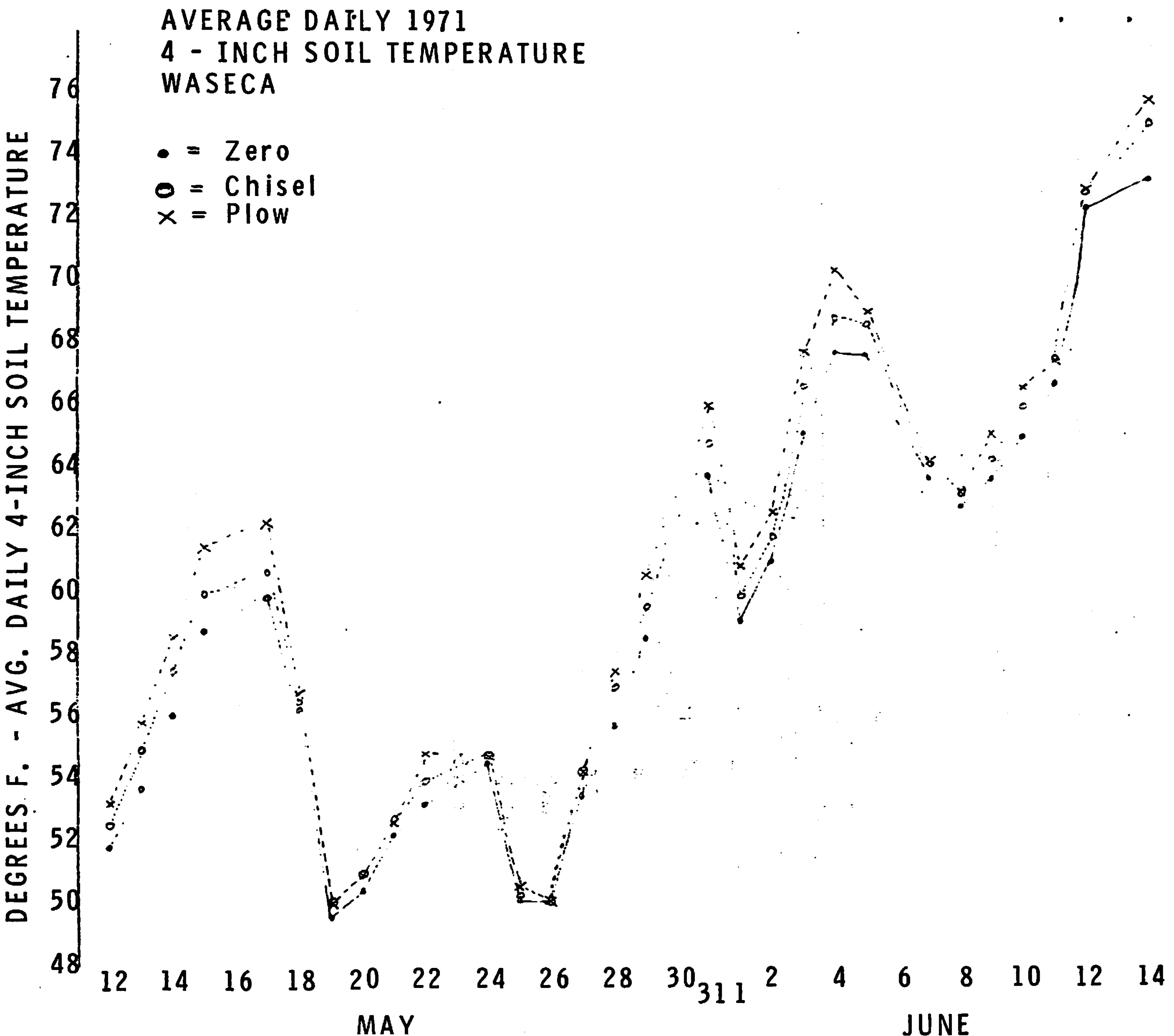
1. Corn yield factorial effects:
   a) In the primary tillage treatment group, chisel yielded significantly greater than No-Plow. The comparison of plow and no-plow approached significance.
   b) In the secondary tillage treatments, there were no significant yield differences.
2. The F test of all treatments showed that significant yield differences were present (at the 5% level). Both the plow and chisel treatments with no secondary tillage (114.8 and 116.2 Bu/A, respectively) were significantly different compared to the no-till treatment with no secondary tillage (96.2 Bu/A). There were no other significant differences.
3. Corn yields were much lower in 1971, averaging only 107 Bu/A compared to 160 Bu/A in 1970. The decrease in yield was due to a severe drought in July and August; between July 9 and August 30 only 1.27 inches of rain fell.
4. There was no significant difference in yield due to use of the fluted coulter.
5. Large significant differences in early growth were measured. Growth differences generally agreed with the growth differences expected based on soil temperature measurements. Soil temperature decreased as mulch rate increased. However, differences in early growth were not correlated with yield.
6. Early growth factorial effects:
   a) Primary tillage: plowing had significantly greater early growth than either the chisel or no-plow treatments.

b) Secondary tillage: conventional had significantly greater early growth than no spring tillage.

c) Where there was no primary tillage, a single disking with a tandem disk doubled early growth.

7. The presence of a water table in July and August was indicated by the water level in neutron access tubing open at 66 inches below the surface. Water levels in the tubes averaged between 40 and 50 inches during July and between 50 and 60 inches in August. By the first week in August, surface cracks over 20 inches deep and 1 inch wide were present, even though water was present at the 4 to 5 foot depth. Neutron moisture measurements indicated progressive use of water from the 3 and 4 foot depth in July and August.


WASECA 1971
WATER HEIGHT
IN ACCESS TUBES
Rep I - AVG 9 Tubes
Rep II AVG 9 Tubes
DEPTH INCHES
SOIL SURFACE
DEPTH IN SOIL
0
10
20
30
40
50
60
1 5 10 15 20 25 30 5 10 15 20 30 2
JULY
AUGUST
SEPT


AVERAGE DAILY 1971
4 - INCH SOIL TEMPERATURE
WASECA
• = Zero
o = Chisel
× = Plow
DEGREES F. - AVG. DAILY 4-INCH SOIL TEMPERATURE
76
74
72
70
68
66
64
62
60
58
56
54
52
50
48
12
14
16
18
20
22
24
26
28
30
31
1
2
4
6
8
10
12
14
MAY
JUNE

LIME PLOTS, WASECA 1971

J. Grava, C. J. Overdahl, D. S. Fairchild,
B. D. McCaslin, R. H. Anderson

A field experiment was established in spring of 1971 at the Southern Experiment Station to study the effects of liming on yield and chemical composition of corn, and chemical properties of soil. The soil type is Le Sueur silty clay loam. The plot had been used for a corn management study, 1967-1970. Average soil tests of samples collected prior to the establishment of the experiment are given in Table 1.

Table 1. Soil test results.

Soil pH	SMP Buffer Index	P Lb/A	K Lb/A	Zn ppm	S ppm	Lime Requirement - Tons/A
5.7	6.1	85	400	1.9	14	5.5 -- 7.0

Dolomitic limestone, used in this experiment, had the following quality characteristics:

Passing 8-mesh sieve	97.3%
Passing 60-mesh sieve	51.7%
Calcium carbonate equivalent	96.1%

The lime rates used were as follows: 0, 2.5, 5.0, 7.5, 10.0 tons per acre. The treatments were replicated six times. Limestone was applied on April 20, 1971. Individual plots are 20 feet wide (8-30" rows) and 60 feet long. All plots received the following: (a) 154 + 128 + 136 lb/A of plant nutrients, expressed as N, P_2O_5, K_2O; (b) herbicide: 1 1/2 lb/A Atrazine, 2 lb/A Lasso; (c) insecticide: 3/4 lb/A Furadan. Pioneer 3582 Hybrid was planted on April 26; planting rate: 26,000. Corn was cultivated on May 29.

The yields of corn and chemical composition of sixth leaf at tasseling are given in Tables 2 and 3. Lime treatment had no effect on corn yields but liming did increase the molybdenum content of leaf tissue.

Table 2. Yield of corn, Waseca lime plots, 1971.

Rate of Lime	Yield
Tons/Acre	Bu/Acre
0	140
2.5	129
5.0	131
7.5	138
10.0	137
Significance	NS*
CV%	12

*N.S. -- Treatment means not significantly different at the 5.0% level.

Table 3. Chemical composition of sixth corn leaf at tasseling, Waseca lime plots, 1971.

Rate of Lime	N	P	K	Ca	Mg	Zn	Cu	Mo	Mn	B	Fe	Al
Tons/Acre	----- Percent in dry matter ------					--------- Parts per million in dry matter -------						
0	2.79	.30	2.00	.49	.17	36	6	7.0a[2]	93	8	131	41
2.5	2.84	.29	1.91	.48	.17	37	5	8.3b	86	7	138	45
5.0	2.90	.30	1.96	.51	.19	37	6	8.6b	86	8	139	44
7.5	2.90	.30	1.99	.51	.17	37	6	8.9b	91	8	137	40
10.0	2.69	.29	1.87	.48	.18	37	6	9.2b	81	7	137	43
Significance	NS[1]	NS	NS	NS	NS	NS	NS	**	NS	NS	NS	NS
CV%	8	5	6	7	9	17	25	10	17	8	9	17

[1]N.S. -- Treatment means not significantly different at the 5.0% level.

[2]Treatment means followed by different letters are significantly different at the 5.0% level.

NITROGEN EXPERIMENTS WITH CORN

W. E. Fenster and C. J. Overdahl

In the fall of 1969, nitrogen experiments were established to determine the rates of nitrogen that would result in the highest economic yields of corn on highly productive land. The soils on which the experiments were conducted are fine textured, high in organic matter, high in P and K, and have reasonably good drainage. Another dimension has been added to these experiments whereby the nitrate-nitrogen in the soil is being monitored to ascertain the downward movement with time as it relates to the rate of application of nitrogen.

Table 1. Corn yields as influenced by nitrogen treatments (3 locations 8 replications).

N (lbs/A) annually	Martin Co. Continuous corn 1970	Martin Co. Continuous corn 1971	Martin Co. Virgin soil 1971	Waseca Co. Continuous corn 1970	Waseca Co. Continuous corn 1971
			yield (bu/A)		
0	120 a	130 a	179 a	82 a	43 a
50	128 ab	142 b	190 bc	109 b	63 b
100	140 c	151 b	187 bc	143 c	93 c
150	132 bc	144 b	183 b	153 cd	131 d
200	131 abc	147 b	194 c	163 d	144 e
400	135 bc	153 b	190 bc	169 d	151 f

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

All plots received a basic treatment of 0+150+200+20 Zn annually.

The soils were classified as Webster silty clay loams.

Table 2. Percentage nitrogen in tissue* (July) as related to fertilizer nitrogen application.

N (lbs/A)	Martin Co. Continuous corn 1971 %	Martin Co. Virgin soil 1971 %	Waseca Co. Continuous corn 1970 %	Waseca Co. Continuous corn 1971 %
0	2.5	2.8	1.9	1.5
50	2.7	2.7	2.2	1.7
100	2.6	2.8	2.5	2.2
150	2.9	2.8	2.7	2.6
200	2.9	2.8	2.8	2.9
400	2.9	2.9	3.0	3.0

* sixth leaf at tasseling

In order to determine the amount of nitrate-nitrogen in the soil profile, soil cores were taken to a depth of 6 feet in Martin County and 5 feet in Waseca County. It is our intent to monitor these nitrates and their movement in the soil for at least 5 years. Preliminary data on the soil nitrate regimes are given in the following tables:

Table 3. Amount of nitrate-nitrogen in the soil profile* on continuous corn in Martin County (average of 4 replicates). Parts per million (ppm) Nitrate-Nitrogen (NO_3-N)

Soil Depth (ft.)	Treatment - lbs N/A applied annually: 0		50		100		150		200		400	
	1970	1971	1970	1971	1970	1971	1970	1971	1970	1971	1970	1971
0-1	8	9	7	9	6	9	8	12	9	23	12	60
1-2	6	5	5	5	6	8	6	17	6	23	9	45
2-3	6	5	9	13	7	13	13	43	7	26	19	30
3-4	12	6	17	15	9	15	44	30	22	20	28	20
4-5	12	7	21	14	11	14	29	28	24	17	18	18
5-6	7	10	20	13	13	14	24	23	17	17	14	18

* soils sampled after corn harvested

Table 4. Amount of nitrate-nitrogen in the soil profile on virgin soil planted to corn in Martin County (average of 4 replicates).

Soil Depth (ft.)	Virgin soil fall 1970	ppm NO_3-N Treatment - lbs N/A applied - 1971					
		0	50	100	150	200	400
0-1	6	17	19	24	15	31	40
1-2	4	10	23	32	29	47	32
2-3	5	7	9	8	14	14	11
3-4	3	3	5	4	5	4	5
4-5	3	3	3	4	5	6	3
5-6	3	4	3	4	4	6	4

Table 5. Amount of nitrate-nitrogen in the soil profile on continuous corn in Waseca County (average of 4 replicates).

Soil Depth (ft.)	ppm NO_3-N Treatment - lbs N/A applied - 1971					
	0	50	100	150	200	400
0-1	4	4	6	6	5	17
1-2	2	2	3	4	3	12
2-3	3	3	3	3	3	27
3-4	2	2	2	3	3	17
4-5	3	2	3	4	4	10

OBSERVATIONS AND SUMMARY

1. In Martin County on continuous corn in 1970 and 1971, significant yield increases were not realized where rates of nitrogen greater than 100 pounds of N/acre were applied.
2. In Martin County on the virgin soil in 1971, the 50 pound N rate was adequate to produce a significant increase in corn yields. Higher rates of N produced no additional increases in corn yields.
3. In Waseca County, the highest significant increases in corn yields were obtained in 1970 with 150 pounds of N/acre and in 1971 with

400 pounds of N/acre. The University still recommends between 150 and 200 pounds of N/acre, however, as the farmer realizes his highest economic yield at these rates.

4. The percentage N in the sixth leaf at tasseling stage correlated very well with amounts of N/acre applied and the corn yields. In general, when 2.7 percent or greater was noted in the plant tissue, yield increases were not realized from additional N applications.

5. The soil nitrates at the three plot sites varied markedly. In general, however, the highest nitrate levels were found in the top 2 or 3 feet of soil at all locations. The highest levels of NO_3-N were observed in Martin county on the continuous corn plots receiving an annual application of 400 pounds of N/acre.

6. At the Martin county location, nitrogen applications in excess of 100 pounds of N/acre on continuous corn appears to result in NO_3-N levels in the soil which may be of concern from an environmental quality standpoint. More years of data are needed to verify these results. Further study is also needed to see if the NO_3-N moves downward in th soil profile with time and further applications of nitrogen.

7. On the virgin soil in Martin county, the applied nitrogen is reflected in the top 2 feet of soil after one year. The levels of accumulation would appear to be in relation to the rates of nitrogen applied. Unlike the continuous corn in Martin county, where the NO_3-N levels are confounded with many years of fertilizer nitrogen and manure applications, the virgin soil profile indicates no additional accumulation of NO_3N from the fertilizer applications in the 3 to 6 foot depth after one year.

8. The NO_3N levels at the Waseca location are relatively low at all nitrogen fertilizer rates except that receiving the 400 pounds of N. It is interesting to note that the soils at Waseca and Martin counties are classified as Websters, since they have quite different nitrogen regimes. This difference may be due in a large measure to differences in rainfall and perhaps other climatic conditions. Of equal importance, perhaps, is the fact that the Waseca location has not received any barnyard manure for at least 20 years, whereas, the Martin county continuous corn site has received several manure applications in recent years.

9. Based on these preliminary data, it would appear that serious consideration should be given to adjusting nitrogen fertilizer recommendations for corn, based on the NO_3-N level on soil samples taken from perhaps 0 to 3 feet in depth.

PHOSPHORUS AND POTASSIUM NEEDS FOR HIGH CORN YIELDS

C. J. Overdahl and W. E. Fenster

To study rates of P and K broadcast or in the row sounds like repetition of corn fertility research done during the past 50 years. Advances in research with corn hybrids, weed control and insect control, however, causes fertilizer research to become out of date rapidly.

In the fall of 1969, we established trials in Martin and Waseca counties to determine broadcast needs of P and K when corn yields are in the range of 150 to 200 bushels per acre. Earlier work of this nature was carried out where yields were in the range of 80 to 100 bushels. The question is whether increased rates of fertilizer should be in proportion to the higher yield goals, or perhaps much higher, and how high should a soil test be before no more broadcast fertilizer is needed.

Broadcast phosphorus applications were made annually at 0, 50, 100, 150 and 200 pounds per acre of P_2O_5 with a blanket treatment of about 200+0+300+20 Zn each year. The annual broadcast potassium applications were made at 0, 50, 100, 200 and 400 pounds per acre of K_2O with a blanket treatment of 200+150+0+20 Zn.

Farmer cooperators were selected on the basis of ability to produce 200 bushels per acre on occasion where great attention is paid to details of tillage and controlling insects and weeds, plus early planting with good hybrids.

The soils were fine textured, high in organic matter, high in P and K, and had reasonably good drainage. Tables 1 through 4 show yields, along with related soil and tissue tests. They also show details about pH, zinc levels in soil and leaves, as well as nitrogen in leaves.

In 1970, there were no significant increases from either broadcast P or K, but significant responses were obtained from starter fertilizer. In 1971 in Martin county, there was a significant response to broadcast phosphate when the soil phosphorus test was 37 pounds of P in the check plot. Phosphorus in the leaf opposite and below the ear sampled July 21 during silking was increased from .28 to .30 percent by the application of 100 pounds of P_2O_5. Results in 1972 and perhaps 1973 will be necessary before one could safely say that 37 pounds of soil P and .28 percent P in the leaves was not high enough. To complicate our thinking, Waseca county results show that raising leaf P from .28 to .30 percent and soil P from 27 to 45 pounds per acre gave no yield increase in 1971. Rainful was more limiting in August at this site and yields were about 15 bushels per acre less than in Martin county. We need yields close to 200 bushels per acre before we can learn about yield differences when soil tests are this high.

Some surprises were encountered. Originally, the zinc levels were moderately low on the Martin county trial, so 20 pounds of actual zinc as zinc sulfate were incorporated for the 1970 crop and again for 1971. Table 1 shows that zinc in the leaves is below 20 ppm, but that zinc soil tests are very high. Zinc research by Dr. MacGregor of the Soil Science Department at the University, shows that zinc applications increase leaf zinc, but often maximum corn yields were reached when leaf content was still below 20 ppm. We are quite sure that 20 pounds of zinc per acre two consecutive years prevented zinc from being a limiting factor in these trials.

Another surprise was the small increase of P and K in plant tissue from broadcast or row applications. Other observations showed that nitrogen applications of 200 pounds produced an average of 2.8 percent N in the leaves, while in an adjacent nitrogen study, 400 pounds of N increased this slightly. It appears difficult to raise the nutrients to very high levels in the plant tissue.

Table 1. 1970 and 1971 corn yields, plant analyses and soil tests in Martin county according to broadcast phosphorus treatment.
(200+0+300+20 Zn applied over all phosphorus plots)

P_2O_5 lbs/acre	Yields bu/acre 1970	1971	% P leaves 1970	1971	Soil Test P lbs/acre 1970	1971
0	155	137 a	.26	.28	46	37
50	151	137 a	.26	.27	36	39
100	162	156 b	.27	.30	56	55
150	146	146 ab	.28	.30	65	63
200	145	154 ab	.28	.30	64	55

	1970	1971
Avg. starter response	4*	2
Avg. % N in leaves	-	2.7
Avg. K soil test	268	352
Avg. % K in leaves	1.70	1.88
Avg. soil pH	7.7	7.2
Avg. Zn leaves ppm	19 low	17 low
Avg. Zn soil ppm	-	5.3 high

Table 2. 1970 and 1971 corn yields, plant analyses and soil tests in Waseca county according to broadcast phosphorus treatment.
(200+0+200 applied over all phosphorus plots)

P_2O_5 lbs/acre	Yields bu/acre 1970	1971	% P leaves 1970	1971	Soil Test P lbs/acre 1970	1971
0	133	139	.31	.28	34	27
50	136	133	.30	.27	31	33
100	132	132	.28	.27	31	40
150	136	135	.29	.30	40	44
200	138	130	.29	.30	53	45

	1970	1971
Avg. starter response	13*	4
Avg. % N in leaves	-	2.8
Avg. K soil test	1.68	1.82
Avg. soil pH	6.4	6.1
Avg. Zn leaves ppm	26	16
Avg. Zn soil ppm	-	2.6 high

Table 3. 1970 and 1971 corn yields, plant analyses and soil tests in Martin county according to broadcast potassium treatment. (200+150+0+20 Zn applied over all potassium plots)

K_2O	Yields bu/acre		% K leaves		Soil Test K lbs/acre	
lbs/acre	1970	1971	1970	1971	1970	1971
0	156	148	1.7	1.8	202	230
50	147	154	1.7	1.8	212	258
100	152	149	1.6	2.1	222	278
200	147	143	1.8	2.1	270	328
400	160	149	1.8	1.9	243	320

	1970	1971
Avg. starter response	16*	3
Avg. % N in leaves	-	2.8
Avg. P soil test	50	62
Avg. % P in leaves	.25	.29
Avg. soil pH	6.4	6.1
Avg. Zn leaves ppm	22	22
Avg. Zn soil ppm	-	8.4 high

Table 4. 1970 and 1971 corn yields, plant analyses and soil tests in Waseca county according to broadcast potassium treatment. (200+150+0 applied over all potassium plots)

K_2O	Yields bu/acre		% K leaves		Soil Test K lbs/acre	
lbs/acre	1970	1971	1970	1971	1970	1971
0	134	123	1.6	1.4	260	210
50	129	120	1.7	1.7	275	213
100	139	131	1.7	1.7	260	220
200	132	116	1.8	1.8	262	223
400	134	120	2.2	1.9	312	310

	1970	1971
Avg. starter response	10*	7*
Avg. % N in leaves	-	2.7
Avg. P soil test	53	52
Avg. % P in leaves	.27	.31
Avg. soil pH	6.4	6.0
Avg. Zn leaves ppm	26	14
Avg. Zn soil ppm	-	3.0 high

ANALYSES OF TILE AND OPEN DITCH DRAINAGE WATERS IN SEVERAL SOUTH CENTRAL MINNESOTA COUNTIES (1968-71)

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, crop species and also on stage of crop growth, or fallow it was not possible to sample each location on a uniform interval schedule. The present report is a brief summary of results obtained during 1971. Some data obtained in the preceding 3 growing seasons has been previously reported in Soil Series 87.

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.

Accurate estimation of areas drained by tile lines is extremely difficult and per acre N and P losses are at best only an estimation. Drainage engineers have advised the assumption of 100' on each side of the tile rather than assuming the entire drainage basin area. Differences in calculated loss per acre are shown for NO_3-N and PO_4-P in drainage waters from 12 farm fields during six summer months in 1971 by the following table.

It is apparent that some tile drains are removing appreciable amounts of nitrate nitrogen (NO_3-N), even disregarding the method of estimation of drainage area nitrate N losses in drainage water is not consistent with amounts of fertilizer N applied in 1970 and 1971. Phosphorus loss is extremely small.

Estimated NO_3-N and PO_4-P Loss in Tile Waters From Twelve South Central Minnesota Farm Fields in 1971 (4/2 to 11/2).

(Textures vary from loam to silty clay loam)

	1970+1971 fertilizer (lbs/A)				Drainage basin	NO_3-N Loss in lbs/A assuming:		PO_4-P Loss in lbs/A assuming:	
County	N	P	1971 Crop	Ft. Tile	(acres)	200'	basin	200'	basin
Meeker	None	None	Corn	1800	15	23.6	12.6	0.02	0.01
Meeker	152	None	Corn	1500	40	0.6	0.1	0.40	0.07
McLeod	118	3	Soybeans	1500	15	3.4	1.6	0.02	0.01
McLeod	354	51	Corn	4000	80	33.0	7.5	0.04	0.01
Sibley	307	44	Corn	14000	130	27.4	13.5	0.02	0.01
Sibley	None	None	Fallow	1430	8	23.0	18.6	0.03	0.02
Sibley	20	42	Corn	2400	38	2.4	0.7	Tr.	Tr.
Sibley	175	26	Corn	2000	35	1.6	0.4	Tr.	Tr.
Renville	375	33	Corn	9000	45	28.0	25.4	0.02	0.02
Kandiyohi	140	26	Oats-alf.	600	10	8.6	2.4	0.12	0.03
Kandiyohi	12	53	Alf.-grass	1250	15	2.5	1.4	0.06	0.03
Kandiyohi	350	44	Corn	1200	8	32.6	32.6	0.01	0.01

METHOD OF PLANTING STUDY FOR CORN

Lancaster, Wisconsin Experimental Farm - 1971

William Paulson, James Swan, Arthur Peterson

Lancaster 1971

Alfalfa Sod No-Till Planting vs. Wheeltrack Planting (WTP).

Yield Summary (Bu/A)

Treatment	Rep I	Rep II	Rep III	Avg.
WTP	123.9	112.8	120.4	119.0
Sod No-Till	144.1	109.9	153.7	135.9

ANOVA

	DF	Sum of Squares	Mean Square	F	F 5%	10%
Reps	2	788.5433	394.2717	2.35	NS	(0.0[illegible]F) NS
Treatments	1	426.7267	426.7267	2.54	(18.51) NS	(8.53=F) NS
Error	2	335.9433	167.9717			

CV = 10.17%

No-tillage (on bare soil) vs. No-Till (mulched) vs. WTP.

Yield Summary (Bu/A)

Treatment	Rep I	Rep II	Rep III	Rep IV	Avg.
No-Till (bare)	78.7	96.4	87.7	78.8	85.4
No-Till (mulched)	131.2	106.5	116.9	104.7	114.8
WTP	99.3	99.6	95.7	121.8	104.1

ANOVA

	DF	Sum of Squares	Mean Squares	F	5%F	10%F
Reps	3	14.74917	4.916389	.03	NS	NS
Treatment	2	1774.062	887.0308	4.97	(5.14) NS	(3.46=F) Significant at 10% level
Error	6	1071.398	178.5664			

CV = 13.17%

Treatments are significantly different at 10% level, but not at 5% level.

Higher yields on mulch would appear to warrant further investigation of possible yield benefits from mulches.

No-Till (stalk residue) vs. WTP.

Treatment	Yield Summary (Bu/A) Rep I	Rep II	Rep III	Rep IV	Avg.
No-Till (stalk)	115.6	99.0	76.4	107.9	99.7
WTP	114.2	114.4	98.2	93.8	105.2

ANOVA

	DF	Sum of Squares	Mean Squares	F	5%F
Reps	3	810.2938	270.0979	2.04	NS
Treatment	1	58.86125	58.86125	0.44	NS
Error	3	397.7237	132.5746		

CV = 11.24%

FERTILIZER RATE STUDY WITH "NEW" VARIETIES OF TIMOTHY AND KENTUCKY BLUEGRASS -- 1971

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

Four experiments were established on mineral soils in fall of 1970 to study effects of NPK rates on seed production of timothy and bluegrass varieties that are being introduced in northwestern Minnesota.

Past experimental work in Minnesota has been mainly with Park Kentucky bluegrass and Climax timothy. Attention has been focused on optimum rates of fertilizer, time of fertilization, and the needs for secondary and trace elements.

Grass seed production in Minnesota is expanding and undergoing some changes. A number of growers are producing timothy seed under contract for foreign markets, and seed of several new bluegrass varieties is produced by some growers. Continued research is required to keep abreast of these new developments.

General information on the experimental sites is given in Table 1. Soil test results are shown in Table 2.

Table 1. Location, soil type and other information concerning the experiments.

Field No.	Location	Soil Type	Species, Variety	Age of Stand	Burned
1.	Roy Kveen Roseau County	Bearden sil	Timothy Lorain	1969 Seeding	Spring 1971
2.	Ernest Brandli Roseau County	Glyndon fsl	Timothy Erecta	1968 Seeding	----
3.	Richard Jackson Roseau County	Glyndon sil	Timothy Evergreen	1969 Seeding	Spring 1971
4.	Lenard Johnson Roseau County	Unnamed sl	K.Bluegrass Primo	1969 Seeding	Post-Harvest Burn

Table 2. Soil Test Results*

Depth of Sampling, Inches	pH	Extractable P pp2m	Exchangeable K pp2m
		Field No. 1	
0- 6	8.0	26	280
6-12	8.2	6	210
		Field No. 2	
0- 6	7.2	9	40
6-12	7.4	4	40
		Field No. 3	
0- 6	8.1	15	80
6-12	8.3	3	60
		Field No. 4	
0- 6	8.0	10	100
6-12	8.2	2	80

* Samples collected in June 1971.

A randomized block design was used with nine treatments replicated four times. Individual plots were 9 feet wide and 20 feet long. The fertilizer treatments were as follows:

TREATMENT	N + P_2O_5 + K_2O LBS/ACRE
A	Check
B	0 + 40 + 40
C	20 + 10 + 10
D	40 + 20 + 20
E	60 + 30 + 30
F	80 + 40 + 40
G	100 + 50 + 50
H	120 + 60 + 60
I	80 + 40 + 40 plus Cu, Mn, Zn.

The nutrients for treatment B were supplied with 0-25-25 grade of fertilizer, while treatments C to I received various rates of 20-10-10 fertilizer. Fertilizer materials were top-cressed with a Gandy spreader on October 14, 1970. Trace elements Cu, Mn and Zn for treatment I were applied in the sulfate form at the rate of 50 lbs/acre of Cu-, Mn-, Zn-Sulfate. These materials were applied by hand on May 4, 1971.

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. Two square-yard samples were harvested from each plot to measure seed yields.

Seed yields and the chemical composition of tissue are reported in Tables 3, 4, 5, 6 and 7.

Lorain timothy seed yields on a Bearden silt loam were nearly tripled by fertilization. The highest seed yield of 505 lbs/acre was produced with the 100+50+50 fertilizer treatment, compared to 157 lbs/acre from the check plots. There was some lodging in the 100+50+50 and 120+60+60 plots. The addition of trace elements, Cu, Mn, Zn, to the 80+40+40 treatment increased the seed yield by nearly 100 pounds per acre.

The concentration of several chemical elements in the tissue of this variety was affected by fertilization. Nitrogen content was increased from 1.66% in tissue from the check to 3.18% from 120+60+60 treatment. Tissue from the 100+50+50 treatment, that produced the highest yield, had 2.95% of N, 0.27% P and 1.64% of K.

Erecta timothy on Glyndon fine sandy loam showed only a slight yield response to fertilization. The seed yield was increased from 87 lbs/acre without fertilizer to nearly 200 lbs/acre with the 0+40+40 treatment. Some lodging resulted from 80+40+40 and higher fertilizer treatments. Trace element application increased the concentration of Cu, Mn, Zn in tissue but had no effect on seed yield. Fertilization also increased the contents of N and P in timothy but had no effect on K concentration.

The lack of response to fertilization and relatively low seed yields obtained on this field of Erecta may not be typical to this variety. Apparently the plots were harvested too early. The seed yields of grass receiving the higher rates of fertilizer (nitrogen) would be affected most seriously by this.

This field of Evergreen timothy was extremely variable in plant type. It appeared that this variety is extremely susceptible to lodging under higher soil fertility levels. These two factors made it difficult to obtain representative yield measurements on this field.

The highest seed yield of 639 lbs/acre was produced with the 80+40+40 treatment compared to 486 lbs/acre on check plots. Lodging was observed on all plots receiving 40+20+20 or higher fertilizer treatments.

Primo Kentucky bluegrass on a sandy loam soil showed highly significant seed yield increases to fertilization. The seed yields were increased from 129 lbs/acre without fertilizer to a maximum yield of 602 lbs/acre with the 100+50+50 treatment. Some lodging occurred on the plots receiving the 100+50+50 and 120+60+60 treatments.

Fertilization with NPK increased the P concentration in grass tissue but had no effect on the N and K contents. Application of Cu, Mn and Zn increased the concentration of these trace elements in tissue but had no effect on seed yield.

Table 3. Effect of fertilization on the seed yield of timothy and K. Bluegrass, 1971.

Treatment* N P_2O_5 K_2O	Field 1 Lorain Timothy	Field 2 Erecta Timothy	Field 3 Evergreen Timothy	Field 4 Primo K.Bluegrass
Lbs/Acre	Yield of Seed, Lbs/Acre			
Check	157a*	87a	486ab	129a
0 + 40 + 40	136a	194b	552ab	207ab
20 + 10 + 10	298b	178b	515ab	340bc
40 + 20 + 20	320bc	247b	567abc	399cd
60 + 30 + 30	426dc	251b	440a	524de
80 + 40 + 40	438dc	242b	689c	524de
100 + 50 + 50	505dc	264b	612bc	602e
120 + 60 + 60	408cd	264b	619bc	542de
80 + 40 + 40 + trace elements	527c	268b	563abc	487de
Significance	**	**	**	**
CV, %	19	27	15	23

* Any letter (letters) different from another letter in a column indicates a significant difference between the means at the 5% level.

Table 4. Effect of fertilization on chemical composition of Lorain timothy tissue, 1971. Roy Kveen, Roseau County.

Treatment	N	P	K	Ca	Mg	B	Cu	Mn	Mo	Zn	Al	Fe
	-----------Percent in Dry Matter-------					-------Parts Per Million in Dry Matter------------						
None	1.66a	.21	1.51a	.19a	.21a	9	3.3a	19a	5.7	14a	13b	40
0 + 40 + 40	1.66a	.20	1.49a	.21abc	.23b	9	3.3a	20a	7.0	14a	17c	46
20 + 10 + 10	1.95b	.22	1.62bc	.20ab	.23b	9	3.7ab	19a	6.3	15ab	12ab	43
40 + 20 + 20	2.21c	.23	1.59b	.22abc	.24c	10	3.6a	20a	6.8	15ab	11ab	46
60 + 30 + 30	2.47d	.25	1.64bc	.23bc	.25d	9	4.3bc	22ab	6.9	16bc	11ab	53
80 + 40 + 40	2.61e	.25	1.61bc	.24c	.26ef	9	4.4c	23abc	6.8	17cd	10ab	48
100 + 50 + 50	2.95f	.27	1.64bc	.24c	.28g	9	5.2d	24bcd	7.4	18cd	11ab	55
120 + 60 + 60	3.18g	.23	1.68c	.25c	.29h	8	5.8d	26cd	7.4	19de	11ab	55
80 + 40 + 40 + trace elem.	2.62e	.25	1.61bc	.23bc	.26ef	8	5.6d	27d	6.8	20e	10a	53
Significance	**	NS	**	*	**	NS	**	**	NS	**	**	NS
CV, %	5	5	3	11	9	11	10	12	11	8	18	16

Table 5. Effect of fertilization on chemical composition of Erecta timothy tissue, 1971. Ernest Brandli, Roseau County.

Treatment	N	P	K	Ca	Mg	B	Cu	Mn	Mo	Zn	Al	Fe
	---------Percent in Dry Matter---------					---------Parts Per Million in Dry Matter------------						
None	1.98a	.20a	1.62	.27a	.14a	12	3a	18a	7.1	15a	24b	55
0 + 40 + 40	2.18a	.20a	1.52	.35ab	.18bc	14	3a	24a	6.3	16a	15a	48
20 + 10 + 10	2.20a	.21a	1.49	.34ab	.16ab	13	3a	22a	5.8	15a	15a	48
40 + 20 + 20	2.48b	.23b	1.61	.35ab	.19cd	13	3a	23a	6.7	16a	13a	50
60 + 30 + 30	2.81c	.26c	1.72	.37ab	.19cd	12	3a	31b	6.3	19b	10a	49
80 + 40 + 40	2.90cd	.27c	1.60	.38b	.19cd	13	3a	31b	6.6	20b	10a	51
100 + 50 + 50	2.92cd	.27c	1.61	.39b	.20cd	14	3a	32b	6.2	20b	11a	52
120 + 60 + 60	3.08d	.28c	1.69	.38b	.21d	11	3a	32b	6.7	20b	10a	53
80 + 40 + 40 + trace elem.	2.74c	.25b	1.64	.38b	.19c	13	6b	49c	6.2	26c	11a	48
Significance	**	**	NS	**	**	NS	**	**	NS	**	**	NS
CV, %	6	6	6	8	8	11	16	15	9	6	33	11

Table 6. Effect of fertilization on chemical composition of Evergreen timothy, 1971. Richard Jackson, Roseau County.

Treatment	N	P	K	Ca	Mg	B	Cu	Mn	Mo	Zn	Al	Fe
	----------Percent in Dry Matter--------					----------Parts Per Million in Dry Matter----------						
None	2.31a	.22a	1.31	.32	.23a	9	3.7a	17ab	6.8	12ab	10	46a
0 + 40 + 40	2.33a	.23a	1.40	.39	.23a	9	4.1ab	16a	5.9	12a	11	47ab
20 + 10 + 10	2.66ab	.24a	1.30	.38	.27ab	9	3.9ab	19bc	7.0	13abc	10	50ab
40 + 20 + 20	2.75bc	.23a	1.23	.36	.28b	9	3.9ab	18abc	6.7	13abc	10	49ab
60 + 30 + 30	3.08cd	.26bc	1.24	.37	.29b	9	4.1ab	20c	7.1	14abc	9	59bc
80 + 40 + 40	3.29d	.27bc	1.29	.40	.29b	8	4.5bc	21cd	6.6	14abc	10	64cd
100 + 50 + 50	3.44d	.29c	1.27	.37	.28b	9	5.0c	23dc	7.3	14c	10	74de
120 + 60 + 60	3.38d	.27bc	1.24	.38	.30b	8	4.9c	22dc	7.5	13abc	9	79e
80 + 40 + 40 + trace elem.	3.14d	.26b	1.26	.40	.26ab	8	8.2d	24c	6.4	23d	11	56bc
Significance	**	**	NS	NS	*	NS	**	**	NS	**	NS	**
CV, %	8	7	6	12	10	11	9	18	11	6	12	13

Table 7. Effect of fertilization on chemical composition of Primo Kentucky Bluegrass tissue, 1971. Lenard Johnson, Roseau County.

Treatment	N	P	K.	Ca	Mg	B	Cu	Mn	Mo	Zn	Al	Fe
	----------Percent in Dry Matter--------					------Parts Per Million in Dry Matter--------------						
None	1.95	.14a	1.34	.29a	.16a	8c	5a	36b	6.1	25a	37	85
0 + 40 + 40	1.75	.22e	1.50	.35ab	.17a	6abc	3a	32ab	6.1	20a	56	102
20 + 10 + 10	1.96	.14ab	1.39	.40bcd	.18a	7bc	4a	32ab	6.6	22a	41	91
40 + 20 + 20	1.94	.17cd	1.42	.37abc	.19a	8c	3a	32ab	6.7	22a	27	68
60 + 30 + 30	2.07	.17cd	1.55	.49d	.22b	6abc	3a	32ab	7.3	23a	52	100
80 + 40 + 40	2.12	.16bc	1.45	.45cd	.22b	7bc	4a	34ab	7.2	24a	42	86
100 + 50 + 50	2.32	.19d	1.46	.46d	.23b	5a	3a	29a	6.3	25a	32	75
120 + 60 + 60	2.30	.19cd	1.56	.45cd	.24b	6abc	3a	30ab	7.2	25a	38	88
80 + 40 + 40 + trace elem.	1.99	.20de	1.63	.45cd	.22b	7bc	8b	41c	6.7	36b	28	80
Significance	NS	**	NS	**	**	**	*	**	NS	**	NS	NS
Cv, %	12	10	21	14	10	12	49	10	12	10	49	28

SULFUR FERTILIZATION OF KENTUCKY BLUEGRASS--1971[1)]

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

A sulfur experiment with Park Kentucky Bluegrass was initiated in spring of 1970. The plots were set up on a Spooner very fine sandy loam located in Lake of the Woods County on Helmstetter Bros. Farm. The soil contained 9 ppm of monocalcium phosphate (500 ppm P) extractable sulfur, indicating medium sulfur availability. The field had been renovated by plow-back in 1967 and had been burned in 1970 soon after harvest. 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. Sodium sulfate, Na_2SO_4, was applied in May of 1970. The NPK fertilizer was topdressed on October 13, 1970. The dimensions of individual plots were 10 by 20 feet.

Seed yields of bluegrass were not increased by applications of sulfur (Table 1).

1) See "A Report on Field Research in Soils," Soil Series 87, March 1971, pp. 114-115 for results obtained from this investigation in 1970.

Table 1. Effect of sulfur treatment on seed yield of Kentucky bluegrass, 1971.

Treatment	Yield of Seed
	lbs/acre
None	286
20 lbs/acre of S as $Na_2 SO_4$*	281
Significance	NS
CV, %	16

* Topdressed in May of 1970; all plots received 90 + 40 + 40 treatment, topdressed on October 13, 1970.

THE EFFECT OF NITROGEN FERTILIZATION ON SEED YIELD AND CHEMICAL COMPOSITION OF GRASSES WHEN APPLIED ALONE OR WITH PHOSPHORUS AND POTASSIUM—1971[1)]

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 the Woods County. General information on the experimental sites is given in Table 1.

A randomized block design was used with six treatments replicated seven times. Individual plots were 10 feet wide and 20 feet long. Ammonium nitrate (33.5-0-0) was used as the N source, and PK was supplied with 0-25-25 fertilizer. The fertilizer treatments were made with a Gandy spreader on October 12, 1970. Plant tissue samples were collected at the emergence of heads or panicles. Total nitrogen in tissue was determined by the Micro-Kjeldahl method, and the other elements were

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1) See "A Report on Field Research in Soils," Soil Series 87, March 1971, pp. 116-119 for results obtained from similar investigations conducted in 1970.

determined in a multi-element emission spectrophotometer. Two square-yard samples were cut from each plot at harvest time for the measurement of seed yields.

Seed yields and the N, P, K concentrations in tissue of grasses are reported in Tables 2 and 3.

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

Field No.	Location	Soil Type	Species, Variety	Age of Stand	Burned
5.	F. Baade L.O.W. County	Ulen VFSL	Timothy, Climax	5th Seed Year	April 1971
6.	Helmstetter Bros. L.O.W. County	Spooner VFSL	K.Bluegrass, Park	1967 Plow-back	Post-Harvest Burn

Table 2. 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
lbs/acre	lbs/acre	Percent in Dry Matter		
N				
60	256a	2.22a	.24	1.57b
90	317b	2.43a	.24	1.56b
120	277ab	2.87b	.25	1.41a
Significance	**	**	NS	**
PK				
None	284	2.53	.22a	1.40a
0 + 40 + 40	282	2.48	.27b	1.63b
Significance	NS	NS	**	**

The seed yield of timothy was increased significantly by increasing the N treatment from 60 to 90 lbs/acre. Increasing the N rate to 120 lb/acre did not result in higher seed yield. The N content of tissue from 120 lbs/acre treatment was significantly higher than N in tissues from the 60 or 90 lbs/acre nitrogen treatments.

While the 0 + 40 + 40 fertilizer treatment did not affect the seed yield, it increased the P and K concentration in tissue. This PK treatment, however, had no effect on the N content of tissue.

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 3. The effect of nitrogen fertilization when applied alone or with phosphorus and potassium on seed yield and chemical composition of Park Kentucky Bluegrass. Hemlstetter Bros., L.O.W. County.

Treatment	Yield of Seed	N	P	K
lbs/acre	lbs/acre	Percent in Dry Matter		
N				
60	193a	1.65a	.22a	1.25
90	245a	1.84b	.22a	1.24
120	363b	2.17c	.24b	1.27
Significance	**	**	**	NS
PK				
None	267	1.91	.21a	1.03a
0 + 40 + 40	267	1.86	.25b	1.48b
Significance	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 0 + 40 + 40 treatment increased the P and K contents of tissue but had no effect on seed yield.

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 -- 1971[1)]

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

An investigation was initiated in 1968 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. 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.

2. Some beef producers had expressed concern about the quality of forage, especially the trace element content of hay produced on organic soils.

3. 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.

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 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 treatment of all four

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1)See "A Report on Field Research in Soils," Soil Series 84, March 1969, pp. 172-176, Soil Series 86, March 1970, pp. 133-138, and Soil Series 87, March 1971, pp. 120-128 for results obtained from similar investigations conducted in 1968, 1969 and 1970.

trace elements. Copper alone increased the seed yield on this field 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 $17.00. Copper chelate treatments, if effective, would cost only about $6.00 per acre. For this reason the copper chelate as well as copper sulfate forms were used in the 1970 and 1971 trials.

In 1970, three field experiments with Kentucky bluegrass were conducted to study the effects of copper and zinc applications to peat on seed yield and chemical composition of tissue. All materials were topdressed on established stands of bluegrass on growers' fields. Fertilization with trace elements increased the concentrations of Cu and Zn in grass tissue but had no effect on the seed yield.

In 1971, the three field experiments with Kentucky bluegrass, established in 1970, were continued. The carry-over effects of Cu-sulfate and Zn-sulfate made in spring of 1970 were studied. The Cu-chelate treatments that had received 1 or 2 lbs/acre of Cu-chelate in spring of 1970, received additional 4 lbs/acre of chelate in spring of 1971. General information on the experimental sites is given in Table 1.

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

Field No.	Location	K. Bluegrass Variety	Age of Stand	Burned
7.	ED Baumgartner Roseau County	Park	1968 Seeding	Post-harvest burn
8.	C. Habstritt Roseau County	Park	1968 Seeding	Post-harvest burn
9.	Earl Swenson Clearwater County	Merion	1968 Seeding	----

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**	4.0 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

* Copper sulfate and zinc sulfate applied once on May 5, 1970 at all locations.

** Copper chelate applied on May 4, 1971. First application of Cu-chelate was made on May 5, 1970; Field No. 7 -- 1 lb/acre, Field No. 8 -- 1 lb/acre, Field No. 9 -- 2 lb/acre.

All plots received a uniform application of the following plant nutrients, expressed as N, P_2O_5, K_2O in lbs/acre: Field No. 7, 15 + 60 + 60; Field No. 8, 10 + 60 + 40; Field No. 9, 12 + 48 + 48. All fields were fertilized on October 14-15, 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 trace elements were determined in a multi-element emission spectrophotometer. Two square-yard samples were cut from each plot at harvest time for the measurement of seed yields.

Seed yields of bluegrass grown on peat were not affected by copper or zinc treatments (Table 2).

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

The Cu content of grass tissue was increased at all three locations from 3 to 4, 5, 6 or 8 ppm by applications of the sulfate and chelate forms of copper. The Zn concentration in bluegrass tissue also was increased significantly at all locations. Thus, a carry-over effect was indicated by plant analysis from Cu- and zinc-sulfate treatments applied at 50 lbs/acre rates in spring of 1970. The rate of 4 lbs/acre of Cu-chelate was sufficient to increase copper concentration of tissue above the critical level.

Table 2. Effect of trace element applications on the seed yield of Kentucky bluegrass on peat, 1971.

Treatments of Trace Elements	Field 7 Park (E.B.)	Field 8 Park (C.H.)	Field 9 Merion (E.S.)
	Yield of Seed, lbs/acre		
1. None	288	196	105
2. Copper sulfate	242	190	83
3. Copper chelate	283	215	78
4. Zinc sulfate	288	203	80
5. Cu-sulfate + Zn-sulfate	223	182	80
6. Cu-chelate + Zn-sulfate	274	228	83
Significance	NS	NS	NS
CV, %	28	18	21

Table 3. Effect of trace element application on the chemical composition of Kentucky bluegrass tissue grown on peat, 1971. Field 7, Park, Ed Baumgartner.

Treatment	B	Cu	Mn	Zn
	Parts Per Million in Dry Matter			
1. None	8	3a	28	22a
2. Cu-sulfate	8	5b	27	24a
3. Cu-chelate	8	8c	27	22a
4. Zn-sulfate	8	3a	26	32b
5. Cu-sulfate + Zn-sulfate	8	5b	26	34b
6. Cu-chelate + Zn-sulfate	8	8c	26	32b
Significance	NS	**	NS	**
CV, %	10	26	7	8

Table 4. Effect of trace element application on the chemical composition of Kentucky bluegrass tissue grown on peat, 1971. Field 8, Park, C. Habstritt.

Treatment	B	Cu	Mn	Zn
	Parts Per Million in Dry Matter			
1. None	9	2.5a	49	23a
2. Cu-sulfate	9	4.3c	50	23a
3. Cu-chelate	9	7.7d	46	24a
4. Zn-sulfate	10	2.7b	50	31b
5. Cu-sulfate + Zn-sulfate	10	4.3b	46	32b
6. Cu-chelate + Zn-sulfate	9	8.2e	46	33b
Significance	NS	**	NS	**
CV, %	8	25	10	8

Table 5. Effect of trace element application on the chemical composition of Kentucky bluegrass tissue grown on peat, 1971. Field 9, Merion, Earl Swenson.

Treatment	B	Cu	Mn	Zn
	Parts Per Million in Dry Matter			
1. None	10	3a	63	28a
2. Cu-sulfate	10	6e	63	29a
3. Cu-chelate	9	6b	64	29a
4. Zn-sulfate	10	4a	66	41c
5. Cu-sulfate + Zn-sulfate	10	7b	61	42c
6. Cu-chelate + Zn-sulfate	11	6b	58	37b
Significance	NS	**	NS	**
CV, %	9	20	11	10

CLASSIFICATION OF NATURAL COMMUNITIES

David Grigal

It is often difficult both to duplicate and to extrapolate the results of field research. Much of this difficulty arises because of lack of control of environmental parameters in the field as opposed to the control that is attainable in the laboratory. Even if such parameters cannot be controlled, however, it is difficult even to decide which are important enough to be measured. If natural vegetation can be considered an integrator of environmental variables over time, then a quantitative vegetation classification system should logically lead to a kind of reference system which can be used as a basis in interpreting, extrapolating, and duplicating results of field research.

Members of the staff of the North Central Forest Experiment Station of the U.S. Forest Service and of the Department of Soil Science are attempting to implement multivariate techniques in the description and ultimate classification of forest ecosystems. We are attempting to define vegetation groups from northeastern Minnesota. We are basing the definitions on forest stand data collected during the past few years in the Boundary Waters Canoe Area. Our goal is a well-defined system of vegetation groups. In addition, we hope to offer a procedure by which other researchers in northeastern Minnesota can assign the forest stands in which they are working to one of our groups. Thus, an animal ecologist, an entomologist, a soil scientist, or a botanist could all quantitatively place their stands on our scheme. We hope to have a number of optional criteria available that can be used for such placement. One primarily concerned with animal populations, for example, need only use limited floristic data (and sacrifice some precision in the placement of his stands) while another concerned with plant community dynamics can use more sophisticated floristic data, yielding more precise stand placement.

The computer programs for this work have been written and the analysis has begun. Next year we hope to report on the results of the analysis and present a quantitative vegetation classification scheme for northeastern Minnesota.

MASS, NUTRIENT AND ENERGY DYNAMICS OF SHRUB SPECIES IN NORTHEASTERN MINNESOTA

David F. Grigal

Shrubs as a life form in forest stands are important in their role as an integral part of the total vegetation, i.e., as they influence nutrient cycling, plant community dynamics, etc. They are also perhaps the most important life form linking populations of larger herbivores in forest ecosystems to the vegetative components of those systems. In northern forest communities, shrubs provide the major winter food for both small animals, such as hares, and larger herbivores, such as moose. Because of their importance, we are now conducting a study of the mass, energy, and nutrient dynamics of five species of shrubs from northern Minnesota. This study is being conducted in cooperation with members of the North Central Forest Experiment Station of the U.S. Forest Service.

The field work for this study was completed during 1971. Samples of each of five shrub species common to northeastern Minnesota were collected biweekly for a 26 week period from June through November. Nine individuals of each species were randomly collected from within a single forest stand at each sample time. The collected shrubs were separated into seven components and each component was dried and weighed. These components included leaves, current annual woody growth, last year's woody growth, fruits, flowers, buds, and stems.

We have begun to analyze the nutrient concentration of the components collected. This, combined with the mass data previously collected, will enable us to make estimates of the quantity of nutrients contained in the various shrub species. More importantly, perhaps, the dynamics of movement within the plants themselves can be ascertained. The final portion of the study is the determination of the caloric content of the sampled material. This will be determined for representative samples of the material. All the data collected concerning these shrub species, and other data concerning their utilization as wildlife food, will be used to assess their importance in the ecosystems of which they are components.

STUDIES OF SOME EFFECTS OF FOREST FIRES

David F. Grigal

A 15,000 acre forest fire in and adjacent to the Boundary Waters Canoe Area (BWCA) of northeastern Minnesota on May 14-17, 1971, provides an exceptional opportunity to examine the effect of fire on a natural forest ecosystem. The fire started in an area of cutover forest along the Little Indian Sioux River south of the Echo Trail, and spread north and east, burning partially in virgin forest that had last seen fire in 1864 or 1759. The fire started in slash left from timber-cutting operations of the past decade. As it spread into the virgin forest, the fire was carried through an understory of balsam fire and white spruce that had been largely killed by the spruce budworm. Here the fire locally rose to crowns of the 100-200-year-old pine trees, killing them and providing further momentum for rapid downwind spread of the fire. Progress eventually slowed as the wind died down and the weather conditions changed. Up to 5 cm of moss and duff were burned, and all the ground cover and shrubs and most of the trees were killed. The organic layer was sufficiently moist at greater depth, however, to resist complete removal--a characteristic of a spring fire.

The ecological effects of fire on virgin forests are little known, because most studies of fire ecology have been concerned either with slash burning or with repeated litter burning. In these cases, other disturbance factors may be important in controlling plant succession. Burning of an old virgin forest can be expected to break down a very large biomass, living and dead. It results in the loss of some nutrient elements, which escape as volatiles and particulates in the smoke, but most nutrients are converted to soluble carbonates and bicarbonates and retained in the ash and on the blackened vegetation. Rains can be expected to dissolve these compounds and make them available either for vigorous plant growth on the land surface or for transport by runoff to the lakes. With this fire-blackened area providing an excellent research opportunity, two relatively distinct studies are being carried out by the Department of Soil Science in cooperation with other organizations.

1. Study of Revegetation and Nutrient Immobilization Following the Burn.

In seven different virgin plant communities, a five year study has begun to assess the rate of growth and of nutrient immobilization by resprouting vegetation. A series of 10 randomly located plots were laid out within each of the plant communities selected for study. The plots were circular and each contained an area of 0.6052 square meters. All living plants within the plot were clipped at ground level and the collected material returned to the laboratory where the plants were separated into species. The number of individuals of each species was recorded. Each species was bagged, ovendried, and weighed. This collecting was done at midsummer, during the peak of vegetative growth. This collecting will be continued for four more years. The samples are now being analyzed for nutrient concentration. With these data we hope to be able to contrast different rates of growth and of nutrient immobilization.

Fast rates of revegetation can be expected to immobilize nutrients presumably released by fire, and prevent their potential loss from the system via runoff and deep seepage. As the mechanisms underlying plant succession begin to operate on the burn, we shall also be able to assess the role of plant species in succession as related to their mass and nutrient content. In addition, we can contrast nutrient concentrations of plants resprouting on the burn with individuals of the same species from off the burn. We will then be able to determine if luxury consumption is occurring on the burn due to greater availability of nutrients.

2. Study of Nutrient Cycling Following the Burn.

The removal of vegetation by fire drastically alters the pathways of transfer and the cycling of mineral nutrients in the forest ecosystem. The amount and rate of runoff flow and soil-water flow (which carry nutrient ions) are usually accelerated by removal of vegetation and litter, because of the lower transpirational losses and because the canopy no longer delays the fall of rain to the ground. Such effects have been noted following removal of vegetation by forest cutting. Infiltration is also retarded, because of the hydrophobic effects of burned and extremely dry litter or soil. Soil erosion can be accelerated by rain impact and increased runoff. Increase in soil moisture, coupled with the high solubility of the ash relative to unburned organic matter, should yield a higher content of dissolved solids to the runoff and seepage water. Thus not only the hydrologic but also the nutrient budget of a lake can be greatly altered by fire in the drainage basin and the flora of the lake can be expected to respond to the nutrient additions.

The Department of Ecology and Behavioral Biology and the Department of Soil Science are cooperating in a study of the effects of the fire on mineral cycling on the watersheds of two small lakes within the burn, and as a control, on one lake outside the burn. The fire occurred in late May 1971, and we have been collecting samples from the area since that time. We plan to continue this sampling for at least an additional year.

Mineral capital of the ecosystems will be determined by sampling forest floor, soil, and standing vegetation. Mineral movement is being measured as follows:

At each watershed, twenty sampling points ("stations") have been established at 150 ft. intervals along compass transects approximately 100-150 ft. long paralleling the lakeshores. At each station the following sampling devices have been placed: a funnel and bottle to collect precipitation throughfall, a screen for litterfall, and a small plastic trough and bottle for collection of "runoff", i.e. transient water on the forest floor. A number of soil-solution tubes have also been placed at some of the stations, and more will be installed. Litter-bags have been set out in the fall of 1971 to study rates of litter decomposition; these have been placed at every station and are well replicated (60 bags per transect). Water samples (throughfall, runoff, and soil solution) are being collected bi-weekly from each station. Litterfall and samples of decomposing litter have been collected monthly. Litterfall will be divided into three components: leaf, wood, and other material (fruits, flowers, etc.). All these samples have been returned to our laboratories for subsequent chemical analysis.

Air temperature, humidity, and soil moisture levels will be monitored during the growing season. These data will be used to estimate differences between burned and unburned sites in evapotranspiration, and the consequent potential difference in runoff and/or seepage to the aquatic environment.

The study is important not only in assessing changes in cycling in terrestrial ecosystems, but directly relates to nutrient levels of the lakes in the monitored areas. Other studies are being conducted in the burn area, including studies of vegetation dynamics, by the U.S. Forest Service, and limnological studies of water and sediments, by members of the Limnological Research Center. The combined results of all these studies will contribute to both basic understanding of the effects of fire in these systems, and will also aid in developing management policy involving the use of fire in natural ecosystems.

ALFALFA AND ALFALFA-BROMEGRASS YIELDS ON BLOWERS SANDY LOAM

Sebeka, Wadena Co.

R.H. Rust and E. Gross

Table 1. Alfalfa yields.

Variety	2 yr. avg. (1971, 1969) tons/A	
Narragansett	3.6	
DuPuits	3.0	"Tap-root" varieties
Norseman	3.0	
Vernal	3.4	
Teton	3.9	
Nomad	3.5	"Spreading-root" varieties
Ladale	3.8	
Rhizoma	3.3	

Yields based on 2 cuttings perseason and adjusted to 15% moisture basis. No yields taken in 1970 due to labor shortage.

Blowers sandy loam is a soil having a fragipan zone at about 30 inches depth. It is suggested that the slightly better performance of the "spreading-root" varieties may be attributed to their adaptation to the shallower, somewhat restricted rooting zone.

Alfalfa plots were established in 1966. Annually top-dressed since fall 1968 with 200 lbs per acre 0-0-60 and 100 lbs per acre 0-45-0.

Table 2. Alfalfa-Bromegrass Hay Yields (Vernal alfalfa and Lincoln brome).

Treatment	3 yr. Avg. (60-71)	% Alfalfa	%P	%K	Soil Test P	Soil Test K
					--lbs/A--	
Initial only	2.4 T/a	35	.22	1.18	13	50
+ K	3.3	60	.24	1.85	10	80
+ K + P	3.8	75	.26	2.34	45	130

Plots established on Blowers sandy loam in 1966 with initial treatment of 4T/A lime, 500 lbs per acre 0-0-60, and 100 lbs per acre 0-45-0.

Beginning fall 1968 annual supplemental treatment has been 175 lbs per acre 0-0-60 and 100 lbs per acre 0-45-0, 300 lbs per acre $CaSO_4$.

"Percent alfalfa" is estimate of alfalfa remaining in stand. Percent K and percent P was determined on hay mixture as cut.

Soil tests made in summer, 1971.

Table 3. Soil temperatures at two depths under alfalfa-bromegrass, Blowers sandy loam, Sebeka, Wadena Co., south slope, .4 percent.

At 6 inches depth, F°

	Jan.15	Apr.15	May 15	June 15	July 15	Sept.15	Nov.15
1967	no record		54	64	68	61	35
1968	20	45	60	63	75	67	37
1969	35	49	54	62	75	67	39
1970	34	37	50	67	74	58	38
1971	28	36	61	80	79	61	41
Avg.	29	42	56	67	74	63	38

At 25 inches depth, F°

	Jan.15	Apr.15	May 15	June 15	July 15	Sept. 15	Nov.15
1967	no record		45	56	60	61	44
1968	30	44	53	63	68	65	39
1969	36	46	51	56	65	67	45
1970	38	36	50	62	66	65	43
1971	34	41	54	65	70	59	48
Avg.	34	42	51	60	66	63	44

5 yr. mean annual temperature
ct 25 inches - 48°F

Temperatures measured with thermistor probes in place.

SOIL RESIDUE STUDIES

R. S. Adams, Jr.

Triazine residue plots were established in 1970 on the old lime plots at the Rosemount Experiment Stations. In 1948 lime had been added to these plots at rates of 0, 3, 6, 12 and 24 tons per acre. In individual replications there is a range of soil pH from pH 5.5 (no lime treatments) to p^H 7.5 (high lime treatments). Significant results were obtained on only the high lime treatments. Consequently only data for no lime and high lime treatments are reported.

In May 1970 corn was planted in the plots and three triazine herbicides applied at equivalent rates. A normal field rate and three times normal field rate was applied. Herbicide treatments were as follows: atrazine 3 and 9 pounds per acre; prometryne 3.36 and 10.08 pounds per acre; and GS 14254 3.5 and 9.45 pounds per acre. There were four replications of each treatment.

Corn yields for the three times normal treatments in 1971 are given in Table 1.

Improved weed control accounted for the increased corn yield with atrazine. A triple rate of prometryne and GS 14254 resulted in severe corn injury in the high lime plots. Bear in mind that GS 14254 will not be recommended for corn and prometryne is not recommended for use in this way. Corn injury occurred only with the triple rate and on the high lime plots.

oat

Table 1. Corn Yields In Old Lime Plots With Three Triazine Treatments.

Lime	Hand Weed Free plots	Atrazine 9lbs/A	Prometryne 10.08 lbs/A	GS-14254 9.45 lbs/A
	bu/A			
None	94	72	84	92
High	78	84	53	25

In 1971 residue persistence was followed by planting the plots to oats, counting the stand after four to six weeks, cultivating out the oats and replanting. Four crops of oats were grown in this way.

Not enough prometryne was used to cause injury to oats at the residue levels persisting. Those data are not reported here. Residue injury from normal rates of triazine application were insignificant. However, injury occurred from residues in the plots receiving triple rates of atrazine and GS-14254 throughout the summer. Data are given in Table 2.

Table 2. Percent Of Check Of Oat Stand As Affected By Previous Lime Treatments And Residues Of Three Triazines.

Herbicide Treatment	Lime	Crop 1	Crop 2	Crop 3	Crop 4
Atrazine, normal rate	none	87	112	89	102
	high	90	117	100	105
Atrazine, triple rate	none	102	94	86	97
	high	57	42	84	102
GS 14254, normal rate	none	109	88	96	84
	high	71	77	102	102
GS 14254, triple rate	none	86	81	91	79
	high	43	18	38	50

Early in the summer precipitation during the period of seedling establishment played an obvious role in the extent of triazine injury. As the season progressed and triazine residues dissipated the influence of precipitation was less obvious. These data are shown in Table 3.

Table 3. Percent Of Check Of Oat Stand As Affected By Precipitation During The First 21 Days After Planting.

Rainfall	Atrazine Normal	Atrazine 3X	GS 14254 Normal	GS 14254 3X
Inches	Percent of Check			
No lime				
1.11 (3)	89	86	96	91
1.51 (1)	87	102	109	86
2.47 (4)	102	97	84	79
4.82 (2)	112	94	88	81
High line				
1.11 (3)	100	84	102	38
1.51 (1)	90	57	71	43
2.47 (4)	105	102	102	50
4.82 (2)	117	42	77	18

() Numbers in brackets denote succession of crop.

Precipitation was greatest in the first 21 days after the June 3 planting of oats. Injury from the triazines was much more severe than with the April 15 planting where only about 1/3 as much precipitation fell.

These data confirm that soil pH and spring precipitation both have a pronounced affect on the occurrence of residue injury from the triazines. As soil pH increases or as spring precipitation increases triazine residue injury can be expected to be more severe.

LIME PLOTS, DAKOTA COUNTY, 1971

J. Grava, C. J. Overdahl, D. S. Fairchild, B. D. McCaslin

A field experiment was established in spring of 1971 on the Earl Almquist farm in Dakota County to study the effects of liming on yield and chemical composition of corn and chemical properties of soil under irrigation. Average soil tests of samples collected prior to the establishment of the experiment are given in Table 1. The soil texture is loam to sandy loam.

Table 1. Soil Test Results.

Soil pH	SMP Buffer Index	P Lb/A	K Lb/A	Zn ppm	S ppm	Lime Requirement - Tons/A
5.6	6.3	48	310	2.2	12	5 -- 6

Dolomitic limestone,used in this experiment, had the following quality characteristics:

Passing 8-mesh sieve	95.3%
Passing 60-mesh sieve	44.6%
Calcium carbonate equivalent	92.6%

Limestone was applied on April 13, 1971. The rates used were as follows: 0, 2.5, 5 and 10 tons per acre. The treatments are replicated six times. Individual plots are 25'4" wide (8-38" rows) and 40' long. All plots received the following: (a) 143 + 114 + 180 Lb/A of total plant nutrients, expressed as N, P_2O_5, and K_2O; (b) herbicide: 10 Lb/A Ramrod, banded; (c) insecticide: 7 Lb/A Bux 10. A 110 day corn variety was planted on May 15 at 25,000 kernels per acre. Due to some germination problems, final population was only 22,000 or less plants per acre. Corn was irrigated about every 1 1/2 weeks after middle of July, applied 4 inches of water in four applications.

The yield of corn and chemical composition of sixth leaf at tasseling are given in Tables 2 and 3. Neither corn yields nor the chemical composition were affected by the lime treatments on this site in 1971.

Table 2. Yield of corn, Earl Almquist's farm, Dakota County, 1971.

Rate of Lime	Yield
Tons/Acre	Bu/Acre
0	125
2.5	131
5.0	142
10.0	126
Significance	NS[1]
CV%	12

[1]N.S. -- Treatment means not significantly different at the 5.0% level.

Table 3. Chemical composition of sixth corn leaf at tasseling, Dakota County lime plots, 1971.

Rate of Lime	N	P	K	Ca	Mg	Zn	Cu	Mo	Mn	B	Fe	Al
Tons/Acre	----- Percent in dry matter ------					----------- Parts per million in dry matter --------						
0	2.80	.27	2.08	.48	.38	15	6	13	99	3	187	82
2.5	2.84	.27	2.00	.51	.42	16	7	14	103	3	183	75
5.0	2.84	.27	1.95	.54	.43	15	6	13	94	3	195	87
10.0	2.82	.27	1.95	.51	.43	17	7	14	88	3	187	79
Significance	NS[1]	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV	6	7	9	9	15	12	9	12	15	29	18	35

[1]N.S. -- Treatments means not significantly different at the 5.0% level.

PASTURE IMPROVEMENT THROUGH FERTILIZATION AND WEED CONTROL
(Results of Trials in Minnesota Red River Basin - 1971)

Charles Simkins, Oliver Strand, Marlin Johnson and Paul Groneberg

Minnesota has more than 2 million acres of unimproved grasslands. Sods of cool season grasses, including mixture of Kentucky bluegrass, timothy, brome, orchard and quack grass serve as major sources of forage on many farms in Minnesota.

Land which is unsuited for cultivated crops is left in permanent stands of grass. To a lesser extent, some land which could be used as cultivated land is also devoted to permanent grass pasture or hayland. In numerous instances, without fertilization and management, this land provides forage for only a very short period of the year (6 to 8 weeks).

The yield response of such grasses has been the subject of repeated investigations. Research in New York, Maine, Wisconsin, Pennsylvania and Minnesota (4)(1)(7)(5)(3) has shown that yield increases of forage equal to 1.4 to 2.0 tons of dry matter per acre can be obtained from the use of 100 pounds of nitrogen per acre. These increases with nitrogen applications are obtained only when sufficient phosphorus and potassium are also available.

Numerous studies (6) indicate that a fertilizer program which supplies an annual equivalent of 50 pounds of P_2O_5 per acre can provide adequate phosphorus for intensive grass production on soils low to medium in available phosphorus.

The critical percentage of potassium in most grasses at harvest time is considered to be about 1 percent K on a dry matter basis. Grava, et al. (2) in Minnesota found an average of 2.19 percent K in Kentucky bluegrass and 2.6 percent in timothy collected from 50 fields in Northwest Minnesota.

Under general farm conditions in Minnesota, the use of fertilizer on grass pastures or haylands is characterized by an excessive use of phosphorus and potassium in relation to the nitrogen. The economical use of fertilizer on grass pastures must be based on (1) the plant food needs of the crop and its responses to nitrogen, phosphorus and potassium; equally important is (2) the management and harvest of the grassland crop.

Interest in beef cow-calf operations in northern Minnesota has stimulated many questions concerning the fertilization and management of existing grass pastures. Investigations on pasture fertilization and weed control were planned and carried out as a result of discussions and cooperation between farmers, University of Minnesota Extension Agents of the Red River Valley and Extension Specialists in Soils and Crops.

These studies were planned with several objectives in mind:

1. To determine the yield response of grass pasture or hayland to varying levels of fertilizer application. Specifically to compare the fertilizer rate common in farm use with a rate of fertilizer known to more nearly meet the needs of good grass growth.

2. To study the influence of weed control on the yield of grass pastures.

3. To determine the influence of fertilizer applications on the protein content of grass pasture.

4. To determine the influence of additions of phosphorus and potassium on yield of grass pastures in northwest Minnesota.

5. The trials were further intended to be used for the dual purposes of (a) collection of data which could help answer the above questions and (b) serve as demonstrations to farmers of the area.

The authors should like to express appreciation for the materials and assistance provided by the University of Minnesota Agricultural Experiment Station, Crookston, Minnesota. This cooperation, so generously extended, made the project possible.

METHODS

County agents in Marshall, Pennington, Roseau, East Polk, West Polk, Norman and Mahnomen counties selected typical pasture areas, assisted in the placement of tests and fencing of the trials. Eleven trials were placed in the seven counties.

Treatments as shown in Table 1 were broadcast on the surface of selected areas in April, 1971.

The trials were fenced to control livestock grazing. In May 1971, 2-4-D low volatile ester at the rate of 1 pound per acre was applied to those plots on which weed control was to be studied. Perennial weeds at this time were 3-4 inches in height. Principal weeds were Canadian thistle, dandelion, goldenrod, and common milkweed. Each trial consisted of 8 treatments replicated 2 times. Each plot was 1/100 acre in size.

During the past season, two cuttings and grazings have been made at all locations. An area equal to 1/2000 of an acre was harvested from each plot. A third has been taken at one location. It is anticipated that a third cutting will be taken at the other locations during the last week of October 1971. The first cutting on most locations was made during the week of June 7, 1971. Second cuttings were taken the last week of July 1971.

DISCUSSION OF RESULTS

The yields of hay obtained from the various treatments from the two cuttings are shown in Table 1. Yields are given for those locations which were predominantly mixed grasses, (quack, timothy, orchard, brome, Kentucky bluegrass) and for those locations which were predominantly Kentucky bluegrass.

These results confirm earlier findings in regard to use of fertilizers in the production of grass hay or pasture. The following conclusions have been interpreted from the data and are further supported by observations and data accumulated by previous research in Minnesota.

1. Pastures with mixed grasses, particularly those containing considerable timothy and quack grass species, produced higher average yields with or without fertilizer use than those pastures which were predominantly Kentucky bluegrass.

2. Fertilizer applications containing an equivalent of 150 pounds of nitrogen, 50 pounds of P_2O_5 and 50 pounds of K_2O resulted in increases in yield of hay of more than 2 tons per acre in two cuttings.

   Yields with the above fertilizer applications were nearly 3 times those obtained from no fertilizer application.

3. The application of 30 pounds of nitrogen per acre in combination with 15 pounds of P_2O_5 and 15 pounds of K_2O resulted in significant increases in yield in the first cuttings, but did not significantly increase yields in subsequent cuttings.

4. Nitrogen applied at the rate of 100 pounds of N per acre in the absence of additions of phosphorus and potassium fertilizer resulted in significant increases in yields. These increases, however, were not of the magnitude obtained when the equivalent quantity of nitrogen was applied in combination with phosphorus and potassium fertilizer. Future work in this area should include specific trials to determine phosphorus and/or potassium needs. It is likely that the response to additions of phosphorus and potassium fertilizer was largely due to the presence of additional phosphorus.

   Soil tests below 10 pounds per acre of P indicate low available phosphorus. A soil test of less than 100 pounds per acre of K indicates a low potassium level.

5. Under conditions of these trials, no significant increases in yields were obtained from the application of weed control materials.

   Data from these trials show that the application of 2-4-D effectively controlled most of the broad leaf weeds. Under the relatively good moisture and growing conditions experienced during this season, grass yields from plots not receiving weed control materials were similar to those in which weeds were controlled. Normally, weed control is an essential part of good pasture management and often can be as effective in increasing yields as fertilizer treatment.

These trials will be conducted for several more years in order to more fully study the influence of weed control and fertilizer treatment on the change of species.

6. Samples of hay obtained from the check plots, weed control plots, and those plots receiving 100 pounds of nitrogen plus 50 pounds each of P_2O_5 and K_2O per acre were analyzed for protein content. These data are shown in Table 3. Increases in protein content, as influenced by nitrogen fertilizer applications, often exceeded 5 percent. There was little difference in the protein content of the mixed grasses as compared with the stands which were predominantly Kentucky bluegrass. In the first cutting, those plots receiving applications of 2-4-D for weed control were generally lower in protein. This was likely due to the reduction in the population of legume plants in the weed control plots.

7. The average protein yield per acre obtained from the two cuttings on both the mixed grass and predominantly Kentucky bluegrass pasture sites was significantly increased by fertilizer applications, as shown in Table 4. The yield of protein per acre on the fertilized plots was more than 3 times that obtained on non-fertilized areas.

Less than 15 percent of the hay and pasture land in Minnesota is fertilized. Farmers as yet have not been motivated to try to shoot for high levels of forage production. While there are many reasons, perhaps one of the most important in northern Minnesota is that farmers feel they do not need additional forage because they keep only sufficient livestock to utilize the forages they normally produce. To be profitable, forages must be fed to livestock. Forages are not easily marketed and, during years of surplus production, the market price is often quite low. There were many instances of under utilization of hay and pastures in Minnesota this past growing season.

Farmers must have sufficient livestock to utilize the additional forages produced as a result of increased fertilization. If forages are not fed or grazed, forage fertilization may not be a paying proposition.

When one compares the production of T.D.N. and protein from grasses with that of corn, we realize that forages properly fertilized and harvested either as forage or pasture can be valuable. Table 5 shows a

Comparison of the production obtained in the trials with an equivalent production of corn.

The possibility of producing 77 bushels of corn per acre in northern Minnesota on land now being used for pasture and hayland is rather unlikely. However, a yield of 3.5 tons of hay per acre from this land is a reality when proper fertilizer weed control and management is employed.

Table 1. Hay yields - pasture fertilizer - weed control trials. Red River Basin - Minnesota - 1971

Treatment ($N + P_2O_5 + K_2O$)	Hay Yields tons/acre: *Mixed Grasses 1st Cut	*Mixed Grasses 2nd Cut	K. Bluegrass 1st Cut	K. Bluegrass 2nd Cut
0 + 0 + 0	.55	.83	.39	.40
0 + 0 + 0 + weed control	.43	.71	.35	.35
30 + 15 + 15	.70	1.10	.49	.43
30 + 15 + 15 + weed control	.73	.84	.57	.43
100 + 50 + 50**	1.75	1.81	1.08	.96
100 + 50 + 50** + weed control	1.75	1.71	1.21	.92
100 + 0 + 0	1.02	1.06	.61	.50
100 + 0 + 0 + weed control	1.13	.90	.69	.52
	5 sites	5 sites	6 sites	4 sites

* Mixed grasses - includes quack, timothy, orchard, brome and Kentucky bluegrass

** Received 50 pounds nitrogen after first cutting

Table 2. Phosphorus and potassium soil test levels - pasture fertilizer - weed control trials.
Red River Basin - Minnesota - 1971.

Location County	Soil Test Level P	K
	lbs/A	
Marshall	5	170
Red Lake	8	600
Pennington	5	200
West Polk	7	160
West Polk	6	170
East Polk	5	160
East Polk	13	140
Roseau	27	340
Norman	18	170
Norman	45	470
Mahnomen	35	560

Table 3. Protein percent - pasture fertilizer - weed control trials.
Red River Basin - Minnesota - 1971.

Treatment	% Protein			
	*Mixed Grasses		K. Bluegrass	
(N + P_2O_5	1st Cut	2nd Cut	1st Cut	2nd Cut
0 + 0 + 0	11.7	11.3	11.9	10.3
0 + 0 + 0 + weed control	10.7	10.9	11.5	10.3
150 + 50 + 50** + weed control	16.8	15.0	15.2	15.5

* Mixed grasses - includes quack, timothy, brome, orchard, Kentucky bluegrass mixtures

** 50 pounds nitrogen applied after first cutting

Table 4. Protein pounds per acre - pasture fertilizer - weed control trials. Red River Basin - Minnesota - 1971.

Treatment ($N + P_2O_5 + K_2O$)	Protein pounds per acre: *Mixed Grasses 1st Cut	2nd Cut	Total	K Bluegrass 1st Cut	2nd Cut	Total
0 + 0 + 0	151	187	338	93	82	175
0 + 0 + 0 + weed control	92	155	247	80	72	152
150 + 50 + 50** + weed control	588	513	1001	367	285	652

* Mixed grasses - includes quack, timothy, orchard, brome and Kentucky bluegrass

** Received 50 pounds nitrogen after first cutting

Table 5. Production of T.D.N. and protein from grass pasture compared to corn.

	Ton Hay/Acre	Pounds T.D.N./Acre	Pounds Protein/Acre
Permanent Bluegrass no fertilizer	.8	800	160
Permanent Bluegrass + fertilizer	2.0	2000	600
Mixed Grasses + fertilizer	3.5	3500	1000
Corn (bu.)	18	800	90*
Corn (bu.)	45	2000	227*
Corn (bu.)	78	3500	393*

* Based on 9 percent protein in corn.

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THE NUTRIENT STATUS OF KENNEBEC POTATOES AS INFLUENCED BY VARIOUS FERTILIZER TREATMENTS GRAND FORKS, MINNESOTA 1971

Charles Simkins, Edwin Plissey and Paul Groneberg

The nutrient content of the potato leaf and its petiole has been used by a number of investigators to determine the nutrient status of the potato plant. As the means and methods for tissue analysis become more efficient, rapid and reliable, critical values for the nutrient content of plant tissue can be established and correlated with nutrient supplies in the soil, crop growth and yield and quality of harvested crop.

In order to help establish critical levels for the potato crop, leaf and petiole samples were taken for a field of Kennebec potatoes which had been previously fertilized at various N, P and K rates. The 4th or 5th leaf from the top was sampled, along with the leaf petiole. Samples were taken on July 15, 1971 about 50 days after emergence of the potato plants. The potato plants were in full bloom stage. Nitrogen determinations were made by a modified Kjeldahl method. Other nutrients, as shown in Tables 1 and 2, were determined by means of emission spectrography.

Discussion of Results

Nitrogen - Levels of nitrogen in the plant tissue were increased by N fertilizer applications. Fifty pounds of nitrogen per acre produced a level in the plant tissue which was equal to that obtained by other rates (100, 150 and 200 lbs. per acre). The level of approximately 5.5% nitrogen produced yield levels which were significantly higher than the non treated plots and equal to those plots treated with higher rates of nitrogen.

Phosphorus - Phosphorus levels in the plant tissue were not significantly altered by phosphorus, nitrogen or potassium fertilizer doses. On the average, those plots receiving phosphorus fertilizer produced leaf samples which were slightly higher in phosphorus. Plots receiving no phosphorus averaged .47 percent phosphorus in the leaf while plots receiving phosphorus applications equal to 200 pounds of P_2O_5 per acre averaged .51 percent P_2O_5. Although the values were not significant, the phosphorus content of the leaves increased with increasing rate of P_2O_5 in the phosphorus rate trial (.484 for control to .597 for 400 lbs. P_2O_5/acre).

Potassium - Significant increases in potassium in the leaf tissue were observed only in the potassium trial where rates of potassium application exceeded 100 pounds K_2O per acre.

Although the percent K increased from 2.2 to 2.8 percent in the tissue, there was no significant increase in yield at harvest time.

Calcium and Magnesium - The quantity of these two cations was not significantly changed as a result of the various fertilizer treatments. The high amount of exchangeable calcium and magnesium in this alkaline soil should furnish ample calcium and magnesium for crop growth.

Aluminum - It was surprising to find that the leaf tissue of the potato grown on these alkaline soils (pH 7.8 to 8.0) contained aluminum in some instances as high as 900 ppm. The author, to date, has found little reference to the possibility of toxicity of aluminum to the potato plant on alkaline soils. It should be interesting to determine where the quantity of soluble aluminum in this soil is high. The content of aluminum in the leaf tissue was significantly decreased by increasing rates of phosphorus. It was noted that the highest levels of aluminum in the plant tissue was observed coming from those plots where the soil test indicated a low level of available phosphorus. A level of more than 400 ppm in the plant tissue is considered to be excessive to many plants, including alfalfa and sugar beets. Perhaps the high soluble aluminum content of the soil and the accompanying high level of aluminum in the plant tissue is responsible for the response obtained from high levels of phosphorus application in the work of A. C. Caldwell et al.

In these trials, the yield increases due to increasing phosphorus application were not significant. The low plant population, however, could be responsible for this.

Iron, Manganese and Boron - The effect of the various fertilizer treatment on quantity of iron, manganese and boron in the plant tissue was similar to the quantity of aluminum found in the tissue. Iron and manganese and boron in the plant tissue decreased with increasing phosphorus applications. This phenomena is not new since it has been well established that phosphorus fertilizer additions can result in a decrease of plant uptake of several micro-nutrients.

Copper - The quantity of copper in the plant tissue was also reduced with increasing phosphorus additions. The quantity of copper in the plants, however, was considerably above the critical level established by several investigators.

Zinc - Zinc levels in the plant tissue were not significantly influenced by fertilizer treatments. Samples from all plots displayed zinc levels well above the 16 ppm considered to be critical for good potato growth.

Table 1. Nutrient content of leaf and petiole of Kennebec potatoes as influenced by nitrogen, phosphorus and potassium fertilizer treatment. Grand Forks - 1971. Average of 4 replications.

Treatment	N %	P %	K %	Ca %	Mg %
0+0+0	4.78 a	.471	2.57	.901	.765
0+200+100	4.63 a	.477	2.58	.816	.695
50+200+100	5.47 b	.511	2.60	.759	.695
100+200+100	5.37 b	.493	2.78	.844	.755
150+200+100	5.70 b	.581	2.85	.725	.637
200+200+100	5.64 b	.548	2.88	.837	.714
Treat. Sig.	**	N.S.	N.S.	N.S.	N.S.
0+0+0	4.82	.484	2.53	.919	.645
150+0+100	5.17	.488	2.85	.914	.744
150+100+100	5.82	.514	2.67	.685	.579
150+200+100	5.56	.504	2.83	.871	.683
150+300+100	5.79	.593	2.56	.674	.572
150+400+100	5.85	.597	2.68	.732	.594
Treat. Sig.	*	N.S.	N.S.	N.S.	N.S.
0+0+0	4.55 a	.460	2.36 ab	.983	.752
150+200+0	5.75 b	.563	2.20 a	.814	.686
150+200+100	5.57 b	.488	2.57 abc	.849	.713
150+200+200	5.43 b	.483	2.84 bc	.858	.702
150+200+300	5.73 b	.529	2.82 bc	.745	.612
Treat. Sig.	**	N.S.	**	N.S.	N.S.

* Denotes 1% level of significance
** Denotes 5% level of significance

Table 2. Nutrient content of leaf and petiole of Kennebec potatoes as influenced by nitrogen, phosphorus and potassium fertilizer treatments. Grand Forks, 1971. (Averages of 4 replications.)

Treatment	Al ppm	Fe ppm	Zn ppm	Cu ppm	Mn ppm	B ppm
0+0+0	450 b	593	29.3	12.5	48.1	25.5 b
0+200+100	308 a	567	29.8	14.8	48.1	27.2 b
50+200+100	230 a	478	32.3	9.2	45.0	22.6 a
100+200+100	171 a	365	29.9	9.2	43.0	21.3 a
150+200+100	282 a	537	41.3	10.5	45.9	21.7 a
200+200+100	234 a	454	34.4	9.2	44.7	20.8 a
Treat. Sig.	**	N.S.	N.S.	N.S.	N.S.	**
0+0+0	584 b	966 c	31.9	13.9	58.2 b	23.6 b
150+0+100	520 b	860 bc	33.8	12.1	56.4 b	23.7 b
150+100+100	291 a	537 ab	41.0	12.4	44.5 a	20.5 a
150+200+100	303 a	546 ab	29.8	8.4	47.3 a	21.5 ab
150+300+100	213 a	428 a	40.8	9.4	43.8 a	19.9 a
150+400+100	210 a	434 a	33.0	7.9	44.7 a	20.7 a
Treat. Sig.	**	*	N.S.	N.S.	**	*
0+0+0	571 b	930 b	29.7	14.1 b	58.3 b	24.1 b
150+200+0	300 a	559 a	36.4	11.3 ab	48.7 a	20.1 a
150+200+100	279 a	519 a	28.2	8.4 a	45.9 a	20.5 a
150+200+200	354 a	620 a	30.6	8.2 a	48.4 a	21.2 a
150+200+300	299 a	635 a	32.4	7.9 a	44.4 a	20.4 a
Treat. Sig.	**	**	N.S.	*	**	**

* Denotes 1% level of significance
** Denotes 5% level of significance

YIELDS AND SPECIFIC GRAVITY OF KENNEBEC POTATOES AS INFLUENCED BY FERTILIZER TREATMENTS GRAND FORKS POTATO RESEARCH CENTER-1971

Charles Simkins, Edward Plissey and Paul Groneberg

Numerous investigations during the past 25 years have shown the need for additions of fertilizer for high potato yields in the Red River Basin of Minnesota. Most recently, the work of A. C. Caldwell and colleagues has indicated that on certain soils of the Red River Valley the application of high rates of phosphorus fertilizer (400 to 600 lbs. P_2O_5 per acre) may be important in obtaining highest yields of marketable potatoes. As management practices change, and more disease resistant varieties are available, a reevaluation of plant food needs are necessary. The goal of researchers and extension workers is to obtain sufficient information regarding fertilizer use by the potato crop to allow for recommendation of concise, economical quantities of fertilizer for a given situation.

This requires the development of a method to determine the present nutrient supplying power of the soil. It also requires that we learn on a given soil type the efficiency with which added plant food nutrients are absorbed by the potato crop. Furthermore, we must establish a realistic and economical yield potential which is consistently attainable under good management practices. Thus a fertilizer experiment should be much more than just a trial where fertilizer rates are applied to a crop and yields are taken. Unless one is relatively certain that the yields obtained from a fertilizer trial were not limited by management factors which could have been controlled by a good farmer, the data is of little value in projecting fertilizer needs.

Methods and Materials

In order to study the influence of various rates of N, P and K fertilizer on the yield and specific gravity of Kennebec potatoes, a site was selected on the Potato Research Center, Grand Forks, North Dakota. The soil was a Bearden silt loam and had previously been cropped to small grain (wheat).

A composite soil sample taken before planting indicated a medium phosphorus level (16 lbs. P per acre), a high potassium level (400 lbs. K per acre), and a medium NO_3N level (60 lbs. per acre). At planting time, additional composite soil samples were taken at 3 locations in the experimental site. The soil samples were analyzed at the soil testing laboratories at the Universities of Minnesota and North Dakota. While the soil testing methods are somewhat different in the two laboratories, the results on the basis of rating of available nutrients was nearly the same. A comparison of the soil test results were as follows:

Place of Sampling in Field	Minnesota	Rating	North Dakota	Rating
East				
Nitrogen	86 lbs/acre	M	76 lbs/acre	M
Phosphorus (P)	20 lbs/acre	M	20 lbs/acre	M
Potassium	410 lbs/acre	H	220 lbs/acre	H
Center pH				
Nitrogen	122 lbs/acre	VH	136 lbs/acre	VH
Phosphorus (P)	39 lbs/acre	VH	61 lbs/acre	VH
Potassium	470 lbs/acre	H	280 lbs/acre	H
West				
Nitrogen	53 lbs/acre	L	41 lbs/acre	L
Phosphorus (P)	3 lbs/acre	L	14 lbs/acre	L
Potassium	360 lbs/acre	M	180 lbs/acre	M

L=Low - M=Medium - H=High

Obviously, with this large variation in original plant nutrient content, one would expect a great variation in yield, crop growth and fertilizer response. This was borne out in observations during the growing season, as well as yields obtained at harvest time. The first impulse when such a variation in soil variation and plant growth are observed is to discard the trial and expend efforts elsewhere. After more careful observation, however, it was found that the soil variation and difference in crop growth corresponded with different replications. With this apparent variation, it was interesting to continue investigations and determine the differences in responses at the various fertility levels.

The trial consists of 3 incomplete factorials involving:

5 N rates	5 P_2O_5 rates	4 K_2O rates
0	0	0
50	100	100
100	200	200
150	300	300
200	400	

In the N trial, an application of 200 lbs. P_2O_5 and 100 lbs. K_2O per acre was applied to all plots including the zero N plots. In addition, in each replication, there was a plot receiving no fertilizer application.

The P trial received a uniform application of N and K_2O at the rates of 150 lbs. and 100 lbs. per acre, respectively.

The K_2O trial received a uniform application of N and P_2O_5 at the rate of 150 and 200 lbs. per acre, respectively.

The potatoes were planted in 40 inch rows. Seed pieces were spaced in the row at 12 inches. Each plot consisted of 4 rows, 24 feet long.

Ammonium nitrate, treble superphosphate and potassium chloride were employed as nitrogen, phosphorus and potassium sources. The fertilizer materials were applied at planting time, approximately 2 inches to side and 2 inches below the potato seed pieces. The potatoes were planted on May 26, 1971. The vines were killed on August 26 and the potatoes were harvested on September 2, 1971 The 4th and 5th leaf, including leaf petioles, were collected from each plot on July 15. These samples were analyzed for N,P,K,Cu,B,Al,Mg,Mn,Mo,Ca,Fe and Zn. (These results are discussed in another paper.) A sample from each plot was taken at harvest time for specific gravity and chipping quality determinations.

Weather and moisture conditions during the growing period were nearly ideal. More than 14.0 inches of precipitation was received during the growing period. The distribution was so favorable that it is likely that the crop was well supplied with moisture at all times.

Discussion of Results

Yields

The yields in general were quite high considering the number of plants per acre. A spacing of 12" x 40" will result in a plant population of approximately 13,000 plants per acre. Under conditions of these trials, it is quite likely that a plant population of 17,000 to 18,000 would have been more desirable. Based on previous research, a production potential of 500 bushels per acre is realistic under good management conditions in the Red River Basin. There were approximately 90 days between the time of planting and harvesting, yet many of the tubers harvested were over sized and too large for good chipping quality. A larger plant population would, no doubt, reduce the size of tubers and increase total yield and chipping quality.

Yields obtained from various fertilizer treatments are shown in Table 1.

Table 1. Yield, specific gravity and chipping quality of Kennebec potatoes as influenced by various fertilizer treatments - Grand Forks, 1971.

Lbs/acre $N-P_2O_5-K_2O$	Yield No. 1's bu/acre	Specific Gravity	Chipping Quality
0 + 0 + 0	338 a	1.083 b	52
0 + 200 +	348 a	1.083 b	49
50 + 200 + 100	417 b	1.083 b	53
100 + 200 + 100	432 b	1.074 a	46
150 + 200 + 100	391 b	1.077 a	45
200 + 200 + 100	346 a	1.073 a	50
Sig. Treatment	***	*	N.S.
0 + 0 + 0	281	1.088 b	48
150 + 0 + 100	310	1.082 ab	45
150 + 100 + 100	348	1.076 a	41
150 + 200 + 100	369	1.079 a	47
150 + 300 + 100	379	1.078 a	48
150 + 400 + 100	363	1.077 a	48
Sig. Treatment	N.S.	*	N.S.
0 + 0 + 0	251 a	1.089 b	49
150 + 200 + 0	337 b	1.081 a	44
150 + 200 + 100	346 b	1.081 a	44
150 + 200 + 200	340 b	1.079 a	47
150 + 200 + 300	378 b	1.081 a	45
Sig. Treatment	**	**	N.S.

* 1% level
** 5% level
***10% level

Although there was considerable variation in fertilizer response due to the differences in soil fertility, the overall response to nitrogen and phosphorus fertilizer application was quite significant.

In the nitrogen trials, the application of 50 lbs. N in combination with 200 lbs. P_2O_5 and 100 lbs. K_2O produced the highest significant increase in average yield.

In the phosphorus trials, statistical significance of fertilizer treatments on yield was not obtained at the 1, 5 or 10 percent levels. Average yields, however, indicate an increase in yield up to the 300 pound P_2O_5 rate.

The addition of potassium fertilizer did not significantly increase yields when used in combination with nitrogen and phosphorus fertilizer materials.

Included in the trials were 12 plots which received no fertilizer applications. Similarly, there were 12 plots which received an application of 150 lbs. N, 200 lbs. P_2O_5 and 100 lbs. K_2O per acre. The average yield for all the check plots was 290 bushels per acre. The above mentioned fertilized plots produced an average yield of 369 bushels per acre, or approximately an 80 bushel per acre increase.

Specific Gravity

As indicated in Table 1, the specific gravities of the potatoes examined from these trials were significantly altered by fertilizer applications. Nitrogen rates of more than 50 pounds of N per acre resulted in a significant decrease in specific gravity. Phosphorus fertilizer applications also contributed to the lowering of specific gravity of the potatoes. The 100 pound rate of P_2O_5 application was as effective in lowering specific gravity as the 200, 300 or 400 pound rates.

The inclusion of potassium fertilizer in combination with nitrogen and phosphorus did not result in additional lowering of the specific gravity of the potatoes when used at 100, 200 and 300 pounds of K_2O per acre.

Chipping Quality

Data obtained from chipping tests did not show significant differences in chipping quality which could be attributed to fertilizer application. It is important to note that the average of 12 no fertilized plots produced a chipping value of 50, while those potatoes examined from the 12 plots receiving 150 pounds of N, 200 pounds of P_2O_5 and 100 pounds of K_2O produced an average chipping value of 44.

FERTILIZER EFFECT ON 1971 SMALL GRAIN YIELDS IN NORTHWESTERN MINNESOTA

by

J. M. MacGregor*

Small grains are grown extensively in northwestern Minnesota and rising farming costs have emphasized lowering unit production cost. The use of commercial fertilizers is well recognized as one way of increasing yields by applying the needed nutrient elements at adequate rates and proportions as an important part of a soil management system.

The use of such essential elements as fertilizer nitrogen and phosphorus has long been appreciated to be of value on these soils. More recently there has been increasing interest of possibly increasing small grain yields by the inclusion of potassium, sulfur, or of one or several of the micronutrient elements such as manganese, zinc, copper, or boron. A three year study on the effects of applying elements to northwestern Minnesota soils for small grain production was commenced in 1970 on 12 fields (2 of barley, 5 of oats, and 5 of wheat). Only one field (barley) responded to a 40 pound per acre rate of N, P_2O_5 and K_2O (40+40+40), there being no significant yield increase to heavy applications of potassium, or to moderate treatment rates of sulfur or of the four micronutrient elements, either alone or combined.

In 1971, nine fertility treatments were broadcast on plowed land, worked into the surface soil and planted on 17 fields scattered over seven northwestern Minnesota counties. The treatments applied corresponded to those of 1970, but with an additional 40+40+0 (N + P_2O_5)

*This study is possible only through the active interest of county extension personnel and cooperating farm operators in several northwestern Minnesota counties. Their contribution is duly acknowledged.

treatment added to study the relative effectiveness of the potash included in the basic treatment (40+40+40). Each of the nine fertilizer treatments was randomly broadcast with an untreated plot in five replications, making a total of 50 individual plots (10' x 15') in each of the 17 fields. Overall dimensions of each experimental area were 75' x 100', or less than one-fifth acre of each of the 17 fields.

A second treatment difference from the 1970 study was the use of "Sol-U-Sul" as a source of sulfur, rather than the "flowers of sulfur" broadcast in 1970. Sulfur from the former product is largely available to plants as soon as it is dissolved in soil water, whereas the "flowers of sulfur" may require several weeks for oxidation to sulfates by soil microorganism to become completely available.

A third change from the 1970 study was that the 40+40+40 broadcast treatment was applied to all of the sulfur and micronutrient plots as a standard fertility application -- irrespective of the starter fertilizer to be applied by the farm operator, or to fertilizer applied earlier for the 1971 crop. In 1970, amounts of each starter fertilizer were subtracted from the 40+40+40 broadcast treatment, resulting in a total (starter + broadcast) fertilizer rate to supply 40+40+40. This 1970 practice was found to be too time consuming, and placed a severe limitation on the number of experimental fields which could be included in the study.

As in 1970, zinc, manganese, and copper were applied as sulfates, which are relatively soluble in water. Boron was also added in a soluble form.

Fields were staked in mid-April as soon as workable, and the fertilizer treatments were broadcast. All stakes were then removed, with the farm operator working and seeding the entire field by the usual procedures. The experimental plot areas were then re-staked in late June after weed spraying operations were completed.

The 1971 growing season was ideal for small grain production in most areas of northwestern Minnesota, although some farms experienced minor drouth or hail damage. Yield samples were harvested in late July or early August by cutting and bagging grain from a 3' x 8' swath from the central part of each plot. This was done just prior to the harvest of the entire field by the farm operator with the exception of two oat fields which were somewhat immature when sampled. (Prestebak and Sperling) (Due to a weed problem, only three replications were harvested on the Jameson wheat field). The grain was dried, threshed, weighed, and the respective yields calculated from the 5 replications of each field. Yields were statistically analyzed -- 13 of the 17 fields showed no significant yield differences. These are reported in the 3 following tables with soil analyses and other pertinent data.

Table 1 shows that the soil texture of the 9 oat fields varied, (with one organic (muck) soil) from a sandy loam to silty clay loam, having a pH range of 5.4 to 8.0 Organic matter in all fields was high, with extractable P varying from 8 to 75 lbs per acre. Nitrate-N ranged from 66 to 395 lbs per acre. Minimum soluble Zn was 0.8 lbs per acre and minimum sulfur was 7 lbs/A Both of these values are in the low range of availability and application of these two elements might prove beneficial to some crop species.

Yields of only 2 of the 9 oat fields responded significantly to the 1971 broadcast fertilizer treatments, and both of these responding fields were damaged by hail after they headed out. It is evident that nitrogen and phosphate fertilization was primarily responsible for the yield increases on these two fields. None of the 9 oat fields produced a significant yield effect from the heavy potash, sulfur, zinc, manganese, boron, or copper applications, either with the 40+40+40, or as a combination "shotgun" treatment and the 40+40+40.

Table 2 shows the soil analyses and yields obtained on the 5 barley fields. These soils were all fine textured, with the greatest variation in nutrient availability shown in the K and NO_3-N analyses. Fertilizer treatment significantly increased barley yields on only 1 of the 5 fields. Apparently the N + P_2O_5 (40+40+0), were responsible for the barley yield increase.

Table 3 data show that all 3 wheat field soils were fine textured, with the main soil differences occurring in the levels of soluble P and NO_3-N. Starter fertilizer had been purposely omitted from the Northwest Experimental Station wheat field at Crookston, and the 40+40+40 broadcast treatment produced significantly larger wheat yields. Since the 40+40+40 broadcast treatment resulted in yields approximately equivalent to the N + P_2O_5 (40+40+0), and extractable soil P was very high, it may be assumed that N was the most effective fertilizer element for increasing wheat yield on this field. It is obvious that heavy rates of K_2O application, or of moderate broadcast rates of sulfur, zinc, copper, manganese or boron (either alone or combined) have failed to significantly increase 1971 yields of wheat on the three 1971 experimental wheat fields.

Table 1. County, Farm Operator, Location, Soil Test, Fertilizer Treatment and 1971 Yields of Nine Northwestern Minnesota Oat Fields.

County	Ottertail	Ottertail	Ottertail	Wilkin	Clay	Norman	Pennington	Pennington	Becker
Operator	M.Erlandson	R.Roehl	G.Bradow	I.Bellmore	P.Brantner	H.Barkve	N.Peterson	C.Prestebak	W.Sperling
Address	F.Falls	F.Falls	F.Falls	Kent	Felton	Ada	T.R.Falls	T.R.Falls	Ponsford
Soil texture	SiCL	L	SL	L	SiCL	SiCL	SL	Muck	L
Soil pH	7.1	6.7	7.3	7.7	8.0	8.0	7.1	5.4	6.8
Soil OM	H.	H.	H.	H.	H.	H.	H.	V.H.	H.
Soil P	8	23	20	75	8	10	65	9	11
Soil K	420	380	240	600+	560	580	200	120	90
Soil NO_3-N	170	197	122	133	395	232	176	116	66
Soil Zn	1.5	12.8	4.2	3.4	0.8	1.6	5.3	3.1	2.5
Soil S	15	11	11	12	13	16	8	40+	7
1970 crop	flax	barley	oats	barley	wheat	wheat	oats	oats	corn
1970 fertilizer (lbs/A)	None	8+27+9	64+57+15	19+48+13	12+57+14	40+29+0	50+18+18	14+14+14	23+8+45
1971 variety	Lodi	Sioux	Sioux	Harmon	Lodi	Lodi	Kelsey	Lodi	Portal
1971 starter (lbs/A)	15+38+10	47+38+10	20+50+13	19+48+13	None	10+29+0	14+14+14	14+14+14	23+8+25
1971 broadcast (lbs/A)	1971 oat yields in bushels per acre								
None	56.4a	91.4	90.7	79.4	102.3	68.9	55.9	61.4	60.8abc
40+40+0	62.4b	87.9	83.3	78.7	104.6	77.0	53.2	61.3	69.9cd
40+40+40	63.1b	85.1	84.8	78.5	93.7	77.9	56.1	59.1	59.0a
40+40+200	65.8b	89.7	85.5	91.6	99.5	71.3	57.8	58.0	59.6ab
40+40+40+10Zn	62.4b	91.2	85.7	81.8	92.6	72.4	48.1	65.0	64.0abcd
40+40+40+10Mn	63.6b	91.0	85.4	80.1	105.4	73.9	60.0	66.7	68.3bcd
40+40+40+2B	66.0b	86.5	85.4	78.5	101.2	77.6	54.9	57.1	67.3abcd
40+40+40+10Cu	65.5b	89.4	90.1	80.0	112.8	69.1	59.1	56.9	63.8abcd
40+40+40+20S	65.4b	90.8	86.4	89.5	105.3	70.0	56.7	66.6	70.0d
40+40+40+10Zn+10Mn +2B+10Cu+20S	65.7b	92.6	87.0	71.1	111.3	76.5	53.3	57.4	66.3abcd
Comments	(hailed)	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	(hailed)

N.S. -- Not Significant

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

Table 2. County, Farm Operator, Location, Soil Test, Fertilizer Treatment and 1971 Yields of Five Northwestern Minnesota Barley Fields.

County	Wilkin	Wilkin	Clay	Norman	Pennington
Operator	R.Fried-ericks	R.Hove-land	C.Brende-muhl	J.Tobin	F.&B.Wald
Address	Foxhome	Lawndale	Kragnes	Flom	T.R.Falls
Soil Texture	SiCL	CL	SiCL	CL	SiCL
Soil pH	7.9	7.6	7.6	7.4	7.0
Soil OM	H	H	H	H	H
Soil P	30	9	33	25	65
Soil K	410	460	600+	190	600+
Soil NO_3-N	210	265	117	65	455
Soil Zn	2.3	0.7	1.0	1.7	1.8
Soil S	20	18	10	12	33
1970 crop	barley	wheat	durum	oats	wheat
1970 Fertilizer (lbs/A)	35+89+24	18+46+0	29+74+0	16+16+10	14+29+29 (+S+T.E.)
1971 Variety	Larker	barley	Larker	Larker	Larker
1971 starter (lbs/A)	23+57+15	51+46+0	37+37+0	22+22+20	18+36+36

1971 broadcast (lbs/A)	1971 barley yields in bushels per acre				
none	38.6	34.3	64.6	45.8a	65.0
40+40+0	36.4	37.2	60.4	58.8bc	62.9
40+40+40	37.3	38.5	60.8	55.8bc	58.9
40+40+200	35.3	33.5	65.0	61.8c	63.2
40+40+40+10Zn	37.8	33.7	64.7	56.4bc	62.8
40+40+40+10Mn	38.2	38.2	58.8	57.3bc	64.6
40+40+40+2B	36.0	40.0	70.0	56.4bc	67.1
40+40+40+10Cu	33.9	42.8	66.0	53.3b	65.1
40+40+40+20S	37.8	38.6	68.6	57.9bc	66.7
40+40+40+10Zn+10Mn+2B=10Cu+20S	35.7	29.7	64.1	59.1bc	66.3
Comments	N.S.	N.S. (dry)	N.S.		N.S.

N.S. + Not Significant

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

Table 3. County, Farm Operator, Location, Soil Test, Fertilizer Treatment and 1971 Yields of Three Northwestern Minnesota Wheat Fields.

County	Clay	Norman	Polk
Operator	F.Kreps	R.Jameson	N.W.Station
Address	Borup	Ada	Crookston
Soil texture	SiCL	SiCL	SiCL
Soil pH	7.8	7.8	8.3
Soil OM	H	H	H
Soil P	57	60	160
Soil K	520	520	600+
Soil NO_3-N	290	186	192
Soil Zn	1.3	2.1	1.5
Soil S	40+	9	40+
1970 crop	oats	S.Fallow	sugar beets
1970 fertilizer (lbs/A)	54+20+20	--	6+157+0
1971 variety	Waldron	R.River 68	Chadron
1971 starter (lbs/A)	none	24+72+0	none

1971 broadcast (lbs/A)	1971 wheat yields in bushels per acre		
none	40.7	41.4	34.1a
40+40+0	46.0	41.5	46.5c
40+40+40	44.3	39.1	44.3bc
40+40+200	44.4	38.9	46.3bc
40+40+40+10Zn	43.7	38.9	46.5c
40+40+40+10Mn	47.9	41.9	47.0c
40+40+40+2B	44.5	36.4	40.8b
40+40+40+10Cu	48.6	43.5	44.5bc
40+40+40+20S	44.0	42.5	44.1bc
40+40+40+10Zn+ 10Mn+2B+10Cu+20S	46.3	39.5	45.2bc
Comments	N.S.	N.S.	

N.S. + Not Significant

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

Conclusions

It is apparent that broadcast applications of sulfur, zinc, manganese, boron, and copper, either alone or combined, as well as light or heavy applications of potash have not significantly increased the experimental yields of 17 small grain fields in northwestern Minnesota in 1971. Significant yield increases resulted on four fields from broadcast applications of 40 lbs of N and P_2O_5 per acre (40+40+0). The results obtained are essentially the same as those reported on 12 fields of small grain grown in northwestern Minnesota during the 1970 growing season.

NITROGEN RATE STUDIES ON SEMI-DWARF WHEAT VARIETIES WEST POLK COUNTY - 1971

Charles Simkins - Samuel Bigger - Richard Arnston

The recent introduction of semi-dwarf wheat varieties in Minnesota has stimulated an increase in wheat production among farmers in the Red River Basin of Minnesota.

During the 1971 harvest season, it was not uncommon to encounter farmers who had produced more than 80 bushels (4,800 lbs.) of wheat per acre. The favorable spring planting season and the good distribution of moisture during the spring and summer growing season, no doubt, contributed considerably to these record yields. However, without adequate fertilizer use,many farmers were obtaining yields of less than 40 bushels per acre.

In the past, largely because of the high organic matter level of soils and the practices of legume fallow and black fallow, nitrogen fertilizer use on small grains produced inconsistent results. In general, phosphorus fertilization of small grains was the key to good fertilizer management for small grain production. Nitrogen use was restricted to 30 to 50 pounds of N per acre if the field had been in a nitrogen depleting crop such as sugarbeets, sunflowers, or potatoes. In most cases, the inherent potassium levels in the soil supplied most crops with sufficient potassium. The wheat varieties available to the farmers did not have a potential of more than 50 bushels per acre. An application of nitrogen fertilizer exceeding 50 pounds per acre often resulted in excessive lodging and poor quality grain.

New short-statured wheat varieties which resist lodging have yield potentials of 100 bushels (6,000 lbs.) of grain per acre. This potential increases the requirement for plant food nutrients and requires continuing research to assure that yields are not limited by an insufficient supply of plant nutrients.

In addition, it is important to study the influence of nitrogen fertilizer applications on wheat milling and baking quality. Most semi-dwarf wheat varieties are relatively low in protein and may exhibit low baking absorption and loaf volume values.

Methods and Materials

Field sites were selected at two locations in West Polk County, one near East Grand Forks, Minnesota (Gulbranson farm), the other near Angus, Minnesota (Miski farm). The soils were classified as Bearden silty clay loam and had been cropped to sugar beets during the 1970 crop season. Soil test results indicated a medium to high phosphorus level; high potassium level and medium nitrate nitrogen level. Sulfur levels as indicated by soil tests were high, above 30 ppm S.

Era wheat was seeded by grain drill at the rate of 90 lbs. per acre. Fertilizer materials were applied at seeding time at the rate of 20 lbs. nitrogen and 50 pounds of P_2O_5 per acre. Additional nitrogen at the rates of 60, 120, and 180 pounds per acre was applied on May 19, June 11, and June 30. Four replications of each treatment were applied broadcast on plots 1/200 of an acre in size. Ammonium nitrate (33.5% N) was used as the nitrogen source. At harvest time, an area 4 feet by 15.5 feet was harvested by hand and threshed by means of Vogel thresher.

Nitrogen content of grain was obtained by modified Kjeldahl method. Samples for yield determinations were taken twice at the Gulbranson location on August 11 and August 16. Yield determinations at the Miski location were taken at the August 16 date.

Results - Yields of Wheat

Yields of Era wheat obtained from the various nitrogen treatments are shown in Table 1.

At the Miski location, nitrogen applied at the rate of 60 pounds N per acre at seeding time (in addition to the 20 pounds of N applied by the farmer) resulted in yield increases of more than 20 bushels per acre, The increases at this level of application (60 pounds N per acre) were equal to those obtained at higher levels of application (120 and 180 pounds N per acre). Field observations indicated some delay in maturity due to the application of 120 and 180 pounds of N per acre. Some lodging also occurred in these plots.

To study the influence of this delayed maturity on the yield of wheat grain, the Gulbranson location was harvested at two dates. At the August 11 harvest date, the wheat kernels at the Gulbranson location were in the hard dough stage. Wheat is often cut at this stage and allowed to remain in the swath for further maturing and reduction in moisture content to accommodate threshing. The wheat kernels at the August 16 date were fully matured and relatively low in moisture content. As indicated by the data obtained from the two harvests, considerable yield increase was obtained by harvesting at a more mature date. Yield differences were greatest at the 120 and 180 pound N rates.

It is interesting to note that data obtained at the August 11 harvest date showned no statistical significance in grain yields as a result of nitrogen applications. This was likely due to the immaturity of the grain. Care should be exercised by farmers as well as researchers to make sure the grain is physiologically mature before harvesting. Yields obtained at the August 16 harvest date showed similar results as those obtained at the Miski location. Sixty pounds N applied at seeding time resulted in the highest significant increase in yield of wheat grain. The results obtained are consistent with those we might expect on soils which, as shown by soil tests, already contained more than 80 pounds of NO_3N per acre.

Results - Protein Content of Wheat

Investigations have shown that soil application of nitrogen can result in increased protein content of grain.

On soils low in available nitrogen, small applications of nitrogen will normally result in yield increases with little or no change in grain protein content, whereas large applications increase grain protein.

Experiments have also shown that late soil applications (flowering time) have resulted in higher protein percentages in the grain than those applications applied at or near seeding time.

The protein content of the harvested wheat at both the Miski and Gulbranson locations was significantly increased by nitrogen fertilizer applications.

In general, the nitrogen fertilizer applied at the time of stooling (June 11) or at flowering stage (June 30) resulted in the highest protein content of grain. Based on the data obtained in these trials, an application of 60 pounds N per acre resulted in the highest significant increase in yield and approximately 1 percent increase in protein content. The 120 and 180 pound rates of nitrogen increased the protein content 2-3 percent, but did not consistently increase yields over the 60 pound rate.

Based on the present premiums for protein in wheat (January 1972) (5¢ for 14% protein) (15¢ for 15% protein) the application of more than 60 pounds N per acre on soils testing 80 pounds NO_3N per acre would be uneconomical.

Table 1. Era wheat yields - West Polk County - 1971

Treatments (lbs. N/acre)	Miski	Gulbranson August 11	Gulbranson August 16
	bu/acre		
CHECK	52 a#	60a	65a
Seeding - May 19			
60	73 b	73a	79 cd
120	71 b	65a	81 d
180	65 b	64a	82 d
Stooling stage - June 11			
60	70 b	63a	69 ab
120	67 b	68a	76 bcd
180	71 b	70a	73 abcd
Flowering stage - June 30			
60	75 b	69a	70 abc
120	64 b	67a	75 bcd
180	65 b	71a	78 bcd
Significance			
Rep	NS	NS	NS
Treatment	**	NS	**
C.V.	10.73	8.77	7.94
Soil Test			
NO_3N	87 lbs/acre	80 lbs/acre	
P	13 lbs/acre	38 lbs/acre	
K	390 lbs/acre	600 lbs/acre	
S	40 lbs/acre	33 lbs/acre	

\# Treatment means followed by the same letter are not significantly different at the 5.0% level. (Duncan's New Multiple Range Test)

Table 2. Protein content of Era wheat - West Polk County - 1971 .

Treatments (lbs. N/acre)	Miski	Gulbranson August 11	Gulbranson August 16
		% protein	
Check	12.0 a #	12.0 a	10.8 a
Seeding - May 19			
60	12.7 ab	12.8 b	13.1 b
120	13.6 bcd	14.1 def	13.3 bc
180	14.1 cd	14.3 ef	13.7 bcd
Stooling stage June 11			
60	13.4 bc	13.0 bc	10.8 a
120	14.0 cd	13.7 cde	14.8 de
180	14.1 cd	13.7 cde	14.8 de
Flowering stage - June 30			
60	13.6 cd	13.4 bcd	12.7 b
120	13.7 cd	14.5 f	14.3 cde
180	14.4 d	14.0 def	15.0 e
Significance			
Rep	NS	NS	NS
Treatment	**	**	**
C.V.	4.14	3.58	5.83

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

THE EFFECT OF NITROGEN RATES ON CHRIS AND ERA WHEAT UNDER IRRIGATION

A.C. Caldwell and D. Fairchild, Department of Soil Science

Five rates of N, (0, 25, 50, 75 and 100 lb/A) were applied broadcast just after planting time to plots of Chris and Era wheat on an irrigated Hubbard sandy loam near Park Rapids, Minnesota. A basic starter fertilizer of 8-16-32 + 2 1/2 S was applied at 150 lb/A. Yield data are given in the table.

There were no effects of N rates on Era, but 50 lb/A and heavier rates of N increased yields of Chris significantly. Era out yielded Chris on the average about 10 bushels per acre, but yields of both varieties were quite low.

There were several contributing factors to the unsatisfactory yields. Rainfall was sparse, and below normal in May (before irrigation was started), and there was some hail damage. Temperatures, also, were below normal for the growing period.

It is hoped to repeat this experiment in 1972.

Yields of Era and Chris as affected by nitrogen rates under irrigation.

	Variety	
	Era	Chris
*N rates lb/A	Yield	bu/A
0	27a**	19a
25	31a	18a
50	29a	23b
75	32a	24b
100	30a	24b

* N applied broadcast as ammonium nitrate.

** Any letter(s) different from another letter in a column indicates a significant difference between the means at the 5% level.

SOYBEAN FERTILIZER PLACEMENT STUDY

G. E. Ham, S. D. Evans, W. W. Nelson and V. L. Ferch

Different N fertilizer rates and P and K fertilizer placement were studied at Lamberton, Morris, and Waseca. Main plots were broadcast P and K which were split into three nitrogen rates (0, 50 and 100 lbs per acre). Each nitrogen rates was divided into row fertilizer treatments (check, seed placement, 2 x 2 band and a combination of band and seed placement). Treatments, fertilizer rates, soybean variety and seed yields are shown in Tables 1, 2 and 3. The response to N fertilizer without P and K was not significant at any location. N fertilizer did increase yields significantly when used with P and K fertilizer at all locations. Broadcast P and K alone did not increase yields compared to row fertilizer alone.

Table 1.

EFFECT ON SOYBEAN SEED YIELD WHEN DIFFERENT FERTILIZER PLACEMENTS WERE APPLIED TO CORSOY SOYBEANS GROWN AT WASECA, MINNESOTA IN 1971.

Starter Fertilizer	0 No Bdcst	0 Bdcst-	50 No Bdcst	50 Bdcst	100 No Bdcst	100 Bdcst
	bu/acre					
Check	34 a*	36 a-c	34 a	38 b-e	37 a-d	36 a-c
Seed Placement	34 a	36 a-c	39 c-f	43 gh	37 a-d	40 d-g
Band	35 ab	34 a	37 a-d	37 a-d	38 b-e	36 a-c
Band + Seed Placement	35 ab	38 b-e	39 c-f	41 e-h	44 h	42 f-h

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)

* Yields followed by the same letter or letters are not significantly different at the .05 level. Yields followed by 2 letters with a hyphen are included in all groupings between the two letters.

Table 2.

EFFECT ON SOYBEAN SEED YIELD WHEN DIFFERENT FERTILIZER PLACEMENTS WERE APPLIED TO CLAY SOYBEANS GROWN AT MORRIS, MINNESOTA IN 1971.

Starter Fertilizer	0		50		100	
	No Bdcst	Bdcst	No Bdcst	Bdcst	No Bdcst	Bdcst
			bu/acre			
Check	24 a*	27 bcd	26 abc	31 ef	26 abc	25 ab
Seed Placement	26 abc	27 bcd	29 de	28 cde	31 ef	28 cde
Band	26 abc	27 bcd	28 cde	33 f	29 de	27 bcd
Band + ZN	25 ab	28 cde	29 de	29 de	33 f	29 de

Fertilizer rates:

Band	10 + 20 + 10
Seed placement	4 + 8 + 4
Broadcast	0 + 60 + 30
$ZnSo_4$ (Zn)	10

Soil test values:

pH	7.7	
P	7	lbs/acre (low)
K	300	lbs/acre (high)

*See Waseca Table .

Table 3.

EFFECT ON SOYBEAN SEED YIELD WHEN DIFFERENT FERTILIZER PLACEMENTS WERE APPLIED TO CORSOY SOYBEANS GROWN AT LAMBERTON, MINNESOTA IN 1971.

Starter Fertilizer	0		50		100	
	No Bdcst	Bdcst	No Bdcst	Bdcst	No Bdcst	Bdcst
			bu/acre			
Check	25 a*	27 a-c	26 ab	30 d-f	26 ab	31 ef
Seed Placement	28 b-d	28 b-d	29 c-e	30 d-f	28 b-d	31 ef
Band	28 b-d	28 b-d	30 d-f	29 c-e	32 f	30 d-f
Band + Seed Placement	29 c-e	29 c-e	31 ef	30 d-f	31 ef	31 ef

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

Soil test values:	p^H	5.7
	P	10 lbs/acre (low)
	K	290 lbs/acre (high)

* See Waseca Table

SOYBEAN NITROGEN FERTILIZER STUDIES

G. E. Ham, W. W. Nelson, S. D. Evans and V. L. Ferch

Ammonium nitrate at the rate of 0, 5, 10 and 15 pounds N per acre was applied with the seed and 25 and 50 pounds N per acre was banded 2 inches to the side and 2 inches below the seed at Lamberton, Morris and Waseca. Soybean varieties and seed yields are shown in Table 1. N increased the seed yield of Merit at Morris, and Corsoy at Waseca. At Waseca, 15 pounds N per acre with the seed decreased seed yield. N did not affect seed yield at Lamberton.

Table 1.

EFFECT OF SEED ZONE OR BANDED NITROGEN FERTILIZER ON SOYBEAN SEED YIELDS IN 1971.

Row Fertilizer Nitrogen	Morris		Lamberton		Waseca	
	Soybean variety					
	Merit	Clay	Merit	Corsoy	Merit	Corsoy
	bu./acre					
0	26 a[+]	33	36	37	31 b	35 a
5	29 bc	30	34	38	31 b	34 a
10	27 ab	32	37	38	32 b	34 a
15	29 bc	30	35	38	27 a	36 ab
25*	29 bc	32	36	38	32 b	37 ab
50*	30 c	32	36	37	33 b	39 b

*25 and 50 lbs. N were banded, other rates placed with seed.

+ Yields under a given variety having the same letters are not significantly different at the .05 level.

SULFUR FERTILIZATION OF CORN AND ALFALFA IN SOUTHERN AND WESTERN MINNESOTA

D. S. Fairchild, W. E. Fenster,
O. M. Gunderson, W. W. Nelson [1]

Ten field experiments were established in 1971 to study the effects of sulfur rates and forms on corn and alfalfa production. All sulfur treatments were applied in the spring of 1971 with the exception being the Lamberton site which was fertilized in 1970.

Continued sulfur research is needed in Minnesota Agriculture as a result of increased use of high-analysis fertilizers that are low in sulfur, increased crop yields, decreased gains of atmospheric sulfur and decreased use of sulfur as a pesticide.

General information on the experimental sites is given in Table 1. Soil test results are shown in Table 2. Sites were selected that had previously tested medium to low in available sulfur. The final sulfur soil test values given in Table 2 were higher than originally anticipated. This may have been due to accidental incubation and subsequent sulfofication which resulted after collection of the samples.

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(1) Efforts of Bobby McCaslin and Paul Groneberg on plot work and statistical analysis are greatfully acknowledged.

Table 1. Location and Soil Type of Experimental Site

Location	Soil Type
Southwest Experiment Station Redwood Co.	Webster Clay Loam
J. Welti Wabasha Co.	Port Bryon Silt Loam
M. Voth Goodhue Co.	Undetermined
J. McCormick Houston Co.	Fayette Silt Loam
L. Kulberg Renville Co.	Nicollet Loam
C. Phillips Chippewa	Borup Loam
Weispfinnig Pope Co.	Esterville Loam
A. Hauge Pope Co.	Osakis Loam
F. Loquai Dodge Co.	Kenyon Silt Loam
G. Von Ruden Steele Co.	Undetermined

Table 2. Soil Test Levels of Experiment Sites.

Location	P	K	S	pH	O.M
	---lbs/A---		p.p.m.		
Redwood Co.	27	235	11	5.9	H
Wabasha Co.	68	390	16	6.8	M
Goodhue Co.	34	350	23	5.9	M
Houston Co.	65	190	16	6.6	M
Renville Co.	45	440	30	6.8	H
Chippewa Co.	52	500	19	7.9	H
Pope Co. (Corn site)	141	280	15	6.4	M
Pope Co. (Small Grain)	18	140	20	5.9	M
Dodge Co.	58	310	19	6.0	M
Steele Co.	28	240	10	6.1	M

A randomized complete block design was used with five treatments replicated six times. The fertilizer treatments were as follows:

Corn Sites	Form of Sulfur	Alfalfa Sites
0 lbs S/A		0 lbs S/A
25 lbs S/A	K_2SO_4	50 lbs S/A
25 lbs S/A	elemental S	50 lbs S/A
50 lbs S/A	K_2SO_4	100 lbs S/A
50 lbs S/A	elemental S	100 lbs S/A

The study at Lamberton included residual sulfur rates of 0, 20, and 100 lbs/A of elemental Sulfur replicated nine times.

All cooperators used optimun rates of N, P and K with good weed and insect control.

Plant tissue samples were collected at the following stages of growth:

1. Corn - whole plants at 10 inches in height and the 6th leave at silking,
2. Alfalfa - Top 1/3 of plant at harvest, and
3. Small grain - Flag leaf at dough stage.

Total nitrogen in tissue was determined by the Micro-Kjeldahl method, and other elements were determined in a multi-element emission spectrophotometer. Sulfate-sulfur in plant tissue was determined by digestion with nitric and perchloric acids. Analysis of sulfur in plant tissue has not been completed as yet. No consistent or significant sulfur interaction with the following elements were noted: N, P, K, Ca, Mg, AL, Fe, Zn, Cu, Mo, Mn and B.

Crude protein determination on the grains showed no significant increase with varying rates of sulfur.

Yields of grain and forage are reported in Tables 3, 4, 5 and 6. Corn yields ranged from 89 - 196 bu/A between experimental sites, but no significant differences were noted within any experiment at the 5.0 or 10.0% level. Only two cuttings of alfalfa were taken in 1971 due to a lack of moisture in late summer.

Table 3. Sulfur treatments and Corresponding 1970 and 1971 Corn Yields at Lamberton.

Fertilizer Treatment lbs/S/A	1970	1971
	----------bu/A----------	
0	155	113
20	157	114
100	154	109
Significance	N.S.#	N.S.

#Not significantly different at the 5% level.

TABLE 4

1971 Corn Yields on Sulfur Fertilization Trials

Treatments	Pope County	Houston County	Wabasha County	Goodhue County	Renville County	Chippewa County
	---------------	Bu/A Shelled	Corn (15.5%)	---------------		
0 lbs. S/A	98	193	145	142	111	90
25 lbs S/A (K_2SO_4)	101	190	144##	144	119	89
25 lbs S/A (Sol-U-Sul)	102	192	157	145	118	90
50 lbs S/A (K_2SO_4)	98	196	157	146	113	90
50 lbs S/A (Sol-U-Sul)	101	184	151	143	114	100
	N.S.#	N.S.	N.S.	N.S.	N.S.	N.S.

N.S. - Not Significantly different at the 5.0% level.

- Yield increases of 0 - 13 Bu/A are indicated in Table 1, but are not statistically different because of variation within plots. Yield increases are the result of chance and not treatment effect.

TABLE 5

1971 Oat Yields on Sulfur Fertilization Trials

Treatments	Pope County	Dodge County
	----------------Bu/A----------------	
0 lbs S/A	63	51
50 lbs S/A (K_2SO_4)	65	47
50 lbs S/A (Sol-U-Sul)	64	47
100 lbs S/A (K_2SO_4)	65	50
100 lbs S/A (Sol-U-Sul)	67	49
	N.S.#	N.S.

#N.S. -- Not significantly different at the 5.0% level.

TABLE 6

1971 Alfalfa Yields on Sulfur Fertilization Trials

Treatments	Steele County 1st Cutting	2nd Cutting	Total
	Tons/A		
0 lbs S/A	2.2	2.0	4.2
50 lbs S/A (K_2SO_4)	2.2	1.9	4.1
50 lbs S/A (Sol-U-Sul)	2.2	2.0	4.2
100 lbs S/A (K_2SO_4)	2.2	1.8	4.0
100 lbs S/A (Sol-U-Sul)	2.1	2.0	4.1
	N.S.[#]	N.S.	N.S.

[#] N.S. - Not significantly different at the 5.0% level.

1972 EXPERIMENTS

The present plots, with the exception of the Lamberton site, will be continued to study residual effects of sulfur. One additional site at the Waseca experiment station will include use of varying rates of sulfur to determine if starter sulfur responses may be realized.

SOIL TESTING

John Grava

Currently the University of Minnesota Soil Testing Laboratory processes over twenty-eight thousand samples annually. The following data show the number of various types of samples analyzed in 1971.

Regular farm, garden and lawn samples		20,438
Florist (greenhouse) samples		1,821
Specials: Nitrate		1,538
Sulfur		1,264
Zinc		702
Soluble Salts		292
pH		448
Limestone		16
Departmental research samples		1,994
	TOTAL	28,513

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 1971.

MONTH	NUMBER OF SAMPLES
January	414
February	435
March	859
April	4,665
May	1,907
June	836
July	896
August	2,174
September	2,995
October	2,922
November	1,683
December	651

SUBJECT INDEX