A Report on Soils and Soil Fertility

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

Department of Soils
University of Minnesota

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Some of the results herein reported are from experiments carried on during 1960 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 probelms 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 Because these are largely one year results they should not be considered as conclusive and the results are not for publication.

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The Weather of 1960

Donald G. Baker

The winter of 1959-60 (December, January, and February) was much milder than usual. The state-wide rains of December 27-28, 1959, brought the soil moisture up to a higher amount than is usual for soils to have over winter. These rains together with the mild temperatures and the fact that the cold periods were usually preceded by a snowfall decreased frost penetration to perhaps 50-75% of the usual depth.

Spring was characterized by cool temperatures and heavy rains. March, 1960, was the second coldest on record and April was too wet for field work, although it was dry enough in north-central Minnesota to create a fire hazard until this area received mid and late May rains. Excessive precipitation fell in south-central and southeastern Minnesota May 16-22 with a 24 hour record, 5.71 inches, occurring at Jordan on May 21. Planting was delayed over most of Minnesota due to the cool and wet season.

Summer weather continued to plague planting due to a wet and cool June. Many fields, particularly in south-central Minnesota, were flooded and had to be replanted. High temperatures occurred in the last half of July and during August together with an extended period during which little rain fell.

Normal September temperatures hastened the maturity of the late developing corn and by September 30 about 85% of the crop was safe from frost damage. In the west-central and central part of the state growing season precipitation was above normal, although much of it fell late in the season and was of little benefit to the crops. The northern protion of the state and even as far south as east-central Minnesota has less than normal precipitation during the growing season.

Except for the south-central and southeastern portions of the state the soil moisture content was lower than usual with the approach of winter 1960-1961. This fact together with the extremely low snowfall in fome areas of the state has resulted in the frost being deeper than usual.

Based upon the above situation we can make the following forecast

1. A late spring heavy snowfall followed by rapid melting will result in flooding with little of the meltwater entering the soil.
2. Without normal to above normal spring rains most areas, except the south-central and southeast, will be in precarious soil moisture condition.
3. A windy and dry spring will result in extensive wind erosion.
4. If spring rains are both sufficient in amount and low in intensity, the soils should soon be thawed, even though frost may be deeper than usual, since their relative dryness means less heat will have to be expended to thaw the soil. This does not include south-central and southeast Minnesota where soil moisture is normal to above normal.

(Source: Strub, J. H., Jr., 1960. Climatological Data, Minnesota)

Soil Moisture Regime Under Corn in Southern Minnesota

Donald G. Baker and Lowell Hanson

Soil test correlation plots were again established in numerous counties for the 1960 season by Lowell Hanson and the Soils Extension staff with the cooperation of the county agents. In addition to the study of fertilizer rates and method of application the soil moisture regime of the corn crop during the course of the season was also considered.

Precipitation data were obtained from the record maintained by the farmer or the nearest observing station of the U.S. Weather Bureau. Soil moisture measurements at the beginning of the season were obtained through the cooperation of the Soil Conservation Service and at the end of the season by Donald Baker. The moisture status of the soil during the growing season was accomplished by calculation.

Results are shown in Table 1. The yields listed in Table 1 are those from the plots fertilized at the rate of 100# N, 100# P_2O_5 and 100# K_2O per acre. The 100# P_2O_5 was applied broadcast at 70# per acre and 30# per acre row placed. The four rows of figures shown by month are as follows:

1. Precipitation: total rainfall that fell during each month.
2. Consumption: amount of water used by plants in transpiration and lost from the soil by evaporation.
3. Deficit: the amount of water required to bring the soil moisture up to field capacity. If soil moisture is maintained at field capacity it is believed that maximum plant growth will occur from the standpoint of soil moisture. The greater the deficit the more important becomes soil moisture as a growth factor.
4. Surplus: The amount of water in the soil in excess of field capacity content. This excess water reduces the volume occupied by air. This excess or surplus water is lost either through drainage or runoff. If it remains too long then plants suffer due to lack of sufficient air and especially oxygen.

Inspection of Table 1 indicates that in none of the counties shown was soil moisture seriously lacking or greatly in excess. Thus major differences in yield were essentially due to other climatic or soil fertility and soil physical factors than simply soil moisture.

Soil moisture may have played some part in yield differences, however, as shown in Table 2. June soil moisture did not appear to be critical at any of the plots (Table 1), except possibly in Rock county. The large June deficit at Rock county is a bit deceiving for there was still a large amount of water available to the plants due to the nature and depth of the Moody soil. The months of July and August may well be the most critical months during the growing season, for it is at this time that tasseling occurs and the ears are being filled. In Table 2 some relationship can be seen between yield and soil moisture deficit. However, it will pay to repeat that the data in Table 1, especially, indicate that soil moisture was not the major factor in corn yields this year in these counties.

Table 1. Yield, precipitation, and soil moisture regime in 1960 in six Minnesota counties, 1960

Yield in Bu. per acre	County and Soil Type	Precipitation, moisture consumption and soil moisture deficit and surplus, in inches, during the season.	May	June	July	Aug.	Sept.	Oct.	Nov.	Total
78.7	Benton Co. Parent Loam	Precipitation	1.15	4.27	1.77	4.52	1.74	0.48	0.05	13.98
		Consumption	0.50	4.29	4.90	4.92	4.97	2.31	0.00	21.89
		Deficit	—	0.02	3.13	0.40	0.40	1.83	—	8.61
		Surplus	1.28	—	—	—	—	—	0.05	1.33
72.8	Dakota Co. Ostrander Silt Loam	Precipitation	0.35	4.75	1.00	3.60	5.45	0.60	0.00	15.75
		Consumption	0.33	4.26	3.68	4.27	3.43	1.24	0.00	17.21
		Deficit	3.18	—	2.68	0.67	—	0.64	—	7.17
		Surplus	—	0.49	—	—	2.02	—	—	2.51
124.5	Kandiyohi Co.	Precipitation	0.00	2.91	3.10	8.10	1.80	0.93	0.00	16.84
		Consumption	0.29	4.01	5.07	5.08	2.87	1.51	0.00	18.83
		Deficit	2.54	1.10	1.97	—	1.07	0.58	0.00	7.26
		Surplus	—	—	—	3.02	—	—	—	3.02
107.2	Redwood Co. Nicollet Clay Loam	P	0.60	5.20	5.20	5.90	3.75	0.62	0.00	21.27
		C	0.55	4.64	5.85	5.40	3.43	1.71	0.00	21.58
		D	—	—	0.65	—	—	1.09	—	1.74
		S	0.71	0.56	—	0.50	0.32	—	—	2.09
96.2	Rock Co. Moody Silt Loam	Precipitation	—	3.10	2.30	5.09	2.60	0.86	0.10	14.05
		Consumption	—	5.03	5.85	5.04	3.43	1.71	0.00	21.06
		Deficit	—	6.01	3.55	—	0.83	0.85	—	11.24
		Surplus	—	—	—	0.05	—	—	0.10	0.15
86.5	Swift Co. Vallers	Precipitation	2.00	3.30	2.40	7.60	2.50	1.49	.T*	19.29
		Consumption	0.33	4.26	5.89	5.08	3.12	1.69	0.00	20.37
		Deficit	0.89	0.96	3.49	—	0.62	0.20	—	6.06
		Surplus	—	—	—	2.52	—	—	—	2.52

*T signifies trace of precipitation, i.e., less than 0.01 in.

Table 2. Yield and total soil moisture deficit of July and August.

County	Yield	Total July and August deficit
Kandiyohi	124.5 bu./A.	1.97 in.
Redwood	107.2	0.65
Rock	96.2	3.55
Swift	86.5	3.49
Benton	78.7	3.53
Dakota	72.8	3.35

Soil Productivity Study

R. H. Rust

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

Since the project began 369 farm cooperators have furnished crop and soil management data on some 95 extensive soil types in the state. Currently 287 cooperators are enrolled in the project. The following kinds of data are recorded: date and rate of seeding; stand estimate; kind and amount of soil amendments used; moisture and temperature conditions during the growing season; weed and insect control measures; yields and losses of yield from harvesting or abnormal conditions; soil tests of pH, available P and K, organic matter.

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

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

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

The results of a multiple regression analysis based on a study of corn yields on groups of somewhat similar soils will be presented in a forthcoming issue of Farm and Home Science.

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

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

Aastad	(7)	(21)
Corn	5	31
Oats	3	76
Soybeans	2	19
Barley	3	49
Afton	(1)	(0)
Anoka	(1)	(1)
Barnes	(18)	(47)
Corn	12	53
Soybeans	7	24
Barley	2	40
Oats	9	64
Alfalfa	4	2.0
Alfalfa-Brome	4	3.0
Wheat	2	27
Flax	4	14
Bearden	(1)	(5)
Beltrami	(2)	(2)
Blue Earth	(2)	(5)
Corn	2	85
Braham	(1)	(0)
Brainerd	(1)	(4)
Buse	(2)	(6)
Alfalfa-Brome	3	1.8
Central	(2)	(4)
Chilgren	(3)	(7)
Clarion	(30)	(74)
Corn	28	75
Soybeans	5	30
Oats	16	68
Sp. Wheat	3	35
Alfalfa	8	2.6
Alfalfa-Brome	9	3.0
Corn Silage	3	11.5
Colvin	(2)	(7)
Alfalfa	2	4.0
Corn	2	54
Comfrey	(1)	(4)
Corn	2	59
Cormant	(2)	(8)
Wheat	2	23
Oats	2	65
Dakota	(1)	(2)
Downs	(2)	(5)
Corn	2	131
Dubuque	(1)	(1)
Dundas	(4)	(9)
Corn	2	54
Oats	2	70
Alfalfa	2	1.7
Enstrom	(1)	(4)
Alfalfa-Brome	3	1.5
Estelline	(1)	(4)
Esterville	(10)	(26)
Corn	11	70
Oats	4	40
Alfalfa-Brome	7	1.8
Corn Silage	3	6.4
Fair Haven	(3)	(8)
Corn	5	75
Oats	2	70
Fargo	(6)	(19)
Oats	2	36
Soybeans	3	23
Barley	2	44
Flax	2	12
Wheat	2	38
Fayette	(6)	(18)
Corn	6	110
Oats	3	81
Leg-Grass Mixt.	2	3.6
Fielden	(1)	(1)
Flom	(6)	(9)
Oats	4	46
Corn	2	94

Floyd	(2)	(8)
Corn	3	90
Oats	2	80
Freer	(2)	(6)
Oats	2	62
Freon	(1)	(2)
Glenco	(1)	(1)
Greenbush	(1)	(1)
Grimstad	(4)	(12)
Oats	2	70
Barley	3	43
Grygla	(2)	(3)
Harpster	(1)	(1)
Hayden	(21)	(49)
Corn	19	94
Oats	10	60
Alfalfa	8	2.8
Alfalfa-Brome	5	3.2
Hegne	(1)	(3)
Hubbard	(12)	(31)
Corn	12	67
Soybeans	6	20
Alfalfa	4	2.7
Oats	6	50
Kenyon	(1)	(3)
Corn	2	87
Kittson	(2)	(7)
Corn	2	52
Kranzburg	(4)	9
Corn	2	65
Flax	4	12
Alfalfa	2	2.2
Lamoure	(1)	(3)
Corn	2	55
Lester	(11)	(29)
Corn	8	67
Oats	6	55
Alfalfa	3	4.5
Alfalfa-Brome	4	3.1
Barley	2	40
LeSueur	(4)	(11)
Corn	4	57
Soybeans	2	23
Marna	(4)	(8)
Corn	7	101

McIntosh	(1)	(4)
Sp. Wheat	3	30
Menahga	(1)	(3)
Oats	2	24
Milaca	(3)	(9)
Mix. Leg-Grass	5	1.8
Moody	(1)	(3)
Corn	3	67
Nebish	(5)	(18)
Oats	7	51
Alfalfa	5	1.3
Alfalfa-Brome	3	2.2
Nicollet	(17)	(41)
Corn	23	81
Oats	6	47
Barley	2	94
Soybeans	3	28
Wheat	2	48
Nokay	(1)	(5)
Corn	2	68
Norwalk	(1)	(3)
Onamia	(2)	(8)
Corn	4	68
Oats	2	68
Alfalfa	2	2.5
Ostrander	(4)	(9)
Corn	3	98
Alfalfa	2	3.2
Parnell	(1)	(3)
Corn	2	45
Pierce	(1)	(1)
Rocksbury	(2)	(4)
Sweetclover-Brome	2	1.6
Shooks	(1)	(0)
Sioux	(1)	(3)
Oats	2	20
Sletten	(1)	(1)
Skyberg	(2)	(6)
Corn	2	94
Oats	2	88
Tama	(3)	(13)
Oats	3	58
Corn	2	106
Alfalfa-Brome	2	4.8
Mixed Leg-Grass	3	3.1

Terril	(1)	(3)
Corn	2	120
Thurman	(1)	(1)
Todd	(1)	(0)
Truman	(2)	(6)
Corn	4	93
Ulen	(3)	(11)
Corn	4	61
Oats	3	50
Alfalfa	2	2.6
Varco	(1)	(3)
Corn	2	27
Alfalfa-Brome	2	2.8
Vienna	(1)	(2)
Corn	1	60
Wadena	(3)	(8)
Corn	3	75
Oats	3	72
Waukegan	(6)	(21)
Corn	8	83
Oats	4	76
Alfalfa-Brome	2	3.5
Soybeans	2	31
Waukon	(6)	(16)
Corn	4	64
Oats	3	66
Alfalfa	6	2.5
Barley	2	56
Webster	(28)	(67)
Corn	34	78
Soybeans	9	23
Oats	10	68
Alfalfa	5	3.1
Alfalfa-Brome	6	2.4
Corn Silage	3	9.5
Wildwood	(1)	(2)
Winger	(1)	(5)
Alfalfa	2	1.1
Barley	2	42
Zimmerman	(3)	(8)
Corn Silage	2	11.5
Corn	2	80
Mora	(2)	(5)

Vallers	(5)	(9)
Corn	3	53
Soybeans	4	20
Litchfield	(1)	(3)
Lerdal	(2)	(9)
Corn	4	80
Alfalfa	2	2.0
Spooner	(1)	(0)
Buse-Barnes	(3)	(7)
Alfalfa	2	2.0
Alfalfa-Brome	3	1.6
Storden-Clarion	(1)	(2)
Oats	2	80
Webster Calc. Var.	(8)	(14)
Corn	5	62
Oats	2	30
Soybeans	2	66
Alfalfa	2	2.2
Colvin ALK phase	(1)	(2)
Corn	2	54
Comfrey Cal. Var.	(1)	(1)
Shallow Peat	(2)	(4)
Deep Peat	(3)	
Soybeans	2	24
Corn Silage	3	9.7
Wabash	(1)	(3)
Kingston	(3)	(7)
Corn	5	91
Kato Calc. Var.	(1)	(2)
Arlington	(1)	(2)
Hamerly	(1)	(1)
Indus	(1)	(0)
Misc.	(21)	(4)
	No. Fields	No. Yields
Grand Total as of January 10, 1961	(358)	(850)

Soil Testing in Minnesota During 1960
By John Grava

Currently the University of Minnesota Soil Testing Laboratory tests about 36,000 samples annually. The following data show the number of various types of samples analyzed in 1960:

Regular farm, garden, and lawn samples	33,955
Florist (Greenhouse) samples	1,247
Limestone samples	144
Departmental research samples	1,210
Total	36,556

Because of adverse weather conditions during the spring of 1960, the prospects of exceeding or even reaching the number of 33,491 farm, lawn, and garden samples tested in 1959 seemed very remote indeed. Only 12,000 samples were received during the first eight months as compared to 21,000 for the same period in 1959. Fortunately, weather conditions during the last four months of the year were extremely favorable for sample collection. Consequently, the "Fall Soil Sample Round-Up" campaign organized by the Agricultural Extension Service, with participation of fertilizer and lime industries, bankers and Vocational Ag. Instructors, really paid off. Close to 22,000 samples were collected during this campaign. Figure 1 shows monthly distribution of samples received by the laboratory during 1960.

Generally 7 to 9 days are required for sample processing (Table 1). However, the unusual sample rush in October, when over 2500 samples were received in a single week, caused a certain delay in getting test results returned to county agents for recommendations. A sample rush in the fall, however, is preferable to one in the spring. Fall sampling and testing permits plenty of time for farmers to receive and use sound recommendations before spring planting.

Table 1. The number of days required for soil sample processing in 1960

Month	Monthly Average Days
January	7
February	7
March	9
April	7
May	8
June	11
July	10
August	8
September	9
October, first half	7
second half	15
November	24
December	21

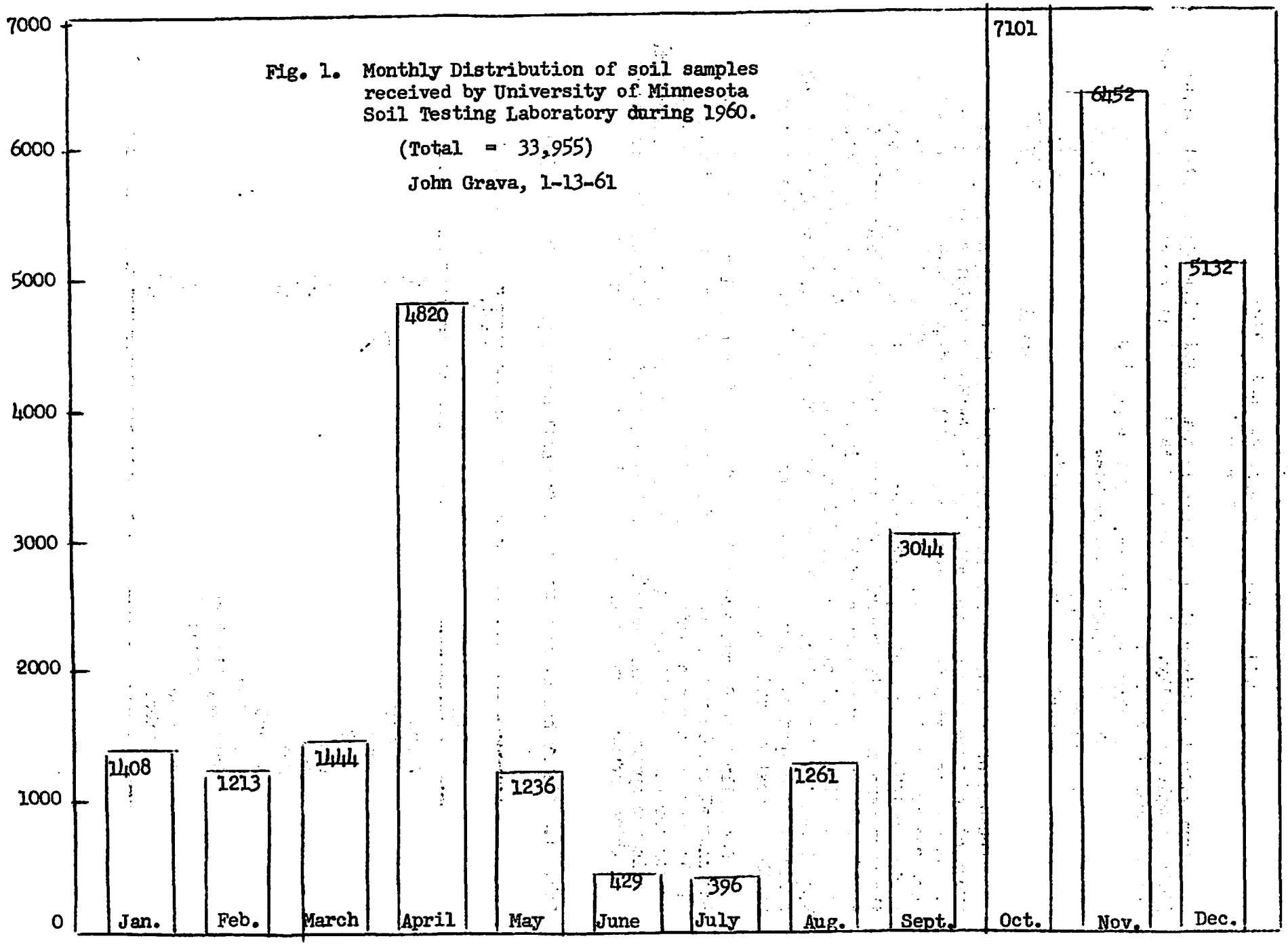

Fig. 1. Monthly Distribution of soil samples received by University of Minnesota Soil Testing Laboratory during 1960.

(Total = 33,955)

John Grava, 1-13-61

Progress Report on N.C.-16 Nitrogen Projects

Minnesota Agricultural Experiment Station
December, 1960

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Studies on Residual Nitrogen Effect.

Wheat was planted in the spring of 1960 on the two 1958-1959 $Ca(NO_3)_2$ -$(NH_4)_2SO_4$ fall-spring-summer treated corn fields. At Crookston, unusually heavy late June rains resulted in some flooding and a heavy growth of wild oats which essentially ruined the residual nitrogen effect study of spring-wheat yield on the flat, fine-textured Hegne soil. The residual wheat crop on the Barnes silt loam at Morris showed marked residual nitrogen effect, and five of the six replicates were sampled for yield. Per acre yields of the 1960 wheat and of the 1959 corn of this Morris field are shown in Table 1. The 1959 corn yield was reduced by a late summer drowth.

Table 1. - Yields of 1960 Wheat and of Preceding 1959 Corn with Variable Nitrogen Fertilization in 1958-1959.

Treatment Label	Treatment lbs. N/A[1]	1960 Wheat (bu/A)		1959 Corn (bu/A)	
		Yield	Increase	Yield	Increase
A	80 N, $Ca(NO_3)_2$, May, 1959	35.1	20.7	40.5	3.3
B	80 N, $Ca(NO_3)_2$, Nov., 1958	30.0	15.6	44.5	7.3
C	80 N, $(NH_4)_2SO_4$, Summer, 1959	29.5	15.1	45.3	8.1
D	80 N, $Ca(NO_3)_2$, Summer, 1959	28.0	13.6	45.2	8.0
E	80 N, $(NH_4)_2SO_4$, Nov. 1958	27.2	12.8	40.6	3.4
F	40 N, $Ca(NO_3)_2$, May, 1959	26.4	12.0	40.0	2.8
G	40 N, $Ca(NO_3)_2$, Nov., 1958	26.2	11.8	44.2	7.0
H	40 N, $(NH_4)_2SO_4$, Nov. 1958	25.2	10.8	38.6	1.4
I	80 N, $(NH_4)_2SO_4$, May, 1959	24.5	10.1	51.8	14.6**
J	40 N, $(NH_4)_2SO_4$, May, 1959	22.8	8.4	35.3	8.1
K	40 N, $(NH_4)_2SO_4$, Summer, 1959	19.1	4.7	37.4	0.2
L	40 N, $Ca(NO_3)_2$, Summer, 1959	17.4	3.0	45.6	8.4
M	Check	14.4	---	37.2	---

[1] Entire area received broadcast application of 0-20-20 at rate of 500#/A.

The only significant difference was in rate of N treatment on the residual wheat yields, but there was a trend toward slightly higher yields with the nitrate form of nitrogen.

Since several recently published investigations have emphasized gaseous losses of ammonia nitrogen from urea applied at different depths in soils of varying texture, pH, moisture, etc., both field and laboratory experiments have been used to study such losses and their effect on crop yield and composition. Two short term field experiments, (one on wheat and the other on corn), were established on the Hegne clay loam at Crookston in northwestern Minnesota, and one long term (10 year) experiment on Nicollet-Webster silty clay loam in southwestern Minnesota. The effect of urea and of ammonium nitrate nitrogen on crop yields were compared with different rates, times, and depths of application. A broadcast application of 0-20-20 at the rate of 500 pounds per acre was made over the entire experimental area and disked in before seeding. The boot stage nitrogen treatments were broadcast on July 6th, nearly two months after the first treatments were made. The resulting wheat yields and increases are shown in Table 2.

Table 2. The effect of N source, time of application, and disking in on yield and composition of 1960 wheat at Crookston (Hegne Clay Loam) and fertilizer N recovery.

Treatment (N in lbs/A)[1]	bu/A	Sig. diff. (5%)	% Protein Grain	% N Straw	% N Recovery
20 (urea) bdct. at boot stage	6.7		13.5	0.62	-4
40 (NH_4NO_3) " " " "	7.9		15.0	0.65	12
Check	8.2		13.0	0.47	--
20 (NH_4NO_3) bdct. bef. seeding, disked	11.7		12.5	0.36	26
40 (urea) bdct. at boot stage	11.9		13.7	0.64	14
20 (NH_4NO_3) " " " "	12.6		13.1	0.56	33
20 (urea) bdct. bef. seeding, disked	15.9		12.5	0.42	50
20 (urea) bdct. after seeding, left on surface	16.1		12.8	0.36	56
20 (NH_4NO_3) " " " " "	16.7		12.8	0.43	73
40 (urea) bdct. bef. seeding, disked	19.6		9.2	0.38	37
40 (urea) bdct. after seeding, left on surface	19.7		12.6	0.42	39
40 (NH_4NO_3) bdct. " " " "	21.3		13.1	0.41	28
40 (NH_4NO_3) " bef. seeding, disked	22.7		13.2	0.41	50

Average N recovery from NH_4NO_3 = 37%
" " " " urea = 39%

[1]Entire area treated with 0-20-20 at 500 lb/A rate.

Using the Student-Newman-Keuls multiple range test, the first five fertilizer treatments do not differ significantly from the check. The 20 pound per acre nitrogen treatments are closely grouped, followed by the heavier treatments. There was no consistent difference for nitrogen source of disking in of one of the two earlier treatments, which does not coincide with some recently reported laboratory studies.

The Crookston corn plots were seriously damaged by flooding and runoff, during the 4.2 inch rain of June 27th. One set of treatments (40 pounds of N as urea applied in early spring and left on the surface) set few or no ears, and no yield was obtainable. The yields (with no statistical analysis attempted) are shown in Table 3.

Table 3. The effect of nitrogen source, time of application, and placement on the yield and composition of 1960 ear corn at Crookston and recovery of fertilizer nitrogen. (Hegne Clay Loam)

Treatment (lbs N/A)[1]	Ear Corn		Fodder		% N Recovery
	bu/A	% Protein	T/A	% N	
Check	52.9	8.5	1.18	0.95	---
40 as NH_4NO_3-disked in early spring	63.1	8.7	1.15	0.95	18
40 as urea " " " "	67.8	9.3	1.15	0.94	32
80 as NH_4NO_3 " " " "	67.6	9.1	1.70	0.94	27
80 as urea " " " "	67.3	9.8	1.65	1.01	34
40 as NH_4NO_3-left on surf.-early spring	66.2	10.1	1.58	1.13	74
40 as urea " " " " "	(no ear set)		1.12	1.12	---
80 as NH_4NO_3 " " " " "	66.4	8.7	1.68	1.01	27
80 as urea " " " " "	60.7	9.4	1.25	1.04	16
40 as NH_4NO_3-sidedressed - July 6th	63.8	9.5	1.55	1.04	61
40 as urea " " " "	57.2	8.3	1.38	0.95	14
80 as NH_4NO_3 " " " "	61.7	9.7	1.38	1.06	22
80 as urea " " " "	60.4	9.9	1.45	0.97	21

[1]Entire area treated with 0-20-20 at rate of 500 lbs/A.

Average N recovery from NH_4NO_3 = 38%
" " " " urea = 23%

With the extensive water damage and yield variation in the four replicates, it is difficult to draw any valid conclusion, but the earlier applications appear to be somewhat better than those side-dressed in early July.

The South-West Experimental Station at Lamberton was activated early in 1960, and an urea-ammonium nitrate comparison experiment as to rate, time of application and covering on corn yield and composition was commenced. Of necessity, plowing and all fertilization was done in the spring of 1960. The

results are shown in Table 4 and it should be emphasized that plots 2, 3, 4, 5, 6, 7, 8, and 9 were fertilized in the spring of 1960, and a wet spring resulted in delayed seeding and in immature crop.

Table 4. The effect of N source, rates and times of application on the yield and composition of 1960 corn at Lamberton and recovery of fertilizer nitrogen.

	Treatment lbs/A of N	Corn grain bu/A	Corn grain % Protein	Fodder T/A	Fodder % N	% N Recovery
1.	Check	49.5	7.3	1.82	0.74	---
2.	40 (NH_4NO_3) on stalks, plowed under in fall	42.3	7.2	1.79	0.84	8
3.	40 (urea) " " " " "	55.1	6.8	1.57	0.61	-28
4.	40 (NH_4NO_3) left on top of plowing in fall	49.0	7.9	1.87	0.84	16
5.	40 (urea) " " " " "	62.3	7.5	1.87	0.76	13
6.	80 (NH_4NO_3) on stalks, plowed under in fall	67.4	7.6	1.85	0.78	5
7.	80 (urea) " " " "	61.7	7.8	1.87	0.88	7
8.	160 (NH_4NO_3) " " " "	69.8	8.2	2.23	0.91	17
9.	160 (urea) " " " "	79.4	7.6	2.18	0.85	12
10.	40 (NH_4NO_3) just bef. planting-Spring	66.2	8.0	1.85	0.87	21
11.	40 (urea) " " " "	45.4	7.6	2.12	0.85	47
12.	80 (NH_4NO_3) " " " "	59.3	7.5	2.07	0.79	12
13.	80 (urea) " " " "	57.7	7.9	2.26	0.82	21
14.	40 (NH_4NO_3) as a late sidedressing	63.6	7.7	2.01	0.89	27
15.	40 (urea) " " " " "	57.7	7.0	1.90	0.77	9
16.	80 (NH_4NO_3) " " " " "	50.4	7.6	1.76	0.89	15
17.	80 (urea) " " " " "	76.9	7.1	1.51	0.81	-11
18.	160 (NH_4NO_3) " " " " "	80.7	7.7	1.65	0.88	0
19.	extra	43.4	Average N recovery from NH_4NO_3-14%			
20.	extra		" " " " urea -18%			

Since treatments 2 to 9 were actually applied in the spring, and with the extreme yield variation, no statistical analyses were made. However, it is evident that the 40 and 80 pound per acre rates were not sufficient on this field, since the 160 pound rates were more effective.

Laboratory Experiments

(a) Ammonium fixation

The ammonium-fixing capacity of 36" profiles of four typical agricultural soils of southern Minnesota soils was determined. Two of the fields had been responsive to nitrogen fertilization, and the remaining two showed essentially no effect from nitrogen treatment on either the first crop of corn or residual effect on the following small grain crop.

The amounts of applied NH_4 fixed in the 36 inch profile depth varied from approximately 5 to 9 m.e.'s (1 to 2 tons of ammonium N per acre), with the most nitrogen responsive soil having the highest ammonia fixing capacity.

(b) Ammonia N losses from urea or ammonium nitrate

Effect of fertilizer N source and depth of placement on loss of ammonia to the air has been studied on five soils, varying in texture from loamy sand to a clay loam. With N applications as NH_4NO_3 on the surface, 0.5 and 1.0 inches below the surface, at rates of 100 pounds of N per acre, there was no ammonia lost as Zimmerman loamy sand dried for one week from 7.0% moisture to 4.6%. Under the same conditions, the same amount of applied urea nitrogen lost 5.8% as ammonia where applied on the surface, 5.0% when urea was covered with one-half inch of soil, and 0.6% at the 1 inch depth.

On a Barnes loam drying for one week from 25% to 21.5% moisture, 100 pound rates of urea nitrogen per acre on the soil surface lost 4% of the N as NH_3, 1% as NH_3 where 1/2 inch below the surface, and none where placed 1 inch beneath the surface. There were no measurable losses as ammonia from urea placed on the surface of Tama silt loam and dried for a week.

Under laboratory conditions, there was usually some loss of ammonia when urea was left on the soil surface, except on the Tama silt loam. The maximum measured N loss was from a Zimmerman loamy sand over a one month period of approximately 6% of the 100 pound per acre rate applied. This is markedly less than the amounts reported by recent investigations in Kentucky and in Florida.

(c) Gaseous losses of fertilizer N as N_2 and oxide forms

Using closed air-soil-fertilizer-moisture systems, gas samples were taken as the soil was dried for 2, 4, 7, and 14 day intervals, and analyzed for N_2, N_2O and NO_2 derived from the added fertilizer nitrogen. These studies are designed to study possible fertilizer nitrogen losses as the soil is alternately wetted and dried.

Nitrogen Fertilization Studies on Turf Grass

R. S. Farnham

Nitrogen fertilization studies on bluegrass turf were started in 1959 on plots located adjacent to the Soil Science Building. The objectives of these studies were as follows:

1. To evaluate the effect of various nitrogen fertilizer materials, both organic and inorganic, on the yield and color of Kentucky bluegrass turf.

2. To determine the optimum rate of nitrogen needed as a single application only and to make a comparison of the effectiveness of the different nitrogen sources.

3. To study the ability of several coated nitrogen materials in controlling the release of nitrogen applied on turfgrass.

Materials and methods:

Nitrogen fertilizer materials included in the 1959 study were ammonium nitrate, uramite, nitroform, leached zone 14-7-7, ammoniated peat, calcium authroxillate, calcium-magnesium anthroxillate, and liquid humate obtained from peat. The plot size was 5 x 4 feet and there were two replications of randomized plots.

Nitrogen was applied at 4 and 8 pounds/1000 sq. ft. in late May all in one application. Phosphorus and potassium were applied as a blanket treatment with all plots receiving the equivalent of 4 lbs. of P_2O_5 and K_2O per 1000 sq. ft.

All materials were applied broadcast and wet down thoroughly to prevent burning.

In 1960 the same fertilizers as in 1959 were used although the rates were increased to 5 and 10 lbs. of N per 1000 sq. ft. In addition some new experiments were begun using differently coated urea nitrogen (45-0-0).

Color ratings were made at time of clipping and plots were watered when necessary.

Table 1. 1959 Turf Plots (Soils Building) Total Clipping Yields and Color Ratings

No.	Treatment	Rate	Analysis	Grams dry wt/Plot	Grams dry wt/1000 sq. ft.	Ave. Color Rating
14	NH_4NO_3 + PK	8# N/1000	(14-7-7)	212.5	20,230	9.75
1	Ca Anthraxillate	2 tons/Ac +	(14-7-7)	197.0	18,754	5.62
9	Allied Chemical's	4# N/1000	14-7-7 (A)	195.5	18,610	6.38
12	16 ozs. liquid humate + NPK		4# N/1000	189.4	18,030	5.63
4	Uramite	8# N/1000 + PK	14-7-7	175.4	16,698	6.25
2	Ca/Mg Anthraxillate	2 tons/ac. + NPK		170.1	16,184	5.25
6	Nitroform	8# N/1000	+ PK	166.2	15,822	7.50
10	Allied's	14-7-7 (B)	4# N/1000	159.1	15,136	4.63
5	Nitroform	4# N/1000	+ PK	157.0	14,946	5.25
11	Allied's	14-7-7 (C)	4# N/1000	155.3	14,784	5.13
13	NH_4NO_3 + PK	4# N/1000	(14-7-7)	153.8	14,641	6.00
8	Allied's Ammoniated Peat	8# N/1000 + PK		137.3	13,071	5.13
3	Uramite	4# N/1000	+ PK	127.5	12,138	4.50
7	Allied Ammoniated Peat	4# N/1000 + PK		122.9	11,690	4.00

Table 2. 1960 Turf Plots (Soils Building) Total Clipping Yields and Color Ratings

No.	Treatment	Grams dry wt/Plot	Grams dry wt/1000 sq. ft.	Average Color Rating
20	Urea Med. Coat 10# N/100 + PK	544.9	51,874	9.38
17	Urea Heavy Coat 5# N/1000 + PK	512.1	48,751	8.88
18	Urea " " 10# N/1000 + PK	487.9	46,448	9.13
16	Urea 10# N/1000 (uncoated) + PK	465.5	44,315	9.06
1	Ca Anthraxillate 2 tons/ac. + NPK 4# N/1000	459.8	43,772	7.94
15	Urea 5# N/1000 (uncoated) + PK	452.0	43,030	8.06
14	NH_4NO_3 10# N/1000 + PK	449.2	42,763	9.13
12	16 ozs. liquid humate + NPK 4# N/1000	445.8	42,440	8.25
6	Nitroform 10# N/1000 + PK	436.0	41,507	8.06
19	Urea Med. Coat 5# N/1000 + PK	402.0	38,346	8.06
4	Uramite 10# N/1000 + PK	374.3	35,633	7.13
5	Nitroform 5# N/1000 + PK	374.0	35,604	6.75
2	Ca Anthraxillate 4 tons/ac +NPK 4# N/1000	364.1	34,662	7.50
11	Allied's 14-7-7 (C) 5# N/1000	361.2	34,386	6.19
8	Allied's Ammoniated Peat 10# N/1000 + PK	361.0	34,367	6.81
9	Allied's 14-7-7 (a) 5# N/1000	351.1	33,424	7.25
13	NH_4NO_3 5# N/1000 + PK	351.1	33,424	7.88
3	Uramite 5# N/100 + PK	305.1	29,045	6.56
10	Allied's 14-7-7 (B) 5# N/1000	300.9	28,645	6.13
7	Allied's Ammoniated Peat 5# N/1000 + PK	276.2	26,294	5.75
21	Check (No Fertilizer)	241.9	23,028	3.13

RATES AND SOURCES OF PHOSPHATE
Northeast Experiment Station

Dale E. Baker, Wallace W. Nelson and A. C. Caldwell

The plots were started in 1958 on an area that had been in meadow for two years and had not been fertilized or limed for at least five years. The purpose of an experiment was to determine the amount of phosphate required to produce an oat-two year meadow rotation and the relative availability of different sources of phosphate.

The plots were plowed in the fall of 1957 and Dalapon applied at the rate of 7-8 pounds per acre on the plowed area for the control of quackgrass. In the spring of 1958, the entire area was limed at a rate 2-3 tons per acre using dolomitic limestone. Prior to seeding, all plots were fertilized with 20+0+180, using ammonium nitrate and muriate of potash. The area was seeded to minhafer oats, alfalfa and bromegrass on May 6. The randomized block design with four replications was used for the phosphate treatments. Each year after the first cutting of hay was removed the plots were treated with 0+0+80 per acre as muriate of potash.

All applications of phosphorus regardless of rate or source resulted in an increase in yields of oat silage and hay each year. There was some variation in the data that is difficult to explain, especially in the yields of silage. It is interesting to note that the application of 150 pounds of P_2O_5 as rock phosphate resulted in yields as high as those obtained from 200 pounds of P_2O_5 from triple superphosphate. Yet, there was no response to 1,000 pounds of rock phosphate over the 500 pound per acre application. By close observation of the relief of the area on which these plots are located, one finds that water drains off from the land above through the center and one end of each block in this experiment. The 1,000 pound rock phosphate plots were located at random, but in all four cases they were placed in one of these small depressions. These slight depressions running through all blocks are responsible probably for the large amount of variation in all forage yields.

Because of the large amount of variation in the data, it can be concluded only that:
1. There was a response to phosphate.
2. Applications of 400 pounds of P_2O_5 as triple superphosphate resulted in the highest yields.
3. The water soluble superphosphate might be more available to oats but not to alfalfa and bromegrass.

RATES AND SOURCES OF PHOSPHATE (1960)
Northeast Experiment Station

Table I

Yields of forages in tons per acre as affected by different rates and sources of phosphate.

Treatment	Oat Silage 1958	1st Yr. Hay 1959	2nd Yr. Hay 1960	Average Hay Yields
Check	5.88	2.22	1.35	1.79
50# P_2O_5/Ac. as Triple Super	7.22	3.04	1.69	2.37
100# " " " " "	7.17	3.15	1.81	2.48
200# " " " " "	6.58	3.13	2.14	2.64
400# " " " " "	7.94	3.69	2.24	2.99
50# P_2O_5/Ac. as Cal-Meta	6.26	3.17	1.72	2.45
500# Rock Phos.	6.60	3.20	1.93	2.56
1000# " "	6.19	3.06	1.88	2.46
Means for years		3.08	1.85	

Confidence Intervals ($D_{.05}$) for comparing:

1. Rates and sources of phosphate on silage yields = 1.90
2. Rates and sources of phosphate on average hay yields = 0.55
3. Average hay yields for different years = 0.18

Phosphorus Source Experiment
Rosemount, 1960

by A. C. Caldwell and J. B. Weber

A phosphorus source experiment was established at Rosemount in 1951. Twelve treatments of various phosphate materials were replicated four times across a regular rotation of corn, wheat, alfalfa, and alfalfa. Potassium fertilizer was supplied according to soil tests.

The crop rotation was changed in 1959 to corn, soybeans, wheat and alfalfa.

Yields of corn, soybeans, and wheat for 1960 were not significantly affected by the various phosphate sources. Experimental error amounted to a considerable portion of the variabion between treatments and hence masked those differences which did exist. A definite over all phosphorus response is evident as nearly all of the treatments had a higher yield than their respective controls. Alfalfa yields were significantly (.05) increased by the various phosphate sources. All sources increased the yield of alfalfa above the control by about 0.8 tons per acre. There were no significant differences between the phosphate sources, but the table indicates that the more available forms were somewhat superior to the less available forms.

Table 1. Effect of various phosphate treatments on the yield of corn, soybeans, wheat, and alfalfa in a rotation, 1960.

Treatments	P_2O_5/A/yr lbs.	Corn[1]		Soybeans		Wheat		Alfalfa[2]	
		bu/A	Diff.	Bu/A	Diff.	bu/A	Diff.	bu/A	Diff.
1. Check	----	90.1	---	22.4	---	25.9	---	3.17	---
2. Ord. Superphos.	40	90.7	0.6	21.9	-0.5	26.5	0.6	4.01	0.84
3. Conc. Superphos.	40	93.5	3.4	23.8	1.4	28.1	2.2	4.10	0.93
4. Ca. Metaphos.	40	99.9	9.8	24.2	1.8	26.9	1.0	4.08	0.91
5. H_3PO_4	40	90.6	0.5	23.2	0.8	28.2	2.3	3.97	0.80
6. Fused Tri Ca.	40	108.2	18.1	23.9	1.5	25.5	-0.4	4.01	0.84
7. Fla. rock + Ord. Super.	20 + 20	99.4	9.3	23.4	1.0	26.9	1.0	4.22	1.05
8. Fla. rock (lt.)	100	94.2	3.1	23.6	1.2	26.8	0.9	3.63	0.46
	lbs. material/A/4 years								
9. Fla. rock (hvy)	1000	106.2	16.1	23.9	1.5	24.9	-1.0	3.95	0.78
10. Western rock	1000	98.0	7.9	25.3	2.9	28.0	2.1	3.45	0.28
11. Col. clay rock	1000	94.4	4.3	24.2	1.8	28.5	2.6	3.77	0.60
12. Tunis. rock	1000	84.8	-5.3	25.0	2.6	26.2	0.3	3.98	0.81
lsd (.05) =			N.S.		N.S.		N.S.		0.48
hsd (.05) =									0.98

[1] @ 15% moisture

[2] Dry weight

Some Field Trials with Secondary and Minor Nutrient Elements on Corn

Merle Halverson and John Grava

In 1959, marked differences in corn leaf color attributable to the presence or absence of starter fertilizer were noted in a demonstration plot planted to corn on a Brainerd loamy sand in Crow Wing County. Untreated plant leaves bore the symptoms of pale-green color and mottling commonly associated with magnesium deficiency. Since the bulk of the phosphorus in the starter fertilizer was derived from ordinary superphosphate, the possibility of secondary or minor element deficiencies was indicated. Soil samples from the area and leaf time samples from all plots were collected and analyzed. The crop was subsequently damaged by drouth and the analysis of corn yields gave no evidence of yield differences. Results of the soil and leaf tissue analyses are listed in Table 1.

Two experiments with corn were established on the same soil in 1960.

In the first, five secondary or minor nutrient elements were individually compared with a check treatment in a randomized block replicated three times. The treatments were superimposed on an area treated with 80 lbs. N, 100 lbs. P_2O_5 and 150 lbs. K_2O per acre applied broadcast and disced into the soil. The nitrogen and phosphate were applied as ammonium-phosphate-nitrate to eliminate possibility of contamination through use of ammoniated superphosphate materials. The area was machine planted by the farmer cooperator in late May using 47" between row and 40" within row spacings. Three kernels per hill were dropped, and no attempt was made to thin to a uniform stand. Yield samples consisting of 20 hills were harvested from each plot in mid-October, and moisture contents determined. Yields calculated on a basis of 15.5% moisture shelled corn are listed in Table 2.

In a second trial established in the same field, four treatments (3 metal ammonium phosphates and a check) were compared by application in the hill to recently emerged corn plants. Each treatment was replicated five times. The metal ammonium phosphates were physically blended with mono ammonium phosphate (11-48-2) and/or muriate of potash (0-0-60) to provide (1) common ratios of $N:P_2O_5:K_2O$ of 1:4.4:4.4 and (2) the desired level of each minor element. Check plots were treated identically except that no minor element was added. Each plot was a single row 20 hills long with 40" within row spacing, and the area was thinned to a uniform stand of three plants per hill. No broadcast applications of P_2O_5 or K_2O were made. Nitrogen at 42 lbs/A was applied sidedress at the time of second cultivation. Yield samples consisting of 20 hills from each plot were harvested in mid-October and moisture contents determined by oven drying. Yields of 15.5% moisture ear corn are listed in Table 3.

The wide differences in over all yield between the two experiments are likely due to differences in the basic broadcast treatments, particularly of nitrogen and potash. Table 2 shows apparent but non-significant yield increases for several of the secondary and minor element treatments tested. No yield differences are suggested in Table 3 where the blended metal ammonium phosphates were applied in the hill to emerged corn.

Crops grown on this soil type are subject to frequent and severe drought damage. Further field trials should be conducted only after response to secondary and minor nutrient elements has been established in greenhouse testing.

Other contributors to this work include Messrs. Ray Norrgard and Glen Smith, County Agent and Assistant County Agent, respectively, who assisted in plot establishment and harvest; Mr. Gary Spalding, Chemist, Soil Testing Laboratory, who ran soil soil and plant tissue chemical analysis, and Mr. B. C. Wilkins, Crow Wing County farmer, who provided the location and equipment and labor for planting.

RESULTS OF CHEMICAL DETERMINATIONS ON SOIL AND CORN LEAVES FROM MR. B. C. WILKIN'S FARM, CROW WING COUNTY

(1) Results of Routine Soil Tests*

pH	Lime Recommended Tons/A	Organic Matter, %	Phosphorus Lbs/A	Exch. Potassium Lbs/A	Soil Texture
4.7	3	2.5 Low	140 V High	320 V. high	Loamy sand

(2) Soil Chemical Properties

Cation Exchange Capacity m.e./100 g. soil		Exchangeable Cations										
		Ca			Mg			K			H	
		m.e.	Lbs/A	%	m.e.	Lbs/A	%	m.e.	Lbs/A		m.e.	%
6.07[1]	(5.25)[2]	3.64	1436 (1800)[3]	60	0.43	103 (144)[3]	7	0.29	226 (234)[3]		1.76	29

(3) Percent Composition of Corn Leaves Collected from Plots on Mr. Wilkin's Farm, Crow Wing Co. (Date of sampling July 22, 1959)

Treatment P_2O_5 Lbs/A	Phosphorus %	Calcium %	Magnesium %	Calcium + Magnesium %
0	0.34	0.709	0.246	0.955
20	0.33	0.817	0.279	1.096
40	0.31	0.931	0.230	1.161
60	0.33	0.872	0.249	1.121
80	0.33	0.931	0.217	1.148
0 + starter	0.32	0.963	0.252	1.214
Striped leaves	0.37	0.573	0.270	0.843
Normal leaves	0.30	1.012	0.319	1.331

* Sample from check plots, July 22, 1969.

1) By summation

2) Determined

3) Desired level, according to Missouri Experiment Station.
Basic application to all plots: 100 lbs N/Acre as ammonium nitrate
120 lbs K_2O/acre as KCl (0-0-60)

Starter: 170 lbs/acre of 4-12-24.

John Grava
Merle Halverson
Gary Spalding

Table 2

Effect of Some Secondary and Minor Nutrient Elements on Corn Yield Loamy Sand Soil - Crow Wing County 1960

(Basic treatment 80+100+150 applied broadcast to all plots, including check)

Nutrient element(s)	Chemical applied Form	lb/A	Yield, bu/A 15.5% moisture shelled corn	decrease over check, bu/A	Increase over check necessary for significance at 0.95 level in variance analysis
Check	--	--	---	---	-----
Ca#and/or S	$CuSO_4$	500	62.6	4.0	8.5
Zn#	$ZnSO_4$	50	65.5	6.9	10.4
Cu#	$CuSO_4$	25	66.0	7.4	11.7
B	$Na_2B_4O_7$	25	66.9	8.3	12.5
Mg#	$MgCO_3$	690	67.2	8.6	13.2

Table 3

Effect of 3 Micronutrients on Corn Yields - Loamy Sand Soil - Crow Wing County - 1960
(all treatments applied in the hill to recently-emerged corn)

40 lb. N/A as ammonium nitrate applied at second cultivation

Treatments, lb/A			Yield, bu/A
N	P_2O_5	K_2O	
10 +	44 +	44	40.6
* 10 + + MgO at 25 lb/A	44 +	44	40.9
* 10 + + ZnO at 10 lb/A	44 +	44	39.9
* 10 + + CuO at 3 lb/A	44 +	44	40.6

* as magnesium ammonium phosphate
* as zinc ammonium phosphate
* as copper ammonium phosphate

1960 Trace Element Experiments on Soybeans and Corn

J. M. MacGregor and R. G. Burau

Three years of laboratory and field research had shown that the application of certain chelated iron compounds would effectively control iron chlorosis in soybeans and flax. However, the cost and trouble of such applications made it unsuitable for general farm practice and it was reasoned that direct applications of chelated iron to seeds might be effective, since only small amounts of iron are necessary to prevent chlorosis, and this is needed largely during the first few weeks of plant growth.

To test the feasibility of this approach, Sequestrene 138, a chelate having low phytotoxic properties, was adsorbed on soybean seeds by low vacuum, high vacuum, air saturated, and oxygen saturated solutions of commercial grade iron chelate. Seeds from each of these treatments were germinated and compared to untreated seeds. Only the oxygen saturated solutions were rejected by this test, all other treatments gave excellent germination.

A second experiment was designed with the following objectives:

1. To devise a method for assaying added iron on soybean seeds (sorbed iron) without destroying the seed.

2. To determine the specific activity of Fe^{59} necessary to give adequate counting rates of all plant parts.

3. To determine the fate of sorbed iron.

4. To determine the efficiency of recovery of sorbed chelated iron as compared to soil treatment.

5. To determine the ability of sorbed iron to prevent chlorosis in soybeans.

To accomplish the first objective, 50 Ottawa Mandarin soybean seeds were treated with saturated Seq. 138 Fe plus 2% methyl cellulose for 4 minutes, while a second batch of 50 seeds were treated with the same solution, but under high vacuum for 4 minutes. After drying each seed was counted first on one side and then on the other side with Geiger Mueller scaler. The two counting rates were then averaged. Twelve seeds having a range of activities were selected from each lot and assayed for total added iron. Since a plot of the data did not show any curvilinear tendencies at moderate activities, a linear correlation was performed. The resulting equation was

$$Y = 1.58\ X + 11.3$$

where Y = counts per minute of assay disc and X = average surface counts per minute. The correlation coefficient for this relationship was r = 0.9 which indicates adequate accuracy.

Five soybeans from each treatment lot whose sorbed iron content was determined by the use of this equation were planted in individual greenhouse pots. As many untreated seeds were also planted. After emergence, the pots were placed in a cold water bath in an attempt to produce a chlorosis-inducing environment. Unfortunately the temperature in the bath remained about 20°C and no soybean plant developed chlorosis. When the second trifoliate leaf was mature, plant tops were cut off

1 cm. above the cotyledonary node; the rest of the plant was designated as root. Cotyledons were removed prior to the main harvest when they began to yellow and wither. Tops, roots and cotyledons were then analyzed for added iron content by a radio assay technique with results shown in Table 2.

Table 2. Distribution of sorbed iron in soybean plant parts.

Seed 1 #	Treatment	ug. Fe. in seed before planting	Top ug. Fe %	Top Recovery Efficiency %	Cotyledons ug. Fe %	Cotyledons Recovery Efficiency %	Roots ug. Fe %	Roots Recovery Efficiency %
1	No vacuum	10.43	1.65	15.8	0.19	1.8	0.46	4.4
2	"	8.64	1.57	18.2	0.26	3.0	0.49	5.7
3	"	7.48	0.96	12.8	0.17	2.3	NA*	NA
4	"	6.86	1.20	17.5	NA	NA	0.37	5.4
5	"	7.41	0.75	10.1	NA	NA	NA	NA
6	High Vacuum	117.1	13.20	11.3	NA	NA	NA	NA
7	"	15.3	1.56	10.2	NA	NA	NA	NA
8	"	9.9	1.21	12.2	NA	NA	NA	NA
9	"	8.0	1.51	18.9	NA	NA	NA	NA
10	"	6.7	0.12	1.8	NA	NA	NA	NA

*NA - Not analyzed.

It should be noted and emphasized that 12 ug. Fe per seed is approximately equal to an iron chelate cost of $.25 per acre. Most of the quantities of sorbed iron are less 12 ug Fe/seed except for seed number 6 and 7 which are due to seed coat cracks sorbed very large quantities of iron chelate under high vacuum.

Largest quantities of iron were recovered in tops, smaller in roots, and smallest in cotyledons. Concentrations in tops will range from 1.5 to 26 ppm Fe in the plant with most concentrations around 2.5 ppm. This is especially significant when it is recalled that many plants which have recovered from iron deficiency chlorosis following the application of iron chelate contain 1 to 5 ppm Fe from added iron. This suggests that sorption quantities higher and lower than 12 ug. Fe/seed might be investigated.

Efficiencies of recovery by tops are very high. This is in line with prediction. Normal recovery efficiencies for soil applications range from 0.2% to 3%.

Seed numbers 6 and 7 were diseased, and although number 6 held its cotyledons full term, cotyledons from number 7 dropped off four days before the other cotyledons were harvested. The significant observation here is that recovery efficiency did not appear low. Possibly seed scarification prior to treatment will increase sorption.

Very low counting rates were observed on roots and cotyledons. If these are to be analyzed in future experiments specific activities of Fe^{59} must be increased by a factor of 10 to 20 times.

Conclusions:

Further testing of this technique is warranted.

A second study was conducted during the summer of 1960 in McLeod County, and consisted of the addition of trace elements (including chelated iron) to the soil of two questionable corn fields. No radio-iron was used in these field experiments. In 1959, Soils Extension Specialists included a trace-element treatment in the experimental design of some statewide soil test-correlation studies. Two of these fields showed a significant yield increase due to trace-element treatments which included manganese, magnesium, zinc, copper, iron, boron, and sulfur (Es-min-el).

Two questions were raised by this study:

1. Is the conclusion a result of statistical error (rejection of the null hypothesis when it is actually true)?

2. If the conclusion is valid, which of the several elements applied was related to the yield increase?

To answer these questions, two experimental sites were selected in McLeod County. One of these sites was near a 1959 correlation experimental area on the John Lietz farm. The other site was on the Albert Schuft farm. In an effort to reduce soil variability within replicates, 578 soil samples were removed from the two fields for determinations of soil moisture, pH, and conductivity of the saturation extract. Sampling areas were located with respect to established reference points using a transit, which was also used for elevation measurements. Contour maps were then constructed and including information on pH, conductivity of the saturation extract, and soil moisture since these factors varied with depth as well as with horizontal displacement. The maps were used to select areas for replicates as homogeneous as possible with respect to these variables.

Treatments consisted of individual trace-element salts applied at rates which were judged to be sufficient to give yield increases if deficiencies existed. Each field included seven replicates of the treatments shown in Table 1.

Treatment did not affect yield on the Schuft location, where overall yield was undoubtedly reduced by soil moisture deficiency in mid-season. On the Lietz farm, iron chelate gave a nearly significant increase of yield over check. The hypothesis of iron deficiency in this soil cannot be firmly established with this one experiment. More important is the suggestion that copper and boron appear to be completely ineffective, which would eliminate these elements in further studies. Very possibly surface response experimental designs may give valuable information upon rates and combinations of the remaining elements with the objective of maximizing yields.

Table 6. Average yield of corn in McLeod County as affected by soil applications of various trace elements.

Compound	Rate of application (lbs. salt/A.)	Schuft Farm	Lietz Farm
		bu. ear corn/acre (15.5% moisture)	
Es-min-el	108	71.6	97.1
$MgSO_4$	100	71.6	108.7
$MnSO_4$	75	70.8	103.8
$Na_2B_4O_7$	30	74.4	99.4
$CuSO_4$	20	73.7	102.2
$ZnSO_4$	10	78.0	107.7
Seq. 330 Fe	10 (as Fe)	73.2	115.1
Check		75.2	97.7
	H.S.D. 0.05	N.S.	18.2

Conclusions:

1. Previous year's conclusions are probably valid.
2. Iron treatment gave the largest yield increase which was nearly significant at the 5% level.
3. Magnesium and zinc should definitely be considered in future experiments and, if space permits, manganese and copper may also be included.

TRACE ELEMENT EXPERIMENT (1960)
Northeast Experiment Station

Dale E. Baker, Wallace W. Nelson, and A. C. Caldwell

The purpose of this experiment was to find if a response to trace elements could be expected from any crop in the oats-meadow rotation.

The trace element treatments were randomized with each of the (4) block being split. One-half of each block was limed at the rate of (3) tons of calcitic lime in the fall of 1957, while the other half was left without lime.

The different trace element treatments were applied in the spring of 1958. Prior to seeding the entire area was treated with 40+120+120 per acre. The plots were seeded to oats, alfalfa and brome grass in the spring of 1958.

The treatments with trace elements had no significant effects on any of the forage yields. The variation in hay yields were not so great as for the silage. The fact that there was a response to lime by all the crops with the difference being significant in the case of the first year hay; indicates that the precision in this experiment was good. It would seem, therefore, that a deficiency of any the trace and secondary elements included in this experiment does not exist in this area of Minnesota.

TRACE ELEMENT EXPERIMENT

Forage yields in tons per acre as affected by different treatments with trace elements under limed and unlimed conditions.

	Oat Silage - 1958		1st Yr. Hay - 1959		2nd Yr. Hay-1960	
	Limed	Unlimed	Limed	Unlimed	Limed	Unlimed
Check	7.86	7.36	3.54	2.95	2.56	2.64
Trace Element Mixture	7.15	7.07	3.58	2.89	2.61	2.23
Molybdenum	7.92	7.06	3.47	3.14	2.13	2.24
Molybdenum and Mix	8.51	7.08	3.40	3.14	2.58	2.54
Average	7.88	7.14	3.50	3.03	2.33	2.26

BORON DEFICIENCY IN ALFALFA

A summary of observations made July 20 and 21, 1960
C. J. Overdahl

Visits were made in July to many of the 0-12-36 and 0-12-36B "quickie" topdressing plots established in northeastern and southeastern Minnesota in 1960. The 0-12-36 was applied at 250 pounds per acre, the boron plot received 25 pounds per acre of fertilizer borate or 3.25 pounds of boron. It was somewhat surprising to find evidences of boron deficiencies in almost all of the alfalfa fields visited. The following is a county-by-county report on observations. Plant tissue samples were taken and chemical analyses were made at Michigan State University.

Sherburne County - The 0-12-36 gave an apparent response, and where boron was applied in addition, the alfalfa was a darker green in color and had a slightly taller growth. No yellowing or purple cast typical of severe boron deficiency was apparent. The alfalfa growth on this field showed rather serious potash deficiency symptoms.

Mille Lacs County - The alfalfa on the Latcham field near Milaca had the most severe boron deficiency observed. Yellowing and purpling was apparent on most of the plants with the boron treated plot showing a healthy color. The 0-12-36 also gave a good response to topdressing (applied June 21). The major part of the field showed rather severe potash deficiency symptoms. Both color, and black and white pictures were taken. Plant tissue analysis for boron content showed the following: PK, 7.8 ppm boron, PKB, 23.6 ppm boron.

Aitkin County - The Otto Piispanen plot showed an interesting story. This was a very good field of alfalfa, but even with its excellent growth potash deficiency symptoms were common in addition to boron deficiency symptoms. The field had over 100 pounds per acre of K_2O but the 90 pounds of K_2O in the 0-12-36 plot gave an additional response and the plot receiving boron had greener leaves. Tissue tests of the alfalfa plants indicated 17.3 ppm boron on the PK plot and 62.4 ppm of boron on the PKB plot.

Crow Wing County - The Walt Schultz alfalfa field had visual boron deficiency symptoms with the boron treated plots showing a darker green.

Wadena County - Potash and boron deficiencies were obvious on an apparently good field of alfalfa. Drouth retarded growth on another field; hence no boron response was evident, although a PK response was obvious.

Todd County - Several fields along the road showed both boron and potash deficiencies. One excellent looking alfalfa field still showed a need for more potash. The Dale Foote field showed a slight boron response and boron deficient alfalfa plants were found throughout the field.

Morrison County - Boron and potash deficiencies were observed on alfalfa in several fields along Highway 10.

In addition to observations made by the extension specialists, county agents were contacted in 15 other counties. Those agents who responded reported no visual responses to boron in Pine, Beltrami, Washington, Wright, Koochiching, Chisago, Benton, Carlton, Houston, Wabash, Goodhue, Winona, and Dakota Counties. A visual response was reported both in Itasca and in Kanabec Counties.

There were 180 so-called "quickie" fertilizer kits mailed to county agents, who in turn established approximately 100 plots with assistance from SCS and vo-ag groups.

The boron response appeared to be confined to soils of low organic matter and soils of sandy loam or coarser texture.

Rainfall in the fall of 1959 and spring of 1960 was above average. Apparent boron deficiencies appeared in July following two weeks of very dry weather.

The Effect of Molybdenum Fertilization on the Yield and Composition of Alfalfa Grown on Some Acid Minnesota Soils.

by Loren E. Ahlrichs, Roger Hanson, and J. M. MacGregor

Significant increases in yields of alfalfa, soybeans and Birdsfoot Trefoil have been obtained on some acid soil with the application of small amounts of molybdenum, in Wisconsin, Michigan, New York, Illinois and other states. In some field experiments soybean nodulation occurred only on the molybdenum treated plots.

Objective of the experiment:

The primary purpose of this investigation was to determine if some acid soils in the state of Minnesota show a growth response in alfalfa with the addition of molybdenum.

Materials and Methods:

The soils were selected on the basis of their possible deficiency in available molybdenum. In general there would be little response to molybdenum expected on soils with pH above 6.3. Michigan studies showed that some organic soils responded to applications of molybdenum.

Information provided by the Sub-Soil fertility studies showed the following Minnesota soils to be acid to slightly acid and these were selected for the experiment:

1. Ostrander silt loam
2. Kenyon loam
3. Tama silt loam
4. Estherville loam
5. Skyberg silt loam
6. LeSueur silt loam
7. LeSueur clay loam
8. Hayden silt loam
9. Fayette silt loam
10. Anoka loamy sand
11. Zimmerman loamy sand
12. Waukegan silt loam
13. Milica sandy loam
14. Hubbard sandy loam
15. Lester loam
16. Kasson clay loam
17. Peat-Aitkin Co.
18. Peat-Aitkin Co.
19. Peat-Anoka Co.
20. Peat-Anoka Co.

Bulk soil samples were taken from the field to the greenhouse and potted in one gallon metal cans with double plastic liners. They were maintained at approximately field moisture capacity levels prior to plantings. All were tested by the Minnesota Soil Testing Laboratory and the recommended applications of phosphate and potash made using reagent grade KCl and CaH_2PO_4. The recommended rate of reagent grade $CaCO_3$ was added to bring half the pots of each soil type up to a calculated pH of 7.0.

Molybdenum was applied at the rates of 0, 1, and 2 lbs/acre in the form of reagent grade MoO_3. The moisture equivalents for each soil were determined and the moisture level of all pots was brought to the moisture equivalent each week in addition to the watering during the week with deionized water.

The crop grown was Vernal alfalfa. Twenty-five inoculated seeds per pot were planted and, upon emergence, all pots were thinned to fifteen plants. Three cuttings of alfalfa were taken at the 1/3 to 1/10 bloom stage.

Nitrogen was determined by the Kjeldahl and molybdenum content by the orange colored molybdenum-thiocynate complex colormetric determination.

Results and Conclusions:

At this time, alfalfa yields are available from six of the experimental soils and these are shown in Table 1. Yields obtained from one organic soil with minor elements added treatment instead of lime are shown in Table 2. A more complete report of alfalfa yields and levels of protein and molybdenum will be published later.

Table 1. Alfalfa yields in tons/acre (Average 3 Reps. - 3 cuttings - at 15% moisture)

Soil type	pH	Molybdenum applied lbs/A 0	1	2	T/A Lime	Molybdenum applied lbs/A with lime 0	1	2	+ H.S.D. (05)	Yield Difference
Fayette silt loam	6.0	3.40	3.49	3.68	2.0	3.60	4.12+	3.54	0.69	N.S.
Hayden silt loam	6.4	2.33	2.29	2.33	1.0	2.56	2.44	2.29	0.60	N.S.
Waukegan silt loam	6.2	3.21	3.85	3.04	1.5	3.26	3.48	3.50	1.36	N.S.
LeSueur clay loam	6.1	3.62	3.88	3.33	1.5	3.76	3.60	3.97	0.82	N.S.
Skyberg	6.2	3.58	3.46	3.34	1.5	3.74	3.74	3.69	1.14	N.S.
Ostrander silt loam	6.4	3.02	2.97	2.84	1.0	3.25+	3.14	3.18+	0.43	Significant at 5% level

There was no significant difference in yield between treatments of lime, molybdenum on lime-molybdenum interaction on the Fayette silt loam. An honest significant difference at the 5% level was apparent between the unlimed no molybdenum and the limed 1 lb/A rate of molybdenum.

There was no significant difference in yield between treatments of lime and molybdenum or lime molybdenum interaction on the Hayden silt loam. No honest significant difference was evident.

No significant difference in yield resulted between treatments of lime and molybdenum or lime-molybdenum interaction on the Waukegan silt loam and there were no honest significant differences.

LeSueur clay loam showed no significant difference in yield between treatments of lime and molybdenum or a lime-molybdenum interaction, as well as no honest significant difference.

No significant difference in yield due to treatments of lime and molybdenum or lime-molybdenum interaction occurred on the Skyberg silt loam and there was no honest significant difference.

There was a significant increase in yield of alfalfa of the limed soil over the unlimed on the Ostrander silt loam. No significant differences in yield of alfalfa were shown by the molybdenum fertilization and there was no lime-molybdenum interaction. An honest significant difference of two of the limed treatments over the unlimed 2 lbs/A molybdenum application occurred on this soil.

Table 2. The effect of molybdenum and other trace elements on the yield of alfalfa growing on a reed and sedge peat from Anoka County. (Tons/A)

(Average 3 Reps. - 3 cuttings - at 15% moisture)

	Molybdenum applied lbs/A			Molybdenum applied lbs/A with other trace elements*				
pH	0	1	2	0	1	2	H.S.D.(0.5)	Yield Differences
5.9	4.60	4.43	3.90	+ 5.28	4.82	+ 5.50	1.03	Significant at 1% level

*Trace element application consisted of:

Compound	Rate/acre
$ZnSO_4 \cdot 7H_2O$	25 lbs.
$MgSO_4$	25 lbs.
$MnSO_4$	25 lbs.
$CuSO_4$	25 lbs.
Chelate 138	30 lbs.
Borax	5 lbs.

On the Anoka County decomposed Reed and Sedge Peat there was a significant difference in treatments at the 1% level. A significant increase in alfalfa yields on the minor element treatments over the pots receiving no minor elements at the 1% level was evident. No significant difference in yield with molybdenum treatments occurred but there was a significant difference due to the minor elements-molybdenum interaction at the 5% level. There was an honest significant difference at the 5% level between minor elements and the no molybdenum and minor elements 2#/A molybdenum and the 2#/A molybdenum only treatment. There was also an honest significant difference at the 5% level between the 1#/A molybdenum only treatment and the monor elements 2#/A molybdenum application.

It would appear that the increase in yield of alfalfa on this Anoka County Reed and Sedge peat increase probably due to one or more of the other minor elements rather than to the addition of molybdenum.

RATES AND SOURCES OF LIME AT VARIOUS FERTILIZER LEVELS EXPERIMENT
Northeast Experiment Station

Dale E. Baker, Wallace W. Nelson, and A. C. Caldwell

Procedure:

This experiment was initiated in 1957 for the purpose of determining the effect of different rates and sources of lime on the growth of oats and meadow when different amounts of phosphate and potash have been added. The plots were laid out in a split-split plot design. Each plot received two sources of lime at a given rate and different fertilizer treatments were applied across each limestone rate and source. The sources of lime were calcitic and dolomitic. Rates of limestone were 0, 3, 6, and 12 tons per acre. Also heavy liming plots, which were not replicated were included with lime application of (24) and (48) tons per acre. The various limestone treatments were applied by hand in the fall of 1957. The experimental area was then cultivated with a Graham-Homme and then plowed. After plowing, the entire area was sprayed with Dalapon at (8) pounds acid equivalent per acre on November 1. In the spring of 1958, before seeding, fertilizer was applied to sub-plots two and three. Sub-plot (2) received 20+120+120 and sub-plot (3) received 40+120+120. Sub-plots (1), (4), and (5) were left as checks for fertilizer.

The entire experimental area was seeded to Minhafer oats, (8) pounds Vernal alfalfa and (8) pounds bromegrass May 6, 1958. The oats crop was sampled for yields of silage July 29, 1958.

After the first cutting of hay was removed in 1959, sub-plot (2) was treated with 0+40+80 and (3) with 0+80+160. Yield samples were taken for each cutting in 1959 and again in 1960.

Soil samples were taken from the plots in 1957, (Table I), before the treatments for soil were made and again in 1959, (Table VI) for test correlation purposes. Before the second cutting was harvested in 1960, the stand of alfalfa was estimated for each sub-plot at each lime level.

Discussion of Results:

The yields of silage obtained in 1958, showed that oats in most cases did not respond to applications of limestone, (Table II). Calcitic limestone had no effect on yields regardless to the rate of application. Dolomitic limestone applications resulted in a decrease in yields of silage on all sub-plots except sub-plot number (3). The depression of yields from dolomitic limestone was statistically significant, (Table III). The small response to the magnesium from dolomitic in sub-plot (3), however, suggests an effect from cationic balance. Additions of calcium and magnesium might have decreased the potassium activity of the soil causing small yields from the unfertilized sub-plots. The application of ample amounts of phosphate and potash to sub-plot number (3), resulted in a small response to the magnesium from the dolomitic limestone over the calcitic form. The slower reaction rate for dolomitic limestone was suggested by the larger response to the higher rates in sub-plot (3). In all cases, the response of oats to limestone was negligible and economically of little importance.

Oats grown in the experiment responded significantly to applications of fertilizer, Tables (II and (III). This response was expected on the basis of soil test results obtained before the plots were treated, (Table I). The higher rate of fertilizer applied to sub-plot (3) resulted in higher yields than were obtained from the lower rate applied to sub-plot (2).

The yields of hay for 1959, (Table IV) and (V) showed the same trends as were obtained for oats in 1958. The results for soil tests made in 1959, (Table VI), for phosphorus and potassium did not indicate that the amounts available in the soil had been changed. Of course, a large amount of the initial application might have already been removed by crops. The results of the soil tests did not indicate that the calcitic lime reacted more rapidly than the Dolomitic. It is interesting to note that none, not even the (12) tons per acre, of the lime treatments had neutralized the soil by 1959. It will be interesting to note pH changes of these plots with time.

The response of hay yields to higher rates of limestone did not appear until 1960, (Table VII). Also, in 1960, the response to dolomitic limestone over calcitic limestone on sub-plots (3) was greater. The small response, however, was still not statistically significant, (Table VIII). The fact that yields of hay did not increase as a result of applications of limestone until three years after the area was treated, suggest that it might be advisable to lime and fertilize an area about two years before it is to be seeded to alfalfa. This would suggest the need for rotations that include corn, potatoes, or winter grain which could be grown for one year before the alfalfa is seeded.

The stand of alfalfa at the time of the second cutting in 1950 indicated that alfalfa had responded to both sources of limestone, especially where phosphate and potash had been applied, Table IX. The stand of alfalfa was not sufficient on any of the plots, however. The relatively poor stand of alfalfa on the treated plots may have resulted from the slow rate at which the soil reaction was corrected as was indicated above, or it might have been due to competition from the oats nurse crop of the bromegrass.

Yields of hay from the heavy liming plots when compared to those from replication (IV), show the same trends as those for the main experiment, (Table X). It does not appear that the very heavy rate of lime were either beneficial or detrimental to the growth of alfalfa and bromegrass.

Conclusions:

1. Applications of limestone regardless of source to acid topsoil in Northeast Minnesota do not increase yields of oats.

2. Alfalfa responds to applications of limestone, especially when the level of phosphate and potash are adequate.

3. Acotionic interaction between calcium, potassium and magnesium was indicated by the results of this experiment.

4. The delayed response of alfalfa to applications of limestone indicates that a crop management system should be such that basic lime and fertilizer treatments are made one or two years before the alfalfa is seeded.

RATES AND SOURCES OF LIME AT DIFFERENT RATES OF FERTILIZERS

Table I

Results of Soil Tests for samples taken prior to treatment with lime and fertilizers.

Rep.	Surface pH	Subsoil	O.M. Surface	Subsoil	P Surface	Subsoil	K Surface	Subsoil
I	5.8-6.0	5.5-5.8	3.8-4.5	1.4-2.1	9-25	7-11	55-90	45-60
II	5.6-5.9	5.7-5.8	3.9-4.4	1.4-1.9	18-28	14-26	55-80	30-65
III	5.7-6.0	5.7-5.9	3.9-4.4	1.6-2.1	18-29	14-21	60-85	45-65
IV	6.0-6.2	5.8-6.1	4.1-4.9	2.2-3.5	10-20	6-15	50-75	30-85

RATES AND SOURCES OF LIME AT DIFFERENT RATES OF FERTILIZERS (1958)

Table II

Yields of oat silage in tons per acre as affected by different rates and sources of lime and different rates of fertilizers

Rates and Sources of Lime	Fertilizers 1	2	3	4	5	Grand Means
Check	4.62	7.04	7.34	4.92	5.07	5.800
3 T./Ac. Dolomitic	4.44	5.09	7.39	5.29	4.15	5.282
3 " Calcitic	6.31	7.07	7.39	5.36	4.88	6.203
6 " Dolomitic	4.11	5.84	7.02	4.86	5.00	5.268
6 " Calcitic	5.84	7.25	6.67	4.61	4.79	5.828
12 " Dolomitic	4.24	6.62	7.50	4.98	4.95	5.661
12 " Calcitic	4.78	6.96	7.32	5.31	4.88	5.852
Grand Means	4.908	6.555	7.233	5.050	4.821	
*24 T/Ac. Dolomitic	2.82	3.58	7.56	3.23		4.30
*24 T/Ac. Calcitic	3.58	4.13	4.74	4.33		4.20
*48 " Dolomitic	4.40	5.84	7.01	4.47		5.43

*Heavy liming plots which were not replicated.

Confidence Intervals ($D_{.05}$) for comparing:

1. Grand means for rates and sources of lime = 0.510
2. Grand means for rates of fertilizers = 0.467

RATES AND SOURCES OF LIME AT DIFFERENT RATES OF FERTILIZERS (1958)

TABLE IV

YIELDS OF FIRST YEAR HAY IN TONS PER ACRE AS AFFECTED BY DIFFERENT RATES AND SOURCES OF LIME AND DIFFERENT RATES OF FERTILIZERS.

Rates and Sources of Lime	Fertilizers 1	2	3	4	5	Grand Means
Check	1.91	3.18	3.23	2.17	2.39	2.576
3 T./Ac. Dolomitic	2.02	2.03	3.54	1.70	1.84	2.426
3 T./Ac. Calcitic	2.20	3.26	3.30	2.10	2.24	2.626
6 T./Ac. Dolomitic	2.06	2.88	3.55	2.39	2.06	2.589
6 T./Ac. Calcitic	2.24	3.52	3.29	2.60	2.35	2.800
12 T./Ac. Dolomitic	2.03	3.39	3.54	1.92	2.42	2.660
12 T./Ac. Calcitic	2.16	3.44	3.46	1.99	2.23	2.655
Grand Means	2.093	3.242	3.416	2.126	2.216	

Confidence Intervals ($D_{.05}$) for Comparing:

1. Grand Means for Rates and Sources of Lime = N.S.
2. Grand Means for Rates of Fertilizers = 0.403
3. Rates and Sources of Lime at a given rate of fertilizer = 0.400

RATES AND SOURCES OF LIME AT DIFFERENT RATES OF FERTILIZERS

TABLE VI

RESULTS OF SOIL TESTS FOR SAMPLES TAKEN IN 1959 TWO YEARS AFTER SOIL HAD BEEN TREATED WITH DIFFERENT RATES AND SOURCES OF LIME AND DIFFERENT RATES OF FERTILIZERS.

Rep.	Fert. Determination	Check	3T./A Dolo.	3T./A. Calc.	6T/A. Dolo.	6 T/A. Calc.	12 T/A Dolo.	12 T/A Calc.
I - 2	pH -0.7	5.4	5.5	5.8	6.0	6.3	6.0	5.8
	" 7-12	5.4	5.5	5.4	5.9	5.4	5.1	5.2
	% O.M. 0-7	4.0	4.4	3.9	4.0	4.4	4.1	4.2
	% O.M. 7-12	2.1	2.7	1.8	2.7	2.2	1.6	2.7
	P (lbs./Ac.) 0-7	18	14	14	14	37	49	31
	" 7-12	10	12	9	11	12	28	17
	K (lbs./Ac. 0-7	30	30	40	50	40	50	50
	7-12	30	50	30	30	20	55	40
I - 3	pH -0.7	5.4	5.9	5.8	6.0	6.1	5.4	6.6
	" 7-12	5.5	5.6	5.6	6.4	5.5		5.6
	% O.M. 0-7	4.7	3.9	3.5	4.0	3.4	2.2	4.0
	% O.M. 7-12	3.1	1.5	2.0	2.2	2.0		2.2
	P (lbs./Ac.) 0-7	20	23	23	39	19	17	28
	" 7-12	10	7	9	200+	7		10
	K (lbs./Ac.) 0-7	30	50	50	50	50	40	40
	K (lbs./Ac.) 7-12	30	30	40	40	30		40
I - 4	pH 0-7	5.4	5.8	5.9	6.2	6.1	5.0	6.5
	" 7-12	5.4	5.5	5.3	5.7	5.5	5.6	5.3
	% O.M. 0-7	4.9	4.7	3.4	4.4	4.4	4.7	4.1
	% O.M. 7-12	2.7	2.5	2.3	2.0	1.6	1.6	2.9
	P (lbs./Ac) 0-7	22	21	77	23	12	28	19
	P (lbs./Ac) 7-12	17	16	12	12	6	13	9
	K lbs./Ac. 0-7	30	30	40	40	50	30	40
	K " " 7-12	30	40	30	40	40	40	40

TABLE VI (Continued)

Rep.	Fert. Determination	Check	3T./A Dolo.	3T./A Calc.	6T./A Dolo.	6T/A Calc.	12T/A Dolo.	12T/A Calc.
III - 2	pH 0-7	5.3	6.2	6.0	5.8	5.6	6.3	6.7
	pH 7-12	5.3	5.6	5.6	5.2	5.4	4.8	5.6
	% O.M. 0-7	4.2	4.4	3.9	4.4	4.0	3.6	3.6
	% O.M. 7-12	1.8	1.6	2.0	2.3	1.9	2.2	2.1
	P (lbs./Ac.) 0-7	60	21	15	27	41	26	28
	P (lbs./Ac.) 7-12	34	10	9	20	18	23	15
	K (lbs./Ac.) 0-7	70	60	50	20	50	40	30
	K (lbs./Ac.) 7-12	40	20	30	20	40	60	30
III - 3	pH 0-7	5.4	5.9	6.0	6.2	6.2	6.1	6.3
	pH 7-12	5.3	5.6	5.7	5.6	5.2	5.7	5.6
	% O.M. 0-7	5.3	4.4	4.4	4.4	4.5	4.4	4.4
	% O.M. 7-12	2.2	2.0	1.6	2.2	1.8	2.3	2.7
	P (lbs./Ac.) 0-7	40	20	37	48	42	51	51
	P (lbs./Ac.) 7-12	17	11	11	20	16	13	19
	K (lbs./Ac.) 0-7	60	40	60	50	70	40	40
	K (lbs./Ac.) 7-12	50	30	20	50	90	30	40
III - 4	pH 0-7	5.4	5.9	6.2	5.9	6.0	6.4	6.2
	pH 7-12	5.4	5.4	5.6	5.5	5.4	5.5	5.5
	% O.M. 0-7	4.4	4.5	4.4	4.2	4.7	4.2	4.1
	% O.M. 7-12	1.7	2.7	2.2	2.3	1.8	2.2	2.1
	P (lbs./Ac.) 0-7	31	25	23	34	37	35	43
	P (lbs./Ac.) 7-12	12	16	15	20	14	28	24
	K (lbs./Ac.) 0-7	60	30	40	40	50	40	40
	K (lbs./Ac.) 7-12	40	20	20	60	60	30	40

RATES AND SOURCES OF LIME AT DIFFERENT RATES OF FERTILIZERS (1960)

TABLE VII

YIELDS OF SECOND YEAR HAY IN TONS PER ACRE AS AFFECTED BY DIFFERENT RATES AND SOURCES OF LIME AND DIFFERENT RATES OF FERTILIZERS:

Rates and Sources of Lime	1	2	3	4	5	Grand Means
Check	1.01	2.10	2.40	1.18	1.10	1.558
3 T/Ac. Dolomitic	1.19	1.96	2.56	1.46	1.20	1.674
3 T/Ac. Calcitic	1.17	2.18	2.46	1.36	1.29	1.689
6 T/Ac. Dolomitic	1.18	2.07	2.61	1.45	1.17	1.694
6 T/Ac. Calcitic	1.23	2.25	2.37	1.39	1.19	1.685
12 T/Ac. Dolomitic	1.24	2.45	2.66	1.45	1.45	1.830
12 T/Ac. Calcitic	1.40	2.20	2.47	1.29	1.39	1.750
Grand Means	1.202	2.173	2.504	1.366	1.241	

RATES AND SOURCES OF LIME AT DIFFERENT RATES OF FERTILIZERS (1960)

TABLE IX

PERCENTAGE STAND OF ALFALFA AFTER THREE YEARS IN PLOTS TREATED WITH DIFFERENT RATES AND SOURCES OF LIME AND DIFFERENT RATES OF FERTILIZER.

Rates and Sources of Lime	Fertilizers					Grand Means
	1	2	3	4	5	
Check	7	22	22	8	5	12.8
3 T/Ac. Dolomitic	9	32	42	6	13	20.0
3 T/Ac. Calcitic	7	39	49	9	10	22.8
6 T/Ac. Dolomitic	10	36	48	12	9	23.0
6 T/Ac. Calcitic	6	35	42	9	6	19.6
12 T/Ac. Dolomitic	10	32	34	5	11	18.4
12 T/Ac. Calcitic	7	29	34	7	6	16.6
Grand Means	8.0	33.1	38.6	8.0	8.5	

RATES AND SOURCES OF LIME AT DIFFERENT RATES OF FERTILIZERS (1960)

TABLE X

YIELDS OF HAY IS TONS PER ACRE AS AFFECTED BY DIFFERENT RATES AND SOURCES OF LIME AT DIFFERENT RATES OF FERTILIZER

	1959					1960					
Check	1	2	3	4	Ave.	1	2	3	4	Ave.	Grand Ave.
Check	2.25	3.09	3.55	2.30	2.80	1.05	1.76	2.23	.85	1.47	2.12
3 T. Dolo.	1.88	3.08	3.87	1.49	2.58	1.13	1.76	2.88	1.10	1.72	2.15
3 T. Calc.	1.92	3.68	4.00	2.13	2.93	.88	1.78	2.24	.95	1.46	2.20
6 T. Dolo.	1.73	2.75	3.77	2.80	2.76	.88	1.95	2.53	1.44	1.70	2.23
6 T. Calc.	1.59	3.10	2.84	3.11	2.66	.74	1.77	2.55	1.34	1.60	2.13
12 T. Dolo.	1.72	3.41	3.70	1.97	2.70	.76	1.93	2.05	.94	1.42	2.06
12 T. Calc.	2.33	3.70	3.49	1.56	2.77	1.13	1.66	1.78	.94	1.38	2.08
24 T. Dolo.	1.94	2.54	3.70	1.71	2.47	.83	1.45	1.78	.82	1.22	1.84
24 T. Calc.	2.35	3.92	3.82	2.35	3.11	.95	1.41	1.39	1.16	1.23	2.17
48 T. Dolo.	2.20	4.29	4.24	2.40	3.28	1.19	1.71	2.21	1.17	1.57	2.42
48 T. Calc.	2.23	3.80	4.46	1.82	3.08	1.03	1.59	2.02	.78	1.33	2.20
Average	2.01	3.42	3.77	2.15		.96	1.71	2.15	1.04		

Lime Experiment
Rosemount, 1960

A. C. Caldwell and J. B. Weber

To study the long time effects of lime on the yields of some common crops and on the physical and chemical properties of the soil, a research project with lime was started at the Rosemount station in the fall of 1951. Plots were laid out consisting of four replications of five treatments. Treatments were 0, 3, 6, 12, and 24 tons of lime per acre. A regular rotation of corn, oats, alfalfa, and alfalfa was set up. Each year corn and grain have received 200 pounds of 5-20-20 per acre as a fertilizer treatment. Alfalfa has received phosphorus and potassium fertilizers as needed according to soil test.

In 1959, it was decided to also study the effect of lime on soybeans, so the rotation was changed to corn, soybeans, oats and alfalfa. The soybeans received 100 pounds of 5-20-20 per acre as a starter fertilizer.

In 1960, an application of 8.7 ounces of Mo per acre, as $(NH_4)_2MoO_4$, was made to one of the check plots in each replicate to study the effect of applied Mo on the yields of the various crops.

Yield results from the four crops for 1960 are included in Table 1. Corn yields were significantly (.05) higher than the control on all of the treatments. The various treatments are not significantly different from each other, however, and it appears that any one of the lime treatments or the molybdenum treatment would increase corn yields to about the same degree. Increased corn yields attributed to liming are most likely caused indirectly by added nitrogen from the previous alfalfa crop. Increased corn yields by the Mo application may be a direct response to Mo, or possibly the Mo improves the nitrogen fixing ability of the alfalfa nodules and is again an indirect affect. It will be noted that the Mo treatment also significantly increased the yield of alfalfa above the control.

Soybean yields were significantly (.05) increased above the control by the 12 and 24 tons of lime per acre treatment and by the Mo application. The treatments, other than the control, are not significantly different from each other but it appears as though the yields of soybeans did continue to increase with increased increments of lime applied.

Oat yields were not significantly affected by either the lime or Mo applications. It is interesting to note, however, that all treatments decreased the yield of oats below that of the control. Oats was equally as lacking to fertilizer response on the rate of seeding experiment in 1960.

Alfalfa yields were significantly (.05) increased by the lime and Mo applications. The 6 and 24 ton per acre rates produced the greatest yield increases above control being 1.39 and 1.45 tons per acre respectively. The 6 ton per acre rate has in the past years been the highest yielder of alfalfa and again seems to conform to that trend. The Mo application, although increasing the alfalfa yield significantly, is much lower than any of the lime treatments.

The included soil pH values are following the same trend as in previous years.

Table 1. The effect of lime and molybdenum on soil pH and the yields of corn, soybeans, oats, and alfalfa in a rotation, 1960.

Treatment	Soil pH	Yields: Corn[1] bu/A	Corn Diff.	Soybeans bu/A	Soybeans Diff.	Oats bu/A	Oats Diff.	Alfalfa Tons/A	Alfalfa Diff.
0 tons lime/A	6.1	132	----	25.4	----	75.4	----	2.67	----
3 tons lime/A	6.5	146	14	24.0	-1.4	66.0	-9.4	3.91	1.24
6 tons lime/A	6.9	147	15	27.1	1.7	70.2	-5.2	4.06	1.39
12 tons lime/A	7.2	141	9	27.8	2.4	71.6	-3.8	3.80	1.13
24 tons lime/A	7.5	152	20	28.7	3.3	73.3	-2.1	4.12	1.45
8.7 oz. Mo/A	6.1	143	11	27.4	2.0	72.1	-3.3	3.30	0.63
lsd (.05) =			9.0		1.9		N.S.		0.50
hsd (.05) =			15.6		3.4				0.94

1 @ 15% moisture

2 Dry weight

The Nicollet County Plots

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

W. P. Martin, Fred Wetherill and H. W. Kramer

Yield Results - 1960

Re: 1959 results, "A Report on Soils and Soil Fertility", p. 74. Department of Soils, Mimeo, April, 1960.

Soils: Webster and closely related Nicollet silty clay loams: level topography, miminum erosion, drainage necessary.

Cropping systems established in 1948: (1) corn-oats, (2) corn-oats with clover as green manure, (3) 4-year rotation of oats-hay-corn-corn extended to 5-years in 1958 with soybeans between two corn years, and (4) continuous corn (established in 1954).

Fertilizer treatments: Multiple rates and materials including barnyard manure at regular and "extra" heavy fertilization levels; see tables for treatments and 1959 report for details on materials, rates and methods of applications. Four replications.

CONTINUOUS CORN (RATE AND TIME OF APPLICATION)

Nitrogen:		Yield results:	
Rate	Time*	Starter only**	+PK broadcast***
None	0-0-0	53 bu.	54 bu.
40 lbs	1-0-0	89	86
80	1-1-0	89	96
120	1-1-1	96	105
80	1-0-1	86	96
80	0-1-1	83	100
40	0-0-1	80	93
40	0-1-0	79	90
80	2-0-0	86	94
120	3-0-0	91	100

*0-0-0 refers to time of application, i.e. planting time-first cultivation-second cultivation.
** 175 lbs. 6-24-12 starter in row at planting time.
***Starter plus 300 lbs. 0-20-20 braodcast.

CORN-OATS (WITH AND WITHOUT LEGUME GREEN MANURE):

	CORN	(with legume)	OATS	(with legume)
1. Check	57 bu.	53 bu.	31 bu.	42 bu.
2. N on oats	60	56	53	53
3. NP on oats	67	81	66	78
4. NPK on oats	68	82	63	69
5. P plowdown	71	72	33	53
6. NPK in hill	78	82	30	46
7. N plowdown	70*	53*	45*	59*
8. N sidedress	74*	43*	59*	51*
LSD (5%)	11	14	11	14

One replication only

Corn-Soybeans-Corn-Oats-Hay (with regular and extra-heavy fertilization levels):

Treatments (regular)	Corn (1)		Soybeans		Corn (2)		Oats		Hay	
	Reg.	Extra*	Reg.	Extra*	Reg.	Extra*	Reg.	Extra*	Reg.	Extra*
6. Check	73 bu.	101 bu.	34 bu.	43 bu.	70 bu.	102 bu.	58 bu.	78 bu.	1.8 tons	4.7 tons
1. P for oats	81	100	39	40	72	84	73	72	3.7	4.2
2. PK for oats	76	98	40	42	74	88	70	72	3.9	4.9
7. NP for oats	77	86	38	39	70	85	84	83	3.7	4.3
3. NPK for oats	78	99	37	40	73	87	87	90	3.4	4.4
10. P for oats & corn	91	102	38	42	82	86	81	106	4.1	4.5
9. P for corn	86	98	37	38	75	83	76	85	3.1	4.8
4. Manure for corn	96	103	43	46	89	87	66	76	3.1	4.7
8. Manure & P for corn	97	100	41	44	89	93	65	79	4.2	4.6
5. Manure & NPK for corn	107	102	42	41	89	107	72	72	3.5	4.7
LSD (5%)	13	13	3	6	13	13	16	14	0.6	0.8

*Refers to extra-heavy fertilization treatments in addition to regular treatments.
Season very wet which delayed planting and early cultivation.

Fertilizer Rotation Studies
(A report on 1960 fertilizer experiments)

Introduction

The permanent fertilizer rotation plots which are established at the Waseca, Morris, and Crookston Branch Experiment Stations have now been in existence for 5 years. These plots were designed to evaluate the effects of the nutrients, nitrogen, phosphorus, and potash, on soil properties and crop response when crops are grown in typical rotations for an area. While all crops receive the three nutrients above and in all combinations with one another the rates of application are selected appropriately for the specific crops. All fertilizers are applied as a broadcast application in the spring with the exception of a small portion for corn which is applied as a starter at planting.

The crops at Morris and Waseca are in a five year rotation. Continuous corn is also grown at both stations. The rotations at the Waseca and Morris stations are as follows:

Waseca	Morris
corn	corn
corn	corn
soybeans	soybeans
oats	flax
alfalfa	alfalfa
continuous corn*	continuous corn*

The Crookston experiment consists of two rotations, a three and a four year rotation. The three year rotation consists of a sequence of sugar beets, wheat and sweet clover fallow. The four year rotation is a sequence of corn, soybeans, wheat and alfalfa.

Besides the regular fertilizer treatments an extra plot has been added to each experiment which receives a very heavy treatment of N, P, and K. These plots, which are known as NPK+ treatments are not analyzed statistically with the rest of the experiment but are used to make qualitative comparisons.

Interpretation of Statistical Data

The data tables show the mean yields of the various crops for each fertilizer treatment, and the differences between these yields and those obtained from untreated plots. In addition each table has a column labled treatment effect. The treatment affects for N, P, or K alone are the best statistical estimates of the effect of these nutrients. The numbers tabulated in this column are the differences between all plots treated with a given nutrient and all plots not treated with that nutrient. This quantity is called the main effect of that nutrient. The main effect of nitrogen for instance is computed as follows:

$$\text{N main effect} = \frac{(N + NP + NK + NPK) - (P + K + PK + \text{check})}{12}$$

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* Not in rotation

When significant treatment effects are shown for NP, NK, or PK treatments this fact indicates that interaction has occurred. This means that the two nutrients together produced some effect which was not due to either one of them alone. A hypothetical example of an NP interaction on corn would appear as follows:

	No N	N
No P	80	100
P	85	130

The first row shows that N increases yields from 80 to 100 bu/A when no P has been applied. The first column shows that P increases the yield from 80 to 85 bu/A when no N is applied. If there were no interaction it would be expected that the NP treatment would result in a yield of 105 bu/A (80 + 20 for N + 5 for P). A yield of 130 indicates that N and P combined produced a yield which is not attributable to either nutrient alone.

In certain cases treatment effects are found which are not significant at the usual 99 or 95 percent levels but nevertheless seem to be important. When this happens in this report the actual probability levels are tabulated after the treatment effect in parentheses.

Waseca Yields

Corn

Continuous corn yields in 1960 ranged from 85 to 125 bushels per acre. The corn at harvest was mature even though late spring rains caused a postponement of planting until June 2, 1960. This was the first year that a significant response to added nitrogen was found although this was the fifth year of continuous corn.

An unusual result was found on the first year corn in that a significant response to K application was obtained. The past five years of experience with these plots has shown no other instance of an increase in corn yields due to K application.

Significant yield increases were found on the second year corn for the applications on nitrogen.

All corn was planted at the rate of 20,000 stalks per acre. Due to the late planting date a 112-115 day variety was used instead of the usual 120 day maturity corn used in previous years. Soil insects were controlled by the use of a broadcast application of alderin and annual grasses were controlled by the use of a band spray application of Randox.

Soybeans

Soybean yields were good, ranging from 29 to 33 bushels per acre. Soybeans in this and other locations respond only occassionally to added fertilizer but this year a small significant increase amounting to 1.5 bu/acre was found due to the application of phosphorus.

Oats

Grain yields were increased slightly by N applications and decreased slightly by NP applications. As in recent years, significant lodging again occurred on plots treated with nitrogen.

Oats for forage were sampled in the dough stage when the average moisture content was 60%. Nitrogen and phosphate treatments both resulted in substantial increases in forage yield.

Alfalfa

Two cuttings of alfalfa were obtained from the Waseca plots, although total annual yield only is tabulated here. As is frequently the case, a significant increase in annual alfalfa yield was obtained due to phosphorus application.

Fertilizer Rotation Experiment - Waseca

Table W-1. Continuous Corn (15% moisture)

Treatment	lbs/ac $N-P_2O_5-K_2O$	Average Yield bu/ac	Diff.	Treatment effect
None	0-0-0	86.9		
N	160-0-0	100.8	13.9	18.8**
P	0-160-0	88.2	1.3	7.0 (90%)
K	0-0-160	85.1	-1.8	
NP	160-160-0	105.4	18.5	
NK	160-0-160	104.1	17.2	
PK	0-160-160	93.1	6.2	
NPK	160-160-160	118.3	31.4	
NPK+	320-320-320	124.9	38.0	

Table W-2. First year corn.

Treatment	lbs/ac $N-P_2O_5-K_2O$	Average Yield bu/ac	Diff.	Treatment effect
None	0-0-0	90.0		
N	40-0-0	98.7	8.7	
P	0-80-0	100.2	10.2	
K	0-0-80	103.9	13.9	7.8(94%)
NP	40-80-0	96.3	6.3	
NK	40-0-80	105.5	15.5	
PK	0-80-80	102.2	12.2	
NPK	40-80-80	104.6	14.6	
NPK+	80-160-160	114.0	24.0	

* Significant at 95% level
** Significant at 99% level

Waseca

Table W-3. Second Year Corn

Treatment	lbs/ac $N-P_2O_5-K_2O$	Average Yield bu/ac	Diff.	Treatment effect
None	0-0-0	91.9		
N	80-0-0	103.4	11.5	17.5**
P	0-80-0	86.4	-5.5	
K	0-0-80	96.8	4.9	
NP	80-80-0	101.8	9.9	
NK	80-0-80	107.1	15.2	
PK	0-80-80	80.9	-11.0	
NPK	80-80-80	113.7	21.8	
NPK+	160-160-160	118.8	26.9	

Table W-4. Soybeans

Treatment	lbs/ac $N-P_2O_5-K_2O$	Average Yield bu/ac	Diff.	Treatment effect
None	0-0-0	29.8		
N	20-0-0	31.1	1.3	
P	0-40-0	31.4	1.6	1.5 (94%)
K	0-0-40	28.9	-0.9	
NP	20-40-0	31.5	1.7	
NK	20-0-40	31.3	1.5	
PK	0-40-40	31.7	1.9	
NPK	20-40-40	32.6	2.8	
NPK+	40-80-80	32.5	2.7	

Waseca

Table W-5. Oats Forage[1]

Treatment	lbs/ac $N-P_2O_5-K_2O$	Average Yield T/ ac	Diff.	Treatment effect
None	0-0-0	6.95		
N	80-0-0	9.09	2.14	2.35**
P	0-80-0	6.82	-0.03	1.05*
K	0-0-80	6.23	-0.72	
NP	80-80-0	10.11	3.16	
NK	88-0-80	8.53	1.58	
PK	0-80-80	8.21	1.26	
NPK	80-80-80	9.88	2.93	
NPK+	120-160-160	11.30	4.35	

[1]60% moisture

Table W-6. Oats Grain

Treatment	lbs/ac $N-P_2O_5-K_2O$	Average Yield bu/ac	Diff.	Treatment effect
None	0-0-0	62.8		
N	80-0-0	79.7	16.9	6.7 (90.3%)
P	0-80-0	67.7	4.9	
K	0-0-80	69.7	6.9	
NP	88-80-0	72.3	9.5	-7.5 (92.6%)
NK	80-0-80	81.2	18.4	
PK	0-80-80	80.3	17.5	
NPK	80-80-80	74.3	11.5	
NPK+	120-160-160	64.1	1.3	

Waseca

Table W-7. Alfalfa (Total of two cuttings)

Treatment	lbs/ac $N-P_2O_5-K_2O$	Average Yield T/ac	Diff.	Treatment effect
None	0-0-0	2.17		
N	20-0-0	2.89	0.72	
P	0-80-0	3.14	0.97	0.64*
K	0-0-80	2.39	0.22	
NP	20-80-0	3.09	0.92	
NK	20-0-80	2.78	0.61	
PK	0-80-80	3.32	1.15	
NPK	20-80-80	3.22	1.05	
NPK+	20-160-160	3.39	1.22	

Morris Yields

Corn

Yields of continuous corn were improved to the extent of 18 bushels per acre by the application of 160 pounds of N per acre. Neither first nor second year corn were similarly affected. It is significant to note that continuous corn at Morris yielded in general well below the levels of first and second year corn. The overall average yield of continuous corn amounted to 67 bushels per acre. First and second year corn on the other hand yielded an average of 79 and 82 bushels per acre respectively. The latter two yields were both significantly greater than the continuous corn yield at the 99% level of confidence.

The stand of corn at Morris amounted to 15,600 stalks per acre. Soil insects were controlled by the use of alderin and annual grasses were controlled by a band spray application of Randox.

An experimental application of amino triozole to thistles growing in the corn was tried. This was done with a small experimental sprayer which had guards installed to prevent any spray from touching the corn. It was hoped that if all thistles between rows were covered with spray, some of it would be translocated within roots and affect the thistles within rows. Three weeks after application, all thistles between rows showed characteristic amino triozole damage and an estimated 40% of the thistles within rows were similarly affected. None of the corn stalks showed any visible damage. This application was made June 18, 1960.

Soybeans

Soybeans averaged about 20 bushels per acre but no treatment effect was noted.

Flax

Flax yields ranged from 19 to about 24 bushels per acre. The nitrogen treated plots averaged slightly but significantly lower in yield than the non nitrogen treated plots.

Alfalfa

Three cuttings of alfalfa were taken and the total annual yields computed. As has happened in every previous year of the experiment, the alfalfa yields were again improved significantly by phosphorus applications.

Alfalfa yields were slightly reduced on plots which have been treated with nitrogen. This occurrence is noted from time to time at all three branch stations considered in this report. It is not known if this is a direct effect of nitrogen or if it is an indirect effect of the heavier grain stand on nitrogen treated plots in the previous year.

Fertilizer Rotation Experiment - Morris

Table M-1. Continuous Corn

Treatment	lbs/ac $N-P_2O_5-K_2O$	Average Yield bu/ac	Diff.	Treatment effect
None	0-0-0	65.2		
N	160-0-0	76.5	11.3	18.7**
P	0-160-0	50.9	-14.3	
K	0-0-40	53.9	11.3	
NP	160-160-0	74.9	9.7	
NK	160-0-40	84.5	19.3	
PK	0-160-40	65.4	0.2	
NPK	160-160-40	74.2	9.0	
NPK+	320-320-80	58.2	-7.0	

Table M-2. First year corn

Treatment	lbs/ac $N-P_2O_5-K_2O$	Average Yield bu/ac	Diff.	Treatment effect
None	0-0-0	76.8		
N	60-0-0	88.4	11.6	
P	0-40-0	85.5	8.7	
K	0-0-40	81.6	4.8	
NP	60-40-0	76.3	-0.5	
NK	60-0-40	72.0	-4.8	
PK	0-40-40	85.4	8.6	
NPK	60-40-40	76.9	0.1	
NPK+	100-120-80	66.4	-10.4	

Table M-3. Second year corn

Treatment	lbs/ac $N-P_2O_5-K_2O$	Average Yield bu/ac	Diff.	Treatment effect
None	0-0-0	81.5		
N	80-0-0	86.1	4.6	
P	0-80-0	94.6	13.1	
K	0-0-40	83.3	1.8	-7.9 (90%)
NP	80-80-0	82.8	1.3	
NK	80-0-40	81.1	-0.4	
PK	0-80-40	77.3	-4.2	
NPK	80-80-40	75.2	-6.3	
NPK+	120-120-80	78.5	-3.0	

Table M-4. Soybeans

Treatment	lbs/ac $N-P_2O_5-K_2O$	Average Yield bu/ac	Diff.	Treatment effect
None	0-0-0	20.5		
N	20-0-0	19.8	-0.7	
P	0-40-0	20.9	0.4	
K	0-0-40	16.7	-3.8	
NP	20-40-0	20.9	0.4	
NK	20-0-40	19.3	-1.2	
PK	0-40-40	19.0	-1.5	
NPK	20-40-40	20.7	0.2	
NPK+	40-80-80	18.9	-1.4	

Table M-5. Flax

Treatment	lbs/ac $N-P_2O_5-K_2O$	Average Yield bu/ac	Diff.	Treatment effect
None	0-0-0	23.9		
N	60-0-0	21.2	-2.7	-2.0*
P	0-40-0	23.6	-0.3	
K	0-0-20	21.3	-2.6	
NP	60-40-0	19.0	-3.3	
NK	60-0-20	22.3	-1.6	
PK	0-40-20	23.0	-0.9	
NPK	60-40-20	21.2	-2.7	
NPK+	120-80-40	21.0	-2.9	

Table M-6. Alfalfa

Treatment	lbs/ac $N-P_2O_5-K_2O$	Average Yield T/ac	Diff.	Treatment effect
None	0-0-0	3.88		
N	20-0-0	3.69	-0.19	-0.26 (93%)
P	0-80-0	5.05	1.17	1.19**
K	0-0-40	3.74	-0.14	
NP	20-80-0	4.70	0.82	
NK	20-0-40	3.51	-0.37	
PK	0-80-40	5.07	1.19	
NPK	20-80-40	4.78	0.90	
NPK+	20-160-80	5.11	1.23	

Crookston Yields

Four Year Rotation

Alfalfa

The average annual alfalfa yields ranged from about 1.3 to 3.8 tons per acre. Significant increases were found due to the application of 40 lbs. P_2O_5 per acre.

Soybeans

Yields ranged from 11.3 to 18.1 bushels per acre with no significant treatment effects.

Corn

Corn yields were better than those obtained in previous years ranging from 76 to 100 bushels per acre. As is usually the case at Crookstion station, yields were improved significantly by 40 pounds P_2O_5 per acre.

Wheat

Wheat yields in the four year rotation were well above those in the three year rotation. The average yield of 4 year rotation wheat was 50.5 bushels per acre while that in the three year rotation amounted to only 29.6 bushels per acre. Yields of wheat in the 4 year rotation were significantly improved by the application of 40 pounds P_2O_5 per acre.

Three Year Rotation

Wheat

Yield data for wheat in the three year rotation tended to be quite variable in ranging from 18.3 to 49.9 bushels per acre. Some of this variation is probably due to early season plot damage by heavy rains. Nevertheless, significant increases in yield were found due to the application of both phosphorus and nitrogen.

Sugar Beets

Sugar beet yields ranged from 14.7 to 20.9 tons per acre and were significantly improved by the application of 120 pounds P_2O_5 per acre.

Soil Testing Results

Soil samples were taken from both the three and four year rotations in 1960. Surface samples (0-6") were taken from the summer fallow plots in the three year rotation and the alfalfa plots in the four year rotation. Soil testing laboratory results were well correlated with previous treatment on the P and K tests while soil pH was shown to be not influenced by fertilizer treatment. (Table C-7 and C-8)

Fertilizer Rotation Experiment - Crookston

Table C-1. Rey - four year rotation

Treatment	lbs/ac $N-P_2O_5-K_2O$	Average Yield T/ac	Diff.	Treatment effect
None	0-0-0	1.62		
N	20-0-0	1.27	-0.35	
P	0-40-0	3.59	1.97	1.25**
K	0-0-20	1.77	0.15	
NP	20-40-0	3.39	1.77	
NK	20-0-20	1.69	0.07	
PK	0-40-20	3.58	1.96	
NPK	20-40-20	3.31	1.69	
NPK+	20-160-80	3.83	2.21	

Table C-2. Soybeans - 4 year rotation

Treatment	lbs/ac $N-P_2O_5-K_2O$	Average Yield bu/ac	Diff.	Treatment effect
None	0-0-0	11.3		
N	40-0-0	16.2	4.9	
P	0-40-0	16.4	5.1	
K	0-0-20	15.3	4.0	
NP	40-40-0	13.1	1.8	
NK	40-0-20	12.5	1.2	
PK	0-40-20	14.9	3.6	
NPK	40-40-20	17.1	5.8	
NPK+	40-120-40	18.1	6.8	

Crookston

Table C-3. Corn - 4 year rotation

Treatment	lbs/ac $N-P_2O_5-K_2O$	Average Yield bu/ac	Diff.	Treatment effect
None	0-0-0	76.3		
N	40-0-0	80.8	4.5	
P	0-40-0	96.5	20.2	8.3*
K	0-0-20	83.7	7.4	
NP	40-40-0	100.6	24.3	
NK	40-0-20	92.0	15.7	
PK	0-40-20	93.7	17.4	
NPK	40-40-20	92.0	15.7	
NPK+	80-120-40	96.7	20.4	

Table C-4. Wheat - 4 year rotation

Treatment	lbs/ac $N-P_2O_5-K_2O$	Average Yield bu/ac	Diff.	Treatment effect
None	0-0-0	41.8		
N	40-0-0	43.8	2.0	
P	0-40-0	54.7	12.9	14.2**
K	0-0-20	40.1	-1.7	
NP	40-40-0	54.5	12.7	
NK	40-0-20	44.0	2.2	
PK	0-40-20	61.6	19.8	
NPK	40-40-20	55.9	14.1	
NPK+	40-120-40	58.2	16.4	