SOIL SERIES 89

A REPORT ON FIELD RESEARCH IN SOILS

The 1973 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 1972 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 Company; 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; Howe Incorporated; International Harvester Company; International Minerals and Chemical Corporation; Jacques Seed Company; King Gas Company; Midland Cooperatives; Minnesota Crop Improvement Association; Minnesota Golf Course Superintendents Association;

Minnesota Limestone Producers Association; Minnesota Plant Food Association; Minnesota Soil and Water Conservation Commission; Monsanto Chemical Corporation; Montana Sulphur and Chemical Company; Natro-Gro, Inc.; Olin Agricultural Division; J. L. Shiely Company; Smith-Douglas Division of Bordens Chemical; St. Paul Ammonia Products; Tennessee Corporation; Tennessee Valley Authority; Trojan Seed Company; The Fertilizer Institute; U.S. Borax and Chemical Corporation; and Wyandotle Chemical Corporation.

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

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Climatological Notes of 1972

by D. G. Baker

I. Review of the 1972 Weather.

by E. L. Kuehnast and D. G. Baker.

The year 1972 shall be long remembered as one of the coldest years, a summer with many flash floods and a "month without the sun". The year was the coldest since 1917; Minneapolis-St. Paul mean temperature in 1917 was 40.6 degrees and for 1972 - 41.3 degrees. Flash floods occurred in every month from May through September. The month of November received the least amount of sunshine of any month since sunshine records began.

Yet the year can be classified as a quiet and peaceful year with respect to severe storms. There were only five tornadoes, compared with the normal of 17 per year, and all five were weak and caused little damage. Also there were less than the average number of damaging hail, wind and snow storms during the year.

January

January was a very cold month with temperatures averaging near 8 degrees below normal across the State. The minus 53 degrees below zero at Moose Lake on the 15th was the coldest temperature in Minnesota since 1936 when Warroad had a minus 55 degrees. Blizzards occurred on the 12th in the north and on the 24th across the whole State.

February

The second consecutive very cold month with temperatures averaging 6 degrees below normal, though precipitation was near normal. One blizzard occurred on the 17th.

March

Slightly below normal month though cold the first ten days, then warm the next 10 days which melted the very early snow cover which began on November 23, 1971. Heavy rains for March of near one inch across the central part of the State occurred on the 21st.

Winter 1971-72

The winter was cold, temperatures averaging 5 degrees below normal. Precipitation was near normal with 3 blizzards.

April-May

Temperatures continued to be below normal averaging near 3 degrees below normal until the 15th-16th of May when temperatures rose from the low 60's into the 80's and 90's and remained high the rest of the month. Heavy rains off and on in the Southwest and West Central Districts continued to delay planting of crops.

June

A relatively dry month with cool temperatures. A flash flood of 8 inches near Madelia on the 7th and 8th. The ice went out of Duluth Harbor on the 9th, only in 1917 had it stayed this late in the season.

Spring

Generally cool except the last half of May which was hot. Rainfalls spotty, with West Central and part of the Southwest District so wet that some farmers were unable to plant a crop.

July

Cold and wet month with rainfalls double the normal amount. The flash flood on the 21st and 22nd was the "grand-daddy" of any flashflood to date within the state. It covered the largest area, had the greatest amount of rainfall and could be the most damaging (once all statistics are in). There were unofficial rainfalls of

more than 13 inches through central Minnesota.

August

Variable with cold, hot then cool ten day periods for the month. Dry in the northwest and south but wet from central through northeast. Duluth and the North Shore had four days with flash floods. The most damaging flood in Duluth's history occurred early morning of the 21st. Property damage was heavy.

September

Cool with exceptionally variable rainfalls, wet in the east and relatively dry in the west. Flash floods again in Duluth and the North Shore on the 20th.

Summer

Cold summer and wetter than normal with many local flash floods. There was only one summer hot spell, a 10 day period in min-August.

October

Very cold and wet with bitter cold wave in mid-October with the season's first significant snowfall of 2 to 4 inches on the 17th and 18th along the southern border.

November

November will be remembered as the "month without the sun" because this was the least amount of sunshine for any month for Minnesota since sunshine records began in 1897. Analysis of the data shows that the State received about 15 percent of possible sunshine. Temperatures were normal and precipitation below normal, with little to no snow during November.

December

Temperatures averaged 8 degrees below normal. The first half of December was the coldest early December ever with 15 consecutive

days having below zero temperatures. Blizzard conditions on the 30th.

Fall

It was a fall of extremes with temperatures alternating several times from warm to extreme cold. Very wet up to the first several days of November then very dry the rest of the fall. Long periods of cloudiness, Minneapolis had a string of 23 days with a total of only 6 hours of sunshine which included a period of 16 consecutive days of no sun, a new record.

At St. Paul the solar radiation has been measured for 10 years with the result that some special remarks can be made relative to the above comments on the summer of 1972 being a "cold summer and wetter than normal" and November as the "month without a sun".

First the solar radiation in 1972 at St. Paul was found to be only 90% of the average for the year as a whole as well as for the May-September 1972 growing season. This, of course, is a reflection of the increased cloud cover during the summer. Secondarily, November was found to have received only 59% of the average amount of radiation. Little wonder then that it could be called the "month without the sun".

A question arises then that with the generally below normal temperatures and less than normal solar radiation why were crop yields as good as they were? It would appear that although temperature and radiation were probably not at optimum levels, the soil moisture remained at a fairly high level. And in particular the

rains were generally distributed so that in most areas the crops were never really subjected to a moisture stress. Material in the following section would seem to indicate this to be true for a large part of the state.

A note should be made here with respect to the very cold temperatures of early December that occurred before an adequate blanket of snow covered the soil. It is quite possible that this condition may be a warning that the winter-kill of plants such as alfalfa may be higher than usual. As a result of the early December low temperatures the soil frost may be more of the "concrete" type than the more porous type that is less damaging to roots.

II. Soil Moisture Survey.

by Donald G. Baker

The soil moisture at the end of the 1972 season was adequate to surplus at all stations sampled except perhaps at Crookston as shown by Table 1.

The column in Table 1 headed "Water Use by Crops" is interesting. Except for the Long Prairie, Todd Co., site the data appear to give very reasonable results with respect to the amount of water used by crops based upon our simple estimates. The Todd Co., results are incorrect due to the heavy rains of July 21-22 which resulted in severe flooding and much runoff. The other stations show that about 17-20 inches are required for most annual crops. The Crookston, Polk Co., data illustrate once again that a crop that grows actively throughout the season such as alfalfa is a large water user compared to annuals at the same site.

Table 1. The 1972 Soil Moisture Survey Results

Station	Sample Dates[1]	Soil H_2O Present[2]	Precip-itation[3]	Water Use by Crop[4]	Crop	Soil Type
Hayfield, Dodge Co.	6/14 11/30	7.87 in 9.04 -1.17 in	20.57 in.	17.34in.	Soybeans	Kasson silt loam
Milaca, Mille Lacs County	5/9 11/9	11.27 14.90 - 3.63	23.99	17.96	Hay	Mora silt loam
Crookston, Polk Co.	5/4 11/1	8.78 5.71 3.07	14.24	15.89	Barley	Hegne silty clay loam
Crookston, Polk Co.	5/2 11/1	10.34 1.81 8.53	14.26	21.36	Alfalfa	Hegne silty clay loam
Crookston, Polk Co.	5/16 11/1	7.63 3.98 3.65	13.38	15.69	Sugarbeets	Hegne silty clay loam
Lamberton Redwood County	5/19 10/25	7.00 6.09 0.91	19.10	18.10	Corn	Nicollet clay loam
Winthrop Sibley Co.	missing 11/1	8.94	--	--	Soybeans	Nicollet clay loam
Long Prairie, Todd Co.	5/10 10/6	13.94 10.12 3.82	31.80	32.44*	Alfalfa	Clovers loamy fine sand
Kellogg Wabasha Co.	4/18 10/25	9.87 13.53 - 3.66	25.29	19.10	Soybeans	Fayette silt loam
Butter-field, Watonwan County	4/10 11/14	9.42 8.56 0.86	21.72	20.41	Corn	Nicollet clay loam

Table 1. (continued)

1. Date in spring and fall when soil sample was obtained.
2. The amount of plant available water in a five foot column of soil.
3. The precipitation measured at nearest National Weather Service Cooperative Station between the soil sample dates.
4. The amount of water presumed to be used by the crop between soil sample dates. It is estimated that 10% of the precipitation is lost by either surface runoff, downward drainage or both.

* Obviously the crop did not use this much water. Much of the precipitation was lost in runoff from the heavy rains of July when a total of 15.55 inches was measured at Long Prairie. Most of the July precipitation fell on July 21-22 when a total of 10.12 inches was measured.

Fig. 1 shows the 1972 soil water profile obtained through the growing season at Lamberton, Redwood Co., compared to an eleven year average. This figure may explain at least in part why in spite of the generally below normal temperatures and below normal solar radiation that the crop yields were as good as they were. That is, there was water present in the soil when needed, and the plants never really suffered from a drought. This is particularly evident in Fig. 1 during the mid- to late- July period when silking begins and the water supply to the plant is apparently quite critical.

There is some additional information obtained as a result of the long-term nature of the soil moisture data that will be of interest to some readers. Table 2 shows the amount of water consumed by a corn crop (evapotranspiration) at Lamberton, Redwood Co., if the assumption that 10% is lost as either surface runoff, drainage through the profile or both. We have to make this simplifying assumption for we do not have the facilities to measure such losses at this time. Runoff measurements of the Cottonwood River watershed, in which Lamberton lies, show that this estimate of 10% loss of precipitation is an acceptable one.

Dr. Olaf Soine has been measuring the soil moisture during the course of the growing season under a number of crops at the Northwest Experiment Station, Crookston, since 1962. Table 3 is a summary of these data. Except when grown in the same year a rigorous comparison between crops with respect to the water consumption cannot be made. For several of the crops, however, enough years have been sampled that a good idea of the water needs of these crops can be obtained.

Table 2. Amount of water consumed by corn crop (evapotranspiration loss) during indicated periods assuming 10% of growing period precipitation is not available for use. Data based upon soil moisture and precipitation measurements by Dr. W. W. Nelson, Southwest Experiment Station, Lamberton.

Year	Period	Water Consumed
1961	5/1-10/2	17.55 inches
1962	5/1-9/26	21.01
1963	5/1-10/19	19.00
1964	5/1-10/1	18.84
1965	5/10-10/6	17.95
1966	5/17-10/17	17.55
1967	4/26-10/21	13.65
1968	4/30-9/13*	17.72
1969	Too wet for late season samples	
1970	4/27-10/5	18.14
1971	5/5-9/17*	16.01
1972	5/19-10/25	18.10
Average		17.77 inches

* A later sample would have been preferred, but it was too wet for sampling. However, little water is lost by evapotranspiration after mid-September.

Table 3. Amount of water consumed (inches) by various crops (evapotranspiration loss) during indicated periods assuming 10% of growing period precipitation is not available for use. Data from soil and precipitation measurements by Dr. Olaf Soine, Northwest Experiment Station, Crookston.

Year	Crop						
	Alfalfa	Barley	Corn	Pasture	Soybeans	Sugarbeets	Wheat
	Period Use						
1962	5/7-10/1 18.32				4/25-10/1 16.19	5/31-10/1 14.78	
1963	5/4-10/1 12.87					5/8-10/3 17.69	5/10-10/3 15.90
1964		5/1-10/1 12.84	5/1-10/1 12.46			5/1-10/1 17.37	
1965						5/28-10/1 10.59	5/17-10/1 12.97
1966				5/9-9/30 15.26		5/31-9/30 25.90	5/31-9/30 12.90
1967				5/18-10/3 13.70		5/26-10/3 16.66	
1968			5/17-10/1 17.03			6/5-10/1 16.06	5/20-10/1 16.10

Table 3. (continued)--

Year	Crop													
	Alfalfa		Barley		Corn		Pasture		Soybeans		Sugarbeets		Wheat	
	Period	Use												
1969			5/3-10/1	16.86							5/10-9/30	17.74	5/30-10/1	13.40
1970	5/13-10/1	23.50									6/2-10/1	18.19	5/18-10/1	14.12
1971	4/30-10/4	16.46									4/30-10/4	21.86	5/7-10/4	11.52
1972	5/2-9/28	19.27	5/4-9/28	13.64							5/16-9/29	12.39		
Average		18.08		14.45		14.75		14.49		16.19		17.25		13.84

Once again I would like to express my appreciation to the following individuals who have been responsible for supplying the soil moisture samples or the computed moisture content of their samples.

Steven F. Crull, District Conservationist, U.S.D.A., Owatonna, Minn.

Duane T. Goerend, District Conservationist, U.S.D.A., Gaylord, Minn.

Roger W. Hoff, District Conservationist, U.S.D.A., Wabasha, Minn.

Lee R. Johnson, District Conservationist, U.S.D.A., St. James, Minn.

William H. Kalton, District Conservationist, U.S.D.A., Milaca, Minn.

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

Wallace W. Nelson, University of Minnesota, Southwest Experiment Station, Lamberton, Minnesota.

Olaf C. Soine, University of Minnesota, Northwest Experiment Station, Crookston, Minnesota.

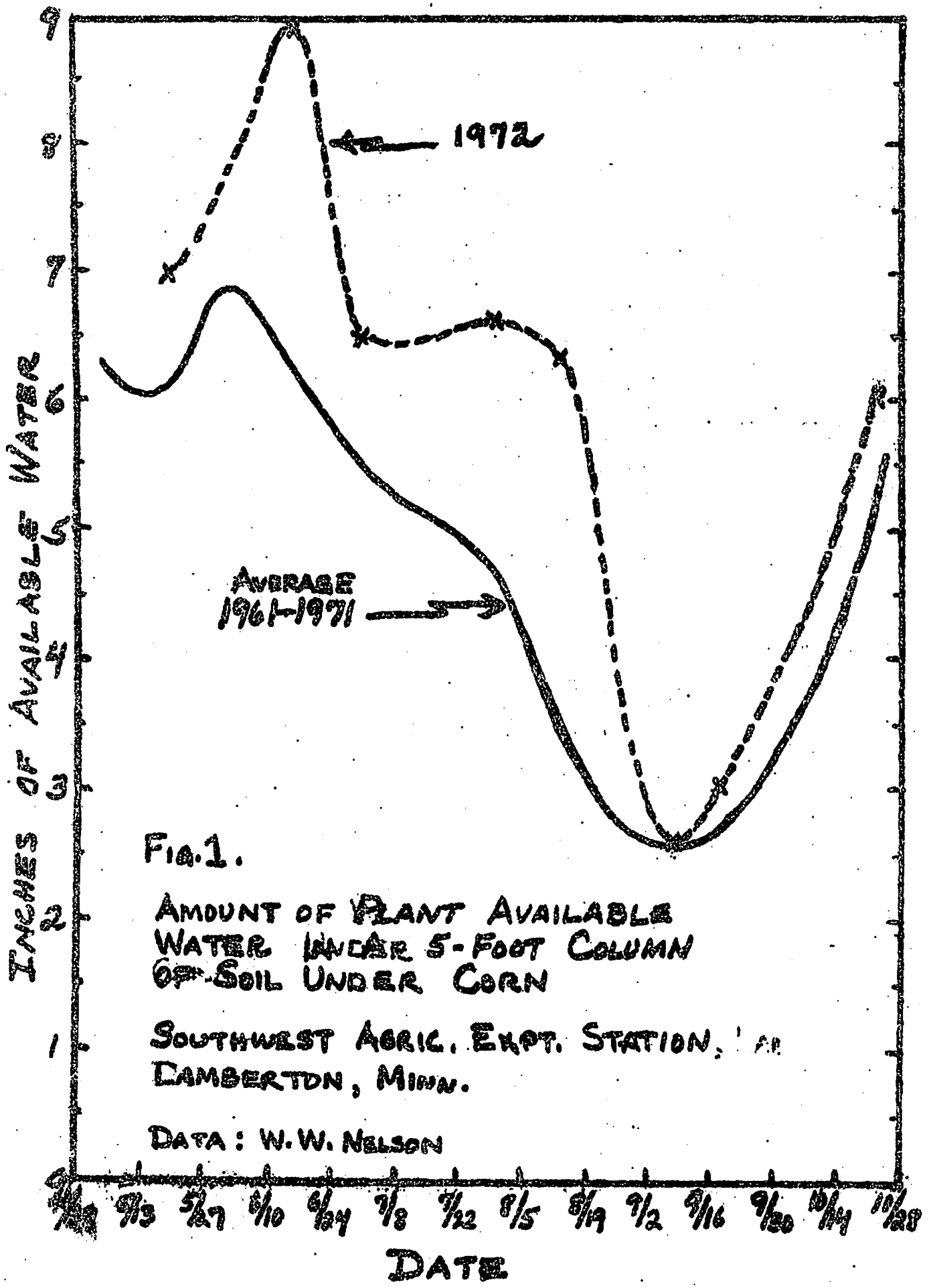

FIG. 1.

AMOUNT OF PLANT AVAILABLE WATER UNDER 5-FOOT COLUMN OF SOIL UNDER CORN

SOUTHWEST AGRIC. EXPT. STATION, LAMBERTON, MINN.

DATA: W. W. NELSON

III. The Future Farmers of America Project
Rain Gage and Phenological Observations
by Donald G. Baker.

The observation of weather in the United States is a function of the National Weather Service (formerly called the U.S. Weather Bureau), Department of Commerce. There are approximately 300 stations in the state with the majority maintained by voluntary observers. Two seasons ago the F.F.A. established the Operation Rain Gage as a project for their members to undertake. The objective of this project is to correctly measure and record all rainfall at the F.F.A. members residence for the 5 month period May through September. This project met with almost instant success for there were about 800 observers in 1971, and this last season there were more than 1200 members who took part. If this project can be continued the possibilities are tremendous with respect to the details that may be learned about the state-wide precipitation patterns, individual storms, and other matters relating to the hydrology of the state.

Thanks in large part to the F.F.A. observers two severe storms of the 1972 season have been recorded in great detail. One occurred near Madelia in northeastern Watonwan county on June 7-8. The second storm was on July 21-22 in Morrison and adjoining counties in North Central Minnesota. The magnitude of the storm was tremendous. Its areal extent was 6300 square miles and the area of more than 5 inches of rain equalled 3500 square miles. Nearly 180 square miles received 13 inches or more. As a result of the combined National Weather Service and Future Farmers of America networks of observers the latter storm may well be the best documented intense storm in the United States.

Fig. 2 shows a map of the rainfall as determined from a total of 245 observers; with 215 of these being members of the F.F.A. Rain Gage project. Lines are drawn for every 2 inches from a 2-inch total rainfall up to 12 inches with a dashed line for the 13 inch zone. An interesting feature of this map is the long and narrow orientation of the rain. This is a common feature of most storms. The reason is that the storm cell or cells from which the heaviest rain falls originate are moving with the upper winds. Because the cells are moving the rainfall distribution usually shows a configuration similar to that in Fig. 2. The high amount of rain that fell over such a large area is certain to be of utmost concern to the designers of structures that either carry or impede the movement of surface water.

One fact that seems to be emerging from these measurements is that the occurrence of high intensity storms in Minnesota is more frequent than previously suspected. The greater frequency of occurrence is not a matter of climatic change but undoubtedly due to the increased density of observers.

The F.F.A. Operation Rain Gage advisors are Mr. Earl Kuehnast and Joseph Strub of the National Weather Service and Donald Baker, Soil Science Department, U. of Minnesota.

Some of the members of the Minnesota F.F.A. also are taking phenological measurements of the crops raised on their farms. Like the precipitation measurements these are now in their second year but the number of observers is still very small. Nevertheless, some very interesting and useful information has been obtained from these measurements. The typical corn and soybean plants in Minnesota develop as shown in Figs. 3 and 4. It was also found that the average planting dates for corn and soybeans were May 13 and May 22,

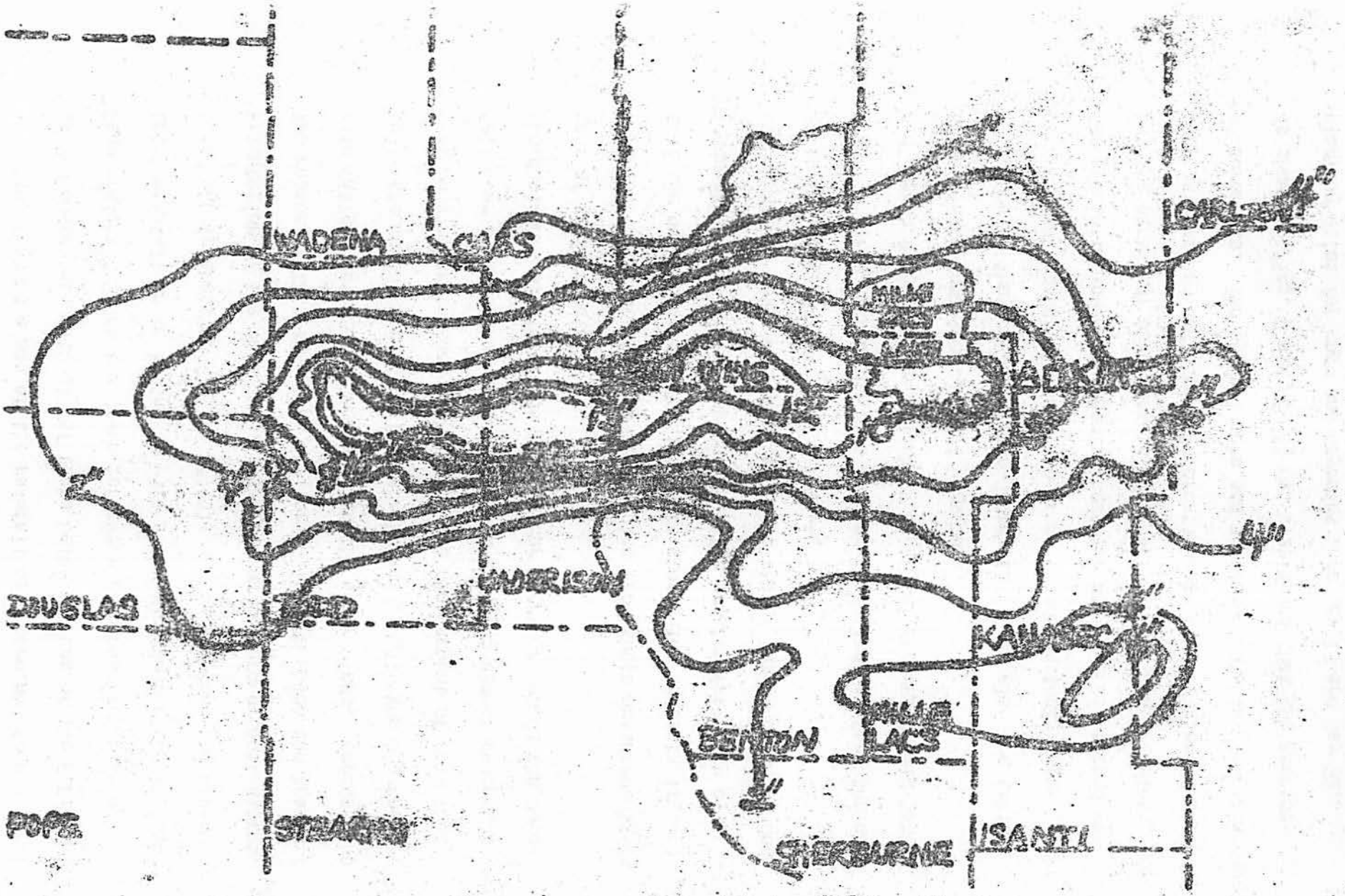

Fig. 2. RAINFALL OF JULY 21-22, 1972. (Map after E. L. Kuehnast, National Weather Service).

respectively.

General as the data shown in Figs. 3 and 4 are, as a result of plant, management, soil and climatic differences, they can be applied to certain practical matters. For example, in combination with certain climatological information it may be found advisable to advance or retard the silking period when meteorological conditions are so important. Plant height is of concern with respect to the design and use of agricultural machinery. And, too, knowledge of plant height or the number of days after planting can be used to estimate plant cover and other features. Data obtained from measurements made at the St. Paul Agricultural Experiment Station, Figs. 5 and 6, show that about 65% of the ground will be covered by soybeans about 60 days after planting in narrow (20 inch) rows and about 70 days after planting in wide rows of 36 inches. A plant cover of 65% is important for at this point the soil is well protected from "gully washers" and the soybean evapotranspiration is equal to that of a full plant cover. In general terms this condition of 65% cover is not reached in Minnesota until about the end of July with respect to soybeans.

We regret that we do not presently have data for corn similar to that shown in Figs. 5 and 6.

Fig. 7 shows the general configuration of the time when the corn plants reached 4 inches in height in 1972. This figure has the same general pattern as does the temperature isolines for the state: a warm area in south-central Minnesota which coincides with the early date of the 4 inch height; cooler temperatures and later dates when 4 inch height is reached in the southeast and southwest; the late season in the northwest; and virtually no crop and much

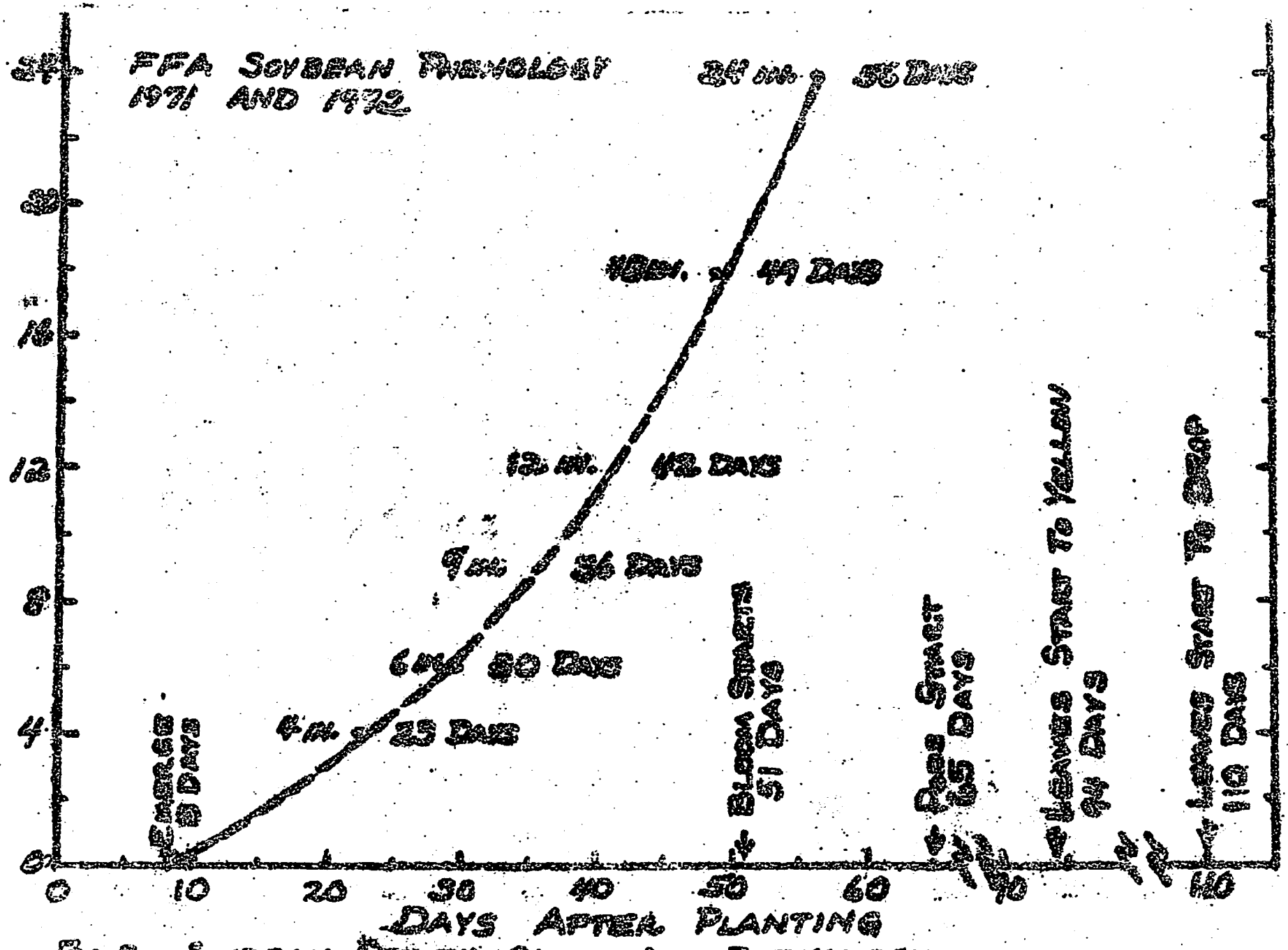

FIG. 3. SOYBEAN GROWTH CURVE AND PHENOLOGY.

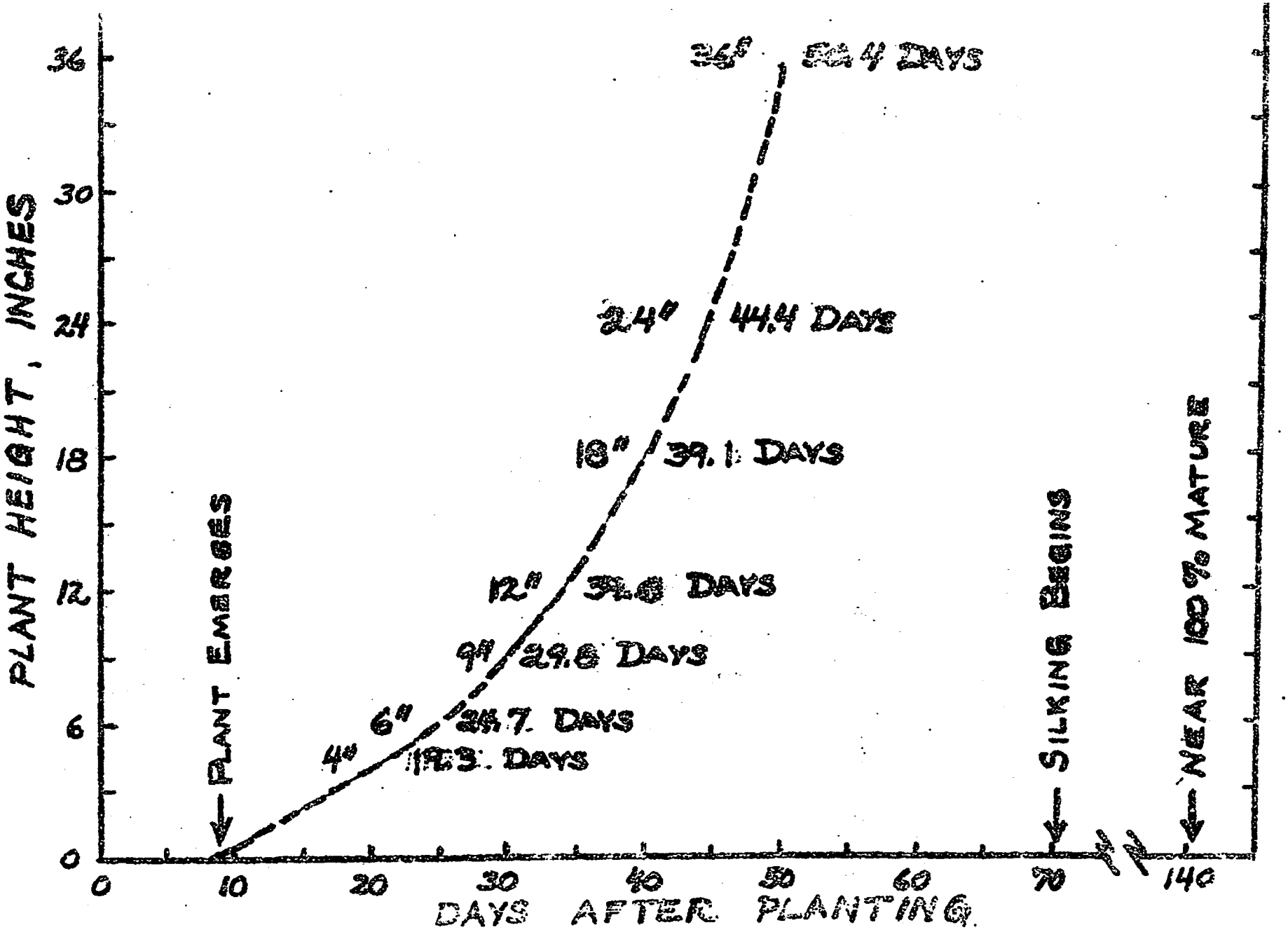

FIG. 4. CORN GROWTH CURVE AND PHENOLOGY

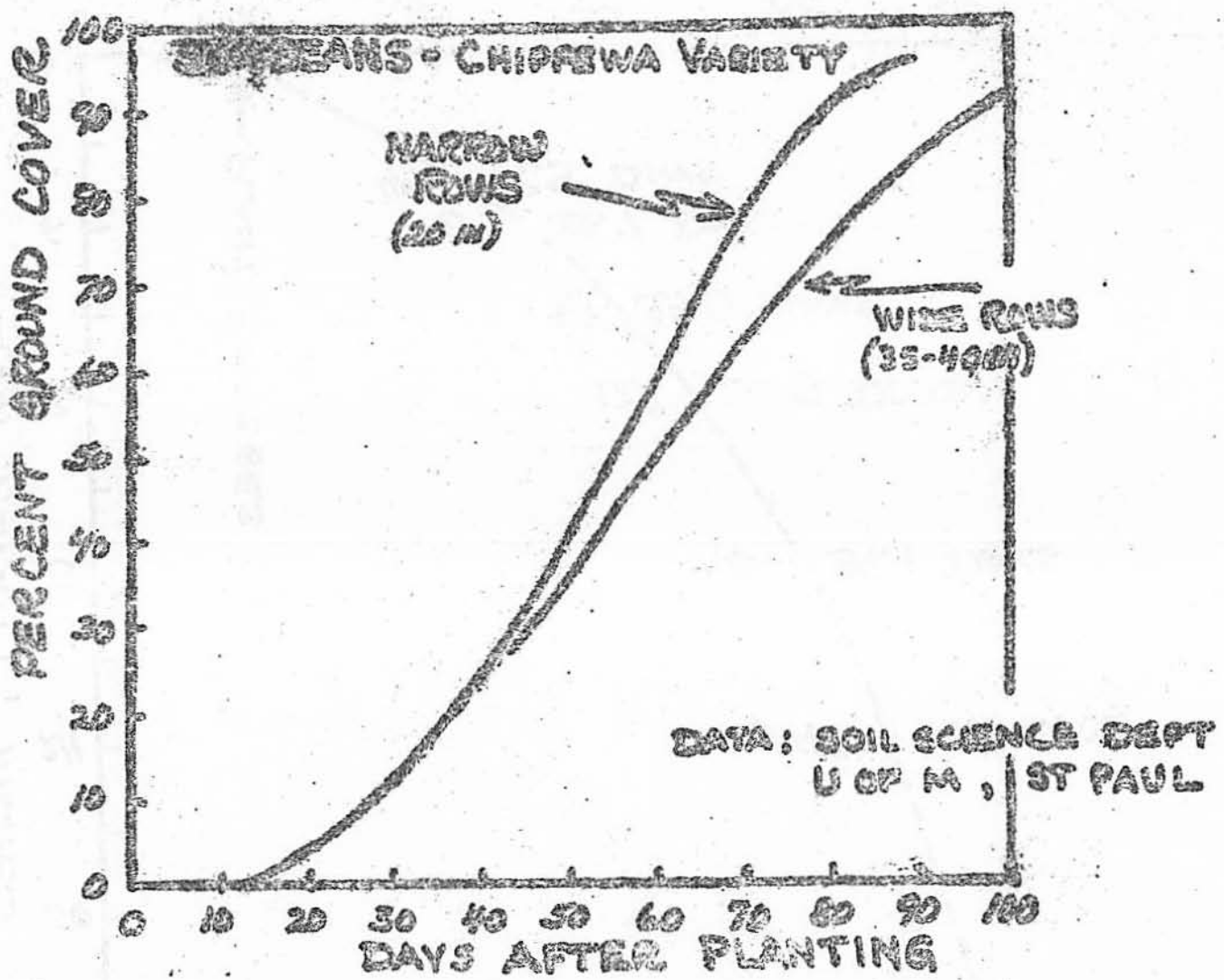

FIG. 5. CHANGE IN SOYBEAN COVER WITH TIME

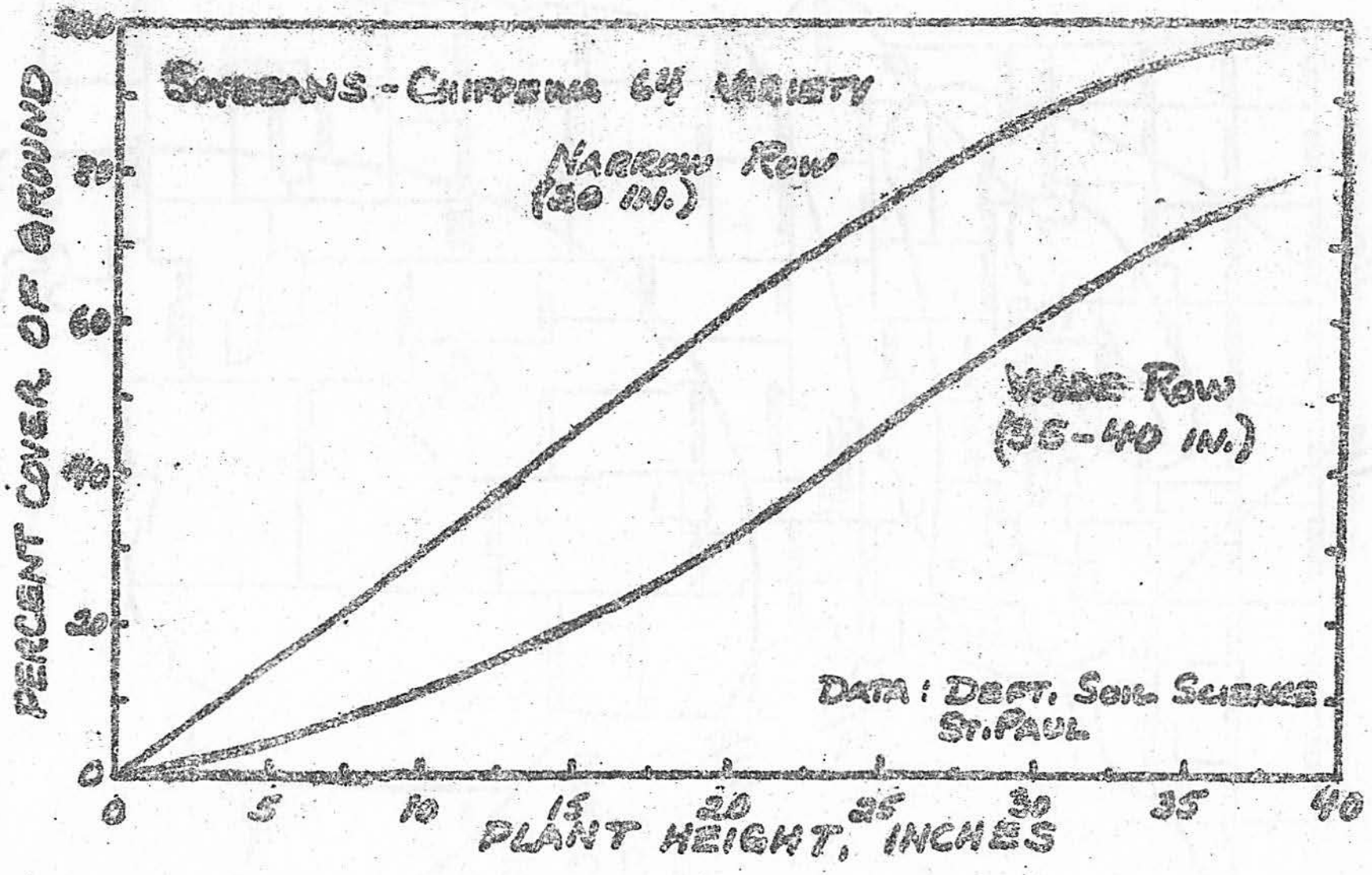

FIG. 6. RELATIONSHIP BETWEEN SOYBEAN HEIGHT AND COVER.

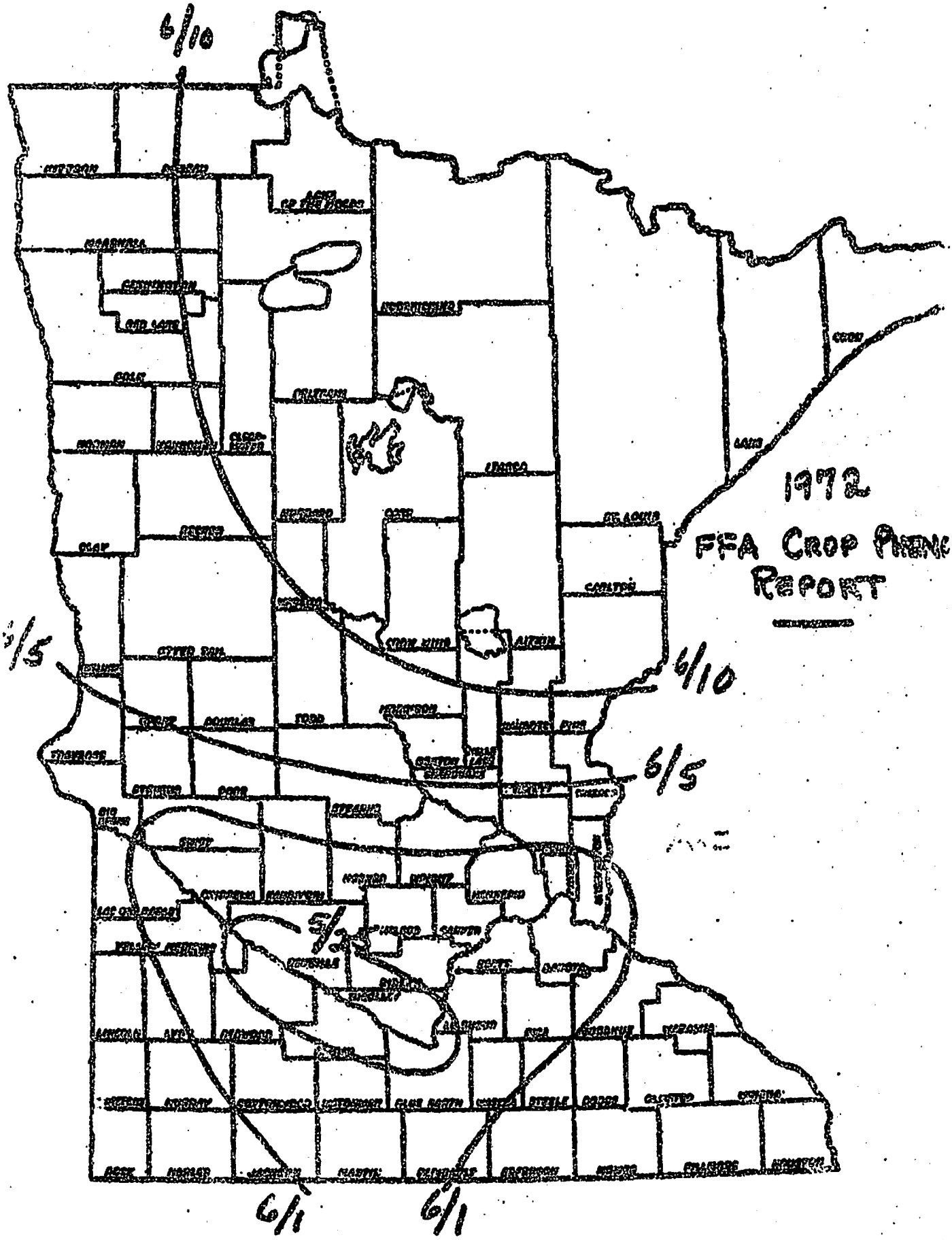

Fig. 7. Average Date in 1972 When Corn Reached 4 Inch Height

lower temperatures in northeastern Minnesota. Meager as the data are upon which Fig. 7 was drawn they do show the strong relationship between crops and temperature.

IV. Spring Runoff

by Donald G. Baker

Armchair reasoning suggests that in those regions where soils freeze measurement of winter precipitation should provide an excellent means of predicting the early spring runoff. The reasoning is as follows: little winter precipitation can enter the frozen soil; the soil cannot thaw to any great extent until free of the precipitation of winter; and therefore most precipitation must be long as spring runoff.

A study was made with the objective of verifying, if possible, the above reasoning and to show that winter precipitation can be used as a predictive tool in spring runoff forecasts.

From the study conducted a high correlation was found between the precipitation that fell when soils were frozen (defined as the "cold period") and the early spring runoff in 8 of 10 watersheds in southern and central Minnesota. The "cold period" precipitation thus becomes a useful tool in predicting early spring runoff amounts in those areas where soils freeze. The results also indicated that the "cold period" precipitation can be entirely accounted for by runoff and sublimation (or evaporation). It was found that additions to the soil water reserves need not be called on to satisfy an accounting of the disposal of the "cold period" precipitation. This runoff prediction method has the advantage of simplicity once a linear regression equation ("cold period" precipitation versus measured runoff) for a watershed is calculated. This method

requires only the measurement of soil temperature and precipitation at one station in each watershed.

The watersheds tested in this study largely lie within agricultural regions of relatively intense cultivation. In forested regions, where soils undergo a less intense winter thermal regime, results may differ from those found in this study.

An example of the "cold period", which was defined as the time when soils were frozen, can be obtained from measurements made at the Southwest Agricultural Experiment Station at Lamberton. The soil might be considered as frozen when the maximum daily soil temperature at 2 inches remains equal to or lower than 32°F. And it remains frozen until the minimum daily spring temperature at 12 inches rises and remains above 32°F. Based upon these criteria Table 4 shows the beginning and ending dates of frozen soil and the duration of this period as it occurred at Lamberton.

Table 4. Soil freezing and thawing dates and duration of the "cold period", Lamberton, 1961-1972.

	Soil Froze	Soil Thawed	Duration
	Dec. 6, 1961	April 24, 1962	139 days
	Dec. 7, 1962	March 29, 1963	112
	Dec. 8, 1963	April 10, 1964	123
	Nov. 20, 1964	April 21, 1965	152
	Nov. 27, 1965	March 30, 1966	123
	Dec. 1, 1966	April 1, 1967	121
	Dec. 14, 1967	April 2, 1968	109
	Dec. 6, 1968	April 14, 1969	129 *
	Nov. 28, 1969	March 17, 1970	109 *
	Dec. 7, 1970	March 30, 1971	113 *
	Dec. 26, 1971	April 11, 1972	106
Average:	Dec. 5	April 6	121

* Soil temperature remained relatively high throughout the winter and soil freezing was shallow. It is possible that drainage could have occurred within the soil almost throughout the winter. This certainly would be the case within soils that had a bit more insulation or vegetative cover.

Based upon data for the period 1961-1968 the early spring runoff from the Cottonwood River watershed, for example, expected for a given amount of precipitation within the watershed during the "cold period", that is, when soils are frozen, is shown in Table 5. Similar data have been obtained for 9 other watersheds in southern and central Minnesota.

Table 5. Predicted runoff from the Cottonwood River watershed as measured at New Ulm for given amounts of "cold period" precipitation.

Cold period Precipitation inches.	Runoff at New Ulm, inches.
0.50	0.00
1.00	0.00
1.50	0.00
2.00	0.21
2.50	0.66
3.00	1.12
3.50	1.58
4.00	2.03
5.00	2.94
6.00	3.85
8.00	5.67
10.00	7.49

SUGARBEET RESEARCH AT NORTHWEST EXPERIMENT STATION, CROOKSTON, IN 1972

Olaf C. Soine, Soil Scientist

Sugarbeet Rotation: The first four-year cycle of this field experiment has been completed, summarized and submitted for publication.

The effect of the six different rotations on the yield, percent sugar, purity, and sugar yield is given in Table 1. The three fallow rotations had the highest yields and highest impurities, while the last three had the highest percent sugar and lowest impurities. There was no difference in the recoverable sugar per acre between the six rotations.

Table 1. Effect of six rotations on yield, percent sugar, impurity index and sugar yield, 1967-70

Rotation	Yield T/A	Sugar %	Impurity* Index	Recoverable Sugar lbs/A
Black fallow	18.0	13.48	828	4258
Legume fallow	17.5	13.83	864	4213
Alfalfa fallow	17.1	14.29	769	4317
Barley	17.0	14.27	711	4342
Soybeans	16.9	14.36	753	4311
Oats	16.0	14.80	639	4286
LSD 5%	1.33	0.81	171	NS

It is interesting to note that beets following black fallow outyielded beets following the oat rotation by two tons per acre but the recoverable sugar yields were nearly identical. This occurred because beets following black fallow had lower percent sugar and higher impurity index. This index is calculated from the amount of sodium, potassium and amino-nitrogen in the beet "brei". Beets following the three fallow rotations contained larger amounts of these three materials which produced more sugar impurities and less recoverable sugar per acre.

Zinc: This zinc trial on sugarbeets in 1972 concludes three years of work with this fertilizer material in the Glyndon-Sabin area. The field data is given in Table 2.

Table 2. Effect of four rates of zinc on the yield and number of beets harvested, 1972, Glyndon.

Treatment	Rate lbs/A	Yield tons/A	No. beets harvested 60-ft. row
Check	0	17.5	50
Broadcast	10	17.2	53
Broadcast	20	17.4	48
Broadcast	40	17.1	52

Soil type: Glyndon silt loam, 2.2 ppm zinc.

The soil test of the plot area which contained 2.2 ppm of available zinc indicates that the beet crop had sufficient amounts of zinc. The data in Table 2 shows that there were no yield increases from the treatments.

Potash: There has been considerable interest in potash fertilization of sugarbeets even though the Red River Valley soil contains sufficient amounts. Generally the soils test from 300 to 600 lbs. of available potash per acre and additional potash will not increase yields. In order to check this out, a potash trial on beets was undertaken in 1972 at the Northwest Experiment Station and the results are given in Table 3.

Table 3. Effect of five rates of potash on yield and number of sugarbeets harvested, 1972.

Treatment	Rate lbs/A	Yield tons/A	No. of beets harvested/60 ft. row
Check	0	15.8	59
Broadcast	50	14.4	64
Broadcast	100	15.1	64
Broadcast	200	14.0	51
Broadcast	400	13.7	46

Soil test: pH 8.1
P 62 lbs/A
K 600 lbs/A
O.M.H.

The available soil potash was very high and the addition of the two high rates of fertilizer resulted in a significant yield reduction. This high potash concentration also reduced the stand of beets as indicated in Table 3.

Micro-Nutrients: Micro-nutrients are needed in very small amounts for plant growth and the Red River Valley soils contain adequate amounts of these elements. Two years of field testing with these nutrients have shown that sugarbeet yields were not increased and the beet plants were not deficient in micro-nutrients. Trials were conducted at Glyndon and the Northwest Experiment Station during 1971 and 1972 and the results are given in Table 4.

Sulfur is not a micro-nutrient but was included because of the interest in this element for beet production. The individual rates of boron, manganese, sulfur and iron were mixed and applied as one treatment and labeled "Blast".

Table 4. Effect of five different micro-nutrients on yield at Crookston and Glyndon, 1971-1972.

Treatment	Rate lb/A	Yield 1972	Yield 1971-72 (Ave. of 1971 & 1972 yields)
		-----tons/A----------	
Check	0	15.8	19.3
Blast	*	16.4	19.4
Boron	2	15.3	19.0
Manganese	10	16.3	19.5
Sulfur	20	15.4	19.3
Iron	0.3	16.0	19.7

* The above materials mixed and applied as one treatment.

Glyndon

Check	0	16.7	18.4
Blast	*	16.4	17.7
Boron	2	16.8	18.4
Manganese	10	16.6	18.3
Sulfur	20	16.0	17.5
Iron	0.3	15.5	17.4

Soil test:

	lbs/A					
	P	K	S	B	Mn	Zn
Crookston	97	420	54	2.8	1	1
Glyndon	14	185	80	2.5	1	1

There were no significant yield increases from any treatment at either location. The iron treatment at Crookston produced a slight yield increase but at Glyndon, the yield was reduced.

Nutrient Levels of Sugarbeet Blades: Leaf samples were taken at Crookston and Glyndon and the nutrient levels are given in Table 5 for 1971 and 1972. Because of the late spring planting in 1972, the samples on August 16, 1972 were in the same stage of growth as those taken on July 19, 1971. Sulfur determinations are not available at this time.

The results are very similar for both locations with a few exceptions. The soil phosphorus at Glyndon was low and at Crookston it was very high. (See bottom of Table 4.) Sodium content was higher at Glyndon. Manganese and boron levels were higher at Crookston, while iron was slightly higher at Glyndon.

All the micro-nutrients were above deficiency levels--there were no great differences between treatments and check, or between treatments.

Table 5. Nutrient Levels of Sugarbeet Leaf Blades at Northwest Experiment Station, Crookston, and Glyndon, 1971-72.

Treatment	Rate lb/a	P	K	Ca	Na	Mg	S	Fe	Zn	Mn	B	Mo
		----------percent----------						----------ppm----------				
Crookston - Sampled July 19, 1971 and August 16, 1972												
Check	--	.40	2.19	.76	2.45	1.09		92	33	115	62	12
Blast	*	.40	2.20	.73	2.45	1.03		91	32	110	64	12
Boron	2	.42	2.27	.66	2.33	.95		93	32	97	62	11
Manganese	10	.42	2.20	.72	2.56	1.01		94	32	108	64	11
Sulfur	20	.42	2.20	.64	2.47	.97		93	33	99	62	11
Iron	0.3	.40	2.19	.69	2.48	.99		89	33	116	65	11
Glyndon - Sampled July 22, 1971 and August 23, 1972												
Check	--	.29	2.36	.78	3.99	1.03		102	33	67	47	13
Blast	*	.28	2.51	.67	3.71	.88		94	39	61	43	11
Boron	2	.28	2.19	.71	3.98	.95		91	33	60	47	12
Manganese	10	.32	2.28	.69	3.76	.92		105	39	64	43	12
Sulfur	20	.30	2.36	.73	3.86	.95		100	34	61	47	12
Iron	0.3	.32	2.43	.73	3.69	.93		100	38	59	47	11

* Above treatments mixed and added as a treatment.

Available Soil Moisture Studies: Moisture held in the soil above the gravitational pull and below the permanent wilting point is available for plant growth. This amount varies with the type of soil, but the Fargo and Bearden soils can hold approximately 17 inches of total available water in the top five feet of soil. However, the amount for optimum plant growth is approximately 8-10 inches.

Soil samples were taken each fall to a depth of five feet from four sites and available moisture determinations were made. Alfalfa, beets, wheat and legume fallow are the crops grown. The data is given in Table 6.

Table 6. Available Soil Moisture at the end of the growing season, Northwest Experiment Station, 1971 and 1972.

Site	Soil Type	Texture	Crop	Available Water 5 ft. depth	
				1971	1972
1	Fargo	S. Clay loam	Alfalfa	6.43 in.	1.81 in.
2	Bearden	Silt loam	Wheat	----	5.71 in.
3	Bearden	Silt loam	Beets	9.91 in.	3.98 in.
4	Bearden	Silt loam	Alfalfa fallow	11.10* in.	4.82** in.

* Black fallow 1971

** 1st crop hay, fallow 1972

The available soil moisture was low at the end of 1972 compared to 1971. Site 1 (alfalfa 1972) was very low and the top three feet were extremely dry. Site 4 (alfalfa fallow 1972) was low, considering that it was in fallow after the removal of the first cutting of alfalfa. The soil moisture in this area was generally low at the end of the cropping season because of the dry fall.

Water Use Per Day: From the available soil moisture study it is possible to calculate the water use per day for the three crops mentioned above. This data is given in Table 7.

Table 7. Water use per day for Alfalfa, Sugarbeets, and Barley, at the Northwest Experiment Station, 1972.

Sample Period	Water use per day in inches		
	Alfalfa	Sugarbeets	Barley
5/2-5/31*	.177	.060	.043
6/1-6/30	.143	.004	.102
7/1-8/1	.097	.077	.195
8/2-8/31	.166	.144	.147
9/1-9/28	.084	.108	.083
9/29-11/1	.060	.084	.065
Total for season	21.89	13.69	19.29

* 5/16-5/31 sample period for sugarbeets.

Alfalfa with its long root system is a heavy consumer of soil moisture, starting with early spring growth and ending at freeze-up time in the fall. Grain crops like wheat and barley use considerable soil moisture during the growing season but are harvested earlier than sugarbeets. Sugarbeets are low users during the early growing season but by mid-season require large amounts of soil moisture.

Weather Summary 1972: Slightly lower temperatures and less precipitation were recorded for 1972 at Crookston. Only four months--March, May, June and August--were above the long-time mean temperature. January was the coldest month with a -.4° compared to the long-time mean temperature of 4.9°. December had a mean temperature of 4.0° compared to 11.6°, the 60-year average.

The weather summary for 1972, which is given in Table 1, includes precipitation, mean temperature, and long-time averages. Table 2 gives the clear and cloudy days.

The last spring frost occurred on May 7 when the temperature dropped to 28°. The first fall frost occurred on September 27 when the low temperature was 30°. A killing frost came on October 17 with a reading of 15.0°.

The frost-free period of 143 days during 1972 was 18 days longer than average.

The total precipitation ended with a deficit of 2.24 inches. Of the total precipitation, 15.63 inches fell as rain and the remaining 2.33 inches came from the 43 inches of snow. The last three months were below normal in precipitation and the soils in this area were drier than usual at the end of the fall. July and August were the only months above average in precipitation.

The snowfall for the calendar year measured 43 inches, and for the winter 1971-72 it was 40 inches. The moisture content per inch of snow for 1972 was .054 inches and for the winter 1971-72 it was .065 inches.

Table 8. Weather Summary for 1972 With Averages for Precipitation and Mean Temperatures for 1900-70.

Month	Precipitation--inch				1900-70	Mean Temperatures in Degrees	
	Snow Inch	Precip. Inch	Rain	Total		1972	1910-70
January	9	.55	0	.55	.56	-.4	4.9
February	6	.46	0	.46	.61	2.7	8.8
March	11	.48	.11	.59	.79	22.5	16.3
April	1	.07	1.28	1.35	1.51	40.3	41.4
May	0	0	1.46	1.46	2.62	60.4	54.6
June	0	0	2.31	2.31	3.36	66.7	64.0
July	0	0	3.85	3.85	2.98	66.4	69.7
August	0	0	3.16	3.16	2.89	70.5	67.5
September	0	0	2.46	2.46	2.11	56.2	57.2
October	4	.23	.79	1.02	1.34	43.7	45.0
November	2	.10	.11	.21	.86	27.1	27.2
December	10	.44	.10	.54	.59	4.0	11.6
Total	43	2.33	15.63	17.96	20.20	Av. 38.3	39.0

Table 9. Number of clear, partly cloudy, and cloudy days for 1972.

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Avg.
Clear	7	10	12	5	8	17	10	11	6	6	1	15	9
P. Cloudy	11	8	4	14	13	9	14	12	12	13	6	4	10
Cloudy	13	11	15	11	10	4	7	8	12	12	23	12	12

Iron and Zinc Trial on Corn: This will conclude two years of field testing with corn and the data will be summarized.

Sequestrene 138 iron and sequestrene zinc chelate were used. The materials were broadcast, the plots were rototilled and harrowed before planting. Both materials were coated on 18-46-0 at 8 lb. per 100 lb. of fertilizer, which helped in obtaining a uniform application. Cargill 185 corn was drilled in 22-inch rows on May 30 and the plots were harvested the first part of October.

Table 10 gives the yield of corn for the various treatments of iron and zinc. The heading "Fertilizer" in Table 10 gives the amount of 18-46-0 that was applied to furnish the required amount of iron and zinc per acre.

Table 10. The effect of iron and zinc on the yield of corn, 1970.

Treatment	Rate	Fertilizer[1]	Yield* 1972	Yield* 1970 & '72 ave.
	lb/A	lb/A	----------bu/A--------	
Check	--	63	142	122
Check	--	125	156	---
Zinc	0.36	32	143	125
Zinc	0.72	63	136	117
Iron	0.30	63	150	120
Iron	0.60	125	143	117

[1]Zinc and iron chelates furnished by Giegy Chemical Company.
138 Iron contained 6% iron
Zinc (Na_2Zn) contained 14.2% zinc

Soil test: pH 8.0 P 58 lb/A
Zn 2.4 K 600 lb/A

The soil phosphorus and potash levels were very high and 100 lbs. of nitrogen (300 lbs. NH_4NO_3) were added to eliminate any possibility of nitrogen deficiency.

Corn yields were very high in 1972 and the check plot which

received 125 lbs/A of fertilizer 18-46-0 produced the highest yield. The high rates of zinc and iron tended to depress the corn yields in 1972, but no great differences appeared. This same pattern appeared in the 2-year average yield data but no significant treatment differences were noted.

NITROGEN TRIALS ON SMALL GRAINS AT THE NORTHWEST EXPERIMENT STATION, CROOKSTON, 1972.

This is the second year of the cooperative trial at Crookston, Lamberton and Morris to determine the proper rates of nitrogen fertilizer for semi-dwarf varieties of wheat, barley and oats.

Fertilizer 0-30-15 @ 100 lbs per acre was broadcast with the various rates of ammonium nitrate and worked into the soil. No drill-applied fertilizer was used. The plot area was in beets in 1972.

The late spring delayed field work. Barley was planted on April 27, wheat on May 6, and oats on May 2.

Table 1 gives the soil analysis of the plot area for each crop.

Table 1. Soil Analysis.

	O. Matter	pH	P	K	NO_3-N	S	Zn
			-----lbs/a---------			ppm	ppm
Wheat	H	7.8	88	600	47	15	2.4
Barley	H	7.9	47	600	55	15	2.4
Oats	H	8.1	62	600	63	15	2.4

Tables 2, 3, and 4 give the yield, percent of protein, and 13 bushel weight for the three classes for 1972 and average for 1971-72.

Table 2. Effect of four nitrogen treatments on yields of wheat, barley and oat varieties for 1972 and 1971-72.

Treatment	1972			1971-72		
	Ciano	Chris	Era	Ciano	Chris	Era
	-----bu/A----------			----------bu/A---------		
Check	22.5	29.8	31.5	30.1	37.3	39.4
40 lb	33.3	38.7	52.9	41.7	49.1	61.3
80 lb	40.9	41.8	62.2	47.2	49.3	71.5
120 lb	41.2	45.1	57.4	49.6	53.3	68.1
LSD 5%	6.5	8.6				
Treatment	Dickson	Larker	65.220	Dickson	Larker	65-220*
	----------bu/A--------			----------bu/A---------		
Check	42.9	41.9	39.2	63.1	55.7	60.4
30 lb	56.1	51.0	64.1	73.5	60.0	64.3
60 lb	61.5	56.8	63.8	78.1	60.5	75.8
90 lb	67.3	57.7	72.1	76.7	65.2	75.6
LSD 5%	6.0	5.3	5.3			

* Variety 64-76 grown in 1971 and averaged with 65-220.

Treatment	Otter	Lodi	Diana	Otter	Lodi	Diana
	-------bu/A----------			----------bu/A--------		
Check	56.9	56.1	43.5	69.6	70.1	53.7
30 lb	70.3	74.4	68.3	72.8	75.8	69.2
60 lb	71.9	77.1	82.8	82.9	83.5	72.0
90 lb	83.6	86.6	69.0	79.7	86.9	80.8
LSD 5%	18.0	24.0	19.0			

Table 3. Effect of four nitrogen treatments on bushel weight of wheat, barley and oat varieties for 1972 and 1971-72.

Treatment	1972 Ciano	1972 Chris	1972 Era	1971-72 Ciano	1971-72 Chris	1971-72 Era
	bu.wt.			bu. wt.		
Check	62	60	60	63	60	60
40 lb	63	61	61	63	61	61
80 lb	63	60	61	63	61	61
120 lb	63	60	60	63	60	61

Treatment	Dickson	Larker	65-220	Dickson	Larker	65-220
	bu. wt.			bu. wt.		
Check	46	49	44	47	48	46
30 lb	49	49	46	48	48	45
60 lb	48	50	46	48	48	45
90 lb	48	49	46	48	47	46

Treatment	Otter	Lodi	Diana	Otter	Lodi	Diana
	bu. wt.			bu. wt.		
Check	38	37	36	38	36	37
30 lb	38	37	36	37	36	37
60 lb	37	38	36	37	37	38
90 lb	37	37	36	37	36	37

Table 4. Effect of four nitrogen treatments on percent protein of wheat and barley varieties for 1972 and 1971-72.

Treatment	1972 Ciano	1972 Chris	1972 Era	1971-72 Ciano	1971-72 Chris	1971-72 Era
	% protein			% protein		
Check	13.3	11.5	11.0	13.1	12.1	10.8
40 lb	14.2	12.4	10.5	13.6	12.6	10.4
80 lb	15.8	12.9	11.2	15.5	13.8	11.7
120 lb	16.8	14.0	13.1	16.0	14.6	13.3
LSD 5%	1.44	0.72	1.15			

Treatment	Dickson	Larker	65-220	Dickson	Larker	65-220
	% protein			% protein		
Check	10.9	11.2	10.8	11.3	11.6	11.1
30 lb	10.9	12.2	11.2	11.5	12.7	11.6
60 lb	11.9	12.4	12.1	12.2	12.9	12.2
90 lb	12.9	13.7	12.4	12.5	13.5	12.3
LSD 5%	1.1	0.5	0.5			

FERTILIZER TRIALS ON ALFALFA - ELK RIVER 1972

C. J. Overdahl and C. P. Klint[1]

The alfalfa plots were reseeded in 1971 and treatments were modified slightly over the preceding years. The plots were mowed twice the seeding year and in 1972 three cuttings were made.

Alfalfa yields, soil test K and percent K in plant tissue for irrigated vs. unirrigated plots were as follows:

	Rates of K_2O/acre and time of application			
	0 0	0 Oct. 240 June	240 Oct. 0 June	240 Oct. 240 June
Irrigated (avg. pH 6.8)				
Yield T/A	3.4a	5.4b**	4.9b	5.3b
Soil test K (Sept.)	72	380	182	565
% K tissue				
1st cut	1.42	2.95	3.18	3.54
2nd cut	1.14	2.68	2.30	2.48
3rd cut	1.19	2.31	2.18	2.62
Non-irrigated (avg. pH 6.3)				
Yield T/A	2.9a	4.4b**	4.2b	4.2b
Soil test K (Sept.)	90	390	242	590
% K tissue				
1st cut	1.84	2.98	3.31	3.72
2nd cut	.99	2.26	2.03	2.67
3rd cut	1.32	2.47	2.38	2.86

** where letters after yield differ from check plot, yields are different statistically at the 1% level of confidence.

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[1] Efforts of Dean Fairchild, Charles Behrens, Bob Schoper, Glenn Titrud and others assisting on plots are gratefully acknowledged.

POTATO FERTILIZATION ON IRRIGATED LOAMY SANDS - ELK RIVER

C. J. Overdahl and C. P. Klint[1]

Norland potatoes have been grown continuously since 1968 except for a one year break in 1971 when the plots were seeded to rye. The variables are potassium, magnesium and nitrogen.

Nitrogen Effect $N + P_2O_5 + K_2O$	Yield, Cwt/acre 1968	1969	1970	1972
75 + 150 + 500	139a	251a	84a	201a
150* + 150 + 500	204b	270b	233c	289b
300* + 150 + 500	216b	285b	187b	222a

* had additional N treatments of 75 and 225 above regular 150 and 300 treatments in 1970.

Potassium-Magnesium Effect $N + P_2O_5 + K_2O + Mg$	Yield, Cwt/acre 1968	1969	1970	1972
200 + 150 + 0 + 0	158	270	267	210
200 + 150 + 150 + 0	170	288	268	320
200 + 150 + 500 + 0	189	286	287	339
200 + 150 + 0 + 50	195	286	237	207
200 + 150 + 150 + 50	199	327	294	334
200 + 150 + 500 + 50	183	305	263	284
	N.S.	N.S.	N.S.	N.S.

Average Potassium Effect

K_2O	1968	1969	1970	1972
0	176	278	252	209a
150	185	306	281	327b
500	186	297	275	311b
	N.S.	N.S.	N.S.	**

Average Magnesium Effect

Mg lbs/a	1968	1969	1970	1972
0	172	282	274	290
50	192	304	265	275
	N.S.	N.S.	N.S.	N.S.

Potassium-magnesium interaction in petiole analyses (1972)

	K_2O Alone 0	150	500	K_2O + 50#/A Mg 0	150	500
% K	.47	5.95	11.16	.79	6.80	10.68
% Mg	1.12	0.42	0.07	1.42	0.52	0.10

[1] Efforts of Dean Fairchild, Bob Schoper, Bob McCaslin, Charles Behrens, Glenn Titrud and others are gratefully acknowledged.

FIELD EXPERIMENTS WITH SOIL MODIFICATION ON AN IRRIGATED HUBBARD SOIL-ELK RIVER-1972

R.S. Farnham and D.S. Fairchild

This soil modification experiment using organic and inorganic detention layers in a sandy Hubbard soil were started in 1969 and continued through 1972. Materials used in the layers include peats, wood products, composted garbage, manure, calcined clay and vermiculite. The objectives of these studies are to improve the air, water, and nutrient conditions in the root zone environment of this droughty sandy soil. Layers were installed in 1969 in both rows and square plots at a depth of 18 inches below the surface. Yields of field corn obtained in 1970 and 1971 seasons seemed to be relatively higher where layers were placed in soil.

1972 STUDIES-CORN

The variety - Minhybrid 4201 - a 110 day corn was planted May 8, 1972 at a population of 25,640 per acre. The row width was 36 inches. A Lasso-Atrazine mix herbicide was applied before planting. Fertilizer applied included 850 lbs. of 8-16-16 broadcast and disked before planting and side dressing of 75 lbs. N on June 5th, and 70 lbs. N on June 17th.

The total rainfall for the growing season May-October inclusive was 20.6 inches which is above average precipitation for the season. July rainfall was 8.47 inches. In addition irrigation water applied totaled 7.0 inches and was applied at weekly intervals.

Table 1 shows the yields of corn obtained on the various plots. Yields varied from a low of 139 on the check plots to a high of 185 with one of the peat layers. Differences in yields in 1972 were not

as great as in 1970 and 1971 probably because of the more than adequate rainfall throughout the season.

The plots were harvested October 20, 1972.

In general the yields were good in 1972 but not as high on the average as in 1970 and 1971.

Table 1. Soil Modification Plots at Elk River - Corn - 1972.

Treatments (Type of Layers)	Yield 1972 Bu/Acre 15.5% H_2O
Check (No layers)	Ave. 139 Range 137-148
A. Square Plots (14' x 14')	
Reed - Sedge peat	153
Sphagnum Peat	164
Hydromulch	145
Calcined Clay	160
Vermiculite	152
B. Row Plots (18" wide)	
Hydromulch	154
Composted Garbage	163
Reed - Sedge Peat (fresh)	154
Reed - Sedge Peat (compost.)	172
Sphagnum Peat	162
Vermiculite 1/2"	165
Vermiculite 3/4"	150
Vermiculite 1 "	155
Calcined Clay	160

1972 Fertigation of Corn on a Hubbard Loamy Coarse Sand in Sherburne County.

John MacGregor, Dean Fairchild, and Robert Munter

Some two or three million acres of sandy soils in Minnesota are, or could be irrigated. These soils are droughty and usually low in organic matter. The availability and addition of water is usually the first requirement for economic crop production. Non-legume crops, such as corn, require large amounts of fertilizer or other nitrogen which is now comparatively low in cost. Fertilizer nitrogen can be readily added in sprinkler irrigation water, but must be followed by a clear water rinsing at the end of each nitrogen sprinkling treatment. Some mineral elements such as potassium may also be initially deficient, and eventually several or even all of the essential mineral fertilizer elements must be applied. Where legumes such as soybeans, alfalfa, or several of the clovers are to be grown, initial liming of many of these soils would be desirable, in addition to the later need of the essential mineral elements.

This 1972 study of the effectiveness of rate and time of nitrogen application to sprinkler irrigated corn was a continuation of a 1971 study previously reported in Soil Series 88, pp 50-57. It will be continued in 1973.

The land was plowed on April 18th, disked on May 3rd, harrowed and planted on May 4th to supply a population of 30,723 plants per acre. The seed was Minhybrid 4201 (110 day) in 30" rows, 2" deep, without starter fertilizer. On May 8th, AAtrex 80 W was applied at the rate of 2 lbs. and Lasso at 1 lb/A in 45 gallons of water. Initial irrigation was on May 9th, with a season total of 6.0" concluding on September 1st. Total May through September rainfall was 21.20", making a total moisture supply (rainfall and irrigation) of 27.20" during the five month period. The 1972 growing season was

comparatively cool, and the mature corn was harvested in late October. The 1971 and the 1972 results are shown in Table 1.

Sixth corn leaf N was determined in 1971 but not in 1972. Since 2.5% N is usually assumed to be the desirable concentration for optimum corn production, it is evident that for N applied at rates of 200 to 300 pounds per acre, such would be best applied at monthly or bimonthly intervals which has increased N concentrations to this concentration in the corn leaves.

The 1972 grain yields were considerably lower than those of the preceding year, but the effect of N on grain yields shows much the same trend. Nitrogen fertilization at the 200 lb/A rate appears most efficient, with the monthly applications being quite effective with all three N application rates. This also seems to be relatively true for the relative amounts of N removed in the corn grain.

It is apparent that when land rental, labor, machinery, irrigation, fertilizer, and all other costs are taken into consideration, four N treatments made at monthly intervals supplying 50 lbs N/A each time would have maximum efficiency. This would provide excellent corn yields at minimum expense, and also would allow relatively little of the applied fertilizer N to be leached into subterranean waters with the minimum possible contamination.

One of the main objectives of this study is to determine the number of years irrigated corn can be grown supplying fertilizer N alone. Phosphorus and potassium fertilizers were last applied for the 1969 corn crop, and N alone has been applied for the crops of 1970, 1971, and 1972. Nutrient element deficiencies to date have been limited to insufficient N fertilization, especially those plots having no N during the last five years of corn production.

Table 1. The 1971 and 1972 yields and N content of corn grain and of corn leaves on irrigated Hubbard loamy coarse sand near Elk River with different rates and times of N fertilization (average of 6 replications).

N applied annually (lbs./A)	Time(s) of N* application	#/A of N per app.	% of N in 6th leaf 1971	% of N in 6th leaf 1972	Bu. Corn/A @ 15.5% H_2O 1971	Bu. Corn/A @ 15.5% H_2O 1972	% N in corn grain 1971	% N in corn grain 1972	# N removed in grain/A. 1971	# N removed in grain/A. 1972
None	----------	-------	0.61	----	43a[1]	21a	0.92	0.84ab	19	8a
100	5/8 after planting	100	1.19	----	92b	68b	0.82	0.88abc	28	30b
100	5/8,6/5,7/8,8/8	25	1.42	----	154cd	109d	1.06	0.83a	77	43c
100	5/8 & 22, 6/5 & 23, 7/8 & 21, 8/8 & 22.	12.5	1.53	----	136c	93c	1.02	0.98abcd	66	43c
200	5/8 after planting	200	1.11	----	158cde	125e	0.99	1.03cd	74	60d
200	5/8,6/5,7/8,8/8	50	1.89	----	185def	143f	1.15	1.09d	101	72d
200	5/8 & 22, 6/5 & 23, 7/8 & 21, 8/8 & 22.	25	2.10	----	192f	141f	1.23	1.00bcd	112	67d
300	5/8 after planting	300	1.15	----	173def	126e	1.02	1.01bcd	84	59d
300	5/8,6/5,7/8,8/8	75	2.05	----	195f	142f	1.33	1.08d	122	71d
300	5/8 & 22, 6/5 & 23, 7/8 & 21, 8/8 & 22.	37.5	2.43	----	189ef	138ef	1.36	1.12d	121	72d

* The 1972 treatments were 3 days earlier than in the 1971 season.

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

The Effect of Four Fertilizer Nitrogen Sources on 1972 Corn Yields Produced on Irrigated Hubbard Loamy Coarse Sand in Sherburne County.

John MacGregor, Dean Fairchild, Curtis Klint

There is periodic interest in possible differences in corn yields when the grower uses different kinds of fertilizer nitrogen. Previous experiments, conducted by the Department of Soil Science, have shown these N sources produced essentially equivalent corn yields when equal rates of nitrogen were applied by acceptable procedures. Since the earlier Minnesota studies had been conducted on unirrigated soils of finer texture, it was considered possible that some yield differences might result if the different N fertilizer sources were applied to the irrigated porous and N deficient sandier soils.

Minhybrid 4201 (110 day) was planted on May 4th in 30" rows to provide a plant population of 30,000 plants per acre. No starter fertilizer was applied. The herbicide was AAtrex 80 W at the rate of 2 lbs/A and 1 lb Lasso applied as a spray in 45 gal of water/A. Sprinkler irrigation was commenced on May 9th and then as needed until September 1st. A total of 6" irrigation water was applied. The May-September (inclusive) rainfall was 21.2", providing a total water supply during the 5 month growing period of 27.2". The growing season of 1972 was comparatively cool.

Each of the 4 N sources supplied N at the rate of 150#/A. There were 5 replications of each treatment, each of the experimental plots being 15' x 50' in size. The corn was sampled in late October, the grain analyzed for N concentrations and the results including per acre N removal are shown in Table 1.

The three solid nitrogen sources (ammonium nitrate, ammonium sulfate, and urea) were broadcast on May 4th. The anhydrous ammonia was knifed into the soil approximately one week later.

1. The three solid nitrogen fertilizers were donated by Howe Fertilizers Inc.
2. The anhydrous ammonia was supplied and applied by the King Gas Company of Osseo.

Table 1. The Effect of Four Nitrogen Fertilizers Spring Applied to an Irrigated Hubbard Loamy Coarse Sand in Sherburne County on 1972 Corn Yield, N Content and Removal in Grain.

Nitrogen broadcast (lbs N/A)	Nitrogen source	Bu/A ear corn @ 15.5% moisture	% N in grain	N removal in lbs/A
none	-----	11 a[3]	0.97	4.6 a
150	Ammonium sulfate	119 b	1.12	61.3 bc
150	Anhydrous ammonia	123 bc	1.02	58.5 b
150	Urea	125 bc	1.11	66.1 bc
150	Ammonium nitrate	152 c	1.14	80.1 c

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

All four nitrogen fertilizer treatments significantly increased corn yields. There was no significant difference between ammonium sulfate, anhydrous ammonia, or urea, the ammonium nitrate being significantly more effective than the same amount of N applied as anhydrous ammonia. Nitrogen concentrations in the corn grain

varied little, and amounts of N removed in the grain were largely dependent on the grain yields obtained from each of the treatments.

The differences in 1972 corn yield resulting from the different fertilizer N sources should not be considered as conclusive and this experiment will be repeated in 1973 for additional information.

The Time of Nitrogen Fertilization and 1972 Yield of Russet Burbank Potatoes Grown on Irrigated Hubbard Loamy Coarse Sand in Sherburne County.

John MacGregor, Curtis Klint, Glenn Titrud, and Dean Fairchild

Since relatively large amounts of nitrogen fertilizer are now usually applied for potato production on the irrigated soils of the Mississippi sand plain, an experiment was designed to test the relative efficiencies of one or several split N fertilizer treatments (having the same total amounts of N applied) on eventual yields of Russet Burbank potatoes previously planted with a basic $N+P_2O_5+K_2O$ starter fertilizer. Four replications of each of four treatments were established in a Latin square design, each of the plots being 20' x 40'.

The starter fertilizer used at planting was 6-12-24* applied at the rate of 834 lbs/A to supply the three major nutrients as 50+100+200. Total N, including the later application(s) was to be at the rate of 200 lbs N/A. Four times of N application were to be studied. These were:

1. N at the rate of 150 lbs/A-applied July 1st.
2. N at 50 lbs/A rate-each on May 15, June 15, and July 15.
3. N at 50 lbs/A rate-each on June 15, July 15, and Aug. 15.
4. N at 25 lbs/A rate-each on June 1 and 15, July 1 and 15, and August 1 and 15.

All four deferred N treatments were as ammonium nitrate, dissolved and applied in the irrigation water.

The experimental area was plowed on April 23rd, disked on April 24th, and herbicide EPTC sprayed on at the rate of 3 lbs/A in 45 gallons of water and worked in. The Russet Burbank potatoes were planted in 36" rows, 11" drop. The potatoes were hilled on

June 18th and sprayed on June 14th with 2 lbs/A Thiodan and 2 lb. Manzate D in 100 gallons of water/A. On June 21st, they were also sprayed with 2 lbs Serin and 2 lbs Kocide 101/100 gal water/A.

Rainfall from planting until harvest (Sept. 11th) totalled 19.17", with approximately 7" being added as sprinkler irrigation. The potatoes were harvested on September 11th with the yields reported in Table 1.

* All fertilizers used in this study were donated by Howe, Inc.

Table 1. 1972 Yields of Russet Burbank Potatoes Grown With Different Timesoof Delayed Nitrogen Fertigation in Hubbard Loamy Coarse Sand in Sherburne County.

Nitrogen Treatment *	1972 Tuber Yield in cwts/A.		
	A. Grade	B. Grade	Total
(1) 150#/A on July 1st	247	28	275
(2) 50#/A on May 15, June 15, and July 15	258	37	295
(3) 50#/A on June 15, July 15, and August 15.	278	29	307
(4) 25#/A on June 1 and 15, July 1 and 15, and August 1 and 15.	244	32	276

* The entire experimental area received N, P_2O_5, and K_2O at the rate of 50+100+200 as a starter fertilizer at planting in addition to the delayed N treatment(s).

None of the yields differed significantly and they approximate those obtained for this variety on the irrigated sandy soils of this area.

LIME PLOTS, LAMBERTON, 1972

J. Grava, W. W. Nelson, D. S. Fairchild

A field experiment was established in 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 four, and (b) in series five, corn (1966, 1968, 1970, 1972) and soybeans (1967, 1969, 1971) in a sequence. Data on crop yields, soil and plant analyses were reported in the departmental "Bluebooks."[1]

Alfalfa yields were not affected by lime treatments (Table 1). Liming decreased concentration of manganese in tissue of second cutting alfalfa (Table 2).

Corn yields were not affected by liming (Table 3). Lime treatments had no effect on chemical composition of corn leaf.

Table 1. Yield of Alfalfa, Lamberton Lime Plots, 1972.

Rate of Lime	First Cutting	Second Cutting	Third Cutting	Total
Tons/Acre		Hay - Tons/Acre		
0	2.0	1.3	1.5	4.8
7*	2.1	1.3	1.5	4.9
16**	2.1	1.2	1.6	4.3
Significance	NS	NS	NS	
CV,%	7	4	12	

[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; Soil Series 88, March 1972, pp. 73-77, for results obtained in previous years.

Table 2. Chemical Composition of Alfalfa, Lamberton Lime Plots, 1972.

Lime Treatment	P	K	Ca	Mg	Zn	Cu	Mn	B	Fe	Al
	-----Percent in Dry Matter------				-------Parts Per Million in Dry Matter-----					
					First Cutting					
0	.31	1.94	1.66	.38	29	9	31	50	184	144
7	.32	1.81	1.81	.41	31	9	22	52	162	122
16	.32	1.90	1.59	.38	28	8	18	46	135	93
Significance	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV, %	12	11	12	11	18	21	21	10	33	43
					Second Cutting					
0	.34	2.38	1.26	.38	28	11	30b	40	103	64
7	.35	2.20	1.34	.41	29	11	19a	41	120	73
16	.37	2.23	1.35	.38	29	11	16a	39	132	89
Significance	NS	NS	NS	NS	NS	NS	**	NS	NS	NS
CV, %	11	13	18	15	13	16	22	12	29	42

Table 3. Yield of Corn, Lamberton Lime Plots, 1972.

Rate of Lime	Yield
Tons/Acre	Bu/Acre
0	134
6*	143
12*	135
Significance	NS**
CV,%	11

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

** NS - Treatment means not significantly different at the 5% level.

Table 4. Chemical Composition of Sixth Corn Leaf at Tasselling, Lamberton Lime Plots, 1972.

Lime Treatment	N	P	K	Ca	Mg	Zn	Cu	Mn	B	Fe	Al
Tons/Acre	---------Percent in Dry Matter----------					------Parts Per Million in Dry Matter------					
0	2.26	.30	1.67	.66	.46	25	11	36	10	147	53
6	2.30	.30	1.67	.71	.46	23	10	32	10	154	56
12	2.38	.30	1.63	.69	.48	20	11	37	10	161	57
Significance	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV, %	6	5	11	13	14	21	12	16	11	14	27

SOIL FERTILITY MATERIALS PLOTS

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

In the spring of 1971, field trials were established at the Southwest Experiment Station, Lamberton, to compare various soil fertility 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. The liquid fertilizer is labelled as Super to identify it as a material claimed to be superior to commonly available fertilizers.

On June 2, 1972, soybeans were seeded in the 1971 plot area and treatments were applied as shown in Table 1.

Table 1. Treatments (soybean crop)

1. Check
2. Super: Seed plus Foliar

   2 gal. (3-18-18) in contact with seed.

   2 gal. (3-18-18) foliar application, 7/24.
3. Super: Seed

   2 gal. (3-18-18) in contact with seed.
4. Soil Conditioner.

   150 lbs. to the side and below seed.
5. Organic.

   150 lbs. (0-1-7) to the side and below seed.
6. Residual from Conventional Fertilizer

   For corn 114+43+22 was applied in spring, 1971.

An additional set of plots, established in 1972, was planted to corn, May 26. This will allow a corn-soybean rotation with results obtained from each crop annually. The treatments for the plots where corn was seeded in 1972 are shown in Table 2.

Table 2. Treatments (corn crop).

1. Check.
2. Super: seed + Foliar.

   4 gal. (9-18-9) in contact with seed.

   4 gal. (9-18-9) over foliage. (2 gal. two times).

   135 lbs. 33.5-0-0 broadcast and worked in.
3. Super: seed.

   4 gal. (9-18-9) in contact with seed.

   135 lbs. 33.5-0-0 broadcast and worked in.
4. Soil Conditioner.

   250 lbs. broadcast and worked in.
5. Organic.

   300 lbs. (6-2-1) broadcast and worked in.

   200 lbs. (6-2-1) to the side and below seed.
6. Conventional Fertilizer.

   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 P and K soil conditions as well as under low P 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. Except for treatments 4 and 5, all plots received a herbicide (Amiben in soybeans,

Ramrod in corn). All plots were cultivated two times. Weeds were a moderate problem in treatments 4 and 5.

1972 Results. 1972 Corn and Soybean Yields are reported in Table 3. Plant measurements available are shown in Table 4.

Table 3. Effect of Fertility Materials on Plant Measurements, 1972.

Treatment		Soybeans Bu/A	Corn Bu/A	Corn % Moist	Corn Date 50% Plts. Silked
Low fertility	1	24.0 a[1]	80 a	31.4	Aug. 1
(0+0+0 B.C.)	2	28.4 b	93 a	29.4	July 30
	3	28.9 b	104 a	28.8	July 30
	4	24.6 a	74 a	30.6	Aug. 1
	5	24.5 a	89 a	30.0	Aug. 1
	6	28.5 b	96 a	30.0	July 29
Med. + Fert.	1	28.0 a	85 a	29.7	July 31
(0+90+45 B.B.)	2	30.0 b	109 a	29.5	July 29
	3	29.4 b	114 a	28.9	July 29
	4	28.3 b	73 a	29.8	July 31
	5	29.2 b	99 a	29.5	July 30
	6	28.0 b	110 a	29.2	July 29
Significance		*	N.S.	--	--

[1] Numbers followed by the same letter are not significantly different at the 5.0% level.

Table 4. Leaf Analysis. Fertility Materials Plots, Lamberton, 1972.

	Treatment	P %	K %	Ca %	Mg %	Al ppm	Fe ppm	Zn ppm	Cu ppm	Mn ppm	B ppm
Corn 0+0+0 broadcast	1	.22	2.14	.34	.22 ab	(1)29	124	27	12	44	8
	2	.26	1.78	.38	.25 bc	43	131	28	13	46	6
	3	.25	1.89	.40	.28 de	38	138	32	15	51	9
	4	.18	1.89	.31	.20 a	32	108	22	9	40	7
	5	.21	2.10	.34	.24 bc	30	119	26	11	41	8
	6	.25	1.69	.46	.34 f	29	125	33	14	61	9
Corn 0+90+45 broadcast	1	.22	2.08	.38	.24 bc	34	117	24	10	43	9
	2	.30	1.84	.42	.27 cd	36	123	28	11	44	7
	3	.26	1.83	.48	.28 de	33	122	29	12	48	7
	4	.22	2.02	.39	.25 bc	37	118	25	10	44	8
	5	.22	2.03	.44	.28 de	42	131	24	11	44	8
	6	.26	1.76	.44	.31 ef	35	126	28	12	50	8
Significance		N.S.	N.S.	N.S.	**	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Soybeans 0+0+0 broadcast	1	.37	2.13	.99 bc	.39	37	172	53	17	69	50
	2	.44	2.16	1.04 c	.41	39	185	57	19	65	52
	3	.39	2.10	.98 abc	.38	34	169	54	17	64	50
	4	.33	2.13	1.01 bc	.37	40	178	54	18	60	50
	5	.39	2.23	1.00 bc	.38	39	170	55	17	68	48
	6	.44	2.22	.93 a	.37	29	166	54	17	62	51

Table 4. (continued)--

	Treatment	P %	K %	Ca %	Mg %	Al ppm	Fe ppm	Zn ppm	Cu ppm	Mn ppm	B ppm
Soybeans	1	.56	2.30	1.00 bc[1]	.39	31	161	55	16	60	51
	2	.53	2.30	1.00 bc	.37	33	171	52	14	66	51
	3	.55	2.31	.93 ab	.34	24	166	53	14	58	51
0+90+45	4	.43	2.25	1.13 d	.38	40	168	54	16	60	51
broadcast	5	.57	2.31	.94 ab	.39	27	165	56	17	62	51
	6	.54	2.39	1.00 bc	.37	29	163	53	15	61	52
Significance		N.S.	N.S.	**	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

(1) Numbers followed by different letters are significantly different at the 5.0% level.

SMALL GRAIN FERTILIZATION

SOUTHWEST EXPERIMENT STATION - LAMBERTON

W. W. Nelson and S. D. Evans

Field experiments were established at the Southwest Experiment Station in the spring of 1970 to study the response of wheat, oats, and barley to nitrogen fertilization. A second objective was to determine the need for starter fertilizer on these crops. Three varieties of each crop were grown at three applied nitrogen levels. The nitrate nitrogen level in the soil in 1971 and 1972 was determined by the University of Minnesota Soil Testing Laboratory. In 1970 the tests were by the North Dakota Soil Testing Laboratory.

A. Oats

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

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

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

Seeding dates - April 15, 1971 and May 5, 1972

Nitrate-nitrogen soil test - 1971 - 101 lbs/A

1972 - 70 lbs/A.

Table 1. Lodging (1-5 scale), Oat Fertility Study, Lamberton, 197[illegible].

Variety	Nitrogen Applied lbs/acre	No Starter	Starter	Average
		-lodging score-		
Lodi	0	2.0	2.3	2.2
	30	3.7	3.0	3.3
	60	4.3	3.7	4.0
	90	4.0	3.3	3.7
Variety Average		3.5	3.1	3.3
Otter	0	3.0	2.3	2.7
	30	3.3	3.3	3.3
	60	3.3	3.3	3.3
	90	4.0	3.7	3.8
Variety Average		3.4	3.2	3.3
Diana	0	2.0	3.0	2.5
	30	2.3	2.3	2.3
	60	4.0	4.0	4.0
	90	3.7	3.0	3.3
Variety Average		3.0	3.1	3.0
Overall average		3.3	3.1	

Table 2. Yield, Oat Fertility Study, Lamberton, 1971.

Variety	Nitrogen Applied lbs/acre	No Starter	Starter	Average
		-Bu/acre		
Lodi	0	75.7	88.2	81.9
	30	81.2	66.1	73.6
	60	66.6	81.1	73.8
	90	66.5	71.4	69.0
Variety Average		72.5	76.7	74.6
Otter	0	78.2	63.5	70.8
	30	70.7	77.2	74.0
	60	69.5	68.5	69.0
	90	74.1	70.6	72.3
Variety Average		73.1	70.0	71.5
Diana	0	75.8	71.8	73.8
	30	77.4	72.0	74.7
	60	87.7	79.7	83.7
	90	72.2	84.8	78.5
Variety Average		78.3	77.1	77.7
Overall Average		74.6	74.6	

Table 3. Groat Percentage, Oat Fertility Study, Lamberton, 1971.

Variety	Nitrogen Applied lbs/acre	No Starter	Starter	Average
		-Groat %-		
Lodi	0	74	76	75
	30	75	72	73
	60	73	74	74
	90	72	75	74
Variety Average		74	74	74
Otter	0	76	76	76
	30	76	76	76
	60	76	76	76
	90	76	75	75
Variety Average		76	76	76
Diana	0	74	75	74
	30	73	73	73
	60	73	75	74
	90	73	75	74
Variety Average		73	74	74
Overall Average		75	75	

Table 4. Analysis of Variance, Oat Fertility Study, Lamberton, 1977.

Source of Variation	Lodging	Bu/Acre	Groat %
Reps	*	NS	NS
Varieties (V)	NS	NS	**
Starter (S)	NS	NS	NS
V x S	NS	NS	NS
Nitrogen (N)	**	NS	NS
N x V	*	NS	NS
N x S	NS	NS	*
N x V x S	NS	*	NS
C.V. (%)	19.2	11.7	1.7

Table 5. Yield, Oat Fertility Study, Lamberton, 1972.

Variety	Nitrogen Applied lbs/acre	No Starter	Starter	Average
		-Bu/acre-		
Lodi	0	70.2	54.0	62.1
	30	73.3	59.5	66.4
	60	75.5	63.7	69.6
	90	69.7	61.5	65.6
Variety Average		72.2	59.7	65.9
Otter	0	72.5	80.2	76.3
	30	75.2	74.7	74.9
	60	82.3	90.0	86.2
	90	89.5	88.7	89.1
Variety Average		79.9	83.4	81.6
Diana	0	65.5	61.7	63.6
	30	78.5	73.7	76.1
	60	80.5	71.7	76.1
	90	76.5	76.5	76.5
Variety Average		75.2	70.9	73.1
Overall Average		75.8	71.3	

Table 6. Groat Percentage, Oat Fertility Study, Lamberton, 1972.

Variety	Nitrogen Applied lbs/acre	No Starter	Starter	Average
		-Groat %-		
Lodi	0	65	62	64
	30	67	64	66
	60	63	56	60
	90	62	65	64
Variety Average		64	62	63
Otter	0	68	70	69
	30	68	71	69
	60	67	69	68
	90	72	66	69
Variety Average		69	69	69
Diana	0	66	66	66
	30	68	66	67
	60	65	68	66
	90	61	70	66
Variety Average		65	68	66
Overall Average		66	66	

The statistical analysis of the 1972 data has not been done.

B. Barley

Main plots - Varieties (1) Dickson, (2) Larker, (3) 64-76 in 1971 and 65-220 in 1972.

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

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

Planting dates - April 15, 1971 and May 5, 1972.

Nitrate nitrogen soil test - 1971 - 117 lbs/A

1972 - 70 lbs/A

Table 7. Lodging (1-5 scale), Barley Fertility Study, Lamberton, 1971.

Variety	Nitrogen Applied lbs/acre	No Starter	Starter	Average
		-lodging-		
Dickson	0	1.0	1.3	1.2
	30	2.0	1.7	1.8
	60	1.7	2.0	1.8
	90	2.0	3.0	2.5
Variety Average		1.7	2.0	1.8
Larker	0	1.7	3.3	2.5
	30	2.7	3.0	2.8
	60	2.7	3.0	2.8
	90	4.3	2.7	3.5
Variety Average		2.8	3.0	2.9
64-76	0	1.0	1.0	1.0
	30	1.0	1.0	1.0
	60	1.0	1.0	1.0
	90	1.0	1.0	1.0
Variety Average		1.0	1.0	1.0
Overall Average		1.8	2.0	

Table 8. Yield, Barley Fertility Study, Lamberton, 1971.

Variety	Nitrogen Applied lbs/acre	No Starter	Starter	Average
		-Bu/acre-		
Dickson	0	58.5	53.6	56.1
	30	58.6	56.5	57.5
	60	60.6	58.4	59.5
	90	57.0	50.6	53.8
Variety Average		58.7	54.8	56.7
Larker	0	57.7	64.9	61.3
	30	64.7	60.9	62.8
	60	58.7	60.2	59.4
	90	51.6	64.1	57.9
Variety Average		58.2	62.5	60.4
64-76	0	56.8	56.6	56.7
	30	63.2	55.6	59.4
	60	56.3	62.5	59.4
	90	61.0	56.0	58.5
Variety Average		59.3	57.7	58.5
Overall Average		58.7	58.3	

Table 9. Percent Protein in Grain, Barley Fertility Trial, Lamberton, 1971.

Variety	Nitrogen Applied lbs/acre	No Starter	Starter	Average
		- % Protein -		
Dickson	0	13.6	13.0	13.3
	30	13.4	14.3	13.9
	60	13.8	14.0	13.9
	90	14.5	14.2	14.4
Variety Average		13.8	13.9	13.9
Larker	0	13.6	14.8	14.2
	30	14.4	14.8	14.6
	60	15.0	14.8	14.9
	90	14.0	15.4	14.7
Variety Average		14.2	15.0	14.6
64-76	0	12.5	13.9	13.2
	30	12.6	13.6	13.1
	60	13.7	13.5	13.6
	90	13.7	13.9	13.8
Variety Average		13.1	13.7	13.4
Overall Average		13.7	14.2	

Table 10. Yield, Barley Fertility Study, Lamberton, 1972.

Variety	Nitrogen Applied lbs/acre	No Starter	Starter	Average
		-Bu/acre-		
Dickson	0	30.0	35.6	32.8
	30	47.1	54.2	50.7
	60	56.1	48.6	52.3
	90	52.3	44.8	48.6
Variety Average		46.4	45.8	46.1
Larker	0	40.3	42.2	41.2
	30	46.0	42.8	44.4
	60	49.3	50.4	49.8
	90	53.4	50.2	51.8
Variety Average		47.2	46.4	46.8
65-220	0	42.8	41.4	42.1
	30	55.5	46.8	51.2
	60	45.5	48.3	46.9
	90	48.8	46.5	47.6
Variety Average		48.2	45.7	47.0
Overall Average		47.3	46.0	

Table 11. Analysis of Variance, Barley Fertility Study, Lamberton, 1971 and 1972.

Source of Variation	1971 Lodging	1971 Bu/Acre	1971 % Protein	1972 Bu/Acre
Reps	NS	NS	NS	NS
Varieties (V)	*	NS	*	NS
Starter (S)	NS	NS	NS	NS
V x S	NS	NS	NS	NS
Nitrogen (N)	**	NS	NS	**
N x V	NS	NS	NS	NS
N x S	NS	NS	NS	NS
N x V x S	**	NS	NS	NS
C.V. (%)	32.2	9.2	5.7	21.5

C. Wheat

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

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

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

Seeding dates - April 27, 1970 and April 15, 1971.

Nitrate nitrogen soil test - 1970 - 101 lbs/A

1971 - 87 lbs/A.

Table 12. Yield, Wheat Fertility Trial, Lamberton, 1970.

Variety	Nitrogen Applied lbs/acre	No Starter	Starter	Average
		-Bu/acre-		
Chris	0	32.3	31.5	31.9
	40	31.8	30.6	31.2
	80	31.4	30.0	30.7
	120	29.2	31.3	30.2
Variety Average		31.2	30.8	31.0
Era	0	41.7	37.2	39.4
	40	46.3	46.6	46.4
	80	42.5	44.0	43.2
	120	40.2	50.5	45.3
Variety Average		42.7	44.6	43.6
Ciano 67	0	33.0	27.9	30.4
	40	33.4	33.4	33.4
	80	30.7	31.2	30.9
	120	30.8	29.7	30.2
Variety Average		32.0	30.5	31.3
Overall Average		35.3	35.3	

Table 13. Lodging (1-5 scale), Wheat Fertility Study, Lamberton, 1971.

Variety	Nitrogen Applied lbs/acre	No Starter	Starter	Average
		-lodging-		
Chris	0	1.0	1.0	1.0
	40	1.7	1.0	1.3
	80	1.7	1.7	1.7
	120	2.3	1.7	2.0
Variety Average		1.7	1.3	1.5
Era	0	1.0	1.0	1.0
	40	1.0	1.0	1.0
	80	1.0	1.0	1.0
	120	1.0	1.0	1.0
Variety Average		1.0	1.0	1.0
Ciano 67	0	1.0	1.0	1.0
	40	1.0	1.0	1.0
	80	1.0	1.0	1.0
	120	1.0	1.0	1.0
Variety Average		1.0	1.0	1.0
Overall Average		1.2	1.1	

Table 14. Yield, Wheat Fertility Study, Lamberton, 1971.

Variety	Nitrogen Applied lbs/acre	No Starter	Starter	Average
		- Bu/acre-		
Chris	0	36.6	36.8	36.7
	40	38.1	40.5	39.3
	80	33.8	37.9	35.8
	120	30.6	32.4	31.5
Variety Average		34.8	36.9	35.8
Era	0	37.2	35.4	36.3
	40	41.2	40.7	41.0
	80	42.6	35.8	39.2
	120	37.8	32.8	35.3
Variety Average		39.7	36.2	37.9
Ciano 67	0	33.3	32.5	32.9
	40	35.5	38.7	37.1
	80	30.4	33.5	32.0
	120	31.1	31.9	31.5
Variety Average		32.6	34.2	33.4
Overall average		35.7	35.8	

Table 15. Percent Protein in Grain, Wheat Fertility Study, Lamberton, 1971.

Variety	Nitrogen Applied lbs/acre	No Starter	Starter	Average
		-% protein-		
Chris	0	16.7	16.4	16.6
	40	15.9	16.8	16.4
	80	17.2	17.0	17.1
	120	17.1	17.4	17.3
Variety Average		16.8	16.9	16.9
Era	0	14.0	14.6	14.3
	40	14.4	14.4	14.4
	80	14.9	15.0	14.9
	120	15.4	15.8	15.2
Variety Average		14.2	15.0	14.7
Ciano 67	0	15.0	15.7	15.4
	40	15.5	15.8	15.6
	80	16.1	16.1	16.1
	120	16.5	16.4	16.5
Variety Average		15.8	16.0	15.9
Overall Average		15.7	16.0	

Table 16. Analysis of Variance, Wheat Fertility Study, 1970 and 1971.

Source of Variation	1970 Bu/Acre	1971 Lodging	1971 Bu/Acre
Reps	NS	NS	NS
Varieties (V)	**	NS	*
Starter (S)	NS	NS	NS
V x S	NS	NS	*
Nitrogen (N)	NS	**	**
N x V	NS	**	NS
N x S	NS	NS	NS
N x V x S	NS	NS	NS
C.V. (%)	16.3	20.2	10.8

The 1972 wheat data was not available at the time of printing.

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. Heiner.

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

Thirteen Years of Field Experiments with Nitrogen Source, Placement and Time of Application to a Webster Loam at Lamberton from 1960 through 1972.

John MacGregor, Wallace Nelson, and Robert Munter

The annual results of this experiment have been previously reported and described in Soil Series 74 to 88 inclusive and need not be repeated here.

The entire area is fall plowed following the harvesting of the ear corn, stalk cutting, and application of the NH_4NO_3-N or the urea-N at the 40, 80, and 160 lb/A rate. Surface applications of two forms of N at the 40 lb/A rate are then broadcast with no further fall working of the soil. The four replications of each of the 18 treatments are plots 20' x 77.5' arranged in a randomized block. Starter fertilizer at planting is 8-24-12 at the rate of 175 lbs/A, supplying 14 lbs of N/A to all plots in addition to the broadcast N treatments. Plant population, using hybrid seed adapted to the area, are slightly in excess of 20,000 plants per acre. Yields, leaf N, dry matter and N content of grain at harvest, and soil N status are shown in Table 1.

Nitrogen concentrations in the 6th (index) corn leaf were much more affected by rate of N fertilization than by time of fertilization. Nitrogen concentrations in the index leaf were significantly higher with the 40 lb/A spring sidedressing than where similar rates of N were applied at planting, but not significantly greater than two of the fall 40 lb applications. The 80 lb. rate increased leaf N, but there was only a trace of more leaf N with later N fertilization. The 160 lb. N rate increased leaf N further, with no significance between fall and late June

sidedressed N.

Grain dry matter at harvest had a narrow range from 64.5 to 69.9 with no consistent trend from N treatment.

Grain yields (15.5% moisture basis) on the 72 plots averaged 128.6 bu/A, ranging from 67.2 to a maximum of 161.6 bushels; the four starter fertilizer plots averaging only 75.6 bu/A. At the 40 lb N rate, June sidedressing produced significantly more grain than equivalent amounts of N either plowed down or left overwinter on the plowed surface. The same rate applied in the spring produced an intermediate yield increase not significantly different than from the fall or sidedressed 40 lb N yields. Eighty pounds of N/A significantly increased grain yields in 5 of the 6 treatments above the 40 lb/A rate, with no effect of application time. This was also true of the corn yields on the 160 lb N/A rate plots.

The 80 lb N rate significantly raised N content of the corn grain, with no effect of either lower or higher N rate.

All three rates of N fertilization increased amounts of N removed in the grain, the lowest N rate being most effective from the June sidedressing. Higher N fertilization rates further increased N removal, but time of fertilization was then less effective.

Where starter alone was used (14 lbs N/A) or the 40 lb rates of N were used (a total of 54 lbs of N/A), more N was removed in the grain than was applied in fertilizer. The 80 lb N rate and starter N (a total of 94 lbs N/A) resulted in a near added fertilizer N- soil N removal balance, whereas the 160 lb rate (174 lb N/A annual total) supplied considerably more N than was removed in the corn grain.

Table 1. Percentage N in Sixth Corn Leaf, Yield of Ear Corn (15.5% H_2O basis), Percentage N in Grain (dry basis) and N Removal in Corn Grain per Acre From NH_4NO_3 or Urea Fertilized Continuous Corn Grown on Webster Loam near Lamberton in 1972 (Four replications).

Treatment[1] (lbs N/A)	% N ~~in~~ 6th leaf	~~Ave.~~ % grain DM ~~at harvest~~	Grain yield in bu/A @ 15.5% H_2O I	II	III	IV	Ave.	Ave.% N in grain	#/A of N removed	Annual N fert. #/A.	Soil N status (#/A)
check	1.40a	67.2	67.2	85.1	71.9	78.2	75.6a	1.21abc	42.6a	14	-28.6
40N-fall plow down	1.80b	67.4	91.8	107.8	129.5	125.4	113.6b	1.17ab	61.9b	54	-7.0
40 Urea N-fall plow down	1.93bc	64.5	121.5	108.7	91.8	133.7	113.9b	1.27abcde	66.6bc	54	-12.6
40N-fall plow surface	1.97bcd	67.0	124.0	103.8	95.0	116.6	109.9b	1.14a	58.0b	54	-4.0
40 Urea N-fall plow surface	1.86b	68.5	97.6	102.8	88.9	137.4	106.7b	1.23abc	60.9b	54	-6.9
80N-fall plow down	2.07cde	69.9	133.7	155.0	142.5	141.3	143.1e	1.47fgh	97.0efg	94	3.0
80 Urea N-fall plow down	2.10cde	68.8	120.9	135.7	152.7	151.1	140.1e	1.42efgh	92.4efg	94	-1.6
160N-fall plow down	2.28ef	69.0	139.9	145.1	151.4	153.9	147.6e	1.50gh	102.1fg	174	71.9
160 Urea N-fall plow down	2.30ef	69.5	145.3	146.3	161.6	153.5	151.7e	1.51gh	106.0g	174	68.0
40 N-spring	1.76b	68.6	106.5	142.4	101.0	118.1	117.0bc	1.32bcdef	72.0bcd	54	-18.0
40 Urea N-spring	1.78b	69.0	101.2	124.8	102.5	137.6	116.5bc	1.25abcd	67.6bc	54	-13.6
80 N-spring	2.27def	68.6	137.7	140.1	140.5	152.4	142.7e	1.32bcdef	86.7defg	94	7.3
80 Urea N-spring	2.19cdef	67.7	135.9	135.4	145.6	151.3	142.1e	1.43efgh	93.9efg	94	0.1
40 N-sidedress	2.10cde	68.3	126.1	137.3	141.6	138.9	136.0cd	1.36cdefgh	85.3def	54	-31.3
40 Urea N-sidedress	2.13cde	68.6	130.1	128.0	145.2	132.3	133.9cd	1.31bcdef	80.7cde	54	-26.7
80N-sidedress	2.39f	67.6	90.2	109.5	144.9	154.1	124.7b	1.39defgh	80.5cde	94	13.5
80 Urea N-sidedress	2.23def	67.9	139.9	142.6	157.2	159.3	149.8e	1.43efgh	98.9efg	94	-4.9
160 N-sidedress	2.46f	69.0	141.[illegible]	154.7	146.3	156.3	150.0e	1.56h	107.6g	174	66.4

Table 1. (continued)

Treatment[1] (lbs N/A)	% N in 6th leaf	Ave. % grain DM at harvest	Grain yield in bu/A @ 15.5% H_2O I	II	III	IV	Ave.	Ave.% N in grain	#/A of N removed	Annual N fert. #/A.	Soil N status (#/A)
Significance											
Replicates	NS						**	NS	**		
Treatments	**						**	**	**		
C.V.	7.7						9.5	7.4	12.0		

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

Thirteen Year Averages

Grain yields harvested over the 13 year period are shown in Table 2.

Where N has been broadcast at the 40 lb/A rate in each of the 13 years, average corn yields have been much the same with the two forms of N, whether plowed down or left on the soil surface. There was also no significant difference for time of N fertilization, but a trend toward greater N efficiency from fall to spring (87.4 to 94.5 bu/A) and from spring to late June sidedressing (94.5 to 96.0 bu/A). Each average is based on 52 plot yields over the 13 year period-the fall averages totalling 104 individual plot yields.

Fall applied N at the 80 lb. rate increased average grain yields to 103.4 bu.- a 16 bushel increase over the 40 lb. rate. Spring fertilization at the higher rate resulted in 108.5 bu - or 5.1 bushels more than fall fertilization and 14 more bushels than the spring 40 lb. rate. Late June sidedressing with 80 lbs. of N showed a yield decrease to 104.8 bushels compared to 95.9 bushels sidedressed at the 40 lb. rate.

The 160 lb N/A rate plowed under each fall has averaged 109.8 bu, and 108.2 as a June sidedressing. These yields are only slightly larger than those obtained with the 80 lb. broadcast treatment rate.

General Conclusions

Urea N is comparable to N as ammonium nitrate, and where continuous corn is grown, annual N applications at the approximate rate of 100 lbs/A are desirable. This supplies ample N for the growing corn with little or no excess which might contribute to unnecessary pollution of soils and/or to surface or subterranean waters.

Table 2. Yields of ear corn during 13 years on a tiled Webster 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	1972	13 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	75.0	66.5a
40 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	113.0	82.6b
40 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	113.9	88.4bcd
40 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	109.9	87.4bc
40 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	106.7	90.9bcde
80 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	143.1	103.7fgh
80 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	140.1	103.0fgh
160 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	147.6	108.3gh
160 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	151.7	111.3h
40 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	117.0	95.3cdef
40 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	116.5	93.7cdef
80 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	142.7	108.1gh
80 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	142.1	108.9gh
40 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	136.0	97.5defg
40 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	133.9	94.4cdef
80 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	124.7	99.3efgh
80 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	149.8	110.3h
160 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	150.0	108.2gh
Ave. 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	128.6	

[1]The entire area received an additional 14 lbs N/A as starter fertilizer annually (8-24-12 @ 175 #/A)
[2]fpd -- fall plow down [3]fps -- fall plow-surface [4]std -- spring topdress [5]sd -- sidedress

Tillage for Soybeans - Lamberton, 1972

W. W. Nelson

A basic tillage trial for soybean production was initiated in the fall of 1971 on a tiled Nicollet-Webster soil. The crop in 1971 was corn and the stalks were chopped. The treatments were fall plow, fall chisel, spring chisel and spring disc. After the treatments were completed and just prior to planting all were disced again. Corsoy soybeans were grown and a broadcast application of Amiben applied. The experiment was replicated five times.

Soybean Tillage

Primary tillage	Bu/A
Fall plow	47.1
Fall chisel	45.1
Spring chisel	42.7
Spring disc	43.7
LSD 5%	3.1

No difference in growth or weed control were evident during the season. Yields were obtained by hand harvesting.

Winter Versus Spring Fertilization of a Webster Clay Loam Near Lamberton on 1968-72 Corn Yields.

W. W. Nelson and J. M. MacGregor

This experiment has now been conducted for each of five years on the nearly level Webster clay loam. Grain yields have been reported annually with the exception of 1969 when only silage corn was harvested. The experimental design and procedures have been previously described in Soil Series 84, 86, 87, and 88. The N, P_2O_5 and N+P_2O_5 (40+0+0, 0+40+0, and 40+40+0) have been broadcast each January or in April on the same plot areas. The relatively low rates of N application are known to be insufficient for optimum corn production. This is desirable since even minor losses of applied N or P_2O_5 should be reflected by reduced corn yields. Analyses of 1972 corn leaves showed 6th leaf N concentrations of 1.35% in the unfertilized area, the leaves from corn plants receiving 0-40-0 contained 1.30% N, whereas both the 40+0+0 and the 40+40+0 plot corn plant leaves were significantly higher with 1.61% N. All of these values are much below the 2.5% leaf N values usually considered desirable for optimum corn production. Grain or silage corn yields for each of the five years with the different treatments and times of application are shown in the following table.

Yields of Corn Grain or of Silage During a Five Year Period (1968-72) with Nitrogen, Phosphate, or Combination, Broadcast in January or in April on a Level Webster Clay Loam near Lamberton.

		Yields @ 15.5% moisture				
Time of Fertilization	Treatment (lbs/A)	1968 grain bu/A	1969 silage T/A	1970 grain bu/A	1971 grain bu/A	1972 grain bu/A
-----	none	93.8a	7.89ab	64.2a	26.8ab	57.6a
January	40+0+0	110.5b	9.46bc	90.6b	52.1c	78.8b
April	40+0+0	116.7b	11.17c	94.9b	66.0de	82.8b
January	0+40+0	101.6ab	8.33ab	69.5a	37.7b	59.9a
April	0+40+0	93.2a	7.23a	66.5a	22.5a	55.0a
January	40+40+0	114.7b	9.54bc	103.0c	54.4cd	81.2b
April	40+40+0	111.5b	9.19b	105.3c	73.0e	87.0b

Nitrogen and nitrogen + phosphate treatments have both significantly increased corn grain yields in each of the four years that grain yields were recorded with the phosphate fertilization producing no yield increase. The 1969 fertilizer effect on corn silage yields is less evident. It is apparent, however, that time of fertilizer application has not influenced grain yields in 3 of the 4 years of the study (1968, 1970, and 1972), but 1971 spring fertilization was significantly more effective on corn yields than the N + P_2O_5 applied three months earlier.

The five year study shows that winter fertilization occasionally may result in partial losses of some of the applied fertility in comparison to spring fertilization.

WEST CENTRAL EXPERIMENT STATION - MORRIS
WEATHER SUMMARY - 1972

Month	Period	Precipitation 1972	Precipitation 84-yr. av.	Precipitation Dev. from av.	Air Temperature 1972	Air Temperature 84-yr. av.	Air Temperature Dev. from av.	Soil (10 cm) Temperature 1972	Soil (10 cm) Temperature 5-yr. av.
January	1-31	.72	.66	+.06	3.2	8.6	-5.4	30.4	23.2
February	1-29	.86	.65	+.21	5.3	12.8	-7.5	28.0	25.0
March	1-31	1.31	1.04	+.27	24.5	26.8	-2.3	30.9	29.2
April	1-10	.36	.60	-.24	30.9	38.3	-7.4	33.6	
	11-20	1.12	.63	+.49	43.6	44.3	-0.7	41.3	
	21-30	1.13	1.10	+.03	44.7	48.4	-3.7	44.2	
Total or Average		2.61	2.33	+.28	39.7	43.7	-4.0	39.7	40.8
May	1-10	.34	.81	-.47	46.8	52.1	-5.3	47.9	
	11-20	1.02	1.01	+.01	63.8	55.6	+8.2	59.4	
	21-31	3.04	1.18	+1.86	64.8	60.0	+4.8	64.7	
Total or Average		4.40	3.00	+1.40	58.6	56.0	+2.6	57.6	55.9

WEST CENTRAL EXPERIMENT STATION - MORRIS. WEATHER SUMMARY - 1972 (continued) --

Month	Period	Precipitation 1972	Precipitation 84-yr. av.	Precipitation Dev. from av.	Air Temperature 1972	Air Temperature 84-yr. av.	Air Temperature Dev. from av.	Soil (10 cm) Temperature 1972	Soil (10 cm) Temperature 5-yr. av.
June	1-10	0	1.34	-1.34	68.9	62.9	+6.0	72.9	
	11-20	1.95	1.16	+ .79	63.3	66.6	-3.3	69.4	
	21-30	.25	1.41	-1.16	66.0	68.2	-2.2	70.0	
Total or Average		2.20	3.91	-1.71	66.1	65.9	-0.4	70.7	68.8
July	1-10	.15	1.57	-1.42	65.5	69.9	-4.4	73.2	
	11-20	2.42	1.06	+1.36	69.9	71.4	-1.5	74.7	
	21-31	3.71	.94	+2.77	70.3	71.7	-1.4	75.1	
Total or Average		6.28	3.57	+2.71	68.6	71.0	-2.4	74.3	75.5
August	1-10	.79	1.10	-.31	61.5	70.6	-9.1	70.7	
	11-20	.01	.91	-.90	77.4	69.1	+8.3	78.6	
	21-31	.92	.96	-.04	68.3	66.8	+1.5	70.7	
Total or Average		1.72	2.97	-1.25	69.1	68.8	+0.3	73.4	74.5
September	1-30	.38	2.26	-1.88	56.3	59.3	-3.0	63.3	62.1
October	1-31	1.81	1.52	+.29	42.3	47.5	-5.2	47.1	47.3
November	1-30	1.43	0.88	+.55	28.7	29.9	-1.2	34.5	34.4
December	1-31	1.74	0.69	+1.05	6.6	15.8	-9.2	30.4	27.3
April-August Growing Season		17.21	15.78	+1.43	60.4	61.2	-0.8	63.1	63.1
Jan.-Dec. Annual		25.47	23.46	+2.01	39.1	42.2	-3.1	48.4	47.0

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 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.

In 1972 the variety used was Pioneer 3932 and the corn was planted on June 8.

Silage Yields

Dry Matter, tons/acre

	1972 Yield	1966-72 Av. Yield
On plots harvested as grain 1965-72:		
Low fertility (74+48+48)	4.15	5.29
High fertility (148+96+96)	5.60	5.66
On plots harvested as silage 1965-72:		
Low fertility (74+48+48)	4.65	5.36
High fertility (148+96+96)	4.88	5.77

Grain Yields

Bushels/acre @ 15.5% moisture

On plots harvested as grain 1965-72:

	1972	1966-72
Low fertility (74+48+48)	63.74	84.79
High fertility (148+96+96)	83.81	90.83

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

Grain (0+0+0)	66.16 bu/A	55.64 bu/A
Silage (0+0+0)	3.62 tons/A	3.94 tons/A

Due to the wet fall in 1971 and wet spring the experiment was planted quite late. The results in 1972 follow those of previous years. There is still no significant reduction in yield after growing eight years of continuous corn silage. Higher fertility increased both silage and grain yields.

EFFECT OF HEAVY APPLICATIONS OF ANIMAL MANURES ON CORN GROWTH AND YIELD AND ON SOIL PROPERTIES

West Central Experiment Station - Morris

S. D. Evans, J. M. MacGregor, R. C. Munter, and P. R. Goodrich

The experimental design and treatment descriptions are given on page 118, Soil Series 88, March 1972 (A Report on Field Research in Soils).

Field Operations (1972 Season)

May 2- Took pictures of all plots - observed a difference in soil drying.

May 15- Tried to take neutron probe readings - water in most of the tubes; some almost full.

May 18- Decided to remove all neutron access tubes due to the water in them - removed tubes.

May 18- Went thru all plots with Graham Home digger to enhance soil drying - disk liquid beef plot No. 4 to try to level it up - liquid beef plots very wet - tractor mired down in all liquid beef plots.

June 1- Dug all manure plots with large field cultivator - dragged plots to level them and to prepare a better seedbed.

June 1- Planted plots in 30-inch rows with Pioneer 3956A (N) @ 20,000 seeds/acre. West six rows of each plot was left without insecticide. Remaining 14 rows received 10 lbs./A of Furadan (10% granule). Plots of the treatment receiving fertilizer got 7-28-28 as a starter (10 + 40 + 40). None of the other treatments received any fertilizer.

June 2- Sprayed all plots with 2 1/2 lb./A of Lasso broadcast.

June 6- Sampled soil in plots 2, 3, 4, and 5 to a 2-foot depth for conductivity analyses.

June 7- Observed the corn 50% emerged on most plots - some skips in solid beef due to manure plugging in front of planter shoe and pushing out seed - some skips in liquid beef due to unevenness and wet conditions at planting.

June 12(Afternoon)- observed some plants wilted in liquid beef plots - took pictures of all treatments.

June 13- put neutron access tubes and porous cup tubes in plots 1 thru 4.

June 16- Finished putting access tubes in plots 5 and 6 - put porous cup tubes in plots 5 thru 12.

June 21- Evacuated porous cups to 0.7 ATM - took stand count in center 2 rows of each plot.

June 22- Took water samples from the porous cups.

June 22-23- Tried to take neutron probe readings again - water in many tubes and probe acting erratically.

June 26- Cultivated all plots for first time.

June 28 (AM)- Evacuated porous cups to 0.7 ATM.

June 30 (PM)- Took moisture samples from porous cups.

June 29 & 30- Plots were handweeded - solid beef plots were the weediest.

July 3- Cultivated all plots for the second time.

July 5- Handweeded plots.

July 7- Took soil samples in plots 1 thru 5 to a 3-foot depth for conductivity analysis.

July 14- Took plant heights on all plots and also took pictures.

July 25- Put up corn rootworm frames and cages.

July 31- Took first rootworm counts in each cage - continued these counts on Monday, Wednesday and Friday of each week.

August 1- Took soil samples in plots 1 thru 5 to a 3-foot depth for conductivity analysis - also evacuated porous cups in the

AM to 0.7 ATM.

August 3- (PM)- Took moisture samples from porous cups.

July 31 thru August 10- Took notes on pollen shedding and silking. On the day the plots silked leaf samples were taken from all sub-plots.

August 16- Took heights on all plots to the top of the tassel.

Mid-August- Installed deep wells (about 20 ft.) on the NW corner of plot 12 and 30 feet east of the center of plot 7.

August 24- Pumped water from deep wells.

August 31- Took samples from deep wells. Water from the west well had a foul odor.

September 14- Took bulk densities on plots.

September 28- Took ear, silage and root samples for analysis.

September 29- Staked standard lengths in each plot for harvest and made plant counts.

October 3- Pulled all pipes out of plots - about 1/2 of the porous cups came off.

October 6- Removed all cages from plots.

October 16- Harvested plots obtaining grain and silage yields.

October 19- Harvested the bulk of the experimental area as shelled corn.

October 23 & 24- Took soil samples to a 10-ft. depth in all plots (3 sub-samples per plot).

October 24- Sampled the three fertilizer plots for routine soil tests.

October 26- Applied 34-0-0 to fertilized plots to provide 110 lbs. of N/Acre.

October 26- Disked and plowed all plots.

Table 1. Manure Analyses (Fall 1970) - Correction of Table 1 on page 119, Soil Series 88, March 1972.

	Solid Beef	Liquid Beef	Liquid Hog
Total Solids	31.35%	10.82%	1.24%
Total Volatile Solids	78.30%	8.43%	99.51%
(from total solids)			
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	1.120%	0.202%	0.234%
NO_3-N	.282%	0.016%	0.014%
PO_4	.288%	0.063%	0.012%

Table 2. Exchangeable Ammonium in Soil Samples (Fall 1972)

Depth (ft.)	Exchangeable Ammonium (NH_4^+-N) ppm in Soil									
	A	B	A	B	A	B	A	B	A	B
0-1/2	5.2	4.9	5.4	8.3	4.9	9.1	5.7	11.7	5.8	12.5
1/2-1	3.9	5.1	4.0	9.0	8.0	8.0	4.8	10.6	4.5	8.4
1-2	2.9	2.8	3.8	6.9	3.3	3.9	2.8	6.9	4.5	4.0
3-4	2.2	2.5	2.8	5.1	1.8	3.8	2.5	2.2	3.3	4.2
	Check		Fertilized		Solid Beef		Liquid Beef		Liquid Hog	

NOTE: A - Readings taken on soil samples taken in the fall of 1970 before manure application.

B - Readings on Soil Samples taken in the fall of 1971 before manure application.

Table 3. Manure Analyses (Fall 1971)*

	Solid Beef	Liquid Beef	Liquid Hog
Total Solids (%)	52.51	10.59	3.59
Total Volatile Solids (%)	--	8.27	2.32
(from total solids)			
C.O.D. (mg/l)	--	147,700	79,000
Total N (%)	1.30	.81	.37
Org. N (%)	.76	.27	.09
NH_4^+-N (%)	.59	.55	.29
NO_3^--N (%)	.0970	< .0035	<.0020
NO_2^--N (%)	.0081	< .0002	<.00005
PO_4 (%)	.975	.451	.172
pH range	7.8-8.0	7.6-8.2	7.8-8.1
Chlorides (%)	1.34	.44	.15
Conductivity mho's	1500	3670	5570

* Average of 2 samples of solid beef, 6 samples of liquid beef, and 6 samples of liquid hog manure.

Table 4. Average Chemical Analyses of Water Collected from Porous Cups on June 22, June 30 and August 3, 1972.

Treatment	Porous cup depth (ft.)	NH_4-N ppm	NO_3-N ppm	NO_2-N ppm	PO_4-P ppm	Electrical Conduc. µmhos/cm
Check	2	.3	25	.2	.014	550
	4	.3	53	.9	.011	884
	6	.3	42	.2	.032	841
Fertilized	2	.3	42	.1	.026	785
	4	.4	149	.7	.049	1633
	6	.3	39	.8	.011	1147
Solid Beef	2	.5	246	.2	.010	2930
	4	.9	316	.3	.048	3470
	6	.5	44	.3	.099	1150
Liquid Beef	2	2.8	277	.5	.308	3317
	4	5.4	226	.9	.192	2950
	6	2.0	53	.4	.209	1174
Liquid Hog	2	.4	134	.3	.365	1832
	4	.8	364	.4	.475	3100
	6	.5	188	.5	.052	1913

Table 4. Electrical Conductivity* of Soil Samples Taken on June 6, July 7, and August 1, 1972.

Treatment	Depth Increment (ft.)	June 6	July 7	August 1
			-mmhos/cm-	
Check	0-1/2	--	.47	.52
	1/2-1	--	.57	.53
	1-2	--	.50	.45
	2-3	--	.92	.83
Fertilized	0-1/2	.82	.68	.45
	1/2-1	.80	.59	.33
	1-2	.80	.56	.52
	2-3	--	.81	.57
Solid Beef	0-1/2	1.90	2.50	1.28
	1/2-1	1.84	2.55	1.46
	1-2	1.82	2.90	1.12
	2-3	--	1.90	1.79
Liquid Beef	0-1/2	3.90	4.40	1.62
	1/2-1	3.60	2.55	1.46
	1-2	2.40	2.85	1.80
	2-3	--	2.20	1.84
Liquid Hog	0-1/2	2.25	2.90	1.25
	1/2-1	1.80	2.45	1.53
	1-2	1.70	1.85	1.30
	2-3	--	1.35	1.06

* Determined on a saturation extract.

Table 5. Plant Measurements Taken During the 1972 Season.

Treatment	Sub Plot Insecticide	July 14 Height of Ext. Leaf -(in)-	Aug. 16 Height Top of Tassel(in)	Date 50% Plants Shedding Pollen	Date 50% Plants Silked	Stalks on 9/29 Broken Below Ear,%	Stalks on 9/29 Broken Above Ear,%	GRAIN % Ear Moisture at Harv.	GRAIN Yield Bu/A @ 15.5% M.	SILAGE % Dry Matter at Harv.	SILAGE Yield #/A Dry Matter	SILAGE Ears as % of Total
Check	W	44	96	8-4	8-8	16.4	2.4	33.6	73.4	58.2	9800	52.7
	W/O	--	--	8-4	8-8	22.8	3.6	32.0	71.1	56.0	7900	56.8
Fertilized	W	53	107	8-2	8-6	15.2	4.1	32.6	102.8	53.7	11700	55.4
	W/O	--	--	8-2	8-6	27.7	8.0	30.8	93.5	53.8	11300	56.1
Solid Beef	W	61	113	7-31	8-4	11.1	6.7	34.3	120.7	38.3	13000	58.6
	W/O	--	--	7-31	8-4	30.8	17.5	31.7	106.2	43.7	12700	53.7
Liquid Beef	W	44	110	8-1	8-5	21.4	7.9	35.7	109.1	41.0	10900	57.6
	W/O	--	--	8-1	8-5	24.2	18.7	33.5	102.2	44.1	12500	53.9
Liquid Hog	W	61	112	7-31	8-4	9.7	7.1	31.5	123.7	44.2	13000	57.7
	W/O	--	--	7-31	8-4	30.5	22.6	32.4	103.8	41.1	10700	56.3

Table 6. Main Plot, Sub Plot, and Interaction Averages and Levels of Significance.

	On Sept. 29		GRAIN		SILAGE		
	Stalks Broken Below Ear %	Stalks Broken Above Ear %	% Ear Moisture at Harv.	Yield Bu/A @ 15.5% M	% Dry Matter at Harvest	Yield Lbs/Ac of Dry Matter	Ears as a % of the Total
Check	20.8	3.0 A	32.8	72.2 AB	57.1 C	8800 A	54.7
Fertilized	21.4	6.1 AB	31.7	98.2 BC	53.7 BC	11500 BC	55.8
Solid Beef	21.0	12.1 BC	33.0	113.4 C	41.0 A	12800 C	56.2
Liquid Beef	22.8	13.3 C	34.6	105.6 BC	42.6 AB	11700 C	55.8
Liquid Hog	20.0	14.8 C	32.0	113.8 C	42.6 AB	11900 C	57.0
Level of Significance	NS	**	NS	**	**	*	NS
+ Insecticide	15.8	5.1	33.5	100.5	48.9	11400	55.8
- Insecticide	26.5	12.4	32.0	91.3	49.1	10500	55.6
Level of Significance	**	**	*	*	NS	NS	NS
Interaction - Level of Significance	NS	**	NS	NS	NS	NS	NS

Table 7. Summary of Analysis of Corn Leaves at Silking.

	N %	P %	K %	Ca %	Mg %	Al ppm	Fe ppm	Zn ppm	Cu ppm	Mn ppm	B ppm
Check	1.56 A	.198 A	1.94 A	.64 B	.40 B	58 B	127 A	14.2 A	7.6	62 A	5.8 A
Fertilized	2.51 B	.286 A	2.00 A	.66 B	.40 B	44 AB	134 A	23.9 BC	9.0	56 A	5.9 A
Solid Beef	2.84 B	.572 B	2.85 B	.53 A	.21 A	32 A	136 A	16.8 AB	8.2	74 A	6.2 A
Liquid Beef	2.93 B	.549 B	2.22 B	.68 B	.20 A	48 AB	164 B	34.4 D	8.1	244 B	8.4 C
Liquid Hog	3.03 B	.510 B	2.45 AB	.70 B	.23 A	34 A	138 A	27.2 CD	9.1	97 A	6.9 B
Level of Significance	**	**	**	*	**	**	**	**	NS	**	**
+ Insecticide	2.47	.395	2.25	.66	.31	43	138	22.8	8.1	111	6.6
- Insecticide	2.34	.378	2.22	.63	.31	48	137	20.8	8.4	88	6.4
Level of Significance	(+)10%	NS	NS	NS	NS	NS	NS	*	NS	*	NS
Interaction-Level of Significance	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS

Table 8. Chemical Analysis of Water from Deep Wells on August 31.

Well Location	NH_4-N ppm	NO_3-N ppm	NO_2-N ppm	PO_4-P ppm	Elec. Cond. umhos/cm
NW Corner of Plot #12 (F)	.5	18	0	0	645
30 ft. east of center of Plot #7 (LB)	.4	5	.1	0	500

Table 9. Soil Tests* Taken on Fertilized Plots in the Fall of 1972 (Oct. 24).

Rep	pH	Organic matter	P lbs/A	K lbs/A	Zn ppm	Soluble Salts mmhos
1	7.2	H	27	250	4.1	0.5
2	6.9	H	47	350	11.0	0.6
3	7.0	H	13	280	10.8	0.5

* Analysis of the University of Minnesota Soil Testing Laboratory.

EFFECT OF RATES OF SOLID BEEF MANURE ON CORN GROWTH AND YIELD

West Central Experiment Station - Morris

S. D. Evans

Solid beef manure was applied to plots at 33 1/3, 66 2/3, and 100 tons/acre (wet weight) and the plots were planted to corn in 1972. The growth and yield on these plots was compared to that on plots receiving fertilizer at recommended rates.

Field Operations (1971-72)

October 15, 1971- Applied solid beef manure to 33 1/3 and 66 2/3 tons/acre plots. Ran out of manure when we had applied only 33 1/3 T/A to 100 T/acre plots.

Applied zinc sulfate at 30 lbs./acre to the fertilizer plots.

Plowed all plots.

May 16, 1972- Finished applying solid beef manure to 100 T/acre plots and replowed these plots only.

May 18- Put 34-0-0 on to provide 110 lbs. of actual N per acre on fertilizer plots. Disk 100 T/A plots.

Dug all plots twice to incorporate manure.

June 1 - Dug all plots with large field cultivator.

Disked all plots.

Dragged plots.

June 1-2 - Planted plots in 30-inch rows with Pioneer 3956 A(N) @ 20,000 seeds/acre. Each main plot was split and one-half received Furadan (10% granule) at 10 lbs/acre and the other half received no insecticide.

The fertilized plots received 7-28-28 to provide 10 + 40 + 40.

June 2- Sprayed all plots with 2 1/2 lb/A of Lasso broadcast.

June 7- Corn 50% emerged - No problems.

June 21- Sprayed all plots with Banvel-D @ 1/4 lb/A broadcast to

control thistle.

June 21- Took a stand count.

June 26- Cultivated all plots for the first time.

July 3- Cultivated all plots for the second time.

July 14- Took plant heights on all plots.

August 2 thru 7 - Took notes on pollen shedding and silking. On the day the plots silked leaf samples were taken from all sub-plots.

August 16- Took plant heights on all plots.

October 17- Harvested all plots obtaining grain yields only.

October 20- Applied 34-0-0 to fertilizer plots to provide 110 lbs. of N/Acre.

October 24- Sampled the three fertilizer plots for routine soil tests.

October 26- Disked and plowed all plots.

Table 1. Manure Analyses*

		Fall 1971	Spring 1972
Total Solids	(%)	52.51	24.54
C.O.D.	(mg/l)	---	84310
Total N	(%)	1.30	.46
Org. N	(%)	.76	.23
NH_4+N	(%)	.59	.23
NO_3-N	(%)	.0970	N.M.A.
NO_2-N	(%)	.0081	N.M.A.
PO_4	(%)	.975	.136
pH range		7.8-8.0	7.0-7.5
Chloride	(%)	1.34	.44
Conductivity	mho's	1500	2650

N.M.A. - No measurable amount.

* Average of two samples on each date.

Table 2. Summary of Plant Measurements during the 1972 Season.

Treatment	% Ear Moisture at Harvest	Yield Bu/Acre @15.5% Moisture
Fertilized	32.6	101.0
Solid Beef @ 33 1/3 T/A	32.6	103.3
Solid Beef @ 66 2/3 T/A	31.4	109.0
Solid Beef @ 100 T/A	30.5	110.8
Level of Significance	NS	(+) 10% level
+ Insecticide	32.2	111.0
- Insecticide	31.2	101.0
Level of Significance	(+) 10% level	**
Interaction -		
Level of Significance	NS	NS

Table 3. Summary of Analyses of Corn Leaves at Silking.

	N %	P %	K %	Ca %	Mg %	Al ppm	Fe ppm	Zn ppm	Cu ppm	Mn ppm	B ppm
Fertilized	2.62	.296A	1.82A	.64	.43C	38	128	24.2B	10.1	72	6.8
Solid Beef @ 33 1/3 T/A	2.60	.407AB	2.30B	.62	.31B	44	142	14.2A	10.7	79	6.5
Solid Beef @ 66 2/3 T/A	2.51	.466B	2.51B	.58	.28AB	43	135	13.6A	8.7	79	6.4
Solid Beef @ 100 T/A	2.60	.420AB	2.36B	.55	.26A	41	131	15.8A	9.0	73	6.5
Level of Significance	NS	*	**	NS	**	NS	NS	**	NS	NS	NS
+ Insecticide	2.61	.407	2.24	.64	.32	40	134	17.4	10.2	77	6.6
- Insecticide	2.56	.388	2.25	.62	.32	43	134	16.6	9.0	75	6.5
Level of Significance	NS	NS	NS	NS	NS	(+)10%	NS	NS	*	NS	NS
Interaction -											
Level of Significance	NS	(+) 10% level	**	NS	NS	*	NS	NS	NS	NS	NS

Fertilizer Materials 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 experiment was set up in a split block design of four replications. Main blocks were (1) no broadcast fertilizer and (2) 80 lbs/acre P_2O_5 broadcast in the spring of 1971. Ten individual fertilizer treatments were superimposed across each main block pair. The individual treatments are described in Table 1. Ten lbs/acre of zinc as zinc sulfate was broadcast over the entire area in the fall of 1971. In 1972 the treatments were on the same plots as in 1971.

1972 Schedule of Operations

May 18- Ran Graham Home cultivator over entire area in an attempt to dry soil.

June 1- Ran field cultivator over area.

June 2- Ran field cultivator thru all plots and dragged for planting.

June 2- Planted all plots with hybrid Pioneer 3956 A. Used Furadan @ 1 lb/acre on all treatments but D & F (3 seeds/hill).

June 3- Sprayed all treatments but D & F with Lasso broadcast @ 2-1/2 lbs/acre.

1972 Schedule of Operations (cont.)--

June 29- Thinned all plots to two plants/hill.

July 7 (5:30-5:45 p.m.)- Applied first foliar treatment to B plots; very little wind, temp. 75-80°, mostly cloudy; 22 inch extended leaf height, 6th leaf coming out (not counting bottom two leaves).

August 3 (6:30-7:00 p.m.)- Applied second foliar treatment to B plots; no wind, temp. 64°, completely overcast; 10th leaf to tassels emerging.

October 19- Harvested reps 1 and 2 only (reps 3 and 4 were severely stunted due to wet soil conditions).

1972 Results.

There was very little effect of the broadcast phosphorus in 1972 (Table 2). The % P in the leaf was increased by .023% which was significant at the 10% level. The amount of aluminum in the leaves at silking was also increased from 92.2 ppm to 94.8 ppm by the addition of phosphorus in 1971. This was significant at the 1% level.

There was a spread of some seven days in pollen shedding (Table 3). The earliest plots were those receiving conventional fertilizer or conventional plus extra N and K. The latest were the organic and soil conditioner which had no pesticide applications. The date at which the plots silked followed the same pattern.

Harvest measurements were all significantly affected by fertilizer materials as shown in Table 3. The greatest percentage of normal ears were from treatments B, C, H, J, and K. Percent moisture in the ears at harvest was significantly higher on treatments D and F than on all other treatments. The highest yields were on treatments H and J. Treatment K followed closely and was not significantly lower. Treatments B and C were 69.8 and 68.2 bu/ac respectively and were

significantly lower than H, J, and K. The lowest yielding treatments were D and F. These two treatments were even lower yielding than the check, A, due to weed competition for moisture and nutrients. The use of pesticides with treatments D and F significantly increased yields by 23.2 and 25.8 bu/ac respectively.

Leaf samples were taken on the date the plants were 50% silked and the results are given in Table 4. Nutrient leaves significantly affected at the 5% level were Ca and Zn. Both elements were the highest on the so-called conventional treatments. N, P, Cu, and Mn were all changed by fertilizer materials and were different at the 1% level. These were all highest on the conventional treatments. B and Al were significant at the 1% level and were lowest on the conventional treatments.

The only measurements where the interaction between phosphorus and fertilizer materials was significant was in grain yield. Here the interaction was significant at the 5% level. The individual yields are given in Table 5.

Table 1. 1972 Morris Fertilizer Materials Trial

Treatment Letter	Treatment Description	Herbicide	Insecticide
A	check	yes	yes
B	120 lbs/acre of ammonium nitrate (40#N) broadcast before planting + 4 gal/acre of liquid 9-18-9* with seed at planting + 2 foliar treatments of 9-18-9x of 2 gal/acre on 7-7 and 3 gal/acre on 8-3.	yes	yes
C	Same as B but no foliar treatments	yes	yes
D	Wonderlife (0-0-0), a soil conditioner, at 250 lbs/acre broadcast before planting.	no	no
E	Same as D	yes	yes
F	Shurgro (6-2-1), an organic fertilizer, at 200 lbs/acre with planter	no	no
G	Same as F	yes	yes
H	313 lbs/acre of ammonium nitrate (105#N) broadcast before planting + 190 lbs/acre of 8-32-16 at planting.	yes	yes
J	Same as H but an addition of 299 lbs/acre of ammonium nitrate (100#N) and 100 lbs/acre of K_2O as 0-0-60 broadcast before planting.	yes	yes
K	120 lbs/acre of ammonium nitrate (40#N) broadcast before planting + 4 gal/acre of liquid 7-21-7 with seed at planting.	yes	yes

* Also contained 1% sulfur and 1/4 pint/acre Sequestrene Liquid Zinc (6.0% Zn).

x Also contained 1% sulfur.

Table 2. Effect of Broadcast Phosphorus on Plant Measurements.

	No P	B'cst P	Significance
Date 50% plants shedding pollen	8-10	8-10	NS
Date 50% plants silked	8-14	8-14	NS
Leaf Analysis:			
N, %	1.62	1.61	NS
P, %	.201	.224	+ (10%)
K, %	1.94	1.88	NS
Ca, %	.629	.666	NS
Mg, %	.431	.464	NS
Cu, ppm	7.3	6.6	NS
Mn, ppm	65	63	NS
B, ppm	7.2	7.3	NS
Al, ppm	92.2	94.8	**
Fe, ppm	176	174	NS
Zn, ppm	20.7	20.6	NS
Harvest Measurements:			
% ears normal in size and/or shape	73	75	NS
% ear moisture at harvest	37.2	36.9	NS
Yield in Bu/Ac 15.5% moisture	62.5	62.8	NS

Table 3. Effect of fertilizer materials on plant measurements.

Treatment Letter	Date 50% plants shedding pollen	Date 50% plants silked	%, ears normal in size and/or shape	% ear moisture at harvest	Yield Bu/Ac @ 15.5% M.
A	8-12 BC(1)	8-15 CD	66.5 C	36.6 A	45.2 BC
B	8-9 AB	8-14 BC	90.5 E	35.2 A	69.8 DE
C	8-9 AB	8-14 BC	85.0 DE	34.8 A	68.2 DE
D	8-14 C	8-17 D	22.5 A	43.0 C	20.4 A
E	8-12 BC	8-15 CD	67.5 C	38.4 AB	43.6 BC
F	8-14 C	8-17 D	39.8 B	41.6 BC	26.0 AB
G	8-10 ABC	8-14 BC	76.5 CD	36.6 A	51.8 CD
H	8-7 A	8-11 A	96.8 E	33.5 A	106.8 F
J	8-7 A	8-11 A	97.0 E	36.5 A	109.6 F
K	8-8 AB	8-12 AB	96.0 E	34.4 A	84.8 F
Significance	**	**	**	*	**

(1) Letters following values indicate significant differences by the Duncan test at the level indicated at the bottom of the column (either 5% or 1%).

Table 4. Effect of Fertilizer Materials on Leaf Analysis (Leaves Sampled at Silking).

Treatment Letter	N %	P %	K %	Ca %	Mg %	Cu ppm	Mn ppm	B ppm	Al ppm	Fe ppm	Zn ppm
	(1)										
A	1.04 A	.164 A	2.16	.478 A	.381	3.8 A	45 A	7.0 A	98.2 BCDE	166	17.0 AB
B	1.62 C	.213 B	1.98	.699 BCD	.431	7.3 BCD	66 ABC	6.5 A	101.1 BCDE	184	20.2 ABC
C	1.60 C	.194 AB	1.99	.698 BCD	.432	8.0 CD	71 ABCD	7.4 AB	87.0 ABCD	169	20.9 ABC
D	1.16 AB	.202 AB	1.88	.550 AB	.362	3.8 A	49 AB	8.6 B	119.4 DE	193	18.0 AB
E	1.13 A	.173 AB	1.86	.660 BCD	.456	5.5 AB	55 ABC	7.7 AB	104.4 CDE	168	20.4 ABC
F	1.12 A	.182 AB	2.04	.562 ABC	.393	3.7 A	48 AB	8.8 B	130.4 E	214	16.3 A
G	1.35 B	.187 AB	1.80	.698 BCD	.456	6.4 BC	72 BCD	6.6 A	104.7 CDE	184	21.4 BCD
H	2.66 E	.310 C	1.75	.759 D	.571	11.7 F	90 D	6.9 A	54.6 A	157	24.6 CD
J	2.64 E	.288 C	1.93	.651 BCD	.467	10.6 EF	79 CD	6.2 A	61.1 AB	161	26.0 D
K	1.86 D	.215 B	1.74	.722 CD	.525	8.6 DE	68 ABCD	6.5 A	73.8 ABC	156	21.7 BCD
Significance	**	**	NS	*	NS	**	**	**	**	NS	*

(1) Letters following values indicate significant differences by the Duncan test at the level indicated at the bottom of the column (either 5% or 1%).

Table 5. Yield of corn grain @ 15.5% moisture with and without broadcast phosphorus.

Treatment Letter	with Broadcast P	without Broadcast P
	---Bu/Ac---	
A	52.7	37.6
B	66.7	72.9
C	66.6	69.8
D	22.5	18.3
E	45.1	42.1
F	24.6	27.4
G	51.4	52.2
H	106.9	106.6
J	108.3	110.9
K	79.8	89.8

NITRATE NITROGEN CONTENT OF AN UNTILLED BARNES LOAM AFTER FIFTEEN YEARS OF NITROGEN FERTILIZATION FOR CONTINUOUS CORN CROPPING (1957-71)

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

A long term fertilizer-soil structure study with annual corn cropping was commenced in the spring of 1957 on an experimental field of Barnes loam on the West Central Experiment Station at Morris. Phosphate and potash were broadcast at the rate of 40 lbs/A each spring at planting with nitrogen at rates of 0, 40, 80 and 240 lbs/A, one of the 40 lbs N rates being plowed down each fall. Five soil structure treatments were included in three replications making a total of 75 individual 25' x 35' plots arranged in a Latin square design.

During the first ten years of the experiment, five different methods of seedbed preparation were included in the study and the desired plant population of 16,000 to 18,000 plants per acre was not uniformly obtained each year on all experimental plots. This seedbed preparation study was discontinued in 1967, and corn yields were somewhat improved with more uniform plant populations during the last five years of the study. During the last three years (1969-71) all of the phosphate, potash, and an additional 10 lbs of nitrogen per acre was applied in the row as a starter fertilizer in an effort to produce fertilizer yield increases.

Annual precipitation during the 15 year period averaged 25.18", which was somewhat greater than the long term average of 22.58". However, uneven precipitation distribution in this area, frequently limited corn production and the average annual yields obtained from the different fertilizer treatments were relatively low due to soil moisture limitation. Total annual precipitation, grain yields, and nitrogen removal in the corn grain per acre are shown in Table 1.

Table 1. Annual precipitation and 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.)

Year	Annual Precip.	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)
		(Bushels of corn per acre @ 15.5% moisture)				
1957 (May -Dec.)	28.06"	65.2	71.0	69.4	72.1	71.3
1958 (12 mo.)	16.92"	73.2	81.5	81.0	82.4	80.3
1959 "	17.99"	36.1	40.9	41.5	39.7	36.8
1960 "	26.14"	53.3	48.2	55.0	53.7	52.5
1961 "	16.98"	32.3	48.3	47.6	45.0	46.1
1962 "	30.42"	38.1	59.0	62.0	65.3	67.1
1963 "	26.29"	62.7	80.9	83.5	77.4	79.5
1964 "	18.89"	33.2	34.1	29.6	29.1	24.7
1965 "	33.48"	50.4	68.3	75.3	80.8	82.8
1966 "	22.20"	49.0	63.7	66.3	75.9	33.1
1967 "	16.79"	66.8	69.2	71.2	69.7	71.3
1968 "	27.68"	64.1	79.6	70.2	78.5	76.0
1969 "	25.47"	76.4	58.0	60.2	59.9	58.7
1970 "	27.33"	59.2	66.9	70.2	78.5	76.0
1971 "	33.16"	64.2	79.9	82.6	83.6	85.4
1972 (Jan.-June 15)	9.91"					
Total	377.71"					
15 Year Average	25.18"	54.3 bu/A	64.0 bu/A	64.8 bu/A	66.1 bu/A	62.8 bu/A

Table 1. continued-

	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)
% 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)	-30	630	630	1230	3630
Approx. N removed grain (lbs/A)	444	599	671	751	807
N balance in soil	-414	+31	-41	+479	+2823

(S) - Fertilizer broadcast in spring

(F) - Fertilizer broadcast in fall

(*) - Commencing in 1969, all phosphate, potash and an additional 10 lbs N/A were applied in the row as starter using 6+24+24 at the rate of 167 lb/A to supply the 10+40+40 treatment.

It is evident that annual applications of nitrogen at the 40 lbs/A rate increased corn yields equivalent to N supplied annually at the higher 80 or the 240 lbs/A rate, although the two latter fertilization rates resulted in higher protein corn and hence a greater N removal per bushel of grain. However, it is evident that over the 15 year period, very large differences in the N balance of the soils have arisen with the different rates of N application. The fate of the excess N applied was examined after nine years in October, 1965, and again in November of 1967, and finally in mid-June of 1972 (after 15 years). The NO_3-N content of these soils found late in 1965 to a depth of 96 inches was reported in Soil Series 80 (February 1966 -- pp. 84-86). After nine years of treatment, the first 48 inches of soil under the annual 40, 80, and 240 lbs/N/A treatments contained 3.3%, 7.1%, and 28.2% as much N as applied, whereas the 48 to 96 inch depths contained 2.3%, 14.7% and 34.3% respectively as much as applied in the fertilizer treatments. Therefore, the first eight feet of soil contained a total of 5.6%, 21.8% and 62.5% as much N as applied previous to that time.

Two years later (November, 1967) three replications of each of the three N treatments (0, 40, and 240 lbs of N annually) were sampled to a depth of 32 feet, and NO_3-N analyses were made of every fourth foot below the 48 inch depth. The results of this study were reported in Soil Series 82 (March, 1968 - pp. 90-92) showing NO_3-N accumulations to greater depths with the 0, 40, and 240 lbs N/A treatments.

Since 1971 the plot area was designated as a future building site, the fertilization experiment was terminated at the end of that year with soil sampling to be done in October or November. However, extremely heavy fall rains made deep soil sampling impossible and this was finally completed amidst the growing corn on June 14 and 15 of 1972

on the same plots as previously sampled. However, soil analyses of one of the 240 lbs N treatment (Plot 35) were much lower in NO_3-N than the same treatments of the other two sampled replications and since it was a depressional area, a similarly treated plot (Plot 35) in the adjoining replicate was sampled and analyzed later in 1972. The results were then averaged with those previously sampled, similarly fertilized plots of the other two main replications. The average NO_3-N content of three profiles of each of the three treatments are shown (in parts per million) in Table 2, and the averages (in pounds per acre) for each depth graphically in Figure 1 (assuming that one acre foot of soil weighs approximately four million pounds).

As might be expected from the calculated soil nitrogen balances reported in Table 1, data of Table 2 and Figure 1 show soil profiles without N fertilization (0+40+40 annually) and those receiving 40 lbs N annually (40+40+40 spring) are consistently low in NO_3-N (the nitrite (NO_2-N) values are also included but these were uniformly less than one part per million).

However, Table 1 shows that soils to which the 240 lbs/A nitrogen (240+40+40 S) treatments were made had little more N removed in the corn grain than either the check or the 40+40+40 treatment, resulting in a positive N balance of 2823 lbs N/A. This accumulation is corroborated by the soil NO_3-N shown in Table 2 and in Figure 1. A large proportion of the N not removed in the grain has now been leached down below the zone of corn root penetration, most occurring as NO_3-N in the 4 to 16 foot soil depth. It is doubtful that any appreciable proportion of this large supply of chemically and biologically available nitrogen can again become available to annual crop plants since roots of these rarely penetrate much below the four foot depth. Deep rooted perennial plants (such as alfalfa) could use at least part of this large NO_3-N supply.

Table 2. Nitrate Nitrogen (in parts per million) present in untiled Barnes loam following fifteen years of corn cropping with different rates of N fertilization. Sampled June 14-15, 1973.

Soil depth (feet)	0+40+40 each of 15 years* Plot Number				40+40+40 each of 15 years* Plot Number				240+40+40 each of 15 years* Plot Number			
	21	46	71	Ave.	10	45	55	Ave.	6	36	62	Ave.
	Nitrate Nitrogen in parts per million											
0.5	4.2	4.2	5.9	4.8	5.6	6.9	9.7	7.4	4.8	2.4	6.2	4.5
0.5-1	6.3	2.6	8.0	5.6	4.4	6.8	4.7	5.3	6.2	11.9	3.8	6.0
1-2	2.4	1.1	5.9	3.1	3.1	3.0	3.7	3.3	5.8	0.9	8.2	4.8
2-3	0.8	0.9	2.8	1.5	3.2	2.8	2.9	3.0	4.8	1.3	8.7	4.9
3-4	0.3	0.9	2.2	1.1	3.2	2.7	3.3	3.1	15.0	2.9	19.1	12.3
4-5	0.2	0.7	1.5	0.8	3.9	2.3	3.1	3.1	54.0	5.6	24.2	27.9
5-6	0.3	1.2	1.1	0.9	4.8	2.8	3.6	3.7	79.0	10.0	38.9	49.3
6-7	0.6	1.3	0.8	0.9	4.5	6.6	3.3	4.8	77.0	22.5	60.9	53.5
7-8	0.7	1.4	0.8	1.0	2.3	6.8	2.1	3.7	63.0	40.5	60.9	54.9
8-9	1.2	0.9	1.2	1.1	1.6	8.1	3.6	4.4	51.0	42.0	55.0	49.3
9-10	1.8	1.0	1.0	1.3	1.6	7.5	2.6	3.9	47.0	56.5	45.5	49.7
10-11	2.2	1.1	1.2	1.5	1.8	7.0	2.2	3.7	43.0	53.5	36.7	44.4
11-12	2.0	1.3	1.6	1.6	2.3	6.9	3.2	4.1	43.0	61.5	33.5	46.0
12-13	2.2	1.1	---	3.3	2.7	9.3	4.3	5.4	41.0	59.0	27.1	42.4
13-14	2.7	1.8	1.3	1.9	2.9	8.7	4.8	5.5	42.0	44.5	27.1	37.9
14-15	2.8	---	1.8	2.3	3.3	9.3	5.9	6.2	37.0	31.0	24.2	30.7
15-16	2.6	---	1.8	2.2	4.0	8.2	5.2	5.8	28.0	19.5	26.4	24.5
16-17	2.5	1.3	1.7	1.8	4.3	10.7	---	7.5	26.0	15.0	18.7	19.9
17-18	2.1	2.0	2.2	2.1	4.7	10.8	4.0	6.5	30.0	12.0	15.9	19.3
18-19	2.5	3.2	3.0	2.9	4.8	8.1	4.1	5.7	29.0	12.0	----	20.5

Table 2. continued--

Soil depth (feet)	0+40+40 each of 15 years*				40+40+40 each of 15 years*				240+40+40 each of 15 years*			
	Plot Number				Plot Number				Plot Number			
	21	46	71	Ave.	10	45	55	Ave.	6	36	62	Ave.
19-20	2.4	4.2	5.2	3.6	5.3	5.2	5.7	4.1	19.2	12.0	----	15.6
20-21	1.8	---	1.9	1.9	4.9	8.8	4.0	5.9	16.9	13.5	19.5	16.6
21-22	1.4	---	4.3	1.9	6.0	---	4.0	5.0	14.0	16.0	10.0	10.0
22-23	1.2	---	4.0	2.6	3.5	---	3.4	3.5	14.1	27.5	7.1	16.2
23-24	1.0	---	---	1.0	4.2	---	2.2	3.2	11.1	28.5	----	19.8
24-25	1.2	---	1.8	1.5	3.4	---	---	3.4	18.8	20.0	----	19.4
25-26	---	---	1.0	1.0	6.3	---	---	6.3	13.5	16.0	----	14.8
26-27	---	---	1.3	1.3	---	---	---	---	10.0	16.0	----	13.0
27-28	---	---	---	---	---	---	---	---	12.3	14.5	----	13.4
28-29	---	---	---	---	---	---	---	---	12.2	12.0	----	12.1
29-30	---	---	---	---	---	---	---	---	7.4	12.5	----	9.9
30-31	---	---	---	---	---	---	---	---	10.2	----	----	10.2
31-32	---	---	---	---	---	---	---	---	10.7	----	----	10.7
32-33	---	---	---	---	---	---	---	---	9.9	----	----	9.9
33-34	---	---	---	---	---	---	---	---	7.8	----	----	7.8

* All plots received an additional 10 lbs N/A in 1969, 1970 and 1971 as starter fertilizer

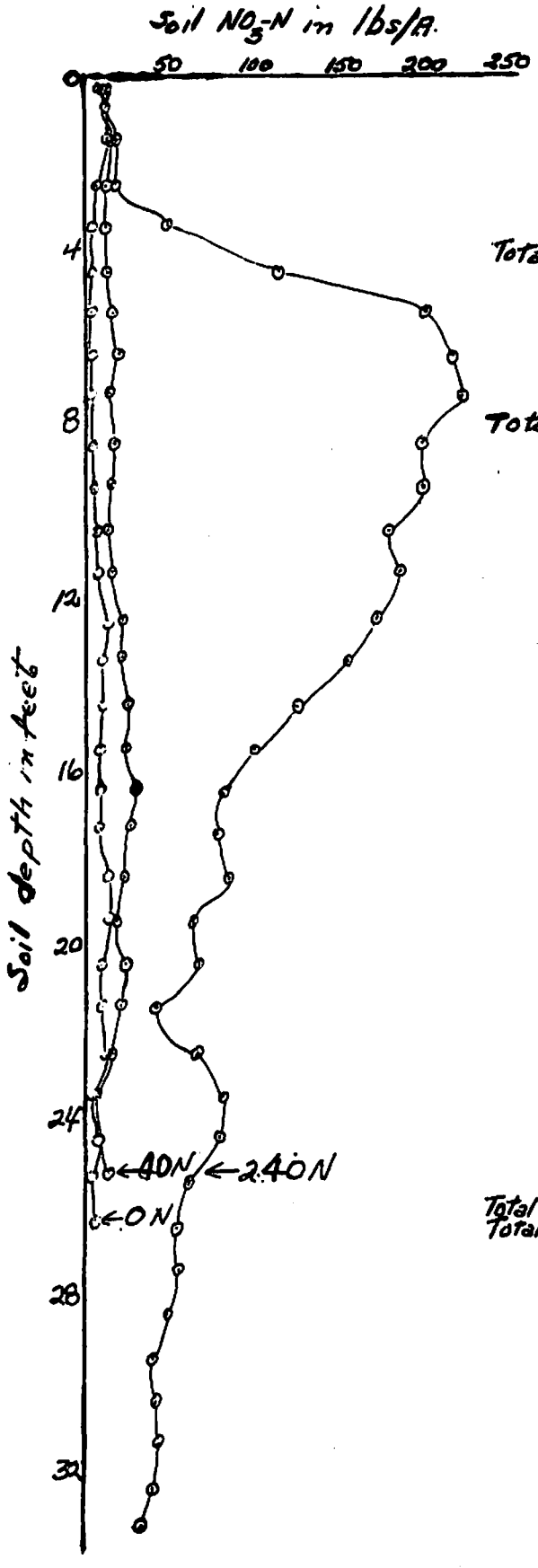
Since increased NO_3-N accumulation is evident to the 34 foot depth, substantial downward movement of N has apparently occurred where heavy rates of N fertilizer were applied for 15 years for corn production under comparatively limited annual precipitation. Such fertilizer practices are quite evidently not justified, either economically, or from their possible contribution of additional NO_3-N to subterranean water supplies.

Ammonium nitrogen (NH_4-N) also occurs in soils, although usually in much lower amounts than occurs as nitrate N (NO_3-N). If soils are water-saturated for a considerable period, much of the N present as NO_3 is then reduced by the lack of free oxygen (O_2) to the NH_4 form, (as in lowland soils on which rice is grown). Soils developed in areas of more limited precipitation such as western Minnesota are usually well aerated, and hence NH_4-N concentrations are comparatively low. Amounts of ammonium N in lbs. per acre foot present at the different soil depths, after 15 years of N fertilization are shown in Figure 2.

It is evident that the continued N fertilization, even at the heaviest rate has not appreciably increased soil NH_4-N to the 34 foot depth.

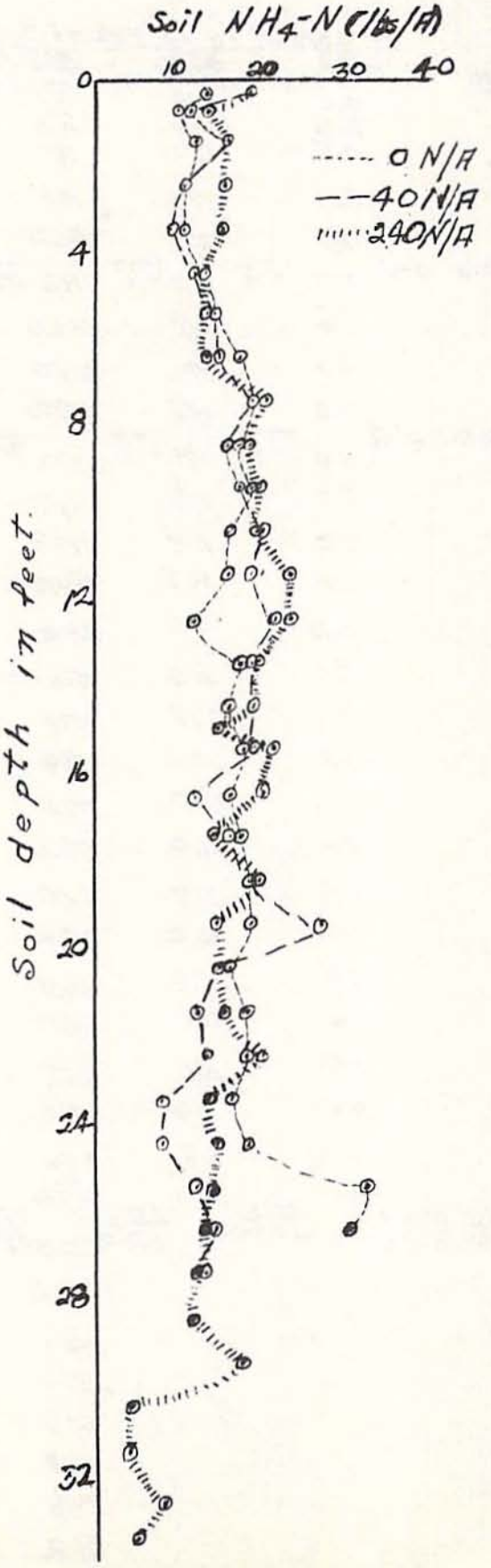
It is evident that 15 years of N fertilization of continuous corn at Morris has resulted in moderate increases in corn yield with moderate fertilization rates. Heavier annual N fertilization rates failed to produce further increases in corn yields and the unused N has largely been leached downward beyond the reach of plant roots and may eventually increase the NO_3-N content of subterranean water supplies.

Figure 1. Nitrate Nitrogen (Pounds per acre) in a Barnes Loam Following Fifteen Years (1957-71) of Annual Corn Cropping with Different Rates of Nitrogen Fertilization. (Sampled June, 1972)



	N applied in 15 years (lbs/A)					
	0		63.8		319.0	
	(Soil NO_3-N in lbs/A)					
	9.6		14.8		9.0	
	11.2		10.6		12.0	
	12.5		13.0		19.2	
	6.0		12.0		19.6	
	4.5		12.4		49.2	
Total 0'-4'	3.2	43.8	12.4	62.8	111.6	109.0
	3.6		14.8		197.2	
	4.0		19.2		214.0	
	4.0		14.8		219.2	
Total 4'-8'	4.4	14.8	17.6	61.2	197.2	742.0
	5.0		15.6		148.8	
	6.0		12.4		177.6	
	6.4		16.4		184.0	
	13.2		21.6		169.6	
	7.6		22.0		151.6	
	9.2		24.8		122.8	
	8.8		23.2		98.4	
	7.2		30.0		79.6	
	8.4		26.0		77.2	
	11.6		22.8		82.0	
	14.4		16.4		62.4	
	7.4		23.6		66.4	
	7.4		20.0		40.0	
	10.4		14.0		64.8	
	4.0		6.4		79.2	
	6.0		6.8		79.6	
	4.0		12.6		59.2	
Total 8'-26'		144.4		372.2		1988.4
Total 0'-26'	5.2	2000		456.2	52.0	2839.4
					53.6	
					48.4	
					39.6	
					40.8	
					42.8	
					39.6	
					31.2	

Figure 2. Exchangeable Ammonium Nitrogen (Pounds per acre) in a Barnes Loam Following Fifteen Years (1957-71) of Annual Corn Cropping with Different Rates of Nitrogen Fertilization. (Sampled June, 1972).



N applied during 15 years (lbs/A)

30	630	3630
(Exchangeable NH_4-N in lbs/A)		
13.4	18.6	18.2
10.0	17.4	13.2
12.0	16.0	16.0
10.8	10.8	15.6
10.8	9.2	15.2
13.2	12.0	13.6
14.8	14.8	13.6
17.2	14.8	13.6
18.8	18.8	20.2
17.2	16.0	18.8
18.8	17.2	19.6
16.0	20.0	19.2
16.0	18.8	23.2
12.0	21.2	23.2
17.2	18.8	19.6
16.0	18.8	18.8
18.0	18.8	14.8
16.0	12.0	21.2
17.2	16.0	20.0
18.8	18.8	14.8
18.8	26.8	19.6
16.0	14.8	14.4
18.0	12.0	15.2
18.0	13.2	20.0
16.0	8.0	13.6
18.0	8.0	14.8
32.0	12.0	14.4
30.0	14.0	13.6
476.0	120	12.4
	437.6	11.6
		17.6
		4.0
		4.0
		8.0
		5.0
		478.0

Small Grain Fertilization

West Central Experiment Station-Morris

S.D. Evans

Field experiments were carried out on Tara silt loam in 1971 and Doland silt loam in 1972 to study the response of wheat, oats, and barley to nitrogen fertilization. Three varieties of each crop were grown at three applied nitrogen levels. The nitrate nitrogen level in the soil was determined by the University of Minnesota Soil Testing Laboratory.

A. Oats

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

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

Seeding date- April 28, 1972

Nitrate nitrogen soil test- 53 lbs/acre.

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

Table 1. Yield, Oat Fertility Study, Morris, 1972.

Nitrogen Applied lbs/A	Variety			
	Lodi	Otter	Diana+	Average
		---Bu/A---		
0	60.0	53.5	23.5	45.7
30	69.9	71.7	34.0	58.5
60	76.5	77.8	36.3	63.6
90	80.3	76.7	50.8	69.3
Average	71.7	69.9	36.2	

+ There was severe bird damage with variety Diana.

Table 2. Lodging Score (1-9 scale). Oat Fertility Study, Morris 1972.

Nitrogen Applied lbs/A	Variety			
	Lodi	Otter	Diana	Average
		---Lodging---		
0	2.3	2.7	2.0	2.3
30	3.3	2.7	2.3	2.8
60	4.0	2.7	1.7	2.8
90	3.3	4.0	2.7	3.1
Average	3.2	3.0	2.2	

Table 3. Groat Percentages, Oat Fertility Study, Morris 1972.

Nitrogen Applied lb/A	Variety			
	Lodi	Otter	Diana+	Average
		---Groat %---		
0	68	69	58	65
30	66	68	53	63
60	68	68	54	64
90	64	68	64	65
Average	66	68	57	

+ There was severe bird damage in the variety Diana.

The statistical analysis of these variables has not been done.

B. Barley

Main plots- Varieties (1) Dickson (2) Larker (3) 64-76 in 1971 and 65-220 in 1972.

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

Seeding date- April 7, 1971 and April 28, 1972.

Nitrate nitrogen soil test- 1971-70 lbs/acre
1972-53 lbs/acre

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

Table 4. Percent protein in grain, Barley Fertility Study, Morris 1971.

Nitrogen Applied lbs/A	Variety			
	Dickson	Larker	64-76	Average
		---% Protein---		
0	11.1	11.3	11.3	11.2
30	10.8	11.9	11.4	11.4
60	11.0	12.1	10.7	11.2
90	12.6	13.1	11.8	12.5
Average	11.4	12.1	11.3	

Table 5. Yield, Barley Fertility Study, Morris 1972.

Nitrogen Applied lbs/A	Variety			
	Dickson	Larker	65-220	Average
		---Bu/A---		
0	27.2	29.9	21.1	26.1
30	34.5	37.0	29.2	33.6
60	46.8	45.4	33.2	41.8
90	40.2	47.1	28.6	38.6
Average	37.2	38.2	28.0	

Table 6. Lodging score (1-9 scale), Barley Fertility Study, 1972.

Nitrogen Applied lbs/A	Variety			
	Dickson	Larker	65-220	Average
		---Lodging---		
0	1.0	1.3	3.7	2.0
30	1.3	1.7	4.0	2.3
60	3.0	2.3	6.7	4.0
90	3.3	3.3	7.0	4.7
Average	2.2	2.2	5.3	

Table 7. Analysis of Variance, Barley Fertility Study, Morris 1971 and 1972.

Source of Variation	1971 % Protein	1972 Bu/A	1972 Lodging
Reps	NS	NS	-not-
Varieties (V)	NS	*	-analyzed-
Nitrogen (N)	*	**	-yet-
V x N	NS	NS	

C. Wheat.

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

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

Seeding date- April 7, 1971

Nitrate nitrogen soil test- 1971-70 lbs/acre. A uniform starter application of 100 lbs of 10-20-20 was used.

Table 8. Percent protein in grain, Wheat Fertility Study, Morris, 1971.

Nitrogen Applied lbs/A	Variety			
	Chris	Era	Ciano 67	Average
	----% Protein---			
0	13.8	12.7	14.0	13.5
40	14.6	12.9	14.3	14.0
80	15.5	12.7	13.9	14.0
120	16.7	13.3	14.5	14.8
Average	15.2	12.9	14.2	

The 1972 wheat data was not available at the time of printing.

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. Heiner

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

SOYBEAN-NITROGEN FERTILIZER SOURCE AND RATE STUDY

G. E. Ham and S. D. Evans

Ammonium nitrate, urea and soybean meal sources of nitrogen at the rate of 100 and 200 pounds of nitrogen per acre were compared at Morris and Rosemount. All fertilizers were applied to the surface and disked in before planting. Non-nodulating and nodulating isolines of Chippewa maturity and Swift soybeans were grown on the plots. The yields for 1972 are shown in Table 1 and 2. Nitrogen fertilizer significantly increased seed yields at Morris but not at Rosemount. The previous crop at Morris was corn and alfalfa at Rosemount which may explain the lack of response to nitrogen at Rosemount. The nodulating plants were well-nodulated at both locations.

Table 1. Effect of nitrogen sources and rates and soybean genotype on soybean seed yield at Morris (1972).

Nitrogen source	Nitrogen rate	Soybean genotype		
		Non-nod	Nod	Swift
	lb/acre	bu/acre		
Check		21 a	33 a	37 ab
Ammonium nitrate	100	27 b	33 a	36 a
Urea	100	27 b	34 a	37 ab
Soybean meal	100	29 bc	34 a	39 bc
Ammonium nitrate	200	33 de	33 a	41 cd
Urea	200	33 de	34 a	39 bc
Soybean meal	200	31 cd	37 b	43 d
Ammonium nitrate	300	34 e	33 a	40 c

Yields under a variety followed by the same letter are not significantly different from each other at the .05 level (Duncan's multiple range test).

Table 2. Effect of nitrogen sources and rates and soybean genotype on soybean seed yield at Rosemount (1972).

Nitrogen source	Nitrogen rate	Soybean genotype		
		Non-nod	Nod	Swift
	lb/acre	bu/acre		
Check		38	44	46
Ammonium nitrate	100	40	42	47
Urea	100	41	44	47
Soybean meal	100	42	43	44
Ammonium nitrate	200	38	43	46
Urea	200	40	46	49
Soybean meal	200	42	43	44
Ammonium nitrate	300	39	41	47

FERTILIZER TRIALS ON IRRIGATED ALFALFA AND RED CLOVER STAPLES, MINNESOTA

C. J. Overdahl, Dean Fairchild and Mel Weins

The plant nutrients phosphorus, potassium, sulfur, boron and copper, under varying rates plus 3 levels of lime, were under study at the Staples Irrigation Farm in 1972.

The first year alfalfa growth was small and yields up to only 3.8 tons per acre were harvested from 3 cuttings. Red clover on this first year was better with yields as high as 5 tons per acre. There was no significant response to any of the nutrients or lime added. This is not easily explained for potassium, since check plot soil tests ranged from 92 to 107, which is quite low.

Phosphorus soil tests were very high, averaging about 90 pounds, sulfur was medium high. The plant analyses on check plots showed 2% potassium, .4% P, which are adequate. All secondary and micro nutrients in the plant analyses were high except copper. Added copper gave no yield increase in 1972. The pH was 6.2 on the surface 6 inches, but averaged 6.5 from 1 to 2 feet and 6.9 from 2 to 3 feet.

Boron readings in alfalfa plant tissue by cutting were: 1st=60 ppm, 2nd=51 ppm, 3rd=45 ppm. Red clover readings were: 1st cut=75 ppm, 2nd cut=35 ppm, 3rd cut=35 ppm. Above 30 ppm is considered sufficient for these crops.

Only limited conclusions can be drawn on one year's data. The 1973 data will probably give more meaningful information.

Efforts of Bob McCaslin, Bob Schoper, Charles Behrens, Fred Bergsrud and others assisting on plots are gratefully acknowledged.

NITROGEN TRIALS ON CHRIS AND ERA WHEAT UNDER IRRIGATION AT STAPLES 1972

A. C. Caldwell, F. G. Bergsrud,
H. J. Miens and D. S. Fairchild

Five rates of N (0, 25, 50, 75, 100 lbs/A) were applied as a broadcast to varieties of Chris and Era wheat on Hubbard sandy loam at Staples. The entire nitrogen rates of 25 and 50 lbs/A were applied before seeding while the 75 lbs of N/A was split into 50 lbs/A at seeding and 25 lbs/A at boot stage, and the 100 lbs rate at 50 lbs/A at seeding and 50 lbs/A at boot stage. A basic starter fertilizer of 8-16-32 + 2 1/2 S was applied at 200 lbs/A.

The nitrate nitrogen level in the 0-24 inch soil zone was at 12 lbs/A. Soil test levels of P and K were very high and medium, respectively.

Table 1 indicates that no significant yield increases were noted in Chris or Era varieties with greater than 50 lbs of N/A.

Table 1. Yields of Era and Chris wheat as affected by nitrogen rates under irrigation, Staples, Minnesota.

Fertilizer Treatments	Variety	
	Era	Chris
(lbs N/A)*	----------Bu/A----------	
0	22 a **	15 a
25	31 bc	19 b
50	37 c	26 c
75	32 bc	26 c
100	29 b	24 c

* N applied as ammonium nitrate

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

The percent nitrogen in the plant tissue from the variety Chris was below the critical level of 2.7% N for treatments receiving 0 and 25 lbs. of N/A. Treatments receiving 50, 75 and 100 lbs. of N/A were not significantly different in % N and above the critical level of 2.7% (Table 2). Nitrogen contents of plant tissue from the variety Era indicated nitrogen deficiencies only in the treatment receiving 0 lbs. of N/A. Significant increases in the nitrogen content of Era's plant tissue were noted with increasing nitrogen fertilizer rates (Table 2).

Table 2. The nitrogen content of plant tissue from Era and Chris wheat as affected by nitrogen rates under irrigation.

Fertilizer Treatment	Variety	
	Era	Chris
(lbs. N/A)	---------% N in dry matter-------	
0	2.5 a*	2.0 a
25	2.8 ab	2.5 b
50	3.0 bc	2.7 bc
75	3.2 cd	2.8 c
100	3.4 d	2.9 c

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

Table 3 indicates the percent nitrogen in Chris and Era wheat grain increased with increasing rates of nitrogen. Significant increases are noted at the 50 and 100 lbs. of N/A rates with the Era grain being slightly lower in nitrogen than the Chris grain.

Table 3. The nitrogen content of grain from Era and Chris wheat as affected by nitrogen rates under irrigation.

Fertilizer Treatments	Variety	
	Era	Chris
(lbs. N/A)	----------%N----------	
0	1.6 a*	1.8 a
25	1.8 a	1.9 a
50	2.0 b	2.1 ab
75	2.1 b	2.4 bc
100	2.4 c	2.6 c

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

Yields of both Chris and Era were not satisfactory and too low to be economical crops under irrigation. This experiment will be repeated in 1973 with greater emphasis on management practices to increase wheat yields and with more extensive soil sampling to monitor the movement of nitrogen on coarse textured soils under irrigation.

THE EFFECTS OF FERTILIZER RATES ON CUCUMBERS UNDER IRRIGATION AT STAPLES, 1972

A. C. Caldwell, F. G. Bergsrud,
H. J. Viens and D. S. Fairchild

The introduction of irrigation and different crops to central Minnesota has created a need for new research to determine crop response to applied fertilizer. To fulfill this need a fertilizer study with cucumbers was initiated at the Staples Irrigation Farm on a Hubbard sandy loam in 1972.

The nitrate nitrogen level in the 0-24 inch soil zone was 54 lbs/A. Soil test levels of phosphorus and potassium were very high and medium, respectively.

A randomized complete block design was used with eight treatments replicated five times. The fertilizer treatments were as follows:

Treatment Code	Treatments	$N+P_2O_5+K_2O+S+B$ --lbs/acre----
A	$N_1 + P_1 + K_1 + S_1 + B$	100 + 75 + 200 + 20 + 3
B	$N_2 + P_1 + K_1 + S_1 + B$	50 + 75 + 200 + 20 + 3
C	$N_3 + P_1 + K_1 + S_1 + B$	100 + 75 + 200 + 20 + 3
D	$N_4 + P_1 + K_1 + S_1 + B$	150 + 75 + 200 + 20 + 3
E	$N_1 + P_2 + K_1 + S_1 + B$	100 + 150 + 200 + 20 + 3
F	$N_1 + P_1 + K_2 + S_1 + B$	100 + 75 + 400 + 20 + 3
G	$N_1 + P_1 + K_1 + S_2 + B$	100 + 75 + 200 + 40 + 3
H	Check	0 + 0 + 0 + 0 + 0

All fertilizer treatments, except the nitrogen rates, were top-dressed and tilled in on June 21, 1972. Nitrogen rates were split into the following amounts and times of application:

1. N_1 - 50 lbs/acre at planting + 50 lbs/acre two weeks after plant appearance,
2. N_2 - 50 lbs/acre at planting,
3. N_3 - 100 lbs/acre at planting, and
4. N_4 - 50 lbs/acre at planting + 50 lbs/acre two weeks after plant appearance + 50 lbs/acre four weeks after plant appearance.

Cucumbers were planted in 22 inch rows on June 27, 1972, at 80-100,000 plants/acre.

Total saleable cucumber yields are reported in Table 1. Highest yields are noted with 100 lbs. of nitrogen/acre either as a split application or as one application at planting. Yield increases are also indicated with the higher fertilizer rates of phosphorus, potassium and sulfur though the increases are not always significant. Six fold increases in yield of fertilized over unfertilized cucumbers are tremendous and it is very apparent that based on one year's results and on this soil, fertilization is a must for satisfactory cucumber yields.

Table 1. 1972 Cucumber yields with variable fertilizer rates under irrigation at Staples.

Fertilizer Treatment Code	Total	Saleable
	-----Yield lbs/acre----------	
A	6192 cd*	5477 de
B	3408 b	2483 b
C	6697 d	4298 cd
D	4585 bc	4109 c

Table 1. (continued) --

Fertilizer Treatment Code	Total	Saleable
	------Yield lbs/acre----------	
E	7875 d *	6017 e
F	6219 cd	5236 cde
G	1348 a	1043 a

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

Plant tissue samples were collected on August 8, 1972, from the fully developed upper leaves at the early bloom stage in growth. Significant increases in nitrogen, potassium, magnesium, sulfur and manganese in the plant tissue are noted in Table 2.

This experiment will be repeated in 1973.

Table 2. Plant analyses of upper leaves from cucumbers with variable fertilizer rates under irrigation at Staples in 1972.

Fertilizer Treatment Code	%						P.P.M.					
	N	P	K	Ca	Mg	S	AL	Fe	Zn	Cu	Mn	B
A	3.98 c*	.82	2.84 b	2.11	.49 a	.64 abc	561	556	67.8	6.4	134 bc	41.5
B	3.21 a	.84	2.74 ab	1.97	.46 a	.69 c	588	576	64.0	6.1	130 b	42.7
C	3.57 b	.82	2.81 b	2.11	.47 a	.68 bc	635	608	71.2	5.9	149 e	39.5
D	4.48 d	.80	2.82 b	2.43	.50 a	.60 a	660	658	70.2	5.6	150 e	42.8
E	4.21 cd	.87	2.79 b	2.20	.49 a	.62 ab	716	678	68.9	6.2	146 de	38.2
F	4.17 cd	.83	2.89 b	2.06	.43 a	.63 abc	621	622	68.6	6.3	143 d	39.4
G	4.08 c	.79	2.74 ab	2.25	.50 a	.69 c	554	545	69.0	5.9	138 c	41.7
H	3.60 b	.89	2.55 a	2.08	.60 b	.69 c	722	650	72.2	8.7	104 a	31.8

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

INFLUENCE OF PHOSPHORUS AND POTASSIUM FERTILIZATION ON ALFALFA YIELDS, WASECA, 1969-1972.

W. E. Lueschen and G. W. Randall

An experiment was established in 1969 at the Southern Experiment Station to evaluate phosphorus and potassium fertilization of alfalfa for south-central Minnesota. The experiment was located on a Webster clay loam soil with a pH of 5.7, P test of 40 and a K test of 240. Prior to seeding the trial a uniform application of 7 tons per acre of limestome was applied. Annual applications of fertilizer were as follows: 30 or 150 pounds per acre of P_2O_5 in combinations with 0, 60 or 300 pounds per acre of K_2O. The initial application of fertilizers was made prior to spring plowing on May 5, 1969; subsequent applications were top-dressed each spring. The trial was seeded on May 14, 1969 with three varieties: Vernal, Saranac and Minn. Syn N. Six replications were established without a companion crop using Eptam and 2, 4-DB for weed control gave excellent initial stands of alfalfa. All plots were harvested to simulate removal as hay with 2, 4, 3 and 3 cuttings removed in 1969, 1970, 1971 and 1972, respectively.

Yield levels were relatively low, as is typical for the Waseca area (tables 1 and 2). The higher yields in 1970 were a result of excellent growing conditions which permitted harvesting 4 cuttings by early September. Lower first and third cutting yields in 1971 reduced that season's total

yield considerably. Removing 4 cuttings in 1970 may have weakened the plants enough to reduce yields for the first cutting in 1971. Inadequate rainfall in July and August of 1971 were mainly responsible for very low third cutting yields.

Saranac tended to be the highest yielding variety in 1969, 1970 and 1971. The response of all three varieties was very similar for all fertilization treatments.

Table 2 gives the effects of the P and K treatments averaged over the three varieties. Although significant yield increases were obtained for phosphorus in 1969 and 1970, the increases were very small; .10 T/A, which would not pay for fertilizer costs. The soil P levels in the upper 6 inches were very high (40 lbs./A) when the trial was initiated in 1969 and remained at very high levels (30 lbs./A) throughout the trial even where only 30 pounds P_2O_5/A were applied annually. Soil tests for phosphorus were increased to 50-60 where an annual application of 150 pounds per acre of P_2O_5 was made. These results explain the lack of large responses to phosphorus. Table 4 gives the percentage phosphorus in plant tissue of the third cutting in 1972. These values were adequate for good alfalfa production even at the low rate of phosphorus fertilization ($<$ 0.20% deficient).

With the exception of 1969, alfalfa yields tended to increase slightly with potassium fertilization. Additions of 60 pounds per acre of K_2O had no effect on yields in 1969 and 1970 but significant increases (0.20 T/A) were observed in 1971 and 1972. As with phosphorus, these increases would not pay for the fertilizer costs using $20/T for the alfalfa and

$.05/lb. of K_2O. Additional yield increases (0.20 T/A) for 300 pounds K_2O/A were observed in 1970 and 1972.

Lack of response in 1969 to potassium fertilization can be explained on the basis of high initial K soil test values (240 lbs./A). Soil tests in the fall of 1972 (table 3) were in the medium range for the 0 and 60 pounds per acre treatment and the high range for the 300 pound rate. With relatively low forage yields in 1972, soil supplied potassium was nearly sufficient to meet plant nutrient needs.

Plant tissue tests for third cutting in 1972 indicate less than adequate K tissue levels ($<$ 1.75% difficient) for the 0 and 60 pound K_2O rate and adequate levels for the 300 pound rate. However, only slight differences in total yield were observed among the treatments in 1972 with no response to K fertilization in the third cutting.

Phytophthora root rot was present in the trial and may have contributed to the poor yields and lack of response to fertilization. New trials are planned with Phytophthora resistant varieties to determine if alfalfa yields can be improved with fertilization of resistant varieties. When severe infestation of this disease exists, extensive damage is done to the root system and this may limit the ability of the plants to extract nutrients from the soil.

Table 1. Influence of phosphorus and potassium fertilization on alfalfa yields, Waseca, 1969-1972.

Variety	P_2O_5 lbs/A	K_2O lbs/A	Hay Yield (T/A @ 12% H_2O) 1969	1970	1971	1972
Vernal	30	0	1.72	5.04	3.31	4.08
"	150	0	1.95	5.25	3.26	4.14
"	30	60	1.72	5.27	3.46	4.13
"	150	60	1.91	5.26	3.41	4.33
"	30	300	1.81	5.43	3.59	4.34
"	150	300	1.80	5.32	3.52	4.18
Variety Average			1.82	5.26	3.43	4.20
Saranac	30	0	1.80	5.50	3.45	4.08
"	150	0	1.95	5.75	3.25	4.02
"	30	60	1.97	5.42	3.70	4.20
"	150	60	2.10	5.61	3.63	4.18
"	30	300	1.92	5.90	3.68	4.07
"	150	300	2.11	5.86	3.72	4.34
Variety Average			1.98	5.67	3.57	4.15
Minn. Syn N	30	0	1.69	5.09	3.01	4.03
"	150	0	1.70	5.08	3.09	3.93
"	30	60	1.75	4.99	3.06	3.87
"	150	60	1.73	5.03	3.19	4.11
"	30	300	1.63	5.19	3.12	4.23
"	150	300	1.77	5.43	3.34	4.37
Variety Average			1.71	5.14	3.14	4.09

Table 2. Influence of phosphorus and potassium fertilization on alfalfa yields (T/A @ 12% H_2O), Waseca, 1969-1972. (Average of 3 varieties)*

Annual K_2O (lbs./A)	Annual P_2O_5 Applications Per Acre 1969 30	1969 150	1970 30	1970 150	1971 30	1971 150	1972 30	1972 150
0	1.74	1.87	5.21	5.36	3.26	3.20	4.07	4.03
60	1.81	1.91	5.23	5.30	3.41	3.41	4.07	4.21
300	1.79	1.89	5.51	5.54	3.46	3.53	4.21	4.28
BLSD (.05) P	.07		.11		ns		ns	
K	ns		.11		.10		.13	

* 2, 4, 3 and 3 cuttings removed in 1969, 1970, 1971 and 1972, respectively.

Table 3. Influence of phosphorus and potassium fertilization on soil tests (Waseca, fall 1970 and 1972).*

Treatments P_2O_5 lbs./A	Treatments K_2O lbs./A	0-6 Inch Depth pH 1970	0-6 Inch Depth pH 1972	0-6 Inch Depth P lbs./A 1970	0-6 Inch Depth P lbs./A 1972	0-6 Inch Depth K lbs./A 1970	0-6 Inch Depth K lbs./A 1972	7-18 Inch Depth pH 1970	7-18 Inch Depth pH 1972	7-18 Inch Depth P lbs./A 1970	7-18 Inch Depth P lbs./A 1972	7-18 Inch Depth K lbs./A 1970	7-18 Inch Depth K lbs./A 1972
30	0	6.1	6.4	50	30	230	160	6.0	5.6	5	14	200	160
150	0	6.0	6.3	60	60	200	160	5.8	5.7	7	17	200	150
30	60	6.1	6.4	50	30	260	170	6.0	5.7	5	16	190	160
150	60	6.1	6.2	75	55	250	170	5.9	5.8	7	17	210	160
30	300	6.1	6.2	50	30	425	280	5.8	5.8	6	14	210	160
150	300	5.9	6.3	75	50	310	220	5.9	5.7	8	14	220	170

* samples from Saranac plots only.

Table 4. Influence of phosphorus and potassium fertilization on percent phosphorus and potassium in plant tissue, Waseca 1972. (cut 3).*

P_2O_5 lbs./A	K_2O lbs./A	% P	% K
30	0	0.30	1.54
150	0	0.39	1.70
30	60	0.30	1.65
150	60	0.35	1.69
30	300	0.28	2.23
150	300	0.33	2.28

* samples from Saranac only.

CORN TILLAGE STUDY

Waseca, 1972

G. W. Randall, W. E. Lueschen, J. B. Swan and J. A. True

A field experiment was initiated in 1969 to evaluate tillage systems for continuous corn production in south-central Minnesota. Eleven tillage treatments were established in a randomized complete-block design with four replications. Each treatment has been super-imposed on the same plot since establishment. The experiment is located on a LeSueur clay loam soil with a 2-5% south-facing slope. Tile lines spaced 75' apart lie perpendicular to the rows within all plots.

A broadcast application of fertilizer (0+60+90 lbs. $N+P_2O_5+K_2O$/A) was applied on October 15 and was followed immediately by the fall primary tillage operations. Nitrogen (175 lbs. N/A as ammonium nitrate) was broadcast on the surface on April 25. The spring primary tillage treatments were installed on April 27 and the secondary treatments on May 8.

Corn (Minhybrid 4201) was planted at a rate of 26,000 ppA on May 9. An Allis Chalmers minimum tillage planter with fluted coulters was used to plant the plots which did not receive primary tillage. For those plots which did receive primary tillage, the fluted coulters were removed.

Starter fertilizer (13+35+45 lbs. $N+P_2O_5+K_2O$/A) and an insecticide (1 lb. active Furadan/A) were applied at planting time. Chemical weed control consisted of 5 lbs. propachlor/A (A.I.) applied at planting in a 14" band and 2 lbs. atrazine (A.I.) + 1½ qt. vegetable oil/A applied postemergence on June 10. With the exception of the fall chisel-none and no-tillage treatments where too much surface residue prevented cultivation, each treatment was cultivated once.

Small plant weights were obtained on June 14 by randomly selecting 10 plants from each plot and oven drying them. Grain yields were determined by combine harvesting two center rows from each plot on October 5.

Small plant weight, weed infestation and moisture content of the grain at harvest were affected significantly, by the tillage treatments (Table 1). In general, early plant growth was greater, the weeds were less numerous and the corn was drier from the moldboard plow treatments, irregardless of secondary treatments. The smallest early plant growth and the wettest corn at harvest resulted from the no-tillage treatment. Highest weed infestation resulted from the fall chisel treatment with no secondary tillage. Quackgrass and fall panicum were the dominant species found. Final population, lodging and yield were not affected by the tillage treatments. In addition the correlation coefficient between yield and small plant weight (.130) was not significant. This was the third year in this study in which final yield was not related to early growth. Weed infestation had

Table 1. Influence of tillage treatments on continuous corn production at Waseca in 1972.

Tillage Treatments Primary	Secondary	Small plant weight g/dry plant	Weed[1/] infestation 1-5	Final population x 1000	Lodged %	Moisture at harvest %	Yield (@15.5%) bu/A
Fall Plow	None	7.4	2.2	24.6	7.9	28.2	135.3
" "	Conventional	6.8	1.8	25.0	6.4	27.7	131.8
" "	Field Cult.	6.1	1.5	24.0	6.7	27.8	136.2
Spring Plow	Conventional	6.8	1.5	25.0	5.8	27.3	134.9
Fall Chisel	"	6.0	2.5	25.4	3.0	28.5	130.8
" "	Field Cult.	5.8	2.8	24.9	6.1	29.1	133.1
" "	None	5.6	4.0	24.9	2.6	30.0	126.2
Spring Chisel	Conventional	6.4	2.8	24.1	6.8	29.2	139.9
" "	Disk	5.3	3.0	25.1	4.0	29.5	133.6
None	None	3.9	3.0	25.0	1.0	31.2	130.1
None	Disk	5.3	2.8	24.9	2.0	30.4	130.8
	Significance:	**	**	ns	ns	**	ns
	CV (%) :	12.9	25.8	5.0	86.6	2.6	5.1
	BLSD						
	.05 :	1.1	1.0			1.0	
	.01 :	1.5	1.3			1.3	

1/ Weed infestation rating of 1-5 : 1 = None 5 = Severe

no effect on the yield (r= -.006).

Other physical measurements as affected by certain tillage treatments were recorded during the growing season. Surface residue accumulation (mulch from the preceding corn crops) was shown to increase markedly with the chisel and no-tillage treatments (Table 2). These accumulations of 3.78 and 6.06 T/A, respectively, are more than 2x as high as in 1971, which shows the additive effect of leaving residues from continuous corn on the surface.

The effect of this mulch on the soil temperature is shown in Fig. 1. These measurements were obtained by using thermocouples installed two days after planting to a depth of 4" beneath the corn row. The minimum and maximum daily temperatures were averaged each day for approximately one month. During the early part of this period, the fall plow-field cultivate treatment showed a 2 to 3 ^{o}F advantage over the fall chisel-field cultivate treatment. Temperatures from the latter treatment were consistently to 1° higher than the no-tillage treatment. Later in the season the temperature differences among treatments were not as great, but the same pattern still held.

May was warmer than normal with temperatures ranging between 83 and 90° from the 16th. thru the 24th.. This resulted in soil temperatures rising well above 50° in all treatments. Consequently, emergence of corn was not affected by tillage treatment.

Depth to the perched water table was monitored in two

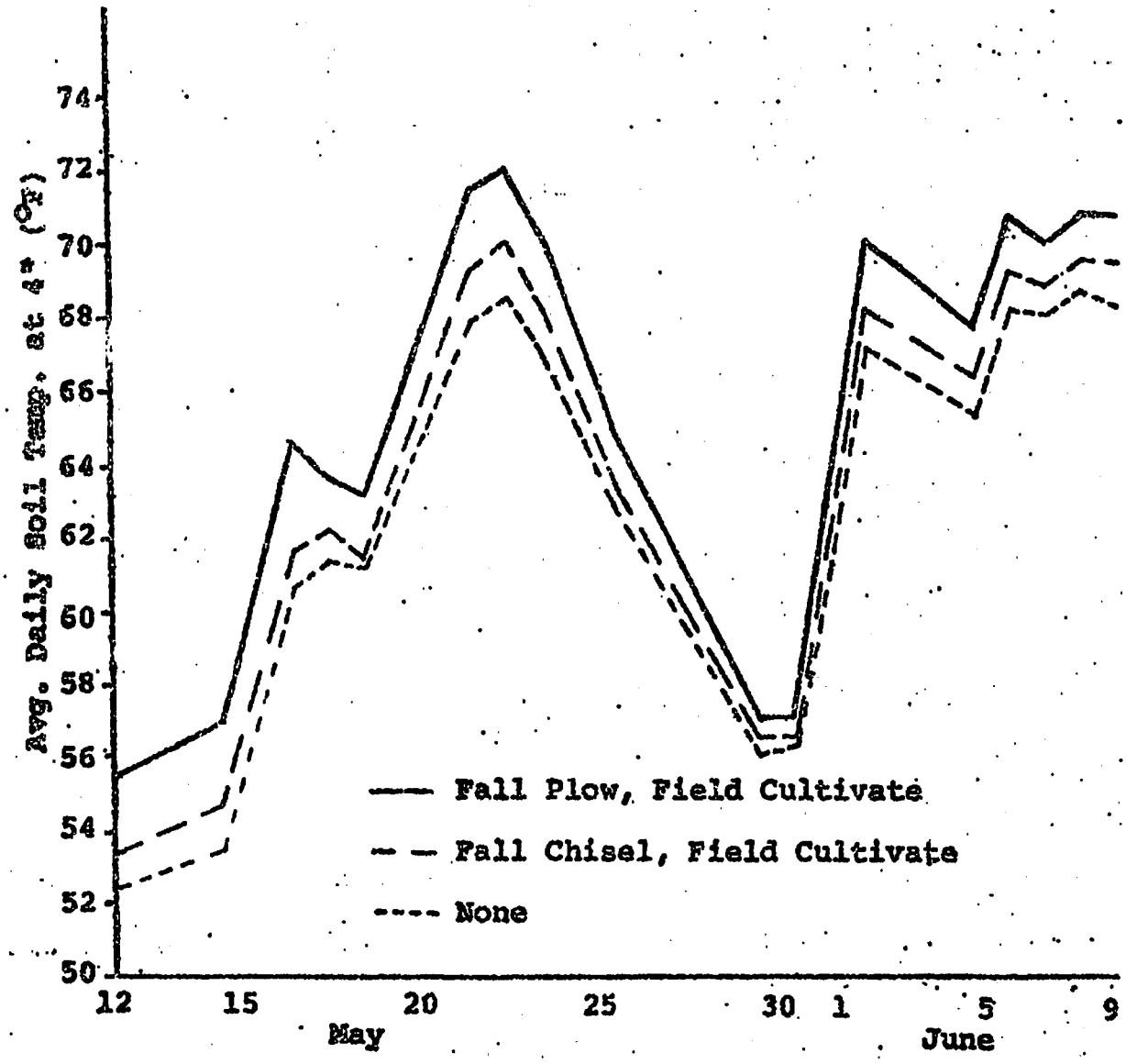


Fig. 1. Influence of three tillage treatments on the 4" soil temperature from May 12 thru June 9.

Table 2. Effect of primary tillage treatments on the surface residue accumulation after three years of continuous corn at Waseca.

Tillage treatment		Surface residue
Primary	Secondary	T/A (Dry Matter)
Fall Plow	None	Trace
Fall Chisel	None	3.78
None	None	6.06

tillage treatments from late June thru mid-September with open-end, 2-inch plastic pipes (Fig. 2). Differences between the water table levels of the fall plow-field cultivate and the no tillage treatments were not apparent throughout the season. The effect of the high July rainfall (7.74", which is 4.48" above normal) is shown by the water table rising from 46" on June 29 to 27" on Aug. 1. August precipitation (1.54") was 1.94" below normal and is reflected by the water table dropping to 60" on Sept. 11. With the water table varying from 27" to 60" during the growing season, it is doubtful that available soil moisture was limiting in 1972.

Attempts were made to take neutron probe moisture data on two tillage treatments throughout the 1972 growing season (Fig. 3). Four stoppered tubes were placed in each of the two treatments from two replications. A complete set of measurements was taken on June 29. Due to the high July rainfall, measurements were not taken until Aug. 28.

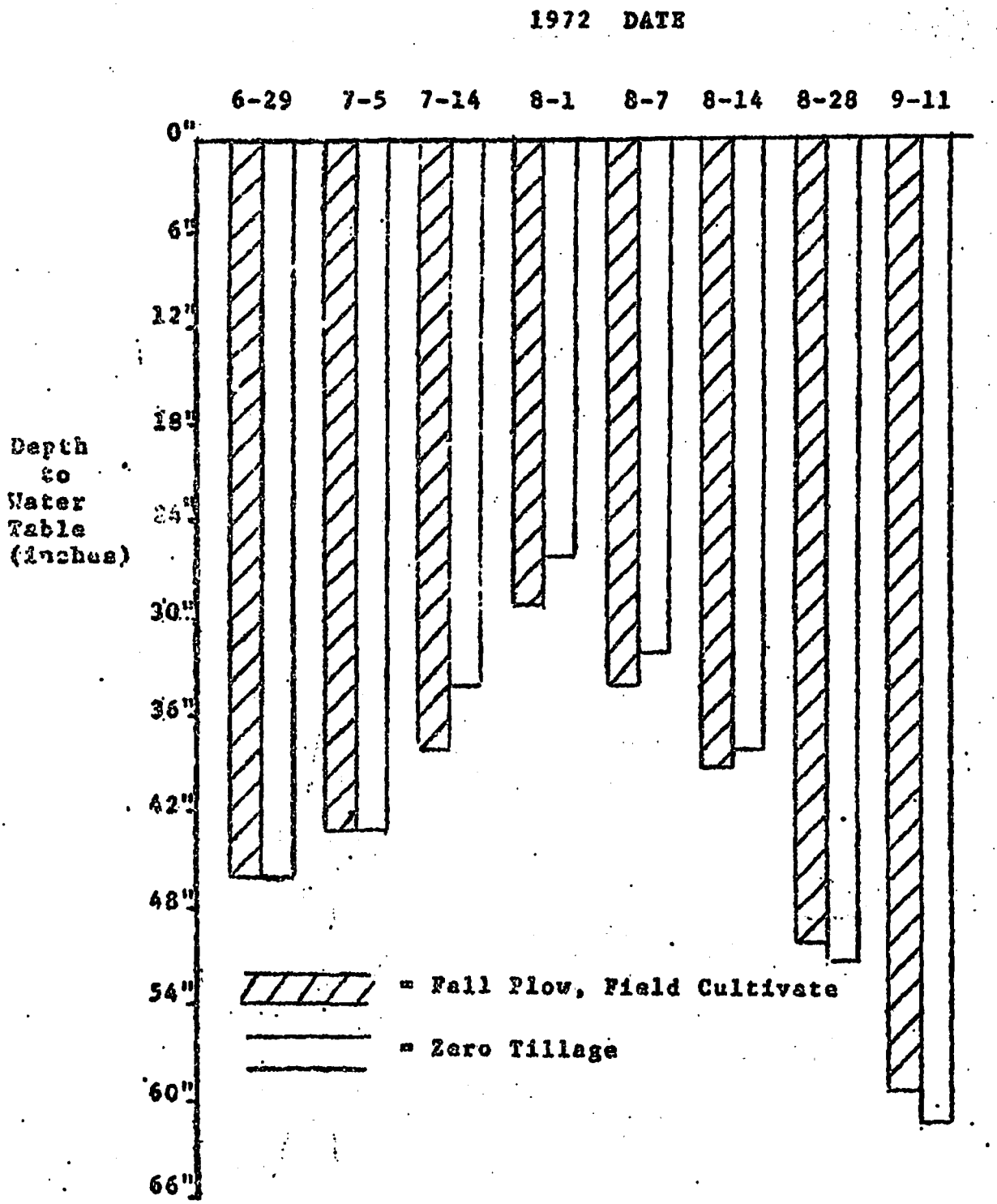


Fig. 2. Water table fluctuation during the 1972 season under two tillage systems.

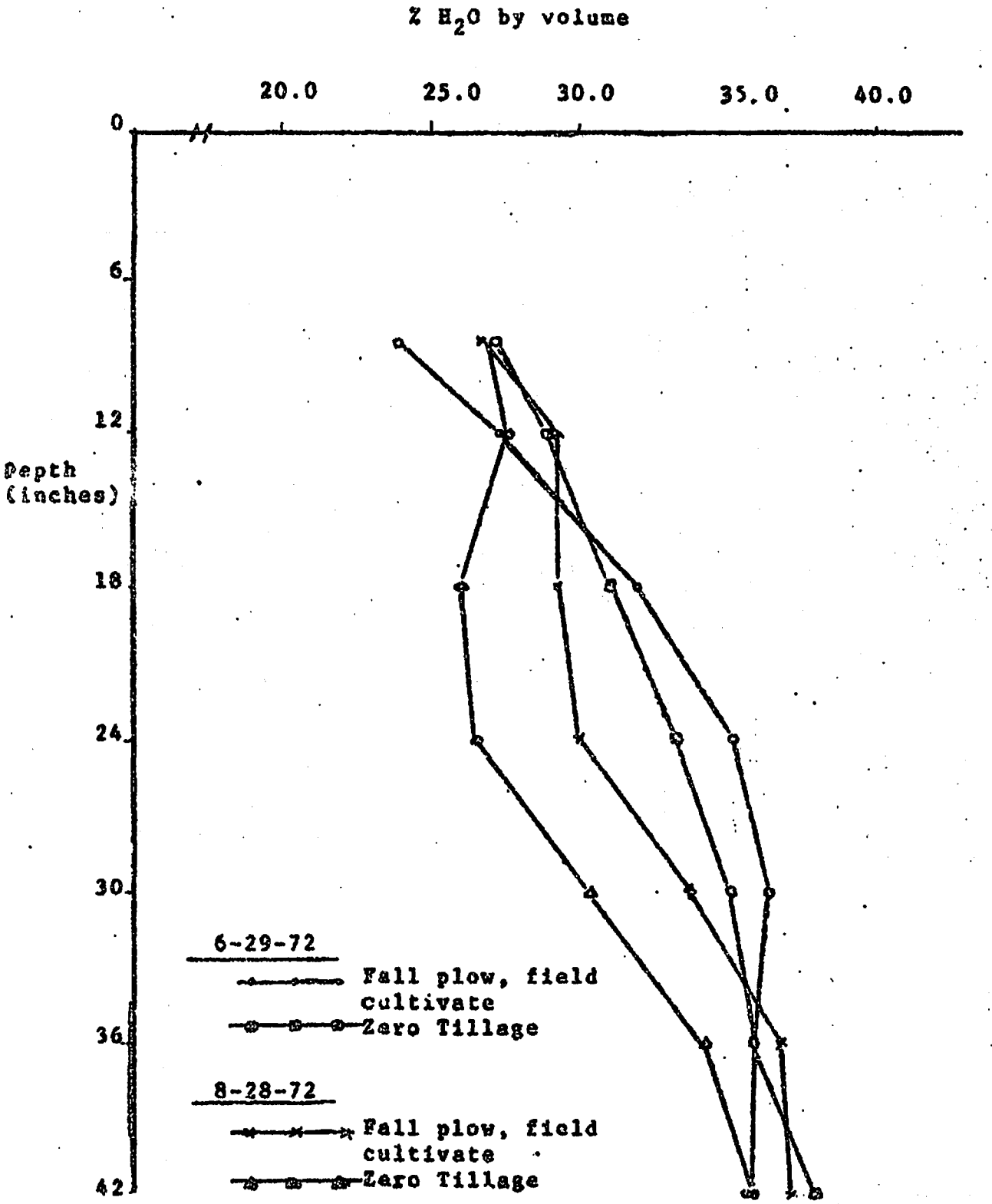


Fig. 3. Effect of tillage treatment on % H_2O by volume at two different dates at Waseca.

Instrumental problems terminated further measurements. In late June soil moisture at the 8" and 12" depths was higher for the no tillage treatment than for the fall plow-field cultivate treatment. This may have been due to the lesser plant growth on the no tillage treatments and the absence of tillage which promotes surface evaporation. However, at the 18, 24 and 30" depths in both June and August, the moisture was greater when fall plowed and field cultivated. This would indicate that infiltration conditions on the tilled treatments were better which allowed the spring and summer rains to soak in rather than partially running off as was the case for the no tillage treatment.

LIME PLOTS, WASECA, 1972

John Grava, C. J. Overdahl, D. S. Fairchild, G. W. Randall

A field experiment was established at the Southern Experiment Station in spring of 1971 to study the effects of liming on yield and chemical composition of corn, and chemical properties of soil[1]. In 1971, lime treatments did not affect corn yield and had no effect on the chemical composition of leaf tissue. This investigation was continued in 1972.

Two other experiments were established on this field, one with soybeans and another one with alfalfa. Dolomitic limestone used in these two experiments had the following quality characteristics:

Passing 8 - Mesh Sieve 96.3%

Passing 60 - Mesh Sieve 38.7%

Calcium Carbonate Equivalent 96.4%.

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 26, 1972. Individual plots were 20 feet wide and 30 feet long. Average soil test results of samples collected prior to the establishment of the experiment are given in Table 1.

Table 1. Soil test results (soybean - alfalfa area, April 1972).

Area	Soil pH	SMP Buffer Index	P LB/A	K LB/A	Zn ppm	S ppm	Lime Requirement Tons/A
Soybeans	5.5	6.0	100	290	3.5	19	6.5-7.5
Alfalfa	5.5	6.1	105	290	3.3	15	5.5-7.0

[1] See "A Report on Field Research in Soils," Soil Series 88, March 1972, pp. 140-141, for results obtained during 1971.

Following is information on management practices, yields, etc. of the three lime experiments during 1972.

Corn

All plots received the following: (a) 193+74+95 LB/A of plant nutrients, expressed as N, P_2O_5, K_2O; (b) herbicide: pre-emergence Sutan 3 LB/A, post emergence atrazine and oil 2 LB/A and 1 1/4 GAL/A; (c) insecticide: Furadan 1 LB/A. Pioneer 3582 Hybrid was planted on May 9, planting rate: 26,000. Corn was cultivated on June 13.

The yield of corn and chemical composition of sixth leaf at tasseling are given in Tables 2 and 3. Lime treatments had no effect on corn yield nor did they affect the concentration of nutrient elements in leaf tissue.

Soybeans

Corsoy soybeans were planted on May 16 in 30-inch rows, 9 beans per foot. All plots received the following: 13+34+45 LB/A of plant nutrients in row; herbicide: 1 LB/A Treflan.

The yield of soybeans and chemical composition of the upper-most mature trifoliate are given in Tables 4 and 5. Neither the yield nor the concentration of plant nutrients in soybean trifoliate were affected by lime treatment.

Alfalfa

Vernal alfalfa was seeded on May 12. All plots received: (a) broadcast 0+46+60 LB/A; (b) 1 LB/A Treflan. No yield was obtained in 1972.

Table 2. Yield of corn, Waseca lime plots, 1972.

Rate of Lime Tons/Acre	Yield Bu/Acre
0	116
2.5	110
5.0	112
7.5	108
10.0	113
Significance	NS*
CV,%	5

*NS - Treatment means not significantly different at the 5% level.

Table 3. Chemical composition of sixth corn leaf at tasseling, Waseca lime plots, 1972.

Rate of Lime	N	P	K	Ca	Mg	Zn	Cu	Mn	B	Fe	Al
	----------Percent in Dry Matter----------					------Parts Per Million in Dry Matter-------					
0	2.56	.32	1.88	.65	.25	39	9	72	6	116a	37
2.5	2.53	.34	1.92	.63	.26	39	9	68	7	115a	34
5.0	2.54	.33	1.86	.66	.27	39	9	60	7	115a	33
7.5	2.61	.34	1.96	.69	.28	45	9	67	7	130b	45
10.0	2.44	.34	1.92	.64	.27	39	9	58	6	120ab	37
Significance	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS
CV,%	4	5	6	7	11	11	9	20	8	6	20

Table 4. Yield of soybeans, Waseca lime plots, 1972.

Rate of Lime Tons/Acre	Yield Bu/Acre
0	51
2.5	51
5.0	49
7.5	52
10.0	51
Significance	NS
CV,%	9

Table 5. Chemical composition of soybean trifoliate, Waseca lime plots, 1972.

Rate of Lime	P	K	Ca	Mg	Zn	Cu	Mn	B	Fe	Al
	-----Percent in Dry Matter-----				-------Parts Per Million in Dry Matter-----					
0	.46	2.10	1.09	.37	46	7	61	47	88	25
2.5	.48	2.18	1.08	.38	45	7	53	47	95	34
5.0	.44	2.0	1.07	.38	44	7	53	45	92	27
7.5	.46	2.13	1.09	.38	46	8	54	47	93	27
10.0	.47	2.09	1.06	.37	67	4	55	47	94	30
Significance	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV,%	7	6	8	8	51	248	15	5	7	26

DETERMINING NITROGEN NEEDS FOR CORN

W. E. Fenster and C. J. Overdahl

In the fall of 1969, nitrogen experiments were established with continuous corn on highly productive land to determine what rates of nitrogen would result in highest economic yields with a minimum of nitrate movement through the soil profile. It is quite apparent that both nitrification and denitrification play major roles in ascertaining amounts of fertilizer nitrogen that should or should not be applied, in any given year, on fine textured, high organic matter soils. This is well illustrated in the Waseca experiment where, in 1971, nitrogen deficiency was noted with nitrogen applications up to and including 200 pounds per acre. After the soil had warmed up in the spring of 1971, excessive amounts of rain kept the soil waterlogged for a period of about 2 or 3 weeks after which time very little moisture fell for the rest of the season. These weather conditions were ideal for excess denitrification (loss of nitrogen to the atmosphere) early in the year and very little nitrification (the forming of nitrates from ammonium forms) later in the summer and early fall. The combination of these two biotic reactions caused severe N deficiency, even with N applications normally considered adequate for maximum corn production.

In 1972, no nitrogen response or deficiency was noted in the nitrogen treatments that exceeded 50 pounds of N per acre. Here the weather conditions varied quite markedly from 1971. The soil was moist early in the spring and periodic rainfalls throughout the summer created ideal conditions for nitrification for much of the growing season. On this particular year, therefore, the soils were able to produce nearly enough available nitrogen to sustain the corn crop in 1972. It is quite obvious that on any given year it may be very difficult to accurately predict fertilizer nitrogen needs. This is mainly due to high or low rates of soil denitrification and/or nitrification which may take place. There is one saving feature, however, on the fine textured soils; if the applied nitrogen is not utilized the first year, it will remain within the rooting zone for corn and be available for subsequent crops.

The yield, tissue, and nitrate-nitrogen results from the Waseca experiment are given in tables 1-3.

Table 1. Waseca county corn yields as influenced by nitrogen treatments (8 replications).

N (lbs/A) annually	Yield (bu/A) 1971	1972
0	43 a	118 a
50	63 b	138 b
100	93 c	134 b
150	131 d	144 b
200	144 e	141 b
400	151 f	144 b

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

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

The soil is classified as Webster silty clay loam.

Table 2. Percentage nitrogen in tissue* (July) as related to nitrogen applications on continuous corn in Waseca county.

N (lbs/A	1971 %	1972 %
0	1.5	2.4
50	1.7	2.6
100	2.2	2.6
150	2.6	2.7
200	2.9	2.7
400	3.0	2.7

* sixth leaf at tasseling

Table 3. Amount of nitrate-nitrogen in the soil profile on continuous corn in Waseca county.

Soil Depth (ft.)	ppm NO_3-N Treatment - lbs N per acre applied 0		50		100		150		200		400	
	1971	1972	1971	1972	1971	1972	1971	1972	1971	1972	1971	1972
0-1	1	2	4	11	6	9	6	32	5	14	17	68
1-2	2	2	2	5	3	3	4	17	3	17	12	52
2-3	3	2	3	4	3	2	3	24	3	21	27	46
3-4	2	2	2	5	2	2	3	6	3	9	17	19
4-5	3	2	2	4	3	3	4	4	4	5	10	6

Conducted under the leadership of:
Dr. Gyles Randall, Soil Scientist, University of Minnesota, Waseca Experiment Station.

Two adjacent nitrogen experiments, one on continuous corn and one established to continuous corn on a virgin soil, were also established in Martin County. The continuous corn experiment was established the same time (fall 1969) as the Waseca experiment and the one on the virgin soil was established one year later. In 1972, a hail storm severely damaged the corn crop. Because of this, the yields are quite low and no meaningful statistical analysis could be run. Also, because of this hail damage, it is apparent that the crop did not draw down the nitrogen in the soil at a normal or expected rate. Yield, tissue, and nitrate-nitrogen results from these experiments are given in the following tables for the years 1971 and 1972.

Table 4. Martin county corn yields as influenced by nitrogen treatments (8 replications).

N (lbs/A) annually	Yield (bu/A) Continuous corn plots 1971	Continuous corn plots 1972	Virgin plots 1971	Virgin plots 1972
0	130 a[1]	68 [2]	179 a	103
50	142 b	78	190 bc	107
100	151 b	68	187 bc	88
150	144 b	76	183 b	103
200	147 b	69	194 c	96
400	153 b	64	190 bc	103

[1] Where letters differ for each experiment, yields are statistically different at the 10% level.

[2] A meaningful statistical analysis could not be run in 1972 because of severe hail damage.

All plots received a basic treatment of 0+150+200+20 Zn. The soils were classified as Webster silty clay loam.

Table 5. Percentage nitrogen in tissue* (July) as related to nitrogen application on corn in Martin county.

N (lbs/A)	% Nitrogen in Tissue Continuous corn 1971	Continuous corn 1972	Virgin plots 1971	Virgin plots 1972
0	2.5	2.4	2.8	2.9
50	2.7	2.9	2.7	2.8
100	2.6	2.8	2.8	2.8
150	2.9	2.7	2.8	2.8
200	2.9	2.9	2.8	2.9
400	2.9	2.7	2.9	2.8

* sixth leaf at tasseling

Table 6. Amount of nitrate-nitrogen in the soil profile on continuous corn in Martin county.

Soil Depth (ft.)	ppm NO_3-N Treatment - lbs N per acre applied 0		50		100		150		200		400	
	1971	1972	1971	1972	1971	1972	1971	1972	1971	1972	1971	1972
0-1	9	5	9	7	9	8	12	13	23	21	60	33
1-2	5	3	5	4	8	6	17	13	23	21	45	42
2-3	5	3	13	9	13	8	43	27	26	19	30	53
3-4	6	6	15	14	15	13	30	23	20	20	26	40
4-5	7	9	14	21	14	15	28	22	17	26	18	37
5-6	10	10	13	24	14	17	23	22	17	24	18	32

Average of 4 replicates.

Table 7. Amount of nitrate-nitrogen in the soil profile on virgin soil planted to corn in Martin county.

Soil Depth (ft.)	ppm NO_3-N Treatment - lbs N per acre applied 0		50		100		150		200		400	
	1971	1972	1971	1972	1971	1972	1971	1972	1971	1972	1971	1972
0-1	17	10	19	17	24	17	15	30	31	24	40	22
1-2	10	6	23	14	32	24	29	38	47	33	32	42
2-3	7	6	9	18	8	25	14	32	14	28	11	56
3-4	3	6	5	11	4	15	5	16	4	21	5	45
4-5	3	5	3	9	4	11	5	12	6	16	3	31
5-6	4	5	3	7	4	9	4	9	6	13	4	22

Average of 4 replicates.

NITROGEN FERTILIZATION OF CORN

Waseca, 1972

G. W. Randall and W. E. Lueschen

Two field experiments were initiated in the fall of 1971 and spring of 1972 to obtain additional information on nitrogen fertilization of corn in south-central Minnesota. Hopefully, results gained from these new studies will supplement information obtained from long-term experiments initiated in 1969 by Fenster, Overdahl and Frazier. Results from the initial experiments have been reported in Soil Series 87, 88 and again are reported herein.

Experiment I

To evaluate various sources of N fertilizer, an experiment involving four sources of N applied at two rates in both the fall and the spring was established at the Southern Experiment Station on a Cordova silty clay loam. The experimental design was a randomized complete-block, replicated four times.

Soil test P and K values were high. Broadcast rates of 26# P/A and 75# K/A were applied before fall-plowing on 11-8-71. All sources of N were fall-applied on 11-10-71 and spring applied on 4-28-72. Soil conditions for both the fall and spring applications were good with adequate moisture.

Corn (Minhybrid 4201) was planted at 24,000 ppA in 30" rows on May 11. Row fertilizer (11+13+32 lbs. N+P+K/A) and

an insecticide (1 lb. active Furadan) was applied at planting time. Weeds were controlled with a combination of Lasso + Atrazine herbicides applied preemergence and one cultivation. The leaf opposite and below the ear leaf was sampled August 8 and was submitted for analysis by Kjeldahl methods. Yields were obtained on October 9 by combine harvesting the center two rows from each plot.

Results

The weather conditions during the 1972 growing season were favorable for soil nitrification processes which probably supplied much of the needed N. Consequently, neither leaf N concentrations nor yields of corn were affected significantly by the 16 N treatments (Table 1). Nitrogen rates of 75# N/A, irregardless of N source or time of application, appeared sufficient for maximum yields under these expermental conditions.

Experiment II

Excessive rainfall over an extended period of time may be expected to result in denitrification reactions in poorly drained, high organic matter soils. This could result in N-deficient corn later in the growing season. Long periods of high rainfall often occur in the spring in south-central Minnesota, and losses of N occur. If these losses are great enough to create N deficiency in corn, a yield response from a second application of N may be expected.

To evaluate split applications of N fertilizer on these poorly drained, fine textured, high organic matter soils, an

Table 1. Effect of source, rate and time of application of nitrogen on the leaf N concentration and yield of corn at Waseca in 1972. (Experiment I)

Treatment				
Source	Rate	Time	Leaf N	Yield (@15.5%)
	lbs.N/A		%	bu/A
Anhydrous Am.	75	Fall	2.38	144.8
"	75	Spring	2.46	142.4
"	150	Fall	2.33	149.7
"	150	Spring	2.40	149.9
Urea	75	Fall	2.45	154.0
"	75	Spring	2.28	160.1
"	150	Fall	2.42	151.9
"	150	Spring	2.46	150.0
Am. Nitrate	75	Fall	2.44	153.7
"	75	Spring	2.30	153.2
"	150	Fall	2.35	140.8
"	150	Spring	2.40	147.7
Aqua Am.	75	Fall	2.50	147.4
"	75	Spring	2.29	151.1
"	150	Fall	2.42	151.7
"	150	Spring	2.21	147.8
Significance			ns	ns
CV (%)			6.6	6.0

Individual Factors:

Source

Anhydrous Am.		2.39	146.7
Urea		2.40	154.0
Am. Nitrate		2.37	148.8
Aqua Am.		2.35	149.5
	Significance	ns	ns

Rate

75# N		2.39	150.8
150# N		2.37	148.7
	Significance	ns	ns

Time

Fall		2.41	149.2
Spring		2.35	150.3
	Significance	ns	ns

experiment was established on a LeSueur clay loam soil on the Roy Lukken farm, which is the site used by Fenster, Overdahl and Randall in other corn fertilization studies. The site for this experiment has 92% of its area within 50' of tile lines, which should provide adequate internal drainage. The experimental design was a randomized complete-block, replicated five times.

Corn had been grown continuously on this site since 1969 with an annual N application of 200# N/A. Broadcast rates of 66# P/A and 166# K/A were applied annually before fall plowing. The first application of N was applied and disked in on May 8. Three of the treatments received a split application of N to the soil surface on June 15 and were followed immediately by cultivation to incorporate the fertilizer. Ammonium nitrate was the N source for all treatments.

Corn (Northrup King PX 47E) was planted at 26,000 ppA in 30" rows on May 9. Row fertilizer (13+15+37 lbs. N+P+K/A) and insecticide (1 lb. active Furadan) was applied at planting time. Weeds were chemically controlled with a combination of Lasso + Atrazine applied preemergence plus one cultivation. The leaf opposite and below the ear leaf was sampled on July 24 and was submitted for analysis by Kjeldahl methods. Yields were obtained by hand harvesting 16' of row from each of the center two rows of each plot.

Results

Leaf N was increased significantly over the check by the N rates (Table 2). However, no significant differences were

noted among the concentrations due to the rates above and including 100#/A.

Table 2. Effect of rate and application method of nitrogen on the leaf N concentration and yield of corn at Waseca in 1972. (Experiment II).

Treatment Date and Rate				
5-8-72	6-15-72	Total N Applied	Leaf N	Yield (@15.5%)
lbs.N/A		lbs./A	%	bu/A
0	0	0	2.27	154.0
50	50	100	2.47	157.1
100	0	100	2.47	150.7
100	100	200	2.54	160.6
200	0	200	2.42	156.6
250	0	250	2.53	149.7
150	150	300	2.44	155.4
300	0	300	2.49	151.7
		Significance	*	ns
		CV (%)	4.3	6.1
		BLSD (.10)	.12	
		(.05)	.15	

A combination of the weather conditions during 1972 and the past high fertility program probably accounted for the lack of yield response. Apparently, adequate amounts of N required for maximum corn yields were produced by soil nitrification reactions. During 1972, weather conditions which may promote denitrification did not exist. Consequently, split applications of N did not improve corn yields over single applications.

BROADCAST PHOSPHORUS AND POTASSIUM FOR CORN ON HIGH TESTING SOILS

C. J. Overdahl and W. E. Fenster

This was the third year of the broadcast experiment in Martin and Waseca counties. In 1972, similar trials for potassium were initiated in Chippewa and Kandiyohi counties.

The soil test level and plant analysis of the check plots are the best observation point in evaluating response or the lack of it. In Martin County (table 3), there was a significant response to potassium. Soil tests from year to year are quite variable.

In spite of no broadcast response on the P plot in Martin County and on the K plot in Chippewa County, there was a response due to row fertilizer.

The work in Waseca County was conducted under the leadership of Dr. Gyles Randall, Soil Scientist, at the Southern Experiment Station at Waseca.

Table 1. 1970, 1971 and 1972 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	Yields bu/acre			% P leaves			Soil Test P lbs/acre		
lbs/acre	1970	1971	1972	1970	1971	1972	1970	1971	1972
0	155	137a	136	.26	.28	.38	46	37	47
50	151	137a	127	.26	.27	.37	36	39	47
100	162	156b	136	.27	.30	.40	56	55	96
150	146	146ab	129	.28	.30	.40	65	63	94
200	145	154ab	130	.28	.30	.44	64	55	109
	N.S.	10%	N.S.						

	1970	1971	1972
Avg. starter response	4*	2	7*
Avg. % N in leaves	-	2.7	2.7
Avg. K soil test	263	352	488
Avg. % K in leaves	1.70	1.88	1.83
Avg. soil pH	7.7	7.2	7.3
Avg. Zn leaves ppm	19 low	17 low	22 suf.
Avg. Zn soil ppm	-	5.3 high	-

Efforts of Dean Fairchild, Bob Schoper, Charles Behrens, Bob McCaslin, Floyd Bellin, Martin Co. Extension Agent and Dick Lambert, Martin Co. Associate Extension Agent are greatly appreciated.

Table 2. 1970, 1971 and 1972 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	Yields bu/acre			% P leaves			Soil Test P lbs/acre		
lbs/acre	1970	1971	1972	1970	1971	1972	1970	1971	1972
0	133	139	140	.31	.28	.29	34	27	39
50	136	133	142	.30	.27	.30	31	33	62
100	132	132	144	.28	.27	.32	31	40	91
150	136	135	141	.29	.30	.35	40	44	87
200	138	130	144	.29	.30	.33	53	45	79

	1970	1971	1972
Avg. starter response	13*	4	4
Avg. % N in leaves	-	2.8	2.5
Avg. K soil test	307	276	387
Avg. % K in leaves	1.68	1.82	1.88
Avg. soil pH	6.4	6.1	6.1
Avg. Zn leaves ppm	26 suf.	16 low	22 suf.
Avg. Zn soil ppm	-	2.6 high	-

Table 3. 1970, 1971 and 1972 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	1972	1970	1971	1972	1970	1971	1972
0	156	148	120a	1.7	1.8	1.6	202	230	295
50	147	154	127ab	1.7	1.8	1.6	212	258	360
100	152	149	129ab	1.6	2.1	1.8	222	278	328
200	147	143	130ab	1.8	2.1	1.9	270	328	415
400	160	149	132b	1.8	1.9	2.1	243	320	490
			5%						

	1970	1971	1972
Avg. starter response	16*	3	1
Avg. % N in leaves	-	2.8	2.8
Avg. P soil test	50	62	99
Avg. % P in leaves	.25	.29	.40
Avg. soil pH	6.4	6.1	6.1
Avg. Zn leaves ppm	22	22	30
Avg. Zn soil ppm	-	8.4 high	-

Table 4. 1970, 1971 and 1972 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	1972	1970	1971	1972	1970	1971	1972
0	134	123	136	1.6	1.4	1.3	260	210	282
50	129	120	138	1.7	1.7	1.5	275	213	322
100	139	131	139	1.7	1.7	1.7	260	220	318
200	132	116	141	1.8	1.8	1.9	262	223	352
400	134	120	143	2.2	1.9	2.1	312	310	478
	N.S.	N.S.	N.S.						

	1970	1971	1972
Avg. starter response	10*	7*	4
Avg. % N in leaves	-	2.7	2.6
Avg. P soil test	53	52	79
Avg. % P in leaves	.27	.31	.36
Avg. soil pH	6.4	6.0	6.0
Avg. Zn leaves ppm	26 suf.	14 low	24 suf.
Avg. Zn soil ppm	-	3.0 high	-

Table 5. 1972 corn yields, plant analyses and soil tests in Kandiyohi County related to broadcast potash treatments. Russell Schow farm. (200+150+0+20 Zn applied over all plots)*

K_2O lbs/acre	Yields bu/acre	% K leaves	Soil Test K lbs/acre
0	146	1.86	430
50	146	1.78	460
100	147	1.91	410
200	142	1.92	440
400	142	2.00	500

Avg. starter response	7 bu/a
Avg. % N in leaves	2.8
Avg. P soil test	87 lbs/a
Avg. % P in leaves	.36
Avg. soil pH	7.6
Avg. Zn in leaves ppm	19 suf.

* Efforts of Marvin Olson, Kandiyohi Extension Agent, Philip Ness, Asst. Extension Agent, Kandiyohi Co., and J. E. Ellis, Area Extension Agent, Soils, are gratefully acknowledged.

Table 6. 1972 corn yields, plant analyses and soil tests in Chippewa County related to broadcast potash treatments. Bernard Brummer farm. (200+150+0+20 Zn applied over all plots)*

K_2O	Yields	% K	Soil Test
lbs/acre	bu/acre	leaves	K lbs/acre
0	172	1.65a	278
50	176	1.68ab	304
100	171	1.85c	317
200	177	1.83bc	330
400	174	1.93c	402

Avg. starter response	10** bu/a
Avg. % N in leaves	2.4
Avg. P soil test	40 lbs/a
Avg. % P in leaves	.33
Avg. soil pH	7.7
Avg. Zn in leaves ppm	11 low

Boron Trial on Corn

A boron trial was superimposed on the potash experiment in Waseca County by Dr. Randall from the Southern Experiment Station at Waseca. He applied 2 pounds of boron per acre on 4 replicates and none on the other 4. There were no differences in yield due to boron in 1972.

	Boron Added	No Boron	
Yield bu/a	137	141	N.S.
B ppm leaves	9	7	N.S.

The boron content in 1971 was on the borderline of being insufficient, probably due to dry weather. In 1972, rainfall was more plentiful.

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* Efforts of Orville M. Gunderson, Area Extension Agent, Soils, Roger Larson, Chippewa County Extension Agent and Gary Miest, Chippewa County Associate Extension Agent are gratefully acknowledged.

STALK ROT AS INFLUENCED BY BROADCAST K

Stalk rot diseases leading to the lodging of corn were quite prevalent in southern Minnesota in the fall of 1972. Climatic conditions during the summer were primarily responsible for the incidence of these diseases. In addition, certain hybrids appeared more susceptible than others.

Application of K fertilizers commonly has been shown to reduce stalk lodging of corn. To determine the effects of broadcast K applied to these fine textured, high K-testing soils, the incidence of stalk rot and lodging was noted in the K experiment. The rotting of the stalks was measured at harvest by squeezing the internodal area between the first and second nodes above ground on 40 plants per plot. If this area collapsed easily, the stalks were considered hollow as a result of the disease organisms. The term "hollow stalks" was then considered to be a measurement of stalk rot.

Results

The incidence of hollow stalks was reduced significantly by the broadcast K treatments; however, differences did not exist among the K rates (table 1). Fifty pounds of broadcast K_2O, in addition to the row-applied K, reduced the "hollow stalk" numbers as much as any K treatment.

Although many of the stalks were hollow, the exterior shell of the corn stalk appeared very strong. With the rigid, sturdy shell prevailing on this corn hybrid, lodging was minimal and was not affected by broadcast K treatments.

Table 1. Effect of broadcast K on the hollow stalk incidence and lodging of corn.

Broadcast[1] K Rate lbs. K_2O/A	Hollow Stalks %	Lodging %
0	45.0	3.4
50	33.4	2.2
100	34.4	2.2
200	33.4	2.8
400	29.7	5.3
Significance	+	N.S.
CV (%)	31.	110.
BLSD (.10)	11.1	

[1] In addition, all plots received 45 lbs. K_2O/A as a row treatment.

SOYBEAN-NITROGEN FERTILIZER RATE AND PLANTING DATE STUDY

G. E. Ham and G. W. Randall

Ammonium nitrate at the rate of 50 and 100 pound nitrogen per acre was plowed down the preceding fall with the corn residues. Soybean varieties, number of seeds per foot of row, planting date and seed yields are shown in Table 1. Only the seed yield of Corsoy planted on May 8th was increased significantly.

Table 1. Effect of nitrogen rates, planting date and soybean genotype on soybean seed yield at Waseca (1972).

Date planted	Soybean variety	Number seeds planted	Nitrogen applied (lb/acre) 0	50	100
		ft.row^{-1}	----------bu/acre-------		
May 8	Steele	6	44	42	45
	Steele	10	41	42	42
	Corsoy	10	44	49*	52*
	Teweles 505	6	42	39	40
	Teweles	10	40	40	41
June 7	Steele	6	39	42	39
	Steele	10	37	36	36
	Corsoy	10	40	40	38
	Teweles	6	33	33	33
	Teweles	10	34	31	31

* Yield significantly greater than the check of the same variety.

FERTILIZER RATE STUDY WITH "NEW" VARIETIES OF TIMOTHY AND KENTUCKY BLUEGRASS-1972[1]

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

Three field experiments were conducted on mineral soils in 1972 to study effects of N, P, K rates on seed production of timothy and bluegrass varieties that are being introduced in northwestern Minnesota. These experiments were established on growers' fields in fall of 1970.

Past experimental work in Minnesota had 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 sulfur and trace elements.

Grass seed production in Minnesota is expanding and under-going 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 tests of samples collected in summer of 1971 indicated high P and K availability for field no. 1, while the soil test results for field no. 2 and 3 indicated low P and K availability. The soils are alkaline on all three fields.

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:

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[1] See "A Report on Field Research in Soils," Soil Series 88, March 1972, pp. 159-167 for results obtained from similar investigations conducted in 1971.

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

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	Post-Harvest
2	Ernest Brandli Roseau County	Glyndon Fsl	Timothy Erecta	1968 Seeding	Spring 1972
3	Leonard Johnson Roseau County	Unnamed SL	K. Bluegrass Primo	1969 Seeding	Post-Harvest

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-dressed with a Gandy spreader on September 21, 1971. Trace elements Cu, Mn and Zn for Treatment I (50 lbs/acre of Cu-, Mn-, Zn- sulfate) had been applied in spring of 1971.

Plant tissue samples were collected at the beginning of 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 Table 2.

Table 2. Effect of fertilization on the seed yield of timothy and K. bluegrass, 1972.

Treatment N P_2O_5 K_2O	Field 1 Lorain Timothy	Field 2 Erecta Timothy	Field 3 Primo K. Bluegrass
lbs/acre	yield of seed, lbs/acre		
Check	130 a[1]	73 a	182 a
0 + 40 + 40	160 b	59 a	297 b
20 + 10 + 10	162 b	95 b	292 b
40 + 20 + 20	257 c	171 d	374 bc
60 + 30 + 30	278 d	138 c	463 cd
80 + 40 + 40	300 e	193 e	605 e
100 + 50 + 50	403 g	264 f	613 e
120 + 60 + 60	268 cd	187 de	617 e
80 + 40 + 40 + Trace Elements	340 f	205 e	519 de
Significance	**	**	**
C.V.%	23	45	13

[1] Any letter(s) different from another letter in a column indicates a significant difference between the means at the 5% level.

Lorain timothy seed yields on a Bearden silt loam were increased by the various fertilizer rates. The highest yield of 403 lbs/acre was produced with the 100 + 50 + 50 fertilizer treatment, compared to 130 lbs/acre from the check plots. A yield depression resulted from the 120 + 60 + 60 treatment. The addition of trace elements, Cu, Mn, Zn, to the 80 + 40 + 40 treatment increased the seed yield by 40 pounds per acre.

It should be noted that the highest seed yield on this field in 1971 was also produced with the 100 + 50 + 50 treatment, and Treatment I (80 + 40 + 40 plus trace elements) increased yield by 89 pounds per acre.

Fertilization increased K concentration of grass tissue only slightly (Table 3) but had no effect on the P content. Trace elements, applied in spring of 1971, had no effect on Cu, Mn, Zn contents in tissue.

Erecta timothy on Glyndon fine sandy loam produced lower seed yields than those of Lorain timothy. Check plots yielded only 73 lbs/acre, while the highest yield of 264 lbs/acre was produced with the 100 + 50 + 50 fertilizer rate. Seed yield was depressed by 77 lbs/acre with the 120 + 60 + 60 treatment. The application of trace elements had no effect on seed yield.

Fertilization increased P content in tissue of Erecta timothy but had no effect on K concentration (Table 4). Zinc and Cu contents were increased by applications made in spring of 1971.

Primo Kentucky Bluegrass on a sandy loam showed spectacular yield increases from fertilization. The seed yield was increased from 182 lbs/acre without fertilizer to a maximum yield of 605 lbs/acre with the 80 + 40 + 40 treatment. The higher rates of fertilizer had no effect on seed yields. Trace element applications did not affect the seed yield of Primo K. bluegrass.

Phosphorus content (Table 5) of Primo K. bluegrass tissue from

check plots was only 0.10%. It was raised to 0.23% P by an application of 40 lbs/acre of P_2O_5. The soil tests indicated low P availability. Fertilization also increased K concentration in tissue from 1.29% (check) to 1.72% K with 30 lbs/acre K_2O. A carry-over effect of Zn and Cu was indicated by higher concentrations of these two trace elements in grass tissue.

A fourth fertilization trial of this type had been established with S-50 Timothy on Y. Magnusson farm near Roseau in fall of 1971. A very poor seed set was obtained. Seed yield varied from 16 to 72 pounds per acre. Fertilization did not improve seed yield of this variety.

Table 3. Effect of fertilization on chemical composition of Lorain timothy tissue, Roy Kveen, Roseau County, 1972.

Treatment	P	K	Ca	Mg	B	Cu	Mn	Zn	Al	Fe
	------ percent in dry matter ------				---- parts per million in dry matter ----------					
None	.27	1.95ab	.15	.21b	7	4.0ab	26c	24	13	33
0 + 40 + 40	.28	1.99abc	.15	.21b	7	3.7a	23bc	22	14	42
20 + 10 + 10	.28	1.98abc	.17	.22c	7	4.1ab	24bc	23	18	39
40 + 20 + 20	.26	1.93ab	.17	.20a	7	4.3abc	19a	22	5	27
60 + 30 + 30	.24	1.99abc	.17	.20a	5	3.8ab	18a	20	6	33
80 + 40 + 40	.25	1.83a	.17	.21b	6	4.5abc	18a	21	4	27
100 + 50 + 50	.25	2.05bc	.18	.24d	6	4.6bc	19a	19	6	33
120 + 60 + 60	.28	2.18c	.20	.29e	5	5.1c	21ab	20	10	43
80 + 40 + 40 + Trace Elements	.24	2.04bc	.17	.22c	5	5.0c	20a	22	7	47
Significance	NS	*	NS	**	NS	*	**	NS	NS	NS
C.V.,%	9	6	13	12	19	13	15	11	86	50

Table 4. Effect of fertilization on chemical composition Erecta timothy tissue, Ernest Brandli, Roseau County, 1972.

Treatment	P	K	Ca	Mg	B	Cu	Mn	Zn	Al	Fe
	----- percent in dry matter --------				---------- parts per million in dry matter -----					
None	.25a	2.05	.29abc	.17ab	9bc	5.0a	16a	20a	19	40
0 + 40 + 40	.29b	2.05	.30abcd	.16ab	10c	5.5a	25bc	20a	18	41
20 + 10 + 10	.26a	2.01	.29abc	.15a	10c	4.8a	21ab	20a	20	41
40 + 20 + 20	.29b	2.08	.27a	.17ab	9bc	5.1a	25bc	27ab	15	39
60 + 30 + 30	.31bc	2.17	.29abc	.17ab	8a	5.4a	29cd	20a	21	48
80 + 40 + 40	.30bc	2.15	.33bcd	.17ab	8a	5.0a	32de	21a	17	44
100 + 50 + 50	.31bc	2.21	.34cd	.19bc	9bc	4.9a	34de	25a	18	49
120 + 60 + 60	.32c	2.18	.34cd	.21c	8a	5.5a	36e	23a	20	53
80 + 40 + 40 + Trace Elements	.30bc	2.14	.35d	.18bc	8a	7.3b	34de	32b	24	54
Significance	**	NS	*	**	*	**	**	**	NS	NS
C.V.,%	5	5	11	10	14	15	16	20	37	16

Table 5. Effect of fertilization on chemical composition of Primo Kentucky Bluegrass tissue, Leonard Johnson, Roseau County, 1972.

Treatment	P	K	Ca	Mg	B	Cu	Mn	Zn	Al	Fe
	-----percent in dry matter --------				-------- parts per million in dry matter -------					
None	.10a	1.29a	.19a	.12a	5	4.1a	30	15ab	18	43
0 + 40 + 40	.23e	1.58bc	.24ab	.14abc	5	4.2a	24	14a	22	50
20 + 10 + 10	.14b	1.46b	.21ab	.13ab	5	4.0a	25	16ab	19	42
40 + 20 + 20	.16b	1.54b	.23ab	.13abc	5	4.0a	25	16ab	17	39
60 + 30 + 30	.19c	1.72cd	.28bc	.15bc	4	4.1a	23	16ab	18	40
80 + 40 + 40	.19c	1.74cd	.29bc	.15bc	4	4.0a	26	15ab	24	53
100 + 50 + 50	.20cd	1.83d	.36cd	.18de	5	4.0a	22	18b	23	54
120 + 60 + 60	.22de	1.90d	.38d	.19e	4	4.1a	22	17b	23	55
80 + 40 + 40 + Trace Elements	.20cd	1.76cd	.26ab	.15bc	4	6.3b	22	21c	16	46
Significance	**	**	**	**	NS	**	NS	**	NS	NS
C.V.,%	7	7	19	11	15	14	15	9	32	22

NITROGEN RATE STUDY WITH PARK KENTUCKY BLUEGRASS ON PEAT-1972

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

A field experiment was conducted on the Charles Habstritt farm, Roseau County to study the effect of different rates of N on seed yields of Park K. bluegrass. This was done in response to inquiries by growers and others. Previous experimental work had indicated that N rates of 20 or 30 pounds may cause severe lodging of bluegrass. Present recommendations call for 15 lbs/acre of N to K. bluegrass on peat.

The experiment consisted of seven treatments replicated six times. The P and K were supplied with 0-25-25 grade of fertilizer and ammonium nitrate (33-0-0) was used as the N source. The fertilizer treatments were made on Sept. 21, 1971.

Soil test results are given in Table 1.

Fertilization, as shown in Table 2, had no effect on the seed yield of Park K. bluegrass.

Table 1. Soil Test Results.

Depth of Sampling inches	pH	Extractable P pp2m	Exchangeable K pp2m
0-3	6.5	4	35
3-6	6.8	5	15
6-12	6.4	7	10

Table 2. Effect of fertilization on the seed yield of Park K. bluegrass* on peat (Ch. Habstritt, Roseau), 1972.

Treatment N P_2O_5 K_2O lbs/acre	Seed Yield lbs/acre
Check	347
0 + 40 + 40	386
10 + 40 + 40	337
20 + 40 + 40	342
30 + 40 + 40	351
40 + 40 + 40	362
80 + 40 + 40	391
Significance	NS
C.V., %	22

* 1970 seeding.

Table 3. Effect of fertilization on chemical composition of Park Kentucky bluegrass tissue, Ch. Habstritt, Roseau County, 1972.

Treatment	P	K	Ca	Mg	B	Cu	Mn	Zn	Al	Fe
	----- percent in dry matter -------				--------- parts per million in dry matter --------					
None	.16a	1.39a	.16ab	.15ab	3	<0.5	22	20	9ab	38abc
0 + 40 + 40	.23b	1.53b	.15a	.14a	3	<0.5	20	18	7a	31a
10 + 40 + 40	.23b	1.53b	.17abc	.15ab	3	<0.5	19	19	9ab	33ab
20 + 40 + 40	.22b	1.53b	.17abc	.15ab	3	<0.5	19	18	11abc	38abc
30 + 40 + 40	.23b	1.56bc	.19bcd	.16bc	3	<0.5	20	19	12abc	38abc
40 + 40 + 40	.23b	1.67c	.19bcd	.17c	3	<0.5	21	19	15c	42cd
80 + 40 + 40	.23b	1.63bc	.20d	.19d	4	<0.5	20	19	14bc	47d
Significance	**	**	**	**	NS	--	NS	NS	*	**
C.V.%	6	5	11	8	18	--	15	8	40	15

THE EFFECT OF NITROGEN FERTILIZATION ON SEED YIELD AND CHEMICAL COMPOSITION OF GRASSES WHEN APPLIED ALONE OR WITH PHOSPHORUS AND POTASSIUM-1972[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, when 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 from topdressed fertilizer as shown by the relatively high P and K soil test levels of the top three inches of soil.

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 1970 two field experiments were established in Lake of the Woods County. General information on the experimental sites is given in Table 1.

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

Location	Soil Type	Species Variety	Age of Stand	Burned
F. Baade L.O.W. County	Ulen VFSL	Timothy Climax	6th Seed Year	Spring 1972
Helmstetter Bros. L.O.W. County	Spooner VFSL	K. Bluegrass, Park	1967 Plow- Back	Post-Har- vest Burn

[1] See "A Report on Field Research in Soils", Soil Series 87, March 1971, pp. 116-119, and Soil Series 88, March 1972, pp. 170-173 for results obtained from similar investigations conducted in 1970 and 1971.

A randomized block design was used with six treatments replicated seven times. Individual plots were 10 feet wide and 20 feet long. Ammonium nitrate (33-0-0) was used as the N source, and P K were supplied with 0-25-25 fertilized. The fertilizer treatments were made with a Gandy spreader on September 20, 1971. Plant tissue samples were collected at the emergence of heads or panicles. Total nitrogen in tissue has not been determined as yet. Other nutrient 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 yield.

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

Climax Timothy (F. Baade)

1970 - The seed yield of timothy was increased significantly by increasing the N rate from 60 to 120 lb/A (spring application). The N content of tissue from 90 lb/A treatment was significantly higher than that in tissue from the 60 lb/A N treatment. While the 0 + 40 + 40 fertilizer treatment did not affect the seed yield, it did increase the P and K concentration in tissue.

1971 - The seed yield was increased by increasing the N rate from 60 to 90 lb/A. Increasing the N rate to 120 lb/A did not result in higher seed yield. The N content of tissue from 120 lb/A treatment was significantly higher than N in tissue from the two lower N rates. The 0 + 40 + 40 fertilizer treatment increased the P and K contents of tissue but had no effect on the seed yield of Climax timothy.

1972 - Sixty pounds of N produced nearly 300 lb/A of seed (Table 2). Increasing the N rate to 90 or 120 lb/A did not result in higher seed yields.

The third year in a row, the only measured effects obtained from the P K treatment were the increased contents of these two elements in

grass tissue (Table 2).

Park Kentucky Bluegrass (Helmstetter Bros.)

1970 - The seed yield, and the N and P contents of bluegrass tissue were increased by increasing the N rate from 60 to 120 lbs/A. The only effect the 0 + 40 + 40 treatment had was an increase in P content of tissue.

1971 - The seed yield, and the N and P contents of bluegrass tissue were increased by increasing the N rate from 60 to 120 lbs/A, same as in 1970. The 0 + 40 + 40 treatment increased the P and K contents of tissue but had no effect on seed yield.

1972 - About 230 pounds of bluegrass seed per acre were produced with 60 lbs/A of N on this field (Table 3). Neither the higher N rates nor the addition of P K fertilizer had any effect on seed yield. There was some lodging observed prior to harvest time on the 90 + 40 + 40 and 20 + 40 + 40 treatment plots. This would indicate that the vegetative growth of bluegrass was somewhat stimulated by the addition of P and K.

Phosphorus and potassium contents of grass tissue were significantly increased by the 0 + 40 + 40 treatment (Table 3). The concentrations of these two nutrient elements in tissue were lowered by the use of higher N rates.

Changes in Soil Test Results

Soil samples were collected from these plots in fall of 1972 to determine to what extent test values have been affected by fertilization. The results are reported in Tables 4 and 5.

Changes in P and K test levels due to +PK and + PK (0 + 40 + 40) treatment occurred mainly in the top 3-inches of soil. Under timothy (Table 4), P availability had been decreased from a high level (24 lb/A) to a low of 6 lb/A by withholding P and K for three years. On the other hand, the high P test level had been maintained in this

soil through annual applications of 0 + 40 + 40. This treatment also increased the exchangeable K content slightly compared to test results obtained three years ago.

Under K. bluegrass, phosphorus availability in top 0-3 and 3-6 inches was very high at the beginning of the experiment (Table 5). The P test level in the top 3 inches was decreased from 72 to 41 pp2m during the three years of seed production with fertilization with N alone. An annual application of 0 + 40 + 40 increased the P soil test to 97 pp2m. Exchangeable K content was maintained at the original level with the application of 0 + 40 + 40, while the -PK treatment resulted in a decreased K test level.

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	P	K
lbs/acre	lbs/acre	percent in dry matter	
N			
60	294	.28	1.96
90	374	.29	2.02
120	399	.30	2.00
Significance	NS	NS	NS
PK			
None	361	.26 a	1.90 a
0 + 40 + 40	350	.32 b	2.08 b
Significance	NS	**	**

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, Helmstetter Bros., L. O. W. County.

Treatment	Yield of Seed	P	K
lbs/acre	lbs/acre	percent in dry matter	
N			
60	229	.240 b	1.49 b
90	232	.224 ab	1.43 ab
120	230	.219 a	1.36 a
Significance	NS	**	*
PK			
None	217	.210 a	1.20 a
0 + 40 + 40	243	.240 b	1.65 b
Significance	NS	**	**

Table 4. Soil test results (F. Baade).

Depth of Sampling inches	Extractable P pp2m Spring '70	Oct. '72 -PK	Oct. '72 +PK	Exchangeable K pp2m Spring '70	Oct '72 -PK	Oct. '72 +PK
0-3	24	6	27	90	90	150
3-6	6	4	5	60	50	50
6-12	6	3	2	50	30	40

Table 5. Soil test results (Helmstetter Bros.)

Depth of Sampling inches	Extractable P pp2m Spring '70	Oct. '72 -PK	Oct. '72 +PK	Exchangeable K pp2m Spring '70	Oct. '72 -PK	Oct. '72 +PK
0-3	72	41	97	130	60	120
3-6	50	30	37	90	40	50
6-12	10	9	9	70	40	40

CLASSIFICATION OF NATURAL COMMUNITIES

David Grigal

As outlined in last year's report[1], in a cooperative project with personnel on the staff of the North Central Forest Experiment Station, U.S. Forest Service, we have used multivariate techniques including numerical classification, canonical analysis, and discriminant functions to describe and classify forest vegetation in the Boundary Waters Canoe Area (BWCA), northeastern Minnesota. The analysis was based on data collected in 106 natural or "virgin" forest stands and in 68 stands which had been logged 40 to 70 years ago. The data used were frequency-of-occurrence of 53 species common in the area. The major upland plant community-types of the BWCA, identified by the analysis include a lichen type, jack pine-oak type, red pine type, jack pine-black spruce type, jack pine-fir type, black spruce-feather moss type, maple-oak type, aspen-birch type, aspen-birch-white pine type, maple-aspen-birch type, maple-aspen-birch-fir type, and white cedar type. Each of these types is based on a complex of the 53 species, though the name may incorrectly imply one or two dominant overstory species are indicative of the type. A report is currently being prepared in which the composition of each type is described in detail. In addition, the report will contain a series of linear transforms which can be used to ascertain the status, in relation to these types, of a newly sampled forest stand or group of stands from in or near the BWCA. Either or both a discriminant

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[1]1972. A Report On Field Research In Soils. Department of Soil Science, University of Minnesota, St. Paul, Soil Series 88.

function and the position in canonical space can be calculated with these transforms.

The major successional trends in the area, without disturbance, lead to fir-birch and ultimately to the white cedar community-type. White-tailed deer may have had an impact on restricting the occurrence and reproduction of the white-cedar type. The major natural agent of disturbance in the area is fire. Because each fire and its subsequent effects are unique, few generalizations can be made concerning its effect on vegetation. Important factors to be considered are season and severity of burn, seed source, post-fire weather, etc. Logging, too, has a spectrum of effects related to the species logged, logging intensity, and post-logging treatment. In general, however, logging in the BWCA appears to have had little effect on the abundance of the most common forest species, but has increased the prevalence of broadleaf types at the expense of conifer types. Spruce budworm, while affecting a late successional stage, results in only a temporary hiatus in stand successional development.

STUDIES OF SOME EFFECTS OF FOREST FIRES

David Grigal

As noted in last year's report[1] two relatively distinct studies of consequences of the Little Sioux Forest Fire, which burned 15,000 acres in northeastern Minnesota in May 1971, are being conducted by the Department of Soil Science. The study of nutrient cycling following the burn is continuing. Samples were collected again during the summer of 1972. We have recently received a research grant from the National Science Foundation. With this money analyses of the many samples which have been collected has begun. Next year in our report we will be able to quantify the nutrient cycle for the two growing seasons following the fire.

A cooperative study with the North Central Forest Experiment Station of the U.S. Forest Service is continuing. Analyses of the vegetation resprouting on the burn during 1971 has been completed. Vegetation was clipped on ten randomly located plots in each of seven forest stands in the burned area. The material was separated by species, weighed, and analyzed. Table 1 shows the total quantity of nutrients immobilized in those communities by resprouting vegetation. These values are comparable to those recorded in the annual litterfall of southern boreal conifer forests, but much of the nutrients in the present study are returned to the woody stem and roots before leaffall. The three communities with large broadleaf components, the two aspen-birch stands and the fir-birch stand, show larger quantities

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[1]1972. A Report on Field Research in Soils. Department of Soil Science, University of Minnesota, St. Paul. Soil Series 88.

of nutrients immobilized. This is due to the greater biomass present in the resprouting suckers of the tree species. The sampling during the 1972 growing season will probably show this effect even more strongly.

Table 1. Quantity of nutrients immobilized by resprouting vegetation on the Little Sioux Burn, northeastern Minnesota, during the first growing season following the fire.

Plant Community	Nutrient				
	N	P	K	Ca	Mg
	g/m^2				
jack pine-black spruce	0.87	0.14	1.00	0.33	0.14
jack pine (oak)	1.40	0.20	1.66	0.58	0.22
aspen-birch	4.08	0.46	2.82	1.38	0.41
jack pine (fir)	1.40	0.29	1.66	0.70	0.21
white pine	1.60	0.31	2.17	1.26	0.28
fir-birch	2.38	0.38	1.71	1.21	0.29
aspen-birch	2.32	0.37	2.03	1.24	0.31

THE EFFECTS OF FERTILIZER RATES ON EDIBLE BEANS IN RENVILLE COUNTY, 1972

W. E. Fenster, P. J. Maher, D. S. Fairchild

The introduction of different crops to western Minnesota has created a need for new research to determine crop response to applied fertilizer. To fulfill this need, three field experiments on pinto and navy beans were established in Renville County in the spring of 1972. General information on the experimental sites is given in Table 1.

Table 1. Location, crop and soil test levels of edible bean experimental sites.

Location	Crop	Soil Tests			
		pH	P	K	Zn
			lbs/A		ppm
James Zenk	Navy beans	6.5	86	550	3.3
William Roebke	Pinto beans	6.8	47	430	2.7

Navy Beans

A split block design with half of each plot receiving starter fertilizer and the other half receiving no starter fertilizer was used to determine effects of increasing rates of phosphorus and zinc on navy beans. The following rates of phosphorus and zinc were added to the starter-no starter plots:

lbs. P_2O_5/A	+	lbs. Zn/A
0	+	0
0	+	20
40	+	0
40	+	20
80	+	0
80	+	20

Navy bean yields are reported in Table 2 with no significant increases in yields with increasing rates of phosphorus and zinc. Bean yields were 200 lbs./acre higher with starter fertilizer, but the increase was not statistically significant (Table 3).

Table 2. 1972 navy bean yields with varying rates of phosphorus and zinc in Renville County.

Fertilizer Treatment P_2O_5 + Zn	Navy Bean Yields
lbs/A	lbs/A
0 + 0	1680 a*
0 + 20	1711 a
40 + 0	1633 a
40 + 20	1616 a
80 + 0	1905 a
80 + 20	1681 a

* Where letters differ, yields are statistically different at the 5% level.

Table 3. 1972 navy bean yields with starter fertilizer versus no starter fertilizer in Renville County.

Fertilizer Treatment	Navy Bean Yields lbs/A
No starter	1603 a*
Starter	1805 a

* Where letters differ, yields are statistically different at the 5% level.

Plant tissue samples were collected from upper leaves at the early bloom stage. No significant interactions were noted between the applied fertilizer treatments and the elements P, K, Ca, Mg, Al, Fe, Cu, Mn and B. Zinc levels in the plant tissue were increased with 20 pounds of zinc fertilizer per acre.

Pinto Beans (phosphorus-zinc)

A randomized block design was used to determine effects of increasing rates of P and Zn fertilizer on pinto bean yields and plant tissue contents. Fertilizer treatments were applied before tillage. An adequate rate of starter fertilizer was used on all plots. Fertilizer treatments included:

lbs. P_2O_5/A	+	lbs. Zn/A
0	+	0
0	+	20
40	+	0
40	+	20
80	+	0
80	+	20

Table 4 indicates no increase in pinto bean yields with increasing rates of P and Zn. Yields were not as high as expected because of rust damage.

Table 4. 1972 pinto bean yields with varying rates of phosphorus and zinc in Renville County.

Fertilizer Treatment P_2O_5 + Zn	Pinto Bean Yields
lbs/A	lbs/A
0 + 0	697 a*
0 + 20	645 a
40 + 0	641 a
40 + 20	738 a
80 + 0	711 a
80 + 20	708 a

* Where letters differ, yields are statistically different at the 5% level.

No interaction of applied fertilizer with the elements P, K, Ca, Mg, Al, Fe, Cu, Mn and B was noted in the plant tissue contents.

Zinc contents of the plant tissue was significantly increased with 20 pounds of zinc fertilizer per acre.

Pinto Beans (potassium experiment)

Potassium rates of 0, 50 and 100 pounds per acre were used in a series of plots randomized and replicated four times. Potassium treatments were applied before tillage with all plots receiving an adequate rate of starter fertilizer.

No increases in yields are noted in Table 5 with increasing rates of potassium fertilizer.

Table 5. 1972 pinto bean yields with increasing rate of potassium fertilizer in Renville County.

Fertilizer Treatment lbs. K_2O/A	Pinto Bean Yields lbs/A
0	594 a*
50	529 a
100	516 a

* Where letters differ, yields are statistically different at the 5% level.

Plant tissue samples indicated no interaction of the elements P, K, Ca, Mg, Al, Fe, Zn, Cu, Mn and B with increasing potassium rates.

1973 Experiments

Edible bean fertilization will be studied further in 1973. Fertilization with phosphorus, zinc, potassium and starter fertilizers will be continued with increased emphasis on disease control which should facilitate higher yields and possible fertilizer responses. Plant analysis will be used to determine amounts of P, K, Ca, Mg, Al, Fe, Cu, Mn, Zn and B in plant tissue and define the critical levels of these elements for edible bean production.

LIME PLOTS, DAKOTA COUNTY, 1972[1]

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 crops, and chemical properties under irrigation.

Corn was grown in 1971. Neither yields nor the chemical composition of corn were affected by lime treatments.

In 1972, Corsoy soybeans were grown. No fertilizer was applied to soybeans. The field was not irrigated in 1972 because of sufficient rainfall. Treflan was sprayed at the rate of two quarts per acre.

Soil samples were collected from all check plots in July (Table 1).

The soybean yield and chemical composition of trifoliate are given in Tables 2 and 3.

Liming had no effect on soybean yield. The manganese concentration in trifoliate was lowered by the lime treatments. The contents of macro elements in soybean tissues were not affected by liming.

Table 1. Soil Test Results

Depth of Sampling, Inches	pH	SMP Buffer Index	Extractable P ppm	Exchangeable K pp2m
0-6	5.7	6.5	61	310
6-12	5.7	6.5	31	220
12-18	5.9	6.7	14	110
18-24	5.9	6.9	12	90
24-30	6.2		13	50
30-36	6.2		12	40

[1] See "A Report on Field Research in Soils," Soil Series 88, March 1972, pp. 196-197 for results obtained during 1971.

Table 2. Yield of Soybeans, Earl Almquist's Farm, Dakota County, 1972.

Rate of Lime Tons/Acre	Yield Bu/Acre
0	52
2.5	50
5.0	50
10.0	52
Significance	NS
CV,%	4

Table 3. Chemical Composition of Soybean Trifoliate, Earl Almquist's Farm, Dakota County, 1972.

Lime Treatment	P	K	Ca	Mg	Zn	Cu	Mn	B	Fe	Al
	-----Percent in Dry Matter------				------Parts Per Million in Dry Matter----------					
0	.45	1.88	.99	.39	47	10.7c	58b	41	112	20
2.5	.46	1.93	.97	.40	44	10.3bc	51ab	39	113	19
5.0	.44	1.86	1.01	.41	43	9.5a	49a	39	110	21
10.0	.45	1.87	1.00	.41	43	9.6ab	49a	38	105	19
Significance	NS	NS	NS	NS	NS	**	*	NS	NS	NS
CV, %	5	7	6	7	6	6	10	6	6	19

PASTURE IMPROVEMENT THROUGH FERTILIZATION

Results of Trials in Minnesota Red River Valley--1972

C. A. Simkins, Oliver Strand, Marlin O. Johnson

Minnesota has more than two million acres of unimproved grassland. Land which is often unsuitable for cultivated crops is left in permanent pastures. To a lesser extent, some land which could be used as cultivated land is also devoted to permanent grass pasture or hay land. In numerous instances, without fertilization and management, this land provides forage for only a short period of the year (6 to 8 weeks). Yields of hay (equivalent) obtained from this pasture management are often less than 1 ton per acre.

Profitable forage production depends on high yields and good quality. Less than 15 percent of the hay and pasture land in Minnesota is fertilized. Few farmers are taking advantage of today's research know-how and our grass lands are neglected acres. While there are many reasons, perhaps one of the most important in northern Minnesota is the fact that farmers do not feel the need for additional forages because they keep only enough 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 low. Minnesota has frequent instances of under utilization of hay and pastures during the growing season. Farmers must have sufficient livestock to utilize additional forages produced as a result of fertilization.

Studies conducted at 11 locations in northern Minnesota (in 1971 and 1972) show clearly that fertilizer use can increase hay yields

on grasses now being used by many farmers.

Table 1 shows yields of grasses in tons per acre of hay obtained from various treatments.

Table 1. Hay yields--fertilizer trials--Red River Basin, Minnesota -- 1971 and 1972.

	Tons/acre*	
	1971	1972
No fertilizer	1.38	1.24
30+15+15	1.80	1.92
100+0+0	2.08	1.67
100+50+50	3.50	3.07

*Mixed grasses--predominantly quack, timothy, orchard, brome, Kentucky bluegrass.

These results illustrate the high potential for dairy, beef, and livestock industries, but as they are used now they are similar to a factory working at less than half capacity.

In growing, harvesting, and feeding forages, especially grasses, nothing is more important than early cutting. Researchers have shown that cows eat only about one-half as much late cut hay as they would comparable early cut hay. Well-managed, well-fertilized forage crops are not only high yielding, but a quality feed that approaches grain in feed value with a bonus in extra protein. Table 2 illustrates the production of T.D.N. and protein from grass pasture compared to corn.

Table 2. Production of T.D.N. and protein from grass pasture--1971

	Tons hay/acre	Pounds TDN/acre	Pounds protein/acre
Grass pasture--no fertilizer	1.38	1,380	151
Grass pasture--plus 30-15-15	1.80	1,800	230
Grass pasture--plus 100-50-50	3.50	3,500	1,000

Fertilizing grasslands increases forage yields and protein content. Early cutting or grazing produces high quality forage which can reduce feed buying and result in increased profits.

Small Grain Yields in 1972 at Eight Locations in the Red River Valley Basin Following Spring Fertilization with Some Major, Secondary and Micronutrient Elements, and General Conclusions of a Three Year (1970-72) Field Study on 39 Fertilized Fields.

J. M. MacGregor*

Small grain production dominates the cropping area of northwestern Minnesota, since these crops are well adapted to both climate and soils of the region. Precipitation is relatively limited and often is poorly distributed during the short growing season. The comparatively level lake-laid soils have poor internal drainage and contain free lime, with accumulations of the more soluble salts in some areas being troublesome, especially with the more salt sensitive crops such as soybeans, flax and several ornamental plant species.

The present study was initiated in the spring of 1970 to determine the fertilizing value of additional potash, sulfur, zinc, manganese, boron, and copper broadcast with a basic N, P_2O_5, and K_2O treatment at the 40 lb/A rate of each.

A number of fields were selected each spring (1970, 1971, and 1972), the soils were sampled and analyzed, and previous management information obtained. The summer or fall plowed fields were staked as soon as dry in the spring, and five replications of nine fertility treatments were broadcast. All field stakes were then removed and the farm operator prepared the seedbed as usual by disking the plowed field. Most operators applied starter fertilizer of their choice when seeding, and in 1970, the amounts of starter nutrients applied were subtracted from the broadcast basic treatment so the total amounts (starter

and that broadcast) totalled 40+40+40 per acre. This procedure was found to be time consuming and impractical, since the many field weighings limited the number of fields which could be fertilized prior to spring seeding. In 1971 and 1972, the basic 40+40+40 treatment was broadcast irrespective of and in addition to the starter fertilizer applied by the farm operator. Also, since some of the 1970 fields showed a significant yield increase from the basic 40+40+40 treatment, an additional treatment with no potash (40+40+0) was included in 1971 and 1972 to determine if the potash of the basic treatment contributed to this effect. The plots of all fields were restaked with 48" wood lath following the usual June herbicide spraying. Yield samples were cut just prior to swathing, using a 36" sickle type mower for an 8' length (24 sq. ft.) from each plot. The samples were bagged, dried in low temperature ovens, threshed and the grain yields calculated and statistically analyzed.

During the 3 year study, only the 1971 growing season was considered ideal for small grain production, a year of early seeding, good rainfall distribution, and relatively cool temperatures. On the other hand, the 1970 and 1972 seasons had very wet springs which delayed planting, followed by very dry weather late in June and July. The results obtained on the 1970 and 1971 experimental fields have been previously reported (see Soil Series 88, pp. 225-227, March 1972).

A total of nine fields (5 of wheat, 2 of oats, and 2 of barley) were fertilized in 1972. One wheat field was so seriously damaged by a July hailstorm that it was discarded. Pertinent information including locations, soil tests, management, and grain yields are

shown in Table 1.

As already mentioned, the 1972 small grain growing season was relatively unfavorable, with heavy spring rains resulting in working wet soils and late seeding. Relatively dry weather followed, with much of the experimental area receiving less than 3" of rain in the critical two month mid-May through mid-July period. Fertilizer effectiveness for grain production was minimal.

Texture of the eight soils was that of a loam or finer, and all were high in organic matter. Available phosphorus was very low on three fields. Soluble salt content was relatively low, even with the high alkalinity (high pH) of the two barley fields. Cropping and fertilizer practice was typical of the area.

Only two of the eight 1972 fields produced significantly larger grain yields from the broadcast fertilizer treatments, and obviously this resulted from the nitrogen phosphate (40+40+0). Additional potash, sulfur, or any of the micronutrients had no significant yield effect, either alone or combined, results typical of the two preceding years of this field study.

Conclusions of the Three Year Study

The growing seasons of both 1970 and of 1972 were characterized by unfavorable precipitation distribution during these small grain growing seasons-with extremely early springs with very dry midsummers following. The small grain growing season of 1971 was almost ideal for maximum grain production.

In 1970,one (barley) of the 12 small grain fields responded to the basic 40+40+40 treatment only. In 1971, one of nine oat fields, one of five barley fields, and one of three wheat fields responded to the 40+40+0 treatment. There was a possible effect of the sulfur

treatment (20 lbs/A) on the responding oat field, which was located in eastern Becker county near Ponsford and was about 20 miles east of the true Red River area basin. In 1972, one of four wheat fields and one of two oat fields (two of eight totals) produced significantly larger yields with the 40+40+0 fertilization, with no effect for additional potassium, sulfur, or any of the four micronutrient elements, either alone or combined.

It may be reasonably concluded that the soils of Red River Valley basin which were included in this study still contain sufficient available potassium, sulfur, zinc, manganese, boron, and copper for optimum small grain production. Nitrogen and phosphorus availability is limited in some fields, but this can easily be remedied by fertilizing with these two major fertilizer elements either as broadcast, starter or both.

* This study was possible only through the active interest of cooperating county extension personnel, farm operators, and research staff at the Northwest Experiment Station at Crookston. Their substantial contribution is duly acknowledged.

Table 1. County, Location, Farm Operator, Previous Management, and 1972 Soil Tests and Small Grain Yields on Eight Northwestern Minnesota Farm Fields.

1972 Crop	Wheat				Oats		Barley	
County	Polk	Clay	Clay	Wilkin	Clay	Clay	Clay	Wilkin
Town	Crookston	Georgetown	Moorhead	Kent	Felton	Felton	Glyndon	Foxhome
Operator	NW Exp.Sta.	Fossum	R.Olson	Bellmore	Brantner	Wetterlin	Kuehl	Friedricks
Soil texture	SiCl	SiCl	SiCl	Loam	SiCl	SiL	SiL	SiL
Soil pH	8.4	7.3	8.4	6.9	8.1	8.7	8.5	8.7
Soil O.M.	H	H	H	H	H	H	H	H
Soil P.	28	10	33	16	10	2	4	3
Soil K.	380	460	560	270	550	80	140	210
Soil NO_3-N	49	104	111	32	40	119	75	205
Soil Zn	1.7	1.1	2.2	3.2	1.6	1.3	3.3	1.4
Soil S	16	13	20	9	27	40	10	12
Soluble salts	0.7	0.7	0.9	0.5	0.7	0.9	0.6	0.8
1970 Crop	barley	alfalfa	fallow	barley	wheat	barley	sugarbeets	barley
1970 fert.	0+115+0	none	none	19+48+0	58+23+0	16+49+16	20+100+20	38+95+25
1971 Crop	sugarbeets	alfalfa	sugarbeets	sunflowers	soybeans	sunflowers	wheat	fallow
1971 fert.	6+42+0	none	20+49+16	none	none	15+37+0	69+29+14	none
1972 variety	Era	1809	wheat	1809	G.C.	Lodi	Larker	Larker
1972 starter fert.	none	23+58+0	36+46+12	23+58+0	44+69+0	24+62+0	69+29+14	none

Table 1. (continued)=

1972 Crop	Wheat				Oats		Barley	
County	Polk	Clay	Clay	Wilkin	Clay	Clay	Clay	Wilkin
Town	Crookston	Georgetown	Moorhead	Kent	Felton	Felton	Glyndon	Foxhome
1972 bct fert. (lbs/A)				1972 Small Grain Yield in bushels per acre.				
none	28.1a	39.8	25.8	26.5	52.7a	83.7	42.1	27.9
40+40+0	44.8b	40.4	23.2	27.2	81.6bc	83.8	45.6	35.6
40+40+40	45.5b	39.5	27.2	33.7	71.9bc	95.0	46.2	36.1
40+40+200	45.1b	38.2	24.5	27.4	75.8bc	87.9	48.3	36.4
40+40+40+10 Zn.	47.4b	40.0	24.5	29.3	78.9bc	85.2	48.0	35.9
40+40+40+10 Mn.	46.6b	41.4	24.0	27.1	73.4bc	77.6	47.6	31.1
40+40+40+2 B.	47.8b	37.9	15.8	27.9	73.0bc	84.9	46.2	34.1
40+40+40+10 Cu.	43.4b	39.1	19.3	34.0	85.2c	91.1	49.9	36.5
40+40+40+20 S.	45.6b	37.0	25.5	25.4	67.2b	89.0	46.6	34.1
40+40+40+10 Zn+ 10 Mn + 2 B + 10 Cu +20 S.	43.0b	41.0	31.3	32.0	79.8bc	81.9	51.2	37.2
		N.S.	N.S.	N.S.		N.S.	N.S.	N.S.

SULFUR RESPONSES IN SOUTHERN MINNESOTA

D. S. Fairchild, W. E. Fenster, O. M. Gunderson, W. W. Nelson*
G. W. Randall

Interest in sulfur as a plant nutrient has increased markedly over the past few years and reports of sulfur deficiencies are rising. Concern over these deficiencies may in part be due to: (1) increased use of high-analysis, sulfur-free fertilizers, (2) increased crop yields, (3) decreased atmospheric sulfur, and (4) decreased use of sulfur in fungicides and insecticides.

Sulfur is an essential element to plant growth. Like nitrogen, phosphorus, potassium, calcium and magnesium, sulfur is a macronutrient and must be available in larger amounts than micronutrients for good crop growth.[2]

HISTORY OF SULFUR RESEARCH

To better understand sulfur's role in Minnesota agriculture, we should review the sulfur research in the north central states.

Designating sulfur deficient Minnesota soils, determining sulfur supplying capacity of soils and defining sulfur crop needs are not new to Minnesota agriculture. Alway (1920-30) found the annual fallout of sulfur from rain, snow, and dust to vary from 100 lbs/A in Minneapolis to less than 5 lbs/A in northern areas of the state.[1] Evans and Rost (1940-50) determined the total sulfur, total organic sulfur, and sulfate sulfur of 39 different Minnesota soils.[4] More recently Caldwell and associates (1960) have done considerable research on defining the sulfur supplying capacity of soils and crop needs for fertilizer applied sulfur in north central Minnesota.[7]

SOIL SULFUR

The University of Minnesota soil testing laboratory provides a

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* Efforts of Bobby McCaslin and Robert Schoper on plot work and statistical analysis are greatfully acknowledged.

soil test for sulfur that extracts soluble and adsorbed sulfates. It is quite reliable for areas in Minnesota where soil organic matter and fallout concentrations of sulfur are insufficient. The chief limitation of the sulfur soil test is that it does not measure two other major forms of sulfur: organic and atmosphere sulfur. Organic sulfur reacts similar to organic nitrogen in that about 2 percent is released each year in the process of organic matter decomposition. Recent work by Bremner in Iowa with a number of soil types common to southern Minnesota have indicated that organic sulfur can account for 95-98 percent of the total sulfur in soils.[8]

PLANT SULFUR

The sulfur requirement of a plant is the minimum amount of sulfur required for adequate nutrition, or the amount of sulfur that is just sufficient to maintain the plant in a healthy, normal condition and provide maximum yield.[5]

Table 1 indicates that crops differ in their requirements for sulfur.

Table 1. Sulfur content of some crops(2)

	Yield/Acre	Sulfur, Lbs./Acre
Alfalfa	6 tons	30
Corn	200 bu.	44
Wheat	80 bu.	22

Research indicates that alfalfa containing less than 0.20 percent sulfur likely will respond to sulfur fertilization. Corn containing less than 0.15-0.20 percent sulfur in the ear leaf likely will respond to sulfur fertilization.[5] Also, nitrogen to sulfur ratios greater than 11:1 indicate a possible sulfur deficiency.[3]

SULFUR NEEDS IN SOUTHERN MINNESOTA

What about sulfur needs for southern and western Minnesota corn farmers? To try and answer this question research was conducted in 1970, 1971, and 1972 with rates, forms, and starter sulfur fertilizers. The following is a summary of this research.

RATE OF SULFUR STUDY (1970-1971)

In the spring of 1970, a project was initiated to determine if corn will respond to additions of sulfur. The experiment was located at the Southwest Experiment Station at Lamberton on a Webster clay loam soil. General soil test information is given in Table 2.

Table 2. Soil test levels of experimental site.

Soil Depth	P	K	S	Zn	pH	O.M.
	lbs/A		ppm			
0-3"	28	240	11	2.7	5.9	H
3-6"	27	235	12	2.8	6.0	H
6-12"	11	195	13	1.7	6.2	H

Elemental sulfur rates of 0, 20, and 100 lbs/A of actual S were broadcast in early spring of 1970 before tillage. No additional sulfur was applied in 1971 as the experimental site was being used for a sulfur residual study. No significant yield responses resulted from the addition or increased rates of sulfur (Table 3).

Table 3. Sulfur treatments and corresponding 1970 and 1971 corn yields at Lamberton.

Fertilizer Treatment	1970	1971
lbs. El. S/A	Yield (Bu/A)	(15.5%)
0	155	113
20	157	114
100	154	109
Significance	N.S.	N.S.

As evidenced from Table 4, there was no significant difference in plant tissue sulfur contents in 1970. Significant increases in plant tissue sulfur contents, however, are indicated in 1971 This would indicate that in 1970 the applied elemental sulfur was not oxidized to an available form to plants. Tissue samples were collected when corn was 10 inches tall and at silking stage of growth.

Table 4. Sulfur content of corn tissue under variable sulfur treatments, Lamberton 1970 and 1971.

Fertilizer Treatment	1970		1971	
	10"	Ear Leaf	10"	Ear Leaf
lbs. S/A	% S in dry matter			
0	0.29 a*	0.28 a	0.23 a	0.22 a
20	0.28 a	0.27 a	0.23 a	0.21 a
100	0.29 a	0.27 a	0.26 b	0.24 b

* Numbers followed by the same letter are not significantly different at the 5.0% level.

INVESTIGATIONS ON FORMS AND RATES OF SULFUR (1971 and 1972)

Ten field experiments were established in 1971 to study the effects of sulfur rates and forms with corn, soybeans, and alfalfa. Five locations representing common soil types in southern and western Minnesota will be presented here. General information on the experimental sites is given in Table 5 and 6.

Table 5. Location and soil type of experimental sites.

County	Cooperator	Soil Type	Crop
Wabasha	J. Welti	Port Byron silt loam	Corn
Houston	J. McCormick	Fayette silt loam	Corn
Steele	G. VanRuden	Kenyon loam	Alfalfa
Chippewa	C. Phillips	Nicollet loam	Corn-Soybeans
Pope	Weispfinnig	Esterville sandy loam	Corn

Table 6. Soil test levels of experimental sites.

County	P	K	S	pH	O.M.
	lbs/A		ppm		
Wabasha	68	390	16	6.8	L
Houston	65	190	16	6.6	L
Steele	28	240	10	6.1	M
Chippewa	52	500	19	7.9	H
Pope	41	280	15	6.4	M

The following forms and rates of sulfur were applied in the spring of 1971 before tillage.

Forms of Sulfur	Corn Sites	Alfalfa Sites
	S (lbs/A)	
--	0	0
K_2SO_4	25	50
Elemental-S	25	50
K_2SO_4	50	100
Elemental-S	50	100

All cooperators used optimum 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-inch height and 6th leaf at silking,
2. Alfalfa - top one-third of plant at harvest,
3. Soybeans - upper fully developed trifoliate at bloom stage.

No significant yield increases resulted with the addition of sulfur to corn, soybeans, and alfalfa (Table 7, 8, 9).

Table 7. 1971 and 1972 corn yields on sulfur fertilization trials.

Treatments	Wabasha		Houston		Chippewa	Pope	
	1971	1972	1971	1972	1971	1971	1972
lbs. S/A	Yield (Bu/A)						
0	145	145	193	164	90	98	86
25 (K_2SO_4)	144	138	190	159	89	101	86
25 (Elemental S)	157	147	192	166	90	102	86
50 (K_2SO_4)	157	142	196	163	90	98	90
50 (Elemental S)	151	144	184	159	100	101	85
Significance	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

Table 8. 1972 soybean yields on sulfur fertilization trials.

Treatment lbs. S/A	Chippewa Yield (Bu/A)
0	38
25 (K_2SO_4)	37
25 (Elemental S)	38
50 (K_2SO_4)	38
50 (Elemental S)	36
Significance	N.S.

Table 9. 1971 and 1972 alfalfa yields on sulfur fertilization trial, Steele Co.

Treatments lbs. S/A	1971 Yield (Tons/A	1972
0	4.2	4.9
50 (K_2SO_4)	4.1	5.2
50 (Elemental S)	4.2	5.1
100 (K_2SO_4)	4.0	5.1
100 (Elemental S)	4.1	5.1
Significance	N.S.	N.S.

STARTER SULFUR

In the spring of 1972, a study was initiated to determine whether or not the addition of sulfur to starter fertilizers would affect early plant growth and yield of corn. The experiment was located at the Waseca Experiment Station on a Cordova silty clay loam. The initial soil test indicated 14 ppm of extractable sulfur. The following sulfur treatments were applied:

1. no sulfur
2. 5 lbs/A sulfur with starter
3. 15 lbs/A sulfur with starter
4. 15 lbs/A sulfur as broadcast.

As shown in Table 10, no significant increases in small plant weights or yield resulted from varying sulfur treatments.

Table 10. Sulfur treatments and corresponding small plant weights and yields at Waseca.

Fertilizer Treatment Lbs. S/A*	Small Plant Weights gms.	Yield Bu/A (15.5%)
0	105	156
5 (starter)	106	161
15 (starter)	104	155
15 (broadcast)	96	166
Significance	N.S.	N.S.

*Used K_2SO_4

However, sulfur applications resulted in significant increase in sulfur content of young plants (Table 11). No significant increase was noted in the ear leaf sulfur contents.

Table 11. Sulfur content of corn tissue under variable sulfur treatments, Waseca 1972.

Fertilizer Treatment lbs. S/A	Small Plants	Ear Leaf
	% S in dry matter	
0	.27 a*	.19 a
5 (starter)	.28 ab	.20 a
15 (starter)	.29 b	.20 a
15 (broadcast)	.30 c	.21 a

* Numbers followed by the same letter are not significantly different at the 5.0% level of population.

CONCLUSIONS

1. In 1970 and 1971, the elemental sulfur was apparently not oxidized to an available form for plants, but was equal to potassium sulfate the second year after application.
2. Three years of research showed no yield increases with varying rates and forms of sulfur applied either as a starter or as a broadcast.
3. No economic yield gains were realized with additional sulfur applications to corn, alfalfa and soybeans on soil types common to southern Minnesota.
4. In all cases, the sulfur content of various plant tissues appeared above the critical level and were adequate for maximum yields.
5. It is presently recommended to apply sulfur only on a trial basis in southern Minnesota when sulfur soil tests are low (less than 7.0 ppm).

LITERATURE CITED

1. Alway, F. J., Marsh, A. W., and Methley, W. J. Sufficiency of Atmospheric Sulfur for Maximum Crop Yields. Soil Sci. Soc. Amer. Proc. 2:229-238. (1937)

2. Bixby, D. W. and Beaton, J. D. Sulfur-Containing Fertilizers: Properties and Applications. Technical Bull. No. 17. The Sulphur Institute, Washington, D.C. (1970)

3. Caldwell, A. C., Seim, E. C., and Rehm, G. W. Sulfur Effects on the Elemental Composition of Alfalfa and Corn. Agron. J. 61:632-634. (1969)

4. Evans, C. A. and Rost, C. O. Total Organic Sulfur and Humus Sulfur of Minnesota Soils. Soil Sci. 59:125-137. (1945)

5. Martin, W. E. and Walker, J. W. Sulphur Requirements and Fertilization of Pasture and Forage Crops. Soil Sci. 101:248-257. (1966)

6. Overdahl, C. J., Caldwell, A. C., Grava, J. and Fenster, W. E. Sulfur for Minnesota Soils. Soil Fact Sheet No. 5 Agric. Ext. Serv. Univ. of Minnesota. (1969)

7. Rehm, G. W. and Caldwell, A. C. Sulfur Supplying Capacity of Soils and the Relationship to Soil Type. Soil Sci. 105:355-361. (1968)

8. Tabatabai, M. A. and Bremner, J. M. Distribution of Total and Available Sulfur in Selected Soils and Soil Profiles. Agron. J. 64:40-44. (1972)

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 1972.

Regular Farm, Garden and Lawn Samples		20,248
Florist (Greenhouse) Samples		1,932
Specials:	Nitrate	1,223
	Sulfur	1,044
	Zinc	446
	Soluble salts	631
	pH	220
Limestone		18
Departmental Research Samples		2,563
	TOTAL	28,325

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 1972.

MONTH	NUMBER OF SAMPLES
January	480
February	337
March	932
April	3,975
May	3,365
June	1,008
July	851
August	1,399
September	2,354
October	3,162
November	1,666
December	749

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