Soil Series 82

A Report on Field Research in Soils

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

Department of Soil Science

University of Minnesota

March 1968

Some of the results herein reported are from experiments carried on during 1967 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 Because these are largely one year results they should not be considered as conclusive and the results are not for publication.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 PAGE

Climatological Notes

1. Some Climatological Notes, Fall 1967 1

Microclimate Studies at Park Rapids-Swan

2. Microclimate Studies at the Park Rapids Sulfur Experimental Field 20

Available Soil Moisture Survey - 1967

3. Available Soil Moisture Survey - 1967 - Northwest Experiment Station Crookston, Minnesota 27

Soil Physics

4. Method of Corn Planting Study - University of Wisconsin Experiment Farm 30
5. Land Forming - Northwest Experiment Station - 1967 32

Herbicide Residues

6. Soil Residue Studies 34

Lime Experiments

7. Lime Plots, Lamberton, 1967 38

Rosemount Experiments

8. Rosemount Soils Farm, General Conditions and Results 42
9. Corn in Crop Rotation System 44
10. Continuous Corn Cropping System 45
11. Corn and Soybean Fertilization With Broadcast 49
12. Broadcast Plow-Down Fertilizer Placement With Band and Band Plus Sidedressed Nitrogen on Continuous Corn and Corn in a Crop Rotation System 53
13. Lime and Manure on Continuous Corn - 1967 56
14. Fertilized Alfalfa Yields 57
15. Continuous Corn - High Fertility Experiment 59

Morris Experiments

16. Weather Summary - 1967 62
17. Comparison of Phosphorus Sources 63
18. Use of Varying Rates of Nitrogen and Starter on Corn in 1967 65
19. Phosphorus and Potassium Fertilization of Alfalfa 66
20. Phosphorus Fertilization of Continuous Corn 68
21. Zinc Fertilization or Continuous Corn 69
22. Continuous Corn Silage 70
23. Corn Irrigation Experiment 71

Page

TVA Demonstration Activities

24. TVA Test Demonstration Activities 72

Irrigation and Fertility Levels for Corn & Alfalfa

25. Effect of Irrigation, Fertility Level and Plant Population on Corn and Alfalfa at Park Rapids, Minn. 79

Nitrogen Experiments

26. The Effect of Nitrogen Source, Placement, and Time of Application to a Webster Clay Loam at Lamberton on 1960-67 Ear Corn Yields and on 1967 Corn Composition 83
27. Nitrate Nitrogen Content of a Barnes Loam Soil at Morris in November, 1967, after Eleven Years of Continuous Corn with Varying Rates of Nitrogen Fertilization 90
28. The Effect of Fertilization on Soil Reaction 93

Phosphorus

29. 1967 Phosphorus Placement Study 94
30. Polyphosphate Investigations 98

Secondary and Micronutrient Elements

31. The Effect of Boron, Phosphorus & Potassium on Soluble Soil Boron & Yield of Grass-Legume Hay on a Vilas Loamy Sand in Carlton County 1965-66-67 100
32. Experiments with Zinc for Corn in Southeastern Kandiyohi County 103
33. The 1966-67 Results of a Zinc Source and a Zinc-Phosphate Interaction Effect on Leaf Composition and Corn Yield on a Calcareous Loam in Swift County 106
34. Micronutrient Uptake by Soybeans 111
35. Sulfur Investigations on Soils and Crops 113

Soybean Inoculation Studies

36. Soybean Inoculation Studies 123

Sugarbeet Rotation Study at Crookston

37. Sugarbeet Rotation Study - 1967 125

Potato Fertilization

38. Potato Fertilization on Sandy Loams 126
39. Magnesium Experiments 128
40. Phosphorus Studies 129
41. Nitrogen Studies 129

Page

Oil Crop Fertilization

42. Fertilizer Trials on Oil Crops 130
43. 1967 Sunflower Fertility Experiment 133

Sugar Corn & Sorghum Studies at Waseca

44. Agronomic Studies with Sugar Corn and Sorghum 135

Alfalfa Fertilization

45, Fertilizing Alfalfa in Morrison County Minnesota 138

Fertilization for Grass Seed

46. Grass Seed Production and Fertilizer Needs 142

Soil Testing

47. Soil Testing in Minnesota during 1967 146

Some Climatological Notes, Fall 1967

by Donald G. Baker (Jan. 1968)

A. Summary of the 1967 Soil Moisture Survey

The Fall, 1967, soil moisture results are shown in table 1. It is apparent that soil moisture reserves are low at nearly every site. The moisture reserves in Fall, 1966, were generally below average and the Fall, 1967, results are almost without exception lower than last year. As might be expected the soil moisture reserves are nearly all below average, table 2.

Figure 1 illustrates the fact that in 1967 all areas within the state have received less than normal precipitation. Maximum negative departures in precipitation occurred in the southwest and in the extreme northeast. Table 3 indicates that negative departures from normal of appreciable consequence also occurred in 1966 at the central and southern stations. The 1965 positive departures of 0.36 and 0.80 inches at Sioux Falls and Rochester, respectively, are really negligible, and thus both stations have suffered rather severe precipitation shortages ever since 1963. The total departure, 1961-1967, at these two stations now equals the rather alarming figure of -13.88 and -18.57 inches, respectively. Fortunately so far the soil reserves do not seem to reflect this large accumulated departure.

Table 1. Fall, 1967, Soil Moisture Results (From sampling to a depth of five feet)

County	Nearby Town	Operator	Soil Type	Crop & Yield	(In.) Total Available Water	% of Possible Water	(In.) Difference Fall '67-Fall '66	(In.) Water Used In Season	
Big Stone	Ortonville	H. Dimberg	Barnes c.l.	Corn	0.4	3.5	-1.7	19.0 (5/12 - 11/10)	OG
Big Stone	Beardsley	Wright	Barnes si.l.	Alfalfa	0.4	3.8	+0.4	13.7 (5/12 - 11/10)	OG
Chippewa	Milan	H. Olson	Rothsay si.l.	Corn	4.7	32.6	-0.6	17.2 (5/9 - 11/10)	OG
Chippewa	Montevideo	Sederstrom	Barnes	Alfalfa	0.4	3.1	-0.6	15.2 (5/9 - 11/9)	OG
Dodge	Dodge Center	Sutherland	Kasson si.l.	Corn	3.2	30.1	+0.4	16.8 (4/28 - 11/22)	SCS
Jackson	Lakefield	Pietz	Primghar si.c.l.	Corn 85 bu/A	3.7	37.7	-	19.4 (5/4 - 11/15)	OH
Kandiyohi	Pennock	Giese	Clarion si.l.	Alfalfa	0.2	1.5	-1.6	21.1 (5/10 - 11/9)	OG
Kandiyohi	Kandiyohi	Arvidson	Nicollet	Soybeans	4.1	28.7	+0.2	20.1 (5/10 - 11/9)	OG
Lac Qui Parle	Bellingham	Glasser	Aastad si. c.l.	Corn	6.9	42.6	-0.7	17.7 (5/12 - 11/10)	OG
Lac Qui Parle	Lac Qui Parle	Heimdahl	Rothsay si.l.	Soybeans	1.0	8.0	+0.2	16.5 (5/12 - 11/10)	OG
Lac Qui Parle	Marietta	Aebli	Rothsay si.l.	Corn	4.3	33.3	-1.6	19.5 (5/12 - 11/10)	OG
Lac Qui Parle	Dawson	Nelson	Aastad si. c.l.	Soybeans	6.2	57.4	+2.8	17.6 (5/12 - 11/10)	OG

Table 1. Fall, 1967, Soil Moisture Results (From sampling to a depth of five feet)

County	Nearby Town	Operator	Soil Type	Crop & Yield	(In.) Total Available Water	% of Possible water	(In.) Difference Fall '67-Fall '66	(In.) Water Used In Season
Lincoln	Arco	Madsen	Barnes c.l.	Corn 80 bu/A	1.1	8.6	-1.1	23.0 (4/29-11/15) GH
Lincoln	Porter	Boulton	Barnes si.c.	Soybeans 23 bu/A	3.7	28.5	-1.3	15.6 (4/29-11/15) GH
Lyon	Marshall	Boerboom	Vallers	Corn 110 bu/A	4.8	39.0	-	14.7 (4/28-11/15) GH
Murray	Slayton	Larson	Barnes si. c. l.	Corn	1.1	8.6	-	No spring sample
Mille Lacs	Milaca	Nichols	Mora si.l.	2nd. yr. Hay	3.5	36.4	+0.6	24.3 GH (4/25-10/30) SCS
Nobles	Fulda	Horn	Primghar	Soybeans 28 bu/A	3.1	31.6	-	15.2 (5/4-11/15) GH
Polk	Crookston	U of M	Hegne si.c.l.	Pasture (1)	1.7	10.0	-7.5	15.9 (5/18-10/30)UM
Polk	Crookston	U of M	Hegne si.c.l.	Sugarbeets (4)	0.6	3.5	-	15.4 (5/26-10/30)UM
Polk	Crookston	U of M	Hegne si.c.l.	Sw. Clover Fallow (5)	7.7	45.3	-	No spring sample (-10/30) UM
Polk	Crookston	U of M	Hegne si.c.l.	Small Grain (7)	2.1	12.3	-1.6	12.0 (6/13-10/30) UM
Pipestone	Pipestone	Bucher	Dranzburg si. l.	Corn 87 bu/A	1.3	9.3	-	20.1 (5/4-11/15) GH
Ramsey	St. Paul	U of M	Waukegan si. l.	Sod	0.0	0.0	-7.7	21.3 (5/9-11/16) UM
Redwood	Belview	Anderson	Nicollet c. l.	Soybeans 24 bu/A	4.9	42.6	+2.5	19.5 (4/29-11/15)GH
Redwood	Lamberton	U of M	Webster c.l.	Corn	3.1	31.6	-1.2	14.8 (4/26-10/20)UM

County	Nearby Town	Operator	Soil Type	Crop & Yield	(In.) Total Available Water	% of Possible Water	(In.) Difference Fall '67 - Fall '66	(In.) Water Used In Season
Redwood	Wabasso	Kuehn	Nicollet	Alfalfa	0.7	5.6	-	20.2 (4/29-11/15)GH
Redwood	Morgan	Prokosch	Nicollet c.l.	Oats/Alfalfa	5.6	56.9	-3.8	20.0 (5/4-11/15)GH
Rock	Hardwick	Hengeveld	Kranzburg si.l.	Corn	7.0	50.0	-	No spring sample 24.2 GH
Sibley	Winthrop	Woods	Nicollet c.l.	Corn	6.1	51.7	-0.5	(4/28-11/8)SCS
Stevens	Morris	U of M	Aastad	Corn	1.3	10.3	-	No spring sample 19.4 OG
Swift	Danuers	Stubbs	Barnes c.l.	Corn	1.1	7.6	-6.6	(5/10-11/10)OG 19.0
Swift	Murdock	Tucker	Vallers si.c.	Soybeans	9.4	64.8	-1.1	(5/10-11/9))G 20.8
Swift	Appleton	Reippel	Aastad	Soybeans	3.2	20.5	--	(5/10-11/9))G 23.8
Wabasha	Kellogg	Zickrick	Fayette si.l.	Corn	7.9	50.6	-0.7	(4/19-10/20)SCS 18.5
Watonwan	Butterfield	Hanson	Nicollet c.l.	Corn	4.8	34.6	-2.8	(4/20-11/3)SCS 21.0
Watonwan	Lewisville	Peterson (3)	Kingston si. l.	Beans	4.7	34.8	-3.8	(4/20-11/2)SCS 19.1
Watonwan	Lewisville	Urvig (6)	Medelia	Corn	6.1	45.2	-4.0	(4/20-11/2)SCS 20.1
	Granite Falls	Velde	Aastad si. c.l.	Soybeans 35 bu/A	4.1	27.1	-4.1	(4/28-11/15)GH

Table 2. Average Fall Soil Moisture Reserves - Inches of Available Water in a Five Foot Column of Soil.

County	Nearby Town	Operator	Soil Series	Average Water Content (in.)	Water Content Fall '67	Years of Data
Big Stone	Ortonville	Dimberg	Barnes	1.3	0.4	2 (1966-67)
Big Stone	Beardsley	Wright	Barnes	0.2	0.4	2 (1966-67)
Chippewa	Milan	Olson	Rothsay	6.4	4.7	5 (1962-67) '65 msg.
Chippewa	Montevideo	Sederstrom	Barnes	3.0	0.4	3 (1965-67)
Dodge	Dodge Center	Sutherland	Kasson	4.4	3.2	8 (1960-67)
Jackson	Lakefield	Pietz	Pringhar	3.7	3.7	1 (1967)
Kandiyohi	Pennock	Giese	Clarion	0.9	0.2	4 (1963-67) '65 msg.
Kandiyohi	Kandiyohi	Arvidson	Nicollet	5.7	4.1	4 (1963-67) '65 msg.
Lac Qui Parle	Bellingham	Glasser	AAstad	9.0	6.9	5 (1962-67) '65 msg.
Lac Qui Parle	Lac Qui Parle	Heimdahl	Rothsay	2.3	1.0	3 (1965-67)
Lac Qui Parle	Marietta	Aebli	Rothsay	5.6	4.3	5 (1962-67) '65 msg.
Lac Qui Parle	Dawson	Nelson	Aastad	6.0	6.2	4 (1963-67) '65 msg.
Lincoln	Arco	Madsen	Barnes	2.7	1.1	5 (1963-67)
Lincoln	Porter	Boulton	Barnes	4.3	3.7	5 (1963-67)
Lyon	Marshall	Boerboom	Vallers	5.7	4.8	4 (1963-67) '66 msg.
Murray	Slayton	Larson	Barnes	1.1	1.1	1 (1967)
Mille Lacs	Milaca	Nichols	Mora	6.0	3.5	7 (1961-67)

County	Nearby Town	Operator	Soil Series	Average Water Content (in.)	Water Content Fall '67	Years of Data	
Nobles	Fulda	Horn	Primghar	3.1	3.1	1	(1967)
Polk	Crookston	U of M	Hegne (1)	5.0	1.7	7	(1961-67)
Polk	Crookston	U of M	Hegne (4)	2.1	0.6	2	(1964, 1967)
Polk	Crookston	U of M	Hegne (5)	7.9	7.7	3	(1964-67) '66 msg.
Polk	Crookston	U of M	Hegne (6)	5.8	-	3	(1964-66)
Polk	Crookston	U of M	Hegne (7)	2.9	2.1	2	(1966-67)
Pipestone	Pipestone	Bucher	Kranzburg	1.3	1.3	1	(1967)
Ramsey	St. Paul	U of M	Waukegan (Sod)	5.1	0.0	3	(1965-67)
Ramsey	St. Paul	U of M	Waukegan (Bare)	7.0	-	2	(1965-66)
Ramsey	St. Paul	U of M	Waukegan (Soybeans)	5.1	-	5	(1962-66) '64, '67 msg.
Redwood	Belview	Anderson	Nicollet	5.5	4.9	6	(1962-67)
Redwood	Lamberton	U of M	Webster	5.2	3.1	7	(1961-67)
Redwood	Morgan	Prokosch	Nicollet	7.6	5.6	3	(1965-67)
Redwood	Wabasso	Kuehn	Nicollet	4.8	0.7	4	(1963-67)
Rock	Hardwick	Hengeveld	Kranzburg	7.0	7.0	1	(1967)
Sibley	Winthrop	Woods	Nicollet	8.5	6.1	7	(1961-67)

County	Nearby Town	Operator	Soil Series	Average Water Content (in.)	Water Content Fall '67	Years of Data	
Stevens	Morris	U of M	Aastad	1.3	1.3	1	(1967)
Swift	Danvers	Stubbs	Barnes	4.6	1.1	4	(1963-67)
Swift	Murdock	Tucker	Vallers	8.8	9.4	4	(1963-67)
Swift	Appleton	Reippel	Aastad	3.2	3.2	1	(1967)
Wabasha	Kellogg	Zickrick	Fayette	8.9	7.9	7	(1961-67)
Watonwan	Butterfield	Hanson	Nicollet	7.4	4.8	7	(1961-67)
Watonwan	Lewisville	Peterson (3)	Kingston	6.6	4.7	2	(1966-67)
Watonwan	Lewisville	Urvig (6)	Medelia	8.1	6.1	2	(1966-67)
Yellow Medicine	Granite Falls	Velde	Aastad	9.4	4.1	5	(1963-67)

Table 3. Total departure in inches of precipitation from normal for the period indicated at several U.S. Weather Bureau stations. (Data from Minnesota Weekly Weather, Crop and Livestock Report).

Station	1961 4/1-11/11	1962 4/1-11/3	1963 4/1-11/8	1964 4/1-11/9	1965 4/1-11/7	1966 4/4-11/6	1967 4/3-11/5	1961-67 Total
Fargo	+0.99	+7.58	-2.12	-0.41	+3.81	+0.44	-5.29	+5.00
Int'l Falls	+2.36	+5.01	+0.99	+2.22	+2.96	-0.78	-2.93	+9.83
Duluth	-5.20	+2.27	-5.85	+4.96	+1.25	+1.57	-6.80	-7.80
St. Cloud	-1.35	+5.80	+2.00	-2.99	+9.47	-3.58	-4.66	+4.69
Sioux Falls	-1.11	+3.62	-3.54	-1.48	+0.36	-2.68	-9.05	-13.88
Rochester	-1.62	+1.01	-4.62	-6.26	+0.80	-4.82	-3.06	-18.57
Mpls-St.Paul	+0.26	+3.48	-3.62	+2.52	+9.49	-1.99	-2.33	+7.81

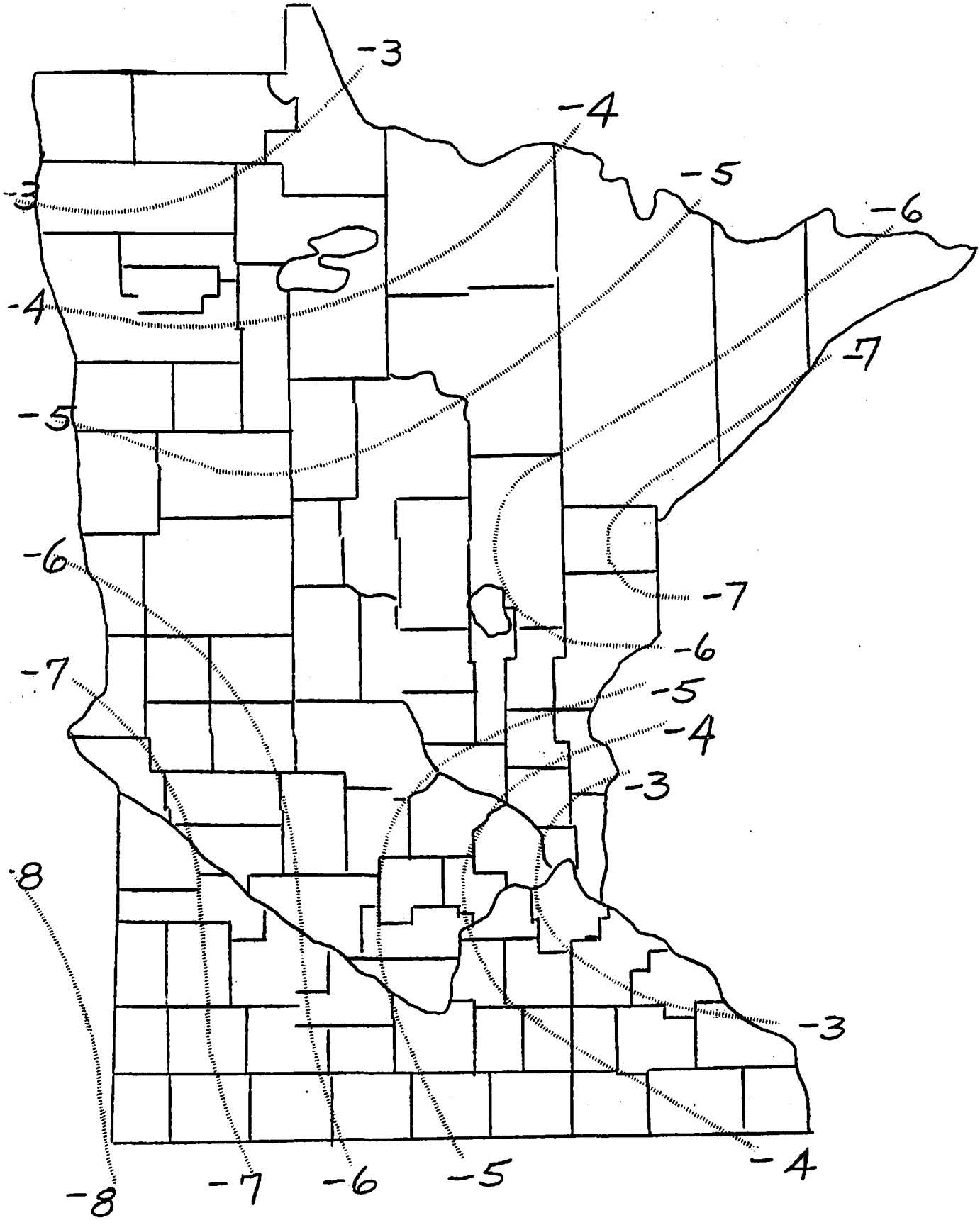


Figure 1. Total departure (in inches) from the normal precipitation during the period April 3 - Nov. 9, 1967. (Data from Minnesota Weekly Weather, Crop and LIvestock Report).

B. Probability of Soil Moisture Replenishment

The question now arises as to what may be expected for the 1968 season? With the soil moisture reserves generally well below average can this deficit be made up?

There are two questions here which must be considered separately. They are:

1. What is the probability of receiving adequate precipitation for crops in the 1968 growing season?

2. What is the probability that soil moisture reserves can be increased by (a) the beginning and by (b) the end of the 1968 growing season.

The probability that at least the normal precipitation will be received during the growing season is about 50% table 4. This is the usual expectation from one year to the next. On the basis of this probability the coming season does not appear alarming. However, because the soil moisture reserves are quite low the plants will have no reservoir to draw upon if the precipitation is inadequate in either amount or time. It is this present lack of a reservoir which could create serious problems if not alleviated.

With reference to replenishment of soil moisture reserves there are normally three times during the year when precipitation is in excess of that required by the plants. One period is in the autumn preceding the winter freezing of soil. The present low reserves are due in part to the abnormally low precipitation this year in September, October and November. (Addendum, page 17)

The second period when precipitation exceeds plant needs is over winter. The precipitation, however, is of little value for two reasons. First, it is a relatively small amount equalling on the average about 9.66 inches in south-central Minnesota. This equals 34% of the annual total. The period included here is approximately mid-October through the first week in May. Strictly speaking more than winter is included in this period. However, this is the average period that exists between our last soil samples in the fall and the first soil samples in the spring.

The second reason that over-winter precipitation is ordinarily of little value is because little of it enters the soil. Our measurements indicate that on agricultural soils only about 30% of this precipitation enters the soil, table 4. (See Addendum, page 17)

Table 4. Average amount of over-winter precipitation that enters the soil.

Site Description	Years of Data	Ave. Fall Sampling Data	Ave. Spring Sampling Data	Ave. Precipitation Between Periods	Percent of Precip. Entering Soi
Arco Lincoln Co.	4	Nov. 7	April 30	5.68	26%
Butterfield, Watonwan Co.	8	Oct. 22	May 6	7.94	22
Crookston, Polk Co.	6	Nov. 1	May 10	4.95	39
Dodge Center, Dodge Co.	9	Oct. 20	May 6	9.94	24
Granite Falls Yellow Medicine	3	Nov. 8	April 27	5.96	32
Lamberton, Redwood Co.	6	Oct. 4	May 4	7.76	24
Milaca, Mille Lacs Co.	7	Oct. 16	April 24	9.26	28
Milan, Chippewa Co.	5	Nov. 7	April 28	6.30	30
Murdock, Swift Co.	3	Nov. 11	April 29	8.01	61
Wabasha, Wabasha Co.	8	Oct. 13	May 4	10.50	19
Winthrop, Sibley Co.	8	Oct. 24	May 9	9.38	23
Average	6	Oct. 27	May 3	7.79 in.	30%

The third period of the year when soil moisture reserves are replenished is in the spring after soils have thawed and before plant water demands exceed precipitation. This period, therefore, extends from about early April to early June. (See addendum page 17. Precipitation well above the normal spring amount is required to bring the soil moisture reserves up and table 5 shows that the probabilities are quite low for this event to occur.

Table 5. Probabilities in percent of receiving selected amounts of precipitation for the period April 15-May 31.

	50% Normal Precipitation	Normal Precipitation	150% Normal Precipitation
Northwest	84%	43%	14%
North Central	85	43	14
Northeast	93	51	18
West central	84	44	17
Central	83	40	14
East Central	82	39	13
Southwest	83	49	20
South central	87	40	11
Southeast	92	50	15

In summary then it can be stated that soil moisture reserves are generally very low in so far as our soil moisture survey records are concerned. Ordinarily there are three times during the year, fall, winter and spring, when the soil moisture reserves are replenished. Fall this year was very dry and a failure as a moisture source period. Winter precipitation is ordinarily low and, in addition, much of it runs off without entering the soil. We are left with the hope that the spring 1968 precipitation will be sufficiently in excess to replenish the reserves.

However high our hopes may be the precipitation probabilities remain very low that above normal precipitation will occur this spring. Not to be confused with the foregoing probability, which is for surplus or above normal precipitation, is the probability of normal precipitation for a crop; this remains fairly good at about 50% chance that the total seasonal precipitation will be normal or above.

Therefore, at the present time it would seem that there is no reason to be unduly pessimistic and make radical management decisions. As long as the 1968 growing season is not one of either prolonged or successive drought periods when soil moisture reserves must be drawn upon the situation need not be a critical one.

C. Water Use by Crops

The influence of crops and fallowing upon soil moisture reserves in the autumn are very strikingly presented with data obtained through the courtesy of Dr. Olaf Soine, Northwest Experiment Station, Crookston. Table 6 shows the results.

Table 6. Total available inches of water in a five foot column of soil at two periods of the growing season under various cropping systems, precipitation and water use. (Data from N. W. Agr. Expt. Sta., Crookston).

Crop	6/30/67	10/30/67	Precipitation	Water Use
Pasture (Plot#1)	9.57 in.	1.71 in.	3.45 in.	11.31 in.
Sugarbeets (Plot#4)	8.15	0.57	3.45	11.03
Sweet Clover Fallow (Plot#5)	*	7.71	3.45	-
Small Grain (Plot#7)	7.91	2.05	3.45	9.31

* Unfortunately not sampled but about like other plots according to observation by Dr. Soine.

In a year of low precipitation such as experienced at Crookston in 1967 the differences between cropping systems are most apparent. The advantage of fallow in such a year is also obvious.

Summarization of Lamberton (Southwest Experiment Station) soil moisture provides interesting and useful information. Table 7 Shows the average daily water use for the period 1961-67. The figures have had to be slightly reduced from previous averages due to the low moisture consumption of this year. The maximum values are unchanged from previous years. From the Lamberton data (table 8) we find that for the period 1961-67 the average total water used by the crop was 19.67 inches between the average

Table 7. Daily and monthly average and maximum water use at Southwest Experiment Station, Lamberton, 1961-67 data.

	Average		Maximum		Average Total
Month	Per Day	Per Month	Per Day	Per Month	Precipitation
April	0.03 in.	0.90 in.	0.05 in.	1.50 in.	2.69 in.
May	0.11	3.41	0.14	4.34	3.69
June	0.17	5.10	0.24	7.20	3.42
July	0.16	4.96	0.21	6.51	4.44
August	0.13	4.03	0.16	4.96	2.41
September	0.08	2.40	0.12	3.60	3.35
October	0.01	0.31	0.03	0.93	1.23

sampling dates of May 4 and October 4. It should be noted that the column designated as "maximum/day" (table 7) actually represents the highest average for a period of about one month, and the amount used in any one day could exceed this value by almost 100%.

Figure 2 shows better than any word description just how greatly this season's low precipitation affected the soil moisture reserves at Lamberton. Because the precipitation was lacking the soil moisture reserves were brought down to an exceedingly critical level.

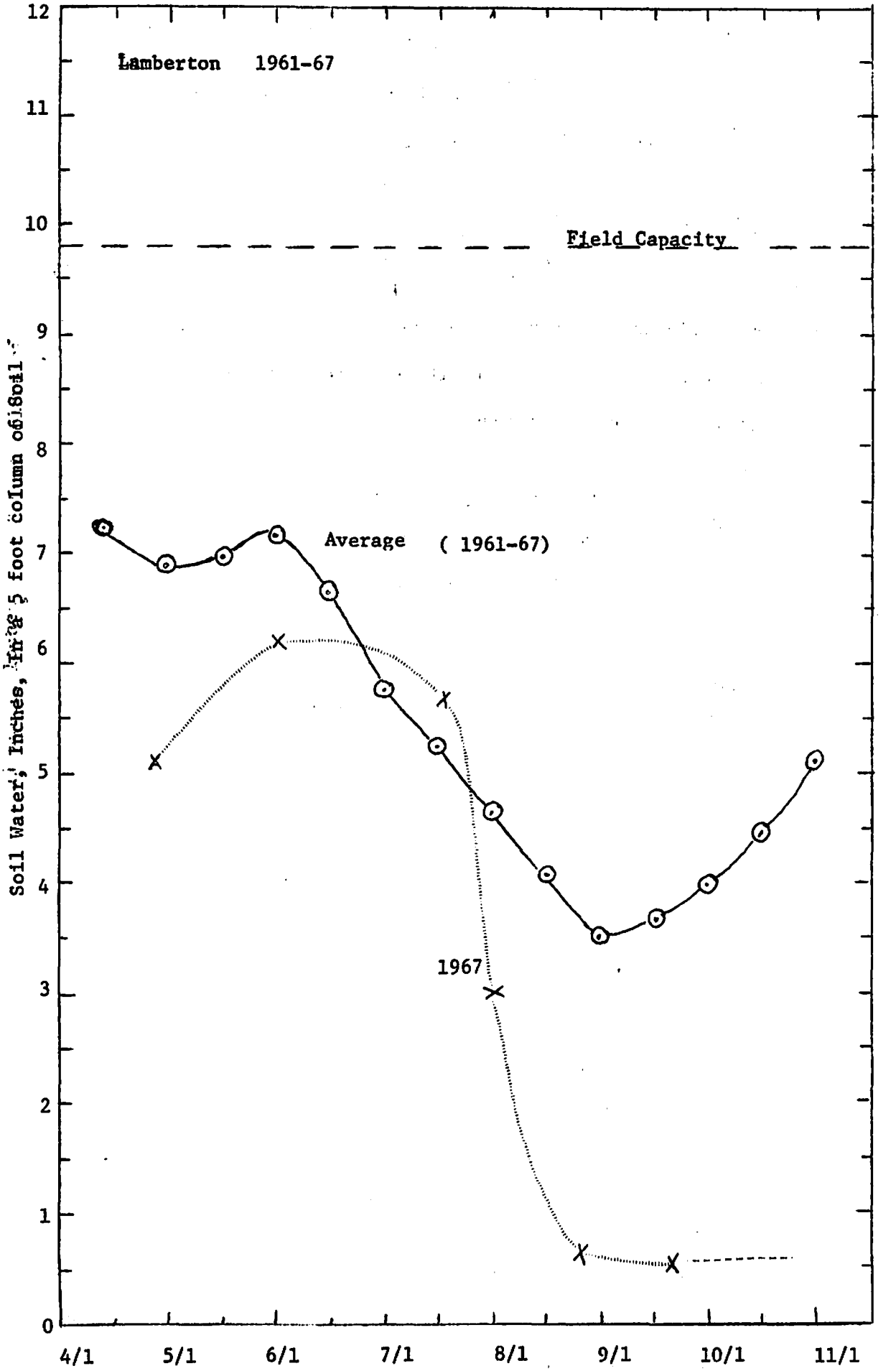
Table 8 shows the importance of soil moisture reserves. Without this additional source of moisture, the precipitation that falls during the growing season would be marginal indeed. The soil moisture reserves are normally replenished, as discussed earlier, primarily by spring rains, secondarily by autumn rains and thirdly by over-winter precipitation. (See Addendum, page 19)

Table 8. Growing season soil moisture reserve use in relation to the growing season percipitation at Lamberton, 1961-67.

Year	Period	Total Water Used	Precip-itation	Total Used-Precipitation *
1961	5/1-10/2	19.02	16.85	2.17
1962	5/1-9/26	23.03	20.23	2.80
1963	5/1-10/19	21.21	22.07	-0.86
1964	5/1-10/1	20.44	15.65	4.79
1965	5/10-10/6	19.74	18.09	1.65
1966	5/17-10/17	16.47	13.38	3.09
1967	4/26-9/20	16.77	12.26	4.51
Average	5/4-10/4	19.53	16.93	2.59

* This represents the net loss in soil moisture reserves between the spring and fall samplings. A negative value indicates a soil moisture gain between spring and fall.

As a final note of caution it should be pointed out that runoff and downward drainage through the soil profile were not measured, and thus become a part of the water listed as used by the crop. Actually our data represent an


Lamberton 1961-67
Field Capacity
Average (1961-67)
1967
Soil Water, Inches, In a 5 foot column of Soil
12
11
10
9
8
7
6
5
4
3
2
1
0
4/1
5/1
6/1
7/1
8/1
9/1
10/1
11/1

upper limit of the water used by a crop since the figures in table 7 and 8, for include runoff and drainage.

From the data secured at Lamberton we can also determine with reasonable accuracy the fraction of the annual precipitation that is consumed in evapotranspiration. Based upon the seven years, 1961-67, an average of 82% of the annual precipitation is used in evapotranspiration (subject to the fact that runoff and drainage are not excluded from the measured data). The remainder, or 4.40 inches on the average, is lost essentially as runoff.

Table 9. Comparison between total water used by a corn crop with the annual total precipitation at Lamberton, 1961-67.

Year	Total Water Used by Crop(E)	Total Annual Precipitation(P)	Ratio of E/P
1961	19.02 in.	22.92 in.	83.0%
1962	23.03	26.63	86.5
1963	21.21	27.33	77.6
1964	20.44	23.11	88.4
1965	19.74	30.39	64.9
1966	16.47	18.98	86.8
1967	16.77	18.12	92.5
Average	19.53	23.93	81.6

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

Mr. E. C. Drogemuller, Work Unit Conservationist, Soil Conservation Service, U.S.D.A., Gaylord

Mr. A. N. Fischer, Work Unit Conservationist, Soil Conservation Service, U.S.D.A., Dodge Center

Mr. O. Gunderson, Area Soils Agent, Morris

Mr. G. Holcumb, Area Soils Agent, Marshall

Mr. W. M. Kalton, Work Unit Conservationist, Soil Conservation Service, U.S.D.A., Milaca

Mr. P. N. Kennedy, Work Unit Conservationist, Soil Conservation Service, U.S.D.A., St. James

Dr. W. W. Nelson, Southwest Experiment Station, Lamberton

Mr. G. J. Stickeler, Work Unit Conservationist, Soil Conservation Service, U.S.D.A., Kellogg

Dr. O. C. Soine, Northwest Experiment Station, Crookston

Addendum:

In analyzing the soil moisture and precipitation data from Lamberton in another manner I arrive at some results that are quite different from those stated earlier. By considering a so-called "hydrologic year" at Lamberton the value of over-winter precipitation becomes apparent. Table 4 is misleading because too great a time span is considered (the average period between sampling dates is Oct. 27 - May 3) and the sampling period overlaps two critical hydrologic dates.

Table 10 shows the average dates of five important hydrologic periods: II (May 1 and June L), IV (September 1 - November 28) and V (November 28 - April 12) are periods when moisture may be added to the soil in contrast to periods I and III.

April 12 is based upon St. Paul data and is the average date when the 32°F isotherm disappears from the soil profile and May 1 from data in Figure 2. June 1 and September 1 are from the average soil moisture content data at Lamberton (Fig. 2). November 28 is the average date when the mean temperature at the 2 inch depth is 32°F at Lamberton.

Table 10 and also Fig. 2 show that a net gain in soil moisture occurs at three periods on the average: in spring (May 1 - June) autumn (Sept 1 - Nov 28) and over-winter (Nov 28 - April 12). The greatest amount is added in the autumn and the precipitation efficiency is also the greatest at this time.

The entrance of water into the supposedly frozen soil is not too difficult to imagine if it is realized that (a) the soils ordinarily contain only slightly greater than 50% of the available capacity going into winter, (b) the surface may thaw briefly several times during the winter, and (c) the upper part of the soil is ordinarily well above 32°F by the time (April 12) The 32°F isotherm has disappeared from the soil.

Perhaps the most surprising part of this is that little of the spring precipitation (April 12 - June 1) enters the soil. It should be remembered that the usual spring runoff period extends from about April 25 - May 15 with the peak expected between April 5 - 22 according to Mr. J. H. Strub, Jr., E. S. S. A. hydrologist and meteorologist.

Table 10. The hydrologic year at Lamberton (1961-67 data).

Period	Total Precipitation	Change In Soil Moisture
I. Soils Thaw to Spring Rains (April 12 to May 1)	1.61 in.	-0.3 in.
II. Spring Rains to Evapotranspiration Greater Than Precipitation (May 1 to June 1)	3.62	+0.3 (8.3%)*
III. Evapotransipiration Greater Than Precipitation (June 1 to September 1)	10.27	-3.7
IV. Precipitation Greater Than Evapotranspiration to Soils Freeze (September 1 to November 28)	5.19	+2.3 (44.2%)*
V. Soils Freeze to Soils Thaw (November 28 to April 12)	3.70	+1.4 (37.8)*
	24.39	0.0

* Percent of precipitation accounted for by change in soil moisture.

A fuller explanation of Figure 2 should also be offered. The average soil moisture curve is interpreted as follows:

1. For the period April 15 to May 1 surface soils are very wet and rapid surface evaporation occurs. A portion of this loss may also

be accounted for by downward drainage beyond the five feet measured.

2. May 1 to June 1 is the time when precipitation exceeds evapotranspiratio (mostly evaporation from cultivated fields at this time with little or no transpiration)

3. June 1 to September the corn is actively growing and transpiring with the result that evapotranspiration exceeds precipitation and a net loss in soil moisture occurs.

4. September 1 to November 1 is one of replenishment of soil moisture reserves since corn requires relatively little water after September 1.

5. November 1 to April 15 is the over-winter period for which no intermediate soil samples are available. Apparently, however it is a period of soil moisture increase.

Microclimate Studies at the Park Rapids Sulfur Experimental Field To Obtain Maximum Yield Goals

J. B. Swan, A. C. Caldwell, E. C. Seim, D. J. Baker

Past efforts at the Park Rapids experimental field have indicated that climati. conditions impose critical limitations on the maximum return from other management inputs (Seed, fertilizer, etc.). Droughth imposed limitations were removed when irrigation facilities were established in 1965. During 1967, measurements of evaporation, maximum and minimum air and soil temperatures (Palmer), and soil temperatures at 2, 4, and 12 inches were recorded.

First year climatological data must necessarily be judged with caution, as wide fluctuations are likely to occur from year to year. Nevertheless, some interesting trends may be observed in the 1967 data which warrant additional study and consideration.

Table 1 reports the mean weekly soil temperature at the 2 inch depth in irrigated and in non-irrigated corn and alfalfa. The measurements were made using 3 thermocouples placed in parallel for each treatment. Readings were taken at 7 Am DST $\pm$ 1 hour to approximate the daily minimum and maximum soil temperatures respectively. The irrigated corn was planted for 35,000 plants of a 65 day hybrid per acre. The non-irrigated corn area had 6000 plants of a 85 day hybrid per acre. Alfalfa was 6" high on May 31. Average temperatures are the weekly averages of the average daily temperatures of each week.

During July and August the afternoon and the average two inch soil temperature in irrigated corn were both substantially lower than those recorded in unirrigated corn. Differences in weekly means afternoon (PM) temperatures reached 16°F. Figure 1 shows the difference between the weekly mean of the average daily soil temperature of the non-irrigated and of the irrigated corn.

Soil temperatures under irrigated corn at the 2 inch depth were generally lower than optimum for maximum plant growth. Weekly means of the daily average soil temperatures at 2 inches never exceeded 77° F. and exceeded 70° F. for only 3 weeks during the entire 1967 growing season.

Vegetative growth for the irrigated corn was much greater than the non-irrigated plants. It is probable that both the more dense shading and the frequent irrigations contributed to the decreased soil temperature. The weekly mean soil temperatures recorded under a killed sod cover at 2', 4', and 12" depths are reported in Table 2. Soil temperatures measured by Palmer-mercury in steel max-min thermometers under potatoes, corn, alfalfa, barley, and under killed sod only are shown in Table 3.

Measurements of the evaporation from a Class A type pan and the estimated evapotranspiration are reported in Table 4.

Table 1. Mean weekly soil temperatures (° F.) at 2 " under corn and under alfalfa, with and without irrigation, Park Rapids, 1967.

Period	Irrigated Soil Under Corn			Non-Irrigated Soil Under Corn			Irrigated Soil Under Alfalfa			Non-Irrigated Soil Under Alfalfa		
	PM	AM	Avg.	PM	AM	Avg.	PM	AM	Avg.	PM	AM	Avg.
May 23 - 27	75.7	50.9	63.3	76.7	51.3	64.0	66.2	50.9	58.6	65.4	51.9	58.6
May 28 - June 3	77.6	53.0	65.2	80.8	52.1	66.4	70.7	52.0	61.3	70.4	52.5	61.4
June 4 - 10	71.1	56.2	63.7	72.3	57.9	65.2	66.1	56.8	61.4	66.2	57.5	61.8
June 11 - 17	73.3	60.0	67.4	73.6	61.5	68.1	66.2	59.4	62.9	66.4	60.2	63.4
June 18 - 24	73.5	57.9	65.6	74.8	58.1	66.6	66.7	56.1	61.1	67.0	57.6	62.3
June 25 - July 1	75.6	58.5	67.3	80.5	60.2	69.8	74.7	58.3	66.2	75.6	59.5	67.3
July 2 - 8	71.2	59.0	65.6	76.9	61.2	69.3	68.5	57.6	63.2	69.2	59.2	64.3
July 9 - 15	82.3	64.5	73.4	89.1	66.3	77.7						
July 16 - 22	83.5	67.8	76.5	97.7	73.1	86.2						
July 23 - 29	79.3	65.6	72.4	94.8	69.6	82.2						
July 30 - Aug. 5	73.6	63.6	69.1	90.1	67.0	79.9						
Aug. 6 - Aug. 12	68.5	60.2	64.2	84.8	59.9	71.6						
Aug. 13 - 19	72.8	62.4	67.6	86.5	64.6	76.3						
Aug. 20 - 26	64.7	58.3	61.2	80.0	62.1	70.8						
Aug. 27 - Sept 2	61.6	56.6	58.8	78.4	61.7	69.1						
Sept. 3 - 9	67.7	56.7	61.0	82.0	59.8	70.7						
Sept. 10 - 16	61.6	55.3	59.0	66.3	56.1	61.9						
Sept. 17 - 18	63.6	55.8	59.6	66.5	56.1	61.4						

Average temperature indicates weekly averages of daily average temperatures. Where either AM or PM reading missing, these data are not included in average.

Alfalfa 6" high on May 31.

Three thermocouples were placed in parallel in each treatment.

AM Readings taken about 7 AM DST ± 1 hour (approximates daily minimum temperature).
PM Readings taken about 5 PM DST ± 1 hour (approximates daily maximum temperature).

Irrigated Corn - 35,000 plants/Acre; 65 day maturity hybrid. Non-irrigated Corn - 6000 plants/Acre; 85 day maturity hybrid.

Figure 1. Weekly mean of average daily soil temperature at two-inch depth under irrigated and non-irrigated corn.

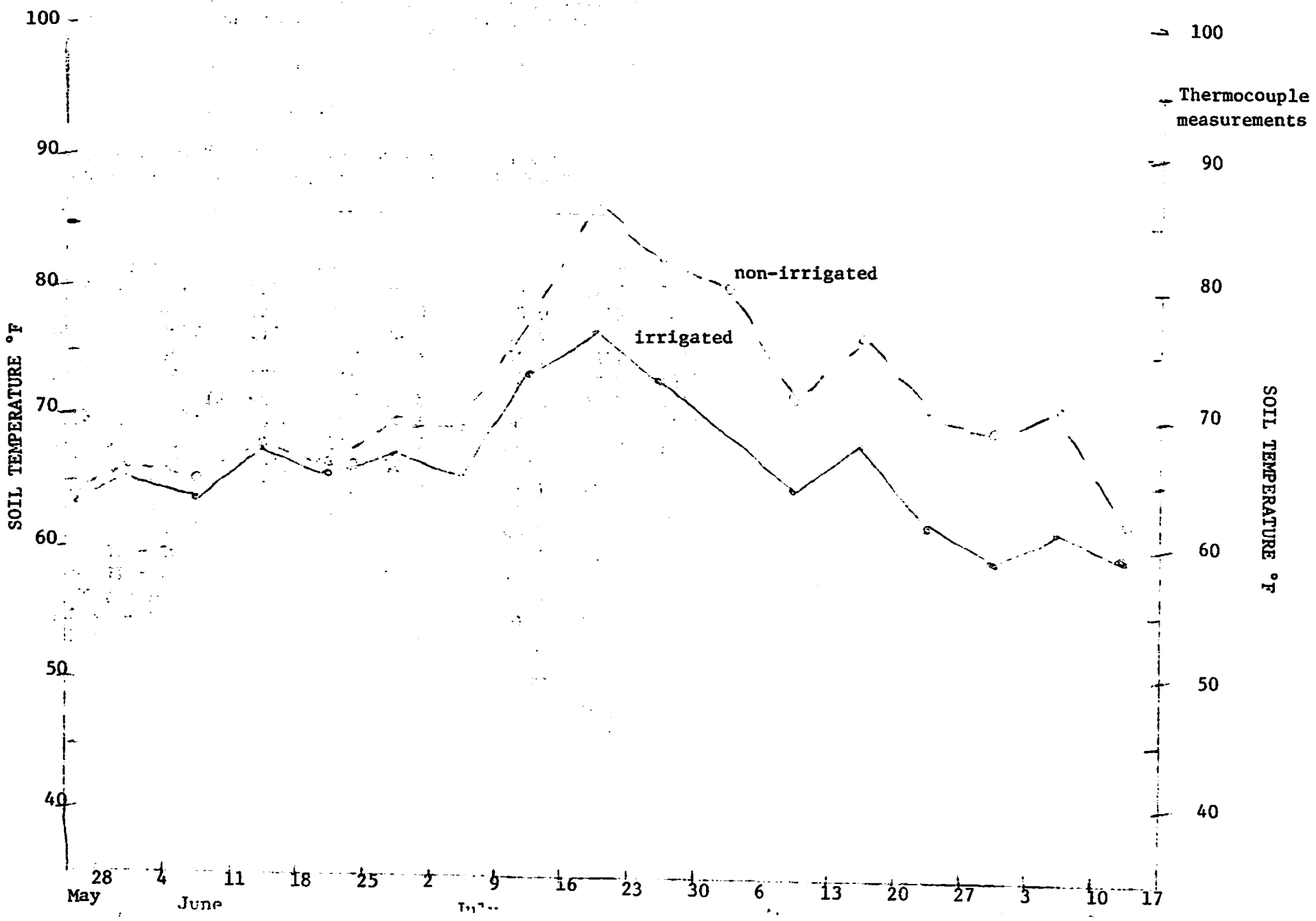


Table 2. Mean weekly soil temperatures (F°) at two, four, & twelve inch depths under a chemically killed sod cover at Park Rapids in 1967.

	Weekly Mean Soil Temperature (°F.)								
	2 Inch Depth			4 Inch Depth			12 Inch Depth		
Date	AM	PM	Avg.	AM	PM	Avg.	AM	PM	Avg.
May 23 - 27	50.4	63.0	56.7	50.9	58.5	54.7	50.5	50.9	50.7
May 28 - June 3	51.8	64.6	58.2	52.1	59.6	55.9	53.2	52.9	53.1
June 4 - 10	56.2	64.9	60.8	56.0	61.6	58.7	56.6	56.7	56.7
June 11 - 17	60.0	66.3	63.2	58.8	61.4	60.5	58.0	57.5	57.9
June 18 - 24	56.5	65.6	61.2	54.5	60.1	57.3	57.9	57.8	57.9
June 25 - July 1	60.0	72.2	66.0	59.6	68.0	63.8	61.2	61.3	61.2
July 2 - 8	59.3	69.8	64.8	58.6	66.7	62.7	61.0	62.2	61.6
July 9 - 15	65.2	84.5	74.8	64.3	78.1	71.2	66.8	67.2	67.0
July 16 - 22	65.0	91.0	78.4	62.9	83.3	73.6	65.7	71.9	69.4
July 23 - 29	68.4	90.5	79.6	68.9	83.8	76.3	73.6	73.8	73.7
July 30 - Aug.5	66.4	85.9	76.5	65.9	80.2	73.1	71.0	71.6	71.3
Aug. 6 - 12	61.0	81.5	71.4	63.2	75.3	69.3	69.5	66.3	68.0
Aug. 13 - 19	64.7	85.9	75.6	65.0	81.7	73.8	69.6	71.9	71.0
Aug. 20 - 26	62.1	78.9	71.3	62.0	74.3	68.5	66.7	67.9	66.9
Aug. 27 - Sept 2	61.7	75.4	68.5	60.7	69.9	65.0	65.6	63.4	64.6
Sept 3 - 9	59.4	80.2	69.7	60.9	74.6	66.0	66.5	66.4	66.4
Sept 10 - 16	55.8	66.1	61.3	56.8	64.0	60.9	61.8	61.7	61.7

Killed sod cover removed July 7

Temperatures measured by three thermocouples in parallel.

AM readings taken about 8 AM DST $\pm$ 1 hour.

PM readings taken about 5 PM DST $\pm$ 1 hour.

Table 3. Soil Temperature measurements (Palmer) under various crops* at Park Rapids, 1967.

Date	Weekly Mean Soil Temperature (° F.)																	
	Soil under Irrigated Potatoes 5 inch (°F.)			Soil under Irrigated Corn 2 inch (° F.)			Soil under Irrigated Alfalfa 2 inch (° F.)			Non-irrigated Soil: Under Barley 2 inch (°F.)			Non-irrigated Soil: Killed sod cover 2 inch (°F.)			Non-irrigated Soil: Under corn 2 inch (°F.)		
	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max	Avg.
June 18 - 24	60			54			58			57			60					
June 28 - July 1	63			60			62			59			64					
July 2 - 8	61			57			59			57			61					
July 9 - 15	65	69	67	62	77	69	64	72	68	60	75	68	65	83	75			
July 16 - 22	67	72	70	64	77	71				67	85	76	70	89	80			
July 23 - 29	67	71	69	64	72	68				68	87	77	69	90	80	68	84	76
July 30 - Aug. 5	65	68	67	63	69	66				66	90	78	67	85	77	66	82	74
Aug. 6 - 12	62	66	64	59	65	62				61	87	74	64	85	75	61	80	71
Aug. 13 - 19	64	67	66	62	70	66				65	91	78	67	86	77	65	83	74
Aug. 20 - 26	61	65	63	58	64	61				62	82	72	64	80	72	62	75	69
Aug. 27 - Sept 2	60	66	63	57	63	60				58	84	71	60	79	70	58	78	68
Sept 3 - 9	63	69	66	57	66	62				60	83	72	61	81	71	60	79	70
Sept 10 - 16	59	62	60	54	60	57				56	67	62	57	66	62	56	64	60

* Irrigated corn - 24 inch rows; 85 day maturity corn, 25000 plants/acre.
Non-irrigated corn - 24 inch rows, 85 day maturity corn, 12000 plants/acre.
Potato vines down about September 1, potatoes grown in 30 inch rows.
Chemically killed sod cover removed July 8.
Barley cut July 27.

Table 4. Pan evaporation of water measurements at Park Rapids, 1967.

Month	Number of days Measured	Inches Pan Evaporation per day	Estimated Potential Evapotranspiration		Estimated Evapotranspiration	
			Penmon Inches/day	Thornthwaite inches/day	Penmon	Thorn-thwaite
May	10	.232	.12	.10	.52	.43
June	30	.182	.15	.16	.83	.88
July	29	.238	.16	.18	.68	.76
August	30	.222	.13	.15	.59	.68
September	17	.184	.09	.09	.49	.49

Class A Type pan used.

Comments on 1967 investigation

1. Weekly means of the daily average two inch soil temperature for irrigated corn were within 2 1/2 (^{o}F.) of those measured for non-irrigated corn until July 1, however, during July and August, the two inch temperatures for non-irrigated corn greatly exceeded those for irrigated corn. Weekly averages of afternoon (PM) temperatures were up to 16° F. greater for non-irrigated corn.

2. Two-inch soil temperatures under irrigated corn were generally lower than optimum. Weekly means of daily average soil temperature never exceeded 77° F. and exceeded 70° F. for only three weeks.

3. Vegetative growth was much greater for the irrigated corn and the dense shading and frequent irrigation may both have contributed to decreased soil temperatures under irrigated corn.

Available Soil Moisture Survey - 1967

Olaf C. Soine, Soil Scientist

Northwest Experiment Station
Crookston, Minnesota

Soil samples were collected from three different cropping systems throughout the season and the moisture determinations were made here at this station.

The data in Tables 1, 2 and 3 gives the sampling dates, inches of available moisture for each depth, and the total for the season. Each table gives the data for October 30, 1966 which makes it possible to calculate the amount of moisture accumulated from the over-winter snowfall and early spring precipitation.

Discussion: In general, the early spring available moisture supply was good at the 3 sampling sites. The above normal rainfall during April and June built up a good supply of moisture. The drought during July and August reduced the moisture supply very rapidly and on August 1 severe moisture deficiencies began to appear in the top 2 feet of soil at all sampling sites. At Site 4 (Table 2) the deficiencies extended down to a depth of 36 inches. The below-normal rainfall during September and October did not improve the moisture supply and on November 1, the available moisture reached the lowest point since 1964.

The first soil samples were taken on May 18 at Site 1 (Table 1). This area with a sod cover did not have as severe frost penetration as Site 7 (Table 3). This area was in sugarbeets in 1966 and the frost penetration was deeper and sampling wasn't possible until June 13.

Table 1. Site 1 - Pasture Plots (pasture plots 1966) available soil moisture in inches - 1967.

Sampling date	Precip. in inches	Depth in inches							
		0-6	6-12	12-18	18-24	24-36	36-48	48-60	Total
10-31-66	--	0.84	1.13	1.10	0.95	2.07	2.07	1.02	9.18
5-18-67	5.82	1.09	1.11	1.00	0.88	1.98	2.26	1.35	9.67
6-5-67	0.25	0.93	0.86	0.99	0.93	2.21	2.05	2.32	10.29
6-30-67	4.25	0.89	0.80	1.04	0.50	2.08	2.27	1.99	9.57
8-1-67	0.31	0.01	0.22	0.39	0.31	1.25	1.80	2.50	6.48
8-31-67	0.70	-.32	-.07	-.02	-.10	0.22	0.75	2.55	3.01
10-3-67	1.71	0.44	0.05	0.27	0.05	0.32	0.42	0.92	2.47
10-30-67	0.73	0.39	0.19	0.11	-.37	0.26	0.37	0.76	1.71

Table 2. Site 4 - Sugarbeets (Sweetclover fallow 1966) available soil moisture inches - 1967

Sampling date	Precip. in inches	Depth in inches							
		0-6	6-12	12-18	18-24	24-36	36-48	48-60	Total
11-4-66	--	0.62	0.46	0.53	0.66	2.08	2.81	0.80	7.96
5-26-67	6.07	0.65	0.63	0.52	0.44	1.76	2.63	1.72	8.35
6-30-67	4.25	0.60	0.71	0.74	0.62	1.79	1.76	1.93	8.15
8-1-67	0.31	-.63	-.58	-.47	0.36	1.36	2.41	1.48	3.93
8-31-67	0.70	-.65	-.82	-.77	-.48	-.21	1.65	0.98	-.30
10-3-67	1.71	0.08	-.67	-.72	-.58	-.81	0.14	0.52	-2.04
10-30-67	0.73	0.03	-.49	-.51	-.48	-.56	0.80	0.64	0.57

Table 3. Site 7 - Small grain (Sugarbeets 1966) available soil moisture in inches - 1967

Sampling date	Precip. in inches	Depth in inches							
		0-6	6-12	12-18	18-24	24-36	36-48	48-60	Total
10-31-66	--	0.08	0.14	0.55	0.01	-.03	1.87	1.11	3.73
6-13-67	8.94	0.79	0.89	0.87	0.82	1.95	2.42	1.56	9.30
6-30-67	1.38	0.58	0.71	0.73	0.41	1.51	2.52	1.45	7.91
8-1-67	0.33	-.59	-.43	0.26	0.05	-.06	2.03	1.18	2.44
9-1-67	0.68	-.56	0.12	0.41	-.12	0.66	1.69	0.66	2.86
10-3-67	1.71	0.17	0.03	0.13	-.18	0.04	1.62	0.88	2.69
10-31-67	0.73	0.24	0.19	-.11	-.07	-.02	1.44	0.38	2.05

Method of Corn Planting Study

Lancaster, Wisconsin - University of Wisconsin Experiment Farm

James Swan and William Paulson, Supt.

The following field experiment was conducted near Lancaster, Wisconsin during the 1967 growing season.

Soil - Fayette silt loam, 6 to 8% south slope, previously in corn.

Fertilizer - 210 to 240 lbs/acre of 6-24-24

Population - planted 23,000 to 24,000; depth of planting 2 inches + ½ inch except till plant varies from 1 to 3 inches of loose soil covering seed.

Corn - 110 days, Expt. 1807

Experimental Design - 4 x 4 Latin Sq. (plot size 40 ft. x 18 ft. with 20 ft. alleys)

Treatments
1. Plow - disc - harrow - wheeltrack - plow May 2 - plant May 4
2. Till plant - plant May 3
3. Coulter (No-till) plant - plant May 3
4. Rotary tillage - roto-till May 2 - plant May 4

Temperature measurement by thermocouples on 2 reps placed @ 3 inches depth in row. 4 couples in parallel/plot.

Treatments	Population June 16 Plants/acre	June 16th observations Dry wt. of 15 plants on June 16th		Final Yield bu/A @ 15.5% moisture
1	20,600	64.5 gms	a	116.6
2	16,300	42.3 "	b	118.2
3	17,500	44.0 "	b	117.4
4	18,800	60.0 "	a	122.4
		significant at 5% level by Duncan's New Multiple Range Test		no significant difference

1967 Weather Record at Lancaster

	Air Temperature				Precipitation	
Month	Max.	Min.	Avg.	Departure from normal	Inches-water	Departure from normal
May	65.7°F	42.6°F	54.2°F	-4.9°F	2.45 inches	-1.40 inches
June	79.1	59.6	69.5	+1.0	4.00	-0.93
July	81.4	58.9	70.2	-3.2	0.25	-3.48
Aug.	78.4	55.0	66.7	-5.0	3.27	-0.56
Sept.	72.7	50.0	61.4	-1.9	4.44	+ .76

Soil Temperatures at Three Inch Depth Under Four Tillage Treatments

(average of 2 reps. - read to nearest 1/2°F)

Dates	Tillage Treatment: Plow-Disc, Harrow Wheeltrack (conventional)			Difference in Soil Temperature for Till-Conv.			Difference in Soil temperature for Coulter-Conv.			Difference in Soil temperature for Roto-Conv.			Number of Reading/Period		
	AM °F	PM °F	Avg. °F	AM °F	PM °F	Avg. °F	AM °F	PM °F	Avg. °F	AM °F	PM °F	Avg. °F	AM °F	PM °F	Avg. °F
May 4-6	--	57.5	--	--	-0.9	--	--	+ .2	--	--	+0.9	--	0	3	0
May 7-13	47.2	57.8	51.3	-0.1	-1.1	-0.4	0	- .3	+ .3	-0.2	+0.3	+0.3	4	2	1
May 14-20	52.9	68.3	60.0	-1.3	-1.9	-1.6	-0.9	-1.2	-1.0	-0.3	-0.3	-0.3	5	4	3
May 21-27	58.3	73.3	64.9	-1.2	-1.2	-1.2	-0.9	-1.1	-1.0	-0.3	-0.2	-0.3	6	6	5
May 28-June 3	56.7	71.7	64.2	-1.1	-0.9	-1.0	-0.7	-1.0	-0.8	-0.3	-0.3	-0.3	6	6	6
June 4-10	66.2	73.7	70.1	-0.6	-0.1	-0.4	-0.3	-0.6	-0.4	0	+0.1	+0.1	4	6	4
June 11-16	70.5	81.9	76.3	-0.6	-0.2	-0.4	-0.6	-1.3	-1.0	-0.1	+0.2	0	5	3	3

31

Note - Read to nearest 0.5°F so differences less than 0.5°F are within error of measurement.
Average readings are for days with both AM & PM readings.

AM readings taken 0745 DST ± 30 min.
PM readings taken 1800 DST ± 30 min.

Conclusions:

1. There were significant differences in early growth associated with tillage treatments. It is of interst that the soil is a well drained silt loam with a slope of 6 to 8% on a south facing slope.

2. Small reductions in three inch soil temperatures for the till plant and coulter plant treatments were associated with decreased early growth on these treatments.

3. There was no significant difference in final yield. Plant population varied between treatments due to differences in emergence.

4. Air temperatures were unusually low in May, July and August and precipitation was appreciably below normal in June and July.

Land Forming

Northwest Experiment Station - 1967
Olaf C. Soine, Soil Scientist

This experiment was laid out in the fall of 1965 to study the effect of 5 different methods of land forming on crop yield in a rotation of corn, wheat, barley, and alfalafa. A fertilizer trial was included in the experiment.

The yields of wheat and barley were very good. The corn yields were good, considering the summer drought. 40-40-20 gave the best increases of barley on the check .02% and .01% slope treatments, and on the Level and Land Smoothing 0-40-20 gave slightly better yields. The fertilizer treatments on corn, wheat, and alfalfa were varied and followed no definite pattern.

The yields on the Level and Land Smoothing plots were the highest.

Effect of 5 different methods of "Land Forming" on the yield of corn, wheat, barley and alfalfa

Land Forming	Fertilizer	Corn *		Wheat		Barley		Alfalfa *
		bu/acre						lbs/acre
Treatments	lbs/acre	1967 -	Av 1966-67	1967 -	Av 1966-67	1967 -	Av 1966-67	1967 - 2 cuttings
CHECK	0-0-0	68.30	75.15	56.0	36.6	60.0	47.5	2943
	0-40-0	66.90	75.17	50.1	35.2	60.5	50.2	2783
	0-40-20	60.47	66.85	52.1	33.4	55.3	43.4	2783
	40-40-20	65.03	76.17	51.1	34.9	64.8	51.7	2743
.02% SLOPE	0-0-0	64.87	72.59	43.4	35.0	43.8	36.0	3416
	0-40-0	59.56	72.89	46.0	35.6	44.0	39.0	3655
	0-40-20	57.13	64.35	42.0	35.4	52.3	43.1	3466
	40-40-20	66.57	79.93	52.0	39.0	76.0	57.7	3702
.01%	0-0-0	46.99	63.75	43.40	31.8	45.5	34.5	2977
	0-40-0	42.85	65.90	45.0	31.7	44.5	33.1	2768
	0-40-20	54.93	70.94	45.1	32.7	52.8	39.9	2822
	40-40-20	55.58	74.51	44.4	35.6	68.5	53.7	3652
LEVEL	0-0-0	62.45	74.99	48.0	35.3	67.0	51.7	3879
	0-40-0	69.18	80.10	46.0	34.7	75.3	55.5	3296
	0-40-20	76.80	75.56	40.0	32.5	82.0	59.1	3502
	40-40-20	68.85	81.71	47.2	36.0	73.8	57.0	30.48
LAND SMOOTHING	0-0-0	67.12	81.25	52.0	37.3	77.3	55.5	
	0-40-0	68.37	79.54	48.0	35.1	67.5	49.8	
	0-40-20	70.58	81.25	57.2	38.8	84.3	58.1	
	40-40-20	66.27	77.47	48.4	35.5	76.0	56.2	

* 15.5% moisture

SOIL RESIDUE STUDIES

R. S. Adams, Jr. and S. E. Nelson

Simulated atrazine residue plots were continued at Lamberton, Morris, and Waseca in 1967. Again "residue" rates of atrazine were incorporated in the spring prior to the seeding of oats and soybeans. Yields for 1967 and averages for 1966 and 1967 are shown in Table 1. Considering the overall averages, slightly more than 1/2 lb/A of atrazine was required to reduce stands by 50%. Slightly more than 1 lb/A was required to reduce grain yields by 50%. Injury was least at Morris in 1967 and greatest at Waseca where an early dry period was followed by heavy rains with some water standing in the plots. Greatest recovery of the oats occurred at Morris where 1 1/2 lb/A of atrazine resulted in only a 48% reduction in grain yield. On the other hand, 1 lb/A reduced grain yields by 45% at Lamberton, and 1/2 lb/A reduced grain yields by 59% at Waseca.

Stand reductions were surprisingly consistent from year to year and station to station. These data gave promise that early estimations of yield reductions could be made from an early evaluation of stand. On the basis of two years data, approximately 40% reduction in stand would not significantly lower yields of oat grain.

Table 1. Stand and yield of oats and soybeans when atrazine was incorporated at three locations. Average of 4 replications.

Atrazine treatment lb/A		Lamberton Stand % Control	Lamberton Yield bu/A	Morris Stand % Control	Morris Yield bu/A	Waseca Stand % Control	Waseca Yield bu/A
				Lodi Oats			
0	1967	100	58.3	100	69.9	100	66.3
	2 yr. avg.	100	50.4	100	78.4	100	74.1
1/4	1967	82	58.4	82	71.9	60	50.9
	2 yr. avg.	82	48.0	80	85.3	77	68.0
1/2	1967	71	59.7	56	70.0	32	27.4
	2 yr. avg.	62	50.8	56	77.9	48	52.6
1	1967	36	32.9	33	47.2	18	15.0
	2 yr. avg.	34	26.4	31	63.6	34	42.9
1 1/2	1967	20	19.4	24	36.3	9	6.2
	2 yr. avg.	22	20.4	22	45.5	19	28.4
				Chippewa 64, Soybeans			
0	1967	100	18.1	100	16.8	100	36.9
	2 yr. avg.	100	19.0	100	19.6	100	32.9
1/4	1967	88	16.4	102	19.8	98	38.8
	2 yr. avg.	90	18.3	100	23.6	104	35.0
1/2	1967	102	17.6	106	17.4	92	27.8
	2 yr. avg.	94	18.4	102	22.6	98	27.3
1	1967	94	12.0	82	16.3	56	20.9
	2 yr. avg.	90	16.8	84	19.9	76	26.2
Weed Free Check 1967			22.0		22.5		39.7

In contrast to 1966, 1 lb/A of atrazine in 1967 gave significant stand reductions of soybeans at all three locations and seed yields were reduced at Lamberton and Waseca. Seed yields of soybeans were not correlated with stand reductions and early stand evaluation appears to give no indication of later yield effects. Yields generally were more severely affected than stand.

Table 2 gives seed yield data from the interaction plots with soybeans for 1967 and the two year averages. In these plots atrazine was incorporated at rates of 0, 1/4, and 1 lb/A in a split plot design across plots containing no chemical, linuron (2 1/2 lb/A), CDAA (5 lb/A), amiben (3 lb/A), and trifluralin (1 lb/A). In these plots in 1967, as in 1966, soybeans grown on the atrazine-linuron and atrazine-amiben plots appeared to suffer greater physical injury from 1 lb/A atrazine than soybeans grown on plots treated with 1 lb/A atrazine alone. Except for the atrazine -linuron plots at Lamberton, and possibly Morris, this effect was not reflected in soybean yields. CDAA (Randox) in combination with atrazine appeared to reduce early physical injury observed in 1 lb/A atrazine plots. However, no significant beneficial effect on yield was noted except at Waseca. Trifluralin-atrazine treatments gave consistently higher yields than the corresponding atrazine treatments at all locations. However, this study must be conducted a few more years before reliable generalizations about possible interactions between atrazine residues and the four herbicides can be made.

Table 2. Yield of Chippewa 64 Soybeans as affected by herbicide chemical treatments at three locations. Averages of four replications.

"Residual" atrazine	No Chemical 1967	No Chemical 2 yr. avg.	Linuron 1967	Linuron 2 yr. avg.	CDAA 1967	CDAA 2 yr. avg.	Amiben 1967	Amiben 2 yr. avg.	Trifluralin 1967	Trifluralin 2 yr. avg.
lb/A	bu/A									
0 (Weed Free Check) 22.0					Lamberton					
0	18.1	19.0	19.2	19.1	18.5	20.6	19.6	21.3	19.2	20.3
1/4	16.4	18.3	18.9	20.2	18.8	20.2	17.7	19.9	19.5	19.6
1/2	17.6	18.4	16.3	18.4	18.9	21.8	16.6	20.0	19.4	20.7
1	12.0	16.8	9.5	14.4	13.8	18.2	15.9	19.8	15.4	18.6
0 (Weed Free Check) 22.5					Morris					
0	16.8	19.6	18.7	27.2	19.2	24.6	20.1	26.8	19.2	26.9
1/4	19.8	23.6	20.6	28.0	19.8	26.8	21.2	28.1	22.7	29.6
1/2	17.4	22.6	19.5	27.2	18.1	24.3	17.4	24.8	19.2	27.4
1	16.3	19.9	14.0	19.6	16.4	24.8	18.0	25.3	22.7	27.9
0 (Weed Free Check) 39.7					Waseca					
0	36.9	32.9	37.5	35.0	40.1	35.0	38.7	35.5	37.5	33.2
1/4	38.8	35.0	36.3	34.1	40.8	33.8	38.1	32.9	38.5	33.1
1/2	27.8	27.3	27.5	27.9	34.7	32.8	35.4	32.2	36.7	34.0
1	20.9	26.3	24.2	27.0	29.6	28.7	27.6	27.9	21.2	24.4

Soybeans in the interaction plots were cultivated. However, sufficient weeds grew in the row that linuron, CDAA, amiben or trifluralin treatments increased yields over the no treatment checks by 1/2 to 3 1/2 bu/A. Two year averages indicated no significant differences in yields on plots treated with the above four herbicides.

LIME PLOTS, LAMBERTON, 1967

J. Grava, W. W. Nelson and G. W. Randall

A field experiment was established in the fall of 1965 to study the effects of liming on crop yields, chemical composition of plant tissue and chemical properties of the soil. The crops grown were: (a) Vernal alfalfa (seeded with oats as a companion crop in 1966), and (b) corn (1966) and Chippewa soybeans (1967) in a sequence, Dolomitic limestone (89.1% C.C.E., 96.4% passing 8-mesh sieve, 42.3% passing 60-mesh sieve) was applied in the fall of 1965 and plowed under. The rates of limestone used were as follows: 0, 3 and 6 6ons per acre. The treatments were replicated five times. Individual plots are 20 feet wide and 40 feet long. Corn and soybeans are grown in 30-inch rows. Yield and plant analytical data of the 1966 corn crop were reported in the "Bluebook" of Feb. 1967, pp. 69-70.

Alfalfa

Three tons per acre of alfalfa were harvested in two cuttings (Table 1). Liming had no effect on the hay yields. The chemical composition of alfalfa tissue is given in table 2. Liming increased significantly the molybdenum content of tissue of first cutting alfalfa. The concentrations of other nutrient elements were not affected by liming.

Soybeans

An average yield of 25 Bu./Acre was obtained on the limed plots (Table 3), compared to 23 bushels per acre for the check. However, the difference was nonsignificant. Lime applications increased significantly the contents of magnesium and zinc in the soybean tissue (Table 4). No fertilizer was applied to soybeans in 1967. The corn in 1966 had received 83+48+24 pounds per acre of N, P_2O_5 and K_2O.

Soil Tests

The effect of liming on the pH of soil under alfalfa is shown in table 5. The only significant relationship was obtained in samples from the sampling depth of 0 to 3 inches. The six ton per acre treatment had caused a slight lessening of the soil acidity. Soil pH increased at lower sampling depths. However, this was due to the nature of the soil and was not related to lime treatments.

Table 6 shows the soil pH from the corn-soybean area. The 6 tons per acre treatment increased the soil pH significantly at the sampling depths of 0-3 and the 6-9 inches. The soil pH of this area is slightly higher when compared with the alfalfa area.

It appears that the lime treatments have been ineffective. This may be due to (a) too low lime rates, and (b) improper incorporation of the limestone. Recently the lime requirement of the soil was reevaluated by using the SMP Buffer. According to this test, about 7 tons/acre of limestone are required to bring the soil to pH 6.5, and nearly 10 tons per acre to reach the neutral point. Consequently, the plots will require the application of additional lime.

Phosphorus and potassium soil test values for the two crop areas are given in tables 7 and 8. The test values of the two elements were not significantly affected by lime treatments.

TABLE 1. YIELD OF ALFALFA, LAMBERTON LIME PLOTS, 1967

Rate of Lime Tons/acre	1st cutting	2nd cutting	Total
	Hay, Tons/Acre		
0	1.9	1.1	3.0
3	1.7	1.2	2.9
6	1.9	1.1	3.0

TABLE 2. CHEMICAL COMPOSITION OF ALFALFA, LAMBERTON LIME PLOTS, 1967

Lime Treatment Tons/Acre	P	K	Ca	Mg	Zn	Cu	Mo	Mn	B	Sr
	Percent				Parts per million					
			(a) First Cutting							
0	.42	2.38	1.33	.36	39	9	.82	41	35	47
3	.42	2.41	1.32	.39	41	9	.90	40	36	46
6	.43	2.48	1.33	.38	41	9	.88	40	36	47

Lime Treatment Tons/Acre	P	K	Ca	Mg	Zn	Cu	Mo	Mn	B	Sr
	Percent				Parts per million					
				(b) Second cutting						
0	.37	2.51	1.78	.42	26	9	1.54	60	55	70
3	.35	2.45	1.70	.41	25	8	1.50	52	51	68
6	.38	2.41	1.76	.41	24	8	1.77	52	52	65

TABLE 3. YIELD OF SOYBEANS, LAMBERTON LIME PLOTS, 1967

Rate of Lime Tons/acre	Yield Bu./ Acre
0	23
3	25
6	25

TABLE 4. CHEMICAL COMPOSITION OF SOYBEAN TISSUE, LAMBERTON LIME PLOTS, 1967

Lime Treatment Tons/Acre	P	K	Ca	Mg	Zn	Cu	Mo	Mn	B	Sr
	Percent				Parts Per Million					
0	.29	1.46	1.15	.44	35	11	.91	45	56	32
3	.30	1.38	1.18	.49	38	12	.95	45	58	35
6	.29	1.42	1.16	.49	39	12	.97	43	57	35

TABLE 5. EFFECT OF LIMING ON SOIL pH, ALFALFA AREA (SERIES 4), LAMBERTON, 1967

Depth Inches	Lime Treatment Tons/Acre		
	0	3	6
		Soil pH	
0-3	5.7	5.6	6.0
3-6	5.8	6.0	6.1
6-9	5.8	6.1	5.8
9-12.	6.2	6.1	6.0
12-18	6.6	6.4	6.4

TABLE 6 EFFECT OF LIMING ON SOIL pH, CORN-SOYBEAN AREA (SERIES 5) LAMBERTON, 1967

DEPTH INCHES	LIME TREATMENT, TONS/ACRE 0	3	6
	Soil pH		
0-3	6.0	6.2	6.6
3-6	6.0	6.0	6.3
6-9	6.0	6.1	6.3
9-12	6.3	6.3	6.4
12-18	6.9	6.7	6.8

TABLE 7. PHOSPHORUS AND POTASSIUM SOIL TESTS, ALFALFA AREA, LAMBERTON LIME PLOTS, 1967

Depth, Inches	Lime Rate, Tons/Acre 0	3	6	Lime Rate, Tons/Acre 0	3	6
	Extr. P, p.p. 2m			Exch. K, p.p. 2m		
0-3	165	157	166	450	500	450
3-6	59	66	48	250	260	230
6-9	42	30	32	240	230	220
9-12	6	6	7	220	210	210
12-18	5	5	5	200	210	190

TABLE 8. PHOSPHORUS AND POTASSIUM SOIL TESTS, CORN-SOYBEAN AREA, LAMBERTON LIME PLOTS, 1967

Depth Inches	Lime Rate, Tons/Acre 0	3	6	Lime Rate, Tons/Acre 0	3	6
	Extr. P, p. p. 2 m.			Exch. K, p. p. 2 m.		
0-3	61	47	54	325	315	305
3-6	42	36	43	265	270	280
6-9	30	33	27	235	265	230
9-12	10	12	8	215	240	200
12-18	3	2	3	210	215	190

ROSEMOUNT SOILS FARM

Rosemount Agricultural Experiment Station

1967

Paul M. Burson

GENERAL CONDITIONS AND RESULTS

The year 1967 was a very unusual year as far as moisture and temperature conditions were concerned. The moisture range was from one extreme to the other. April was wet with 4.56 inches of rain in the first 21 days. No more rain came until May 1st and 2nd with 1.4 inches. The total for May was only 2.05 inches which left the remainder of May and the first 4 days of June very dry. The remainder of June received 10.0 inches. No field work or plot harvest was done in June. All alfalfa plot and field harvest was delayed until after July 1. The remainder of the season was dry with only .59 of an inch of rain coming in September. As a result of the dry and cool May during corn and soybean planting, the stands were injured by slow uneven germination, emergence and a poor stand. As far as corn was concerned the stands were reduced from 2500 to more than 3000 plants per acre. The greatest reduction in stand resulted in the plantings made after May 20th. In the case of soybeans the difference in emergence resulted in a large proportion of small immature beans in the fall. The general reduction in corn yield ranged from 20.0 to 25.0 bu. per acre as compared to the more nearly normal years. Soybean yields were reduced in similar proportion. Some plots and fields were drowned out in June and were not harvested. Parts of other wet fields were plowed in mid-summer to control weed growth.

All corn and soybeans were planted in 30 inch rows in 1967. The Soils Department was the only department at Rosemount to plant in 30 inch rows. The planting rate of corn in 1967 was 26,000 seeds per acre. The final average stand was reduced to 20,000 to 21,000 plants per acre which was about 80% of the planting rate. In normal seasons the final stand is about 12% less than the planting rate.

All banded and broadcast fertilizer treatments were based on soil test. On corn and soybeans the banded fertilizer was applied at 300 lbs. per acre of 4-12-36. For corn the actual N was 160 lbs. per acre on continuous and 2nd year corn following alfalfa. On 1st year corn following alfalfa the actual N was 100 lbs. per acre. When the N was sidedressed on corn it was applied at the first cultivation. The basic weed spray treatments were Atrazine and Randox. On continuous corn Atrazine was used but where soybeans were included in the rotation Randox or Treflan or Ramrod was used. Dowpon was used to control grasses on all fields being seeded to alfalfa. Root worm injury has appeared from year to year as well as in 1967. Injury has appeared on all check areas with the most serious on the continuous corn plots. However, regardless of the cropping system used, no root worm injury has appeared on any of the areas where a regular fertilization program is being carried out from year to year.

30 inch vs. 40 inch row spacings for corn

In 1967 all the corn and soybeans on the Soils Farm were planted in 30 inch rows with a J. D. 4-row Flexi Integral Toolbar planter. This planter can be adjusted from 40 inch to any width down to 20 inch rows. Comparisons were made on corn at 40 and 30 inch row spacing with each row spacing planted at the rate of 26,000 kernels per acre.

The yield on the 30 inch check was 90.0 bu. per acre. However, with this same spacing but banded with 300 lbs. per acre of 4-12-36 and sidedressed at the first cultivation with 160 lbs. of actual N per acre the yield was 134.0 bu. per acre. With all fertilizer conditions being the same, except where the row spacing was 40 inches, the yield was 124.0 bu. per acre, or an increase of 10.0 bu. per acre in favor of the 30 inch row spacing.

Atrazine was broadcast and harrowed in after planting for weed control. This field No. 18, has been in continuous corn since 1952.

Corn in Crop Rotation System

The 1st year of corn following alfalfa hay had top yields in 1967 ranging from 135.0 to 145.0 bu. per acre depending on the time of planting and the physical condition of the soils. The early plantings, in the 1st week of May, were better than the later plantings. The fertilizer treatments included banded placement at 300 lbs. per acre of 4-12-36 and 100 lbs. of actual N per acre sidedressed at the 1st cultivation and 300 and 600 lbs. per acre of 0-20-20 broadcast and plowed down every 3rd year beginning in 1959. The check yields ranged from 64.0 to 100.0 bu. per acre. The yields further indicate that the basic broadcast treatment of 300 and 600 lbs. per acre that the 300 lb. rate was just as effective as the 600 lb. rate per acre. In the comparison of the band method of placement as to the broadcast method, one about offsets the other as the basic fertility level becomes higher.

Corn grown following a green manure crop of alfalfa with the same combination of fertilizer treatments and same methods of placement as on the 1st year of corn following alfalfa hay, the yields were practically the same. This would seem to indicate the importance of the alfalfa legume crop in the rotation regardless how long the alfalfa remained in the crop rotation.

On the 2nd year corn following alfalfa hay the same fertilizer treatments and methods of placement were used, except that 160 lbs. of actual N was sidedressed at the 1st cultivation. The top yields ranged from 130.0 to 135.0 bu. per acre with broadcast, band and sidedressing combination of fertilizer rates and methods of placement. However, where no fertilizer band and sidedressing placement were used the yields ranged from 54.0 to 60.0 bu. per acre even though the usual broadcast treatments were made. Where band and broadcast were used the yields ranged from 113.0 to 122.0 bu. per acre but when 160.0 lbs. of actual N per acre was sidedressed at the 1st cultivation the yields went up to 136.0 bu. per acre. This would seem to indicate that the benefits of the legume nitrogen in the rotation was exhausted after the 1st year of corn and that N was the most limited nutrient.

CONTINUOUS CORN CROPPING SYSTEM

There are 4 fields on the Soils Farm at Rosemount that have been in continuous corn from 7 to 15 years. These fields in 1967 did not produce as well as the fields that have been in a regular crop rotation system. The check yields ranged from 50.0 to 90.0 bu. per acre. Banded fertilizer at 300 lbs. per acre of 4-12-36 with no N produced yields ranging from 95.0 to 112.0 bu. per acre. However, when 160 lbs. of actual N was sidedressed at the first cultivation, the yields ranged from 116.0 to 135.0 bu. per acre. The lower yields were on soils that have been eroded, on slopes around 6% and were lower in organic matter and nitrogen. The basic broadcast plow-down placement in combination with the other fertilizer methods of placement, did not change the yields per acre. Again the band and the broadcast placement methods about offset each other after the basic fertility had been much improved. Throughout the years, the corn in rotation with no fertilizer has out-yielded the continuous corn with no fertilizer by at least 20.0 bu. per acre. This indicates the difference in favor of a crop rotation or better land use on upland rolling soils that have been previously eroded and are still subject to soil erosion losses in seasons of higher rainfall intensity.

BROADCAST PLOW-DOWN WITH BAND AND POP-UP (STARTER) FERTILIZER FOR CORN

Trials were continued in 1967 with pop-up (starter) placement with band, broadcast and with band + broadcast. The results for 1967 were erratic because of the extreme variation in moisture conditions with a very dry May during planting and germination time and then followed by a very wet June. In June a number of the plots were drowned out and later were plowed to control weed growth. Emergence varied as much as 2 weeks because of the dry May. At the 1st. cultivation the late emerging corn was covered which helped to reduce the overall stand. The late emerging corn would have

produced a high proportion of soft and unmarketable corn.

Table 1. Pop-up (Starter) and Band Placement with Variable Rates of Broadcast Fertilizer for Corn - 1967.

Plot No.	Fertilizer Treatments	Yields in Bu. per acre					
		Check	Lbs. Fertiiizer per acre Broadcast				
			300	450	600	750	
1	Check	73.0	71.0	89.0	88.0	87.0	
2	Check + N(2)	125.0	126.0	129.0	131.0	116.0	
		Pop-up (Starter) 10 - 30 - 12 (Dry)					
3	10 lbs. NK + N (4)	119.0	117.0	125.0	114.0	119.0	
4	15 lbs. NK + N (4)	90.0	81.0	88.0	80.0	81.0	
5	20 lbs. NK + N (4)	88.0	95.0	105.0	93.0	83.0	
6	10 lbs. NK + B(3) + N	136.0	134.0	139.0	134.0	131.0	
7	15 lbs. NK + B(3) + N	136.0	134.0	144.0	146.0	142.0	
8	20 lbs. NK + B(3) + N	131.0	124.0	128.0	121.0	129.0	
9	Band + N	106.0	104.0	111.0	105.0	91.0	Too wet
		Pop-up (Starter) 7-21-7 (Liquid)					
10	10 lbs. NK + N	119.0	123.0	136.0	139.0	122.0	
11	15 lbs. NK + N	123.0	113.0	127.0	119.0	129.0	
12	20 lbs. NK + N	119.0	114.0	121.0	131.0	121.0	
13	Band + N (4)	105.0	112.0	119.0	110.0	107.0	
14	10 lbs. NK + B + N	142.0	125.0	130.0	132.0	146.0	
15	15 lbs. NK + B + N	131.0	124.0	126.0	126.0	131.0	
16	20 lbs. NK + B + N	132.0	133.0	137.0	129.0	127.0	
17	Band (5)	82.0	80.0	104.0	105.0	91.0	Too wet
18	Check (5)	Too wet and too poor to harvest.					
	Fields 7 and 8						

(1) 4-12-36 plow-down in spring.

(2) 160 lbs. N broadcast and disked in before planting.

(3) 300 lbs. per acre banded (2" X 2")

(4) These plots were on the upper side of the field strips 6 and 7 and were very dry. Extending from these strips the moisture conditions were more favorable.

(5) On plots 17 and 18 there was excessive moisture that ruined the yield results.

Planting date - May 16

In Table 1, pop-up (starter) placement with band and different rates of broadcast placement indicate some increase in yield for a combination of band and broadcast placement over the starter. There was no injury to stand where the pop-up (starter) was used. There appeared to be no difference between the liquid and dry pop-up (starter) in yield and stand. Nitrogen was the most important single nutrient on these trials. No broadcast treatments had ever been applied on these fields so the basic fertility was about average to medium. The variations in treatments are generally the result of variable moisture and soil conditions. The planting date of May 16 was getting too late because of the continued dry weather for the remainder of May. All pop-up (starter) was applied at 3 rates of 10, 15, and 20 lbs. per acre for a total N and K. The two grades of fertilizer used was 10-30-12 (dry) and 7-21-7 (liquid).

Table 2. Broadcast, Band and Pop-up (starter) Fertilization for Corn - 1967.

Fertilizer Treatments	Yield in bu. per Acre			
	Lbs. Broadcast Placement per Acre (1)			
	Check	300 lbs. 1967	300 lbs. 1967 600 lbs. 1966	600 lbs. 1966
Check (North)	106.0	103.0	73.0	76.0
Check + N(1)	111.0	101.0	106.0	100.0
Band (2)	106.0	95.0	88.0	103.0
Band + N	137.0	130.0	134.0	136.0
Check (South)	85.0	88.0	47.0	66.0
	12-24-12 Dry Pop-up (Starter) (3)			
NK-10 lbs. + N	115.0	114.0	122.0	125.0
NK-15 lbs. + N	124.0	126.0	111.0	113.0
NK-20 lbs. + N	129.0	124.0	116.0	116.0

Field 34A
Planted May 15

(1) Nitrogen sidedressed at first cultivation at 160 lbs. of actual N per acre

(2) Band fertilizer at 300 lbs. per acre of 4-12-36

(3) Pop-up (Starter) applied with the seed at planting time of 10, 15, and 20 lbs. total N and K.

1967 broad cast fertilizer was 4-12-24 was applied to fall plowing and thoroughly disked in.

Cropping system - corn - soybeans - corn - soybeans

The purposes of the trials reported in Table 2 were to determine the residual carry-over of broadcast plow-down placement in 1966 with the broadcast plow-down made in 1967 in combination with pop-up (starter) and band placement. Here again N was the most important essential nutrient. Rates of the pop-up (starter) were 10, 15, and 20 lbs. per acre of total N and K as 12-24-12 (dry) grade. These results again reflect the variability

in moisture conditions since the planting was too late (May 15) when the remainder of May was very dry. The rate of 300 lbs. broadcast was the same rate per acre as that used in the band to see how the 2 placement methods would compare. Custom services are suggesting they apply all the basic fertilizer needs in the fall as plow-down and the farmer will then apply a small amount of starter in the spring at planting time. It would appear that the broadcast fertilizer in 1967 was as effective as the same grade and same amounts per acre placed in a band.

CORN AND SOYBEAN FERTILIZATION WITH BROADCAST, BANDED AND POP-UP (STARTER) PLACEMENT

Trials were continued in 1967 with various methods of fertilizer placement on corn and soybeans. Because of the extremely dry weather in May at planting time, some additional results were obtained on both corn and soybeans. Soybeans are not as sensitive to fertilizer salts of N and K as is generally believed but are more sensitive than corn. However, some of the better soybean producers in Minnesota are reporting excellent results from pop-up (starter) on soybeans. As the basic soil fertility is increased by use of the fall plow-down placement, the total amount of N and K can be reduced. Even under the variable moisture conditions in 1967 on some of the older fields with longer programs of fall plow-down, 15 lbs. per acre of total N and K were just as effective as the higher rates of 20 lbs. As planting dates were delayed following the first of May, all fertilizer methods of placement seem to appear less effective. Especially was this true when plantings were made after May 15th. Under that dry weather conditons with soybeans planted May 29 when both liquid and dry pop-up (starter) fertilizers were compared, the liquid fertilizer was much better as is shown by the yields given in Table 4. On this same field a comparison of two planting rates of soybeans of 60 and 45 lbs. per acre. Table 4 shows the yields were comparable which tends to bear out why some of the better

soybean producers are planting at lighter rates per acre. Tables 2 and 3 on both corn and soybeans planted May 15 indicate the difference in comparative yields from treatment to treatment placement apparently because of more favorable moisture conditons at that time of the month. On the very late planting date of soybeans on Field 37 when the liquid and dry pop-up (starter) fertilizers were compared there apparently was a greater diffusion of the injurious fertilizer salts of N and K where liquid fertilizer was used. Injury to stand from the dry fertilizer was easily visible from 1/8 of a mile away. In Field 35A, Table 3, soybeans planted on May 15, there was no injury to stand that could be determined from the use of the dry pop-up (starter) fertilizer at the rates of 10 and 15 lbs. total N and K per acre. However, there was injury to stand at the 20 lbs. total N and K rate per acre. Pop-up (starter) advanced tasseling of corn about 4 to 6 days and resulted in at least 2.0% to 3.0% less moisture in the grain at harvest time.

Table 3. Broadcast, Band and Pop-up (starter) Fertilization for Soybeans - 1967

Fertilizer Treatments	Yield in bu. per acre			
	Lbs. Broadcast Placement per Acre (1)			
	Check	300 lbs. 1967	300 lbs. 1967 600 lbs. 1966	600 lbs. 1966
Check	26.6	26.6	28.3	26.6
Band (2)	26.6	28.3	28.3	28.3
NK-10 lbs. (3)	30.0	25.0	31.6	30.0
NK-15 lbs. (3)	31.6	28.3	31.6	28.3
NK-20 lbs. (3)	26.6	28.3	26.6	28.3

Field 35A

Planted May 15.

(1) Broadcast fertilizer was 4-12-24 in 1966 (plow-down) and 4-12-24 in 1967 (Disked in thoroughly).

(2) Band placement was 4-12-36 at 300 lbs. per acre.

(3) Pop-up (starter) was applied at 10, 15, and 20 lbs. per acre total N and K in contact with the seed at planting time. (12-24-12-dry).

Variety - Merit

Weed Spray - Banded with Randax.

Cropping system -- Soybeans - Corn - Soybeans - Corn.

Table 4. Liquid vs. Dry Pop-up (starter) Fertilizer for Soybeans at Two Planting Rates - 1967.

Fertilizer Treatments	Yield in bu. per Acre							
	60 lbs. planting rate/acre				45 lbs. planting rate/acre			
	Dry (1)		Liquid (2)		Dry		Liquid	
	No Broad-cast	(3) Broad-cast	No Broad-cast	Broad-cast	No Broad-cast	Broad-cast	No Broad-cast	Broad-cast
Check	28.3	28.3	28.3	28.3	23.3	25.0	23.3	25.0
Band (4)	25.0	25.0	25.0	25.0	31.6	30.0	31.6	30.0
NK-10 lbs. (5)	20.0	20.0	26.6	26.6	25.0	21.6	30.0	23.3
NK-10 lbs. + Band	20.0	28.3	23.3	26.6	21.6	21.6	28.3	26.6
NK-15 lbs.	18.3	23.3	28.3	26.6	21.6	15.0	30.0	25.0
NK-15 lbs. + Band	23.3	21.6	30.0	28.3	26.6	15.0	28.3	26.6
NK-20 lbs.	13.3	15.0	28.3	21.6	18.3	13.3	28.3	23.3
NK-20 lbs. + Band	20.0	16.6	28.3	26.6	16.6	13.3	25.0	26.6

Field 37

(1) Dry fertilizer was 10-30-12

(2) Liquid fertilizer was 7-21-7

(3) Broadcast fertilizer was plow-down of 800 lbs. per acre 4-12-24 in spring of 1966.

(4) Band fertilizer was 4-12-36 at 300 lbs. per acre.

(5) Pop-up (starter) was applied at 10, 15, and 20 lbs. per acre total N and K in contact with the seed at planting time.

Variety - Merit

Weed Spray - Jaeflan

Planted May 29 (very dry)

BROADCAST PLOW-DOWN FERTILIZER PLACEMENT WITH BAND AND BAND PLUS SIDEDRESSED NITROGEN ON CONTINUOUS CORN AND CORN IN A CROP ROTATION SYSTEM

Trials were continued in 1967 where a basic broadcast plow-down placement of fertilizer has been made every three years regardless of the crop that appeared in that particular year of the rotation. The grade of fertilizer applied was based on soil test and applied at two rates of 300 and 600 lbs. per acre. This study was started in 1959 using 0-20-20 but because the levels of potash remained at a medium range the grade was changed in 1966 to 4-12-24 and to 4-12-36 in 1967. Additional treatments of band and sidedressing with N were made each year on continuous corn and on corn in three different crop rotation systems based on soil type topography and the degree of erosion. Less row crop was included in the more rolling and eroded soils. The rotations included were corn-oats-alfalfa hay (2 years), corn-soybeans-oats-alfalfa hay (1 year), and corn-soybeans-grain (alfalfa, green manure)-corn-oats-alfalfa hay (1 year). In 1966 the oats were discontinued because of their shattering at combining time that resulted in a volunteer growth in the fall that injured the stand and yield of the alfalfa hay crop the following year. Instead of the oats crop the fields are sprayed for grassy weed control in the spring and the alfalfa is then seeded in June. As a result of this practice the alfalfa hay yields have increased by at least 35 percent over the practice of seeding with a companion crop of oats. The yields of corn given in Tables 5 and 6 show the advantage of a crop rotation as compared to continuous corn. Yields increased from 68.4 bu. per acre for continuous corn to 77.0 bu. per acre for corn in the rotation. No fertilizer has ever been applied to these check areas. The big increase in yield when comparing the two cropping systems is the increase in response to nitrogen on the continuous corn. Yields can be comparable on

continuous corn if sufficient nitrogen is applied to make up for what is not supplied by the legume crop in the rotation. Difference over the years in favor of the rotation on the rolling and eroded soils have generally averaged above 20.0 bu. per acre in favor of the crop rotation system. There appears to be very little difference between the 300 and 600 lbs. rate of broadcast fertilizer. The band plus nitrogen about off-sets the band plus broadcast plus N. In Table 6 where the cropping system was continuous corn since 1956 the yields are generally much lower than the corn yields in a crop rotation system with the same fertilizer treatments and placement. In Table 7 similiar yields without broadcast fertilizer placements were obtained under the continuous corn cropping systems. These soils are not subject to erosion and have been cropped to continuous corn since 1952 except for fields 19A and 24A that have been in continuous corn since 1959. The check yield of 68.4 bu. per acre reflect the need for fertilizer or show the reduced level of fertility in terms of yields where no fertility and organic matter is added except from the corn stalk residue.

Table 5. Fertilized Corn Yields in a Crop Rotation System with Broadcast and Band Fertilizer Placement - 1967

Fertilizer Treatments	Yield in bu. per acre						
	Check	1959 1962 1965		1960 1963 1966		1961 1964 1967	
		300	600	300	600	300	600
Check	77.0	86.7	85.7	88.2	84.2	87.0	91.2
Band (1)	123.0	117.7	117.2	120.5	118.0	120.2	123.2
Band + N (2)	127.0	131.7	129.7	130.0	133.7	136.7	134.5

Yields includes first and second corn follow alfalfa hay and corn follow a green manure crop of alfalfa.

Fields 19-26-32-36

(1) Banded fertilizer 4-12-36 at 300 lbs. per acre.

(2) Nitrogen sidedressed at first cultivation with 100 lbs. of actual N per acre. (Ammonium Nitrate)

Table 6. Fertilized Corn Yields in a Continuous Corn Cropping System with Broadcast and Band Fertilizer Placement - 1967.

Fertilizer Treatments	Yield in bu. per acre						
	Check	1959 1964 1966		1960 1964 1967		1961 1964 1967	
		300	600	300	600	300	600
Check	70.0	64.5	78.0	79.0	76.5	84.5	94.5
Band (1)	103.7	107.5	111.5	110.0	116.5	116.0	120.0
Band + N (2)	125.0	125.0	134.0	125.5	132.0	125.5	123.0

Fields 10 and 31

(1) Banded fertilizer 4-12-36 at 300 lbs. per acre

(2) Nitrogen sidedressed at first cultivation with 160 lbs. of actual N per acre. (Ammonium Nitrate)

Table 7. Fertilized Corn Yields in a Continuous Corn Cropping System with Band Fertilizer Placement - 1967.

Fertilizer Treatments	Yield in bu. per acre
Check	68.4
Band (1)	102.5
Band + N(2)	127.2

Fields 17W-18-18A-19A-24A

Fields 17W-18-18A have been in continuous corn since 1952 --- 19A and 24A since 1959.

(1) Band --- 4-12-36 at 300 lbs. per acre.

(2) Nitrogen sidedressed at first cultivation at 160 lbs. per acre of actual N.

LIME AND MANURE ON CONTINUOUS CORN - 1967

On field 48 that has been in continuous corn since 1952, limed at 3 tons per acre in the fall of 1961 and has received 10 tons of manure per acre, per year trials were continued to compare lime and no lime for corn.

Many of the plots were drowned out in June following the dry month of May so the yield results are not complete for 1967. The results are shown in the following table.

Soil Treatments	Yields in bu. per acre
Check	69.0
Manure	116.0
Manure-lime	126.0
Band (1)-manure-lime	128.0 (Too wet)

Planted May 9

(1) Band --- 6-24-12 at 175 lbs. per acre.

Weed Control --- Atrazine broadcast after planting and disked in.

As soil fertility levels improve, high plant populations are used and larger amounts of fertilizer are applied . Corn is continuing to show more

response to the application of agricultural limestone.

FERTILIZED ALFALFA YIELDS

Trials were continued on alfalfa production in the various crop rotation systems of land use on crop land. Broadcast plow-down was made every three years regardless of the crop that appeared in that particular year of the rotation. The basic broadcast fertilizer applications included 0-20-20 and 4-12-24 at 300 and 600 lbs. per acre as previously described under the same treatments for corn in rotation. The year 1967 was not a good alfalfa hay year because of the very wet June which delayed hay harvest causing loss of leaves, coarse growth and reduction of the second crop which had started growth before the first hay crop was removed. In comparison to more normal years as far as distribution of moisture the 1967 fertilized hay yields were reduced more than 1.0 tons per. Total yields for 2 cuttings are usually 5.0 tons or more per acre.

Table 8 gives the yields for 2 cuttings of alfalfa hay. The yields in tons per acre compares the broadcast plow-down fertilizer and the yields per acre for the broadcast plow-down plus the residual carry-over of fertilizer applied previous years as a band placement for corn. These data indicate the response that maybe expected from the residual banded corn fertilizer in the improvement of the yield of alfalfa and the increase of the basic soil fertility level as corn fertilization continues in the crop rotation system. Both the broadcast and band placement contribute to the top yields of alfalfa hay.

Table 8. Fertilized Alfalfa Yields - 1967

Cuttings of Hay	Check	Yield in Tons per Acre					
		1959 1962 1965		1960 1963 1966		1961 1964 1967	
		300	600	300	600	300	600
		No Banded Residual Corn Fertilizer					
1st. cutting	2.02	2.24	2.11	2.22	2.42	2.40	2.56
2nd. cutting	1.04	1.36	1.51	1.44	1.60	1.16	1.62
Total	3.06	3.60	3.62	3.66	4.02	3.56	4.18
		Banded Residual Corn Fertilizer					
1st. cutting	1.77	2.36	2.29	2.41	2.43	2.59	2.60
2nd. cutting	1.41	1.67	1.67	1.73	1.79	2.04	2.07
Total	3.18	4.03	3.96	4.14	4.22	4.63	4.67

Fields 22 - 25 - 30.

Variety - Vernal

Alfalfa seeded without companion crop in June.

Continuous Corn - High Fertility Experiment
Rosemount Experiment Station
Established 1953

P. M. Burson, W. P. Martin, and G. W. Randall

This experiment was established in 1953. Yields have been measured annually for 15 years. During this time, soil and plant samples have been periodically taken and analyzed. Yield results from past years may be found in the 1963, 1964, 1965, 1966, and 1967 mimeographed "Bluebook".

Fertilizer treatment rates and population levels have been upgraded throughout the years to the present levels. Over the long term P and K have been applied at approximately a 1 : 1 ratio.

The corn was planted in 30 inch rows on May 16. Atrazine plus one cultivation was used to control weeds.

Yields obtained in 1967 were generally quite good, however, none were exceptionally high (Table 1). A slight response was shown to the first 100 pound increment of N at all levels of P and K. A further N addition of 100 pounds did not significantly increase the yields. Phosphorus and potassium applications gave no yield response. After 15 years yields from the check treatment were still over 100 bushels. A possible reason for this continued high yield may be due to the 4 foot depth of colluvium material on which this experiment is located. This soil would not be typical of most Minnesota soils.

Although some fertilizer response has been shown by the 15 year average yields, no striking yield differences have appeared. This again may be due to the plot location mentioned previously.

Table 1. The fertility treatment and corresponding 1967 and 15 year average corn yields.

Trt No.	Fertilizer Treatment*	1967 Yield** bu/a	15 Year Avg.** bu/a
1	0 + 0 + 0	100.1 a***	84.8
2	12 + 36 + 108	105.1 ab	92.9
3	112 + 36 + 108	114.2 cd	96.6
4	212 + 36 + 108	115.0 cd	99.9
5	28 + 84 + 252	106.4 abc	93.6
6	128 + 84 + 252	117.8 d	100.7
7	228 + 84 + 252	113.9 bcd	100.4
8	44 + 132 + 396	113.5 bcd	97.3
9	144 + 132 + 396	115.2 cd	102.3
10	244 + 132 + 396	113.9 bcd	102.6

* Pounds of $N+P_2O_5+K_2O$ applied this year.
** Combined yield average of the high and low populations at each fertility treatment.
*** Numbers followed by the same letter belong to the same .05 level population (Duncan's Multiple Range Test).

All fertility treatments were tested at two plant populations. Results given in Table 2 show higher yields at the high populations in 1967 and also over the 15 year period.

Table 2. The plant population and corresponding 1967 and 15 year average corn yie

Population plants/acre	1967 Yield * bu/a	15 Year Avg. bu/a
Low 20,000	102.8 a	91.5
High 26,000	120.2 b	102.7

* Combined yield average of all ten fertility treatments at each population.

Sixth leaf samples were taken at the silking stage from all high population plots for tissue analysis. Results are presented in Table 3.

Among the ten fertilizer treatments, highly significant differences were found in the leaf tissue concentrations of N, P, K, Mg, An, Mo and Mn. Concentration of N, P and K increased as the amount of each respective nutrient in the fertilizer treatments was increased. Manganese (Mn) content also increased with the higher fertilizer rates.

Leaf content of Mg, Zn, and Mo decreased with the higher rates of phosphate and potash. However, it appeared that the decreasing trend of Zn was reversed as higher rates of N were applied at eac h P and K treatment.

No significant differences among treatments were found in the tissue content of Ca, Fe, Cu and B.

Table 3. Spectographic analyses of sixth leaf in 1967 of continuous corn under variable fertilizer treatments.

Trt. No.	Fertilizer Treatment	%					ppm						
		N	P	K	Ca	Mg	Sr	Fe	Zn	Cu	Mo	Mn	B
1	0 + 0 + 0	2.54ab	.296a	1.51a	.639a	.448d	6.60c	210a	20.2cd	6.2a	.97c	50.1a	7.1a
2	12 + 36 +108	2.41a	.298a	1.93b	.599a	.339c	4.92abc	198a	14.0ab	5.7a	.82bc	49.3a	6.6a
3	112 + 36 +108	3.09d	.320ab	1.92b	.572a	.340c	5.49bc	207a	23.8d	6.6a	.87c	66.5b	7.0a
4	212 + 36 +108	2.96cd	.324ab	1.95b	.555a	.342c	4.13ab	227a	21.1cd	8.0a	.85c	69.7b	7.5a
5	28 + 84 +252	2.44a	.334abc	2.15bc	.590a	.273b	4.96abc	231a	13.0ab	5.1a	.70ab	65.2b	6.7a
6	128 + 84 +252	2.92cd	.378bcd	2.40cd	.519a	.257ab	4.17ab	228a	17.8bc	6.2a	.68ab	66.7b	7.4a
7	228 + 84 +252	3.03cd	.314ab	1.97bc	.475a	.204a	3.88ab	204a	15.4abc	5.5a	.63a	65.1b	6.5a
8	44 +132 +396	2.66abc	.402d	2.36cd	.528a	.232ab	3.23a	221a	11.8a	5.5a	.69ab	62.7b	6.4a
9	144 +132 +396	2.88bcd	.397cd	2.48d	.512a	.230ab	4.70abc	263a	16.9abc	5.9a	.69ab	83.4c	7.5a
10	244 +132 +396	2.98cd	.407d	2.45d	.546a	.249ab	4.70abc	244a	16.2abc	6.1a	.68ab	96.6d	7.8a
Significance		**	**	**	NS	**	**	NS	**	NS	**	**	NS
F value		5.07	4.48	10.53	1.98	12.60	2.33	1.61	4.38	1.35	4.90	3.47	1.24
CV		8.0	12.1	9.1	12.3	14.2	26.0	14.0	21.3	22.3	13.2	7.1	12.7

Weather Summary - 1967
West Central Experiment Station - Morris
Samuel D. Evans

Month	Period	Precipitation 1967	Precipitation Average 1930-59	Precipitation Deviation from Nor.	Air Temperature 1967	Air Temperature Average 1930-59	Air Temperature Deviation from Nor.	Temp. Soil(10cm) 1967
January	1-31	2.04	.56	+1.48	9.6	10.1	- 0.5	--
February	1-28	1.10	.67	+ .43	4.0	14.7	-10.7	--
March	1-31	.15	1.11	- .96	26.9	27.5	- 0.6	--
April	1-10	.60			37.5			38.8
	11-20	1.71			43.8			43.4
	21-30	.02			41.0			44.0
	Total	2.33	2.05	+ .28	40.8	43.3	- 2.5	42.1
May	1-10	.43			39.9			44.1
	11-20	.08			50.0			50.6
	21-31	.01			60.2			59.9
	Total	.52	3.07	-2.55	50.3	56.6	- 6.3	52.0
June	1-10	3.05			62.9			62.3
	11-20	1.43			65.6			65.4
	21-30	.61			64.2			67.2
	Total	5.09	3.79	+1.30	64.3	66.4	- 2.1	65.1
July	1-10	.72			64.7			67.0
	11-20	.52			68.3			70.3
	21-31	.14			72.0			74.4
	Total	1.38	3.25	-1.87	68.4	71.8	- 3.4	71.1
August	1-10	.59			67.1			69.0
	11-20	.62			68.3			70.5
	21-31	.37			72.0			64.9
	Total	1.58	2.87	-1.29	66.3	69.8	- 3.5	68.0
September	1-30	.59	1.94	-1.35	58.7	59.8	- 1.1	62.3
October	1-31	1.02	1.44	- .42	44.2	48.9	- 4.7	46.5
November	1-30	.07	1.09	-1.02	30.0	30.4	- 0.4	32.4
December	1-31	.92	.59	+ .33	18.0	17.0	+ 1.0	19.8
April 1-August 31 (Growing Season)		10.90	15.03	-4.13	58.1	61.7	- 3.6	59.7
January 1-Dec. 31 Annual		16.79	22.43	-5.64	40.3	43.0	- 2.7	--

Comparison of Phosphorus Sources
West Central Experiment Station
Samuel D. Evans

Plots were established at the West Central Experiment Station in 1967 to determine the effectiveness of 4 phosphorus materials supplied by TVA.

Table 1. Soil test values of the experimental area (McIntosh silt loam)

	Replicate					
	1	2	3	4	5	6
pH	7.4	7.4	7.4	7.4	7.4	7.5
O.M.%	6.2	5.1	6.3	5.7	5.7	5.7
Ext. P	10	8	7	7	18	6
Exch. K	250	250	260	240	270	240

Table 2. Zinc content (ppm) of corn plants harvested 7/10/67.

P source	Applied P_2O_5 - lbs./acre *			
	0	12	24	48
	Zinc in parts per million			
20-20-0 (Nitric Phosphate)	-	22.6	20.9	21.0
29-29-0 (Urea Ammonium Phosphate)	-	22.5	20.6	18.8
15-60-0 (Ammonium Polyphosphate)	-	24.4	22.6	19.7
15-56-0 (Ammonium Orthophosphate)	-	22.3	21.1	21.3
Check (No phosphorus applied)	25.2	-	-	-

* Additional nitrogen was applied to all plots to bring the total to 100 lbs. of actual N per acre. All of the above materials were broadcast and plowed down in the fall of 1966. The starter fertilizer used was 33 1/2-0-0 at 100 lbs./acre.

Table 3. Phosphorus content (ppm) of corn plants harvested 7/10/67.

P source	Applied P_2O_5 - lbs./acre 0	12	24	48
	Phosphorus in parts per million			
20-20-0	-	2750	3100	2975
29-29-0	-	2750	3050	3150
15-60-0	-	2800	2825	3100
15-56-0	-	2800	2850	3150
Check	2725	-	-	-

Table 4. P/Zn ratio of corn plants harvested 7/10/67.

P source	Applied P_2O_5 - lbs./acre 0	12	24	48
	P/Zn ratio			
20-20-0	-	123	151	142
29-29-0	-	123	149	169
15-60-0	-	117	128	158
15-56-0	-	126	136	148
Check	109	-	-	-

Table 5. Yield - Corn bushels/acre @ 15.5% moisture

P source	Applied P_2O_5 - lbs./acre 0	12	24	48
	Ear corn in bushels/acre			
20-20-0	-	66.88	72.90	68.64
29-29-0	-	64.12	71.48	87.02
15-60-0	-	70.96	71.40	72.44
15-56-0	-	68.95	70.82	72.26
Check	59.34	-	-	-

Summary: The urea-ammonium phosphate (29-29-0) significantly decreased the zinc content of the young plants, increased the P/Zn ratio, and increased yield. None of the other materials had a significant effect on these variables.

Variety - Trojan F98 Planted - May 20, 1967

Use of Varying Rates of Nitrogen & Starter on Corn in 1967
West Central Experiment Station - Morris
Samuel D. Evans

In the spring of 1967 an experiment was initiated on Doland silt loam to determine the effect of varying rates of nitrogen and starter on corn yields.

Table 1. Soil test results.

Sample No.	pH	O.M.%	Ext. P	Exch. K
1	6.9	5.5	12	310
2	6.7	5.5	9	260

Table 2. The yield of 1967 ear corn at Morris with varying rates of nitrogen and starter fertilizer.

Nitrogen lbs./acre	Starter (6-24-24) Applied (lbs./acre) 0	50	100	200
	Yield of ear corn @ 15.5% moisture			
0	69.1	72.0	64.8	76.2
50	74.4	76.7	67.4	73.0
150	73.2	83.4	67.7	71.1

Summary: Neither the nitrogen nor the starter fertilizers increased yields significantly over the check. All yields were low due to the dry, cool weather.

Variety - DeKalb XL 304 Planting date - May 17, 1967

Use of Seed Incorporated (Pop-up) Fertilizer
West Central Experiment Station - Morris
Samuel D. Evans

In the spring of 1967 an experiment was initiated to determine the effect of small amounts of seed incorporated fertilizer on early growth and yield of corn. The experiment was set up on a Doland silt loam on which various broadcast fertilizer rates were applied in the fall of 1966.

Table 1. Soil test data of the experimental area.

Sample No.	pH	O.M.%	Ext. P	Exch. K
1	6.9	5.5	12	310
2	6.7	5.5	9	260

Table 2. Yield (bushels/acre @ 15.5% moisture)

Broadcast treatment	Row treatment			
	Check	Pop-up(1)	Starter(2)	Pop-up + starter
100 + 0 + 0	81.2	106.4	113.7	116.4
100 + 25 + 25	52.2	76.5	78.8	83.3
100 + 50 + 50	97.6	88.3	84.7	76.6
100 + 75 + 75	89.6	93.1	95.4	92.8
100 + 100 + 100	104.6	106.6	99.9	96.3

(1) Pop-up - 37.5 lbs. of 8-32-16
(2) Starter - 150 lbs. of 8-32-16

Summary: Due to the dry weather, there was a large variation in yields and therefore no significant difference between treatments. There was no apparent difference in early growth between treatments.

Variety - DeKalb XL 304 Planting date - May 17, 1967

Phosphorus and Potassium Fertilization of Alfalfa
West Central Experiment Station
Samuel D. Evans

In the fall of 1966 an alfalfa fertility experiment was established at the station on Forman clay loam (formerly Barnes). Two cuttings were made in 1967 but dry weather seriously reduced yields.

Table 1. Soil test data of experimental area.

Sample No.	pH	O.M.%	Ext. P	Exch. K
1	7.2	5.7	24	370
2	7.2	5.6	13	480

Table 2. First cutting yields - 1967

P_2O_5 applied	K_2O applied 0	60	120	240	480	Average
	Lbs. alfalfa hay/A @ 15% moisture					
0	3193	3210	3556	3018	3364	3268
57	3148	3431	3169	3380	3344	3294
114	3388	3451	3382	3579	3580	3476
229	3102	3431	3718	3541	4004	3559
458	3564	3518	3674	3262	3829	3669
Average	3278	3408	3500	3456	3624	

Table 3. 2nd cutting yields - 1967

P_2O_5 applied	K_2O applied 0	60	120	240	480	Average
	Lbs. alfalfa hay/A @ 15% moisture					
0	3618	2552	2890	2277	3423	2952
57	2192	2615	2608	2527	3232	2635
114	2680	2690	2826	2469	2558	2645
229	2344	3057	2867	2588	3194	2810
458	3029	2926	2405	2960	3142	2892
Average	2772	2768	2719	2564	3110	

Table 4. Total 1967 yields

P_2O_5 applied	K_2O applied 0	60	120	240	480	Average
	Lbs. alfalfa hay/A @ 15% moisture					
0	6811	5762	6446	5295	6787	6220
57	5340	6046	5777	5907	6576	5929
114	6068	6141	6208	6048	6138	6121
229	5446	6488	6585	6129	7198	6369
458	6593	6444	6079	6222	6971	6561
Average	6050	6176	6219	6020	6734	

Table 5. Analysis of variance.

	1st cut	2nd cut	Total
Reps	NS	NS	NS
Phosphorus rates	*	NS	NS
Potassium rates	NS	NS	NS
P x K interaction	NS	NS	NS

Summary: There was a response to phosphorus fertilization on the first cutting, but the yield increase was not sufficient to pay for the fertilizer used.

Phosphorus Fertilization of Continuous Corn
West Central Experiment Station - Morris
Samuel D. Evans

In 1965 a phosphorus experiment was set up on Forman clay loam to determine: (1) the interaction of row and broadcast levels of phosphorus on corn yields and, (2) the effect of high phosphorus applications on the zinc content of corn leaves and corn yield.

All plots received a uniform row application of 10+0+20 and nitrogen was plowed down at the rate of 120 lbs. of actual N per acre.

1967 Yield

Broadcast P trt. (lbs./acre)	NP treatment (lbs./acre) 0 P	15 P	30 P	45 P	45 P+10 Zn	Average
	Bushels of ear corn/A @ 15.5% moisture					
0 P	64.34	59.52	65.26	62.88	70.63	64.53
45 P	71.76	69.41	65.54	65.02	72.39	68.82
Average	68.05	64.47	65.40	63.95	71.51	

Yields were extremely variable in 1967 due to the dry weather. The coefficient of variation for broadcast treatments was 34.59% and that for row treatments was 19.14%. With these large variations there were no significant differences between treatments. However, the yields again indicate, as those in 1965 and 1966 did, that the use of phosphorus on this soil tends to depress yields slightly and that this depression can be corrected by the addition of 10 lbs. of zinc per acre.

In September 1967, soil was collected from all plots and tested for phosphorus. The results are as follows:

Phosphorus Soil Test, Fall 1967* (1:10 dilution)

Broadcast P trt. (lbs./acre)	Row P treatment (lbs./acre) 0 P	15 P	30 P	45 P	45 P+10 Zn
	Pounds of soil P per acre				
0 P	24.0	23.7	28.8	47.5	47.2
45 P	53.0	67.5	78.0	117.3	92.5
Increase for 45 lbs/P/A applied	29.0	43.8	49.2	69.8	45.3

* Three applications of the annual rates had been made by this date.

Variety - DeKalb XL 304 Planting date - May 16

Zinc Fertilization of Continuous Corn
West Central Experiment Station - Morris
Samuel D. Evans

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

Treatment *	When Applied	Yield Bushels/acre @ 15.5% moisture
Check	----	80.61
5 lbs. zinc as $ZnSO_4$	1965	76.88
10 lbs. zinc as $ZnSO_4$	1965	76.58
10 lbs. zinc as $ZnSO_4$	yearly	84.42
20 lbs. zinc as $ZnSO_4$	1965	87.29
0.5 lbs. zinc as ZnChel.	yearly	72.74
45 lbs. P broadcast	yearly	78.35
45 lbs. P broadcast + 10 lbs. zinc as $ZnSO_4$	yearly 1965	79.77

* Zinc 45 Chelate, ZnChel - all zinc applied in the row at planting time, all plots received a uniform row application of 125 lbs. of 8-32-16, 120 lbs. of actual N was applied in 1967.

Summary: There were large differences in yields due to the dry weather, resulting in a large coefficient of variation (14.87%). Therefore there were no significant differences in yield due to treatment. However, there is an indication of a response to the higher rates of zinc; 10 lbs. yearly and 20 lbs. per acre applied in 1965. Variety - DeKalb XL 304 Planting date - May 15, 1967

Continuous Corn Silage
West Central Experiment Station-Morris
Samuel D. Evans

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

1967 Silage Yields
Dry Matter, tons/acre

On plots harvested as grain 1965-67:

Low fertility	(74+48+48)	- 5.30 tons
High fertility	(148+96+96)	- 5.26 tons

On plots harvested as silage 1965-67:

Low fertility	(74+48+48)	- 5.58 tons
High fertility	(148+96+96)	- 6.05 tons

1967 Grain Yields
Bushels/acre @ 15.5% moisture

On plots harvested as grain 1965-67:

Low fertility	(74+48+48)	87.24
High fertility	(148+96+96)	83.34

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

Grain (0 + 0 + 0) - 32.63 bushels/acre

Silage (0 + 0 + 0) - 3.59 tons/acre

Summary: Three years of continuous corn silage caused no reduction in silage yields. Additional fertilizer above the 74+48+48 did not increase grain or silage yields.

Variety - Pioneer 3681 Planting date - May 20, 1967

Corn Irrigation Experiment
West Central Experiment Station-Morris

L. K. Lindor, S. D. Evans, and R. E. Smith

In the spring of 1967 an experiment was initiated at the station on a shallow river bottom soil to determine the effect of irrigation on corn at three populations, namely 16,000, 22,000, and 28,000 plants per acre and three nitrogen rates of 60, 120, and 180 pounds of actual nitrogen per acre. The irrigated portion was compared to an unirrigated check where the population was 16,000 plants per acre and the nitrogen rate was 60 lbs. per acre.

Table 1. Soil test results.

Sample No.	pH	O.M.%	Ext. P	Exch. K
1	7.3	over 8.5	3	240
2	7.0	over 8.5	3	200

The variety Trojan F98 was planted on May 22. Starter was applied at the rate of 200 lbs. of 6-24-24 per acre. A total of 11 inches of water was applied starting on July 21 with 2 inches being applied per irrigation at about 10 day intervals. Tensiometers were used to determine the time of irrigation and water was applied before the tension reached 1/2 atmosphere.

Table 2. Corn yields.

Nitrogen rate lbs/acre	Populations 16,000	22,000	28,000	Average
	Bushels of ear corn @ 15.5% moisture			
60	92.38	96.74	103.70	97.61
120	103.80	109.93	105.63	106.46
180	100.70	107.71	106.58	104.98
Average	98.96	104.79	105.31	

Unirrigated check (16,000 plants/acre & 60 lbs. N/acre)

18.66 bu/acre

Summary: One year's results on this soil indicate the maximum yield occurred at a population of 22,000 plants/acre and a nitrogen level of 120 lbs./acre.

TVA TEST DEMONSTRATION ACTIVITIES

H. L. Meredith & J. O. Jacobson

In 1967 corn plots were established to study varietal differences and the influence on yield as a result of fertilization.

Fourteen hybrid varieties were evaluated in 13-inch rows at 37,000 plants per acre and in 30-inch rows at 32,000 plants per acre. These data appear in Table 1.

Table 1. Yield of corn and percent moisture of 14 varieties grown on an Estherville sandy loam at Verndale, Minnesota 1967.

			Yield, Bu/A (15.5% moisture)	
Company	Variety	Moisture	13" rows 37,000 Pop.	30" rows 32,000 Pop.
Pride	R-200	31.3	145	142
Northrup-King	PX-22	33.6	136	97
Pioneer	3985	19.9	135	150
Pfister	SX-48	26.2	133	110
Funks	4170	18.0	132	93
DeKalb	XL-304	22.4	132	86
Trojan	TXS-102	35.8	131	Silage
Jacques	900J	25.9	122	131
Trojan	TX-90	19.7	111	123
Jacques	J-952	23.7	108	101
Jacques	JX-853	26.8	101	70
United Haggie	UH-108*	17.5	97	106
United Haggie	UH-127A	36.1	87	84
DeKalb	XL-307*	24.5	86	109

* Because of the location of the plot relative to the irrigation boom, the UH-108 and XL-307 plots likely did not receive sufficient water.

Shelling percentage ranged from 78 to 84.5 on the above samples. Samples were collected for spectrographic analysis at various stages of development to study uptake patterns, Table 2.

Table 2. Nutrient composition of various stages of development, Estherville sand, Verndale, Minnesota 1967.

		CORN SAMPLES (Leaves)								
Date		P	K	Ca	Mg	Zn	Cu	Mo	Mn	B
6/23/67	HF*	0.710	3.43	0.50	0.20	87.4	13.2	0.33	93.0	6.8
"	FF	0.877	3.30	0.41	0.21	44.6	5.9	0.27	81.0	5.3
7/6/67	HF	0.528	2.81	0.47	0.20	75.9	6.25	0.43	85	8.5
"	FF	0.462	2.66	0.42	0.21	50.3	6.17	0.50	53	5.5
7/17/67	HF	0.364	2.21	0.86	0.26	97.1	7.9	0.50	115.7	4.4
"	FF	0.382	2.61	0.79	0.31	70.7	6.4	0.67	89.7	6.2
8/2/67	**HF	0.366	2.48	0.90	0.31	46.8	6.5	0.67	74.1	4.8
"	FF	0.330	2.47	0.72	0.33	28.0	7.1	0.79	47.3	4.7

* High Fertility (HF) 320-120-400
(40# zinc sulfate/acre)
(20# copper sulfate/acre)
(1# Boron/acre)

Field Fertility (FF) 195-60-270 (No micronutrients)
(150# 10-40-20 starter)
(400# 0-0-60 broadcast)
(600# 30-0-0 broadcast)

**Silking stage

Spectrographic analysis was determind at silking stage for 14 varieties. This data appears in Table 3.

TABLE III.

PLANT ANALYSIS-Corn (6th leaf)

Variety	P
Funks 4170	0.4281
Jacques TX853	0.4119
Jacques 900J	0.3696
UH 108	0.3655
DeKalb XL307	0.3575
UH127A	0.3496
DeKalb XL304	0.3436
Jacques TX952	0.3436
Pride R-200	0.3337
Trojan TX90	0.3257
Pioneer 3985	0.3257
NKPX22	0.3218
PAGS X48	0.2981
Trojan TXS102	0.2903

AVE: .3474
Range: .4281-2903
% Range: 47.4

Variety	K
UH127A	2.7937
DeKalb XL304	2.6207
Pioneer 3985	2.5543
Trojan TX90	2.5422
Funks 4170	2.4947
UH108	2.4787
Jacques TX853	2.4267
DeKalb XL307	2.3944
NKPX22	2.3457
Jacques 900J	2.3376
Pride R-200	2.3376
PAGS X48	2.2266
Jacques TX952	2.1683
Trojan TXS102	1.8864

AVE: 2.4004
Range: 2.7937-1.8864
% Range: 48.0

Variety	Ca
UH108	0.90040
Trojan TXS102	0.8778
DeKalb XL307	0.8336
PAGSX48	0.8000
UH127A	0.7657
Funks 4170	0.7544
DeKalb XL304	0.7478
Pride R-200	0.6990
Pioneer 3985	0.6904
Jacques TX952	0.6861
Jacques 900J	0.6661
Jacques TX853	0.6606
NKPX22	0.6470
Trojan TX90	0.6213

AVE: .7538
Range: .9040-.6213
% Range: 45.5

Variety	Mg
Trojan TXS102	0.3707
DeKalb XL304	0.3118
UH108	0.3103
DeKalb XL307	0.2983
UH127A	0.2897
Pride R-200	0.2548
Funks 4170	0.2403
NKPX22	0.2308
Pioneer 3985	0.2214
Trojan TX90	0.2148
PAGS X48	0.1976
Jacques 900J	0.1805
Jacques TX952	0.1674
Jacques TX853	0.1305

AVE: .2442
Range: .3707- .1305
% Range: 185

Analyses of 6th Corn Leaf (TVA)

Variety	Zn
PAGS X48	68.3040
Jacques TX952	67.5449
Jacques TX853	65.5700
Jacques 900J	63.4412
Trojan TXS102	53.9878
UH108	46.7926
Funks 4170	46.0257
Trojan TX90	44.0302
DeKalb XL304	43.7231
Pioneer 3985	41.1102
UH127A	40.3410
NKPX22	39.4176
Pride R-200	39.2637
DeKalb XL307	36.7989

AVE: 49.7393
Range: 68.3040 - 36.7989
% Range: 85.6

Variety	Mo
DeKalb XL304	0.7537
DeKalb XL307	0.7139
UH108	0.6746
Trojan TXS102	0.6164
Pride R-200	0.5215
Trojan TX90	0.5029
UH127A	0.5029
Pioneer 3985	0.4659
NKPX22	0.4659
Funks 4170	0.4476
PAGSX48	0.4112
Jacques TX952	0.4112
Jacques TX853	0.4112
Jacques 900J	0.3396

AVE: .5170
Range: .7537 - .3396
% Range: 121.8

Variety	Cu
DeKalb XL304	7.92
Pioneer 3985	7.85
Trojan 102	7.63
NKPX22	7.56
Trojan TX90	7.49
UH127A	7.13
PAGSX48	6.99
Pride R-200	6.99
DeKalb XL307	6.70
UH108	6.49
Funks 4170	6.20
Jacques 900J	5.70
Jacques TX853	5.63
Jacques TX952	5.55

AVE: 6.845
Range: 7.92 - 5.55
% Range: 42.7

Variety	Mn
Jacques 900J	135.7120
Jacques TX853	110.2313
DeKalb XL307	96.8643
PAGS X48	92.3467
Funks 4170	89.4565
Jacques TX952	82.5327
DeKalb XL304	81.8815
UH108	74.1294
NKPX22	70.0554
Pride R-200	66.3987
Trojan TX90	65.2839
Trojan TXX102	62.7566
UH127A	61.8374
Pioneer 3985	59.4884

AVE: 82.0696
Range: 135.712 - 59.488
% Range: 128.1

Analysis of 6th Corn Leaf (TVA)

Variety	B
Jacques TX952	6.1637
DeKalb XL304	6.1061
Funks 4170	4.8941
DeKalb XL307	4.8941
UH108	4.8363
Trojan TX90	4.8363
Trojan TXS102	4.8363
Jacques 900J	4.6048
Jacques TX853	4.5469
UH127A	4.4890
NKPX22	4.2572
Pride R-200	4.1992
PAGSX48	4.1413
Pioneer 3985	4.0833

AVE: 4.7777
Range: 6.1637-4.0833
% Range: 50.9

A nitrogen study was conducted to determine the most feasible rate of nitrogen to apply. These data are presented in Table IV.

TABLE IV. Nitrogen Application Rates, Yields of No. 2 Corn and pH, Esterville Sand, Verndale, Minnesota 1967.

Nitrogen Applied #/Acre	Yield Bu/Ac (15.5% H_2O)	Soil pH
12	53	6.2
62	103	6.2
112	88	5.8
162	111	5.9
212	122	5.9
262	130	5.5
312	128	5.5
412	100	5.6

Percent Protein on Corn Grain in 13" Row Width

It was convenient to determine the variation between varieties on a protein basis in this study. Kjeldahl results appear in Table V. The values for protein were adjusted to 15.5% moisture to give a more realistic interpretation.

TABLE V. Percent Protein of Hybrid Varieties, Grain

Hybrid	%N	% Protein	#2 Corn, 15.5% H_2O % Protein	Yield Bu/Ac #2 Corn	Pounds, Total Protein/Acre in Grain (% Protein X Yie
DeKalb XL-307	2.00	12.50	10.56	86	908
Pride R-200	1.91	11.94	10.09	145	1463
Jacques 900J	1.87	11.69	9.88	122	1205
United Haggie 127A	1.86	11.62	9.82	87	854
DeKalb XL-304	1.86	11.62	9.82	132	1296
Trojan TX-90	1.86	11.62	9.82	111	1090
Trojan TSX-102	1.83	11.44	9.67	131	1267
United Haggie 108	1.81	11.31	9.56	97	927
Funks 4170	1.78	11.12	9.40	132	1241
Northrup King Px-22	1.76	11.00	9.29	136	1263
Jacques J952	1.73	10.81	9.13	108	986
Jacques 853	1.66	10.38	8.77	101	1158
Pfister SX-48	1.65	10.31	8.71	133	1158
Pioneer 3985	1.65	10.31	8.71	135	1176

Spectrographic analysis was determined on the mature grain following harvest. These values are on an oven-dry basis, Table VI.

TABLE VI. SPECTROGRAPHIC ANALYSIS OF CORN GRAIN OF 14 HYBRIDS.

Hybrid	%P	%K	% Ca	% Mg	ppm Zn	ppm Cu	ppm Mo	ppm Mn	ppm B	ppm Fe
900J	.30	.28	*	.11	20.8	3.3	*	6.6	*	16.7
UH-127A	.43	.47	*	.14	26.1	*	.93	6.6	1.8	26.6
SX-48	.30	.27	*	.11	21.3	*	*	6.5	*	17.6
952	.36	.34	*	.13	24.7	*	*	7.5	*	21.2
XL-304	.35	.32	*	.12	23.6	3.5	.51	7.3	*	23.9
XL-307	.36	.38	*	.15	37.0	*	*	8.3	1.2	27.5
R-200	.29	.32	*	.11	23.8	3.6	*	5.4	*	20.3
4170	.36	.33	*	.13	23.3	*	*	6.3	*	31.1
TXS-102	.33	.35	*	.13	25.8	4.4	*	7.1	1.0	16.7
TX-90	.42	.38	*	.14	33.0	*	*	7.5	1.6	30.2
PX-22	.35	.40	*	.13	25.2	*	*	5.5	*	27.5
3985	.38	.42	*	.13	23.8	3.9	.60	6.5	1.3	49.1
UH-108	.36	.37	*	.13	28.4	5.5	*	7.6	1.0	16.7
J-853	.36	.34	*	.14	23.3	*	*	7.1	*	14.0

* Indicates value in tissue lower than following:

Ca - less than 0.005%
Cu - less than 1.5 ppm
Mo - less than 0.25 ppm
B - less than 0.5 ppm

Effect of Irrigation, Fertility Level and Plant Population on Corn and Alfalfa at Park Rapids, Minn. 1967 - A. C. Caldwell, J. Grava, E. C. Seim, G. Rehm, E. R. Allred, J. Eix, J. B. Swan

A demonstration of the interaction of two fertility management levels with water management on a sandy loam soil (Dorset) in north central Minnesota produced outstanding evidence that neither moisture nor fertility can be neglected if profitable yields are to be achieved. Population levels were chosen in accordance with the water management level. Two 85 day hybrids and one 65 day hybrid were used in the demonstration.

The field received 9.70 inches of precipitation during the growing season. July and August rainfalls were three inches less than normal. The irrigated plots received a total of 17 inches of water applied on a schedule of 1 1/2" - 2" every 7 days adjusted for natural rainfall.

Temperature averaged below normal in May, June, July and August. In May the average monthly temperature was 48.1 F, or 5.1° below the normal average. The growth degree days (GDD50°) totaled 1768 for the 1967 growing season. This is 166 less than the GDD50° reported in 1966 but is much better than the 1529 GDD50° recorded for 1965.

Table 1 lists the hybrids and populations used for the study. Table 2 shows the average yield of all three hybrids for each fertility and water management level. Tables 3, 4, 5 show the yields, moisture at harvest, shelling percentage, actual population at harvest and % barren stalks for each hybrid.

Low fertility (100# 5-10-30 as starter) and low population levels (6-17000 plants/acre) produced 23.3 bu./acre of #2 corn without irrigation. Full fertility treatment (240# N, 25# P, 200# K, 25# S, trace applications of B, Zn and Cu, and 40# of 5-10-30 starter) without irrigation actually reduced yields by 7.7 bu. during this exceedingly dry year. Irrigation and increased populations (25 - 50000 plants/acre) without additional fertility inputs over the 100# of 5-10-30 starter produced a 7.2 bushel increase. Irrigation plus full fertility treatment at the high population levels produced 103.8 bushels of #2 corn per acre, an 80.5 bushel

increase over the low fertility, low water, and low population production.

Moisture levels are high as animal damage to the plots made it necessary to pick the corn before it had thoroughly dried. Yields however, have been calculated as #2 corn at 15.5% moisture. The highest yielding plot yielded 122.5 bushels/acre of Pioneer XE-65. This short extra early hybrid and others like it deserve much more intensive investigation as not only was it able to respond as well as the 85 day hybrids when fertility and moisture were adequate but under adverse conditions (drought or low fertility) it produced over 10 bushels more corn per acre than the 85 day hybrids.

Table 1. Hybrids and populations.

Hybrid	Maturity	Population: Non-irrig.		Population: Irrigated	
Minn. 806	85 day	6000	12,000	25,000	35,000
Pioneer 3985	85 day	6000	12,000	25,000	35,000
Pioneer 65	65 day	8000	17,000	35,000	50,000

Table 2. What fertility plus irrigation can do; corn yields on a Dorset sandy loam, Park Rapids, Minn. 1967.

Management level	Corn Yield bu/acre	Difference bu/acre
Low fert. Low pop. No irrig.	23.3	--
High fert. Low pop. No irrig.	15.6	-7.7
Low fert. High pop. Irrigated	30.5	+7.2
High fert. High pop. Irrigated	103.8	+80.5

Table 3. Yield of Pioneer XE (65) at four fertility-water management levels.

Treatment	Population plants/ acre	Yield bu/ acre	% Moisture	Shelling %	Ear Wt.	Barren Stalks (%)	% S in 6th leaf
High Fert. Irrigated	35,000	92.0	42.4	84.5	.18	7	.271
	50,000	102.6	43.8	81.9	.14	13	.281
Low Fert. Irrigated	35,000	37.1	46.3	79.8	.08	7	.207
	50,000	37.0	49.4	82.8	.06	12	.183
High Fert. Non-irrig.	8,000	26.6	37.5	81.9	.23	--	.250
	17,000	23.1	37.5	81.9	.14	--	.245
Low Fert. Non-irrig.	8,000	32.3	37.5	81.6	.23	--	.270
	17,000	34.2	37.5	82.4	.14	--	.218

Table 4. Yield of Minn. 806 at four fertility-water management levels.

Treatment	Population plants/ acre	Yield bu/ acre	% Moisture	Shelling %	Ear Wt.	Barren Stalks (%)	% S in 6th leaf
High Fert. Irrigated	25,000	108.1	36.1	79.1	.31	2	.342
	35,000	106.7	35.0	77.3	.22	1	.284
Low Fert. Irrigated	25,000	25.4	48.3	75.7	.06	17	.221
	35,000	25.7	48.8	76.1	.07	19	.271
High Fert. Non-irrig.	6,000	17.3	48.4	67.4	.06	50	.269
	12,000	6.2	60.6	63.2	.15	48	.253
Low Fert. Non-irrig.	6,000	19.2	45.5	71.9	.22	4	.249
	12,000	22.8	50.8	75.3	.13	40	.215

Table 5. Yield of Pioneer 3985 at four fertility-water management levels.

Treatment	Population plants/ acre	Yield bu/ acre	% Moisture	Shelling %	Ear Wt.	Barren Stalks (%)	% S in 6th leaf
High Fert. Irrig.	25,000	109.8	40.3	81.8	.27	4	.308
	35,000	103.5	39.6	80.2	.22	6	.309
Low Fert. Irrigated	25,000	28.2	51.4	75.5	.08	17	.199
	35,000	29.6	52.1	76.8	.07	19	.190
High Fert. Non-irrig.	6,000	9.3	60.0	76.5	.12	50	.217
	12,000	10.9	60.5	80.6	.09	48	.263
Low Fert. Non-irrig.	6,000	17.2	53.8	76.1	.19	4	.249
	12,000	14.3	61.6	75.5	.12	40	.215

The Effect of Nitrogen Source, Placement, and Time of Application to a Webster Clay Loam at Lamberton on 1960-67 Ear Corn Yields and on 1967 Corn Composition

John M. MacGregor, Wallace W. Nelson and Gyles W. Randall

A field fertilizer experiment was commenced with the 1960 growing season to determine the relative effect of annually applied N as either urea or ammonium nitrate. These were broadcast and plowed down or broadcast on the plowed surface in the fall, broadcast and worked in during corn planting in spring, or side-dressed in late June. The effect on yields and composition of field corn grown each year was the objective. The nitrogen rates were 40, 80, and 160 lbs. per acre annually in a randomized block having four replications of each treatment. Adequate amounts of phosphate and potash were supplied.

For the first three years, the entire corn plants and grain were analyzed for nitrogen content, and it was evident that much of the applied nitrogen was not being taken up and utilized. This practice was then discontinued, since the only actual N removal was that present in the grain (since all other plant residues were plowed down each fall). The nitrate nitrogen content of the soil, corn leaves, upper stalks, and lower stalks on several treatments were studied monthly during the growing seasons of 1964, 1965 and 1966 and have been previously reported (Soil Series 75, 76, 77).

The 1967 growing season at Lamberton was characterized by a dry May (1.15"), a wet June (5.69"), and a very dry July, August and September with a total three month rainfall of only 4.39". Lack of soil moisture adversely affected grain yield, but all fertilized treatments produced significant increases in yield as shown in Table 1. Pioneer 368 was the hybrid grown and the sixth leaf was sampled for analyses on August 3rd.

Table 1. The Effect of Rate, Kind, Time and Placement of Fertilizer Nitrogen on the 1967 Ear Corn Yield and Composition of the Sixth Leaf.

Trt. No.	Treatments	(1) bu/A Ear Corn Yield	(2) % Pl N	(3) % Pl P	(4) % Pl K	(5) % Pl Ca	(6) % Pl Mg	(7) ppm Pl Sr	(8) ppm Pl Fe	(9) ppm Pl Zn	(10) ppm Pl Cu	(11) ppm Pl Mo	(12) ppm Pl Mn	(13) ppm Pl B
			← 6th Leaf Tissue →											
1	CHECK	53.4a	1.54a	.214a	2.24a	.527a	.343a	7.8a	183.a	10.6a	5.9a	1.02a	27.7a	12.6a
2	40# NH_4NO_3 PDfall	75.6b	1.95bc	.246abc	2.43abc	.588a	.402abc	9.7abcd	221.a	13.4a	8.5ab	1.18a	38.2abc	13.5a
3	40# Urea "	86.9bc	2.01bcd	.248bc	2.33ab	.600a	.405abc	10.0abcd	192.a	12.6a	7.9ab	1.18a	32.0ab	12.9a
4	40# NH_4NO_3 Top-F	75.1b	1.81ab	.223ab	2.28a	.620a	.428abcd	10.3abcd	197.a	12.5a	7.8ab	1.34a	31.9ab	13.6a
5	40# Urea "	87.2bc	2.15bcdef	.257bcd	2.74c	.628a	.408abc	9.5abc	224.a	13.3a	11.0bcd	1.05a	39.3abc	14.5a
6	80# NH_4NO_3 PD-F	114.8def	2.60gh	.286def	2.34ab	.601a	.435bcd	11.7bcd	212.a	13.1a	9.6bc	1.25a	46.7c	13.1a
7	80# Urea "	117.2ef	2.50fg	.299ef	2.27a	.607a	.503d	12.6cd	216.a	14.3a	11.1bcd	1.34a	47.9c	13.3a
8	160# NH_4NO_3 "	127.4f	2.90h	.293ef	2.11a	.627a	.414abc	13.5d	211.a	14.7a	13.2d	1.16a	58.9d	12.4a
9	160# Urea "	121.2f	2.60gh	.313f	2.39abc	.623a	.416abc	12.5cd	212.a	14.8a	12.2cd	1.22a	60.5d	14.1a
10	40# NH_4NO_3 TDspr	99.8cd	2.20cdef	.250bc	2.44abc	.572a	.408abc	11.1abcd	200.a	13.4a	9.5bc	1.20a	37.2abc	13.9a
11	40# Urea "	95.0c	2.41efg	.262c	2.25a	.604a	.431bcd	11.0abcd	211.a	12.6a	10.3bcd	1.32a	40.2bc	13.3a
12	80# NH_4NO_3 "	128.2f	2.57gh	.289def	2.08a	.580a	.434bcd	11.2abcd	196.a	15.3a	10.6bcd	1.21a	44.4bc	12.8a
13	80# Urea "	128.6f	2.42efg	.297ef	2.25a	.632a	.439cd	11.9bcd	217.a	13.5a	10.1bcd	1.35a	44.0bc	13.3a
14	40# NH_4NO_3 S.D.	96.8c	1.97bc	.242abc	2.28a	.596a	.371abc	9.5abc	198.a	13.7a	9.0abc	1.12a	35.7abc	13.7a
15	40# Urea "	86.1bc	2.12cde	.249bc	2.56bc	.566a	.349ab	8.0ab	190.a	12.7a	8.1ab	1.04a	32.6ab	12.9a
16	80# NH_4NO_3 "	101.6cde	2.33defg	.270cde	2.43abc	.589a	.407abc	9.9abcd	231.a	14.2a	9.6bc	1.21a	40.4bc	12.7a
17	80# Urea "	117.0ef	2.42efg	.266cde	2.24a	.629a	.388abc	9.5abc	209.a	12.0a	10.3bcd	1.13a	37.9abc	14.0a
18	160# NH_4NO_3 "	120.2f	2.68gh	.307f	2.18a	.624a	.456cd	12.1cd	209.a	14.4a	12.3cd	1.20a	63.8d	13.3a
	Significance	***	**	**	*	NS	*	*	NS	NS	**	NS	**	NS
	F value	15.07	9.75	6.78	1.86	1.41	2.24	1.85	0.71	0.81	3.51	0.91	7.78	0.41
	CV	10.9	9.7	8.2	9.9	7.7	12.0	21.5	14.5	19.1	19.8	17.7	17.3	13.2

The minimum fertilized ear corn yield increase was approximately 22 bushels per acre where 40 pounds of NH_4NO_3-N was broadcast in the fall and left over winter on the plowed surface. There was no significant difference in yield from the two N sources (ammonium nitrate and urea). However, the spring applied 40 pound N rate produced an average of 97.4 bushels in comparison to a 78.2 bushel average of the fall N treatments. Where 80 pounds of N were applied in the fall the corn averaged 116.0 bushels in comparison to 128.4 with a similar rate in the spring. Doubling the 80 pound N rate failed to further increase yield. While late June sidedressing was more effective than fall broadcast N, there was less corn production than where similar N rates were broadcast at planting time.

The nitrogen content of the sixth leaf parallels both fertilizer N treatment and ear corn yield, all showing significant increases with the exception of Treatment 4. The relationship between leaf nitrogen and corn yield has been previously well established.

Mineral leaf analyses were made on the Jarrel-Ash emission spectrometer. Significant differences occurred in leaf concentrations of phosphorus (P), potassium (K), magnesium (Mg), strontium (Sr), copper (Cu), and manganese (Mn). No significant differences from N fertilization were evident in concentrations of calcium (Ca), iron (Fe), zinc (Zn), molybdenum (Mo), or of boron (B). While the relative effect of N fertilization on the concentrations of these elements is not well understood, the accumulation of additional data on this subject may become helpful in future studies.

Since the primary farmer interest in fertilizer use is grain production, the total eight year yields were summarized and are shown in Table 2. The eight year average yield shows that all treatments other than No. 2 (40 lbs. N/A as NH_4NO_3 plowed down in late fall) are significantly greater than the check yield.

Table 2. The Effect of Rate, Time, Kind, and Placement of Fertilizer Nitrogen on Ear Corn Production from a Webster Clay Loam at Lamberton for Eight Years (1960-67).

Trt. No.	1960	1961	1962	1963	1964	1965	1966	1967	Total	8 Yr. Avg.
					Bushels of ear corn per acre @ 15.5% moisture					
1	49.5	88.2	26.1	132.6	72.9	33.1	11.1	53.4	466.9	58.4 a
2	42.3	87.5	30.9	148.6	88.3	34.9	26.8	75.7	535.0	66.9 ab
3	55.1	78.2	29.1	148.8	100.3	38.8	19.8	86.9	557.0	69.6 bc
4	49.0	96.7	29.6	140.1	101.5	45.6	24.3	75.1	561.9	70.2 bc
5	62.3	101.3	37.0	140.7	84.1	57.4	30.9	87.2	600.9	75.1 bcd
6	67.4	97.9	43.6	149.6	100.8	63.4	47.3	114.8	684.8	85.6 def
7	61.7	76.9	36.7	154.5	104.9	73.0	37.8	117.2	662.7	82.8 def
8	69.8	97.9	46.7	147.7	100.9	70.8	38.5	127.4	699.7	87.5 ef
9	79.4	112.5	43.5	152.8	112.4	73.5	37.7	121.3	733.1	91.6 f
10	66.2	92.0	45.4	152.2	99.8	63.4	23.7	99.8	642.5	80.3 cdef
11	45.4	91.1	31.4	147.6	100.6	59.8	33.8	95.0	604.7	75.6 bcd
12	59.3	90.0	32.7	149.2	112.5	74.2	49.0	128.3	695.2	86.9 ef
13	57.7	99.1	40.5	149.3	115.7	84.4	41.8	128.6	717.1	89.6 f
14	63.6	92.6	39.5	148.6	90.4	54.8	38.6	96.8	624.9	78.1 cde
15	57.7	95.6	24.9	142.3	94.1	48.4	50.4	86.1	599.5	74.9 bcd
16	50.4	98.4	46.7	140.7	113.0	68.1	43.8	101.6	662.7	82.8 def
17	76.9	86.4	48.2	143.8	121.4	64.7	47.3	117.0	705.7	88.2 ef
18	40.7	97.4	77.7	151.7	109.5	77.6	51.4	120.2	726.2	90.8 f
Avg.	58.6	93.3	39.4	146.7	101.3	60.3	36.3	101.8		

ANOVA

SV	df	SS	MS	F
Total	143	202,031	--	--
Years	7	179,133	25,590	274.8 **
Trts	17	11,818	695	7.46**
Error	119	11,079	93	--

During the 1960-63 cropping seasons, the experimental area was not tile drained and frequently the corn suffered from excessive soil moisture. For this reason, the eight year corn yields shown in Table 2 were separated into two four year periods and the mathematical significance determined for the two four year periods and the data are shown in Tables 3 and 4.

Table 3. The Effect of Rate, Kind, Time and Placement of Fertilizer Nitrogen on Ear Corn Production from a Webster Clay Loam at Lamberton (1960-63).

Trt. No.	Treatment Lbs. N/A Kind, Rate & Time	Year 1960	1961	1962	1963	Total	4 Yr. Avg.
		Bushels of ear corn per acre @ 15.5% moisture					
1	CHECK	49.5	88.2	26.1	132.6	296.4	74.1 a
2	40 NH_4NO_3 P.D.Fall	42.3	87.5	30.9	148.6	309.3	77.3 ab
3	40 Urea "	55.1	78.2	29.1	148.8	311.2	77.8 ab
4	40 NH_4NO_3 Top Fall	49.0	96.7	29.6	140.1	315.4	78.8 ab
5	40 Urea "	62.3	101.3	37.0	140.7	341.3	85.3 abc
6	80 NH_4NO_3 P.D.Fall	67.4	97.9	43.6	149.6	358.5	89.6 bc
7	80 Urea "	61.7	76.9	36.7	154.5	329.8	82.4 abc
8	160 NH_4NO_3 "	69.8	97.9	46.7	147.7	362.1	90.5 bc
9	160 Urea "	79.4	112.5	43.5	152.8	388.2	97.0 c
10	40 NH_4NO_3 Spring	66.2	92.0	45.4	152.2	355.8	89.0 abc
11	40 Urea "	45.4	91.1	31.4	147.6	315.5	78.9 ab
12	80 NH_4NO_3 "	59.3	90.0	32.7	149.2	331.2	82.8 abc
13	80 Urea "	57.7	99.1	40.5	149.3	346.6	86.6 abc
14	40 NH_4NO_3 S.D.	63.6	92.6	39.5	148.6	344.3	86.1 abc
15	40 Urea "	57.7	95.6	24.9	142.3	320.5	80.1 ab
16	80 NH_4NO_3 "	50.4	98.4	46.7	140.7	336.2	84.0 abc
17	80 Urea "	76.9	86.4	48.2	143.8	355.3	88.8 abc
18	160 NH_4NO_3 "	40.7	97.4	77.7	151.7	367.5	91.9 bc
	Average	58.6	93.3	39.4	146.7		

ANOVA

SV	df	SS	MS	F
Total	71	126,000	--	--
Years	3	119,680	39,893	527.2 **
Trts	17	2,461	144.8	1.91*
Error	51	3,858	75.7	--

Table 4. The Effect of Rate, Kind, Time and Placement of Fertilizer Nitrogen on Ear Corn Production from a Webster Clay Loam at Lamberton (1964-67).

Trt. No.	Treatment Lbs. N/A Kind, Rate & Time		Year 1964	1965	1966	1967	Total	4 Yr. Avg.
			Bushels of ear corn per acre @ 15.5% moisture					
1	CHECK		72.9	33.1	11.1	53.4	170.5	42.6 a
2	40 NH_4NO_3	P.D.Fall	88.3	34.9	26.8	75.7	225.7	56.4 b
3	40 Urea	"	100.3	38.8	19.8	86.9	245.8	61.4 bc
4	40 NH_4NO_3	TopFall	101.5	45.6	24.3	75.1	246.5	61.6 bc
5	40 Urea	"	84.1	57.4	30.9	87.2	259.6	64.9 bc
6	80 NH_4NO_3	P.D.Fall	100.8	63.4	47.3	114.8	326.3	81.6 def
7	80 Urea	"	104.9	73.0	37.8	117.2	332.9	83.2 def
8	160 NH_4NO_3	"	100.9	70.8	38.5	127.4	337.6	84.4 ef
9	160 Urea	"	112.4	73.5	37.7	121.3	344.9	86.2 f
10	40 NH_4NO_3	Spring	99.8	63.4	23.7	99.8	286.7	71.7 cde
11	40 Urea	"	100.6	59.8	33.8	95.0	289.2	72.3 cde
12	80 NH_4NO_3	"	112.5	74.2	49.0	128.3	364.0	91.0 f
13	80 Urea	"	115.7	84.4	41.8	128.6	370.5	92.6 f
14	40 NH_4NO_3	S.D.	90.4	54.8	38.6	96.8	280.6	70.2 cd
15	40 Urea	"	94.1	48.4	50.4	86.1	279.0	69.8 bcd
16	80 NH_4NO_3	"	113.0	68.1	43.8	101.6	326.5	81.6 de
17	80 Urea	"	121.4	64.7	47.3	117.0	350.4	87.6 f
18	160 NH_4NO_3	"	109.5	77.6	51.4	120.2	358.7	89.7 f
	Average		101.3	60.3	36.3	101.8		

ANOVA

SV	df	SS	MS	F
Total	71	72,727	--	--
Years	3	56,149	18,716	263.0 **
Trts	17	12,948	761.6	10.70**
Error	51	3,630	71.2	--

The data of Tables 3 and 4 show that corn yields were relatively high during the first four years but significant differences due to the nitrogen fertilizer treatments occurred only where 160 pounds of N per acre was applied. In the second four year period (Table 4) the effect of tile drainage and soil nitrogen depletion was becoming more evident with significant effects of the nitrogen treatments becoming consistently evident with spring and side dressed nitrogen being more effective.

The nitrogen content of 1967 corn grain from one of the four replicates was determined. Crude protein content was calculated, which in combination with

grain yield, indicated apparent crude protein production per acre, and these data are shown in Table 5.

Table 5. The Effect of Rate, Kind, Time and Placement of Fertilizer Nitrogen on Crude Protein Concentration and Production of Field Corn at Lamberton in 1967 (Data from only 1 replication).

	Treatment (lbs N/A)	% Crude Protein in Corn Grain	Lbs./A of Crude Protein
(1)	Check	7.6	243
(2)	40 NH_4NO_3 -plowed down-fall	6.9	365
(3)	40 Urea " " "	7.5	328
(4)	40 NH_4NO_3 -top of plowing-fall	--	--
(5)	40 Urea " " " "	7.9	364
(6)	80 NH_4NO_3 -plowed down-fall	9.4	596
(7)	80 Urea " " "	8.8	566
(8)	160 NH_4NO_3 " " "	11.3	766
(9)	160 Urea " " "	10.3	870
(10)	40 NH_4NO_3 -at spring planting	8.1	395
(11)	40 Urea " " "	7.6	352
(12)	80 NH_4NO_3 " " "	9.0	588
(13)	80 Urea " " "	10.8	736
(14)	40 NH_4NO_3 -as late sidedressing	7.5	328
(15)	40 Urea " " "	8.6	356
(16)	80 NH_4NO_3 " " "	9.3	656
(17)	80 Urea " " "	8.1	580
(18)	160 NH_4NO_3 " " "	11.3	766

The data of this table shows the comparative effect of fall, spring and side dress application. Although corn grain from only one replication was available for analysis and crude protein concentrations and per acre production computed, it is evident that rate of annual N fertilization has a marked effect on corn grain protein.

The Effect of Nitrogen Time of Application on Field Corn Yield 1960-67 from N Plots at Lamberton

	Corn Yields		
	Fall Trts 2,3,6,7	Spring 10,11,12,13	Side Dress 14,15,16,17
1960-67 (8 years)	75.1	83.1	81.1
1960-63 (4 years)	81.8	84.3	84.8
1964-67 "	70.7	81.9	77.3
1967	98.6	112.9	100.4

Nitrate Nitrogen Content of a Barnes Loam Soil at Morris in November, 1967, after Eleven Years of Continuous Corn with Varying Rates of Nitrogen Fertilization (1957-67).

J. M. MacGregor, G. R. Blake, S. Evans & R. Thompson

A continuous corn fertilizer experiment was commenced in 1957 on a Barnes loam at the West Central Experiment Station at Morris. Adequate amounts of phosphate and potash were applied annually with four rates of N application. Although a plant population of 16-18,000 corn plants per acre was desired, this was not always obtained, since different methods of seedbed preparation were employed. All vegetative residues remained on the field, either being plowed down or worked into the surface. Ear corn yields for the eleven years are shown in Table 1.

Table 1. The Effect of Annual Fall or Spring Nitrogen Topdressings on a Barnes Loam at Morris on Ear Corn Yield (1957-67).

N Appl. (Lbs/A)	(a)	Year 1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	11 Yr. Av.
		Bushels of ear corn per acre at 15.5% moisture											
0	(S)	65.2	73.2	36.1	53.3	32.3	38.1	62.7	33.2	50.4	49.0	66.8	50.9
40	(F)	71.0	81.5	40.9	48.2	48.3	59.0	60.9	34.1	68.3	63.7	69.2	60.5
40	(S)	69.4	81.0	41.5	55.0	47.6	62.0	83.5	29.6	75.3	66.3	71.2	62.0
80	(S)	72.1	82.4	39.7	53.7	45.0	65.3	77.4	29.1	80.8	75.9	69.7	62.8
240	(S)	71.3	80.3	36.8	52.5	46.1	67.1	79.5	24.7	82.8	33.1	71.3	58.7

(a) 40 pounds of both phosphate and potash were applied to all plots at time of N application.

(S)= Spring

(F)= Fall

During the eleven years of continuous corn, it is evident that while the annual 40 pound per acre N fertilization rate increased ear corn yields approximately 10 bushels per acre, further increases in the rate of annual N fertilization rate did not result in a further increase in corn yields.

Late in October of 1965 soils of four treatments were sampled to a depth of 96 inches and analyzed for NO_3-N in an attempt to locate any accumulated N with continuing N applications. As was reported in the "Blue Book" of February, 1966 (page 85, Soil Series 80) where 40 lbs/A of N was applied in each of the nine years 3.3% of this remained as NO_3-N in the first 4' soil depth and 2.3% was present in the 4 to 8 soil depth. Where 80 pounds of N/A was annually applied (a total of 760 lbs of N/A), 7.1% remained in the upper 4', and 14.7% was in the 4' to 8' soil depth. Where 240 lbs N/A had been applied in each of the nine years (a total of 2160 lbs N/A), 28.2% was in the upper 4' and 34.3% was in the 4' to 8' depth. These values indicated that there was a downward movement of applied N in nitrate form, expecially with the continued heavier annual applications of fertilizer nitrogen. In the entire 8' soil depth, 5.6% of the 40 lb N rate, 21.8% of the 80 lb rate and 62.5% of the 240 lb. rate persisted as nitrate N.

The question of NO_3-N movement to soil depths greater than 8' remained, so in early November 1967, three replications of the annual 0-40-40, the 40-40-40 and of the 240-40-40 treatment soils were sampled at 4' intervals to a 32' depth and analyzed for NO_3-N. The results are shown on Table 2.

Table 2. Pounds of Nitrate Nitrogen per acre in Barnes Loam after Eleven Years of Increasing Rates of N Fertilization.

Soil depth (ft)	Annual	Nutrient application in pounds per acre 0-40-40	40-40-40	240-40-40
	11 year total N	0	440	2640
		Pounds of nitrate nitrogen per acre		
0-0.5		20.4	33.0	83.4
0.5-1.0		11.1	13.0	122.0
1-2		8.8	10.4	123.8
2-3		9.4	9.6	110.8
3-4		6.6	12.2	72.3
7-8		8.9	18.3	145.8
11-12		17.3	22.8	47.9
15-16		19.7	24.3	42.8
19-20		18.6	16.4	22.9
23-24		10.7	14.0	13.6
27-24		12.8	11.9	16.7
31-32		13.2	11.6	13.4

From the data of Tables 1 and 2 it appears that where 40 pounds of N was applied per acre annually during the eleven years of this study, ear corn yields increased approximately 10 bushels but some of the excess N at this low rate penetrated the subsoil as nitrate to a minimum depth of 16 feet. The 240 pound rate of N fertilization resulted in no additional corn yield and apparently more of the applied fertilizer N moved downward as the nitrate to a minimum 28 foot depth in those plots.

It is apparent that the continued application of excessive amounts of fertilizer N should be avoided both on the basis of additional fertilizer expense, and the possible contamination of both subsoils and of subterranean water supplies even under the relatively limited annyal precipitation of western Minnesota.

STRUCTURE - NITROGEN STUDY

MORRIS 1967

pH 1/

Fertilizer	pH	Statistical Notes
	0 - 6 inches	
0-40-40	7.26	a
40-40-40 (fall)	7.28	a
40-40-40	7.14	a
80-40-40	7.11	a
240-40-40	6.50	b 99% level
	8 - 12 inches	
0-40-40	7.29	A > C 99% level
40-40-40	7.17	B > C 95% level
240-40-40	6.87	
	20 - 24 inches	
0-40-40	7.65	Reps only, significant
40-40-40	7.51	
240-40-40	7.55	
	32 - 36 inches	
0-40-40	7.82	Reps only, significant
40-40-40	7.83	
240-40-40	7.70	

1/ Tillage Method had no effect on pH.

1967 Phosphorus Placement Study
Southwest Experiment Station
W. W. Nelson and G. W. Randall

An experiment was initiated at Lamberton in the spring of 1966 to determine the effect of various methods of row applied fertilizer on the 1) early growth of corn, 2) chemical composition of the plant at both an early stage and again at silking stage, and 3) the yield of corn. In 1967 the experiment was expanded to include 1) the measurement of nutrient uptake by the small plant and 2) the effect of planting date on the growth, uptake, composition and yield of corn. The design used for each planting date was a split plot with four row treatments and two broadcast treatments, all replicated four times.

All plots received 100# N broadcast before planting. Ramrod and diazonon were applied at planting time along with atrazine + oil applied post emergence for control of weeds and root worm. The soil type, Nicollet silty clay loam, had soil test values of pH = 6.0, O.M. = 4.7%, P = 7 (Low) and K - 270 (Very High). Corn yields were again somewhat low in 1967, probably due to a lack of rainfall (0.11 inch) between July 10 and August 20.

Table 1. Row and broadcast treatments applied to the phosphorus placement experiment.

Row Treatment		Fertilizer Treatment*			
		No Broadcast 100+0+0		Broadcast 100+60+30	
Placement	Nutrients Applied (lbs/A	Trt. No.	Total Nutrients (lbs/A)	Trt. No.	Total Nutrients (lbs/A)
No Row	0+0+0	1	100+0+0	5	100+60+30
Pop-Up	5+16+8	2	105+16+8	6	105+76+38
2 x 2 Band	16+48+24	3	116+48+24	7	116+108+54
Pop-Up + 2 x 2	21+64+32	4	121+64+32	8	121+124+62

* all plots received broadcast N at the rate of 100 lbs. N/A

Table 2. Average weight, height, yield and moisture content of corn planted May 3.

Trt. No.	Weight*	Height*	Yield**	Moisture percent at harvest
1	671 gm.	16.2 in.	59.5 bu/A	23.8
2	1484	21.8	80.4	17.6
3	1382	20.8	80.6	18.0
4	2004	23.5	90.1	16.6
5	1410	20.8	72.7	17.9
6	1778	23.2	80.3	16.7
7	1934	22.2	83.2	16.1
8	1904	21.5	81.8	15.8

* weight and height of 10 small plants harvested June 28.

** bushels of ear corn per acre at 15.5% moisture

Table 3. Average weight, height, yield, and moisture content of the corn planted May 3 from the row treatments with broadcast treatments combined.

Trt. No.	Description	Weight gms	Height inches	Yield bu/A	Moisture %
1. (1+5)	No Row	1041 a*	18.5 a	66.1 a	20.8 b
2. (2+6)	Pop-Up	1631 b	22.5 b	80.4 b	17.2 a
3. (3+7)	2 x 2 Band	1658 b	21.5 b	81.9 b	17.1 a
4. (4+8)	Pop-Up + 2 x 2	1954 c	22.5 b	86.0 b	16.2 a

* numbers followed by the same letter belong to the same .05 level population (DMRT).

Table 4. Average weight, height, yield and moisture content of corn planted May 3 from the broadcast treatments with row treatments combined.

Treatment	Weight gms	Height inches	Yield bu/A	Moisture %
No Broadcast	1385 a	20.6 a	77.6 a	19.0 a
Broadcast	1756 b	21.9 a	79.5 a	16.6 a

Table 5. Average weight, height, yield, and moisture content of corn planted June 1.

Trt. No.	Weight*	Height*	Yield**	Moisture percent at harvest
1	2199 gms	26.5 in.	53.0 bu/A	35.7
2	4033	34.5	74.6	27.5
3	3871	36.0	75.4	28.0
4	4340	36.0	75.7	29.2
5	3970	32.5	72.3	28.4
6	4413	35.5	75.4	29.2
7	4659	36.5	85.7	28.2
8	4632	37.2	86.6	27.8

* weight and height of 10 small plants harvested July 19

** bushels per acre at 15.5% moisture

Table 6. Average weight, height, yield, and moisture of ear corn planted June 1 from the row treatments with broadcast treatments combined.

Trt. No.	Description	Weight gms	Height inches	Yield bu/A	Moisture %
1. (1+5)	No Row	3085 a	29.5 a	62.6 a	32.0 b
2. (2+6)	Pop-Up	4223 b	35.0 b	75.0 b	28.4 a
3. (3+7)	2 x 2 Band	4265 b	36.2 b	80.5 b	28.1 a
4. (4+8)	Pop-Up + 2 x 2	4486 b	36.6 b	81.4 b	28.5 a

Table 7. Average weight, height, yield, and moisture of ear corn planted June 1 from the broadcast treatments with row treatments combined.

Treatment	Weight gms	Height inches	Yield bu/A	Moisture %
No Broadcast	3610 a	33.2 a	69.7 a	30.1 a
Broadcast	4419 b	35.4 b	80.1 a	28.4 a

Interpretation

May 3 planting

The small plant weight and height, yield and moisture content of the corn were all significantly affected by the row treatments. The corn fertilized with pop-up, 2 x 2 band, or combination (pop-up + 2 x 2 band) treatment showed a significant increase in weight, height, and yield as well as a significant decrease in moisture over the no row (check) treatment. In all cases except plant weight, there were no significant differences among the pop-up, 2 x 2 band,

or combination treatments. However, the highest plant weight and yield, and the lowest moistures were obtained with the combination treatment.

Small plant weight was also significantly increased with the broadcast treatment of 0+60+30. Although the height and yield were greater and the moisture was less from the broadcast treatment, these differences were not significant.

June 1 planting

Even at this late date of planting, the small plant weight, height, yield, and moisture content were all significantly affected by the row treatments. Again, the corn fertilized with pop-up, 2 x 2 band, or combination treatment showed a significant increase in weight, height, and yield and a significant decrease in moisture over the no row (check) treatment. In all cases there were no significant differences among the pop-up, 2 x 2 band or combination treatments.

The broadcast treatment of 0+60+30 significantly increased the small plant weight and height, but did not significantly increase the yield or decrease the moisture.

Comparing the planting dates, lower yields (74.9 vs 78.5) and higher moisture contents (29.2 vs 17.8) were obtained with the June 1 planting.

Polyphosphate Investigations

A. C. Caldwell
and
Richard C. Leslie

Field trials comparing polyphosphates and orthophosphates were run at Lamberton and Rosemount Experiment Stations. Three different phosphate treatments at two rates were employed at both stations, as shown in Table 1. One yield row and two border rows were planted for each plot.

Table 1. Phosphorus treatments.

No.	Phosphate Material	Rate #/Acre	Application
1	Check		
2	Ortho. Dry 11-14-0	62.5	2 x 2
3	Ortho. Dry 11-14-0	62.5	Pop-up
4	Ortho. Liq. 8-24-0	125.0	2 x 2
5	Ortho. Liq. 8-24-0	125.0	Pop-up
6	Poly. Liq. 11-37-0	81.1	2 x 2
7	Poly. Liq. 11-37-0	81.1	Pop-up

At Rosemount, treatments were replicated five times, using Chippewa soybeans. At Lamberton, treatments were replicated four times using Merit soybeans. In addition to the phosphate treatments at Lamberton, three nitrogen treatments, at 200#/Acre, were applied by three different means, (1) broadcast before planting as processed feathers and disced in, (2) broadcast as 33.5-0-0 in a single application and disced in before planting, (3) broadcast as 33.5-0-0 in split applications, 100# before planting and 100# in early July.

The plants in the non-nitrogen fertilized plots were randomly sampled at three different growth stages, whole plants 4 to 6 inches high, and the uppermost fully matured trifoliate leaves at the flower and pod stage.

Total dry matter was determined for the first sampling only. Elemental analyses were run on the check, liquid orthophosphate 2 x 2, and liquid polyphosphate 2 x 2 plants from the first and third samplings. Yields were determined on all plots including the nitrogen fertilized.

RESULTS

Yields

The yields at Lamberton are presented in Table 2.

Table 2. Effect of Phosphate Fertilizers on Soybean Yields at Lamberton

	Treatments						
	Check	Ortho Dry 2 x 2	Ortho Dry Pop-up	Ortho Liq 2 x 2	Ortho Liq. Pop-up	Poly Liq. 2 x 2	Poly Liq. Pop-up
	Bu/Acre						
No Nitrogen	18.1	21.5	21.2	20.9	19.9	21.4	22.3
200 lbs. Nitrogen as Feathers	22.8	27.4	25.5	25.7	25.8	28.2	23.7
200 lbs. Nitrogen as 33.5-0-0 single appl.	26.3	28.1	28.9	29.1	27.7	28.4	24.6
200 lbs. Nitrogen as 33.5-0-0 split appl.	24.3	25.1	24.5	26.8	26.3	26.8	25.6

The soybean yields were adversely affected by a lack of optimum moisture throughout the growing season. The yield data shows polyphosphate fertilizer to be an adequate source of phosphorus. The addition of 200 lbs. of nitrogen produced an increase in yields of all treatments.

The effect of Boron, Phosphorus & Potassium on Soluble Soil Boron & Yield of Grass-Legume Hay on a Vilas Loamy Sand in Carlton County 1965-66-67 (Gerald Mower Farm - Cromwell)

J. M. MacGregor, P. Borich & G. Randall

In July of 1964 following the removal of first cutting hay, experimental plots were established on four Carlton County farms to determine the effect of phosphorus and potassium alone and with different rates of boron application to soils on grass-legume hay fields common in this area. A 6 X 6 Latin square design was used with plots of one square rod. The major results have already been reported in previous "Bluebooks" of 1965, 1966, and 1967. (Soil Series 79, 80, and 81).

Early in 1965 a fifth field was established on a one-year-old legume-grass stand on a Vilas loamy sand, approximately 2 miles southeast of Cromwell. Two cuttings were made in each of the three years. In October of 1967, soils of three of the six replications were sampled to a 24 inch depth and three sample depths from each plot were analyzed for soluble boron content.

During the first cutting year (1965) there was a growth difference in the appearance of the alfalfa on the phosphate-potash treatments, but little effect of boron. During the second year (1966) the phosphate-potash only plots and those receiving only one pound of boron per acre showed some indications of leaf yellowing and slight rosetting. During the third year, the symptoms of boron deficiency on the no boron, or on the one or two pound plots became more pronounced.

The following table shows the hay yields obtained in 1967 and the total yield for the three year period, based on 15% moisture of the two annual cuttings.

Table 1. The Effect of Phosphate-Potash and of Boron Fertilization on the Three Year Yield of a Grass-Legume Hay on a Vilas loamy sand.

	Tons hay per acre at 15% Moisture			
	1967			1965-67 total
Treatment (lbs/A)	1st. cutting	2nd. cutting	total	
Check	2.17a	0.43a	2.60a	9.83a
0 + 60 + 180	2.26ab	0.64b	2.90abc	10.69b
0 + 60 + 180 + 1B(1965)	2.57c	0.58b	3.17bc	11.02bc
0 + 60 + 180 + 2B(1965)	2.58c	0.65b	3.23c	11.51c
0 + 60 + 180 (+ 1B in 1965, 1966, 1967)	2.50bc	0.53ab	3.03bc	11.56c
0 + 60 + 180 (+ 2B in 1965, 1966, 1967)	2.30abc	0.53ab	2.83ab	10.56ab

The terms a,b,c refer to significant differences in yield.

It is apparent that alfalfa on this field which showed boron deficiency symptoms, the total application of boron at rates 1, 2 and 3 pounds per acre during the three growing seasons resulted in a significant yield increase in 1967 and for the total three year period (1965-67). During the first two years of the experiment (1965 & 1966) there was no clearly established yield increase due to the application of boron. It is probable that such a treatment becomes more effective as the stand becomes older on this sandy soil. Phosphate-potash treatment, however effectively increased hay yields in the first year (1965). Therefore, phosphate-potash fertilization was initially effective for increasing hay yields on this sandy soil, but boron treatments were needed in the third cropping season.

Soils of three replications were sampled in October 1967 and the soluble boron content of three depths are shown in the following table.

Table 2. Soluble Boron Content of Vilas Loamy Sand in October 1967.

Soil Treatment (lbs/A)	Soil Depth (Average of 3 replications) 0 - 6"	6" - 12"	12" - 24"
	Boron in parts per million		
Check.	0.81	0.78	0.79
0 + 60 + 180	0.87	0.77	0.70
0 + 60 + 180 + 1B(1965)	0.95	0.90	0.91
0 + 60 + 180 + 2B(1965)	0.79	0.77	0.76
0 + 60 + 180(+ 1B in 1965, 1966, 1967)	1.25	1.07	1.03
0 + 60 + 180(+ 1B in 1965, 1966, 1967)	1.50	1.62	1.05

The 1965 applications of boron at rates of 1 or 2 pounds per acre had largely disappeared by late in 1967. Where the same amounts were applied annually increases in soluble boron evident, illustrating the comparatively rapid loss of this element from this soil.

Experiments with Zinc for Corn in Southeastern Kandiyohi County (1962 - 67)

John M. MacGregor, Orville Gunderson and Gyles Randall

In 1962, an experiment was commenced (with the cooperation of personnel of the U.S.D.A. Soil and Water Research Station at Morris) on the effect of form, placement and rate of zinc application to an unnamed calcareous silty clay loam about two miles northwest of the village of Lake Lillian for corn production. Powdered zinc sulfate at four rates was broadcast and plowed down in May, similar rates were applied as a starter band 2 inches to one side and 2 inches below the seed, both alone and with ammonium nitrate nitrogen at the rate of 20 pounds of N per acre. One treatment of chelated zinc was included where the seed was dusted with Na_2Zn zinc chelate at the rate of 8 ounces per bushel of seed. Corn was grown in 1962, 1964, 1965, 1966 and 1967. Soybeans were planted in 1963, but were killed by the residual effect of a heavy dosage of atrazine in 1962 to control quack grass as much as possible on the experimental area. The experimental design was a randomized block having three replications.

The sixth (index) leaf was sampled each year in late July and these were analyzed for zinc content. Observation has generally indicated that the critical zinc level in leaves at this time is approximately 15 parts per million (ppm). Ear corn yields were also obtained and both leaf zinc and yields for the five years are shown in the following table.

The Effect of a 1962 Zinc Treatment to an Unnamed Calcareous Silty Clay Loam in Southeastern Kandiyohi County on Succeeding Yields of Ear Corn
(Averages of three replications)

1962 Trt. lbs/A	Leaf zinc in ppm					Yield of ear corn in bu/A (15.5% moisture)						
	1962	1964	1965	1966	1967	1962	1964	1965	1966	1967	Total	Average
No zinc	9	19	8	10	13	43	40	38	41	36	198	39.6 a
Zinc broadcast and plowed under in spring of 1962												
15 $ZnSO_4$	13	19	12	10	14	69	58	59	54	43	283	56.6 de
30 "	19	20	20	14	13	66	56	58	51	47	278	55.6 cde
60 "	27	27	25	15	19	76	56	69	56	43	300	60.0 e
120 "	29	28	31	25	21	67	50	69	52	41	279	47.6 b
Zinc sulfate and/or nitrogen applied as a band starter												
20 N alone	9	--	11	11	12	61	41	47	45	44	238	47.6 b
20 N + 15$ZnSO_4$	10	--	13	12	13	59	53	55	51	36	254	50.8 bcd
20 N + 30$ZnSO_4$	10	--	14	11	14	63	58	56	61	52	290	58.0 de
20 N + 60$ZnSO_4$	11	--	13	16	18	64	65	65	60	35	289	57.8 de
30$ZnSO_4$	12	--	20	12	14	63	62	59	51	49	284	56.8 de
Zinc chelate coated on 1962 seed corn (7½ oz. NaZnEDTA per bu.)												
Seed trt alone	9	--	8	9	11	55	51	48	48	42	244	48.8 bc
Seed trt +30$ZnSO_4$P.U.	22	--	17	13	16	74	67	67	64	43	315	63.0 e

P.U.=Plowed under

Both sources of inorganic zinc were apparently more efficient for increasing both corn leaf zinc and ear corn yield, but since an extremely small amount of the chelated zinc (NaZnEDTA) was applied to the seed in 1962, the results could hardly be considered to be representative of the effectiveness of this zinc source.

Several conclusions may be made from this 65 month study:

1. One treatment of zinc sulfate effectively increased corn yield for several years.

2. Zinc as the sulfate when broadcast and plowed down was found at greater concentrations in the corn leaves than where similar rates of application were banded two inches below and two inches to one side of the seed, with

or without ammonium nitrate nitrogen.

3. Although the zinc sulfate appeared to be somewhat more effective than banding along the row during the first year, there were no significant placement yield differences for the total five year yield.
4. The banded N applications increased corn yields in the first year only.
5. Zinc sulfate at rates of 15 and 30 pounds per acre maintained leaf zinc concentrations at satisfactory levels for three crops before dropping below the so-called "critical" levels in the fourth and fifth year. Corn yields decreased more gradually.
6. During the entire study, limited plant populations apparently lowered possible higher yields, since seed germination on this fine textured, calcareous and cold soil was relatively poor each year.
7. A residual corn yield effect of zinc is evident after several years of cropping to corn, especially where rates in excess of 30 pounds of $ZnSO_4$ were applied.

The 1966-67 Results of a Zinc Source and a Zinc-Phosphate Interaction Effect on Leaf Composition and Corn Yield on a Calcareous Loam in Swift County

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

In the spring of 1966, a project was commenced to study:

1. The effect of several commercial zinc fertilizer materials, and
2. The effect of increasing amounts of phosphate fertilization on the zinc and phosphorus content of the sixth corn leaf and on the resulting ear corn yield.

Two randomized block experimental areas were established in mid-May of 1966 on the Richard Mikkelson farm some 2 to 3 miles north of Benson in Swift County. Each experiment consisted of 7 treatments replicated 4 times. All zinc treatments except one chelated zinc source (which was row applied each year) and all P treatments were broadcast and then plowed down. The farm operator also applied a total of 100 + 40 + 40 per acre as a blanket broadcast application before plowing. In 1966 the spring was late, so 90 day maturity corn was planted. Atrazine was applied on June 1st and leaf samples were taken in early September. In 1967, the planting season was earlier and a 100 day corn maturity was used. A mid-September frost materially decreased the 1967 ear corn yield. The soil pH was 8.2.

One of the problems in field experiments with zinc fertilization is the extreme variability of soils in their response to zinc applications. For this reason, large apparent differences may not be statistically significant.

The zinc and phosphorus content of the sixth (index) corn leaf collected in August of 1967 is shown in Table 1.

Table 1. Zinc and Phosphorus Content of the Sixth Corn Leaf Growing with Various Zinc Applications to the Soil.

Zn Treatment (lbs/A)	Leaf Zn in ppm 1966	Leaf Zn in ppm 1967	Leaf P - % 1966	Leaf P - % 1967
1. None	7.2c	9.2d	0.400a	0.367a
2. 10 as $ZnSO_4$-plowed down-1966	11.7bc	13.8c	0.297bc	0.304bc
3. 20 " " " " "	14.0b	18.2b	0.259c	0.273c
4. 40 " " " " "	18.0a	26.5a	0.259c	0.281bc
5. 10 as ZnMNS " " "	9.3bc	12.8cd	0.326abc	0.285bc
6. 0.5 as Na_2Zn-row-1966 & 1967	8.6c	11.8cd	0.394a	0.331ab
7. 2.5 " " -plowed down-1966	8.3c	11.5cd	0.372ab	0.323abc

The 20 and 40 pound rates of zinc as the sulfate significantly increased leaf zinc in both years, while the 10 pound rate as sulfate or as ZnMNS gave a lesser and non-significant increase. Both chelate applications were least effective in raising leaf zinc concentrations.

As rates of zinc fertilization increase, phosphorus decreases in corn leaves, with the heavier $ZnSO_4$ treatments producing a significant depression with chelated zinc having the least effect on leaf P.

Zinc is applied to soils primarily to increase corn yields and these are shown in Table 2.

Table 2. The Effect of Zinc Applications on the Yield of Field Corn in 1966 and 1967.

Zn Treatment (lbs/A)	Ear Corn @ 15.5% moisture - bu/A 1966	Ear Corn @ 15.5% moisture - bu/A 1967
1. No zinc	92.0bc	56.1
2. 10 as $ZnSO_4$-plowed down-1966	115.4a	77.5
3. 20 " " " " "	111.8a	75.6
4. 40 " " " " "	109.3a	81.7
5. 10 as ZnMNS-" " "	103.8ab	79.2
6. 0.5 of Na_2Zn-in row-1966 & 1967	85.5c	69.7
7. 2.5 " " -plowed down-1966	93.3bc	58.4
		N.S.

The more mature crop of 1966 showed significant yield increases with the three rates of $ZnSO_4$ application, with the ZnMNS effect being less clear cut. The two chelated zinc treatments failed to significantly increase yields.

As mentioned previously, a mid-September frost in 1967 materially lowered yields. The variability in yields amongst the four replicates was large, resulting in no significant effect of the zinc treatments.

The second portion of this experiment was to determine the effect of applied phosphate zinc and phosphorus content of corn leaves and on eventual corn yield. The effect of increasing rates of phosphate fertilization on leaf Zn and P are shown in Table 3.

Table 3. The Effect of Phosphate Fertilization on Zinc and Phosphorus Concentrations of the Sixth Corn Leaf.

	Leaf Zn in ppm		Leaf P - %	
1966 Soil Treatment (lbs/A)	1966	1967	1966	1967
1. 40 P_2O_5	10.0ab	10.2abc	0.351bc	0.317c
2. 80 "	10.2ab	12.5ab	0.313bc	0.312c
3. 160 "	8.4bc	10.5abc	0.359bc	0.323c
4. 320 "	7.5c	9.0bc	0.400b	0.436b
5. 640 "	7.3c	8.2c	0.486a	0.570a
6. 320 " + 10 Zn as $ZnSO_4$	12.4a	13.2a	0.325bc	0.308c
7. 640 " " " "	11.0a	12.0ab	0.304c	0.310c

It is evident that the higher rates of phosphate fertilization have significantly decreased the zinc content of the leaves and the application of 10 pounds of Zn per acre as the sulfate results in a sharp increase in leaf zinc levels. Increasing P_2O_5 fertilization increases leaf P and $ZnSO_4$ soil treatments repress P levels.

The 1966 and 1967 ear corn yields of the zinc-P experiment are shown in Table 4.

Table 4. The Effect of Phosphate and of Zinc Sulfate Fertilization on Ear Corn Yield in 1966 and 1967.

1966 Soil Treat (lbs/A)	Ear Corn Yield @ 15.5% moisture (bu/A)	
	1966	1967
1. 40 P_2O_5	98.4ab	68.5a
2. 80 "	96.9ab	65.8a
3. 160 "	96.3ab	60.8a
4. 320 "	96.8ab	50.2a
5. 640 "	83.4b	34.3a
6. 320 " + 10 Zn as $ZnSO_4$	113.6a	74.8a
7. 640 " " " "	107.6a	74.7a

Since zinc deficiency in corn is more likely to occur on the more calcareous soils, most of severely deficient areas occur on relatively low lying lands which are subject to wet soil conditions in the spring and this often delays planting and maturity. In 1966, the corn was relatively mature when frost ended the growing season and the 640 pound P_2O_5 treatment produced the lowest corn yield. Applying 10 pounds of zinc per acre to the two higher P_2O_5 treatments resulted in significantly increasing these yields.

In 1967, the harvested corn was immature, and though the yield trend was similar to that of 1966, none of the differences were significant. Corn maturity is essential for maximum zinc or phosphate effect on yields. Zinc uptake by the corn plants in August of both years is much the same (Table 3) and it would be logical to believe substantial differences in ear corn yield would result if the corn matured. When early frost terminates corn growth, variability is marked and yield differences do not reach mathematical significance.

Conclusions

1. Heavy P fertilization of calcareous soils represses leaf zinc and corn yield while increasing P content of the leaves.
2. Applying zinc sulfate corrects this situation.
3. $ZnSO_4$ remains available to corn plants for at least two years.
4. Immature corn results in lower yields and increases yield variation, thereby significance due to zinc fertilization.

Micronutrient Uptake by Soybeans

V. D. Krentos and R. H. Rust

The supply potential of surface horizons from 11 Minnesota soils for copper, molybdenum, and zinc was investigated in a controlled environment study. The soils used in the study were Aastad, Bearden, Fayette, Hegne, Kranzburg, Lester, Milaca, Nicollet, Ulen, Webster, and Zimmerman- soils which occur in the existing and expanding soybean growing areas. Cu, Mo, and Zn uptake in relation to certain Rhizobia strains was also studied. Plants of the Chippewa 64 variety were grown to 35 days in a 16-hour light and 8-hour dark cycle at 70° F.

Zinc applied at a rate of 5 ppm generally decreased phosphorus content in plants grown on either calcareous (Hegne, Blue Earth) or non-calcareous (Webster) surface materials (0 - 6"). On the other hand, applications of phosphorus increased dry matter yields on these three soils with a possible optimum between the 60 and 120 ppm P rates.

Zinc content in the soybean tops was higher, by a factor of 4, on the more acid soils such as Fayette and Milaca as compared to the alkaline soils such as Bearden, Hegne, and Ulen. Zn concentration ranged from 50 - 70 ppm in plants grown on the Fayette and Milaca to 10 - 20 ppm on Bearden and Ulen soils.

Neither copper content nor concentration in the plants were significantly different as grown on the 11 soils. Copper concentration was 5 - 6 ppm in the 35 day old soybean tops.

Molybdenum content was about two times higher in plants grown on the calcareous Bearden and Hegne compared to the somewhat acid Fayette, Lester,

or Milaca soils. Mo concentrations ranged from 0.7 ppm in plants grown on Zimmerman to about 2 ppm on Ulen.

Additions of zinc and molybdenum at the rates of 5 ppm and 0.25 ppm, respectively, resulted in increased uptake on all soils but the increase for added Zn was highest on the somewhat acid soils and for added Mo, on the calcareous soils.

Nitrogen content and concentration were increased on most soils when seeds were inoculated with an effective Rhizobia strain although certain indigenous strains were as "effective" as the introduced. Content of N and yield of N were increased by added Zn, Cu, and Mo, particularly when added in combination at the rates of 5 ppm Zn, 1 ppm Cu, and 0.25 ppm Mo. Statistical analyses suggested that the addition of Mo was more effective in increasing N content and concentration than Cu or Zn.

The establishment of Rhizobia, as indicated by the character of nodulation, seemed to be favored most in Aastad, Kranzburg, and Webster soils and least in Zimmerman and the calcareous soils, especially Hegne. It should be noted, though, that only one effective strain was used for inoculation. In most of the soils indigenous strains of Rhizobia apparently were as effective in increasing N as the introduced strains.

While increases in N content and concentration and in P and Zn content were associated with "effective" Rhizobia, no significant differences were observed with boron, calcium, copper, iron, magnesium, or potassium uptake as related to inoculation treatment.

SULFUR INVESTIGATIONS ON SOILS AND CROPS

A. C. Caldwell, E. C. Seim, G. W. Rehm, and H. Feilinger

The current research on sulfur had its beginning in 1962. Since that time major investigations have included studies on the oxidation of elemental sulfur in soil, effects of rates and kinds of sulfur-bearing materials on field crops, the movement of sulfur in soil, the measurement of sulfur in the atmosphere and rainfall, development of a satisfactory method for the determination of sulfur in plant tissue, an examination of the S-bearing compounds present during oxidation of elemental sulfur in soil, studies on the effects of soil type characteristics on sulfur oxidation, and an evaluation of the S-supplying power of some of the major soil types of Minnesota.

An experimental field was established near Park Rapids, Minnesota in the spring of 1962. Over the years tests have been conducted on alfalfa, corn, soybeans, potatoes, sunflowers, barley, oats, wheat and red clover-brome. An overhead irrigation system was established in 1965 to provide supplemental irrigation for the sulfur experiments. Additional experiments utilizing new sulfur bearing materials are in effect this year. New studies also include soil and air temperature and soil water measurements.

This report includes 1967 yield data and analytical studies completed or summarized since December 1966.

Appreciation is expressed to the Sulphur Institute and the Tennessee Valley Authority for help in the financing of these studies.

Alfalfa

A rate and form of sulfur study in alfalfa was established in 1962. First cutting alfalfa yields for 1967 and the sulfur content of the tissue sampled at that time are reported in Tables 1 and 2. Annual

applications of sulfur about doubled the yield over the unsulfured plot. All rates and forms of sulfur supplied adequate amounts of sulfur to the plants when they were applied annually. Sulfur and gypsum treatment applied in 1962, however, are no longer supplying sulfur at an adequate rate for maximum production. The 100 lbs. of elemental sulfur per acre treatment and the heavy gypsum treatment (1000#s/acre) continue to produce significant yield increases over the check but sulfur content has fallen below .3%.

Table 1. Effects of annual applications of S on yields of alfalfa and on % S in tissue.

Material	Rate # S/Acre	Yield (1st. cutting) tons/Acre	S in tissue (1st. cutting) % S
0	0	.63	.193
Sulfur	25	1.42	.350
Sulfur	50	1.15	.353
Sulfur	100	1.10	.360
Gypsum	50	1.12	.371
lsd (.01)		.28	.045
hsd (.01)		.37	.059

Table 2. Effects of residual applications of S on yield of alfalfa and on % S in tissue.

Material	Rate # S/Acre	Yield (1st. cutting) tons/Acre	S in tissue (1st. (cutting) % S
	0	.35	.170
sulfur	25	.53	.176
sulfur	50	.79	.204
sulfur	100	1.18	.230
gypsum	50	.48	.169
gypsum	1000	1.23	.284
lsd (.01)		.22	.032
hsd (.01)		.29	.044

On another established alfalfa field, nitrogen was supplied to some plots to determine whether cold weather might be limiting nitrification and nitrogen fixation. Thirty lbs. of sulfur and 32 lbs. of nitrogen were applied to plots whose previous history indicated all effects of

of sulfur materials applied in 1962 had been dissipated. The results are shown in Table 3. Nitrogen increased yields of the first cutting from .6 to 1.9 ton. All of the increased tonnage was not alfalfa however, as the nitrogen greatly stimulated the growth of grass and other weeds. There are indications that ammonium nitrogen increased the uptake of sulfur relative to the same amount of sulfur supplied with nitrate nitrogen or without nitrogen.

Table 3. Effects of sulfur and nitrogen materials on yield of alfalfa and on % S in tissue.

Material	#S/Acre	Date of application	1967 fertilization N	P	K	Comments	Yield 1st. cut ton/acre	S in tissue % S
None	0#	-----		18	90		.40	.199
Sulfur	25# 30#	1962 1967	#32	18	90	NO_3-N	1.02	.331
Sulfur	50#	1962		18	90		.73	.237
Sulfur	100#	1962		18	90		.89	.240
Gypsum	60#	10# (1962) 50# (1963)		18	90		.66	.248
K_2SO_4	10# 30#	1962 1967		18	90	N-check	.62	.348
16-20-0+S	10# 30#	1962 1967	#32	18	90	NH_4-N	1.08	.395
Trace Elements 25 +S		1962 10# S as Zn-Mn-N-S						
		15#S as Trace Element Mixture 1963		18	90		.36	.214
lsd (.01)							.31	.084
hsd (.01)							.45	.121

Small Grain

In 1967 sulfur treatments gave early indications of increasing growth and vigor in barley, wheat and oats. Sulfur produced only small or insignificant increases in yields of grain however. No sulfur-bearing material was consistently better than the others. The yields, sulfur content of the whole plants at the boot stage and the sulfur content of the grain are reported in Table 4.

Table 4. Effect of sulfur-bearing materials on yield and sulfur content of small grain.

Small Grain	Material	# S/Acre	%S-Boot Stage	%S-Grain	Yield bu/acre
Wheat	none	0	.171	.193	15.2
Wheat	Elem. S	10	.186	.224	16.1
Wheat	Gypsum	10	.187	.215	14.8
Wheat	Na_2SO_4	10	.170	.195	13.9
			N.S.	N.S.	N.S.
Oats	none	0	.163	.207	51.9
Oats	Elem. S	10	.178	.232	51.3
Oats	Gypsum	10	.175	.226	54.9
Oats	Na_2SO_4	10	.179	.224	53.7
			lsd(.05).012	lsd(.05).013	N.S.
			hsd(.05).017	.018	
Barley	None	0	.210	.151	43.6
Barley	Elem. S	10	.236	.165	44.3
Barley	Gypsum	10	.215	.162	47.8
Barley	Na_2SO_4	10	.207	.149	46.0
			lsd(.05).018	N.S.	N.S.
			hsd(.05).025)		

CORN

Although the corn exhibited sulfur deficiencies early in the season, 10 lbs. of sulfur as Na_2SO_4 broadcast and disked in before planting did not significantly increase the yield of corn. Corn which did not receive sulfur produced 90.3 bushels per acre, sulfur-treated corn produced 91.9 bushels per acre. Sulfur treatments increased the sulfur content of

the 6th leaf from .261 to .282%.

Table 5. Effect of sulfur on the yield and sulfur content of corn. (Minn. 806 - irrigated).

Treatment	%S 6th leaf	Yield bu/Acre
Check-No Sulfur	.261	90.3
10# S/acre as Na_2SO_4	.282	91.9
	N.S.	N.S.

POTATOES

Yields of irrigated Burbank Russet potatoes ranged from 432.0 bushels (259 cwt) per acre to 625.4 bushels (375 cwt) per acre. Sulfur treatments did not consistently affect the yield or quality of the potatoes as indicated by specific gravity, but both gypsum and elemental sulfur treatments (50# S/acre) significantly increased the sulfur content of the potato petioles. The sulfur content of the petioles from untreated plants averaged .192% sulfur while those receiving 50 lbs. of sulfur per acre as elemental sulfur or gypsum averaged .295 and .282% S respectively.

Table 6. Effect of sulfur on yield of irrigated Burbank Russet potatoes.

Treatment	Rate #S/acre	Yield bu/acre	Yield cwt/acre	S in petioles % S	Specific gravity
None	0	521.5	312.9	.192	1.098
Elem. S	50	570.4	347.2	.295	1.090
Gypsum	50	502.9	301.8	.282	1.092
		N.S.	N.S.	lsd (.01) .055 hsd (.01) .065	N.S.

SOYBEANS

Yields of soybeans ranged from 26 to 30 bushels per acre but treatment differences due to applications of elemental sulfur and gypsum were not significant (Table 7).

Table 7. Effect of sulfur on the yield of soybeans
Park Rapids, Minnesota - 1967

Treatment	#S/Acre	Yield bu/Acre	% of S-Grain
Check	0	28.27	.364
Sulfur	25	26.86	.355
Sulfur	50	28.74	.348
Gypsum	50	30.21	.366
		N.S.	N.S.

Effects of Sulfur Treatments on pH of Surface Soil

A survey of the pH of the surface soil of alfalfa plots treated with annual applications of sulfur and gypsum indicated that the sulfur applications were lowering the ph of the surface. Consequently a more extensive sampling was made in the spring before the 1967 treatments were applied. Samples were taken by one inch increments to three inches and another from 3 to 6 inches. Each plot sample was a composite of five cores taken at random within each plot. The data presented in Table 8 are the averages of six plots.

Table 8. Effect of S treatments on the pH of the surface of a Dorset sandy loam.

Treatment	Rate	pH			
	lbs.S/acre/yr.	0 - 1"	1 - 2"	2 - 3"	3 - 6"
None	0	6.67	6.53	6.28	6.52
Elemental S	25	5.90	5.75	5.87	6.20
Elemental S	50	5.65	5.82	5.92	6.32
Elemental S	100	5.07	5.42	5.77	6.25
Gypsum	50	6.53	6.15	6.12	6.37
lsd (.01)		.32	.32	.25	N.S.
hsd (.01)		.42	.43	.33	N.S.

SULFATE LEACHING

A study was established in the spring of 1964 to trace the movement of sulfate sulfur in the profile under field conditions. Sulfur treated plots received 200 lbs. of sulfur per acre as gypsum. Sweet corn was grown on both treated and untreated plots. Periodically, soil samples were taken from these plots at 6 inch intervals to a depth of 36 inches. Sulfate sulfur in these samples was extracted with a .15% $CaCl_2$ solution and measured turbidimetrically as $BaSO_4$.

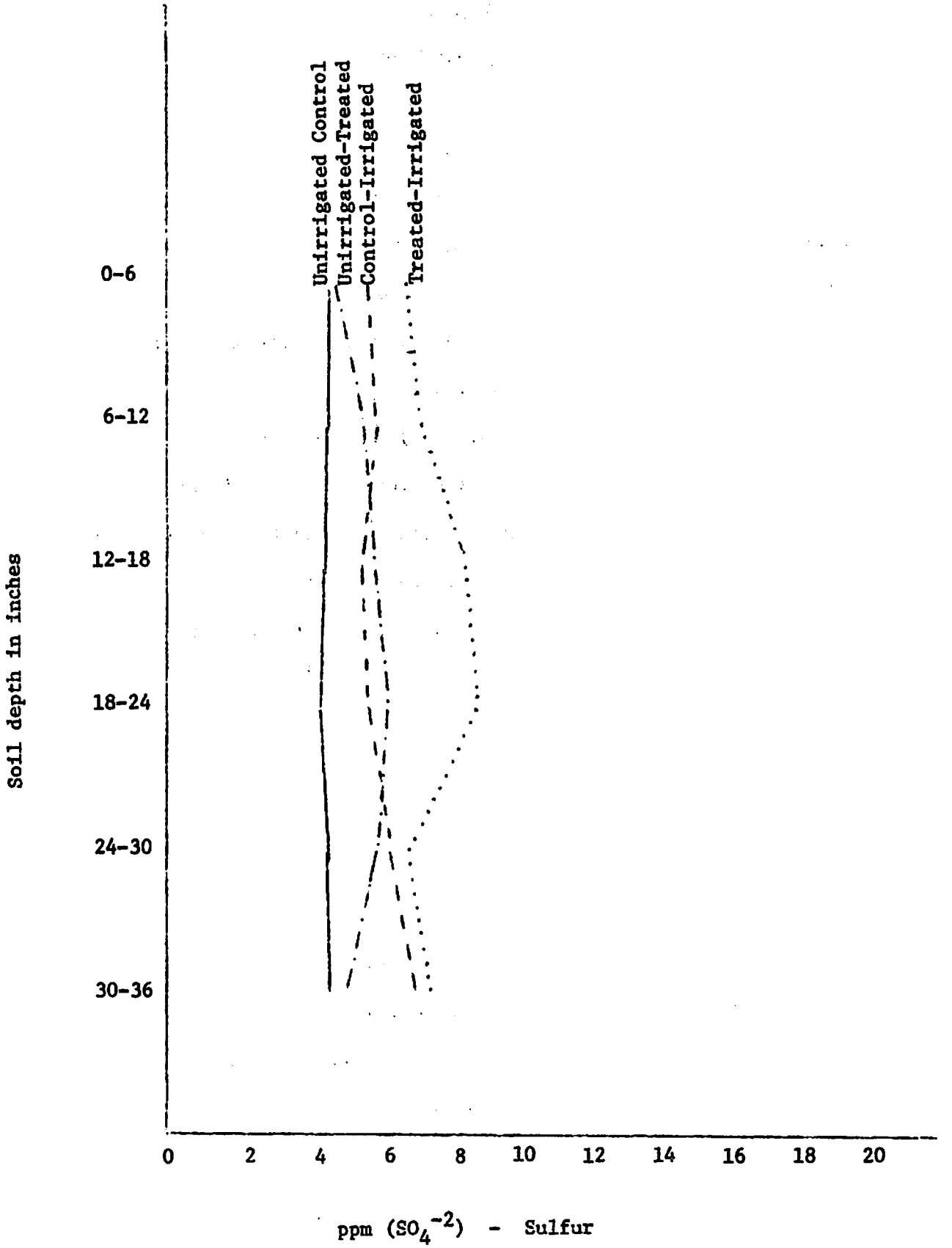
The detailed results of previous samplings were given in previous reports (Sulfur Investigations on Soils and Crops. Reports 6,7,and 9).

The results of the sampling made October 1, 1966 are reported in Table 9 and depicted graphically in Figure 2.

Table 9. Sulfate sulfur in the profile of a Dorset sandy loam on October 1, 1966.

Treatment	Core	Plot	Depth of Sample (inches) 0-6	6-12	12-18	18-24	24-30	30-36
Unirrigated No S	1	1	6.8	6.8	6.0	5.8	4.5	5.3
			6.0	6.3	6.8	5.3	5.0	5.0
	2	1	5.0	5.0	4.5	5.0	6.5	5.8
			5.0	5.0	5.0	5.3	5.8	5.3
	3	1	2.8	2.5	2.3	2.5	2.5	3.3
			2.8	2.3	2.5	2.3	2.3	3.3
	Average		4.7	4.6	4.5	4.4	4.6	4.7
Irrigated No S	7	3	5.0	4.5	4.5	5.8	5.0	5.3
			5.0	4.5	5.3	5.3	5.0	5.8
	8	3	6.0	7.8	6.0	6.0	6.0	5.8
			6.0	7.3	6.0	6.0	6.0	6.0
	9	3	6.3	6.3	6.3	5.0	8.0	7.0
			6.3	6.3	5.3	6.8	8.0	7.0
	Average		5.8	6.1	5.6	5.8	6.4	6.1
Unirrigated Gypsum @ 200 lbs. S/acre in 1964	4	2	4.0	7.0	7.3	7.0	6.3	4.3
			4.3	6.8	7.8	6.3	6.0	4.3
	5	2	6.5	5.0	5.5	5.3	5.3	5.3
			6.3	5.0	5.3	5.5	6.3	5.8
	6	2	4.3	5.5	5.3	6.8	6.0	6.0
			3.5	4.3	5.0	6.8	6.3	6.0
	Average		4.8	5.7	6.0	6.3	6.0	5.2
Irrigated Gypsum @ 200 lbs. S/acre in 1964	10	4	5.8	6.8	6.0	10.3	6.0	7.3
			5.8	6.0	8.5	8.0	6.0	7.3
	11	4	6.7	8.8	9.5	10.5	7.8	7.8
			8.0	8.0	10.3	8.7	7.8	8.0
	12	4	8.0	7.0	8.0	7.8	7.0	7.8
			7.0	7.0	8.5	7.8	7.0	7.0
	Average		6.9	7.3	8.6	8.9	6.9	7.5

Sulfate sulfur in the profile of a Dorset sandy loam
(200 lbs. S/acre as Gypsum applied in Spring 1964)
Fall "66"



Soybean Inoculation Studies

George E. Ham

Six strains of Rhizobium japonicum (soybean rhizobia) obtained from the USDA, Beltsville collection were used to inoculate three different varieties of soybeans at Grand Rapids in 1967. The peat-based inoculants were applied to the seed the night before planting and kept refrigerated until planted. Three replications with three-row plots were utilized with the center row of each plot inoculated. Inoculation increased the seed yield of both Portage and CMI by 8 bushels per acre (Table 1). Few or no nodules were present on the roots of the uninoculated plants.

Nitrogen fertilizer (ammonium nitrate) was added at planting time at the rate of 50, 100, and 200 pounds of nitrogen per acre in order to determine the amount required to produce a seed yield equal to the inoculated plants. No inoculum was applied to the seed. In no case did the addition of nitrogen fertilizer increase yields as much as inoculation with the best nitrogen fixing rhizobia (Table 2). The heavier rates of nitrogen reduced the stand and shortened the plants.

Inoculation experiments at Waseca, Lamberton and Big Lake showed no yield increase for inoculation when rhizobia were already present in the soil. Samples of soybeans that had been preinoculated with liquid and peat-based cultures and samples hand inoculated immediately before planting were compared to the uninoculated check. Paired samples taken before and after inoculation were grown in adjacent three-row plots in order to remove any variation due to seed source. Nodulating and non-nodulating soybean isolines of Chippewa maturity produced seed yields of 36 and 26 bushels per acre, respectively, at Rosemount during 1967.

Table 1. Influence of different strains of Rhizobium japonicum on soybean seed yields on a rhizobia-free soil at Grand Rapids in 1967.

Rhizobium strain	Soybean variety		
	Portage	CMI	55-14
	Seed yield bu/A	Seed yield bu/A	Seed yield bu/A
0	25	24	26
38	27	25	28
110	30	26	27
122	28	28	29
123	26	28	28
135	27	25	28
138	33	27	28
Mixture *	26	32	28

* Mixture is a composite of the six different strains
lsd (.05) = 3 bu/ acre
lsd (.01) = 4 bu/ acre

Table 2. Influence of nitrogen fertilizer on soybean seed yields at Grand Rapids in 1967.

Nitrogen fertilizer rate	Soybean variety		
	Portage	CMI	55-14
lb/A	bu/A	bu/A	bu/A
0	26	25	30
50	28	24	29
100	28	26	27
200	27	24	26

Sugarbeet Rotation Study - 1967
Northwest Experiment Station, Crookston
Olaf C. Soine, Soil Scientist

Sugarbeet production in the Red River Valley is a highly specialized enterprise with a large investment in land, machinery, and high production costs. Most growers use a 4-year rotation which includes 1 year of legume or black fallow. This gives the grower 3 cash crops in a 4-year period. This sugarbeet rotation study was initiated in the spring of 1967 to appraise the economic return from various systems of cropping.

The crop yields for the 6 rotations are as follows for 1967.

Rotation 1	Beets	Wheat	Barley	Sw. cl. fallow
	13.11 T.	55.7 bus.	101.2 bus.	_____
Rotation 2	Beets	Wheat	Barley	Oats
	13.72 T.	55.6 bus.	100.9 bus.	136.7 bus.
Rotation 3	Beets	Potato	Wheat	Barley
	13.13 T.	195 bus.	52.2 bus.	91.5 bus.
Rotation 4	Beets	Wheat	Barley	Alf-hay-fallow
	12.02 T.	49.7 bus.	105.6 bus.	_____
Rotation 5	Beets	Wheat	Barley	bl. fallow
	13.33 T.	60.1 bus.	100.4 bus.	_____
Rotation 6	Beets	Wheat	Barley	Soybeans
	13.40 T.	57.5 bus.	91.1 bus.	33.6 bus.

Chris wheat sown May 20 - harvested August 24, 1967.

Larker barley sown May 20 - harvested August 15, 1967.

Norland potato planted May 22 - harvested August 31, 1967.

Merit soybeans planted May 22 - harvested October 2, 1967.

Sugarbeets planted May 20 - harvested September 22, 1967.

POTATO FERTILIZATION ON SANDY LOAMS

Curtis J. Overdahl
Extension Specialist in Soils

Potato experiments under irrigation were conducted in 1966 and 1967 near Osseo in Hennepin County and Clear Lake in Sherburne County. The objective was to determine the fertilizer need on soils that had been fertilized intensively for several years and soil tests having been built to very high levels. Also of interest was the effect of high potassium fertilization on magnesium availability. Two farms were selected where a contrast was possible between a very high build-up of fertility over several years, and one which had not had the benefit of this nutrient build up. The latter farm was recently purchased and put under irrigation and intensive potato production.

Yields and related factors were as follows:

Potassium Experiments:

Soil tests at beginning of experiment were as follows:

Tessman Farm, Hennepin County P=200+, K=600+, pH=5.4, sandy loam

Gray Farm, Sherburne County P=17 lbs., K=130, pH=5.4, sandy loam

1966 Results

	Yield* CWT/Acre		Petiole Analysis			
			Tessman		Gray	
Fertilizer Treatments	Tessman	Gray	%K	%Mg	%K	%Mg
100 + 100 + 0	332	207	11.6	.14	-	-
100 + 100 + 50	315	-	12.0	.17	-	-
100 + 100 + 100	293	232	12.3	.09	8.3	.55
100 + 100 + 250	356	313	13+	.15	10.0	.38
100 + 100 + 500	277	338	12.8	.14	11.8	.31
100 + 100 + 1000	-	341	-	-	11.3	.37

* Norland variety

1967 Results

Fertilizer Treatments	Yield* CWT/Acre Tessman	Yield* CWT/Acre Gray **	Petiole Analysis Tessman %K	Petiole Analysis Tessman %Mg	Petiole Analysis Gray %K	Petiole Analysis Gray %Mg
150 + 150 + 0	206	111	8.0	.22	4.5	.49
150 + 150 + 100	-	194	-	-	7.6	.22
150 + 150 + 150	225	-	8.0	.20	-	-
150 + 150 + 250	-	198	-	-	9.0	.15
150 + 150 + 500	222	199	7.9	.20	9.0	.13
150 + 150 + 1000	-	203	-	-	9.0	.15

* Average of two varieties
**This plot had severe hail June 30, but the moderately late bounty variety recovered quite well, while the somewhat earlier Norland yielded considerably less.

Where the potassium (K) test was 600+ at Tessman's, there was no K response in 1966. In 1967, there was considerable yield variation and no apparent response. Tissue analysis for K showed little treatment effect. Magnesium (Mg) content tested low for all treatments of K.

At Gray's Farm near Clear Lake in 1966, potato yields increased directly with K treatments, K in the petiole also increased directly with treatments and magnesium content was correspondingly decreased but not nearly to such a low level as at Tessman's. In 1967, the results may not be as meaningful because of severe hail damage. The first 100 pounds of K_2O gave the only important yield increase, but hail apparently reduced chances of the potatoes being able to capitalize on any high K treatments. Magnesium content was reduced seriously as K content was increased due to K treatment.

Changes in soil test due to K treatment are also of interest, particularly on the Clear Lake Farm where we started from a relatively low level. This land is usually plowed about seven or eight inches deep.

Potassium Treatment K_2O lbs/acre	K Soil Test After 1966 Crop 0 - 6"	6 - 12"	After 1967 Crop 0 - 6"	6 - 12"
0	130	50	150	70
100	150	50	170	75
250	180	100	180	105
500	200	250	345	330
1000	230	400	340	365

MAGNESIUM EXPERIMENTS

In 1967, a magnesium experiment was established on the Tessman farm. There was no significant yield response to magnesium or effect on the magnesium content in the petioles. Results with the bounty variety were as follows:

	Magnesium Treatment lbs/acre 0	25	50	75	300
Yield CWT	339	328	341	344	322
% Mg in petioles	.22	.23	.26	.25	.23

Magnesium was applied as magnesium sulfate. All material was applied in the row except 225 pounds of the 300 pound treatment. The NPK rates were 150 + 150 + 500. This plot was adjacent to the other experiments but was in rye for soil improvement in 1966.

Two years results with magnesium containing dolomitic limestone on nearby plots gave no yield increase with four varieties and little, if any, effect on magnesium petiole content. Magnesium in the petioles in 1967 ranged from .19 to .25. Limestone rates ranged from 0 to 8000 pounds per acre.

PHOSPHORUS STUDIES

There was no apparent phosphorus response in 1966 at Osseo where the P test was 200+, but in 1967 there was an obvious starter P response. Where the P soil test was only 17 pounds per acre at Clear Lake, results were as follows:

1966 Treatment	CWT*/A	%P	1967 Treatment	CWT*/A	%P
100 + 0 + 500	255	.29	150 + 0 + 500	98	.16
100 + 100 + 500	325	.26	150 + 150 + 500	233	.43

* 1966 Norland Variety, 1967 Average of Bounty and Norland Varieties.

The P soil test after one year was raised from 17 to 26 and after two years was raised to 40 pounds of absorbed P per acre.

NITROGEN STUDIES

Response to nitrogen at Tessman's indicated that 200 pounds per acre was superior to 100 pounds, while at Gray's there was a good response from 100, but 200 pounds in 1966 yielded no better. In 1967, the 200 pound treatment looked best but hail kept these plots from producing very well and conclusions on nitrogen could not be drawn.

Funds for this project were supplied by the American Potash Institute. Efforts in plot work leadership by G. W. Randall, C. P. Klint, as well as county agents, George Roadfeldt, Enoch Bjuge, Horticulture specialist, O. C. Turnquist, and TVA specialist, Harvey Meredith, are gratefully acknowledged. The excellent cooperation of Howard Gray and Eldon Tessman in the use of their machinery, as well as their land, is much appreciated.

FERTILIZER TRIALS ON OIL CROPS

Northwest Experiment Station
Crookston, Minnesota - 1967

Olaf C. Soine, Soil Scientist

Sunflowers: The yield data for sunflowers for 1967 and the 1966-67 averages are given in Table 1. The yields were lower in 1967 than in 1966 due in part to the summer drought. The 20-40-0 treatment gave the best yield response in 1967 and also for the 2-year average. There was very little variance in the bushel weights.

Tame Mustard: The yield data for tame mustard is given in Table 2. The yields in 1967 were low, due in part to the summer drought. Six treatments were above the check plot, and 7 were below. The *10-40-0 treatment gave the highest yield response in 1967, and the *20-40-0 gave the best response in the 2-year data.

Table 1. The effect of fertilizer on the yield and bushel weight of sunflowers.
Northwest Experiment Station, 1967 and 1966-1967 average.

Treatment lbs./acre	Yield lbs./acre		Bus. wt.	
$N - P_2O_5 - K_2O$	1967	Av. 1966-67	1967	Av. 1966-67
20-40-0	2205	1894	28	28
40-80-0	2094	1882	28	29
20-40-20	1971	1749	28	28
40-80-40	1711	1688	28	29
0-0-20	1791	1671	27	28
0-40-20	1754	1630	28	28
0-80-0	1680	1565	28	28
20-0-0	1626	1546	28	28
0-80-40	1638	1525	28	29
0-0-0	1578	1488	28	29
40-0-0	1319	1470	28	28
0-40-0	1393	1454	28	29
80-160-80	1390	1390*	27	27
0-0-40	1290	1289	28	28

Table 2. The effect of fertilizer on the yield of tame mustard. Northwest Experiment Station, 1967 and 1966-67 average.

Treatment lbs./acre $N - P_2O_5 - K_2O$	Yield-1967 lbs./acre	Av. Yield 1966-1967 lbs./acre
**20-40-0	820	1093
*10-40-0	918	1073
**30-40-0	905	1017
*30-40-20	818	1009
20-40-20	861	990
0-40-0	860	978
**20-0-0	735	953
10-40-0	835	946
0-0-0	852	940
*10-0-0	814	922
*20-40-0	809	899
**60-80-40	---	1266+
40-80-40	852	852++
**40-40-20	840	840++
80-160-80	791	791++

\+ 1966 data
++ 1967 data
Treatments *10-0-0 and **20-0-0 broadcast before seeding.
Remaining treatments applied alone and in combinations with broadcast treatments in a band at seeding time (e.g. **20-40-0---**20-0-0 broadcast + 0-40-0 with drill).
Sown May 6, 1967 -- Harvested August 3, 1967

1967 Sunflower Fertility Experiment

A. Heikkila, H. Shurson, F. Jorgenson, and G. Randall

An experiment was established in the spring of 1967 in Clearwater County to determine the effect of differnet fertility treatments on the seed yield of sunflowers. The variety Arrowhead was used. All treatments were replicated three times.

Experimental Field Soil Test Values

Sample No.	pH	O.M. %	P lbs/A	K lbs/A	Texture
1.	7.5	8.5+ Vh	16 M	240 H	Silt loam
2.	6.9	8.5 Vh	27 H	310 Vh	Silt loam

Table 1. The Effect of the Fertilizer Treatment on Number of Harvested Heads and Seed Yield.

Treat No.	Treatment lbs N + P_2O_5 + K_2O	Number Heads	(DMRT)*	Yield lbs/A	(DMRT)
1	0 + 0 + 0	51	a	728	bc
2	0 + 0 + 30	45	a	610	c
3	0 + 30 + 0	38	a	795	bc
4	0 + 30 + 30	41	a	549	c
5	30 + 0 + 0	54	a	1166	a
6	30 + 0 + 30	51	a	1012	ab
7	30 + 30 + 0	43	a	766	bc
8	30 + 30 + 30	49	a	784	bc
9	30 + 30 + 60	47	a	970	ab
10	30 + 60 + 30	46	a	869	abc
11	60 + 30 + 30	47	a	1036	ab
12	60 + 60 + 60	52	a	998	ab

*Duncan's Multiple Range Test; those numbers followed by the same letter are not significantly different at the .05 level.

Results showed no significant differences among the treatments regarding the number of heads harvested, but significant yield responses were observed. The addition of 30# N gave a 262 pound seed yield increase, even on these soils high in organic matter. Phosphate and potash treatments did not increase sunflower seed yields. High and very high P and K soil test levels showed little possibility of response for adding these elements. Increasing the fertility rates up to 60#/A did not significantly increase the yields above the 30 + 0 + 0 treatment.

AGRONOMIC STUDIES WITH SUGAR CORN AND SORGHUM

Russell D. Frazier, Waseca

Interest developed in 1967 for agronomic studies on sugar corn and sorghum due to the introduction of a new industry in southcentral Minnesota. The acreage in 1967 was some 11,000 acres. The entire above-ground portion of the crop is harvested, the juice is extracted and refined as liquid sugar. While the potential of the industry to southern Minnesota is clearly apparent, the agronomic factors involved have not been well studied. Northland Research entered into an agreement with the University to conduct research, particularly in the areas of the effects of soil fertility conditions on the production, extraction and refining of sugar. Plant content of nitrogen and potassium at harvest time was thought to affect the sugar extraction processes used. The objective of the initial study was to study the effect of the amount and placement of nitrogen and potassium fertilizer on early seedling vigor and other agronomic variables in both high sugar corn and sorghum. To our knowledge, there have been no previous studies in this country of the effects of soil fertility on the sugar content of high sugar corn. An N-K factorial experiment was initiated using N at the 70, 140 and 200 lb. levels with K_2O at 0, 200 and 400 lb. per acre rates. Four replicates were provided; P_2O_5 treatment was uniform at 100 lbs. per acre, as was a starter fertilizer of 175 lb. of 6-24-24. Each plot was split with and without a "pop-up" application of 50 lb. of 15-39-9.

Percent sugar and pounds per acre production of sugar were calculated using a hand refractometer reading directly in percent sugar. Readings were taken on the expressed sap from six plants harvested per plot. In calculating sugar yield, the assumption was made that the sugar content of the entire plant was represented by this sap. While the data thus obtained do represent the sugar content of the stalks, the leaves, ears, and tassels of the plant contain

a lesser content of sugar and thus the data tend to over-estimate the sugar concentrations and the sugar production per acre. Fresh and dry weights were obtained on samples from each plot and pounds per acre sugar production as well as total dry matter calculated on this basis. Plant population was a uniform 25,000 plants per acre. Soil tests for P and K are in the high range.

Table 1. Percent Sugar in Stalks, Sugar Corn Research, 1967, Southern Experiment Station, Waseca. (One year's data, not for publication.)

	Fertilizer nutrients applied					
	K_2O 0		K_2O 200		K_2O 400	
(% sugar)	Starter	Band	Starter	Band	Starter	Band
August 22-25			Percentage sugar			
N_{70}	9.0	9.6	9.3	9.4	9.2	9.0
N_{140}	9.0	9.3	9.1	9.1	9.2	9.2
N_{210}	8.8	9.1	8.8	9.2	9.3	9.2
September 14						
N_{70}	13.0	14.0	13.0	13.9	12.9	13.5
N_{140}	13.0	13.0	13.1	13.3	13.6	13.5
N_{210}	13.3	13.8	12.8	13.3	13.3	13.5
October 2						
N_{70}	11.1	11.2	12.5	12.3	12.5	11.6
N_{140}	11.9	11.0	12.7	12.6	13.0	11.9
N_{210}	12.4	12.1	11.3	12.0	11.7	12.2

Table 2. Pounds per acre sugar production, sugar corn research, 1967; Southern Experiment Station, Waseca, Minnesota 1967.

	Fertilizer nutrients applied					
	K_2O 0		K_2O 200		K_2O 400	
	Starter	Band	Starter	Band	Starter	Band
August 22-25			Percentage sugar			
N_{70}	5054	5779	6514	6825	6594	6726
N_{140}	5996	6284	5808	6333	6219	6494
N_{210}	6018	6067	6447	6374	6829	5646
September 14						
N_{70}	8248	8478	8805	9235	9294	9624
N_{140}	8321	7817	8705	8716	9662	10157
N_{210}	9549	8856	9434	9123	9472	9449
October 2						
N_{70}	3665	3585	8257	7978	4769	4609
N_{140}	4252	3887	4744	4792	4895	4985
N_{210}	7318	7367	4283	4501	4960	4632

This data is incomplete and not for publication. Pounds per acre sugar is subject to the sampling methods used, and probably over-estimates true production.

Table 3. Dry Matter Pounds Per Acre, Southern Experiment Station, Waseca, Minnesota, 1967.

	Fertilizer nutrients applied					
	K_2O 0		K_2O 200		K_2O 400	
	Starter	Band	Starter	Band	Starter	Band
August 22-25			Percentage sugar			
N_{70}	20,833	16,874	20,417	19,791	16,562	17,708
N_{140}	17,500	18,125	24,479	18,541	18,437	18,125
N_{210}	17,916	17,604	20,104	17,187	16,145	15,520
September 14						
N_{70}	18,183	16,595	17,940	17,994	18,667	19,063
N_{140}	17,771	16,529	17,295	17,015	18,917	19,177
N_{210}	19,498	18,033	17,505	20,334	18,514	20,322
October 2						
N_{70}	17,050	16,832	18,265	17,381	18,340	19,788
N_{140}	16,729	16,934	17,443	18,792	16,696	18,618
N_{210}	18,477	16,588	17,923	19,298	20,289	19,277

This data is incomplete and not for publication.

FERTILIZING ALFALFA IN MORRISON COUNTY MINNESOTA

Curtis J. Overdahl
Extension Specialist in Soils

Limited experiments and field demonstrations indicate that high yielding, high quality alfalfa can be grown if details of fertilization, liming, variety, and proper cutting times are observed.

Alfalfa is seldom grown successfully on sandy textured soils that test low in potassium or have pH values below 6.3.

These conditions generally prevail in soil areas of Minnesota approximately north and east of a line from the Twin Cities to Alexandria, Minnesota to the Canadian border. There are, of course, many exceptions to such a general description. Although many of these soils are not sandy textured, the nutrient deficiencies are often similar.

Experimental plots on alfalfa were established at Pierz in Morrison County in the fall of 1962 on non-irrigated land. These plots were established to determine needed rates of potassium, lime, and phosphorus, but sulfur and boron were applied to be sure a deficiency of these elements didn't limit growth.

Results definitely show that high rates of potassium, both at seeding time and topdressed later, are necessary for most economical production. There is a lime response even with initial pH levels of 6.2 or 6.3. Alfalfa winter killed in 1966 hence no data are available for that year.

Table 1. Alfalfa yields in tons per acre and related profits according to varying 1963 treatments of potash and 1964, 1965, and 1967 yields.

Year	Cuttings	1963 Seeding time rates of K_2O, pounds per acre				
		0	60	120	180	240
1964	2	2.31	2.40	2.60	2.70	3.00
1965	3	4.02	4.16	4.50	5.08	5.36
1967	3	1.32	1.23	1.32	1.70	1.71
3-year yield total		7.65	7.79	8.42	9.48	10.07
Potash cost/acre		0	3.00	6.00	9.00	12.00
3-year increase tons/acre		0	.14	.77	1.83	2.42
Value of increase at $18/ton		0	$2.52	$13.86	$32.94	$43.56
Hay value increase less potash cost (three year total)		0	$-.48	$ 7.86	$23.94	$31.56

In Table 1, it can be seen that the effect of the 1963 potash treatments has about disappeared after three crop years. All plots fertilized in 1963 were split three ways in the fall of 1964 and were topdressed annually at 0, 120, and 240 pounds of K_2O. Each year all plots received 60 lbs/acre of P_2O_5. Borated gypsum at the rate of 300 lbs/acre supplying 50 pounds of actual sulfur and 4 1/2 lbs/acre of boron was applied in 1963 and 1967 over all plots.

Soil samples were taken in May 1967, tissue tests were made at the time of the first cutting. Yields were taken June 13, July 26, and August 31.

Table 2. Soil treatments of K_2O and its relationship to 1967 soil tests, tissue analysis and alfalfa yields. Only two replicates are involved in this sampling.

K_2O Treatment						
	annually	Soil Test			Tissue	1967 Yield
1963	1964, 65, 66	pH	P	K	% K	tons/acre
0	0	6.9	21 high	30 V. low	0.7	0.8
60	0	6.3	42 V. high	40 V. low	0.7	0.9
120	0	6.6	40 V. high	40 V. low	1.0	1.0
180	0	6.9	33 V. high	50 V. low	1.3	1.9
240	0	7.1	21 high	40 V. low	0.9	1.7
0	120	6.8	18 med.	150 med.	1.8	2.5
60	120	7.0	18 med.	100 med.	1.9	4.5
120	120	6.9	20 M. high	130 med.	2.1	4.3
180	120	6.8	23 high	190 med.	2.0	3.5
240	120	6.7	21 high	150 med.	1.9	3.9
0	240	6.5	28 high	390 V. high	2.2	4.1
60	240	6.8	28 high	350 V. high	2.3	4.9
120	240	6.9	19 M. high	340 V. high	2.3	4.1
180	240	6.3	28 high	250 high	2.2	3.6
240	240	6.8	16 med.	380 V. high	2.4	5.2

In the soil tests above, with only a few exceptions, we are quite certain the pH is at an adequate level after five years with five tons of lime. Phosphorus levels appear quite adequate, but P_2O_5 levels have been increased to 120 pounds for 1968.

Table 3. 1967 Averages from 20 replications of alfalfa.

	K_2O Annual Treatments after 1963		
	0	120	240
Yield 1967 tons/acre	1.52	4.14	4.51
% K in tissue	.93	1.96	2.25
Soil test, K	42 V. low	173 med.	325 V. high

Table 4. Lime Results. Alfalfa yields increases in tons/acre from 1962 lime treatments. Adequate P, K, S, and B added regularly.

	Tons per acre of lime*	
	2.5	5
1964 (2 cuts)	.24	.39
1965 (3 cuts)	.14	.41
1967 (3 cuts)	.60	.88
Total increase to date	.98	1.68
pH (6.3 initially) 1967	6.7	7.0

* Calcium carbonate equivalent of the lime was 93%, 31% of the lime passes a 60 mesh screen and 94% passes an 8 mesh screen. Lime is from Bryan's Quarry at Shakopee.

Table 5. Phosphorus Results. Increase in alfalfa yields in tons/acre and related soil test and tissue test. Adequate lime, K, S, and B added.

	Annual Treatment P_2O_5	
	30	60
1964 (2 cuts)	.30	.45
1965 (3 cuts)	.74	1.03
1967 (3 cuts)	1.37	1.86
Annual average increases	.80	1.11
% P tissue*	.22	.28
Soil test P* lbs/acre 1967	18	27

* With no phosphorus tissue contained .19% P, and soil tested 10 lbs/acre.

Acknowledgement is due the American Potash Institute for financial support of this project, to L. D. Hanson in assisting the establishment of the project, to Gyles Randall assisting in plot work and statistical analysis, and to Roderick Boser for excellent cooperation with field work and use of his land.

Grass Seed Production and Fertilizer Needs

John Grava, D. M. Larsen, G. W. Randall, and R. S. Farnham

Seed production of turf and forage grasses is a very important farm enterprise in northwestern Minnesota. Nearly one million dollars in cash sales are realized annually by seed producers in Roseau, Clearwater, Lake of the Woods and East Polk Counties. Cleaning plants at Roseau and Gully processed 1.5 million pounds of Kentucky bluegrass and 4.5 million pounds of timothy seed in 1965.

Optimum yields of high-quality seed require sufficient supply of plant nutrients. This is well recognized by the growers. They invest from seven to thirteen dollars per acre each year for commercial fertilizers. Generally, about one-third of the total production costs is spent on fertilization. Thus, soil fertility problems, proper fertilization, and diagnostic techniques used in the evaluation of plant nutrient needs are of utmost interest to the producers of grass seed.

Fertilization studies with Kentucky bluegrass and timothy have been conducted by several staff members of the Department of Soil Science since 1959. Information has been obtained on optimum rates of N, P, and K, on effects of time of fertilization, chemical properties of soils, soil tests, and plant analysis.

During the 1966/67 growing season, 8 field experiments were conducted on growers'fields in northwestern Minnesota. The investigations consisted of: (a) Date of fertilization, 3 trials with K. bluegrass and 2 trials with timothy, (b) Fertilization of 6 to 9 year old timothy stands, three trials. The determinations included the measurement of seed yield, determination of 16 chemical elements in grass tissue, and climatological measurements at selected sites.

Since the experimental data on timothy will be used by D.M. Larsen for

his M.S. thesis problem, data from K. bluegrass plots only is given in this report.

Cool season grasses, such as K. bluegrass and timothy prefer somewhat cool and moist weather. The 1966/67 season, as shown in Table 1, was characterized by slightly less than normal precipitation during fall and winter, and above normal rainfall during the spring of 1967. The average temperature at the Roseau weather station was about normal in the fall of 1966, and below normal during winter and spring seasons.

Fertilization of production fields in the prime of their productivity can double or triple the seed yields of K. bluegrass. This was the case with Field No. 1 on a Bearden sicl soil (Table 2). The field was renovated in the fall of 1965 and yielded about 100 lbs./Acre of seed in 1966. The dried-up vegetative growth was burned off in spring of 1967. Fertilization increased seed yields by 400 lbs./Acre.

The productivity of K. bluegrass fields seems to be affected by a number of factors. Age of stand may be one such factor. Field No. 2 on peat, was seeded in spring of 1963 and yielded, by grower's estimate, more than 600 lbs./Acre of seed in 1966. The field was burned in summer of 1966, after seed harvest. Fertilization with 20+40+40 increased seed yield from 136 to 247 lbs./Acre. Apparently the field was past its prime and the grower had planned to renovate it in the fall of 1967.

The removal of old straw and dried up vegetation by burning, clipping or grazing often is related with high seed yields of K. bluegrass. Non-removal of such residue then would be expected to have a certain depressive effect on seed yields. This may have been the case with Field No. 3 on a Rocksbury loam, Lake of the Woods County. The field was seeded in spring of 1964 and yielded, by grower's estimate, about 600 lbs./Acre of seed. The grower does not burn his fields but utilizes the vegetative growth after

seed harvest by grazing and occasional clipping. The plot area was fenced in to protect it from grazing animals. In the spring the plot area had a relatively thick mat of dried-up vegetation which was not removed. The application of 60+46+46 lbs./Acre of plant nutrients increased the seed yield from 76 to 199 lbs./Acre.

Field trials on the effect of time of fertilization--- fall, winter, or spring---have not shown any consistent differences in favor of either application time. The results of the 1967 experiments, however, indicated that fertilization during late summer (Aug. 25) or late spring (May 20) resulted in lower seed yields when compared with the other dates of fertilization (Table 3). Growers are encouraged to apply fertilizers in the fall, from the middle of September on.

Table 1. Climatological Data as Measured at Roseau U.S. Weather Station

PERIOD	PRECIPITATION (INCHES) TOTAL	DEPARTURE FROM NORMAL	TEMPERATURE (°F.) AVE.	DEPARTURE FROM NORMAL	GDD T_b = 40° F.
1966/67					
Aug. - Oct.	5.46	-1.46	54.5	-0.4	1335
Nov. - Mar.	4.43	-1.11	9.1	-3.4	---
Apr. - July	10.96	1.48	52.0	-3.6	1592
Total	20.85	1.14			2927
Average			34.8	-2.9	

Table 2. Effect of Fertilization on the Seed Yield of Park Kentucky Bluegrass 1967.

PLANT NUTRIENTS APPLIED N P_2O_5 K_2O LBS./ACRE	FIELD 1. E.B. ROSEAU CO. BEARDEN SICL	FIELD 2. E.B. ROSEAU CO. PEAT	FIELD 3. L. O. W. CO. ROCKSBURY L.
	YIELD OF SEED LBS./ACRE		
None	163	136	76
40+46+46	339	---	---
60+46+46	567	---	199
60+92+46	---	---	184
10+40+40	---	245	---
15+40+40	---	224	---
20+40+40	---	247	---

Table 3. Effect of Date of Fertilization on the Seed Yield of Park Kentucky Bluegrass.

DATE OF FERTILIZATION	FIELD 1. BEARDEN SICL	FIELD 2. PEAT	FIELD 3. ROCKSBURY L.
	YIELD OF SEED, LBS. /ACRE		
1966 Aug. 25	497	210	137
Sept. 15	567	247	199
Oct. 15	531	251	237
1967 May 1	421	266	168
May 20	295	235	147
SPLIT (1/2 on Sept. 15, 1/2 on May 1.)	567	266	202

Soil Testing in Minnesota during 1967

John Grava

Currently the University of Minnesota Soil Testing Laboratory processes nearly thirty five thousand samples annually. The following data show the number of various types of samples analyzed in 1967:

Regular farm, garden and lawm samples	31,384
Florist (Greenhouse) samples	2,244
Limestone	67
Departmental research samples	764
Total	34,459

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 1967.

Month	Number of Samples
January	1650
February	1544
March	1860
April	3997
May	1476
June	1307
July	840
August	1525
September	3480
October	4520
November	4798
December	4387