A Report on Field Research in Soils

(A compilation of recent experimental results by personnel of the Department of Soils and Extension Specialists and Agronomists at the Branch Stations at Crookston, Duluth, Grand Rapids, Lamberton, Morris, Rosemount, and Waseca).

Department of Soils
University of Minnesota

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Some of the results herein reported are from experiments carried on during 1962 only, and should not be regarded as the results obtained over a number of years. The investigations are those of a more practical nature, and do not include some of the more theoretical problems presently under study in greenhouse and in the laboratory. Because these are largely one year results they should not be considered as conclusive and the results are not for publication.

TABLE OF CONTENTS

Weather and Soil Moisture

		Page
1.	Summary of 1962 Minnesota Weather and the St. Paul Experimental Plot Data.	1

Soil Testing

2.	Soil Testing in Minnesota During 1962	7

Soil Productivity

3.	Soil Productivity Study	9

Nitrogen

4.	The Effect of Nitrogen Source, Placement and Time of Application on the Yield and Composition of Continuous Corn on Webster Clay Loam at Lamberton	15
5.	The Effect of Nitrogen Fertilization On Yield and Composition of Wheat at Crookston in 1960, 1961, and 1962	19

Phosphorus

6.	Comparison of Phosphorus Sources	23

Secondary and Micro (Trace or Minor) Elements

7.	The Effect of Lime and Molydenum on the Yield of Alfalfa, Oats, Corn and Soybeans	24
8.	Effect of Sulfur-bearing Materials on Alfalfa (Park Rapids, 1962)	25
9.	Field Experiments with Zinc on Corn	26
10.	1962 Studies of Boron and FTE Fertilization for Corn	29
11.	Boron and FTE Fertilization Studies on Alfalfa-Grass Stands in Wabasha County on Fayette Silt Loam	32

Rotations

12.	Soil Fertility and Crop Production Studies on the Webster Soils of Southern Minnesota	34

Corn

13.	Profit Possibility Plots	36
14.	The Effect of Very High Fertilizer Rates and Ratios on Stand of Corn	40
15.	Field and Laboratory Studies with Corn	42
16.	Results of Six Years of Continuous Corn Fertilization at Morris	46
17.	Continuous Corn - High Fertility Experiment	47

Fertilizer Placement

18.	NPK - Rate and Placement Studies with Corn on Fayette Soils - 1962	49

19. Proper Fertilizer Placement Can Improve Stand and Yield of Corn 54
20. The Effect of Potash Placement in Starter Fertilizer on the Yield of Corn 55

Soil Erosion On Continuous Corn - Plowing Vs. Deep Cultivation

21. Comparative Effects of Deep Tillage Versus Plowing on Soil and Water Losses and Corn Yield over Four Years (1959-62) on Port Byron Silt Loam at Rosemount 56

Small Grains

22. Comparison of Fertilizer Materials on Spring Wheat 58
23. Clay County Barley Demonstrations-1961 59
24. Kittson County Barley Demonstrations-1962 60

Legumes

25. Residual Effects of Fertilizer on First Year Yield of Vernal Alfalfa Following a Decade of Fertilized Alfalfa Production 61
26. Residual Effects of Fertilizer on Soybeans Grown Continuously 63

Pasture Forages

27. The Effect of Pasture Fertility and Management of Beef Production 64

Grass Seed

28. Fertilizer Experiments on Park Kentucky Bluegrass Seed Production in Roseau County 66
29. The Effect of Fertilizer on Yield of Climax Timothy 71
30. Effect of Fertilizers on Timothy Seed Yields in Clearwater 74

Potatoes

31. Woodchip(sawdust)- Nitrogen Experiment on Potatoes at Grand Rapids Experiment Station 76
31. Fertility Studies on Organic Soils at Hollandale 77

Cucumbers

32. Fertilizer Experiments with Cucumbers - 1962 78

Turf

33. Nitrogen Fertilization Studies on Turf - 1962 82

Summary of 1962 Minnesota Weather and the St. Paul Experimental Plot Data.

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The 1962 Growing Season Weather

The growing season weather proved to be generally unsatisfactory except for hay and pastures. The exceptionally great precipitation of May, in some places amounting to more than 200% of normal, while of doubtful benefit to the water resources of the state greatly delayed planting and adversely affected small grains. In July and August, critical months for the growth and maturation of corn, precipitation remained high. Although in some areas of coarse textured or "droughty" soils the excessive precipitation was beneficial. By the end of the season almost all areas, except perhaps the southeast, were well above normal (table 1). And, as might be expected, air temperatures (table 2) and soil temperatures were lower than normal.

Table 1. Total departure of precipitation from the long term normal, April 1-October 21, 1962. (U.S. Weather Bureau data).

Duluth	+2.94 in.	Rochester	+1.50 in.
Fargo	+7.82	St. Cloud	+6.36
International Falls	+5.52	Sioux Falls	+3.88
Minneapolis-St. Paul	+4.06		

Table 2. Departure of air temperature from long term normal. April-September, 1962 (U. S. Wea. Bur. data).

Station	April	May	June	July	August	September	Ave.
Crookston	-2.1	-0.1	+1.5	-2.5	+1.4	-0.9	-0.4
Duluth	-3.3	+0.3	-2.5	-5.2	-2.4	-2.8	-2.6
Fairmont	-2.2	+4.7	-0.7	-4.2	-1.2	-3.0	-1.1
Grand Rapids	-1.8	+2.5	-0.8	-4.0	-0.2	-1.6	-1.0
International Falls	-3.0	+1.5	+1.7	-2.7	-0.1	-1.0	-0.6
Minneapolis	-2.5	+3.0	-1.1	-5.5	-2.2	-4.1	-2.1
Morris	-3.5	+1.4	-1.4	-4.6	-0.3	-3.4	-2.0
Rochester	-3.0	+4.6	-0.6	-4.4	-1.7	-4.1	-1.5
St. Cloud	-2.8	+3.3	-0.3	-4.0	-0.6	-2.7	-1.2
Waseca	-3.4	+2.8	-2.4	-5.3	-2.3	-5.6	-2.7
Worthington	-2.8	+4.2	-1.4	-4.2	-1.6	-3.8	-1.6

Table 3. Percent of possible sunshine received compared with the long term normals, April-September, 1962 (U.S. Wea. Bur. data).

Station	May	June	July	August	September
Duluth	35	59	50	59	56
(normal)	58	63	69	62	51
Minneapolis	39	55	49	67	55
(normal)	58	61	69	66	61

Of equal or greater importance was the increased cloudiness which resulted in greatly decreased sunshine as shown in table 3.

In addition to the excessive precipitation, greatly reduced sunshine and lower air and soil temperatures, there was an early and severe cold wave which crossed Minnesota in the third week of September. The lowest temperature recorded was 17°F. at Cotton in St. Louis County. This cold wave effectively terminated the season in many areas. Although minimum temperatures of around 32°F. are to be expected in September, temperatures in the 20s are not. This severe cold wave occurred about three to four weeks earlier than normal in the south and one to two weeks earlier in the north.

Soil Moisture Survey

The generally above normal precipitation during the 1962 season is reflected in the survey results (table 4). Perhaps the most important feature of table 4 is that all stations, where a comparison was possible, have greater soil moisture reserves this fall than last fall. It is interesting to note that the crops apparently use about 20-25 inches of water.

The Polk County, Crookston, soil moisture data indicate that water use by the crops in decreasing order are alfalfa, soybeans and sugar beets. However, a major portion of the difference is believed to be due to the difference in sampling dates, and that the real difference, between the three crops is far less than indicated.

Weather Station Plot Data, St. Paul.

A summary of the above and below ground meteorological information obtained at the experimental plot on the St. Paul campus is shown in tables 5 and 6.

The soil temperature data, table 5, show the influence that a cover has upon temperature. The sod cover, with the grass at no time being longer than about four inches, exerted an influence upon soil temperatures to a depth of about 80 cm. Under the sod the summer temperatures were cooler and in the winter were warmer than under the bare soil. In winter the sod acted as an insulator, and in the summer the temperature difference was due to the insulating effect as well as the cooling effect of the transpiring surface and, to a minor degree, the color difference.

The previous winter, 1960-61, was quite open and comparison with last winter shows an obvious influence that the snow cover had. For example, in January, 1961, snow cover averaged less than 0.5 inches, and in January, 1962, it averaged about 3-4 inches deep. As a result the January, 1962, soil temperates at 1 cm. averaged 6 and 7 degrees F. higher than the previous year.

The maximum soil temperature this last summer was not observed on the bare plot, as might be expected, but rather in the soybean plot. The temperature recorded was +122°F. at 1 cm. depth. The reason for this is that the plants had not yet grown enough to shade the soil surface completely but were tall enough to effectively decrease wind movement and reduce heat losses by convection.

The average soil temperature at each depth for the period October, 1961-September, 1962 (table 5) gives the impression that there is a big difference between depths. It is true that the shallow depths will show a slightly higher average of perhaps a degree or less, in this area at least, however the main reason for the large difference is the time when the observations were made. These data were obtained from only the 5 p.m. observation and are not hourly averages. Thus it is believed that the diurnal heat wave is largely responsible for the rather larger differences.

Table 4. 1962 soil moisture survey

County & nearby town	Soil	Crop	Sampling dates	Available water present[1]	% of maximum avail. water	Water use by crop [2]	Increase (+) or decrease (-) in water content of Fall 1962 over Fall 1961.
Chippewa, Milan	Rothsay si. l.	Corn	May 1	7.4 in.	54.0%	--	
			Nov. 8	8.2	59.9	21.85 in.	Not sampled in 1961
Chippewa, Montevideo	Aastad si. c. l.	Corn	April 27	12.1	92.4	--	
			Nov. 12	9.3	71.0	24.36	Not sampled in 1961
Dodge, Dodge Center	Kasson si.l.	Alfalfa	April 20	8.0	76.9	--	
			Sept. 24	5.1	49.0	22.23	+ 2.5 in.
LacQuiParle Bellingham	Aastad si. c. l.	Corn	April 27	9.5	59.7	--	
			Nov. 9	11.5	72.3	20.60	Not sampled in 1961.
LacQuiParle Marietta	Rothsay si. l.	Flax	May 1	6.3	48.1	--	
			Nov. 9	8.3	63.3	24.00	Not sampled in 1961
Lyon Minneota	Rothsay si. l.	Corn	April 30	8.1	86.2	--	
			Oct. 31	6.8	72.3	23.99	Not sampled in 1961
Mille Lacs Milaca	Mora si. l.	Hay	May 21	11.0	114.6	--	
			Sept. 25	8.3	86.5	21.94	+ 5.2 in.
Polk Crookston	Hegne si. c.	Alfalfa	May 7	8.4	49.4	--	
			Oct. 31	5.1	30.0	22.61	+ 2.1 in.
Polk Crookston	Fargo si. c.	Soybeans	April 25	7.9	46.5	--	
			Oct. 31	8.1	47.6	19.54	+0.8 in.
Polk Crookston	Fargo si. c.	Sugar beets	June 1	11.5	67.6	--	
			Nov. 2	6.6	38.8	18.68	Not sampled in 1961

Table 4. Continued

County & nearby town	Soil	Crop	Sampling dates	Available water present[1]	% of maximum avail. water	Water use by crop[2]	Increase (+) or decrease (-) in water content of Fall 1962 over Fall 1961.
Ramsey	Waukegan	Soybeans	May 25	8.7	103.6	--	
St. Paul	si. l.		Dec. 1	10.1	120.2	21.21	+5.9 in.
Redwood	Nicollet	Corn	April 30	8.3	58.0	--	
Belview	c. l.		Oct. 26	6.7	46.8	24.34	Not sampled in 1961
Redwood	Webster	Corn	May 1	8.7	85.3	--	
Lamberton	si. c. l.		Oct. 31	7.3	71.6	23.09	+1.2 in.
Sibley	Nicollet	Corn	May 3	9.2	78.6	--	
Gaylord	c. l.		Oct. 31	9.2	78.6	22.01	+0.7 in.
Wabasha	Fayette	Corn	May 31	10.4	67.5	--	
Kellogg	si. l.		Sept. 26	11.5	74.7	25.19	+4.0 in.
Watonwan	Nicollet	Corn	May 28	12.7	91.4	--	
Butterfield	c.l.		Oct. 25	8.8	63.3	22.28	+3.3 in.

Soil moisture samples obtained through courtesy of E. C. Dragemuller, A. N. Fischer, W. M. Kalton, P. N. Kennedy, G. F. Sickeler, Soil Conservation Service, USDA; W. W. Nelson, S.W. Expt. Sta.; O. C. Soine, N.W. Expt. Sta.; O. Gunderson, L. Hanson, G. Holcomb, Minn. Agric. Ext. Service

[1]Plant available water in a five foot column of soil.

[2]Based upon difference between first and last soil samplings plus precipitation. No attempt has been made to account for water runoff or percolation through the soil.

Table 5. Summary of soil temperatures (°F.) at experimental plot, Dept. of Soil Science, Univ. of Minn., St. Paul, Oct. 1961-Sept. 1962. (Observation time 5 P.M., C.S.T. daily; Waukegan silt loam soil.)

Depth (cm.)	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Ave.
						Bare Plot							
1	55	34	30	23	25	30	48	71	83	82	87	68	53.0
5	56	35	31	24	25	30	47	69	81	81	85	69	52.7
10	56	35	31	25	25	30	44	65	76	78	80	67	51.0
20	53	36	32	26	25	30	39	60	70	73	75	63	48.5
40	53	39	34	29	26	30	35	56	65	70	72	62	47.6
80	55	43	38	34	29	31	33	50	60	67	69	63	47.7
						Soybean Plot							
1	-	-	-	-	-	-	-	-	-	79	80	60	--
5	-	-	-	-	-	-	-	-	-	78	78	60	--
10	-	-	-	-	-	-	-	-	-	75	75	60	--
20	-	-	-	-	-	-	-	-	-	71	71	59	--
40	-	-	-	-	-	-	-	-	-	67	68	59	--
80	-	-	-	-	-	-	-	-	-	65	65	60	--
						Sod Plot							
1	53	36	32	29	28	31	44	63	74	75	74	65	50.3
5	54	37	32	29	28	31	42	62	73	75	74	65	50.2
10	54	37	33	30	28	31	40	60	70	73	72	64	49.3
20	53	38	35	31	29	31	36	57	66	70	70	63	48.3
40	53	41	35	33	31	31	34	53	62	66	68	63	47.5
80	55	45	38	35	33	32	32	48	58	64	65	63	47.3
120	57	48	41	38	35	34	35	45	54	61	63	62	47.7
160	57	50	43	39	37	35	35	43	52	59	61	61	47.7
320	57	54	49	46	43	41	40	41	46	51	55	57	48.3
640	-	-	-	-	-	-	-	-	-	45	48	49	--

Next year the plans are to have a complete set of soil temperature data from the soybean plot.

Table 6 is a summary of the above ground metecrological data obtained at the experimental plot.

Perhaps the most interesting feature in this table is the difference between the extreme minimum temperatures of the ambient (air) temperature, as measured in the standard weather shelter, and at 1 cm. above the sod, the bare soil and within the soybean plot. During the growing season the extreme minimum temperature at 1 cm. above the sod ranged from 4 to 15°F. colder than the extreme minimum measured in the temperature shelter. It should be noted, too, that lower minimum temperatures were observed over the sod than over the bare plot.

During the winter the difference between minimum temperatures over the sod and bare plot disappear due to the snow cover. While snow cover was present the minimum temperatures were measured, as nearly as possible, at 1 cm. above the snow surface. It can be very cold at or just above the snow surface as shown by the extreme minimum of -37°F. recorded in March, while the extreme minimum in the temperature shelter was but -24°F.

Table 6. Summary of atmospheric conditions, experimental plot, Dept. of Soil Science, Univ. of Minn., St. Paul, October, 1961-September, 1962.

Ambient Temp. (5 1/2 ft. above ground	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Average or Extreme
Ave. Max.	63	41	24	18	21	34	54	71	76	78	80	68	52
Ave. Min.	40	26	9	1	7	19	32	51	56	58	59	49	34
Average	52	34	17	9	14	27	43	61	66	68	69	58	43
Departure**	+2	+1	+2	-6	-4	-4	-3	+2	0	-6	-2	-4	-3
Extreme Max.	83	63	53	36	39	50	88	87	90	87	90	80	90
Extreme Min.	26	14	-12	-24	-23	-24	9	39	42	47	53	33	-24
Minimum Temp. (°F.) 1 cm. above sod													
Ave.	34	22	8	-2	3	14*	31	47	51	52	53	43	30*
Extreme	14	4	-22	-25	-25	-37	5	27	31	33	38	27	-37
Minimum Temp. (°F.) 1 cm. above bare soil													
Ave.	37	25	8	-2	3	14*	32	49	53*	54*	55	45	31*
Extreme	21	11	-22	-25	-25	-37	5	34	40	36*	43	30	-37
Minimum Temp (°F.) 1 cm. above soil in soybean plot													
Ave.	-	-	-	-	-	-	32	48	M	M	57	48	-
Extreme	-	-	-	-	-	-	5	33	36	M	44	35	-
Precipitation (in.)													
Total	3.58	1.18	1.50	0.43	1.77	2.20	1.36	8.12	4.74	6.04	4.54	3.57	39.03
Departure**	+1.93	-0.26	+.65	-.37	+.88	+.72	-.55	+5.00	+.48	+3.37	+1.75	+.72	+14.32
Greatest Day	1.40	1.00	0.86	0.09	0.50	0.85	0.41	1.73	1.56	2.17	1.13	1.30	2.17
Days with prec.	11	7	21	14	16	9	13	22	11	20	15	17	176***
Wind													
Total miles	3864	4022	4515	4567	3713	3078#	4900	4871	2847	2674	2559	2607	3685
Ave. mi/day	125	134	146	147	133	106	163	157	95	86	83	87	122
Ave. mph/day	5.2	5.6	6.1	6.1	5.5	4.4	6.8	6.5	3.9	3.6	3.4	3.6	5.1
Prevailing direction##	SE	NW, S	NW	NW, NNW	NW	W	NW	SW	NE	NW	S	S	NW
% Frequency**	15	17	20	16	25	13	20	16	13	23	19	17	14
Relative Humidity													
Ave. Max	93	94	92	87	86	86	83	85	88	91	91	95	89
Ave. Min.	50	63	76	69	67	61	38	46	45	43	40	43	53
Ave.	71	77	83	78	77	74	61	65	66	67	65	69	71

*Estimated values
**Departure from long term mean of U.S.W.B. Minneapolis Station
***Total days with recorded precipitation; average precipitation days per month = 15
#Two days missing; anemometer buried in snow.
##at 5 p.m.

SOIL TESTING IN MINNESOTA DURING 1962

John Grava

Unusually high precipitation in the early part of the year made sample collection extremely difficult. Consequently, fewer soil samples were received by the Soil Testing Laboratory in 1962 than during previous years (42,350 in 1961). The following data show the number of samples analyzed in 1962:

Regular farm, garden and lawn samples	30,832
Florist (greenhouse) samples	1,312
Limestone	116
Departmental research samples	2,206
TOTAL	34,466

Norman County won the Minnesota Fall Soil Sampling Roundup. A plaque was presented by "The Farmer" magazine to Norman County Extension Agents during the annual Soils and Fertilizer Shortcourse. The purpose of this recognition is to call attention to excellent cooperation among fertilizer dealers, extension agents and other agricultural leaders in promoting soil testing. The plaque was awarded for the highest number of soil samples per commercial farm received from a county by the University of Minnesota Soil Testing Laboratory from July 1 to November 30.

Table 1. List of top ranking counties with outstanding soil testing programs in the fall of 1962.

County	Samples Per 100 Farms Number	Samples Per 100 Farms Rank	Total Number of Samples Number	Total Number of Samples Rank	Number of Farms*
Norman	49	I	575	II	1177
Swift	42	II - III	625	I	1481
Big Stone	42	II - III	346		818
Watonwan	41		529	III	1275

* Adjusted by excluding (1) cropland acreage not harvested or pastured in 1959, and (2) excluding non-commercial farms (less than 50 acres).

Figure 1 shows monthly distribution of samples received by the laboratory during 1962.

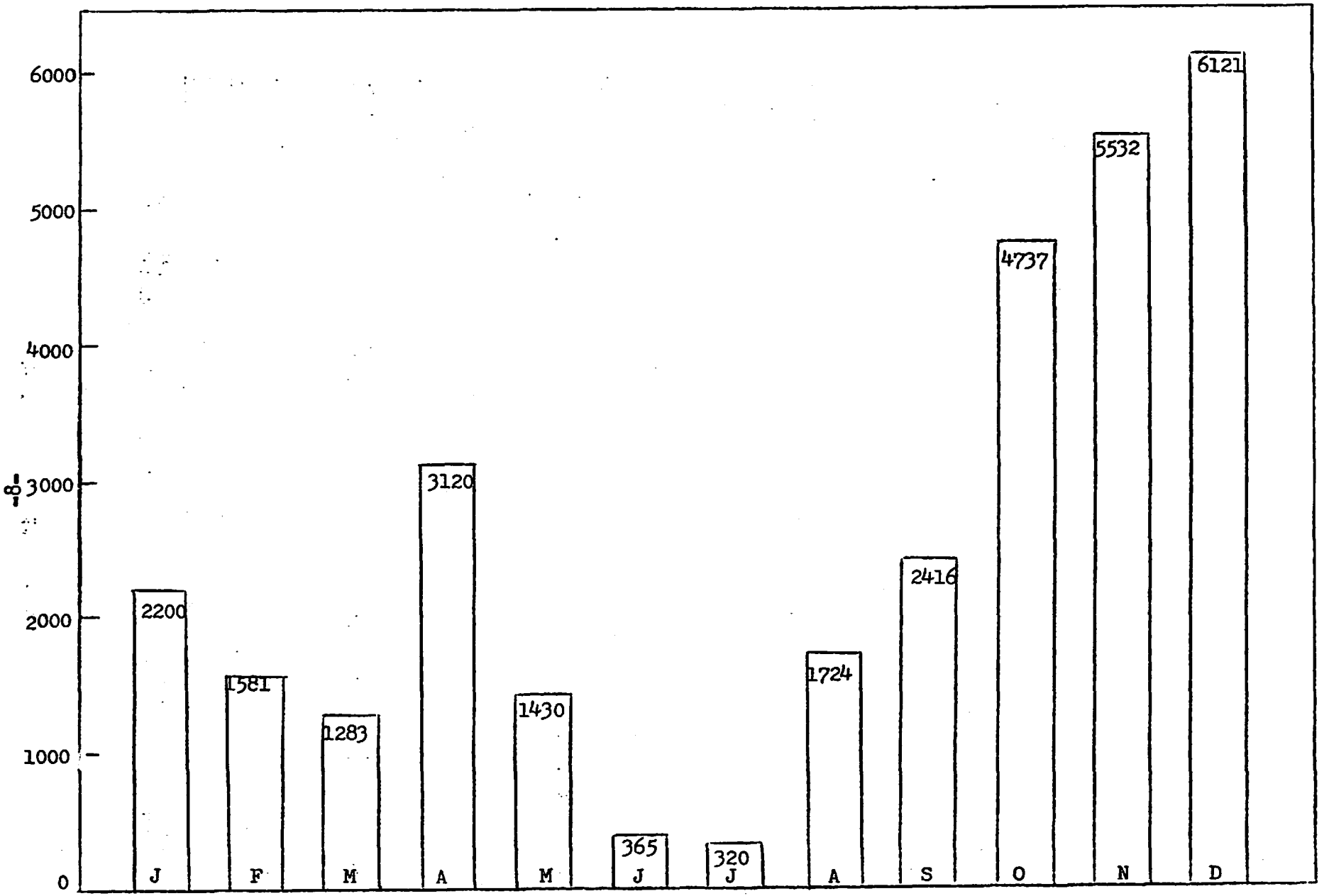

Figure 1. Monthly distribution of soil samples received by the University of Minnesota Soil Testing Laboratory during 1962. (TOTAL = 30,832).

Soil Productivity Study

R. H. Rust

The soil productivity study which began in 1956 is an attempt to gain reliable estimates of the productivity of major soil types in Minnesota. This productivity is estimated for the major crops under several generally specified soil management programs. The estimates are incorporated in the soil survey reports published for the individual counties by the Soil Conservation Service, USDA, and The Experiment Station, cooperatively.

Since the project began 487 farm cooperators have furnished crop and soil management data on some 98 extensive soil types in the state. Currently 372 cooperators are enrolled in the project. The following kinds of data are recorded: date and rate of seeding; stand estimate; kind and amount of soil amendments used; moisture and temperature conditions during the growing season; weed and insect control measures; yields and losses of yield from harvesting or abnormal conditions; soil tests of pH, available P and K, organic matter.

Since it is planned that productivity estimates be based on multiple regression analysis and since there are a number of factors to be studied, a relatively large number of observations (generally more than 30) of each crop on each soil is necessary in order to establish reliability. In addition, the evaluation of yield variation associated with weather observations (chiefly rainfall and temperature) necessitates collection of data over sev eral years.

In the following table the various soils included in the study are listed together with (1) number of fields, and (2) number of yields. Where 2 or more yields of a crop have been recorded, the crops, number of fields, and the average yields are given. The reader may establish the location of the listed soils by reference to Soils of Minnesota, Ext. Bul. 278, or to the appropriate county soil report.

It should be noted that the average yields listed do not necessarily reflect the relative productivity of the soils listed. They serve only to indicate the nature of yield levels attained in the last one to five years by farmers who are in general using above average management. Many of the yields also reflect very favorable weather patterns as well as very unfavorable seasons. For those personnel concerned the data may serve to indicate where additional effort is needed.

Table 1. Soil series, number of fields, and number of yields included in soil productivity study to date. Average yields of selected crops given where two or more yields received.

*Number of fields on this series
**Number of yields on all crops

Aastad	(11)*	(32)**
Corn	10	49
Flax	5	14
Oats	4	57
Spring Wheat	2	32
Barley	3	49
Hay (other)	2	4.6
Alfalfa-brome-past.	3	136
Anoka	(1)	(1)
Arlington	(1)	(1)
Barnes	(15)	(65)
Corn	21	54
Flax	6	8
Soybeans	5	24
Spring wheat	4	31
Corn silage	2	6.0
Oats	11	61
Alf-Brome	5	1.6
Alfalfa	5	1.9
Barley	4	48
Beardon	(6)	(11)
Spring wheat	2	36
Sugar beets	3	11.6j
Barley	2	62
Beltrami	(4)	(9)
Corn	2	66
Oats	2	66
Alfalfa	2	2.1
Alf-Brome-Past.	2	76s
Blue Earth	(2)	(10)
Oats	2	25
Soybeans	2	16
Corn	3	48
Alf-Brome	2	3.0
Braham	(1)	(1)
Brainerd	(3)	(7)
Corn	2	52
Oats	2	42
Brickton	(2)	(2)
Buse-Barnes	(2)	(10)
Alf-Brome	3	1.6
Flax	2	9
Soybeans	2	13
Central	(3)	(3)
Chilgren	(5)	(17)
Alfalfa	2	2.3
Hay (other)	3	2.4
Oats	2	35
Barley	3	47
Flax	2	10
Spring wheat	2	25
Clarion	(34)	(208)
Corn	40	76
Oats	21	69
Alfalfa	9	2.6
Mix. Leg-grass	3	5.0
Soybeans	10	29
Spring wheat	6	32
Alf-brome	10	2.9
Alf-brome-past.	2	175
Corn silage	2	12.3
Colvin	(5)	(12)
Alfalfa	3	3.4
Corn	5	61
Comfrey	(1)	(6)
Corn	2	60
Sorghum	2	8.5
Cormant	(4)	(9)
Alf-brome	2	3.8
Oats	4	49
Downs	(3)	(10)
Corn	5	112
Alfalfa	3	3.4
Dubuque	(1)	(1)
Dundas	(4)	(11)
Alf-brome	3	4.5
Alfalfa	2	1.7

Enstrom	(1)	(4)
Alf-brome Pasture	2	222
Estelline	(1)	(2)
Esterville	(13)	(40)
Corn	13	57
Oats	10	42
Corn Silage	5	7.8
Alf-brome	8	2.2
Alfalfa	2	3.1
Fairhaven	(4)	(12)
Corn	6	62
Oats	4	63
Fargo	(19)	(46)
Barley	4	22
Soybeans	3	23
Spring wheat	11	31
Alfalfa	2	3.1
Flax	5	11
Sugar beets	5	12.8
Oats	7	42
Alf-brome	3	1.6
Fayette	(7)	(30)
Oats	5	50
Corn	14	92
Alfalfa	2	2.9
Alf-brome	5	6.4
Flom	(8)	(22)
Oats	6	56
Soybean	2	24
Flax	2	18
Corn	7	73
Corn silage	2	14.5
Floyd	(5)	(14)
Corn	8	85
Oats	2	80
Soybeans	2	28
Fossum	(2)	(2)
Foxhome	(1)	(2)
Freer	(3)	(11)
Oats	4	59
Corn silage	2	6.7
Hay (other)	3	2.3
Freon	(3)	(6)
Oats	4	56
Glencoe	(1)	(1)
Greenbush	(2)	(5)
Corn silage	2	12.5
Hay (other)	2	1.5
Grimstad	(5)	(18)
Barley	4	44
Flax	3	10
Soybeans	3	15
Spring wheat	3	27
Oats	3	75
Grygla	(3)	(6)
Oats	3	35
Hammerly	(1)	(2)
Harpster	(1)	(2)
Oats	2	34
Hayden	(22)	(70)
Alfalfa	13	3.4
Corn	21	74
Oats	15	55
Alf-brome	12	3.8
Alf-brome-past.	5	269
Hegne	(5)	(10)
Spring wheat	3	36
Alfalfa	2	1.2
Barley	3	47
Hibbing	(2)	(2)
Hubbard	(14)	(52)
Alfalfa	5	2.4
Corn	21	63
Soybeans	11	21
Alf-brome	2	2.0
Potatoes	4	392
Oats	6	43
Corn silage	2	15.4
Kasson	(2)	(4)
Oats	2	65
Kato	(1)	(4)
Kenyon	(2)	(7)
Corn	3	88
Hay (other)	2	4.0

Kingston	(3)	(11)
Corn	8	78
Soybeans	2	27
Kittson	(2)	(8)
Corn silage	2	4.9
Kranzberg	(2)	(6)
Alfalfa	2	2.3
Alf-brome	2	1.9
Lamoure	(2)	(10)
Corn	4	56
Sweet corn	3	7.0
Soybeans	2	34
Lerdal	(1)	(5)
Corn	3	82
Lester	(9)	(29)
Oats	6	58
Corn	8	71
Alf-brome	4	3.1
Alfalfa	9	3.8
LeSueur	(9)	(25)
Corn	15	79
Soybeans	4	24
Oats	3	53
Barley	2	49
Litchfield	(1)	(6)
Corn	2	83
Marcus	(1)	(1)
Marna	(5)	(13)
Corn	8	95
Soybeans	2	38
Mavie	(1)	(1)
McDonaldsville	(1)	(1)
McIntosh	(3)	(13)
Corn	2	70
Oats	3	61
Spring wheat	4	35
Barley	2	56
Menahga	(3)	(9)

Milaca	(6)	(20)
Corn	3	54
Corn silage	3	10.8
Oats	2	36
Mixed leg.-grass	4	2.0
Hay (other)	4	2.0
Moody	(2)	(6)
Corn	4	70
Mora	(3)	(10)
Corn	3	55
Oats	2	75
Mixed leg.-grass	2	1.9
Nebish	(7)	(24)
Oats	9	48
Alfalfa	5	1.4
Alf.-brome	4	2.0
Alf.-brome-past.	3	58
Nicollet	(19)	(79)
Corn	34	75
Soybeans	9	28
Oats	12	57
Barley	2	94
Spring wheat	3	32
Corn silage	3	9.1
Alfalfa	9	3.7
Alf-brome	4	4.0
Nokay	(3)	(7)
Corn	4	65
Onamia	(3)	(15)
Corn	4	68
Oats	4	64
Alfalfa	3	2.1
Alf-brome	2	1.8
Ostrander	(4)	(12)
Corn	4	97
Soybeans	2	26
Alfalfa	2	4.8
Parnell	(1)	(6)
Corn	3	44
Oats	2	75
Deep Peat	(6)	(16)
Mix. Leg.-grasspast.	2	242
Timothy (seed)	2	330
Corn	3	77
Corn silage	2	6.5

Shallow Peat	(5)	(7)
Soybeans	3	24
Barley	2	56
Pierce	(1)	(1)
Racine	(1)	(1)
Redby	(3)	(5)
Mix. Leg.-grass	2	1.0
Mix. Leg.-grass-past.	2	68
Rocksbury	(12)	(24)
Oats	8	66
Flax	3	9
Alfalfa	2	2.3
Hay (other)	4	1.6
Hay (Other)past	3	117
Sweet clover-brome	2	1.7
Rockwell	(5)	(10)
Corn silage	2	12.9
Oats	3	52
Barley	2	27
Alfalfa	2	1.7
Sioux	(2)	(5)
Oats	2	21
Alfalfa	2	.8
Shooks	(2)	(4)
Skyberg	(3)	(7)
Corn	2	91
Mix. Leg.-grass-past.	2	154
Sletten	(1)	(2)
Soybeans	2	30
Storden-Clarion	(1)	(5)
Oats	2	80
Alfalfa	3	2.5
Tama	(8)	(27)
Corn	5	99
Corn silage	2	15.3
Oats	8	62
Alfalfa	2	4.3
Alf-brome	2	4.8
Alf-brome-past.	3	178
Mix. Leg.-grass	3	3.0
Taylor	(1)	(2)
Terril	(1)	(2)
Todd	(2)	(4)
Alf-brome	3	2.2
Truman	(3)	(8)
Corn	3	100
Ulen	(3)	(17)
Corn	5	56
Corn silage	2	15.5
Oats	5	45
Alfalfa	2	2.6
Vallers	(3)	(14)
Corn	4	55
Soybeans	5	20
Oats	2	63
Varco	(1)	(5)
Corn	3	88
Alf-brome	2	2.8
Vienna	(2)	(5)
Corn	3	63
Wabash	(1)	(4)
Corn	3	109
Wadena	(4)	(12)
Corn	5	76
Soybeans	2	21
Oats	3	80
Wakegan	(8)	(28)
Corn	13	82
Oats	6	79
Alf-brome	3	3.1
Waukon	(9)	(28)
Corn	6	62
Oats	5	55
Barley	3	43
Spring wheat	2	30
Alfalfa	9	2.1
Mix. Leg.-grass	2	3.2
Webster	(35)	(116)
Corn	58	89
Corn silage	5	10.1
Soybeans	12	19
Oats	16	61
Alfalfa	11	4.1
Alf-brome	8	2.9
Alf-brome-past.	2	75

Webster Calc. Var.	(8)	(28)
Corn	10	89
Soybean	9	34
Oats	2	87
Alfalfa	3	32
Wildwood	(2)	(5)
Oats	2	33
Winger	(4)	(15)
Barley	3	46
Oats	5	74
Spring wheat	2	31
Alfalfa	3	1.6
Zimmerman	(3)	(11)
Corn	2	71
Oats	2	57
Corn silage	3	11.0
Hay (other)	2	10.9

Grand Total as of December 20, 1962	No. Fields (469)	No. Yields (1581)

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

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

The long time effect of urea or of ammonium nitrate nitrogen applied at three different rates and times using two placements on the yield and the composition of field corn where grown every year is the object of an investigation commenced on the Southwest Experiment Station at Lamberton early in 1960.

Four replicates of 18 different treatments are established on corn plots six rows in width and 77.5 feet in length. Ample phosphorus and potassium are applied in the starter fertilizer. A plant population of 18,000 stalks per acre is grown and all crop residues are plowed under after harvest in the late fall. The primary objective is to find an answer to four important questions:

1. The relative effectiveness of equal amounts of nitrogen as urea or as ammonium nitrate when applied to this soil at different rates per acre.

2. The relative efficiency of such nitrogen forms when they are applied in the late fall, in the spring at time of planting, or as a sidedressing in late June or in early July.

3. The relative values of fall plowing down two nitrogen sources in comparison to overwintering of the nitrogen fertilizer on the surface of the fall plowed soil.

4. To find if there was any possible fertilizer nitrogen accumulation in the soil, the relative amounts removed by the corn crop and losses sustained through leaching, losses to the air, or losses by soil erosion.

For the first few years, all data is to be obtained by harvesting and chemically analyzing the corn plants, and computing nitrogen removal and relative efficiency based on amounts actually present in the corn plants. Later in the experiment, possible nitrogen accumulations in the soil will be measured directly.

It was not possible to fall plow and fertilize late in 1959, and the area was spring plowed early in 1960 and the first fertilizer treatments were applied at planting time. Fall plowing and fertilizing was carried out both in 1960 and in 1961. The 1961 nitrogen sidedressing with urea or with ammonium nitrate was applied on June 23rd, and the following visual observations were made on July 27th:

1. 40# of applied N/A or less - the corn leaves of all plants were "firing".

2. 80# of applied N/A - fall nitrogen - leaves fired
   spring nitrogen - some firing
   sidedressed - leaves green

3. 160# of N/A - corn leaves of all treatments were a deep green.

4. Nitrogen source, whether from urea or from ammonium nitrate had no visual effect on severity of leaf "firing".

The yield and composition of the 1960 and the 1961 corn grain and fodder are shown in the following tables.

The Effect of Nitrogen Source, Rates & Time of Application on the Yield and Nitrogen Content of 1960 & of 1961 Field Corn at Lamberton, and the Percentage N Uptake by the Corn
Webster silty clay loam
(Average of four replicates)

Treatment (lbs. N per acre)[1]	Ear Corn bu./A 1960	Ear Corn bu./A 1961	Ear Corn % N 1960	Ear Corn % N 1961	Fodder Tons/A 1960	Fodder Tons/A 1961	Fodder % N 1960	Fodder % N 1961	Percentage uptake of fertilizer nitrogen 1960	Percentage uptake of fertilizer nitrogen 1961	Percentage uptake of fertilizer nitrogen 2-yr. average
None	49.5	88.2	1.17	1.20	1.82	3.03	0.74	0.41	--	--	
40 as NH_4NO_3--fall plowed under	42.3	87.5	1.15	1.19	1.79	3.00	0.84	0.50	8	- 9	0
40 as urea --- " " "	55.1	78.2	1.09	1.22	1.57	3.87	0.61	0.50	-28	90	31
40 as NH_4NO_3--left on plowed surface	49.0	96.7	1.26	1.15	1.87	4.03	0.84	0.48	16	86	51
40 as urea --- " " " "	62.3	101.3	1.20	1.37	1.87	3.89	0.76	0.57	13	74	44
80 as NH_4NO_3--fall plowed under	67.4	97.9	1.22	1.24	1.85	3.30	0.78	0.67	5	43	24
80 as urea --- " " "	61.7	76.9	1.25	1.20	1.87	3.46	0.88	0.50	7	27	17
160 as NH_4NO_3- " " "	69.8	97.9	1.31	1.34	2.23	4.50	0.91	0.70	17	58	38
160 as urea -- " " "	79.4	112.5	1.22	1.46	2.18	4.37	0.85	0.86	12	71	42
40 as NH_4NO_3-- at planting	66.2	92.0	1.28	1.21	1.85	3.55	0.87	0.54	21	67	44
40 as urea --- " "	45.4	91.1	1.22	1.19	2.12	3.60	0.85	0.61	47	27	37
80 as NH_4NO_3-- " "	59.3	90.0	1.20	1.17	2.07	3.63	0.79	0.60	12	43	28
80 as urea --- " "	57.7	99.1	1.26	1.32	2.26	4.03	0.82	0.60	21	40	31
40 as NH_4NO_3-- as late sidedressing	63.6	92.6	1.23	1.19	2.01	3.66	0.89	0.57	27	80	54
40 as urea --- " " "	57.7	95.6	1.12	1.33	1.90	3.51	0.77	0.54	9	107	58
80 as NH_4NO_3-- " " "	50.4	98.4	1.22	1.24	1.76	2.96	0.89	0.63	15	34	25
80 as urea --- " " "	76.9	86.4	1.14	1.37	1.51	3.92	0.81	0.70	-11	95	42
160 as NH_4NO_3- " " "	40.7	97.4	1.23	1.50	1.65	3.58	0.88	0.97	0	54	27

[1] The entire area received 0-30-15 at the rate 125#/A as band applied starter + 150#/A broadcast before plowing.

The growing season of 1962 at the South West Experiment Station was much wetter than normal. Frequent heavy rains kept the soil essentially saturated until mid-July. The corn was planted early but developed very slowly during the cool, wet summer. A killing frost terminated growth in mid-September.

Nitrogen deficiency of the corn leaves was evident in many of the treatments during much of the growing season, the only treatments appearing to have adequate available nitrogen being the three rates of side dressed nitrogen. The fall and spring applied nitrogen apparently was not available to the growing corn in adequate quantities. The 1962 results are shown as follows:

The Effect of Nitrogen Source, Rates & Time of Application on the Yield and Nitrogen Content of 1962 Field Corn at Lamberton, and the Percentage N Uptake by the Corn
Webster silty clay loam
(Average of four replicates)

Treatments (lbs. N per acre)[1]	Ear Corn		Fodder		lbs.N	% uptake	
	bu/A	% N	Tons/A	% N	removed /A.	fert. 1961&62	Nit. 62
None	26.1	1.32	1.13	0.80	44.1	-	-
40 as NH_4NO_3--fall plowed under	30.9	1.45	1.82	0.75	58.1	0	35
40 as urea --- " " "	29.1	1.38	1.39	0.70	48.7	31	11
40 as NH_4NO_3--Left on plowed surface	29.6	1.51	1.24	0.80	49.6	51	14
40 as urea --- " " " "	37.0**	1.48	1.76	0.76	63.6	44	49
80 as NH_4NO_3--fall plowed under	43.6**	1.31	1.67	0.84	71.6	24	34
80 as urea --- " " "	36.7**	1.31	1.53	0.60	55.1	17	14
160 as NH_4NO_3-- " " "	46.7**	1.33	1.91	0.85	79.3	38	22
160 as urea --- " " "	43.5**	1.24	1.66	0.78	69.4	42	16
40 as NH_4NO_3--- at planting	45.4**	1.36	1.52	0.77	68.7	44	62
40 as urea --- " "	31.4	1.55	1.39	0.76	52.5	37	21
80 as NH_4NO_3-- " "	32.7*	1.47	1.53	0.60	51.0	28	9
80 as urea --- " "	40.5**	1.39	1.35	0.59	56.4	50	15
40 as NH_4NO_3--as late sidedressing	39.5**	1.41	2.04	0.65	66.2	54	55
40 as urea --- " " "	24.9	1.25	1.56	0.70	46.9	58	7
80 as NH_4NO_3--- " " "	46.7**	1.46	1.79	0.81	75.6	25	39
80 as urea --- " " "	48.2**	1.38	2.10	0.62	74.1	42	38
160 as NH_4NO_3- " " "	77.7**	1.42	2.69	1.11	137.6	27	58

* L.S.D. (5%) 6.3 bu.
** L.S.D. (1%) 8.0 bu.

Comments

The yields of corn grain grown on the different nitrogen treatments were variable in all three years of the experiment, and it is hoped that these will tend to be more uniform as the experiment is continued. Such variability prevents any meaningful conclusions at present on the relative effectiveness of the two nitrogen sources or as to the most efficient time of applying such forms of nitrogen. In the wet summer of 1962, early and late spring application of nitrogen produced the higher yields.

The relative proportions of additional nitrogen taken up by the corn growing on the nitrogen fertilized plots is of interest. So far, fall plowing and the turning under of broadcast fertilizer nitrogen on the cornstalks was not advantageous from considerations of corn yield or efficiency of nitrogen uptake by the corn. The efficiency of nitrogen uptake varies greatly and at least five years of results should be obtained before even preliminary conclusions can be made.

The Effect of Nitrogen Fertilization On Yield and Composition of Wheat at Crookston in 1960, 1961, and 1962

J. M. MacGregor, H. W. Kramer, & O. C. Soine

Ammonium nitrate has been the most popular form of solid nitrogen fertilizer in Minnesota for some fifteen years. Urea manufacture and sale has been gradually increasing during the last several years, since it contains 45% N in comparison to the 33% N of the ammonium nitrate, urea manufacturing costs have been reduced, and urea storage (both as to space and possible explosiveness) is simpler than with ammonium nitrate. On being moistened, urea hydrolyzes to ammonium carbonate with the nitrogen being utilized either as the ammonium ion, or after gradual oxidation to the nitrate form. As the urea hydrolyzes, there is a sharp, but localized increase in soil pH - a condition favoring ammonia losses to the atmosphere. Many laboratory and a few field experiments have shown some losses of urea nitrogen as ammonia, but the magnitude of such losses under field conditions and the comparative effectiveness of urea nitrogen to other fertilizer nitrogen sources have not been well established.

The present experiment was designed to study the effect of urea and of ammonium nitrogen on the yield and nitrogen composition of wheat, in order to establish the relative proportions of nitrogen from the two sources actually taken up by wheat. Since laboratory experiments have demonstrated that calcareous soils are subject to greater volatilization of ammonia nitrogen from urea than are acid soils, and immediate covering of the applied urea may reduce such losses, the calcareous Hegne clay loam at Crookston was selected for this trial.

Urea or ammonium nitrate nitrogen was applied in quadruplicate treatments at the rate of 20 or 40 pounds of nitrogen per acre with three basic differences:

1. The nitrogen fertilizers were disked in at time of seeding.

2. The nitrogen fertilizers were broadcast and left on the soil surface immediately following seeding.

3. The nitrogen fertilizers were broadcast when the wheat was in the boot stage and left on the soil surface.

Both wheat grain and straw samples were analyzed for yield and N content, and the additional nitrogen present in the nitrogen-fertilized plants was considered to be due to the addition of nitrogen fertilizer and this was computed as percentage recovery of the applied fertilizer nitrogen. The results are shown in the following tables.

The 1962 growing season at Crookston was excessively wet and relatively cool-for example, the field corn was planted so late and grow so slowly that it was not sufficiently mature to harvest as grain. Three of the wheat plots were drowned out and results were quite variable.

Anhydrous ammonia treatments to supply 40 and 80 pounds of N per acre were applied just before seeding, the first time this nitrogen source was included. The 1962 wheat yields are shown in the following table.

The effect of nitrogen source, time and depth of covering on nitrogen content of 1962 wheat on Hegne clay loam at Crookston and percentage uptake of the applied fertilizer nitrogen.
(Average of four replicates)

NITROGEN TREATMENT (lbs/A)[1]	Grain bu/A	Grain % N	Pounds of N in grain/A
None	7.7	1.94	
20 as NH_4NO_3- disked in at seeding	7.7	1.96	9.1
20 as urea — " " " "	12.6	2.02	15.3
40 as NH_4NO_3- " " " "	18.4*	2.17	22.7
40 as urea— " " " "	17.3*	2.05	20.7
20 as NH_4NO_3- left on surface at seeding	15.0	2.08	17.9
20 as urea — " " " " "	15.1	2.07	18.7
40 as NH_4NO_3- " " " " "	15.0	2.03	18.4
40 as urea — " " " " "	11.9	2.07	14.8
20 as NH_4NO_3- broadcast at boot stage	11.2	2.06	13.6
20 as urea — " " " "	13.8	2.06	16.2
40 as NH_4NO_3- " " " "	17.4*	2.08	21.7
40 as urea — " " " "	18.8*	2.07	23.2
40 as anhydrous NH_3 at seeding	37.4**	2.31	51.8
80 " " " " "	28.1**	2.54	42.7

* LSD (5%) 8.3 bu.
** LSD (1%) 11.1 bu.

The results of three years (1960-62) of wheat fertilization on yields at Crookston are shown in the following table.

Table 2. The effect of nitrogen source, time and depth of covering of nitrogen fertilizer on the yield and nitrogen content of 1960, 1961 and 1962 wheat on Hegne clay loam at Crookston. (Average of four replicates)

Nitrogen Treatment (lbs/A)[1]	Wheat yield in bushels per acre				Percentage nitrogen			
	1960	1961	1962	3 year average	1960	1961	1962	3 year average
None	8.2	12.4	7.7	9.4	2.08	2.30	1.94	2.11
20 as NH_4NO_3- disked in at seeding	11.7	15.5	7.7	11.6	2.00	2.40	1.96	2.12
20 as urea -- " " " "	15.9*	20.7*	12.6	16.4	2.00	2.53	2.02	2.18
40 as NH_4NO_3- " " " "	22.7*	17.9*	18.4*	19.7	2.11	2.52	2.17	2.27
40 as urea -- " " " "	19.6*	20.5**	17.3*	19.1	1.47	2.55	2.05	2.02
20 as NH_4NO_3- left on surface at seeding	16.7*	15.4	15.0	15.7	2.05	2.35	2.08	2.16
20 as urea -- " " " " "	16.1*	17.2	15.1	16.1	2.05	2.60	2.07	2.24
40 as NH_4NO_3- " " " " " "	21.3*	19.9**	15.0	18.7	2.10	2.63	2.03	2.25
40 as urea -- " " " " "	19.7*	21.3**	11.9	17.6	2.02	2.65	2.07	2.25
20 as NH_4NO_3- broadcast at boot stage	12.6	15.9	11.2	13.2	2.10	2.59	2.06	2.25
20 as urea-- " " " "	6.7	14.6	13.8	11.7	2.16	2.60	2.06	2.27
40 as NH_4NO_3- " " " "	7.9	16.8*	17.4*	14.0	2.40	2.80	2.08	2.43
40 as urea -- " " " "	11.9	12.7	18.8	14.5	2.19	2.74	2.07	2.33
* Significant at the 5% level	5.9	5.2	8.3					
** " " " 1% "	8.1	6.9	11.1					

Tentative Conclusions (on three years of results)

1. Urea or ammonium nitrate nitrogen broadcast at the time of wheat seeding, and either disked in or left on the surface, was much more effective for increasing wheat yield and nitrogen recovery, than were similar applications made some weeks later when the wheat plants were in the boot stage.

2. Urea was equal in effectiveness to ammonium nitrate nitrogen, both for increasing wheat yields and for increasing the nitrogen content of the wheat.

3. Anhydrous ammonia was used only in 1962, but it was a very effective source of nitrogen for both increasing wheat yield and nitrogen content of the grain.

Comparison of phosphorus sources

A. C. Caldwell

A phosphorus source experiment was established at Rosemount in 1951. Twelve treatments of various phosphate materials were replicated 4 times across a regular rotation of corn, wehat and 2 years of alfalfa. Potassium was applied according to soil test, Lime was applied to 2 replicates in the fall of 1961. In 1959 the rotation was changed to corn, soybeans, wheat and alfalfa.

In general, yields of corn and soybeans were not influenced by the various phosphorus sources. Wheat did respond, particularly to the more available materials. As in past years large increases in yield of alfalfa resulted from almost all sources whether the phosphorus was readily available or not.

Effect of various phosphate fertilizers on yield of corn, soybeans, wheat and alfalfa (Rosemount, 1962).

Treatments	P_2O_5/A/Yr lbs	Corn bu/A	Soybeans bu/A	Wheat bu/A	Alfalfa bu/A
None	--	144.8	22.2	20.9	1.55
Ord. Super.	40	143.6	19.8	26.4	2.50
Conc. Super.	40	141.2	21.4	22.6	2.76
CalMeta	40	139.2	20.7	27.6	3.08
Phos. Acid	40	149.6	16.7	30.6	2.43
Fused Trical. Phos.	40	160.6	21.4	28.3	2.71
Fl. Rock + Ord. Super	20 + 20	147.9	24.2	27.7	3.21
Fl. Rock	100	146.8	19.5	22.1	2.97
	P_2O_5/A/4 yrs.				
Fl. Rock	1000	144.3	24.4	24.6	2.69
Western Rock	1000	153.2	22.5	21.7	2.88
Cal. Clay Rock	1000	147.1	24.5	22.6	2.03
Tunis. Rock	1000	141.1	21.5	25.6	3.07

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

A. C. Caldwell

To study the long time effects of lime on the yields of some common crops and on the physical and chemical properties of the soil, an experiment with lime rates was started in the fall of 1951. Treatments were 0, 3, 6, 12 and 24 tons of dolomitic lime per acre, replicated 4 times. A rotation of oats, 2 years of alfalfa and corn was set up. Each year corn and oats have received 200 pounds of 5-20-20 per acre. Alfalfa has received P and K as needed according to soil test.

In 1959 soybeans were substituted as a crop for one of the years of alfalfa. Soybeans get 100 pounds of 5-20-20 per acre as a starter fertilizer.

In 1960 an application of 8.7 ounces of Mo per acre, (as $(NH_4)_2MoO_4$), was made to one of the check plots in each replicate to determine the effect of this nutrient.

Effects of the different treatments on yields are shown in the table. Alfalfa yields have been mostly affected by lime, as has been the case in the past. 3 tons of lime have been as effective as higher rates. Molybdenum has also been rather surprisingly effective in increasing yields above the untreated.

The results on oats are quite at variance with what was found in other years when increases (sometimes substantial) resulted from lime applications. In 1962 yields were lower than usual with a lot of variation from plot to plot. Consequently no significance can be attached to the increases or decreases shown.

All treatments resulted in increases in corn yields. This is in general agreement with results in other years.

There were no major effects of lime on soybeans.

Effect of lime and molybdenum on yields of alfalfa, oats, corn and soybeans (Rosemount 1962).

Lime treatment tons/acre	Alfalfa bu/a	Alfalfa diff.	Oats bu/a	Oats diff.	Corn bu/a	Corn diff.	Soybeans bu/a	Soybeans diff.
0	2.01		48.5		139.4		24.9	
3	3.16	1.15	50.0	1.5	152.1	12.7	26.6	1.7
6	2.99	0.98	41.2	-7.3	149.4	10.0	24.7	-0.2
12 2	2.62	0.61	54.8	6.3	152.9	13.5	24.9	--
24	3.01	1.00	46.9	-1.6	152.2	12.8	23.4	-1.5
0 + 8.7 oz. Mo/a	2.99	0.98	50.0	1.5	151.9	12.5	25.4	0.5

Effect of sulfur-bearing materials on alfalfa (Park Rapids, 1962)

In the spring a sulfur experimental field was established on a Todd sandy loam near Park Rapids. To plots planted to alfalfa was applied elemental sulfur at rates of 25, 50 and 100 pounds and gypsum at 50 and 100 pounds S per acre. The table shows the yield of hay obtained and the % S in young alfalfa plants from the various treatments.

Both sources of sulfur and all rates resulted in yield increases. These were not large in terms of pounds, but do nevertheless represent a 20+% increase in forage obtained. This was the year of establishment of the alfalfa so full growth had not been obtained. Yields do include some grass and weeds.

Sulfur analysis was on pure alfalfa sorted out from other plants. All treatments resulted in an increase in sulfur in the plant. Increase in plant sulfur went up with larger application rates of elemental sulfur. The young plants took up more sulfur from gypsum than from elemental sulfur.

Effect of sulfur-bearing materials on alfalfa yields (Park Rapids, 1962)

Treatment	S lbs/A	Alfalfa Yield lbs/A	Diff.	S in Tissue % S	Diff.
None	-	1795		.117	
Sulfur	25	2118	323	.139	.022
Sulfur	50	2277	482	.160	.043
Sulfur	100	2299	504	.189	.072
Gypsum	50	2293	498	.228	.111
Gypsum	1000	2022	227	.263	.146

FIELD EXPERIMENTS WITH ZINC ON CORN

Orville Gunderson and John Mac Gregor*

Minnesota soils, considered about average in zinc content in comparison with other soils of the United States, may not supply enough zinc for some crops. As the natural lime content of the soil increases, crop plants generally find it increasingly difficult to take up sufficient zinc for normal growth. This problem is naturally more serious in the relatively short-lived, high production plants such as corn.

Zinc deficiencies of corn have been observed for some years on the high lime soils of many western states, especially under irrigation. Irrigation indirectly tends to induce such microelement deficiencies since high crop yield removes more nutrient elements.

Zinc deficiency is especially noticeable under irrigation agriculture because of the associated land forming that exposes subsoil layers-and perhaps because of the use of high analysis fertilizers in greater quantity, although nitrogen fertilizer placed near the seed has frequently resulted in normal plant growth.

This indirect effect of fertilizer nitrogen has two possible explanations. When nitrogen is placed with zinc or alongside seed in the soil, the supply of native available zinc is increased due to the acidic residue of the nitrogen fertilizer. Ammonium sulfate is especially effective in this way. The increased effectiveness of band applied zinc sulfate ($ZnSO_4$) when mixed with a small amount of nitrogen could be due to the above mechanism, or to some other mechanism that diminishes toxicity produced by high zinc concentrations of the bands.

Zinc deficiency of corn was first reported from central Minnesota during the 1961 growing season, and limited field studies were made at that time. The deficiency on corn is characterized by initial stunting, followed by the later development of a longitudinal striping of the leaves. The veins remain green and interveinal tissue yellows and, in serious cases, dies. The younger leaves may be almost white. Corn grown on high lime peat or on mineral soil may be affected, especially on low lying, recently drained areas.

Field experiments in 1962 consisted of trials on (1) a recently pumped calcareious clay loam on the Litch farm north and west of Lake Lillian (Kandiyoki County),(2) a slightly higher lying clay loam on the Larson farm 2 to 3 miles fabther north, and (3) a pumped area of peat soil a mile south of Lake Koronis, on the Behr farm in western Meeker County.

Each field was spring plowed shortly after the plowdown zinc sulfate treatments were broadcast. A two-row tractor attached corn planted with fertilizer band placement equipment especially built by the Morris ARS Station, was used to plant corn and to apply the banded zinc and nitrogen about an inch to the side and below the seed.

A third type of treatment consisted of coating corn seed with a zinc chelate (Na_2Zn chelate) at the rate of 8 ounces per bushel.

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