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

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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 Because these are largely one year results they should not be considered as conclusive and the results are not for publication.

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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

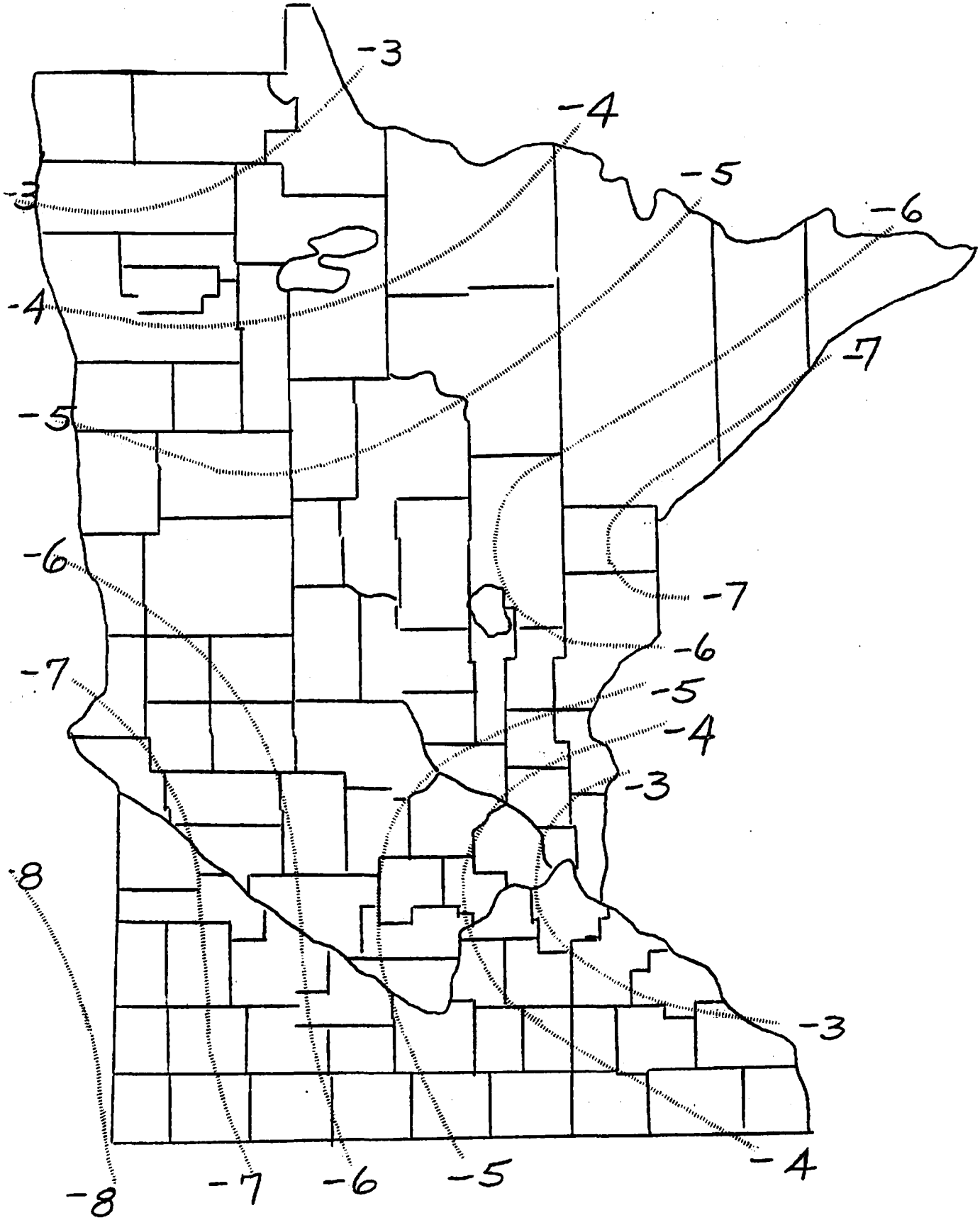


Figure 1. Total departure (in inches) from the normal precipitation during the period April 3 - Nov. 9, 1967. (Data from Minnesota Weekly Weather, Crop and LIvestock Report).

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.

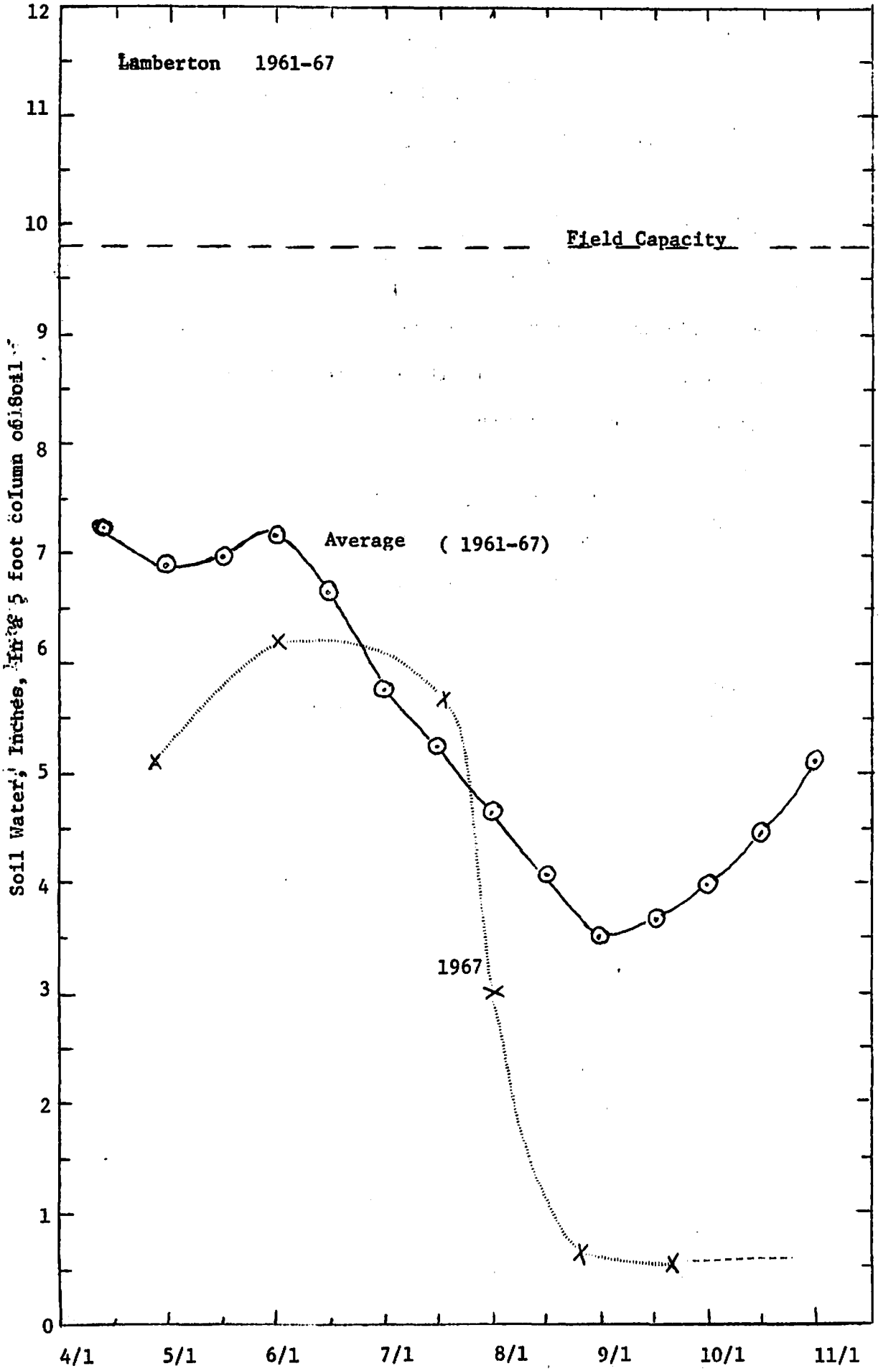
Table 8 shows the importance of soil moisture reserves. Without this additional source of moisture, the precipitation that falls during the growing season would be marginal indeed. The soil moisture reserves are normally replenished, as discussed earlier, primarily by spring rains, secondarily by autumn 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:

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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.

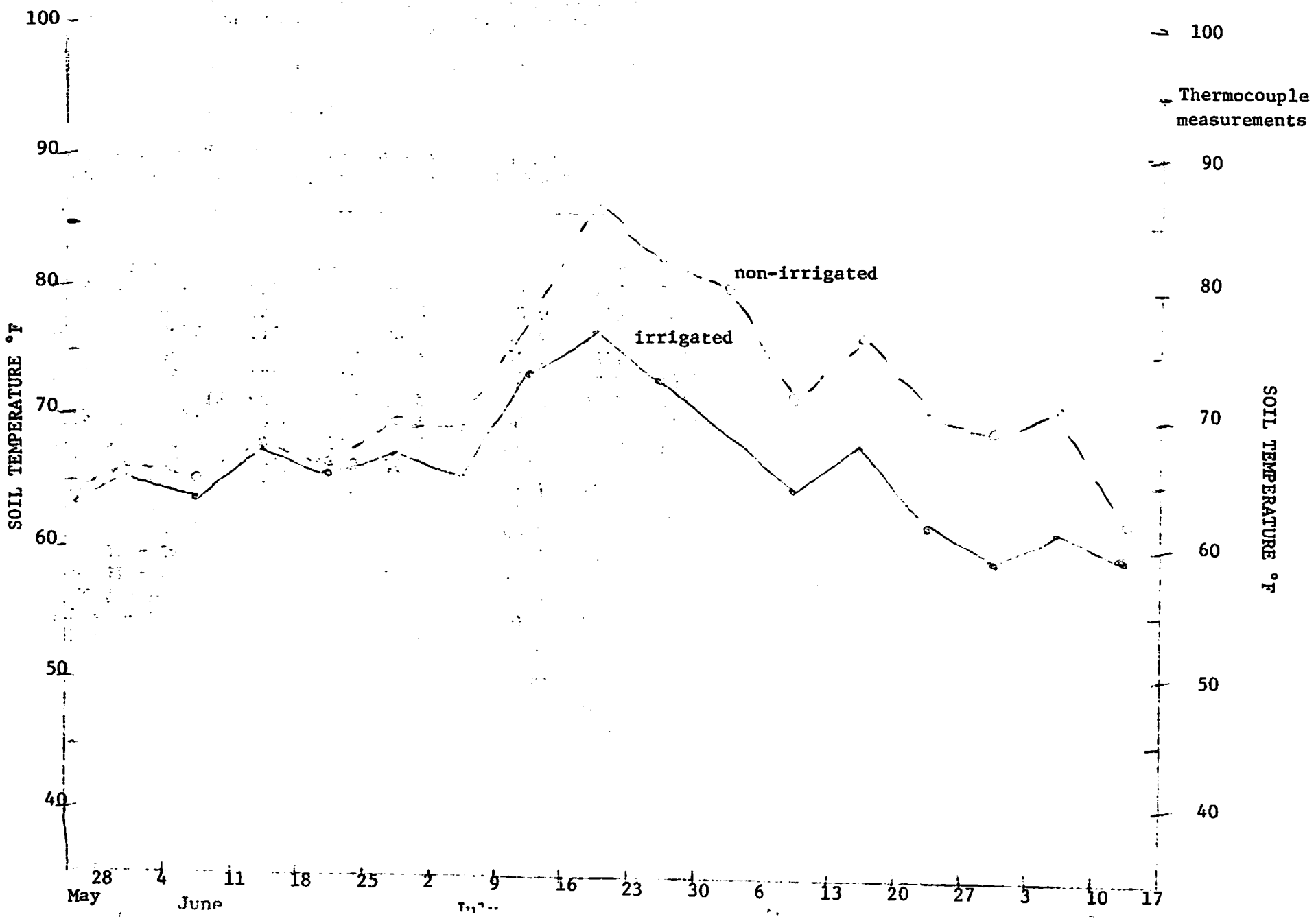

Table 2. Mean weekly soil temperatures (F°) at two, four, & twelve inch depths under a chemically killed sod cover at Park Rapids in 1967.

	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

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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						