A Report on Field Research in Soils

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

Department of Soil Science

University of Minnesota

February, 1965

Some of the results herein reported are from experiments carried on during 1964 only, and should not be regarded as the results obtained over a number of years. The investigations are those of a more practical nature, and do not include some of the more theoretical problems presently under study in greenhouse and in the laboratory. Because these are largely one year results they should not be considered as conclusive and the results are not for publication.

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"Climatological and Microclimatological Investigations of 1964" by Donald G. Baker, which is a summary of results obtained from (a) the Soil Moisture Survey and studies in (b) Solar and Net Radiation, (c) Soil Heat Budget and Soil Temperatures, (d) Air Temperature in the Microclimate and (e) the Climate of Minnesota: Its Temperature Characteristics is available upon request. Those interested may write for Soil Series 72 .

Subsoil Regeneration Study

Lamberton

Bulk Density

June 25, 1964

Data Book 23:43-63
G. R. Blake and W. W. Nelson

Depth in Inches	Corn				Alfalfa				Significance[1/]	
	Packed		Not Packed		Packed		Not Packed			
	Irrig.	Not Irrig.	Irrig.	Not Irrig.	Irrig.	Not Irrig.	Irrig.	Not Irrig.	Crop	Packing
4- 8	1.23	1.27	1.26	1.22	1.40	1.37	1.34	1.41	***	NS
8-12	1.35	1.43	1.40	1.30	1.52	1.43	1.33	1.27	NS	***
12-16	1.56	1.48	1.36	13.7	1.50	15.1	1.29	1.36	NS	***
16-20	1.50	1.43	1.37	1.38	1.46	1.45	1.36	1.37	NS	**
20-24	1.51	1.45	1.38	1.37	1.40	1.40	1.36	1.34	NS	**
24-28	1.44	1.40	1.38	1.36	1.39	1.40	1.35	1.45	NS	NS
28-32	1.47	1.48	1.44	1.41	1.45	1.44	1.38	1.45	***	NS

1/ * = Significance at 10%, ** = Significance at 5%, *** = Significance at 1%, NS = Not Significant

Replication significant, 1%, at 16-20" and 28-32" depths. Irrigation was significantly higher at the 5% level at 8-12" depth. Irrigation x Packing and Irrigation x Crop were significant it 10% at 8-12" depth. Packing x Crop significant at 5% level at 8-12" depth.

Subsoil Regeneration Study

Lamberton

Soil Moisture Percentages

June 25, 1964

23:65-85

G. R. Blake and W. W. Nelson

Depth in Inches	Corn				Alfalfa				Significance1/	
	Packed		Not Packed		Packed		Not Packed			
	Irrig.	Not Irrig.	Irrig.	Not Irrig.	Irrig.	Not Irrig.	Irrig.	Not Irrig.	Crop	Irrig. x crop.
4- 8	18.52	21.26	21.00	20.34	18.16	18.76	19.12	17.06	NS	*
8-12	20.60	21.80	21.36	20.78	16.70	17.82	16.90	16.26	***	NS
12-16	20.88	21.16	20.06	21.16	17.02	17.92	16.38	15.96	***	NS
16-20	20.70	20.40	19.80	20.82	16.68	16.70	16.74	16.14	***	NS
20-24	19.84	20.04	20.08	20.62	16.74	17.54	17.42	16.28	***	NS
24-28	19.38	20.14	20.50	20.76	17.36	18.06	18.62	15.80	***	NS
28-32	18.86	20.36	20.52	20.64	18.20	18.06	18.46	15.80	**	NS

1/ 10%, 5%, 1%, one, two and three stars respectively

Irrigation NS

Irrigation x Packing interaction (1%) and Irrigation x Crop interaction (10%) significant at 4-8" depth. Packing significant at 1% at 8-12" depth. Replication significant at 10% level at 12-16" depth and at 5% level at 16-20", 20-24", 24-28", 28-32" depths.

Subsoil Regeneration Study

Lamberton, 1964

Corn Grain Yield (bu./A. @15.5% water);

Percent Moisture in Grain,

Alfalfa Yield(lbs./A @20% water)
and Alfalfa Height

G. R. Blake and W. W. Nelson

	Date Harvested	Date Book Reference	Packed Irrig.	Packed Not irrig.	Not Packed Irrig.	Not Packed Not irrig.
Corn Yield	10/13/64	23:123-125	106.3	91.8	90.7	103.2
% Moisture	10/13/64	23:127-128	33.3	34.0	33.8	32.5
Alfalfa Yield	6/5/64	23: 91-93	5354	5499	5300	5590
Alfalfa Yield	7/7/64	23: 96-98	3249	3104	2977	2940
Alfalfa Yield	8/26/64	23:101-103	3285	3086	3539	2904
Alfalfa Height	6/5/64	23: 94-95	26.6	26.6	27.0	26.0
Alfalfa Height	7/7/64	23: 99-100	23.4	22.2	23.4	22.2
Alfalfa Height	8/26/64	23:104-105	19.6	19.6	20.4	18.4

Irrigation x packing interaction was significant at the 90% level in corn grain yield and in the percent moisture of the grain. Replication was significant at 90% level in percent moisture of the grain.

Replication was signficant in the alfalfa yield in the 1st cutting at the 95% level and in the 3rd cutting at the 90% level. Replication was significant in the alfalfa height in the 3rd cutting at the 95% level. Irrigation was significant in the alfalfa height in the 2nd cutting at the 95% level.

Corn after Fallow

Lamberton, 6/25/64

Soil Water Content, %

G. R. Blake, W. W. Nelson, and R. R. Allmaras

Depth inches	Fall Plow Not Packed	Fall Plow Packed	Fallow Summer, 1963
		Rep I	
0 -12"	16.17	22.83	25.63
12-24"	18.53	24.90	26.07
24-32"	16.95	24.60	19.30
		Rep II	
0 -12"	20.37	21.33	25.13
12-24"	28.77	20.60	25.80
24-32"	31.35	18.95	25.35

Differences not significant at any depth.

Corn after Fallow

Lamberton, 6/25/64

Soil Bulk Density

G. R. Blake, W. W. Nelson, and R. R. Allmaras

Depth inches	Fall Plow Not Packed	Fall Plow Packed	Fallow Summer, 1963
		Rep I	
0--12"	1.17	1.17	1.21
12-24"	1.45	1.46	1.41
24-32"	1.58	1.48	1.64
		Rep II	
0 -12"	1.13	1.15	1.22
12-24"	1.42	1.50	1.42
24-32"	1.41	1.62	1.45

Differences not significant at any depth.

Corn after Fallow

Lamberton, 1964

Soil Temperatures, 4" depth, °F.

Averages of 5 daily readings per week

G. R. Blake, W. W. Nelson, and R. R. Allmaras

Week Ending	Time[2/]	Fallow 1963	Fall Plowed, Packed	Fall Plowed, Not Packed
May 28[1/]	A.M.	60.6	60.7	60.3
	P.M.	69.1	68.1	67.3
June 5	A.M.	57.7	57.8	58.3
	P.M.	68.4	66.7	66.6
June 12	A.M.	64.2	64.4	64.5
	P.M.	70.0	69.4	69.2
June 19	A.M.	62.3	62.4	62.7
	P.M.	67.5	67.2	67.2
June 26	A.M.	67.1	67.1	67.1
	P.M.	75.2	74.5	74.9
July 3	A.M.	71.8	72.3	72.1
	P.M.	77.7	77.5	77.2
July 10	A.M.	73.5	73.6	73.2
	P.M.	81.0	80.5	80.1
July 21[3/]	P.M.	79.7	80.6	80.4

1/ 3 days only

2/ 8-9 A.M. 4-5 P.M.

3/ Single date

Structure - Nitrogen Study

Waseca, 1964

Soil Temperatures at 4" depth, °F.

Averages of 12 readings on 3 reps

G. R. Blake, J. M. MacGregor, and L. E. Ahlrichs

Week Ending		Air Temp.	Tillage, when plowed Minimum Spring	Minimum Fall	Regular Fall	Field Cultivate
May 2	max	61.6	54.1	56.7	56.3	57.1
	min	46.4	49.1	51.2	51.1	51.8
	mean	54.0	51.6	54.0	53.7	54.5
May 9	max	73.8	62.2	63.6	62.9	64.9
	min	54.6	57.8	58.2	58.9	60.3
	mean	64.2	60.0	60.9	60.9	62.6
May 16	max	73.7	64.0	67.3	66.4	66.7
	min	46.5	54.7	55.8	56.4	56.3
	mean	60.1	59.6	61.6	61.4	61.5
May 23	max	82.3	70.5	71.8	72.0	72.6
	min	57.9	63.3	64.9	64.9	64.9
	mean	70.1	66.9	68.4	68.5	68.8
May 30	max	72.7	71.2	71.7	71.7	73.5
	min	49.8	62.9	63.6	63.5	64.6
	mean	61.3	67.1	67.7	67.6	69.1
June 6	max	74.8	73.7	75.4	75.1	76.3
	min	45.9	64.0	65.3	64.8	65.6
	mean	60.4	68.9	70.4	70.0	71.0
June 10	max	81.2	74.8	76.6	76.9	77.0
	min	60.2	68.4	69.8	69.5	70.0
	mean	70.7	71.6	73.2	73.2	74.5

Primary Tillage for Potatoes

R R Valley Potato Research Farm

Soil Analyses. Sampled 9/14/64

G. R. Blake and G. W. French

Year and Range	Sample No.	Plot and Rep.[1/]	Particle size analysis, %					pH	Organic Matter, % [2/]	
			Sand	Silt	Clay	Course silt	Fine silt		(a)	(b)
1961 4S	1	V & VI	3.9	65.7	30.4	54.7	11.0	7.8	9.38	5.8
	2	VII & VIII	3.6	69.5	26.9	57.2	12.3	8.0	9.07	6.8
	3	I & II	4.1	68.4	27.5	57.0	11.4	8.0	8.77	5.2
	4	III & IV	3.9	67.5	28.6	56.1	11.4	8.0	10.27	6.6
1962 2S	1	V & VI	2.6	66.9	30.5	54.4	12.5	7.6	7.54	6.1
	2	VII & VIII	3.2	64.7	32.1	53.0	11.7	7.6	9.37	6.9
	3	I & II	3.0	69.9	27.1	57.6	12.3	8.0	6.75	6.9
	4	III & IV	3.0	66.0	31.0	53.7	12.3	7.9	9.85	6.8
1963 6S	1	V & VI	4.7	---	---	56.6	---	7.9	7.60	6.4
	2	VII & VIII	4.7	68.5	26.8	56.4	12.1	7.8	7.95	7.0
	3	I & II	7.5	65.2	27.3	54.4	10.7	8.1	7.95	6.0
	4	III & IV	4.8	68.9	26.3	57.0	11.9	8.0	7.56	6.3

[1/] Sample taken between reps indicated.

[2/]

(a) Values of carbon furnace include free carbonites with O.M.
(b) Dichromate method, Soil Testing Lab.

Soil Salinity and Crop Growth in Southern Minnesota

J. M. MacGregor, R. Munter, G. Holcomb and O. Gunderson

On several relatively lower lying soils of southern Minnesota, corn or soybeans have frequently not grown normally, and in some years have not survived after the first few weeks of growth. Since applications of fertilizers or of iron or zinc chelates to some of these soils failed to improve or promote normal plant growth, it was decided late in 1964 to sample a number of these areas to determine if soil pH and soluble salt content as measured by electrical conductivity of water extracts were related to the poor growth conditions. In addition, the calcium carbonate content, concentrations of soluble sodium and of sulfate were determined. From this information, the sodium absorption ratio, the sodium hazard, and the salinity hazard of these soils was determined. A total of 24 soil profiles were sampled in the locations shown on the accompanying map.

Since water soluble salts are a frequent cause of poor crop growth in western irrigated areas, a salinity scale has been developed showing the relation of the electrical conductance of saturation extracts of soils and crop growth on affected soils and this is shown below.

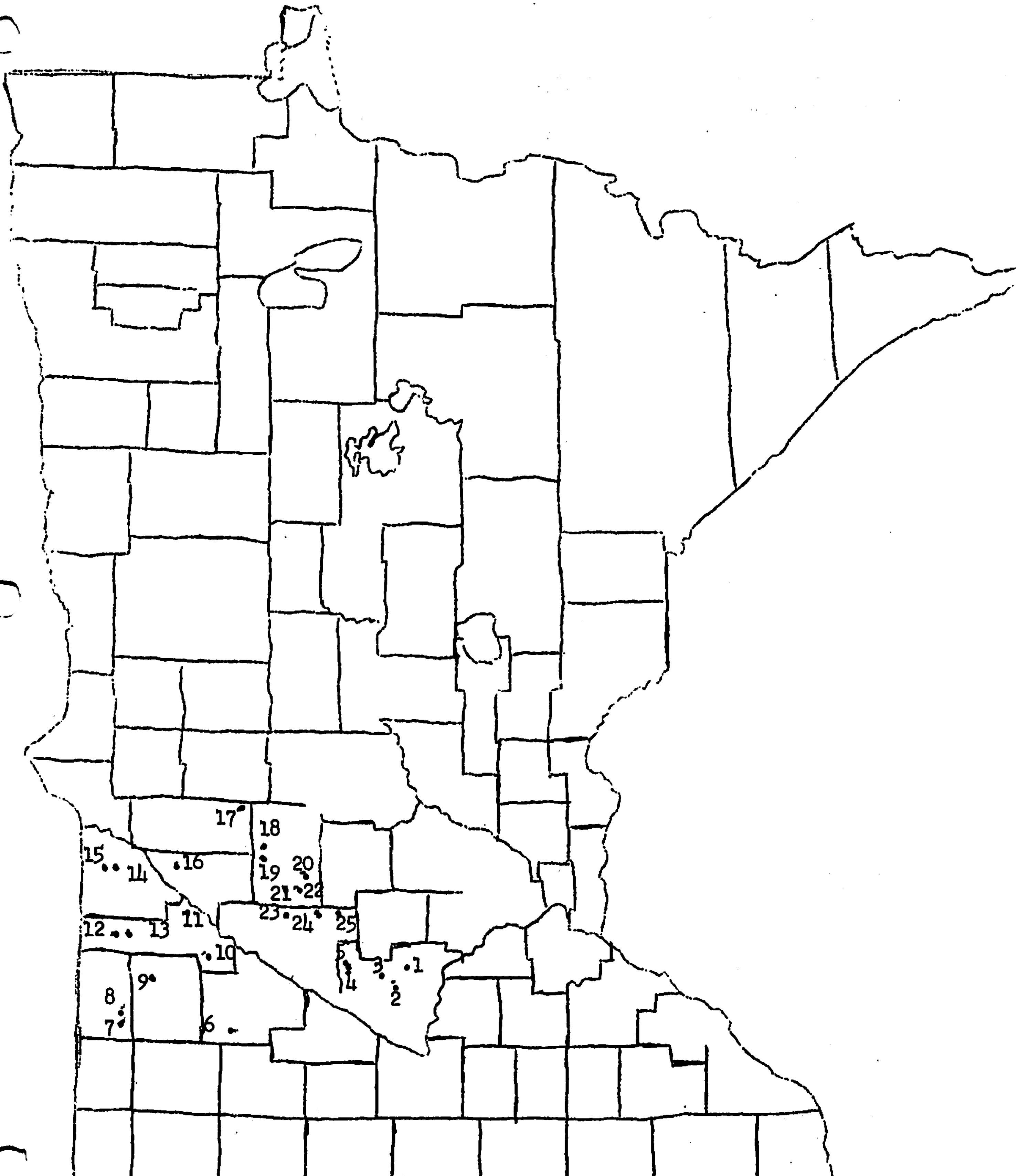
Salinity Scale Table

Specific conductance of the saturation extract of soil (mmillimhos per cm.)

0	2	4	8	16
Non-saline	Very slightly saline	Moderately saline	Strongly saline	Very strongly sal
Salinity affects mostly negligible	Yields of very sensitive crops may be stricted	Yields of many crops restricted. Alfalfa, cotton, sugarbeets, cereals and grain sorghums adapted.	Only tolerant crops yield satisfactorily. Bare spots appear because of injury to germination.	Only a few very tolerant crops yield satisfactc Only salt tolera grasses, herbaceious plants, shrubs and tree grow.

Where the electrical conductivity of the saturation extract exceeds 2 millimhos per centimeter, the soluble salt content of the soil has an increasingly serious affect on several crops grown in Minnesota. The chemical analyses on the soil samples from the location sites on the preceding map are shown in the following tables.

Location of Soil Sample Sites



Map site no.	Cty, farm operator and soil type and crop symptoms	Soil depth (inches)	Soil pH	% $CaCO_3$ equivalent	Saturation extract Conductivity mmhos/cm.	Na meq/l	Ca +Mg meq/l	SO_4 (ppm)	SAR[a]	Na hazard	Salinity hazard
1	Sibley County	0- 6	7.2	17.4	1.15	1.0	15.9	45	1	L	H
	Elmer Battcher-Gaylord	6-12	7.4	17.8	0.86	0.8	12.2	45	1	L	H
	Harpster clay loam	12-24	7.1	20.5	0.92	0.7	12.4	45	1	L	H
	Soybean yellowing	24-36	7.5	19.0	1.04	0.9	14.2	2454	1	L	H
2	Sibley County	0- 6	7.6	4.5	0.80	0.4	12.2	45	1	L	H
	B. Weckworth-Gaylord	6-12	7.5	5.1	0.79	0.7	10.3	14	1	L	H
	Harpster silty clay loam	12-24	7.8	4.7	0.63	0.6	12.0	14	1	L	M
	Soybean yellowing	24-36	7.8	9.2	0.80	1.1	9.8	41	1	L	H
3	Sibley County	0- 6	7.5	14.0	1.01	1.1	16.2	113	1	L	H
	K. Turbitt - Gaylord	6-12	7.4	17.5	1.80	1.2	26.6	306	1	L	H
	Glencoe clay loam (Calc)	12-24	7.4	12.1	1.03	0.8	15.2	63	1	L	H
	Soybean yellowing	24-36	7.4	5.6	0.77	0.9	9.8	68	1	L	H
4	Sibley County	0- 6	7.4	22.8	1.01	1.7	13.5	41	1	L	H
	E. Bierman-Gaylord	6-12	7.6	27.8	0.81	0.9	11.7	45	1	L	H
	Webster silty C L (calc.)	12-24	7.9	30.4	0.83	1.0	11.1	18	1	L	H
	Soybeans yellow and die	24-36	7.7	26.0	1.29	2.0	15.9	18	1	L	H
5	Sibley County	0- 6	7.5	29.1	1.00	0.6	15.0	68	1	L	H
	E. Bierman-Gibbon	6-12	7.4	30.4	0.90	0.8	13.4	27	1	L	H
	Harpster silty clay loam	12-24	7.6	29.4	0.90	0.9	11.7	27	1	L	H
	Soybeans yellow and die	24-36	7.6	15.4	0.95	1.6	10.7	27	1.0	L	H
6	Redwood County	0- 6	7.7	20.8	3.30	3.2	45.4	519	1	L	VH
	G. Boelter-Lamberton	6-12	7.7	6.1	1.80	0.9	25.5	207	1	L	H
	Haprster silty clay loam	12-24	7.6	16.0	1.04	0.6	14.5	68	1	L	H
	Soybeans yellow	24-36	7.7	7.3	1.90	1.8	25.6	248	1	L	H
7	Lincoln County	0- 6	7.9	17.0	16.0	32.3	263	9225	2.8	L	VH
	John Wichern-Tyler	6-12	7.8	18.3	12.0	19.7	191	2925	1.9	L	VH
	Blue Earth silt loam	12-24	7.8	11.6	9.9	14.4	191	5259	1.4	L	VH
	Corn fails to grow	24-36	7.8	28.6	8.5	10.7	139	3870	1.3	L	VH

[a]SAR = sodium absorption ratio L = low, M = medium, H = high, VH = very high.

Map site no.	Cty, farm operator and soil type and crop symptoms	Soil depth (inches)	Soil pH	% $CaCO_3$ equivalent	Saturation extract Conductivity mmhos/cm	Na meq/l	Ca + Mg meq/l	SO_4 (ppm)	SAR[a]	Na hazard	Salt hazard
8	Lincoln County	0- 6	7.2	24.6	14.0	6.0	179	3690	1	L	VH
	John Wichern-Tyler	6-12	7.4	25.8	8.3	4.0	123	3375	1	L	VH
	Vallers silty clay loam	12-24	7.5	25.6	7.3	4.0	115	3714	1	L	VH
	Corn fails to grow	24-36	7.5	22.9	8.2	4.3	135	3690	1	L	VH
9	Lyon County	0- 6	7.6	25.6	6.8	27.2	61	4839	4.9	L	VH
	Maurice Regnier-Ghant	6-12	7.6	25.5	5.3	20.6	53	4770	4.1	L	VH
	Vallers silty clay loam	12-24	7.6	22.4	5.0	22.4	47	4050	4.6	L	VH
	Soybeans yellow and die	24-36	7.6	30.6	3.5	10.6	41	1356	2.3	L	VH
10	Yellow Medicine County	0- 6	7.7	16.0	5.0	10.6	71	6414	1.7	L	VH
	Marquardt	6-12	7.8	16.5	7.8	40.0	107	4974	5.4	L	VH
		12-18	7.7	16.5	5.3	21.4	73	4455	4.9	L	VH
		18-24	7.6	12.5	6.8	20.1	89	4613	3.1	L	VH
		24-36	7.6	14.2	5.5	15.2	75	3750	2.5	L	VH
11	Yellow Medicine County	0- 6	7.6	24.5	4.5	3.8	68	4995	1	L	VH
	Kermit Velde	6-12	7.6	18.6	4.2	3.4	71	5244	1	L	VH
	Vallers silty clay	12-24	7.6	29.9		7.1	118	1431	1	L	VH
	Corn fails to grow	24-36	7.6	26.2	5.8	4.4	87	654	1	L	VH
12	Yellow Medicine County	0- 6	8.0	16.0	7.0	34.4	71	5604	5.8	L	VH
	Nels Wollum-Porter	6-12	8.0	15.4	9.3	45.4	88	5064	6.8	L	VH
	Vallers clay loam	12-24	7.8	21.9	5.3	22.2	66	4659	3.9	L	VH
	Soybeans die										
13	Yellow Medicine County	0- 6	8.1	25.3	11.8	114	82	5775	17.8	M	VH
	Nels Wollum-Porter	6-12	8.1	24.6	11.0	84	65	6300	14.6	M	VH
	Vallers silty clay loam	12-24	8.0	21.4	9.8	81	63	6405	14.4	M	VH
	Soybeans die	24-36	7.8	18.5	7.3	46	65	4989	8.2	L	VH
14	Lac qui Parle County	0- 6	7.6	19.4	4.5	15.1	53	3939	2.9	L	VH
	J. Tollefson	6-12	7.6	7.2	5.0	16.3	55	3780	3.1	L	VH
	Sletten silty clay loam	12-18	7.5	7.9	2.9	8.8	28	284	2.4	L	VH
	Soybeans die at 6"	18-24	7.5	11.5	2.3	6.9	25	158	2.0	L	VH
		24-30	7.5	13.3	2.6	5.8	30	225	1.5	L	VH

Map site no.	Cty, farm operator and soil type and crop symptoms	Soil depth (inches)	Soil pH	% $CaCO_3$ equivalent	Saturation extract Conductivity mmhos/cm.	Saturation extract Na meq/l	Saturation extract Ca+Mg meq/l	SO_4 (ppm)	SAR[a]	Na hazard	Salt hazard
15	Lac qui Parle County										
		0- 6	7.5	5.6	3.5	2.9	52	1284	1	L	VH
	J. Tollefson	6-12	7.5	5.9	3.9	6.0	59	1230	1.1	L	VH
	Vallers silty clay loam										
		12-24	7.5	4.8	3.8	6.3	55	3825	1.2	L	VH
	Corn grows but	24-36	7.3	6.8	3.2	2.8	46	4410	1	L	VH
	very poor soy-										
	bean growth	36-42	7.4	24.2	3.0	2.4	40	657	1	L	VH
16	Chippewa County	0- 6	7.7	18.9	1.3	0.7	14	50	1	L	H
	Ray Quam	6-12	7.8	29.1	1.0	1.2	12	36	1	L	H
		12-24	7.7	19.9	0.9	1.3	11	122	1	L	H
	Soybeans grow	24-36	7.5	21.2	3.0	1.6	41	384	1	L	VH
	poorly										
17	Swift County	0-6	8.0	23.2	1.4	5.9	14	59	2.2	L	H
	E. Mitteniss	6-12	8.1	30.3	4.4	18.9	46	46	4.0	L	VH
	Borup silt loam	12-24	8.0	26.1	6.8	35.0	71	990	5.9	L	VH
	Corn is zinc	24-36	8.1	30.5	9.5	46.0	113	1035	6.1	L	VH
	deficient	36-43	8.0	28.5	8.3	39.6	108	1554	5.1	L	VH
18	Kandiyohi County	0- 6	7.9	30.6	2.5	3.1	29	369	1	L	VH
	Hauser	6-12	7.9	27.2	1.4	2.6	16	81	1	L	VH
	Calvin silty clay loam										
		12-24	7.9	30.2	0.9	1.7	10	41	1	L	H
	Soybeans grow	24-36	7.9	19.5	0.6	1.3	6	14	1	L	H
	poorly	36-42	8.0	17.9	0.8	1.4	8	14	1	L	H
19	Kandiyohi County	0- 6	7.6	51.8	2.3	3.7	28	348	1.0	L	VH
	Gilbertson-Pennock										
		6-12	7.9	55.2	1.6	2.7	19	135	1.0	L	H
	Calvin silt loam	12-24	7.7	26.4	1.3	2.3	16	113	1	L	H
	Soybeans yellow	24-36	7.5	30.4	2.8	2.0	40	180	1	L	VH
20	Kandiyohi County	0- 6	7.9	13.4	0.8	26.6	11	23	11.2	L	H
	C. H. Litch-Lake										
	Lillian	6-12	8.0	8.3	1.3	3.9	14	14.4	1.5	L	H
	Unnamed silty clay loam										
		12-24	8.2	19.5	2.9	7.8	32	194	2.0	L	VH
	Zinc deficiency	24-36	8.0	18.4	3.0	9.5	37	360	2.2	L	VH
	in corn	36-44	8.1	18.9	3.1	9.3	35	468	2.2	L	VH
21	Kandiyohi County	0- 6	7.4	25.2	3.5	2.2	53	4500	1	L	VH
	G. Hopman, Lake	6-12	7.5	29.8	3.4	1.1	52	4458	1	L	VH
	Lillian										
	Unnamed clay loam										
		12-24	7.3	24.7	2.9	1.5	43	4275	1	L	VH
	Yellow soybeans	24-36	7.4	28.3	3.0	1.6	46	4410	1	L	VH

Map site no.	Cty, farm operator and soil type and crop symptoms	Soil depth (inches)	Soil pH	% $CaCO_3$ equivalent	Saturation extract Conductivity mmhos/cm.	Na meq/l	Ca + Mg meq/l	SO_4 (ppm)	SAR[a]	Na hazard	Salt hazard
22	Kandiyohi County	0- 6	7.6	22.2	4.6	4.2	59	3465	1	L	VH
	Portinga, Lake Lillian	6-12	7.6	22.8	5.1	5.5	61	4164	1.0	L	VH
	Unnamed clay loam	12-24	7.4	21.4	4.6	8.9	56	2559	1.7	L	VH
	Soybeans yellow and die	24-36	7.4	21.6	5.9	9.0	66	4050	1.6	L	VH
23	Renville County	0- 6	7.4	29.5	0.50	0.4	9	50	1	L	M
	W. Benderhagen-Bird Island	6-12	7.5	28.8	2.95	1.0	45	1185	1	L	VH
	Biscay silt loam	12-24	7.4	28.3	1.60	0.8	21	186	1	L	H
	Yellowed soybeans	24-36	7.6	16.2	1.75	1.8	34	50	1	L	H
24	Renville County	0-6	7.5	51.1	1.5	1.0	21	261	1	L	H
	Novotny, Hector	6-12	7.5	20.6	2.1	1.3	30	396	1	L	H
	Harpster silty clay loam	12-24	7.5	42.6	2.0	1.1	29	270	1	L	H
	Yellowed soybeans	24-36	7.4	52.7	2.0	1.5	28	576	1	L	H
25	Renville County	0- 6	7.4	19.4	2.9	0.6	42	1431	1	L	VH
	J. Dascher-Buffalo Lake	6-12	7.4	25.5	1.9	0.6	29	684	1	L	H
	Harpster silty clay loam	12-24	7.4	22.0	3.2	2.3	45	252	1	L	VH
	Yellowed soybeans	24-36	7.5	12.8	2.2	1.3	32	189	1	L	H

Although the samples were all alkaline, only those of three profiles sites had a pH of 8.0 or above (site numbers 13, 17 and 20). The calcium carbonate equivalent varied widely from 4.5% (Site 2) to 55.2% (Site 19), the higher concentrations of which could contribute to the poor growth problem.

The conductivity values, which are largely to measure of water soluble salt content are generally very high with values above 8 millimhos per centimeter (strongly saline) in profile sites 7, 8, 13 and 17, and these concentrations would eliminate all but those plants most tolerant to salt injury. Six profiles had samples having conductivities of 4 to 8 (sites 5, 9, 10, 11, 12 and 14) and this would be sufficient to restrict crop growth. In addition Sites 6 and 15 showed conductivities in excess of 2 millimhos which would restrict yields of the more sensitive crops.

The analytical results from these problem soils indicate that moderate amounts of sodium are present and may contribute to crop damage, but it is more probable that the total content of water soluble salts is the main cause of poor or no crop growth, with the relatively less soluble calcium and magnesium carbonates having a lesser contributive effect.

Since the problem salts are comparatively readily leached from most soils, a more adequate drainage of these soil areas would solve the problem, although a period of at least five to ten years of good drainage would be essential.

Herbicide Residue Studies

Russell S. Adams, Jr.

During the summer of 1964, soil samples were taken from several fields in Minnesota where atrazine carry-over was reported. Only fields where atrazine had been broadcast were examined. Soil samples were taken from spots where injury was greatest (R or residue in Table 1), and where injury was least (N-R or no residue in Table 1). In addition to the usual soil tests the cation exchange capacity, caly, and water holding capacities of each soil sample was determined.

The object of this study was to determine if laboratory results could be confirmed by field observations. As was expected the most conspicuous difference between the extremes of atrazine carry-over in the fields examined was a difference in the organic matter content of the soil. That is, where injury from atrazine carry-over occurred the organic matter content of the soil was generally lower than where carry-over was slight or non-existent. Typically atrazine carry-over is observed first on the so called "clay knolls" in the field. In no case observed this summer was the clay content of these knolls higher than the surrounding soil. However, all were lower in organic matter. As seen in Table 1 marked differences in organic matter between "residue" and "no-residue" areas were reflected in more pronounced differences in cation exchange capacity.

The pH, available water, or exchangeable K could not be associated with differences in carry-over. However, in at least two locations (4 and 5 in Table 1) and possibly a third (3 in Table 1) the extractable phosphorus content of the soil was much higher where injury from carry-over occurred, and may have contriubted to injury. Laboratory and greenhouse experiments in this department indicated that high levels of phosphorus may increase injury from triazine herbicides. More detailed accounts of this work will be reported in the 1964 fall issue of the Minnesota Farm and Home Science and an issue of Weeds early in 1965.

That the level of phosphorus may be a factor in weed control is supported by a comparison of the degree of weed control and the amount of extractable-P found in soil samples taken from Dr. Harley Otto's County Demonstration Weed Control Plots. These data are shown in Table 2. In both 1961 and 1962 the level of extractable-P was generally higher where weed control was good. However, this relationship was not apparent in 1963 and 1964. In those seasons extremes in rainfall over the state overshadowed the influence of other factors upon the activity of the herbicide. On the other hand the four year averages indicate a distinct increase in extractable-P at the highest levels of weed control.

Table 1. Soil characteristics where injury from atrazine residues occurred in several Minnesota locations in the summer of 1964.

Location	Exchange capa.		Clay		Organic Matter		Extractable P		Exchangeable K		pH		Available water[1]	
	R[2]	N-R[3]	R	N-R	R	N-R	R	N-R	R	N-R	R	N-R	R	N-R
	meq./100g		%		%		lbs/A		lbs/A				%	
1	34	35	21	19	4.0	5.1	6	12	155	135	7.2	7.4	11	10
2	21	30	41	41	6.6	8.0	7	9	270	230	7.6	7.8	14	14
3	16	17	29	30	3.7	4.5	110	52	520	380	7.1	6.4	17	15
4	22	21	33	34	5.4	5.5	140	56	310	390	5.9	5.6	14	13
5	17	19	30	29	5.3	4.5	60	35	230	240	7.2	6.9	16	16
6	17	18	28	29	5.1	5.4	45	48	400	500	6.5	6.7	13	14
7	17	18	32	32	5.1	5.7	27	33	230	340	6.5	6.3	17	14
8	17	16	27	27	3.8	5.0	32	52	210	190	7.0	7.2	15	15
9	24	30	48	43	4.0	6.3	9	32	240	300	8.0	6.7	10	10

1 Available water is the difference between water holding capacities at field capacity and the wilting point (1/3 and 15 atmosphere tension respectively).

2 R means severe carry-over occurred.

3 N-R means carry-over was slight or non-existant.

Table 2. Comparison of weed control by 2 lbs/A of atrazine to Bray 1 extractable-P in County Demonstration Weed Control Plots.

Years and Weed Type	Evaluation of Weed control									
	Locations	50% control	Locations	50-75% control	Locations	75-85% control	Locations	85-95% control	Locations	95% control
1961	No.	lbs/A, P	No.	lbs/A, P	No.	lbs/A, P	No.	lbs/A, P	No.	lbs/A, P
Grass	18	38	15	33	12	39	5	111	8	55
Broad-leaf	10	37	8	29	4	27	8	62	23	57
1962										
Grass	1	35	7	36	11	27	16	56	4	86
Broad-leaf	0	--	6	39	5	31	6	45	17	59
1963										
Grass	2	29	6	31	12	55	8	51	5	33
Broad-leaf	0	--	2	45	6	53	5	49	18	42
1964										
Grass	21	48	13	33	9	50	4	25	0	--
Broad-leaf	11	36	8	39	6	26	11	66	6	28
Four year average										
Grass	42	40	41	33	44	43	33	59	17	55
Broad-leaf	21	36	24	33	21	35	30	60	64	50

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 managment 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 513 farm cooperators have furnished crop and soil management data on some 92 extensive soil types in the state. Currently 307 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. On those soil series where data is available, yields are given according to the mapping phase, i.e., slope plus erosion. The reader may establish the location of the listed soils by reference to Soils of Minnesota, Ext. Bul. 278 (1963), or to the appropriate county soil report.

It should be noted that the average yields, particularly when only a few yields are included, 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 seven 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.

Note: A-1 = 0-2 percent slopes, little or no erosion
B-1 = 2-6 percent slopes, little or no erosion
C-1 = 6-12 percent slopes, little or no erosion
B-2 = 2-6 percent slopes, one-third to two-thirds of surface eroded
D-2=12-18 percent slopes, one-third to two thirds of surface eroded

Where yields are given according to mapping unit (e.g., B-1), only the years 1960-63 are included.

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. Yields of grain crops in bushels; hay, silage, and sugar beets, in tons; pasture, in cow-acre days.
* Number of fields on this series
** Number of yields on all crops

Aastad	(11)*	(43)**
Corn	13	53
Flax	6	12
Oats	6	57
Spring wheat	3	32
Barley	3	49
Alfalfa-brome-past.	3	136
Soybeans	3	25
Hay (other)	2	4.6
Pasture (other)	4	171
Anoka	(1)*	(1)**
Arlington	(1)	(5)
Oats	2	64
Alfalfa	2	3.4
Barnes	(16)	(82)
Corn	30	59
A-1	2	66
B-1	20	57
B-2	3	51
C-2	3	51
Oats	11	61
Flax	8	8
Soybeans	7	23
Alfalfa-brome	7	1.9
Barley	5	42
Alfalfa	5	1.9
Spring wheat	4	31
Corn silage	2	6.0
Bearden	(7)	(18)
Corn	4	56
Barley	4	53
Spring wheat	4	38
Sugar beets	3	11.6
Oats	2	58
Beltrami	(4)	(14)
Oats	3	66
Alfalfa	6	3.1
Alfalfa-brome-past.	2	76
Corn	2	66
Blue Earth	(3)	(11)
Corn silage	4	8.9
Corn	3	48
Soybeans	3	18
Oats	2	25
Alfalfa-brome	2	3.0
Borup	(1)	(1)
Braham	(2)	(2)
Brainerd	(5)	(14)
Oats	5	38
Corn	3	48
Corn silage	2	13.0
Hay (others)	2	2.8
Brickton	(4)	(6)
Alfalfa-brome	2	3.1
Buse-Barnes	(2)	(14)
Alfalfa-brome	3	1.6
Flax	2	9
Soybeans	3	15
Central	(4)	(5)
Chilgren	(5)	(29)
Oats	7	42
Barley	3	47
Flax	2	10
Spring wheat	3	18
Alfalfa	3	2.7
Alfalfa-tim.	3	2.4
Hay (other)	3	2.4
Corn silage	3	9.3
Wheat	4	33
Pasture (other)	2	243
Clarion	(37)	(240)
Corn	51	76
B-1	26	77
B-2	6	67
C-2	7	74
Oats	26	65
B-1	22	71
B-2	2	43
C-2	1	71
Soybeans	12	29
Spring wheat	8	31
Alfalfa-brome	13	3.1
Alfalfa	12	2.9
Mix. Leg. grass	3	5.0
Corn silage	3	14.5
Alfalfa-brome-past	3	228
Colvin	(6)	(15)
Alfalfa	4	3.6
Corn	6	68
Comfrey	(1)	(8)
Sorghum	4	8.1
Corn	2	60

Cormant	(4)	(15)
Oats	7	31
Alfalfa-brome	4	3.9
Downs	(3)	(13)
Corn	6	105
Oats	2	72
Alfalfa	3	3.4
Dubuque	(4)	(12)
Alfalfa-brome	3	4.5
Alfalfa	2	1.7
Enstrom		
Alfalfa-brome past.	2	222
Estelline	(1)	(3)
Esterville	(14)	(55)
Corn	18	60
A-1	10	61
B-2	1	72
Oats	12	45
Alfalfa-brome	9	2.2
Alfalfa	7	3.3
Corn silage	6	7.8
Fairhaven	(7)	(14)
Corn	7	62
Oats	4	63
Fargo	(20)	(69)
Spring wheat	17	37
Oats	8	41
Soybeans	3	23
Flax	6	12
Barley	7	30
Alfalfa-brome	6	1.5
Alfalfa	2	3.1
Sugar beets	9	13.5
Fayette	(7)	(36)
Corn	15	92
B-1	8	89
B-2	3	65
Oats	6	50
Alfalfa-brome	6	6.0
Alfalfa	3	3.0
Flom	(8)	(35)
Corn	12	73
Oats	6	56
Soybeans	3	17
Flax	5	19
Corn silage	3	15.0
Floyd	(5)	(20)
Corn	10	84
Soybeans	5	27
Oats	3	87
Fossum	(2)	(5)
Barley	2	49
Foxhome	(1)	(4)
Freer	(3)	(18)
Oats	5	66
Hay (other)	4	2.0
Corn silage	3	8.1
R.-Cl.-tim.	2	2.0
Freon	(6)	(11)
Oats	6	52
Glencoe	(1)	(1)
Greenbush	(3)	(8)
Corn silage	2	12.5
Hay (other)	2	1.5
Corn	2	65
Grimstad	(7)	(25)
Barley	4	44
Flax	3	10
Soybeans	3	15
Spring wheat	6	31
Oats	3	75
Grygla	(3)	(13)
Oats	4	36
Pasture (others)	2	112
Pasture (mix-leg-grass)	2	81
Alsike-tim.	2	1.3
Hamerly	(1)	(4)
Flax	2	15
Hantho	(1)	(3)
Harpster	(1)	(2)
Oats	2	34
Hayden	(23)	(89)
Corn	27	76
B-1	2[illegible]	101
B-2	3	98
C-1	1	66
D-2	2	86
D-3	4	77

Oats	15	55
Alfalfa	18	3.5
Alfalfa-brome	17	3.7
Alfalfa-brome-past.	8	301
Hegne	(7)	(17)
Spring wheat	6	34
Barley	3	47
Alfalfa	2	1.2
Potatoes	2	251
Hibbing	(4)	(6)
Alfalfa	2	3.1
Hubbard	(14)	(65)
Corn	26	62
A-1	13	67
B-2	4	29
Soybeans	11	21
Oats	8	42
Potatoes	5	425
Alfalfa	7	2.4
Alfalfa-brome	3	2.3
Corn silage	3	15.5
Kasson	(2)	(10)
Oats	2	65
Corn	2	83
Kato	(1)	(6)
Corn	2	72
Kenyon	(2)	(11)
Corn	4	86
Hay (other)	3	3.7
Alfalfa	3	2.7
Oats	2	66
Kingston	(3)	(15)
Corn	9	80
Soybeans	4	22
Kittson	(2)	(10)
Corn silage	2	4.9
Alfalfa	3	4.4
Kranzberg	(2)	(7)
Alfalfa-brome	3	2.3
Alfalfa	2	2.3
Lamoure	(2)	(13)
Corn	5	68
Soybeans	3	32
Sweet corn	3	7.0
Lerdal	(1)	(7)
Corn	4	82

Lester	(12)	(45)
Alfalfa	15	4.0
Corn	10	70
Oats	7	55
Alfalfa-brome	7	3.4
LeSueur	(9)	(38)
Corn	23	79
A-1	4	82
A-2	3	50
B-1	9	89
Soybeans	6	25
Oats	3	53
Barley	2	49
Litchfield	(2)	(15)
Corn	4	84
Soybeans	2	23
Oats	3	72
Potatoes	3	383
Alfalfa	3	4.0
Marcus	(1)	(1)
Marna	(6)	(18)
Corn	10	95
Soybeans	3	38
Alfalfa	2	5.1
Mavie	(1)	(2)
McDonaldsville	(1)	(3)
McIntosh	(3)	(18)
Oats	4	66
Spring wheat	6	35
Barley	3	64
Corn	2	70
Alfalfa	2	3.0
Menahga	(6)	(16)
Oats	3	38
Alfalfa-brome	6	3.0
Corn silage	4	9.4
Pasture (alfalfa brome)	3	147
Milaca	(8)	(30)
Oats	4	41
Corn	4	61
Hay (other)	6	2.6
Mix leg.-grass	4	2.0
Corn silage	5	11.4
Alfalfa	2	3.4
Alfalfa-brome	2	2.8
Moody	(2)	(6)
Corn	4	70

Mora	(4)	(16)
Corn	6	67
Oats	2	75
Mixed leg.-grass	3	3.1
Nebish	(7)	(34)
Oats	10	47
Alfalfa	6	1.6
Alfalfa-brome	7	4.4
Alfalfa-brome-past.	6	76
Nicollet	(21)	(100)
Corn	43	75
A-1	21	82
B-1	12	74
Oats	13	58
Soybeans	13	30
Spring wheat	4	32
Barley	2	94
Alfalfa	13	3.7
Alfalfa brome	4	4.0
Corn silage	4	7.9
Nokay	(5)	(13)
Corn	6	60
Oats	3	59
Corn silage	2	12.0
Nymore	(1)	(3)
Alfalfa	2	1.8
Onamia	(5)	(22)
Oats	5	63
Corn	5	69
Alfalfa	4	3.5
Alfalfa-brome	2	1.8
Pasture (brome)	2	200
Ostrander	(7)	(21)
Corn	7	83
Soybeans	3	27
Alfalfa	3	4.5
Parnell	(1)	(8)
Corn	5	47
Oats	2	75
Deep Peat	(6)	(22)
Corn	3	77
Soybeans	2	24
Timothy (seed)	3	334
Corn silage	2	6.5
Hay (other) past.	3	116
Leg,-grass past.	2	242
Shallow Peat	(5)	(7)
Soybeans	3	24
Barley	2	56
Pierce	(1)	(1)
Racine	(1)	(1)
Redby	(3)	(13)
Leg.-grass hay	3	1.5
Leg.-grass past.	4	81
*R. Cl-tim.	5	2.5
Oats	2	40
Rocksbury	(12)	(39)
Oats	10	60
Flax	5	8
Alfalfa	3	2.9
Hay (other)	6	1.5
Sweet corn-brome	2	1.7
Hay (other) past.	3	117
Wheat	3	23
Rockwell	(5)	(16)
Oats	3	52
Barley	3	23
Alfalfa	2	1.7
Corn silage	2	12.9
Wheat	2	29
Rothsay	(1)	(1)
Sioux	(4)	(11)
Oats	5	37
Soybeans	2	12
Alfalfa	2	0.8
Shcoks	(2)	(7)
Oats	3	42
Alfalfa	2	2.0
Skyberg	(3)	(12)
Corn	5	78
Oats	2	83
Leg.-grass past.	2	154
Sletton	(1)	(4)
Soybeans	3	30
Storden-Clarion	(1)	(7)
Oats	2	80
Alfalfa	5	2.9
Tama	(8)	(42)
Oats	11	65
Corn	14	91
A-1	6	87
B-1	4	97
B-2	2	106
C-1	1	43
C-2	1	43
Corn silage	3	14.2
Alfalfa	4	4.1
Alfalfa-brome	3	4.6

Leg.-grass hay	4	3.3
Alfalfa-brome past.	3	178
Taylor	(1)	(4)
Terrill	(1)	(2)
Todd	(2)	(7)
Alfalfa-brome	4	2.2
Corn silage	2	7.5
Truman	(3)	(10)
Corn	4	90
Ulen	(4)	(25)
Oats	9	48
Corn	6	52
Corn silage	2	15.5
Alfalfa	2	2.6
Vallers	(3)	(17)
Corn	4	55
Oats	2	63
Soybean	6	21
Varco	(1)	(6)
Corn	4	88
Alfalfa-brome	2	2.8
Vienna	(2)	(6)
Corn	3	63
Oats	2	60
Wabash	(1)	(4)
Corn	3	109
Wadena	(4)	(18)
Corn	7	76
Soybean	4	21
Oats	3	80
Waukegan	(9)	(36)
Corn	15	78
A-1	7	76
B-1	6	73
Oats	8	81
Alfalfa-brome	3	3.1
Alfalfa	3	2.2
Soybeans	2	33
Waukon	(10)	(38)
Corn	8	59
Oats	7	57
Barley	4	36
Spring wheat	3	30
Alfalfa	9	2.1
Mix. leg.-grass	3	4.1
Webster	(39)	(150)
Corn	69	88
Oats	26	62
Soybeans	16	20
Alfalfa	16	4.1
Alfalfa-brome	9	2.8
Corn silage	5	10.1
Alfalfa-brome past.	2	75
Mix-Leg grass	2	3.2
Webster Calc. Var.	(8)	(36)
Corn	12	89
Oats	3	85
Soybeans	10	34
Alfalfa	4	3.2
Wildwood	(2)	(6)
Oats	2	33
Winger	(4)	(21)
Oats	8	79
Barley	4	42
Spring wheat	4	29
Alfalfa	3	1.6
Zimmerman	(3)	(14)
Corn	3	62
Oats	2	57
Corn silage	3	11.0
Hay (other)	2	10.9

Grand total as of December 1964

	No. Fields	No. Yields
	530	2120

SOILS AND CROP MANAGEMENT SYSTEMS

Roy L. Thompson, Samuel D. Evans, and Lowell Hanson.

In 1960 an experiment was set up at the West Central Experiment Station to evaluate several crop management practices in combination with one another. Much work has been done on evaluating the individual factors such as fertilizers, varieties, and insect and disease control. It was the purpose of this experiment to apply these practices to different crops and to demonstrate the cumulative effect of the management practices and the economic feasibility of following them.

The experiment was divided into two parts; a management system designated as base which includes the recommended practices currently being used by farmers in the area and a management system designated as test which includes practices which may or may not have shown potentiality for increasing crop production and efficiency. These management systems are applied to continuous corn, soybeans, and alfalfa and to a rotation of oats, hay, soybeans, and corn.

The individual plots and treatments are as follows:

<u>Continuous Soybeans:</u>

Cultural Practice	Base Level	Test Level
Seeding rate	60 lbs./acre	90 lbs./acre
Weed control	3 cultivations	Amiben-Broadcast-3 lbs./a
Fertilizer	None	0-45-0 100 pounds/acre
Row width	40 inches	20 inches
Variety	Merit	Merit

<u>Continuous Corn:</u>

Population, plants/acre	14,000-16,000	18,000-20,000
Row width	40 inches	20 inches
Soil insecticide	No	Yes
Fertilizer	8-32-16 80 lbs./acre Nitrogen 40 lbs./acre	8-32-16 160 lbs./acre Nitrogen 100 lbs./acre
Weed control	3 cultivations	Atrazine-Broadcast-3 lbs./acre

Variety	Various Minhybrids	Various Minhybrids

Continuous Alfalfa:

	Base Level	Test Level
Variety and seeding rate	10 lbs. Vernal	10 lbs. Vernal
Fertilizer	0-45-0 100 lbs./acre	0-45-0 200 lbs./acre
Cuttings	2 or 3	2 or 3

The crop was initially established without a companion crop using 2,4-DB and Dalapon for weed control.

Rotation:

Oats (1960)	Base Level	Test Level
Variety and seeding rate	2½ bu. Minton	4 bu. Minton
	8 lbs. Vernal alfalfa	8 lbs. Vernal alfalfa
	3 lbs. Lincoln Brome	3 lbs. Lincoln Brome
Fertilizer	None	9-36-0 280 lbs./acre
		Nitrogen 50 lbs./acre

Harvest for determination of silage yield in addition to grain yield.

Hay (1960)		
Fertilizer	0-45-0 100 lbs./acre	0-45-0 100 lbs./acre

Harvest separate yields obtained from the plots where the oats was removed as silage as well as where oats was taken for grain yields.

Soybeans (1962) - Same treatments as the continuous soybean plots.

Corn (1963) - Same treatment as the continuous corn plots except for weed control. Weeds were hand hoed in the test plots.

Oats (1964) - The 1960 treatments were repeated with the following exceptions:

(1) Garland substituted for Minton

(2) No fertilizer on test plots other than carry-over from the previous crops.

Table 1. Five-Year Yields from Continuous Cropping Systems

	Continuous Soybeans		Continuous Corn		Continuous Alfalfa	
	Base	Test	Base	Test	Base	Test
	Bushels/Acre		Bu/A @ 15% Moisture		Tons/Acre	
1960	16.8	23.1	61.2	70.3	1.4	1.8

1961	20.7	28.4	62.0	65.5	2.2	2.0
1962	21.2	26.4	67.0	87.4	4.8	5.1
1963	23.4	36.7	72.7	73.1	4.9	4.9
1964	15.6	22.1	36.7	34.2	3.0	3.1
Average	19.5	27.3	59.9	66.7	3.3	3.4

Table 2. Five-Year Yields from Rotation Cropping Systems

	Rotation		Base	Test
1960	(Oats) Grain:		86.7 Bu/A	90.0 Bu/A
		Silage:	7.9 T/A (green wt.)	8.2 T/A (green wt.)
1961	(Hay) From grain plots:		1.87 T/A	1.79 T/A
		From silage plots:	2.44 T/A	2.19 T/A
1962	(Soybeans)		24.1 Bu/A	25.6 Bu/A
1963	(Corn)		86.4 Bu/A	113.9 Bu/A
1964	(Oats) Grain:		65.1 Bu/A	94.2 Bu/A
		Silage:	1.14 T/A (dry wt.)	1.76 T/A (dry wt.)

The results of this experiment show that soybeans, corn, and alfalfa have been grown continuously for five years with very few problems. The five-year averages show a 7.8 bushel per acre increase for soybeans grown under the test management system as compared to the base management system. This probably results from both the use of phosphate, narrower rows, and weed control. Soybeans on a different rotation plot on the station have shown an average response of 2.3 bushels per acre to 40 pounds of P_2O_5 over an eight-year period. It would appear that under the conditions of this experiment, there are factors which increased yeild in addition to the fertilizer response. This probably is due to the narrow rows.

Continuous corn grown under the test management system has yielded 6.2 bushels per acre more than under the base management system. The cost of the additional seed, fertilizer, and herbicide is substantial, so it appears that this combination of treatments is not economically feasible. However, this does not mean that one or more of these treatments would prove unprofitable when used alone. Atrazine has worked fairly well on controlling the weeds in the 20-inch rows. For best results, some means of cultural weed control should also be available to supplement the effects of the chemicals when weather conditions are not favorable for the chemical. Fertilizer rates which are considerably in excess of soil test recommendations may give increased yields but the cost of these increases may exceed their value.

Continuous alfalfa has shown no yield increase under the more intensive test management. It appears that 45 pounds of phosphate is adequate to obtain maximum yields under western Minnesota soil and moisture conditions. The slightly lower yields from the test management alfalfa plots in 1961 may be accounted for by a difference in harvest dates. The first crop of hay was removed from the test plots six days before the base management system. The yield of protein and TDN would have been about equal from both plots because of a higher per cent of protein and TDN from earlier harvest.

Yields from the crops in the rotation have been very good. Comparisons between the continuous cropping system and the rotation system should be made using the yields for a particular year rather than using the five-year average yield for the continuous cropping system.

The oats yields in 1960 show only a slight advantage from the test management system. In 1964 the test system gave a 54 per cent increase in dry matter as silage and a 45 per cent increase in grain yields. It is rather doubtful that the higher seeding rate has as much effect on the yields as the fertility, especially where sufficient seed is used to get a satisfactory stand.

The rotation alfalfa yields in 1961 compared favorably with the continuous croppin system alfalfa. The same cutting dates were used for the rotation alfalfa as the continuous cropping system which may account for the reduced yield under the test system.

Removal of the oats as silage approximately ten days to two weeks before the small grain harvest in 1960 resulted in a considerable increase in hay yields from alfalfa in 1961. Similar results have been observed elsewhere from the early removal of a companion crop on new alfalfa seedings.

The rotation corn yields in 1963 were extremely good on both the base and test management levels but the test level showed a 27.5 bushel advantage. The difference between the corn grown in the rotation and the continuous cropping corn is substantial. There was no obvious reason for this difference since the corn under either system appeared to be satisfactory. The comparison of corn between the two systems will have to be watched very carefully when they occur together again.

Soybean yields showed little difference between the rotation and continuous cropping systems.

In general there appeared to be little advantage to growing these crops in a rotation. This is true especially when the production is considered from an economic standpoint over the period of time needed to complete a rotation cycle.

No obvious difficulty was encountered due to diseases and insects. With the northward movement of corn rootworm and perhaps some root rots of soybeans, the use of rotations or alternating crops may be more essential. Where soil erosion is a problem, crop rotation with limited cultivated crops is one of the very effective means of control. However, it may be possible to leave the areas most subject to erosion in continuous sod crops while utilizing level land for continuous corn. Where continuous cropping of cultivated crops is followed, careful management to return crop residues should be practiced in order to maintain soil tilth.

The Nicollet County Plots
Soil Fertility and Crop Production Studies on the Webster Soils of Southern Minnesota

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

These long term fertility plots commenced in 1949 have now been conducted for fifteen years and were discontinued with the harvesting of the 1964 crop. The results were first reported in 1957 by C. O. Rost and H. W. Kramer in Minnesota Agricultural Experiment Station Bulletin 438 entitled "Soil Management Studies on the Webster Soils of Southern Minnesota." Later results have been annually reported in the Department of Soil Science "Blue Book" of 1960 through 1964.

Since a terminal report on the entire project will soon be available, the 1964 yields are not reported at this time.

High Fertility - Rosemount

W. P. Martin

Yield results 1964 (For experimental design and past years results see p. 47 in mimeographed "blue book", Feb., 1963 and p. 67, Jan., 1964).

Fertilizer Treatments*	Bu. Per Acre 19,500 Plants	Bu. Per Acre 16,500 Plants
1. Check	85.0	94.7
2. H*	98.5	101.0
3. H S1	110.0	103.5
4. H S_2	116.0	117.5
5. B1 H	96.5	96.7
6. B1 H S1	94.5	104.7
7. B1 H S2	99.0	104.7
8. B2 H	101.0	108.5
9. B2 H S1	96.5	106.3
10. B2 H S2	105.0	110.5

* H = 200# 10-20-10 banded starter
S1= 100# 33-0-0 sidedressed
S2= 200# 33-0-0 sidedressed
B1= 400# 6-12-24 broadcest
B2= 800# 6-12-24 broadcast

Killing frost on south one-half of field on August 13 was scattered over rest of plots. Very dry soil conditions were experienced during much of the 1964 growing season which seriously affected the yield data.

LAMBERTON MAXIMUM CORN AND SOYBEAN DEMONSTRATIONS

Wallace Nelson and Lowell Hanson

The 1964 yields of these two demonstrations were down markedly from the 1963 yields because of drought. 1963 Corn yields ranged from 88 to 116 bushels while the 1964 yields were from 43 to 65 bushels. The total May 15 to August 15 rainfall was only 6.6 inches at the Lamberton station.

While the narrow row, fertilized soybeans showed a 12 bushel advantage in 1963, results were considerably different in 1964. The Amiben herbicide treatment was not very effective on the narrow row plot in 1964. Actually, the average 21.7 bushel yield on this plot is surprising in spite of the weed competition and drought.

Corn Demonstration

Treatment	Plot	Yield	Plants/Acre
30,000 - planting rate 300# 8-24-12 500# 0-30-15 200# N	1	42.9	24,636
20,000 - planting rate same fertilizer as above	2	65.4	20,755
15,000 - planting rate No fertilizer	3	34.2	16,220
15,000 planting rate 125# 8-24-12	4	53.8	17,267
20,000 - planting rate Same fertilizer as above	5	44.1	21,017

Soybean Demonstration

Treatment	Yield, bushel/acre
40 inch row 60 lbs. seed per acre No fertilizer	22.0
18 inch row 120 lbs. seed per acre 200 lbs. 8-24-12, planter attach 200 lbs. 0-30-15, broadcast	21.7

Fertility Experiment on Alfalfa

Morrison Co. Pierz, Minn., 1964.

Merle Halverson, Lowell Hanson, Curtis Overdahl

Apparent effects of nitrogen, lime, phosphorus, and potassium on 1964 first and second cutting forage yields of Vernal alfalfa. Joe and Roderick Boser Farm, Pierz (Morrison County) Minnesota. The soil is Brainerd sandy loam, pH 6.4, P 19 (med), K 70 (low).

		Cuttings		
		1st	2nd	Both
Check yield, tons/acre forage at 20 percent moisture*		0.77	0.65	1.42
Forage yield inc. (tons/acre) due to:				
(a.) lime broadcast and disced in before seeding at:	2.5 tons/acre	0.15	0.09	0.24
	5.0 tons/acre	0.28	0.11	0.39
(b.) nitrogen topdressed spring '64	40 lb/acre	0.02	0.00	0.02
(c.) phosphorus broadcast and disced in before seeding at:	30 lb P_2O_5/acre	0.10	0.20	0.30
	60 lb P_2O_5/acre	0.24	0.21	0.45
(d.) Potassium broadcast and disced in before seeding at:	60 lb K_2O/acre	0.29	0.12	0.41
	120 lb K_2O/acre	0.32	0.15	0.47
	180 lb K_2O/acre	0.26	0.13	0.39
	240 lb K_2O/acre	0.40	0.31	0.71

* Entire area, including check, received 300 lb/acre gypsum and 4.5 lb/acre boron.

NPK - RATE STUDY WITH CORN ON SANDY SOILS - 1964

John Grava

Three corn fertilization trials were conducted in Anoka, Benton and Isanti Counties in 1964. Each experiment consisted of 12 treatments, replicated five times, for a total of 60 plots. The fertilizer treatments consisted of four nitrogen rates: 10, 60 110 and 160 lb./A. N, applied with 32 lb./A. P_2O_5 and 96 lb./A. K_2O. Base rate of 10 lb./A. N was applied in row, and the 50, 100 and 150 increments were broadcast and disked in prior to planting. Phosphorus rates included 0, 16, 32 and 64 lb./A. P_2O_5 used with 110 lb./A. N and 96 lb./A. K_2O. All phosphorus was row applied. Potassium treatments consisted of: 0, 24, 48, 96 and 192 lb./A. K_2O used with 110 lb./A. N and 32 lb./A. P_2O_5. All potassium, up to the 96 pound rate was applied in row, half of the potassium of the 192 pound rate was broadcast and disked in. The applications of starter fertilizer were made with a belt applicator and placed with a disk-type planter attachment, two inches below and two inches aside the seed. Each individual plot was 25 feet long and four-40 inch rows wide.

A 95-day corn variety was planted on May 21-23 by hill dropping. Atrazine was applied pre-emergence and the corn was cultivated once. The corn was thinned to a uniform stand of 16,000 plants per acre. The sixth corn leaf was randomly sampled from eight representative plants from the two border rows of each plot at silking time. Oven-dry leaf samples were ground and analyzed for total N, P and K. Yields were determined by harvesting ears from 40 plants from the two middle rows of each plot. Moisture in the ears at harvest was determined in five representative ears from each treatment after drying for seven days at 65° C.

Soil tests (Table 1) indicated low organic matter content, medium to very high phosphorus availability and very low to medium levels of potassium. The preceding crops in 1963 on experimental sites were as follows: Expt. 1, and old, grass and weed infested stand of alfalfa; Expt. 2, corn receiving 45 + 15 + 45 pounds per acre of nutrients and yielding about 70 Bu./A.; Expt. 3, soybeans fertilized with 90 lb./A. of K_2O and yielding about 25 Bu./A.

Table 1. Soil Test Results.

Expt. No.	Location	Soil Type	pH	Organic Matter %	Extractable P lbs./A.	Exchangeable K lbs./A.
1	F. Carlson, Isanti Co.	Anoka lvfs	6.1	1.6	76	155
2	A. Sorteberg, Anoka Co.	Hubbard s	5.9	2.2	30	100
3	D. Stumvoll, Benton Co.	Milaca l	6.6	2.9	17	55

Corn growth was affected by drought at all three locations. Most severely stricken by drought were the experiments (2 and 3) in Anoka and Benton Counties. Available soil water and rainfall data are given in Table 2. Lack of moisture caused poor germination and development of corn in Expt. 3 in Benton County. Corn was only knee to waist high on July 27. A large portion of the corn plants were tasseled out but with no silks visible. Consequently, no ears were developed and the experiment was abandoned. The corn on Expt. 2 in Anoka County also suffered from drought, especially at tasseling and silking time. Corn plants in the 110 + 32 + 96 treatment plots had about 80% nubbins and yielded only 10 bushels per acre.

Table 2. Available soil water and rainfall data of experimental fields.

		Available Water in Soil at Planting[1]		Rainfall June and July	
Expt. No.	County	Inches	% of Maximum	Inches	% of Normal
1	Isanti	8.8	100	7.6[2]	93
2	Anoka	1.6	44	3.0	39
3	Benton	5.3	66	3.0	39

1) In a 5-foot profile
2) Including: 2.5 inches received on June 23 and
3.3 inches received on July 9

The moisture supply was adequate at planting time on experimental site No. 1 in Isanti County. About 7.5 inches of rainfall (93% of normal) were received at this location during June and July. However, 5.8 inches of that amount came down in two major downpours, and might have been partially lost by runoff. There was only a slight curling on corn leaves observed at silking time. However, yield measurements and nubbin counts at harvest time indicated that corn had been affected by lack of moisture even at this location. The damage was more serious in some replications than in others. For example, Replication 5, with the least damage, had only 10% nubbins and 81 Bu./A. average yield. In contrast, 48% of nubbins and only a 38 Bu./A. average yield were obtained in Replication 2.

The effects of fertilizer applications on corn yield, as well as the percentage of nubbins on the Anoka lvf sand in Isanti County, are shown in Tables 3, 4 and 5.

While nitrogen applications above the base rate of 10 lb./A. did result in more nubbins, the yield responses were slight and inconclusive. Potassium applied to this soil, with a 155 pound K test, had no effect on corn yields or the percentage of nubbins. The most striking effects in corn on the Anoka soil were obtained from phosphorus treatments. The application of 16 lb./A. P_2O_5 increased corn yield by 20 Bu./A. over the no phosphorus treatment. This rate also decreased the number of nubbins. However, higher phosphorus treatments, especially the 64 lb./A.

Table 3. Effect of nitrogen fertilization on the yield of corn. Anoka loamy very fine sand, Isanti County 1964.

Rate of Nitrogen[1] (N)	Shelled Corn[2] At 15.5% Moisture	Nubbins
Lb./A.	Bu./A.	%
10	60	16
60	50	34
110	60	25
160	53	37

[1] Base rate of fertilizer: 10 + 32 + 96 row; 50, 100 or 150 lb./A. N above base rate was broadcast.

[2] Averages of five replications.

Table 4. Effect of phosphorus fertilization on the yield of corn. Anoka loamy very fine loamy sand, Isanti County 1964.

Rate of Phosphorus (P_2O_5)	Shelled Corn At 15.5% Moisture	Nubbins
Lb./A.	Bu./A.	%
0	48	38
16	68	21
32	60	25
64	40	44

Base rate of fertilizer: 10 + 0 + 96 row
100 lb./A. N broadcast

Table 5. Effect of potassium fertilization on the yield of corn. Anoka loamy very fine sand, Isanti County 1964.

Rate of Potassium[1] K_2O	Shelled Corn At 15.5% Moisture	Nubbins
Lb./A.	Bu./A.	%
0	57	24
24	56	31
48	58	28
96	60	25
196	55	33

[1] Base rate of fertilizer: 10 + 32 + 0 row, and 100 lb./A. N broadcast. All potassium was row applied, except 96 lb./A. K_2O broadcast application in highest rate.

rate, increased the percentage of nubbins and resulted in substantially lower yields.

The effects of fertilization on chemical composition of corn leaves collected from the Isanti and Anoka County experiments are shown in Tables 6 and 7.

Table 6. Effect of fertilization on the N, P and K content of sixth corn leaf at silking time.
Anoka loamy very fine sand, Isanti County 1964.

Treatment No.	Nutrients Applied	N	P In Corn Leaf	K
	Lb./A.	%	%	%
1	110 + 32 + 0	2.82	.298	1.28
2	110 + 32 + 24	2.78	.309	1.89
3	110 + 32 + 48	2.88	.301	2.28
4	110 + 32 + 96	2.98	.320	2.30
5	110 + 32 + 192	3.10	.315	2.42
6	10 + 32 + 96	2.26	.255	2.75
7	60 + 32 + 96	2.77	.294	2.67
8	160 + 32 + 96	3.04	.291	2.42
9	110 + 0 + 96	3.09	.302	2.68
10	110 + 16 + 96	2.75	.309	2.46
11	110 + 64 + 96	2.86	.305	2.41
12	None	2.14	.258	2.12

The nitrogen content in the sixth corn leaf at silking time was increased by nitrogen treatments from 2.26 to 3.04 on Anoka loamy very fine sand and from 2.30 to 2.88% N on Hubbard sand. Nitrogen deficiencies in corn also were observed in 10 and 60 lb./A. N treatment plots on the Anoka soil. Deficiency symptoms were eliminated by the application of 110 lb./A. of N, the average N content in the sixth corn leaf of this latter treatment was 2.98%.

Corn leaves from no phosphorus treatments but with adequate nitrogen contained about 0.300% P. Additions of phosphorus increased the P content in corn leaf only slightly. However, fertilization with nitrogen had a most striking effect on the phosphorus content in corn leaf on Anoka soil (Table 6; Treatment No. 6, 7 and 4). Leaves from the 10, 60 and 110 lb./A. N treatments had P content of 0.255, 0.294 and 0.320, respectively. These data would indicate that applications of nitrogen increased the absorption of phosphorus by corn from the fertilizer source, and probably even more so from the soil.

Table 7. Effect of fertilization on the N, P and K content of sixth corn leaf at silking time.
Hubbard sand, Anoka County 1964.

Treatment No.	Nutrients Applied	N	P In Corn Leaf	K
	Lb./A.	%	%	%
1	110 + 32 + 0	2.67	.281	1.12
2	110 + 32 + 24	2.77	.306	1.65
3	110 + 32 + 48	2.72	.314	2.12
4	110 + 32 + 96	2.73	.306	2.33
5	110 + 32 + 192	2.74	.313	2.26
6	10 + 32 + 96	2.30	.300	2.45
7	60 + 32 + 96	2.69	.304	2.40
8	160 + 32 + 96	2.88	.304	2.29
9	110 + 0 + 96	2.76	.298	2.22
10	110 + 16 + 96	2.78	.306	2.39
11	110 + 64 + 96	2.74	.317	2.31
12	None	2.33	.290	1.68

The potassium contents in corn leaf from no potassium treatments on the Hubbard and Anoka soils were 1.12 and 1.28% K, respectively. Fertilization with 48 lb./A. K_2O increased the content of leaf K to 2.12 on the Hubbard sand and to 2.28% on the Anoka soil.

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ROSEMOUNT SOILS FARM
Rosemount Agricultural Experiment Station
1964
Paul M. Burson and E. G. Bonnell

It was thought that 1963 had the most extreme and critical moisture conditions in the history of the Rosemount station. However, 1964 was much more critical than 1963. During May of 1964 there was a total of 5.22 inches of rain. In the early part of June there was another 2.84 inches but these rains came with such high intensity that resulted in such excessive runoff that they were of little value.

For example, on June 19th there was .90 inches in 20 minutes and again on June 22 there was .35 inches in 10 minutes with the same amount again on June 23.

Because of these high intensity rains at no time since the soils farm was established has the erosion been so severe. The severe drought conditions actually started June 24th. From June 24th to July 24th there was only 1.17 inches of rainfall. From July 24th to August 20th there was another .51 inches making a total of only 1.68 inches from June 24th to August 20th. Because of these drought conditions trial results were very poor. A number of trial plots did not produce enough to harvest. It was of interest to observe that the fields that had the most top soil remaining were not so severely injured from the dry weather as those areas where all or most of the top soil had been eroded away before the Rosemount Experiment Station was established. Much less drought damage occurred on the finer textured soils higher in clay content as compared to the more upland soils of medium texture that had been subjected to erosion years before. It was generally observed in 1964 that where a consistant fertilizer program was in existance the hazards of drought were greatly reduced as reflected in the crop yields of the check as compared to the fertilized yields. Many barren corn stalks were universal in 1964.

The Effect of Pasture Fertility and Management on Beef Production
1964
P. M. Burson, Soils; A. R. Schmid, Agronomy;
A. L. Harvey, and O. E. Kolari; Animal Husbandry.

On May 13, 1964, light weight "good to choice" Angus steer calves were lotted as uniformly as possible and turned onto pasture. Pasture E was renovated and seeded in 1962. Prior to 1962 one-half of each pasture was fertilized and the other one-half not fertilized. Beginning in 1962 all of the pasture area was fertilized except for a 2 rod strip adjacent to the center fence in the original unfertilized area. On this area a basic treatment of 500 lbs. per acre of 0-20-20, according to soil test, was applied at the time of renovation. No other treatment will be made until it is renovated again. On the original fertilized area the usual annual application of 200 lbs. per acre of 0-20-20 was made.

Because of the severe drought the 1964 pasture season was only 79 days long as compared to 112 days in 1963. However, the smaller Angus steer calves produced almost as much beef in the shorter grazing period as compared to the heavier Holstein steers in 1963. In 1963 the Holstein steers produced 354 lbs. of beef in 112 days while the Angus steers produced 342 lbs. in only 79 days. However, the total steer-days were 1207 in 1964 compared to 1057 in 1963. In terms of steer-days per acre it was 155 days in 1964 and only 136 days in 1963.

A 4 pasture rotation grazing system was used in 1964 with 1.9 acres in each pasture. The gross value of beef produced per acre was $71.82 in 1964 as compared to $63.72 per acre in 1963. Often the costs for lime, fertilizer, seed and tillage changes were deducted the net value of beef was $59.93 or $8.10 per acre more than in 1963. In 1964 the beef produced per acre was $37.04 on the check or $22.89 more beef produced per acre on the fertilized pastures. See annual report September 24, 1964.

Beef Production from Renovated and Fertilized Grass Pastures. 1964

A. R. Schmid, Agronomy; P. M. Burson, Soils; A. L. Harvey and O. E. Kolari, Animal Husbandry

Four types of pastures were compared on G pastures consisting of grass with no fertilizer, grass with 8 tons of manure per acre applied annually the fall before, grass with 80 lbs. of N per acre applied in early spring and early June and in split applications in April or June and July and renovated pastures. All pastures except the check received an annual spring application of 0-40-40. In 1964 after all costs for lime, fertilizer, seed and tillage costs were deducted the net return in term of beef was highest for manure of $59.01 per acre, nitrogen $54.81 per acre, renovated $49.22 per acre and the check $37.04 per acre.

The three year average not return per acre for 1962, 1963 and 1964 is as follows: check $43.03, manure $60.92, N $61.92 and renovation $62.47.

Plowing Vs Field Cultivator in Preparation of Soybean Land for Corn. 1964

Paul M. Burson and E. G. Bonnell

The problem has been raised by farmers in southern and western Minnesota about the blowing and washing of land that the previous year had grown soybeans. A common cropping system is the alternating from year to year of corn and soybeans. Some farmers claim they are eliminating this erosion problem by preparing the soybean land for corn with a field cultivator instead of plowing. This type of cropping system is being used on some fields on the soils farm at Rosemount. In 1964 plowing and field cultivating seedbeds were compared for corn following the growing of soybeans in 1963. The field cultivation consisted of three trips over the field tilled about 10 to 12 inches deep. The three trips over the field were about equal in time to a single operation of plowing. The 1964 corn yields are as follows:

Fertilizer Treatments	Bushels per acre: Plowing	Bushels per acre: Field cultivator
Check	83.0	80.0
Residual starter (RS)	72.0	76.0
RS + starter(1)	72.5	72.5
RS + starter + 80#N(2)	90.0	92.5

(1) 4-12-24 banded
(2) 80# N sidedressed at 1st cultivation
Final stand 18,000 plants per acre

Past-Emergence Liquid Nitrogen and Atrazine on Corn
1964
Paul M. Burson, R. D. Curley, and E. G. Bonnell

Three rates of liquid nitrogen (28-0-0) were broadcast as past-emergence when the corn had made about a 2 inch growth. Four lbs. of atrazine per acre was added to the liquid nitrogen to control grassy weeds. This is a practice that is being used in certain areas of the state where liquid N materials are available. Reports indicate there is a burning injury or a partial defoliation from this practice but not sufficient in extent to discourage its use. The rates of the liquid nitrogen were 100, 200 and 300 lbs. per acre plus the atrazine added to each rate. All trial plots received 250 lbs. per acre of 4-12-24 starter fertilizer banded 2 inches to the side and 2 inches below the seed. There was definite injury on the leaves of all corn plants, on all three rates but most serious on the 300 lb. rate. The recovery was much slower on the 300 lb. rate. Ten days later after injury was visible the 100 and 200 lb. rates had recovered but on the 300 lb. rate injury was still visible and the growth had been retarded. The 1964 yield results are as follows:

Fertilizer Treatment	Bu. Yields Per Acre
Check	43.0
Starter	78.0
Starter + Past-emg. Atrazine Broadcast	77.5
" + 250 #dry 33-0-0 (82# N) sidedressed + Atrazine Broadcast	97.0
" + 100 #liquid (28# N) + Atrazine all Broadcast	97.0
" + 200 # " (56# N) + " " "	97.5
" + 300 # " (84# N) + " " "	92.5

Manure, Lime and Starter Fertilizer on Continuous Corn
1964
Paul M. Burson and E. G. Bonnell

Manure, lime and starter fertilizer on 12 years of continuous corn was the best combination of soil treatments under the dry weather conditions in 1964. Lime was applied in December, 1961 at the rate of 3 tons per acre according to soil test. Manure is applied annually at the rate of 10 tons per acre. The started fertilizer, 6-24-12 was placed in a band 2" to the side and 2" below the seed at 175 lbs. per acre according to soil test. The soil types are Judson and Clyde silty clay loams. The 1964 yield results are as follows:

Fertilizer Treatment	Bu. Yield Per Acre	
	No Lime	Lime
Check	68.0	69.5
Manure	74.5	84.5
Manure + Starter	74.5	90.0

Irrigation and Starter Fertilizer for Corn
1964
Paul M. Burson and E. G. Bonnell

An irrigation trial on a small scale was conducted at Rosemount in 1964. The trial was limited in scope because of the lack of sufficient equipment. The soil type was an upland soil of Port Byron silt loam and had been in continuous corn for

9 years. Three different starter fertilizers were banded at planting time; 4-12-24, 5-20-20 and 6-24-12 and the supplemental liquid nitrogen, usually sidedressed, was applied with the starter at planting time. The yield results are as follows:

	Bu. Yield Per Acre	
	check	all fertilizer
No irrigation	11.5	28.8
Irrigation	58.0	85.0

Residual starter Vs Starter Vs Starter and Sidedressing for Corn
1964
Paul M. Burson and E. G. Bonnell

On 9 fields of corn residual starter, starter, and starter + sidedressed nitrogen fertilization were compared in 1964. The starter fertilizer of, 6-12-24 applied at 250 lbs. per acre was banded with 80 lbs. of N sidedressed at the first cultivation. The yield results are as follows for 4 soil types(1):

Fertilizer Treatment	Bu. Per Acre Yield
Check	75.0
Residual starter	79.2
Starter	86.9
Starter + sidedressed N	100.3

(1) Judson and Clyde silty clay laom
Port Bryon silt loam
Ostrander silt loam

Starter Fertilization for Soybeans
1964
Paul M. Burson and E. G. Bonnell

Two fields of soybeans were fertilized with 250 lbs. per acre of 4-12-24 according to soil test. The fertilizer was banded 2" to the side and 2" below the seed. All beans were inoculated. The yield results are as follows:

Fertilizer Treatment	Bu. Yield Per Acre	
Check	22.4	
Starter fertilizer	30.1	
Inc. from fertilizer		+ 7.7

Variety - mint
Soil types - Clyde and Judson silty clay loams.

Continuous Soybean Fertility Study

(Rosemount, 1964)

Dr. A. C. Caldwell, E. C. Seim, G. W. Rehm.

An experiment was begun in 1957 on a Port Byron silt loam at Rosemount, Minnesota. to measure the long term effect of fertilizer applications on the yield and quality of soybeans grown continuously.

In 1964 the experiment was continued. A severe period of drought in mid-summer slowed growth and reduced the final yield of beans.

Drought periods usually cause increased variation in yield due to non-uniform plot conditions. Despite this, differences in growth were observed and recorded when yields were measured. The yields are reported in Table 1. All of the treatments gave an average increase over the control, many of which were statistically significant at the 95% level. Plots which had received heavy application of 0-400-400 and 0-400-400 + 6 T manure 7 years ago increased the 1964 yield by 6.87 and 5.90 bushels per acre respectively.

It is interesting to note that despite the low yields due to drought a more distinct pattern of fertilizer response emerged in this dry year than in several previous years with normal rainfall.

Residual Effect of Fertilizer Treatments on the Yield of Soybeans Grown Continuously. (Rosemount, 1964 - Fertilizer applied in 1957).

Treatment No.	N	P	K	Manure	1964 Yield Bu/acre	Diff.
1	0	0	0		11.39	--
2	0	20	20		11.93	+ .55
3	0	40	40		12.88	+1.50
4	0	60	60		14.40	+3.02
5	0	80	80		13.25	+1.87
6	0	400	400		18.25	+6.87
7	0	400	400	+ 6 T man.	17.28	+5.90
8	0	0	0		12.50	+1.12
9	0	20	20		12.65	+1.27
10	0	0	0		14.73	+3.35
11	0	80	80		13.00	+1.62
12	0	0	0		15.30	+3.92
13	0	400	400		14.20	+2.82
14	0	0	0	+ 6 T	15.23	+3.85
15	0	0	0	+ 6 T	13.03	+1.18
	lsd (.95)				3.47	
	hsd (.95)				6.22	

The Effect of Nitrogen Source, Placement and Time of Application on the Yield and Nitrogen Content of Continuous Corn on Webster Clay Loam at Lamberton in 1964.

J. M. MacGregor and W. W. Nelson

The effect urea and ammonium nitrate as sources of nitrogen on the yield and composition of corn is being studied. The nitrogen materials are being plowed down and surface applied. The plowed down treatments are fall applications. The surface treatments were applied in fall, spring and a late sidedressing. This study was started in 1960.

Each experimental plot is 77.5 feet long and six corn rows wide. Each treatment is replicated four times. Sufficient phosphorus and potassium is applied as broadcast and starter applications. A plant population of 18,000 plants per acre is established. The primary objectives of this field project is to investigate:

1) The relative effectiveness of equal amounts of nitrogen as urea or as ammonium when applied to this soil at different rates.
2) The relative efficiency of such nitrogen forms when they are applied in the late fall, in the spring at time of planting, or as late sidedressing in late June or in early July.
3) The relative values of fall plowing down of two sources in comparison to overwintering of the nitrogen fertilizer on the surface of the fall plowed soil.
4) To find if there was any possible fertilizer nitrogen accumulation in the soil, the relative amounts removed by the corn crop and losses sustained through leaching, losses to the air, or losses by soil erosion.

For the first few years, all data was obtained by harvesting and analyzing the corn plants, and computing the nitrogen removal and relative efficiency based on amounts actually present in the corn plants. The plant parts were divided into ears, leaves, upper stalk and lower stalk. Soil samples were collected from some treatments during 1962 and 1963. The depths sampled were 0-6", 6-12" and 12-24" and the results of this study are also reported here.

The 1960, 1961 and 1962 corn yields were somewhat affected by weather, but the area did not seem to drain well, and in 1963, tile drains were laid down along the outer end of each of the plots. Corn yields of 1963 and 1964 have been much more satisfactory than in the three earlier years, although the summer of 1954 was relatively dry during several intervals of the growing season.

The yields of ear corn for each of the five years are shown in Table 1, ranked in order of yield magnitude for 1964. Only the two first treatments (121.4 and 115.7 bushels per acre) were significantly different from the rest by Duncan's multiple rank test.

Table 1. The Effect of Nitrogen Source, Rate and Time of Application on the Yield of Continuous Corn at Lamberton from 1960 through 1964. (Ranked according to 1964 yield - average of 4 replicates)

Rank	Treatment (lbs. N/A)	Yield of ear corn - bu/A @ 15.5% moisture					Average
		1960	1961	1962	1963	1964	
1	80 urea - late sidedressing	76.9	86.4	48.2	143.8	121.4	
2	80 urea - at planting	57.7	99.1	40.5	149.3	115.7	
3	80 NH_4NO_3-late sidedressing	50.4	98.4	46.7	140.7	113.0	
4	80 NH_4NO_3- at planting	59.3	90.0	32.7	149.2	112.5	
5	160 urea-plowed under-fall	79.4	112.5	43.5	152.8	112.4	
6	160 NH_4NO_3-late sidedressing	40.7	97.4	77.7	151.7	109.5	
7	80 urea-plowed under-fall	61.7	76.9	36.7	154.5	104.9	
8	40 NH_4NO_3-top of plowing-fall	49.0	96.7	29.6	140.1	101.5	
9	160 NH_4NO_3- plowed under-fall	69.8	97.9	46.7	147.7	100.9	
10	80 NH_4NO_3-plowed under-fall	67.4	97.9	43.6	149.6	100.8	
11	40 urea - at planting	45.4	91.1	31.4	147.6	100.6	
12	40 urea - plowed under-fall	55.1	78.2	29.1	148.8	100.3	
13	40 NH_4NO_3 - at planting	66.2	92.0	45.4	152.2	99.8	
14	40 urea - late sidedressing	57.7	95.6	24.9	142.3	94.1	
15	40 NH_4NO_3- late side-dressing	63.6	92.6	39.5	148.6	90.4	
16	40 NH_4NO_3 - plowed under-fall	42.3	87.5	30.9	148.6	88.3	
17	40 urea - top of plowing-fall	62.3	101.3	37.0	140.7	84.1	
18	check	49.5	88.2	26.1	132.6	72.9	

Total corn yields for the five years of continuous corn have varied considerably, and these are shown in Table 2, along with the pounds of fertilizer nitrogen applied for each bushel of increase obtained. A range of 2.3 to 8.5 pounds of nitrogen was applied for each additional bushel of corn produced.

Table 2. Total Five Year Corn Yield, Increase and Pounds of Nitrogen Applied per Bushel of Yield Increase as Influenced by Nitrogen Source, Rate and Time of Application at Lamberton.
1960 - 64.

(Ranked according to 5 year total - average of four replicates)

Rank	Treatment (lbs. N/A)	Bu/A.	Bu/A.	Applied 5 yrs.	lbs. N/bu
1	160 urea - plowed under-fall	500.6	131.3	800	6.1
2	160 NH_4NO_3 - late sidedressing	477.0	107.7	800	7.4
3	80 urea - " "	476.7	107.4	400	3.7
4	160 NH_4NO_3 - plowed under-fall	463.0	93.7	800	8.5
5	80 urea - at planting	462.3	93.0	400	4.3
6	80 NH_4NO_3 - plowed under-fall	459.3	90.0	400	4.5
7	40 NH_4NO_3 - at planting	455.6	86.3	200	2.3
8	80 NH_4NO_3 - late sidedressing	499.2	79.9	400	5.0
9	80 NH_4NO_3 - at planting	433.7	74.4	400	5.4
10	80 urea - plowed under - fall	434.7	65.4	400	6.1
11	40 NH_4NO_3 - late sidedressing	434.7	65.4	200	3.1
12	40 urea - top of plowing - fall	425.4	56.1	200	3.6
13	40 NH_4NO_3 - top of plowing-fall	416.9	47.6	200	4.2
14	40 urea - at planting	416.1	46.8	200	4.3
15	40 urea - late sidedressing	414.6	45.3	200	4.4
16	40 urea - plowed under-fall	411.5	42.2	200	4.7
17	40 NH_4NO_3 - plowed under-fall	397.6	28.3	200	7.1
18	check - no nitrogen	369.3	---	---	---

Although the higher total corn yields were obtained with the heavier rates of nitrogen application, these rates were not the most efficient. The lowest rate of 40 pounds of nitrogen per acre was generally the most effective per pound of nitrogen fertilizer used. It should be emphasized that investment for fertilizer nitrogen is relatively small in comparison to the fixed per acre costs of crop production, which might well justify a heavier rate of nitrogen application to obtain a larger yield increase.

The effect of nitrogen source rate and time of application on the total nitrogen content of 1964 corn from the continuous corn plots is given in Table 3.

Table 3. The Effect of Nitrogen Source, Rate of Application, and Time of Application on the Total Nitrogen Content of 1964 Corn Plants from the Continuous (1960-64) Corn Plots at Lamberton.
(Total above ground plant parts - average of 4 replicates)

Treatment (lbs. N/A)	Leaves	Ears	Upper stalks	Lower stalks	Total	Increase
check	17.7	49.0	2.7	7.8	77.2	---
40 as NH_4NO_3 plowed down-fall	22.2	94.9	3.2	15.1	135.4	58.2
40 as urea " " "	29.6	96.8	4.0	7.4	137.8	60.6
40 " NH_4NO_3-left on surface "	24.8	96.9	3.3	9.8	134.8	57.6
40 " urea - " " "-"	28.8	98.5	4.1	13.4	144.8	67.2
80 " NH_4NO_3 - plowed down-fall	28.8	93.3	5.2	15.1	142.4	65.2
80 " urea - " " -"	28.6	106.4	5.1	17.5	157.6	80.4
160 " NH_4NO_3 - " " -"	30.5	83.1	5.7	16.8	136.1	58.9
160 " urea - " " -"	28.6	121.3	4.5	21.6	175.9	98.7
40 " NH_4NO_3- at planting	24.2	79.8	3.4	8.1	115.5	38.3
40 " urea - " "	20.8	79.4	3.9	8.9	113.0	35.8
80 " NH_4NO_3 -" "	29.1	108.3	4.0	15.4	156.8	79.6
80 " urea - " "	39.3	150.4	5.1	21.4	216.2	139.0
40 " NH_4NO_3- late sidedress-ing	30.8	90.4	6.0	11.3	138.5	61.3
40 " urea - " "	20.2	83.2	3.6	8.3	115.3	38.1
80 " NH_4NO_3- " "	27.9	97.7	5.0	12.5	143.1	65.9
80 " urea- " "	28.8	113.6	6.1	17.2	165.7	88.5
160 " NH_4NO_3- " "	38.3	97.3	6.7	20.8	163.1	85.9

Considering the nitrogen present in the corn ears alone, it is evident that the 40 pound per acre rate of nitrogen approximately equalled the amount removed in the grain, whereas with the higher rates more fertilizer nitrogen was applied than was removed in the corn grain. This should be reflected in a build up in the amounts of soil nitrogen on those plots receiving the annual application rates of either 80 or 160 pounds of nitrogen. As will be reported in the following article, soil analyses for total nitrogen indicates no consistent increase in the amounts of nitrogen on the more heavily fertilized plots, but concentrations of soil nitrate nitrogen were much higher under the heavier fertilization treatments.

The Effect of Urea or Ammonium Nitrate Nitrogen on the Nitrate Content of Surface Soil and of Different Parts of the Corn Plant at Lamberton in 1964 (Webster clay loam)

J. M. MacGregor and W. W. Nelson

Many farmers have become concerned with the effect of nitrogen fertilization on the nitrate content of corn plants during the growing season, especially where growth is retarded by dry soil conditions at some period of growth. Research in several mid-western states has shown that drowth conditions result in marked increases in the nitrate content of corn. Olson (1) stated that forages and silages containing less than 0.15% of nitrate nitrogen appear safe to feed, feeds containing 0.15% to 0.40% nitrate nitrogen should be supplemented to supply a ration averaging less than 0.15% nitrate nitrogen, whereas those forages containing over 0.45% nitrate nitrogen are potentially dangerous to feed, even at restricted levels. He concluded that nitrate poisoning of livestock is relatively rare, and that fertilizer practices should be based on Experiment Station recommendations without concern for the possibility of nitrate poisoning.

A long term nitrogen fertilizer experiment has been in progress at the Southwest Experiment Station at Lamberton on a Webster soil planted to continuous corn beginning with the 1960 growing season. Nitrogen has been annually applied at rates of 40, 80 or 160 pounds per acre, either as ammonium nitrate or as urea for five years.

In 1964 corn plants were randomly sampled from two replications on each of five different nitrogen treatments in mid-June, mid-July, mid-August, and finally in mid-September. Soil samples were also taken at the same times at the six-inch depth immediately adjacent to the corn roots. The corn plants were immediately chilled following sampling, and dried in a circulating air oven at 55°C. After drying, the tissues were separated into leaves, upper stalks and lower stalks (with the exception of the mid-June sampling which consisted entirely of leaves). The soil samples were also chilled and all samples were then analysed for nitrate content.

The nitrate values obtained on all samples are shown in the following table. The tissue samples considered to be at toxic levels for uncontrolled animal feeding by Olsons nitrate values are identified with the symbol 't'.

The nitrate content of the soil was directly related to the amounts of fertilizer nitrogen applied over the five year period, with the relatively large amounts present in mid-June rapidly decreasing as the growing season progressed.

Nitrate levels of the corn leaves sampled in mid-June were relatively high, and as the rates of nitrogen applied increased, toxic nitrate levels were consistently present. By mid-July, however, nitrate levels of the leaves were and remained at relatively low levels for the remainder of the growing season.

Upper stalks, which were not available for the June sampling, could be considered relatively safe for feeding during the three months in which these were analyzed.

However, in the lower stalks, these tissues growing on the plots receiving no nitrogen, had relatively low concentrations, but as rate of nitrogen fertilization increased (especially in July with relatively high soil nitrate levels) these tissues consistently contained toxic nitrate concentrations which decreased as the growing season progressed. The nitrate content of lower corn stalks sampled in August and September were relatively safe for feeding where nitrogen was applied annually at the 80 pound per acre rate. However, when this N fertilization rate was doubled to an annual application rate of 160 pounds per acre, the lower corn stalks contained toxic nitrate levels through the entire growing season.

This illustrates that heavy nitrogen fertilization results in abundant soil nitrate and toxic nitrate levels in some corn tissues grown under these conditions in 1964. It is probable that either legume ground or soils receiving heavy applications of barnyard manure would result in similar trends, but of lower magnitude.

(1) Olson, Oscar: Nitrate Problems in Livestock Feeds. Report of the Fourteenth Annual Soils and Fertilizer Short Course. Leamington Hotel, Mpls, Minn., November 23-24, .

Soil Nitrates (ppm) and Percentage Nitrate Nitrogen in Lamberton Fertilizated Corn in 1964

(NH_4NO_3 or urea applied to Webster clay loam)

1st treatment	ppm soil nitrates				Percentage nitrate nitrogen in corn tissues: Leaves				Upper stalks			Lower stalks		
	June	July	August	Sept.	June	July	August	Sept.	July	August	Sept.	July	August	Sept.
check	8	2	1	1	0.10									
					0.40									
					0.33	0.03	0.03	0.02	0.07	0.03	0.02	0.01	0.03	0.01
					0.30									
	2	2	1	1		0.02	0.02	0.02	0.05	0.05	0.02	0.04	0.03	0.01
Average	5	2	1	1	0.28	0.03	0.03	0.02	0.06	0.04	0.02	0.03	0.03	0.01
80#/A NH_4NO_3-N (spring)	26	7	3	1	0.35									
					0.41	0.11	0.03	0.03	0.45	0.06	0.02	1.06[t]	0.15	0.03
	11	2	3	2	0.70[t]									
					0.41									
					0.47[t]	0.01	0.04	0.01	0.02	0.08	0.01	0.30	0.17	0.06
Average	19	5	3	2	0.47[t]	0.06	0.04	0.02	0.24	0.07	0.02	0.72[t]	0.16	0.05
80#/A urea-N (spring)	33	4	2	2	0.79[t]									
					0.20									
					0.20	0.01	0.05	0.03	0.05	0.06	0.03	0.18	0.44	0.26
					0.51[t]									
	13	3	5	1	0.48[t]	0.08	0.03	0.02	0.45[t]	0.06	0.03	0.55	0.15	0.08
Average	23	4	4	2	0.44	0.05	0.04	0.03	0.25	0.06	0.03	0.42	0.30	0.17
160 #/A NH_4NO_3-N (fall)	48	45	4	6	0.62[t]									
					0.70[t]	0.12	0.04	0.02	0.37	0.16	0.09	0.87[t]	0.82[t]	0.60[t]
					0.48[t]									
	43	21	8	2	0.58[t]	0.10	0.03	0.01	0.41	0.15	0.07	0.73[t]	0.82[t]	0.45[t]
Average	46	33	6	4	0.60[t]	0.11	0.04	0.02	0.39	0.16	0.08	0.80[t]	0.82[t]	0.53[t]
60#/A urea-N (fall)	36	7	7	2	0.70[t]									
					0.50[t]	0.12	0.07	0.01	0.37	0.13	0.02	0.65[t]	0.83[t]	0.51[t]
					0.57[t]									
	36	5	2	2	0.53[t]	0.16	0.07	0.01	0.48[t]	0.11	0.03	0.68[t]	0.68[t]	0.25
Average	36	6	5	2	0.58[t]	0.14	0.07	0.01	0.43	0.12	0.03	0.67[t]	0.76[t]	0.38

t = toxic to animals, even with limited quantity.

The Effect of Continued NH_4NO_3 and Urea Applications to a Webster Clay Loam on the Nitrate Nitrogen Content of the Soil Under Continuous Corn Cropping at Lamberton.

J. M. MacGregor, R. Munter and W. W. Nelson

A long term nitrogen fertilizer experiment on continuous corn was initiated at the Southwest Experiment Station in the spring of 1960, with annual applications of either ammonium nitrate or urea nitrogen at rates of 40, 80 or 160 pounds per acre. Field corn has been grown each year with a plant population of approximately 18,000 plants per acre. Analyses of the corn have consistently shown that annual nitrogen removal has been at the approximate rate of fifty pounds per acre, and it was thought that the annual fertilizer nitrogen additions should result in the increase in the nitrate nitrogen and in the total soil nitrogen. It was considered that a possible nitrogen increase in the soil would be more amply reflected in the nitrate and in the exchangeable ammonium content of the soil.

Commencing late in April of 1962, soil samples from three soil depths (0"-6", 6"-12", and 12"-24") were sampled on two replicates from ten different nitrogen fertilized plots at monthly intervals until late October. Difficulty was encountered in the analyses and only a portion of the 1962 plot samples were analyzed. The sampling of October, 1963 were analyzed for total nitrogen (Kjeldahl procedure) as well as for nitrate and exchangeable ammonium nitrogen. The ammonium content of the soil showed little variation and since the procedure was detailed and time consuming, ammonium nitrogen content was not determined for the entire 1963 season on the samples from those plots receiving intermediate rates of nitrogen fertilization. Also, since the incomplete analyses of 1962 were much the same as those obtained from the 1963 samples, only the 1962 results are presented in the following tables.

As expected, the average nitrate content of the check (or no nitrogen) plots is considerably lower than in the soils receiving the annual nitrogen treatments. As the rate of nitrogen fertilization increases, the highest nitrate concentrations usually accumulate in the 6"-12" depth, with smaller amounts present in either the surface or in the 12"-24" levels. Nitrates tend to be low in the relatively cool soil of April increase rapidly in May as the soil warms up, and then decrease rapidly during the summer months, even where heavy nitrogen applications have been made. They then increase rapidly in late October as the growing season comes to an end and withdrawal by the corn plants becomes a minimum. As the rate of fertilization was increased, more nitrates (and more total nitrogen in October) seems to accumulate in the 12"-24" soil depth, which may indicate the possibility of nitrate movement to lower soil depths.

If this nitrate movement continues to much lower depths, there is a possibility that some of the nitrogen may be moving down below the reach of the corn roots and thus be lost to crop production. If this does occur, it would at least partially account for the limited nitrogen increase in the upper two feet of the profile with the relatively large amounts of nitrogen fertilizer being applied.

The concentrations of exchangeable ammonium present in the 1963 soil samples under the different treatments are shown in Table 2.

The concentrations of exchangeable ammonium were generally slightly higher in the 6"-12" soil depth, but there was no pattern or definite trend in relation to the kind or rate of fertilization, although there was a slight decrease during the summer months. With the apparent lack of correlation in relation to both fertilization and soil fertility conditions, this type of analysis was soon curtailed to include only the two extremes of fertility treatment.

Table 1. The Nitrate Content of Three Depths of Webster Clay Loam Fertilized with Urea or NH_4NO_3 Nitrogen Under Continuous Corn at Lamberton in 1963.

(Average of two replications).

Soil Depth	Annual Treatment (lbs N/A)	April	May	June	July	August	Sept.	Oct.	Total soil N in ppm October
		Time of Sampling in 1963							
			Nitrate nitrogen in parts per million						
0"- 6"	check	3.7	15.9	6.3	1.8	1.2	2.2	2.3	2140
6"-12"	"	5.1	9.8	5.5	1.3	1.0	2.1	3.3	2200
12"-24"	"	1.9	2.5	3.5	0.8	1.0	0.4	0.7	990
0"- 6"	80 NH_4NO_3	23.1	27.6	19.9	2.4	2.9	3.0	21.0	2300
6"-12"	plowed down in	12.7	50.7	24.7	2.0	2.1	5.5	13.1	2260
12"-24"	the fall	6.2	15.3	9.1	2.3	2.6	1.8	1.8	1010
0"- 6"	80 urea	16.2	22.9	24.4	2.4	3.4	4.1	13.3	2290
6"-12"	plowed down	24.2	40.7	30.7	1.8	1.5	5.0	11.1	2120
12"-24"	in fall	3.0	3.6	10.5	2.0	1.1	1.1	1.6	950
0"- 6"	160 NH_4NO_3	7.0	16.1	26.8	4.2	4.3	3.7	36.5	2350
6"-12"	plowed down	25.4	48.4	25.0	7.6	11.9	7.8	25.2	2590
12"-24"	in fall	7.5	10.4	9.3	10.2	9.5	13.2	9.6	1100
0"- 6"	160 Urea	22.9	28.4	54.4	4.7	6.2	3.2	30.5	2600
6"-12"	plowed down	42.6	35.3	44.0	6.3	13.1	5.1	17.7	2390
12"-24"	in fall	7.8	18.1	11.7	8.6	8.9	11.3	7.0	960
0"- 6"	80 NH_4NO_3	6.3	70.7	23.6	2.9	3.6	3.2	3.6	2300
6"-12"	broadcast be-	6.6	10.1	19.8	2.0	2.3	1.8	3.5	2290
12"-24"	fore spring planting	1.7	2.1	3.6	2.3	1.1	1.2	1.4	1210
0"- 6"	80 Urea	17.0	28.2	11.2	2.6	1.9	3.2	3.2	2240
6"-12"	broadcast be-	9.4	13.6	8.2	2.2	1.3	2.9	3.5	2310
12"-24"	fore spring planting	1.2	2.9	5.9	4.3	1.3	0.8	1.4	1470
0"- 6"	80 NH_4NO_3	6.3	10.6	9.7	2.6	2.2	4.8	4.2	2040
6"-12"	late sidedress	6.9	7.2	7.8	1.9	1.2	2.6	3.6	2180
12"-24"	June	1.3	3.2	3.5	7.5	0.8	0.9	2.3	1150
0"- 6"	80 Urea	5.2	9.0	4.4	3.6	8.0	4.4	5.3	2220
6"-12"	late sidedress	6.3	7.3	6.8	2.3	4.5	3.4	3.7	2000
12"-24"	June	1.6	2.8	5.1	1.5	2.0	1.6	1.8	2060
0"- 6"	160 NH_4NO_3	7.5	11.2	13.5	12.9	23.1	8.7	9.5	2070
6"-12"	late sidedress	9.0	12.3	16.7	9.7	12.6	4.3	10.4	2170
12"-24"	June	1.5	3.3	10.1	11.8	9.5	7.7	5.4	1090

Table 2. The Exchangeable Ammonium Content of Three Depths of Webster Clay Loam Fertilized with Urea or NH_4NO_3 Nitrogen Under Continuous Corn at Lamberton in 1963.

(Average of two replications).

Soil depth	Annual Treatment (lbs N/A)	April	May	June	July	August	Sept.	Oct.
		Time of Sampling in 1963 — Exchangeable NH_4- N in parts per million						
0"- 6"	check	10.4	15.9	2.8	8.3	7.6	5.2	4.8
6"-12"	"	4.3	17.0	14.5	7.0	7.8	5.8	3.6
12"-24"	"	2.3	5.5	7.4	6.2	5.9	4.3	2.2
0"- 6"	80 NH_4NO_3	12.8	17.9	11.6				
6"-12"	fall plow down	12.3	11.5	4.7				
12"-24"		3.6	2.1	3.8				
0"- 6"	80 urea	21.6	12.2					
6"-12"	fall plow down	14.0	14.8					
12"-24"		1.5	5.5					
0"- 6"	160 NH_4NO_3	6.8	8.6	10.5	10.2	8.4	5.8	16.7
6"-12"	fall plow down	10.0	5.4	12.0	8.4	8.3	5.0	17.7
12"-24"		4.9	4.6	5.6	5.2	5.8	3.7	5.0
0"- 6"	160 urea	28.9	---	17.1	11.6	9.1	3.4	75.6
6"-12"	fall plow down	19.9	10.2	11.8	10.4	7.1	3.1	13.9
12"-24"		3.6	4.5	5.0	4.8	5.1	6.5	6.9
0"- 6"	80 NH_4NO_2	6.3	11.0					
6"-12"	broadcast before	7.4	8.5					
12"-24"	spring planting	4.5	9.1					
0"- 6"	80 urea	5.3	8.7					
6"-12"	broadcast before	3.4	9.4					
12"-24"	spring planting	2.2	2.4					
0"- 6"	80 NH_4NO_3	8.1	9.2					
6"-12"	late sidedress	9.9	4.6					
12"-24"		3.3	1.6					
0"- 6"	80 urea	12.4	13.9					
6"-12"	late sidedress	8.5	3.1					
12"-24"	.	4.9	2.4					
0"- 6"	160 NH_4NO_3	8.8	3.8					
6"-12"	late sidedress	4.7	6.9					
12"-24"		2.0	---					

Comparison of Phosphorus Sources

A. C. Caldwell; E. C. Seim; G. W. Rehm.

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, and two years of alfalfa. In 1959 the rotation was changed to corn, soybeans, wheat, and alfalfa. Potassium has been applied as required according to soil test. Lime was applied to two replicates in the fall of 1961.

All of the 1964 crops were adversely affected by a prolonged period of dry weather in early summer. Corn yields were severely damaged by the drought and no treatment yields were recorded. The average yield of the corn was about 15 bushels per acre. The second cutting of alfalfa was also drastically reduced by the drought. Soybeans were adversely affected in that they made very slow growth in the early part of the season.

All of the phosphate sources gave significant increases in alfalfa yield over no phosphate treatment but differences between phosphate sources were too small to be significant at the 5% level. Florida Rock, the highest yielding treatment, gave a higher increase than it has in past years while fused tricalcium phosphate, the second highest yielding treatment was also one of the best treatments in 1963.

No significant differences in the wheat yields were measured by the F test in 1964, although several treatments approached significance when measured by the least significant difference.

As in 1963 and past years, 1964 soybean yields show small increases which are not significant at the 5% level but which are consistently better than the checks.

Effect of various phosphate fertilizers on yield of alfalfa, wheat, and soybeans. (Rosemount, 1964).

Treatments	P_2O_5/A/Yr. lbs.	Alfalfa tons/A.	Wheat Bu./A.	Soybeans Bu./A.
None		1.77	14.9	16.0
Ord. Super	40	2.66	23.1	19.0
Conc Super	40	3.08	23.5	17.6
Cal. Meta	40	2.93	18.0	16.1
Phos. Acid	40	2.89	22.2	18.0
Fused trical phos.				
Fl. rock + Ord. Super	20 + 20	2.92	21.7	18.6
Fl. rock	100	2.76	24.3	17.9
	P_2O_5/A/4 Yr.			
Fl. rock	1000	3.14	22.7	17.7
Western rock	1000	2.39	18.7	18.6
Col. clay rock	1000	2.60	18.3	17.9
Tunis, rock	1000	2.67	19.9	16.2
Std Error ($S_{\bar{x}}$)		.28	2.1	1.6
Lsd (.05)		.81	6.1	4.7
Hsd (.05)		1.40	12.6	8.2

EFFECT OF POTASSIUM FERTILIZATION ON THE YIELD AND POTASSIUM CONTENT OF ALFALFA

H. J. Hopen, A. C. Caldwell and R. S. Grant

Farmers in northeastern Minnesota have had difficulty in establishing and maintaining stands of alfalfa. Soils in the eastern part of Minnesota tend to be acidic and low in native soil potassium. Alfalfa grown on unfertilized soil exhibits the typical yellow or brown deficiency symptoms together with winter killing and uneccnomic yields.

In 1960[1] a study was undertaken at Duluth to determine the effect of 0, 100, 200, 400 and 800 lbs. K_2O/A. on the growth of alfalfa. The fertilizer treatments were broadcast and plowed down in the fall of 1960 and planted to a small grain nurse crop in 1961. In 1963, 200 lbs. was applied as a split-plot topdressing to one half of the 100 lb., 200 lb. and 400 lbs./A. treatments.

The entire experimental area received 125 pounds of phosphorus per acre in 1960 to eliminate this element as a variable. Soil tests in 1963 and 1964 indicated that phosphorus was at medium to high levels in all plots. A unifcrm application of Boron was applied to the entire experimental area in 1962.

The (I) hay yields in 1962, 63, and 64, (II) tissue K content in 1962, 63 and 64 and the (III) soil content of exchangeable K in 1963 and 64 were used to determine the effect of K fertilization on the growth of alfalfa in this study.

1 Appreciation is expressed to Dr. D. G. Baker for assistance during the planning of this study.

I. YIELD OF FORAGE.

Table 1. Yield of forage (2 crops per year) as influenced by single K application.

Lbs. of K_2O Applied per Acre Fall 1960	Tons/Acre 1962	1963	1964	Average Annual Yield	Relative* Yield
0	2.71	2.37	1.05	2.04	1.00
100	3.14	3.03	1.67	2.62	1.28
200	3.54	3.69	1.85	3.02	1.48
400	3.42	3.89	2.15	3.16	1.54
800	3.55	4.27	2.45	3.42	1.67

*Yield at treatment level ÷ yield at 0#K_2O/A = Relative Yield

As the amount of fertilizer K was increased the yield was increased. Yield was more than doubled in 1964 in spite of a June and July drought. Admittedly, the yields were low, but the beeficial effect of fertilization are more apparent in an adverse season.

An initial application 200 lbs. K_2O/A. resulted in significantly higher yields than the no K treatment in all three years. As mcre than 200 lbs. K_2O was applied the yield increase per unit of added K decreased. The 400 lbs. K_2O treatment did not consistently result in higher yields than the 200 lbs. treatment over the three year period; but showed up as an advantage in relative yield in the adverse 1964 growing season. Farmers aiming at yields of four or more tons of forage per acre would be wise to apply 400 lbs. K_2O/A. at seeding and topdress with additional K later in the rotation. The 800 pounds of K_2O/A. appears to be more than is needed as one application.

With Muriate of potash (0-0-60) costing $55 per ton, an 800 lb. K_2O/A. application would be $36. The 400 lb., 2001b. and 100 lb. applications of K_2O would require an investment of $18, $9 and $4.50 per acre respectively.

With alfalfa hay selling at $25 per ton, an increase of only 1/3 ton per acre pays for 200 lbs. K_2O per acre with 0-0-60 retailing at $55 per ton. In this study the smallest yield increase from 200 pounds of K_2O/A. was 1/3 ton per year.

Figure 1. Effect of initial and topdressed K on three cuttings following topdressing.

A potash topdressing in 1963 increased yields above those of the initial application. Topdressing 200 lbs. K_2O/A. after the first harvest in 1963 produced a yield increase in the second harvest in 1963. The 400 lbs. of K_2O applied in 1960 plus 200 lbs. of K_2O in 1963 gave approximately the same yield as the 800 lb. application in both 1963 and 1964. From these data a split application, part as seeding and part as a topdressing, would seem to be the most economical use of K fertilization.

II. TISSUE CONTENT OF POTASSIUM.

Figure 2. Percent K in first and second cutting alfalfa tissue at 0, 100 (+200), 200 (+200), 400 (+200) and 800 lbs. K_2O/A. (1962 tissue data is not included as only the 0, 200 and 800 lb. K_2O/A. were evaluated).

As the level of K applied increased, the amount of K in the alfalfa tissue increased. The K topdressing following the first cutting in 1963 increased the K content of the second cutting of alfalfa. Tissue K levels were greater from topdressed than from non-topdressed areas in both harvests of 1964. The low K content in 1964 was probably due to the dry periods in the fall of 1963 and the mid-season 1964 growing season drought.

Tissue K levels were used in this study to evaluate the uptake and utilization of the soil application of K. If one were to try to keep the tissue K at the desired level of 2.0 to 2.25% in this study, a minimum of 400 lbs. of K_2O/A. would have to be applied at seeding plus an annual topdressing. As higher yields are produced, more K is removed from the soil (Table 2.)

Table 2. Potassium removal as influenced by average annual yield and average tissue K content.

Lbs. K_2O Applied/Acre Fall 1960	Average Annual Yield (Table 1) Tons/Acre	Average % Tissue K (Figure 2)	Average Lbs. of K_2O Removed Each Year/Acre
0	2.04	1.00	49
100	2.62	1.40	88
200	3.02	1.44	104
400	3.16	1.78	136
800	3.42	2.33	191

III. SOIL CONTENT OF EXCHANGEABLE POTASSIUM.

The amount of exchangeable K increased as the application of fertilizer K was increased. In the fall of 1963 and 1964 the check plot (0 pounds of K in 1960), 100 and 200 pound per acre applications contained essentially the same amount of exchangeable K. Therefore, without additional K, within 2 years of seeding, the 200 lbs. of K_2O/A. application was not adequate for forage production on this soil. Exchangeable K in the 400 and 800 lb. K_2O treatments was not depleted to the extent that it had been under lower levels of application.

Table 3. Pounds of exchangeable K at several soil depths in 1963 and 1964.

Lbs. of K_2O Plowed Down in 1960 Lbs./A.	K_2O* Topdressed in 1963 Lbs./A.	Exchangeable K - Lb./A. Fall of 1963 0-6 in.	Fall of 1964 0-3 in.	Fall of 1964 3-6 in.
0		70	67	73
100		80	--	--
100	200	140	--	--
200		83	83	77
200	200	147	133	120
400		106	90	83
400	200	246	207	203
800		203	--	--

*After first harvest in 1963.

Topdressing of 200 lbs. of K_2O/A. in the summer of 1963 approximately doubled the exchangeable K levels compared to non-topdressed plots the same fall. The 400 lb. treatment with topdressing contained twice as much exchangeable K as the single 400 lbs./A. K_2O treatment.

In 1963 topdressing of 200 pounds of K_2O per acre showed up in approximately equal amounts in the 0-3 and 3-6 inch levels when sampled in the fall of 1964. This indicates that although it may be more desirable to incorporate the fertilizer elements at time of seeding, there was appreciable downward movement of topdressed K on this loam soil. The fact that the topdressed K was utilized is verified by the increased K content of the tissue together with the yield increases obtained from topdressing.

Adequate fertilizer K should be supplied on soils of northeastern Minnesota to maintain satisfactory yields and tissue K content. One hundred lbs. of K_2O/A. at time of seeding provided a greater yield than the check plot. Typical visual K deficiency symptoms were often evident on the 100 lb. K_2O treatment. Two hundred lbs. of K_2O/A. at seeding consistently provided significantly greater yields than the check plot. No K deficiency symptoms were evident when 200 lbs. of K_2O/A. or more was used.

Winter killing of alfalfa was reduced by the application of 200 lbs. of K_2O or more at least once in the four year rotation.

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

A. C. Caldwell, E. C. Seim, G. W. Rehm.

The purpose of this experiment, started in the fall of 1951, is to study the long time effects of lime on (1) the yields of some common crops and (2) on the physical and chemical properties of the soil. Treatments were 0, 3, 6, 12, and 24 tons of dolomitic lime per acre, replicated 4 times. A rotation of corn, oats, and 2 years of alfalfa was set up. Each year corn and oats have received 200 pounds of 5-20-20 per acre. The alfalfa has received P and K as needed according to soil tests. Since 1959 soybeans have replaced one year of alfalfa in the rotation. The beans receive 100 pounds of 5-20-20 per acre as a starter fertilizer.

In 1960, molybdenum (as $(NH_4)_2 MoO_4$) was applied at the rate of 8.7 ounces per acre on one of the check plots in each replicate.

The effect of the different treatments on the 1964 yields are shown in the Table. No yields were measured for the corn replicates because of drouth damage. As in past years the most striking response to the lime or molybdenum treatment has been in the yield of alfalfa hay from 2 cuttings. These increases are significantly different at the 1% level. All of the rates of lime application were about equally effective in increasing the alfalfa yield. Molybdenum alone was also significantly effective in increasing the yield of alfalfa but as in 1962 and 1963 the yield increas was not as great as those obtained by liming.

Oat yields were increased by all lime treatments and by molybdenum but these increases were not significant at the 5% level. This has generally been the pattern in past years.

There were no major effects on the yield of soybeans as has been the case in 1963 and previous years.

Effect of lime and molybdenum on yields of alfalfa, oats, and soybeans.
(Rosemount, 1964).

Lime Treatment Tons/A.	Alfalfa Tons/A.	Alfalfa Diff.	Oats Bu/A.	Oats Diff.	Soybeans Bu/A.	Soybeans Diff.
0	1.33	---	43.0	---	14.1	
3	3.16	+1.83	53.7	+10.7	16.3	+2.2
6	2.69	+1.36	51.2	+ 8.2	14.6	+ .5
12	2.84	+1.51	54.5	+11.5	18.2	+4.1
24	3.08	+1.75	55.5	+12.5	14.4	+ .3
0 + 8.7 oz. Mo/A.	2.38	+1.05	47.1	+ 4.1	16.8	+2.7
Std. error	.30		4.7			1.8
lsd. (.05)		.89	14.1			5.5
lsd. (.01)		1.23				
hsd. (.05)		1.36	21.5			7.1
hsd. (.01)		1.72				

The effect of lime on the chemical properties of soils 13 years after application.

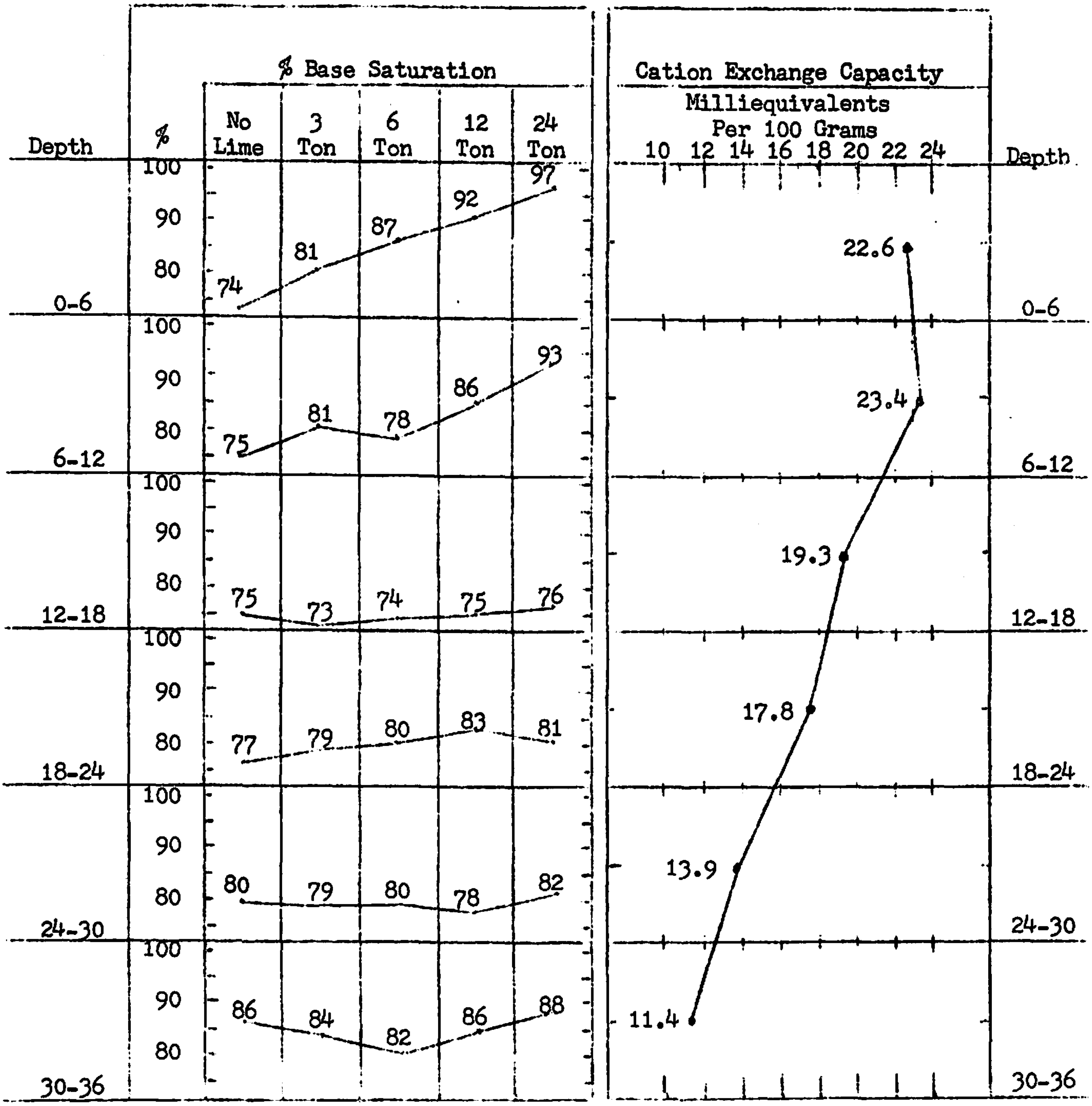
A. C. Caldwell and R. C. Munter

This is one phase of the long time lime study at Rosemount as outlined in the preceding pages of this report. The purpose of this phase of the experiment is to study the effect of various lime treatments on the chemical properties of the soil. The treatments were 0, 3, 6, 12, and 24 tons of dolomitic limestone per acre.

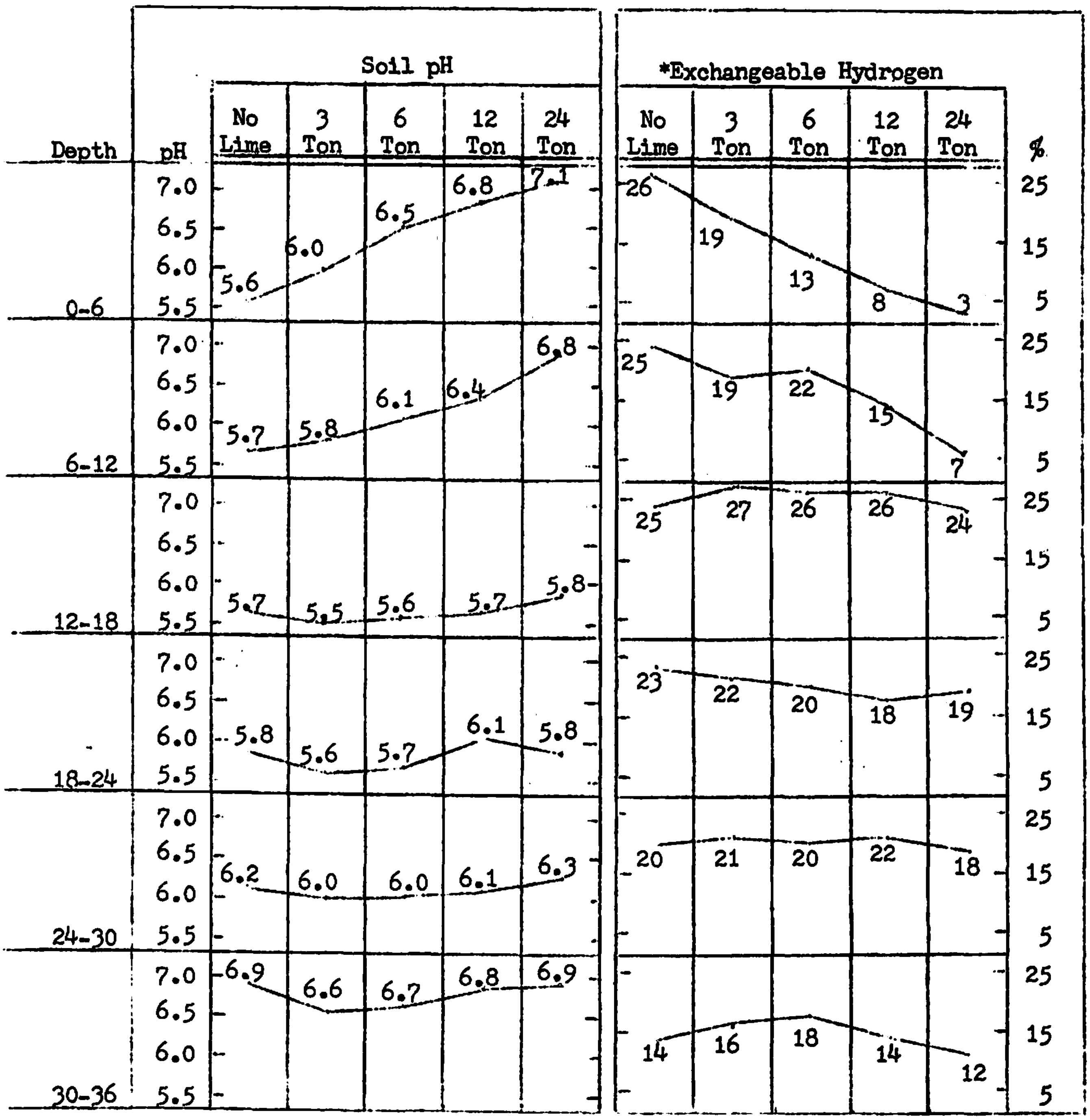
Dolomitic limestone was applied in the fall of 1951. In the fall of 1963, soil samples were obtained in duplicate from all 4 replicates of the various treatments. Soil samples were obtained at 6 depths to a depth of 36 inches. They were then analyzed for exchangeable calcium, magnesium, potassium, hydrogen; pH, phosphorous, organic matter, and total cation-exchange-capacity. The soil type is Port Byron silt loam; a well drained soil having a deep silt loam profile.

The effect of limestone on various chemical properties is represented by figures 1, 2, and 3. Exchangeable Calcium, Hydrogen, and pH show a good relationship to the corresponding lime treatments. There was no change in the amount of exchangeable magnesium. The total cation-exchange-capacity was determined only on the 0 treatment, or check plot. The exchange-capacity decreased with depth. This was because of the loss of organic matter content and the presence of material coarser than silt loams in some profiles below 24 inches.

Total Cation Exchange Capacity From Non-treated Soil, and the Effect of Lime on Percent Base Saturation

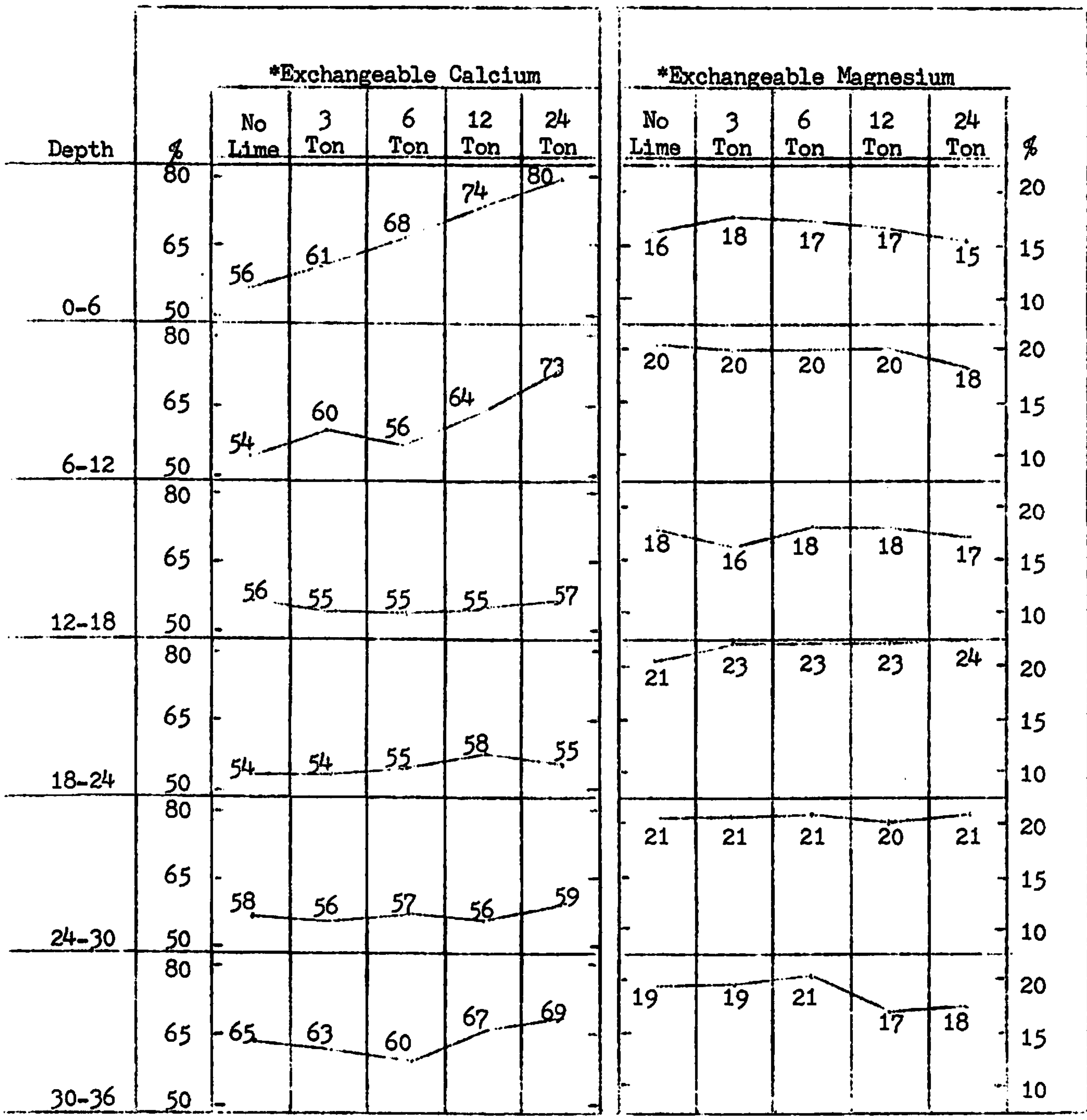


Effect of Lime on Soil pH and Exchangeable Hydrogen
Rosemount



*Percentage of Total Exchangeable Cations (H, K, Ca, Mg)

Effect of Lime on Exchangeable Calcium and Magnesium in Soil
Rosemount



*Percentage of Total Exchangeable Cations (H, K, Ca, Mg)

Field Research

E. C. Seim

In 1964 the alfalfa experiments established in 1962 were continued as were the experiments with corn, soybeans, and alfalfa following corn. New areas were devoted to studies on the effect of sulfur on yield and sulfur content of barley, oats and sunflowers.

Alfalfa

The yields of alfalfa in 1964 and the sulfur content of sulfur in the tissue are reported in Tables 1-4. Yields and sulfur content for the two previous years have been reported in Sulfur Report No. 1, 2, 3, and 4. This experiment compares the effects of annual applications of three rates of elemental sulfur (25, 50, 100 lbs. S/acre), and a 50 lbs. S/acre application of gypsum with a control (0 lbs. S/acre). A similar experiment including a heavy gypsum treatment (1000 lbs. S/acre) was treated only upon initiation of the experiment so that information regarding the residual effec of the various sulfur bearing materials at different rates of application might be obtained. All plots received complete applications of phosphorus and potassium according to soil tests at the start of the experiment. Borax (20 lbs./acre) was applied after the first cutting in 1962. Additional potassium has been topdressed as needed.

Two cuttings of alfalfa were obtained in 1964. A third cutting might have been obtained if the excellent fall growing conditions could have been forecast. The early growth of the alfalfa was stopped by drought. The first cutting was taken at this point. Treated plots consist of almost 100% alfalfa. The checks, however, have such a sparse stand of alfalfa that some grass and weeds have again become established on them.

The effect of the sulfur on the yield of alfalfa is quite striking. Treated plots produce 3 times as much alfalfa hay as the check plots. The increase in yield has been achieved on the residual plots as well as on those receiving annual applications of sulfur materials. On the residual study the heavier applications of elemental sulfur gave somewhat higher yields than the 25 lbs. per acre rate. These increases wer still not statistically different, however. Neither was there any statistical differen in the yield between the two gypsum application rates.

Table 1. Effect of annual applications on sulfur-bearing materials on the yield of Alfalfa

Material	Rate lbs. S/acre	Yield 1st Cut. Tons/acre	2nd Cut. Tons/acre	Total Tons/acre
None	0	.39	.31	.69
Sulfur	25	1.13	1.26	2.39
Sulfur	50	1.19	1.26	2.45
Sulfur	100	1.15	1.22	2.36
Gypsum	50	1.11	1.16	2.27
lsd (.05)		.27	.26	.49
(.01)		.37	.36	.67
hsd (.05)		.40	.40	.73
(.01)		.50	.50	.91

Table 2. Residual effect of sulfur-bearing materials on the yield of three year old alfalfa.

Material	Rate lbs. S/acre	Yield 1st Cut. Tons/acre	2nd Cut. Tons/acre	Total Tons/acre
None	0	.32	.44	.75
Sulfur	25	1.09	.96	2.04
Sulfur	50	1.12	1.09	2.21
Sulfur	100	1.26	1.21	2.49
Gypsum	50	1.31	1.19	2.51
Gypsum	1000	1.26	1.13	2.39
lsd (.05)		.28	.24	.50
(.01)		.38	.33	.67
hsd (.05)		.42	.37	.74
(.01)		.51	.45	.91

Table 3. Effect of annual applications of sulfur-bearing materials on the sulfur content of alfalfa.

Material	Rate lbs/S/acre	Sulfur Content of Tissue (%) 1962 Young	1962 Mature	1963 1st Cut.	1963 2nd Cut.	1964 1st Cut.	1964 2nd Cut.
None	0	.192	.133	.220	.236	.167	.192
Sulfur	25	.221	.165	.313	.358	.231	.308
Sulfur	50	.242	.175	.360	.425	.274	.377
Sulfur	100	.283	.192	.403	.444	.336	.423
Gypsum	50	.341	.238	.457	.416	.323	.424
lsd (.05)		.024	.018	.046	.032	.042	.043
(.01)		.032	.024	.063	.043	.058	.058
hsd (.05)		.036	.027	.072	.048	.064	.065
(.01)		.045	.036	.089	.060	.079	.080

Table 4. Residual effect of sulfur-bearing materials on the sulfur content of alfalfa.

Material	Rate lbs/S/acre	Sulfur Content of Tissue (%) 1962 Young	1962 Mature	1963 1st Cut.	1963 2nd Cut.	1964 1st. Cut.	1964 2nd Cut.
None	0	.194	.139	.221	.304	.167	.178
Sulfur	25	.228	.164	.236	.285	.188	.209
Sulfur	50	.256	.181	.308	.381	.226	.250
Sulfur	100	.285	.191	.319	.377	.278	.292
Gypsum	50	.337	.220	.332	.358	.243	.224
Gypsum	1000	.392	.275	.489	.466	.378	.414
lsd (.05)		.027	.018	.048	.089	.023	.037
(.01)		.037	.025	.065	.120	.045	.051
hsd (.05)		.039	.028	.073	.132	.050	.056
(.01)		.048	.034	.089	.162	.061	.069

The tables on the sulfur content of the alfalfa show greater differences between the rates and types of sulfur materials than is reflected in the yields. For annual applications 25 lbs. of sulfur per acre in the elemental form raised the sulfur content of the alfalfa significantly. Each increasing rate of application increased the sulfur content of the tissue. The 100 lbs./acre elemental sulfur application now produces alfalfa with the same sulfur content as alfalfa supplied with 50 lbs. of sulfur annually as gypsum.

The data for the residual study seems to indicate that all of the sulfur materials and rates produced a peak sulfur supply in 1963 (the year after application). The levels of sulfur in the 1964 cuttings has dropped below the 1963 levels in all treatments. Although gypsum (50 lbs. S/acre) produced forage with a higher sulfur content than elemental sulfur in the year of application, in 1964 the 50 lbs. per acre rate of elemental sulfur has been equally as effective as 50 lbs. of sulfur as gypsum in supplying sulfur to the alfalfa. The 100 lbs. per acre rate of elemental sulfur is now superior to 50 lbs. of sulfur as gypsum in supplying sulfur to the plants. In 1964 only the heavy gypsum application continued to supply sulfur at levels which produced forage with sulfur contents greater than .3%.

In 1963 the area which had been used in 1962 to check the effect of various sulfur bearing materials on corn was planted to alfalfa. No further sulfur applications were made to those plots which had received elemental sulfur, 16-20-0-S, or K_2SO_4. The plots which had initially received 10 lbs. S/acre as gypsum were treated with an additional 50 lbs. S/acre as gypsum. In August of 1963 a trace element mixture containing Zn, Cu, Mn, Mo, and Fe was applied to those plots which initially had received the Cominco product containing Zn, Mn, N, and S. Sulfur applied as part of the trace element salts was 15 lbs. per acre. No harvest was taken of the young alfalfa in 1963. In 1964 the early growth was severely hit by drought. Consequently, no yields were recorded. The field was clipped and sprayed with Dalapon to control quack grass. Treatment differences began to appear almost immediately in the new growth. By the time of the second cutting the checks were easily visible in every replication. In the plots which had originally received 10 lbs. S/acre as K_2SO_4 in the corn row the position of these old corn rows were clearly outlined by improved growth of the alfalfa. As all of the plots had received 300 lbs. of K_2O per acre before planting the alfalfa, it seems unlikely that this effect could be due to the additional potassium. Best growth was recorded on those plots which had received the trace element sulfur-treatment.

Yields of this second cutting and the percent sulfur in the tissue are reported in Table 5. The residual effect of the sulfur applied on the corn has significantly increased the second cutting yield of alfalfa. Those plots which received additional sulfur treatments have not produced more alfalfa than the residual treatments. The additional treatments have, however, increased the percent sulfur in the alfalfa tissue.

Barley-Oats

Trials were again conducted in 1964 to study the effects of sulfur-bearing materials on barley and oats. Earlier barley and oat trials were reported in reports 1, 2, and 4. In 1964 the sulfur treatments used were 10 lbs. of sulfur per acre as elemental sulfur, sodium sulfate, and gypsum. Treatments were applied in the row with a sulfur-free starter fertilizer.

The gypsum and elemental sulfur treatments were duplicated on the barley experiment using radioactive gypsum and elemental sulfur (tagged with S^{35}). Plants grown on these plots were used to measure "A" values and the percentage of sulfur in the tissue which came from the fertilizer treatment. The methods and results of this part of the barley study are reported elsewhere in this paper.

The barley yields in 1964 averaged about 40 bushels per acre, (Table No. 6). Only the non-radioactive gypsum treatment gave a significant yield increase. Although the sodium sulfate and radioactive gypsum treatments did not produce yield increases, they increased the sulfur content of the whole plant and of the grain on the same order as the gypsum treatment. The fact that elemental sulfur did not increase the yield of barley nor the percentage of sulfur in the plants or grain seems to indicate that this material which needs to undergo oxidation to sulfate before it is readily available to the plant is not as effective as gypsum and sodium sulfate for short cool season crops such as barley. This disadvantage could perhaps be overcome by applying the sulfur to the previous crop so that sufficient oxidation will have occurred by the following spring.

The oats showed no significant yield response to any of the sulfur materials (Table No. 7). Gypsum and sodium sulfate significantly increased the percent sulfur in the whole plant but only the sodium sulfate treatment significantly altered the percent sulfur in the oat grain.

The grain from the barley trial was checked for kernel size and crude protein to determine if the sulfur treatments had any effect on quality. The data is inconclusive but interesting (Table No. 8). Gypsum and elemental sulfur slightly decreased the percent of thin kernels and increased the percent of plump kernels. Sodium sulfate, on the contrary, seems to have had an adverse effect upon kernel size, as this treatment produced 2.7% fewer plump kernels than the untreated plots. The slight decrease in the quality of the grain from the plots which had received radioactive treatments may indicate that these treatments were not free of harmful effects despite the low level of radioactivity with which these materials were tagged. Crude protein of the barley grain as measured by total Kjeldahl nitrogen showed a slight but consistent increase with sulfur application.

Corn and Soybeans

In 1964 corn and soybeans were replanted on the same plots which were in corn and beans in 1963. No additional applications of sulfur were made. Treatments on the corn trial consisted of four levels of sulfur (0, 5, 15, 25 lbs.S/acre) applied as sodium sulfate in 1963. The soybean treatments applied in 1963 were (1) no sulfur, (2) 25 lbs. of sulfur per acre as elemental sulfur, (3) 50 lbs. of sulfur per acre as elemental sulfur, and (4) 50 lbs. of sulfur per acre as gypsum.

Table 5. Effect of sulfur-bearing materials on the yield and sulfur content of alfalfa following corn.

Material	Rate lbs/S/acre	Date of Application	Yield (2nd Cutting) tons/A	S in Tissue %
Check	0		.38	.198
Sulfur	25	1962	.65	.215
Sulfur	50	1962	.67	.275
Sulfur	100	1962	.65	.306
Gypsum	60	10 lbs. S in 1962	.64	.345
		50 lbs. S in 1963		
K_2SO_4	10	1962	.64	.233
16-20-0-S	10	1962	.53	.2222
Trace-S	25	10 lbs./A Zn-Mn-N-S in 1963	.68	.305
		15 lbs. S in Trace El. mix. 1963		
lsd. (.05)			.20	.043
(.01)				.058
hsd. (.05)			.32	.068
(.01)				.082

Table 6. Effect of sulfur-bearing materials on the yield and sulfur content of barley.

Material	Rate lbs.S/acre	Yield bu./acre	Sulfur whole plant %	Content grain %
None	0	39.0	.103	.138
Gypsum	10	44.7	.124	.150
Elem. Sulfur	10	39.8	.109	.142
Na_2SO_4	10	40.6	.131	.155
Gypsum-S^{35}	10	41.0	.119	.155
Elem. Sulfur-S^{35}	10	37.8	.105	.139
lsd. (.05)		4.2	.010	.007
(.01)			.013	.009
hsd. (.05)		6.3	.015	.010
(.01)			.018	.012

Table 7. Effect of sulfur-bearing materials on the yield and sulfur content of oats.

Material	Rate lbs.S/acre	Yield bu./acre	Sulfur whole plant %	Content grain %
None	0	53.5	.124	.173
Gypsum	10	51.6	.142	.177
Elem. Sulfur	10	51.5	.126	.175
Na_2SO_4	10	55.5	.154	.194
lsd. (.05)		N.S.	.011	.007
(.01)			.015	.009
hsd. (.05)			.015	.009
(.01)			.019	.012

The corn yields for 1964 and the percent sulfur in the tissue and grain are reported in Table 9. There were no significant differences in the yields from the several levels of sulfur application. It may be noteworthy that the plant population in 1964 was double that of 1963 (19,400 plants per acre). This population was contingent upon the availability of irrigation facilities in 1964. Irrigation was not available to the 1964 crop because of numerous unavoidable delays and although the corn plants never suffered serious physiological damage there were indications that plant nutrient uptake and ear development were impaired by moisture deficiency.

No significant differences were found in the percent sulfur in the 6th leaf tissue samples or in the grain. The constancy of the sulfur level in both tissue and grain is of interest because it poses the problem of how the plant regulates sulfur uptake and why alfalfa differs in this respect from corn.

Soybean yields are reported in Table 10. As with the corn, the yields were curtailed by the effects of drought. No significant increases were obtained by sulfur fertilization. The percent sulfur in the soybean grain indicate that soybeans like corn may possess a mechanism to regulate the uptake of sulfur. Soybeans, however, contain a much higher amount of sulfur than corn.

Sunflowers

Sunflowers treated with 50 lbs. of sulfur per acre as gypsum were compared with untreated plants. The variety of sunflowers was Mingren. Treatments were replicated six times. In 1964 the yield of sunflower seed (Table 11) was not altered by the sulfur treatment.

Table 8. Effect of sulfur-bearing materials on the kernel size and protein content of barley.

Material	Rate lbs.S/acre	Kernel % thins	Size T plump.	Protein %
None	0	34.3	18.3	11.4
Gypsum	10	33.7	19.1	11.6
Elem. Sulfur	10	31.3	19.8	11.6
Na_2SO_4	10	34.8	15.5	11.5
Gypsum-S^{35}	10	36.5	15.8	
Elem. Sulfur-S^{35}	10	35.7	16.2	

Table 9. Effect of sulfur on the yield and sulfur content of 2nd year corn.

Material	Rate lbs.S/acre	Yield bu./acre	Sulfur in Tissue 6th leaf	grain
None	0	79.2	.188	.135
Na_2SO_4	5	78.4	.196	.136
Na_2SO_4	15	79.9	.190	.136
Na_2SO_4	25	75.5	.192	.138
		N.S.	N.S.	N.S.

Table 10. Effect of sulfur-bearing materials on the yield and sulfur content of soybeans.

Material	Rate lbs.S/acre	Yield bu./acre	% S in Grain %
None	0	19.8	.322
Sulfur	25	20.2	.321
Sulfur	50	19.1	.325
Gypsum	50	19.4	.327
		N.S.	N.S.

Table 11. Effect of sulfur on the yield of sunflower seed.

	Gypsum (50 lbs.S/acre) lbs./acre	Check lbs./acre
	1443	1226
	1438	1199
	1150	1263
	1042	1047
	1115	1216
	1111	1424
Total	7299	7375
Ave.	1217	1229

Sulfur "A" Values

For the past three years several experiments have been conducted to compare the effectiveness of various sulfur-bearing fertilizers. In these experiments yield increases and the percentage of total sulfur in the plant tissue at various stages of growth were the criteria used to measure effectiveness.

Another measure of the efficiency of a fertilizer material is the availability of the nutrient element in the fertilizer relative to the availability of the total amount of the nutrient present in the soil mass. This may be expressed as the percent of the nutrient in the plant which came from the fertilizer or by the "A" value as defined by Fried and Dean[1].

In 1964 gypsum and elemental sulfur tagged with radioactive S-35 were used to determine "A" values for the Todd sandy loam. Gypsum and elemental sulfur were tagged with sulfur-35 in the laboratory according to the method of Jordan and Baker[2]. The radioactive materials were applied in the row with a starter fertilizer application of 100 lbs. of 12-32-16 at the time of seeding the barley. Samples of the whole plants and of the grain were taken at maturity and analyzed for total sulfur. Yields of grain were also recorded at this time. The samples were digested by the nitric-perchloric acid method. Sulfur was precipitated as barium sulfate, plancheted on fritted stainless steel discs and counted in a proportional flow counter. Samples were counted for a period of time necessary to reduce the counting error to 2% or less.

The percentages of sulfur in the mature barley samples which came from the tagged gypsum or elemental sulfur are recorded in Table 12. The "A" values are recorded in Table 13. The average percentage of the total sulfur in the barley grain which came from the gypsum was 31.4%. When elemental sulfur was used the per cent was 8.9%. These results are not surprising as it is well known that the

1. Fried, M. and Dean, L. A. A concept concerning the measurement of available soil nutrients. Soil Sci. 73: 263-271, 1962.

2. Jordan, J. V. and Baker, G. O. Studies in N. Idaho soils using radiosulfur. Soil Sci. 88: 1-6, 1959.

Table 12. Percentage of plant sulfur from applied fertilizer

Plot	Gypsum 10# S/acre Whole plant %	Grain %	Elemental Sulfur 10# S/acre Whole plant %	Grain %
1	37.2	28.0	13.9	7.6
	34.5	31.3	13.9	9.0
2	25.7	30.7	9.3	7.6
	35.4	28.2	11.1	5.5
3	30.4	19.3	6.8	9.6
	33.6	35.3	7.8	10.4
4	32.3	35.4	9.3	6.7
	25.4	33.5	13.9	8.1
5	27.5	35.4	15.0	12.1
	31.7	28.5	16.0	10.7
6	38.9	35.3	8.6	8.4
	42.5	35.3	9.5	10.5
Average	32.9	31.4	11.3	8.9

Table 13. Sulfur "A" values for mature barley grown in the field on a Todd sandy loam

Plot	"A" value equivalent to 10# S/acre as Gypsum Whole plant lbs. S/acre	Grain lbs. S/acre	"A" value equivalent to 10# S/acre as El. S. Whole plant lbs. S/acre	Grain lbs. S/acre
1	16.88	25.71	61.94	121.58
	18.98	21.95	61.94	101.11
2	28.91	22.57	97.53	121.58
	18.25	25.46	80.09	171.82
3	22.89	41.81	137.06	94.17
	19.76	18.33	118.20	86.15
4	20.10	18.25	97.53	139.25
	29.37	19.85	61.94	113.46
5	26.36	18.25	56.67	72.64
	21.55	25.09	52.50	83.46
6	15.71	18.33	106.28	109.05
	13.53	18.33	95.26	85.24
Average	21.02	22.83	85.58	108.29

sulfate ion is the primary form of sulfur taken up by the plant. In gypsum the sulfur is in the sulfate form and no transformation need occur before the fertilizer can be utilized by the plants. Elemental sulfur however needs to undergo oxidation to the sulfate form before it is readily available to the plants. Although the utilization of the elemental form of sulfur was much less than the utilization of the gypsum form of sulfur the plants did not suffer from visible signs of sulfur deficiency nor was there any significant decrease in grain yield. It is interesting to note however, that with elemental sulfur the difference between the percent of sulfur in the grain and in the whole plants approached significance. If the plants were functioning at a minimum level of sulfur nutrition, we could expect most of the sulfur to be immediately incorporated into organic compounds including protein. Very little or none would be mobile if an actual sulfur deficiency occurred. Later, at the time of grain development the large root system could be expected to take up a larger percentage of soil sulfur relative to uptake from the fertilizer band. The answer may also lie in the effect of moisture on the oxidation rate of the elemental sulfur.

The Todd sandy loam has an "A" value of 22.8 lbs. of sulfur per acre equivalent in biological availability to barley as 10 lbs. of sulfur as gypsum. There are 108.3 lbs. of sulfur per acre equivalent in biological availability to 10 lbs. of elemental sulfur per acre. Neither of these figures can be considered low as is evidenced by the normal check yields obtained. Part of this available sulfur present in each "A" value may have been contributed to the soil by atmospheric fallout in rain, snow, and dust or by direct adsorption of SO_2 by the soil and plants. The greater variation among the elemental sulfur "A" values is probably a reflection of different localized conditions such as temperature, moisture, and microbical spectrum which could affect the oxidation of the sulfur to the sulfate.

If the "A" value for gypsum is assigned a value of 100% availability, then for a 10 lb. application of elemental sulfur only 2.03 lbs. will be equally as available as the sulfur in a 10 lb. application of gypsum. Therefore, in this experiment elemental sulfur was only 20.3% as available as the sulfur in gypsum.

Leaching of SO_4-S

A new leaching study was established in the spring of 1964. Sulfur treated plots received 200 lbs. of sulfur per acre as gypsum. Sweet corn was grown on both treated and untreated plots. An analysis of soil samples taken from these plots at 6 inch intervals to a depth of 36 inches on September 26th is now in progress.

Sulfur in the Atmosphere

The collection and analysis of rainwater and snowfall for sulfur and the measurement of the SO_2 content of the atmosphere by the lead peroxide "candle" method has continued. At the end of September, 1964, 24 consecutive months of measurements were completed for each of the four locations where samples are taken. The data recorded for the months May to October, 1964 are reported in Tables 14 and 15. Previous monthly data has been reported in reports 1, 2, 3, and 4. Table 16 reports the sulfur in precipitation totals for the two year period beginning October 1st, 1962. Table 17 presents the atmospheric sulfur totals for the same period.

For the two year period the average annual amount of sulfur brought to earth in rain and snow was about four times as great at St. Paul as at Park Rapids. Amounts recorded for Lamberton and Duluth were about 1.8-2.2 times as great as Park Rapids respectively.

The amount of sulfur absorbed annually by the lead peroxide coated surface averaged over six times greater at St. Paul than at Park Rapids. The average amount absorbed at Duluth was almost twice as great as Park Rapids. The average amount absorbed annually at Lamberton, Minnesota was similar to the amount absorbed at Park Rapids.

Table 14. Sulfur in the atmosphere and sulfur in precipitation at Park Rapids and Lamberton, Minnesota from May 1964 to October 1964.

Period	Park Rapids			Lamberton		
	Rainfall (inches)	S in Rainfall (lbs S/A)	SO_2 in atmosphere (lbs S/A)	Rainfall (inches)	S in Rainfall (lbs S/A)	SO_2 in atmosphere (lbs S/A)
May	1.28	0.31	0.40	3.14	0.76	0.25
June	8.06	0.66	0.29	1.65	0.49	0.22
July	3.20	0.22	0.21	3.17	0.82	0.20
August	4.52	0.52	0.22	3.80	0.77	0.22
Sept.	3.42	0.34	1.38	3.89	0.73	0.36
Oct.	0.26	0.46	0.22	0.50	0.32	0.31
TOTAL	20.74	2.51	2.72	16.15	3.89	1.56

Table 15. Sulfur in the atmosphere and sulfur in precipitation at St. Paul and Duluth, Minnesota from May 1964 to October 1964.

	St. Paul			Lamberton		
Period	Rainfall (inches)	S in Rainfall (lbs S/A)	SO_2 in atmosphere (lbs S/A)	Rainfall (inches)	S in Rainfall (lbs S/A)	SO_2 in atmosphere (lbs S/A)
May	2.56	1.25	1.39	5.61	1.03	0.54
June	2.03	0.46	1.78	3.51	2.12	0.29
July	2.00	1.38	1.70	2.26	.58	0.38
August	6.28	2.56	0.89	7.16	1.89	0.33
September	4.47	1.81	1.38	7.83	0.54	0.44
October	0.60	0.69	2.29	0.54	0.26	0.47
TOTAL	17.94	8.15	9.43	26.91	6.42	2.45

Table 16. Sulfur in precipitation.

Location	Park Rapids Precip. inches	Park Rapids S lbs/A.	St. Paul Precip. inches	St. Paul S lbs/A	Duluth Precip. inches	Duluth S lbs./A	Lamberton Precip. inches	Lamberton S lbs/A
(Oct. '62- Sept. '63)	19.67	3.10	20.74	13.26	19.18	6.91	26.56	6.38
(Oct. '63- Sept. '64)	27.78	4.37	23.75	14.70	36.37	9.49	22.08	6.84
24 Month Total	27.45	7.47	44.49	27.96	55.55	16.40	48.64	13.21
Yearly Average	23.72	3.74	22.24	13.98	27.77	8.20	24.32	6.60

Table 17. Sulfur in the atmosphere.

Location	Park Rapids SO_2 lbs./A	St. Paul SO_2 lbs./A	Duluth SO_2 lbs./A	Lamberton SO_2 lbs./A
(Oct. '62- Sept. '63)	6.50	33.72	9.33	5.58
(Oct. '60- Sept. '64)	3.43	34.11	5.92	3.02
24 Month Total	9.93	67.83	15.25	8.60
Yearly Average	4.96	33.92	7.63	4.30

Sulfur Status of Minnesota Soils

G. W. Rehm

In May of 1964 a study of the sulfur status of Minnesota soils was started. For this study seventy nine samples were collected from widely scattered sites in Minnesota. These soils are being examined in two ways. In one instance the sulfur oxidizing power is being investigated; in the other case the sulfur supplying power to plants is under examination.

Sulfur Oxidation

Of the samples collected, fifty two were selected for this study. These samples were taken from surface horizons and represent a wide range in pH (from 4. 3 to 7. 7), organic matter content, and texture classes.

Procedure:

For this experiment 100 grams of air dried soil was mixed with 100 ppm of elemental sulfur (100 mesh) in a 1/2 pint polyethylene box. The treatments were replicated three times. Water was added to the boxes to maintain a moisture level of 1/2 field capacity. The boxes were aired every three days and water was added once a week to maintain the moisture level. At the end of 30, 60 and 90 days the soils were analyzed for SO_4-S by extraction with 0. 5M ammonium acetate in 0. 25N acetic acid according to the procedure of Bardsley and Lancaster.[1] The pH readings were also taken at the time of extraction.

[1]Bardsley, C. E. and Lancaster, J. D. Determination of Reserve Sulfur and Soluble Sulfates in Soils. Proc. Soil Sci. Soc. Am. 24:265-268. 1960.

Results and Discussion:

At the present time analyses are completed for 31 of the 52 soils in this study. The data are presented in Tables 18, 19 and 20. On the basis of studies completed at this time it is generally true that the added sulfur was more completely oxidized in the sands, loams, and silt loams than in the clay loams and silty clays.

In 90% of sandy soils more than 55% of the sulfur was oxidized at the end of 90 days. Except for the Dakota soil, more than 75% of the sulfur was oxidized at the end of 90 days in those soils with a pH greater than 6. 0. The Isanti soil with a pH of 4. 3 oxidized only 40. 4% of the sulfur. Thus in the sandy soils there may be a relationship between soil pH and the amount of sulfur oxidized. However, there seems to be no relationship between the organic matter content of the sandy soils and sulfur oxidation.

With the loams and silt loams more than 55% of the added sulfur was oxidized after 90 days in 75% of the soils studied. In 37% of the soils in these textural classes more than 70% of the sulfur was oxidized. With these textural classes there does not seem to be a relationship between sulfur oxidation and soil pH. In the Adolph soil with a pH of 5. 2, 95. 7% of the sulfur was oxidized; in the Marna soil of pH 7. 2 only 39% of the sulfur was oxidized. As with the sandy soils, there appears to be no correlation between sulfur oxidation and the organic matter content of the soils in this group.

It is interesting to note that more than 100% oxidation occurred in the Winger soil. A possible explanation is that the microbial activity may have been stimulated by the added sulfur thus causing mineralization of the organic matter. Since this soil is extremely high in organic matter, the excess sulfur may have come from this fraction.

In the clay loam and silty clay textural classes more than 55% of the sulfur was oxidized in 43% of the soils studied. There were no instances where more than 70% oxidation occurred. If the Vallers soil is excluded, there again appears to be a relationship to soil pH. Greater oxidation occurred in the soils with a pH greater than 6. 0.

When the analysis is completed on the other soils in this study, we may be able to draw more definite conclusions.

Table 18. The Oxidation of Elemental Sulfur in Loam Sands and Sandy Loams.

Soil Type	pH	% O. M.	Incubation Time (days) 0	30 OS added	30 100 ppm S added	30 S Oxid.	60 OS added	60 100 ppm S added	60 S Oxid.	90 OS added	90 100 ppm S added	90 S Oxid.
			ppm S									
Bock Sandy Loam	5.7	5.1	12.2	25.7	65.8	40.1	26.9	83.6	56.7	33.3	100.4	67.1
Chetek Loamy Sand	5.7	1.8	14.2	11.9	40.0	28.1	13.8	57.4	43.6	11.4	68.5	57.1
Dakota Sandy Loam	6.6	2.9	31.7	32.9	58.3	25.4	38.6	86.7	48.1	37.4	93.1	55.7
Grygla Loamy Sand	7.6	3.5	17.3	22.4	54.6	32.2	22.4	64.4	42.0	31.7	109.6	77.9
Hiwood Loamy Sand	6.2	2.2	20.0	22.3	59.2	36.9	15.8	78.8	63.0	17.8	93.0	75.2
Isanti Loamy Sand	4.3	8.5+	10.7	34.8	63.7	28.9	38.7	85.8	47.1	39.6	80.0	40.4
Lino Loamy Sand	5.0	4.0	6.6	24.3	57.9	39.6	24.4	67.9	43.5	28.2	84.4	56.2
Sverdrup Sandy Loam	6.8	3.0	13.8	20.5	58.0	37.5	25.0	89.0	64.0	27.8	107.2	79.4
Swatora Loamy Sand	5.5	2.8	22.8	24.7	54.4	29.7	27.5	81.6	54.1	29.0	94.3	65.3
Ulen Sandy Loam	7.4	5.2	21.5	18.2	90.8	72.6	17.1	94.3	77.2	22.0	110.6	88.6

Table 19. The Oxidation of Elemental Sulfur in Loams and Silt Loams.

Soil Type	pH	% O. M.	Incubation Time (days): 0	30: OS added	30: 100ppm S added	30: S Oxid.	60: OS added	60: 100ppm S added	60: S Oxid.	90: OS added	90: 100ppm S added	90: S Oxid.
			ppm S									
Adolph Loam	5.2	8.5+	31.5	44.9	87.4	42.5	60.4	125.9	65.5	54.8	150.5	95.7
Bearden Silt Loam	7.6	6.1	45.3	71.4	85.9	14.5	72.9	99.9	27.0	75.3	152.3	77.0
Beltrami Loam	6.8	4.8	9.3	15.9	32.2	16.3	39.0	109.8	70.8	89.0	163.8	74.8
Fayette Silt Loam	6.1	8.5+	12.7	23.2	53.8	30.6	27.0	74.7	47.7	27.4	91.2	63.8
Marna Silt Loam	7.2	7.0	37.1	43.3	71.3	28.0	50.5	92.2	41.7	62.7	101.7	39.0
Moody Silt Loam	7.1	4.9	16.3	19.0	56.8	37.8	20.9	75.1	54.2	28.4	85.4	57.0
Mora Loam	6.6	3.3	12.7	41.8	79.8	38.0	39.0	97.2	58.2	66.0	132.8	66.8
Nebish Silt Loam	6.4	3.8	24.2	30.3	71.4	41.4	34.1	99.7	65.6	38.8	112.0	73.2
Onamia Loam	6.0	2.3	5.6	22.7	63.0	40.3	20.8	80.2	59.4	24.4	96.9	72.5
Parnell Silt Loam	7.3	8.5+	64.3	92.0	110.0	18.0	101.7	143.5	41.8	145.2	214.8	69.6

Table 19 (cont'd)

Soil Type	pH	% O. M.	Incubation Time (days) 0	30 OS added	30 100ppm S added	30 S Oxid.	60 OS added	60 100ppm S added	60 S Oxid.	90 OS added	90 100ppm S added	90 S Oxid.
			ppm S									
Port Byron Silt Loam	5.7	5.2	30.6	29.0	46.0	17.0	26.3	62.6	36.3	28.8	73.5	44.7
Shooks Loam	5.5	2.8	12.4	19.1	42.8	23.7	21.8	63.5	43.7	26.0	85.7	59.7
Tama Silt Loam	6.9	5.0	7.6	25.7	46.0	20.3	32.6	55.3	22.7	29.6	76.4	46.8
Wadena Loam	5.6	5.5	10.2	24.5	46.6	22.1	28.6	57.3	28.7	25.1	60.3	35.2
Winger Silt Loam	7.9	8.5+	86.0	96.0	208.4	112.4	118.0	242.5	124.5	136.3	261.3	125.0
Zim Loam	5.5	6.1	26.8	34.4	57.6	23.2	39.0	89.4	50.4	42.0	102.8	60.8

Table 20. The Oxidation of Elemental Sulfur in Silty Clays and Clay Loams.

			Incubation Time (days)									
			0	30			60			90		
Soil Type	pH	%O. M.		OS added	100ppm S added	S Oxid.	OS added	100 ppm S added	S Oxid.	OS added	100ppm S added	S Oxid.
			ppm S									
Brickton Clay loam	5.4	6.4	37.8	30.8	50.7	19.9	37.4	69.8	32.4	45.6	86.6	41.0
Dalbo Clay loam	5.2	4.3	20.2	15.5	39.8	24.3	17.1	55.3	38.2	20.0	69.7	49.1
Kittson Clay loam	7.6	5.7	29.7	31.9	83.3	51.4	34.2	90.5	56.3	44.5	112.3	67.8
Nessel Clay loam	5.7	4.2	28.8	28.8	55.9	27.1	30.2	70.7	40.5	25.4	78.3	52.9
Rothsay Clay loam	7.1	6.7	27.3	26.2	75.9	49.7	28.3	89.6	61.3	37.3	98.6	61.3
Vallers Silty clay	7.5	5.5		256.7	280.0	23.3	244.2	266.7	22.5	301.5	339.7	28.2
Vienna Clay loam	6.5	5.6	13.4	26.0	45.3	19.3	22.2	60.2	38.0	24.9	84.3	59.4

Sulfur Supplying Power

As a result of studies during 1962, 63 and 64, we know that the certain crops grown on the Todd sandy loam will respond to the application of sulfur. (Reports 1, 2, 3 & 4). In 1964 a study was started to determine if other Minnesota soils were more so or just as sulfur deficient as the Todd sandy loam. For this study the seventy nine samples previously described were used.

For this study an airtight chamber 6 ft. x 6 ft. x 4 ft. was used to maintain a sulfur dioxide free atmosphere. Since the atmosphere of St. Paul, Minnesota contains a large amount of sulfur dioxide it is necessary to maintain a sulfur dioxide free atmosphere to accurately measure the sulfur power of soils.

Procedure:

To determine the sulfur supplying power of these soils 350 grams of soil were placed in a waxed cottage cheese carton 4 inches in diameter. Treatments consisted of sulfur as gypsum at 11#/A and no sulfur. These treatments were replicated three times for each soil. Grain sorghum was then planted at a rate sufficient to give 40 plants per cup. The cups were then placed into the chamber, the chamber was completely sealed and the plants were allowed to germinate and grow for 21 days. The cups were watered to field capacity every 3 or 4 days depending upon weather conditions. A nutrient solution was used at alternate watering times. This nutrient solution contained N, P, K, Ca, Mg, Zn, Fe, Mn and B in relatively the same concentrations as described by Hoagland.[2] At the end of 21 days the plants were

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[2]Hoagland, D. R. and Arnon, D. I. The water culture method for growing plants without soil. Calif. Ag. Exp. Sta. Cir. 347: 1950.

harvested, the dry weight taken and the total sulfur determined by wet digestion.

Results and Discussion:

At the present time analyses are completed for fifteen of the seventy nine soils. The data are presented in Table 21. It is interesting to note that plants grown on the Rockwood soil that received no sulfur were much lower in total sulfur than those grown on the Todd soil. This would indicate that this soil is even more sulfur deficient than the Todd. Plant grown on the control pots of the Lino, Moody, Sverdrup, Swatara, Ulen, and Wadena soils had relatively the same sulfur content as those plants grown on the Todd soil. This indicates that these soils may also be sulfur deficient or show a response to sulfur in the field.

It is also interesting to look at the sulfur content of the plants grown on the sulfur treated soils and then to compare the differences in percent sulfur between plants grown on the control and the sulfur treated soil. Plants grown on the Rockwood soil had a percentage difference of .505 compared to a difference of .328 for plants grown on the Todd soil. Soils which show differences of the same relative magnitude as the Todd are the Lino, Sverdrup and Swatara. Although plants grown on the Ulen soil were low in total sulfur, the plants grown on the sulfur treated soil did not show a great deal of an increase in the total sulfur content. Apparently something is limiting sulfur uptake from this soil.

The studies of sulfur oxidation and the sulfur supplying power of Minnesota soils are being continued. Other work in progress includes the determination of total, available, phosphate extractable and water soluble sulfur in these Minnesota soils.

1964 Boron Experiments on Alfalfa

J. M. MacGregor

For some years the Department of Soil Science has been recommending preventative applications of boron to fertilized alfalfa fields of northeastern Minnesota. The recommendation was originated following the observation of boron deficiency symptoms in alfalfa in several counties of northeastern Minnesota during the relatively dry summer of 1960. A comparatively wet spring followed by a relatively dry mid-summer season favors the development of boron deficiency symptoms, and since the amounts recommended of one to two pounds of boron (10 to 20 pounds of borax) per acre are relatively low in cost, the preventative recommendation has been comparatively routine since 1961.

Several Carlton County farmers with relatively large areas of limed and fertilized legumes (which they leave down from three to five years) have questioned the value of the recommended boron treatment for increasing yields of legume hay, and it was decided early in 1964 to initiate relatively long term studies on several legume fields as to boron effect on both vegetative boron deficiency symptoms and annual hay yields.

Following the removal of the first cutting of hay, three fields were established, and a fourth on a new seeding. Second cutting yields were obtained on the three established fields, although they were relatively light. Ample phosphorus and potassium fertilizer was applied in addition to the boron using six replications in a latin square design.

The following results were obtained:

Treatment No.	Treatment (lbs/A)	Second cut dry hay yield (tons per acre) Benson	Oraskovitch	Waisanen
1	none	0.41	0.22	0.36
2	500 # of 0-12-36/A	0.55	0.22	0.47
3	" " " /" + 1 # of B	0.69	0.19	0.47
4	" " " /" " 2 # " "	0.62	0.24	0.49
5	" " " /" " 1 # " "	0.62	0.23	0.55
6	" " " /" " 2 # " "	0.62	0.24	0.48

On the Benson and Waisanen fields, growth and yellowing seemed improved by the addition of the 0-12-36 and the two rates of boron seemed to decrease the yellowing further, but did not remove it entirely. Although it is still much too early to make any conclusions, the PK treatment improved, but the boron seemed to have little effect on the second cutting of 1956. The Oraskovitch field showed neither visual nor yield effect of either the PK or the B treatments.

Annual applications of boron to treatments 5 and 6 shall be made each spring to determine the effect of annual boron additions to both vegetative color and legume hay yield.

A fifth field shall be established in western Carlton County in the early spring of 1965.

Zinc Deficiency of Corn in Minnesota

Orville Gunderson, David Bezdicek and John MacGregor*

Introduction

All plants require zinc for normal growth and seed production. Since relatively small amounts are essential, zinc is known as one of the 'trace' or 'micronutrient' elements. The average zinc content of corn grown on an acre of Minnesota soil is only about three ounces or less than the amount needed in the manufacture of a ten quart galvanized pail. Since growing plants are unable to extract all of the zinc from the soil, it is essential that a larger total quantity be present in soils.

Although zinc deficiencies may occur in plants growing on acid soils, they are usually first observed on alkaline (high pH) organic and mineral soils containing substantial amounts of free lime (calcareous in nature). These soils are found extensively in western and parts of southern Minnesota where the deficiency has been most frequently observed (see map). Such deficiencies are more frequently observed on soils naturally high in phosphorus, or soils that have recently received heavy applications of phosphate fertilizer.

Corn following sugar beets is frequently zinc deficient, and many attribute this to the relatively heavy phosphorus fertilization for the beet crop. Zinc deficiency

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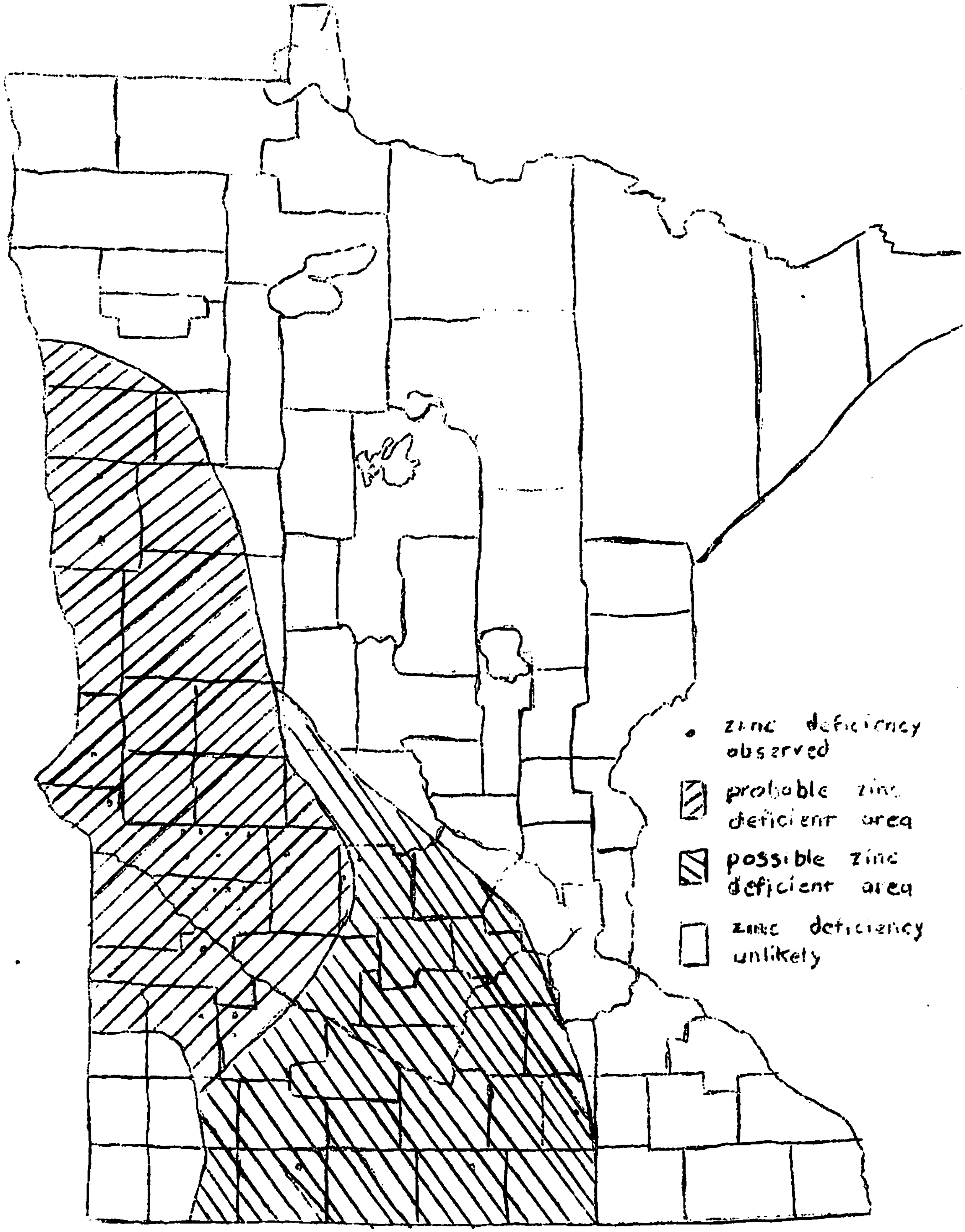
* A similar presentation of the zinc problem in Minnesota will soon be published in an extension or experiment station bulletin.

Zinc Deficiency of Corn in Minnesota



is more frequently observed following a cool, wet planting season and under poorly drained soil conditions.

Recognizing Zinc Deficiency in Corn

Zinc deficiency symptoms of corn generally occur in a characteristic sequence. More commonly the plants remain green during the first month but have a stunted growth. Then in late June or early July, thin, longitudinal, pale yellow stripes develop between the edge of the leaves and the midrib. These stripes extend from the base to the top of the leaf and often occur in irregular patterns.

The first leaves affected are the older (lower) leaves which are striped and comparatively narrow. The younger (upper) leaves may remain green unless the deficiency is severe. In severe deficiencies, the lower leaves may develop the pale yellow striping shortly after emergence. These pale stripes may then become bleached and appear to dry up. A reddish-bronze coloration is sometimes evident over portions of the seriously deficient leaves. The ears produced by serious deficient plants are poorly filled with chaffy kernels.

In mild deficienceis, only minimal striping of the lower leaves is observed, and bronzing does not occur. A minimum of stunting may be present, and as the growing season progresses, growth appears to be nearly normal with only slightly reduced yields.

The degree of zinc deficiency may vary considerably in a single field depending on local soil conditions. In areas where the deficiency is severe, poor and untimely pollination may occur. Although the entire field may be treated with zinc, such treatment is usually essential only on those portions of the field on which the corn plants are visibly affected.

Results of Field Experiments in Minnesota

In 1962, three field experiments were established in south central Minnesota to determine the most effective methods of zinc application and the rates needed to correct deficiency of corn. At two of the experimental plot locations, severe zinc deficiency sumptoms had been observed on growing corn during the previous year. The third soil site was one that was suspected of being deficient in available zinc.

All three soils were calcareous; one was a peat soil in northwestern Meeker County, and the other two were fine textured mineral soils in southern Kandiyohi County. The experimental plots were fertilized at rates of 100 lbs. nitrogen, 100 lbs. phosphate, and 50 lbs. of potash per acre to insure that adequate amounts of these nutrients would be available for the corn plants. The fertilizer was broadcast and plowed under.

The zinc treatments consisted of various rates of zinc sulfate either broadcast and plowed under, or banded using a corn planter fertilizer attachment. Tw ments of zinc chelate (Na_2Zn) coated to the seed corn were included with tl tions of each treatment on each field.

The results of the various treatments on one field in Kandiyohi County are shown in the table to illustrate the first year effectiveness of the zinc treatments. A heavy application of atrazine was used late in June 1962 to control a serious quack-grass problem. In 1963, this field was planted to soybeans, and the residual atrazine effect reduced the stand of the soybeans so severely that no crop was harvested. The field was planted to corn in 1964 and the yields were checked in the plot area. The residual effects on zinc applied in 1962 on corn yields in 1964 are also shown in the table.

During the 1962 growing season, severe symptoms of zinc deficiency were observed on the corn plants where no zinc was applied. Broadcasting and plowing the zinc sulfate under at the rate of 30 pounds per acre eliminated essentially all of the vegetative symptoms. The 15 pound-per-acre-rate resulted in about 20% of the corn plants being either stunted or with a noticeable striping of the lower leaves. Analyses of the leaves confirmed the field observation that the zinc sulfate broadcast at the rate of 15 pounds (5 pounds of zinc) per acre and plowed under was barely adequate to correct the zinc deficiency of corn on this field.

The 1962 yield of ear corn was increased by 16 bu. per acre by the application rate of 15 lbs. of zinc sulfate per acre broadcast and plowed under. Rates higher than 30 lbs. of zinc sulfate seldom showed a significant increase in the 1962 corn yields.

Research has shown that when zinc is applied as a starter fertilizer, it is usually more effective when mixed with some form of ammonium nitrogen. The nitrogen apparently increases the zinc uptake by the growing corn plants. This interaction was evident in the 1962 yields when comparisons were made between the treatment rates of 30 pounds of zinc sulfate per acre, either with or without nitrogen.

Nitrogen without zinc, applied as starter fertilizer, increased the yield of corn over the no zinc corn. This increase probably was due to (1) the placement of the nitrogen stimulating root development in the cool wet spring, and (2) the acidic effect of the nitrogen residue may have increased zinc availability. Zinc alone, applied with a corn planter fertilizer attachment, resulted in a lower yield of corn than where the zinc was mixed with nitrogen fertilizer and applied in the same way.

Zinc banded near the seed was not as effective in correcting the zinc deficiency symptoms of the corn plants as was that broadcast and plowed down. An X-ray fluorescent analysis of the corn leaves showed a greater uptake of zinc by corn plants growing on the broadcast treatments. Yields of ear corn from the banded zinc treatments were slightly lower than those from the broadcast treatments.

Seed treatment (coated) with zinc chelate (Na_2Zn) was apparently not an effective method to correct zinc deficiency of corn in 1962. Yields of corn grain were increased only slightly where the seed was coated with the zinc chelate. No growth response

The Effect of 1962 Zinc Fertilization of a Zinc Deficient Soil in Southern Kandiyohi County on the Yields of 1962 and 1964 Field Corn.

Ear corn yield in bushels per acre at 15.5% moisutre

	Direct effect in 1962	Residual effect in 1964
1962 Treatment (lbs/A)		
No zinc	43	40
Zinc sulfate broadcast and plowed under		
15 of zinc sulfate	69	58
30 of " "	66	56
60 of " "	76	56
120 of " "	67	60
Zinc sulfate and nitrogen applied as banded starter		
20 of nitrogen (N) alone	61	41
30 of zinc sulfate	59	53
20 of N plus 15 of zinc sulfate	63	58
20 of N plus 30 of " "	63	58
20 of N plus 30 of " "	64	65
20 of N plus 60 of " "	63	62
Zinc chelate coated on seed corn ($7\frac{1}{2}$ oz. Na_2Zn per bushel)		
Seed treatment alone	55	51
Seed treatment plus 30 lbs. of zinc sulfate plowed under	74	67

was noted and there was but little increase in the uptake of zinc by plants from this method of application.

One of the two other fields where the deficiency of zinc was severe showed similar results to those described here. An early fall frost reduced the corn yields, but yield increases from the use of zinc were still significant.

On the third field, only a few corn plants were deficient in zinc. No significant increase in corn yields from any of the rates or methods of application of zinc were obtained on this soil although yields on those plots treated with zinc were 2 to 7 bu. per acre higher than on those where no zinc was applied. Where corn exhibited no symptoms of zinc deficiency, there was little if any increase in yeild from applying zinc.

Residual Effects of Soil Applied Zinc

Carryover or resiudal effect on succeeding crops is of primary interest to corn growers who have zinc deficient soils. Research shows that a soil application of zinc will benefit crops for several years even though some of the applied zinc may be converted to unavailable forms. However, the total amount of zinc taken up by an acre of corn is relatively small and residual effects may be expected for some years. Soil composition will determine how much of the applied zinc remains available in succeeding years, and this will vary from one soil to another.

Residual zinc effect on corn growth was studied in 1964 following the 1962 zinc treatments. No additional zinc was applied. The 1964 corn yields were shown in the previous table.

The 1964 increases in corn yield from the residual 1962 applied zinc were much the same as those obtained two years previously. As little as 15 pounds of zinc sulfate per acre, broadcast in 1962, resulted in an increased corn yield of 26 bu. per acre in the first year and of 18 bu. two years later. There were no significant differences in the yields on those plots receiving higher rates of zinc. There was an increase in the uptake of zinc by the plants with the increased rate of application.

The plots with zinc banded in 1962 also showed a good residual effect. The field had been plowed both in the fall of 1962 and 1963 across the plots and apparently this did a thorough job of mixing the zinc with the soil.

Correction of Zinc Deficiency

If zinc deficiency symptoms are found in a field it is generally difficult to correct it in that year, although Nebraska researchers advise an injection of nitrogen and zinc sulfate water solution. However, zinc should be applied before planting sensitive crops in the following year. In most cases it is not economical to apply zinc fertilizer until a definite deficiency has been observed in the field.

There are several zinc carriers available for farmers which are economically effective in correcting zinc deficiency of corn. The most widely used materials are zinc sulfate and Na_2Zn (chelate) although any water soluble form of zinc would be beneficial. Most fertilizer dealers can readily obtain a supply of suitable zinc materials. Granular zinc containing compounds which are easy to handle are available and they can be blended with most commercial fertilizers.

Commercial fertilizers with added trace elements usually do not contain enough zinc to correct zinc deficiencies of corn unless specifically manufactured for that purpose. Most research workers agree that the best way to use micronutrients is to identify the deficiency in the crop and then add only those elements needed in quantities sufficient to correct the deficiency.

The recommended rate of zinc application for corn is 10 pounds of zinc per acre when an inorganic carrier such as zinc sulfate is used. Zinc sulfate contains from 26 to 40% zinc. When a chelated form of zinc is used, the rate of application should be 0.5 to 1 pounds of zinc per acre. Chelated zinc compounds usually contain from 6 to 14% zinc. New products of higher analysis will undoubtly be available in the future.

Broadcast and plowed down zinc fertilizer has been shown to be more effective for corn than the starter application. A spot treatment of only the deficient areas in a field may be given a broadcast treatment and it is essential that the zinc be plowed under to get maximum results in the first growing season.

Zinc fertilizer may also be banded slightly below and to the side of the corn seed using a fertilizer attachment on the corn planter. Greater benefits may be obtained when the zinc is mixed with fertilizer containing nitrogen with little, or preferably, no phosphate.

Zinc for Corn Following Sugar Beets

It has been reported in Minnesota and in other states that when corn follows sugar beets in a crop rotation the corn frequently fails to develop normally and often the yields are low. Research has shown that sugar beets are heavy users of zinc but they will seldom respond to applied fertilizer zinc.

When a zinc-sensitive crop such as corn follows sugar beets there is usually a deficiency of zinc for that crop. The deficiency of zinc is most obvious during the early growth of the corn until about mid July. As previously mentioned, heavy phosphorus fertilization of the sugar beet crop may be at least partially responsible for the zinc deficiency of the corn.

When corn is planted after sugar beets on calcareous soils which have had heavy rates of phosphate fertilization, some zinc should be applied to the soil. This can be done when the fertilizer is broadcast for the sugar beets, or with a fertilizer attachment on the corn planter. Rates of application are the same as those suggested above.

Zinc effectiveness may be shown by applying the same rates of fertilizer to the entire field. On part of the field, apply zinc along with the fertilizer and make careful observations should be made both during the corn growing season and at harvest.

The Zinc Concentrations in Corn Leaves of Ten Commercial Hybrids Growing at Waseca, Lamberton and Morris in 1964.

J. M. MacGregor, D. Bezdicek and Robert Peterson

Previous research on the zinc concentrations of corn leaves growing on several soil types in Minnesota had shown a good correlation between the analytical data and the visual evidence of zinc deficiency in corn (striping of the leaves). Other investigators have shown that corn plants whose sixth corn leaf contains less than 15 parts per million (ppm) of zinc will probably respond to zinc fertilization, plants with leaves having 15 to 20 ppm zinc may respond to zinc treatments, while those having leaves with 20 or more ppm. Zinc are not likely to be deficient. Studies conducted on Minnesota soils and corn plants during the past three years have generally been in agreement with this observation.

However, it was desirable to determine the extent of variation in the zinc content of corn leaves of different commercial hybrids growing on the same soil type, since, if significant differences occurred in plants of different hybrids, obviously this would nullify, or at least make much more difficult the analytical separation of zinc deficient corn on the bases of soil type. For this reason five leaves (6th) were sampled on each of four replications from ten different commercial corn hybrids growing on the Corn Performance Trials (Dept. of Agronomy and Plant Genetics) at Waseca, Lamberton, and Morris in mid-July. These leaves were washed, dried, ground, and analyzed for zinc content by the x-ray fluorescence method in the Department of Soil Science, and also by the spectrographic procedure (quantometer) at the Ohio State University. The corn hybrids and the average analyses of leaves from each of four replicate corn plots were as follows:

The Average Zinc Concentrations in Sixth Corn Leaf of Ten Commercial Hybrids Grown at Waseca, Lamberton and Morris in 1964 by X-Ray Fluorescence and by Quantometer Analyses..

(Average of four replicates)

	X-ray fluorescence data			Quantometer data (Ohio		
Corn hybrid	Waseca	Lamberton	Morris	Waseca	Lamberton	Morris
Cargill E 40[2]	27	29	--	33	49	
De Kalb x L 45	34	27	--	44	32	
" " x L 441	--	22	--	--	27	
Kingserost KM571	28	28	--	43	40	
Pioneer 352	31	28	--	52	34	
" 371	25	22	--	25	31	
" 349	29	30	--	30	42	
United Haie UH138	26	22	--	41	22	
Minhybrid 417	33	25	--	45	37	
" 418	33	27	--	51	31	
Cargill 570	--	--	17	--	--	12
De Kalb 61	--	--	20	--	--	16
" " x L 15	--	--	19	--	--	18

(con't)

Kingserost PX487	--	--	22	--	--	19
Pioneer 377A	--	--	18	--	--	20
" 384	--	--	19	--	--	11
" 385	--	--	18	--	--	14
United Hagie UH127	--	--	17	--	--	12
Minhybrid 611	--	--	24	--	--	22
" 612	--	--	18	--	--	14

It is evident that the two methods of analysis from the same samples do not always produce the same values. The quantometer data from Ohio more frequently indicates the leaf zinc concentrations to be much higher than that obtained by x-ray fluorescence equipment in this department. However, both methods of analysis show zinc concentrations of the corn leaves from Waseca and Lamberton to be well above the minimum zinc level previously mentioned as critical for normal corn growth.

At Morris, three plot replicatss were located on the lower lying Aastad soil and one replicate on Barnes loam, about a half-mile distant. The corn leaves from the Aastad soil were markedly lower in zinc than those from plants growing on the Barnes loam.

The corn leaves from Morris contained much lower zinc concentrations than leaves from either Lamberton or from Waseca, but since they were all different hybrids with a shorter maturity, it is not clear whether the lower zinc content is due to the smaller amount of available zinc in the two Morris soils or is caused by the earlier maturing hybrid growth. In general, the hybrids grown at Morris contained questionably low levels of zinc (by both analytical methods) and might respond to zinc fertilization, whereas those from either Lamberton or Waseca apparently contained ample zinc for normal corn growth.

Since the variations in the zinc content of the corn leaves between replications and methods of analysis were quite large, there was no mathematically significant difference between the corn leaves of the different commercial hybrids investigated.

SOIL FERTILITY INVESTIGATIONS OF GRASS SEED PRODUCTION FIELDS IN NORTHWESTERN MINNESOTA - 1964

J. Grava, R. S. Farnham, M. V. Halverson
W. P. Martin and J. M. MacGregor

Grass and legume seed production has become an important agricultural enterprise in Roseau, Lake of the Woods Counties and adjacent areas in Northwestern Minnesota. Kentucky bluegrass and timothy are the two grass species grown for seed production in that area.

Soil fertility investigations were conducted by P. M. Burson, J. M. MacGregor and co-workers from 1959 to 1963[1)]. The investigations dealt mainly with the effects of fertilization with primary nutrient elements N, P and K on the yields of grass seed. Fertilizer rates and the time of application were studied on mineral and organic soils in the main seed production areas. The findings of those studies have been helpful to growers in the use of commercial fertilizers on seed production fields.

This report deals with the findings of a survey made in 1964 on the chemical composition of soils and plants obtained from seed production fields. Investigated were eleven fields in Roseau County and one field in Lake of the Woods County. Seven of a total of nine Park Kentucky bluegrass fields were on mineral soils and two on peat. Also studied were two timothy fields on mineral soils.

Plant samples were obtained about the time when grasses were heading out. Soils were classified and samples were collected from the same spots within each field from which the plant material had been obtained.

The <u>mineral soils</u> (Tables 1 to 9) showed the following main characteristics: All of the soils were strongly alkaline, with pH values of 7.4 to 8.1 in surface and 7.8 to 8.6 in subsoil. The exchangeable sodium content in five soils ranged from 0.3 to 0.7 m.e. per 100 grams of soil, in three other soils from 0.3 to 2.1 m.e., and in a Bearden sicl from 1.3 to 4.1 m.e. The electrical conductivity, indicating presence of soluble salts, in saturation extract of the Bearden sicl ranged from 3.1 to 5.2 mmhos./cm. Soils with conductivity readings of more than 4 mmhos. are classified as moderately saline, and the yield of many crops may be restricted. The saturation extract from this Bearden soil also contained sulfates, ranging from 1350 ppm. $SO_4^{=}$ at 4 - 5 inches to 239 in the 18 - 24 inch layer. The corresponding contents of chlorides were 20.3 ppm. Cl^- at 4 - 5 inches and 56.8 ppm. at 18 - 24 inches. The conductivity values in other mineral soils were not as high and ranged from 0.65 to 3.5 mmhos.

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1) Preliminary results of the investigations have been reported in the Soil Science Department "Blue Books" of 1961, 1962, 1963 and 1964.

The mineral soils also contained free carbonates, particularly in the subsoil. While the total carbonate content of the topsoils did not exceed 6%, the subsoils, below a depth of 8 or 10 inches showed a carbonate content of 10 to 40%. The cation exchange capacity of soil in the top one inch ranged from 12 - 30 m.e. per 100 grams and 7 - 15 m.e. at the depth of 18 - 24 inches.

The presence of free carbonates in soils may affect the nutrition of grasses. Applied phosphorus may be fixed and thus become unavailable to plants. The uptake of potassium also may be impaired. Sodium and other soluble salts may be detrimental to the seed production of grasses.

Phosphorus availability in the calcareous soils formed from lacustrine sediments is known to be low. Routine soil tests indicated that the P and K top-dressed by growers had remained mainly in the top two to three inches of soil. Present recommendations of limiting the soil depth to the top two or three inches when sampling meadows or grass production fields are substantiated by these findings.

The two peat soils studied were located on the Charles Habstritt farm in Roseau County. The surface horizon of these deep peats were partly decomposed to well decomposed with some fine fiber. Beginning at 10 inches the horizons below the surface were very fibrous to fibrous consisting of plant remains with some finely divided decomposed organic material between fibers.

The data in Tables 10 and 11 show these peats to be high in calcium with pH values at the surface varying from 6.5 to 7.6 extractable phosphorus is concentrated in the surface horizons as is to some extent the extractable potassium. The bluegrass on field No. 9 containing deep peat had the highest content of nitrogen of the two fields sampled, 2.97% N (see Table 12). This might account for the lodging of bluegrass which was observed in July 1964. Excellent stands of bluegrass were observed on both peat soils, however, some late spring frost damage had occurred.

Chemical analysis of plant material involved determinations of 17 elements. The determinations of N, P and K were made at the Soil Science Department. There did not seem to be any obvious differences in N, P and K contents between the two grass species. However, bluegrass from an old and rather unproductive field (No. 6) had the following chemical composition: 1.16% N, 0.13% P and 0.83% K. Much higher nutrient contents were found in bluegrass from a newly seeded field: 1.62% N, 0.24% P and 1.75% K.

Bluegrass with a good seed set from a dense stand on peat had the following composition: 2.97% N, 0.3% P and 2.55% K. Thus a certain relationship seems to exist between the contents of N, P and K in plant material and the growth and productivity of grasses.

Plant samples were also submitted to the Plant Analysis Laboratory, Ohio State University for determinations of secondary and trace elements with an emission spectrograph. Since there is little or no information available on the levels of these elements in grasses, particularly when used for seed production, these determinations were of an exploratory nature. It was essential, however, to establish a certain level of sufficiency in the trace and secondary element contents of grasses for future reference.

The results of these chemical analyses of soils and plant material are given in the following Tables 1 to 12.

ACKNOWLEDGMENTS

Appreciation is expressed to Mr. William N. Provance, Agricultural Extension Agent of Roseau County, and Mr. Robert C. Munter, Junior Scientist, Soil Science Department, for their assistance in these studies.

Table 1

Field No. 1 (1964)

Soil Type: Bearden silty clay loam

Location: Yvonne Magnuson, Roseau County
SE¼ of SW¼ Sec. 11, Jadis Twp.

Crop: Timothy, new seeding

Depth Inches	pH (1:1)	Organic Matter	Ex-tract-able P	Ex-change-able K	Total Exchange Capacity	Total Carbo-nates	Sol. Salts (Sat. Extr.)	Ex-change-able Na
		%	pp2m.	pp2m.	m.e. per 100 g.	%	mmhos. per cm.	m.e. per 100 g.
0-1	7.7	4.7	51	320	19.2	4.7	1.2	.4
1-2	7.9	3.9	20	180	37.2	8.7	.9	.4
2-3	8.0	4.1	12	150	21.5	8.7	1.0	.7
3-4	8.0	4.0	11	160	21.3	8.5	1.2	.8
4-5	8.1	3.9	12	190	22.0	8.6	1.4	.8
5-6	8.1	4.4	13	200	19.1	8.7	1.5	.9
6-8	8.1	4.0	10	190	19.9	5.4	1.5	.7
8-10	8.2	2.4	7	130	16.7	11.5	1.6	.5
10-12	8.4	1.1	6	70	17.5	9.3	1.3	.7
12-18	8.2	0.9	6	60	8.2	19.1	3.0	.8
18-24	8.2	0.9	7	80	9.1	21.9	3.0	.7

Table 2

Field No. 2 (1964)

Soil Type: Glyndon fine sandy loam

Location: Albert Efshen, Roseau County
NW¼ of NW¼ Sec. 16, Jadis Twp.

Crop: Bluegrass

Depth Inches	pH (1:1)	Organic Matter	Ex-tract-able P	Ex-change-able K	Total Exchange Capacity	Total Carbo-nates	Sol. Salts (Sat. Extr.)	Ex-change-able Na
		%	pp2m.	pp2m.	m.e. per 100 g.	%	mmhos. per cm.	m.e. per 100 g.
0-1	7.4	3.4	50	270	12.2	2.2	1.7	.4
1-2	7.5	2.8	14	70	12.1	2.0	1.8	.4
2-3	7.6	2.8	8	40	12.9	1.9	1.0	.4
3-4	7.7	2.7	9	50	12.0	2.3	1.2	.4
4-5	7.9	1.9	7	50	11.8	2.0	.9	.4
5-6	7.8	1.0	6	60	12.4	1.9	.8	.4
6-8	7.9	0.8	4	70	9.7	1.4	.8	.3
8-10	7.7	0.7	6	60	11.4	1.4	-	.3
10-12	8.1	0.9	5	60	8.1	1.4	.8	.3
12-18	8.6	0.9	6	30	7.1	16.9	1.2	.4
18-24	8.6	0.8	5	30	-	17.9	1.0	-

Table 3

Field No. 3 (1964)

Soil Type: Glyndon (light) silty clay loam

Location: Kveen, Roseau County
SW¼ of NW¼ Sec. 9, Jadis Twp.

Crop: Bluegrass

Depth Inches	pH (1:1)	Organic Matter	Ex-tract-able P	Ex-change-able K	Total Exchange Capacity	Total Carbo-nates	Sol. Salts (Sat. Extr.)	Ex-change-able Na
		%	pp2m.	pp2m.	m.e. per 100 g.	%	mmhos. per cm.	m.e. per 100 g.
0-1	8.1	3.8	78	260	19.2	5.0	1.3	.3
1-2	8.2	3.7	20	160	19.3	5.8	1.7	.3
2-3	8.1	3.5	10	100	19.7	5.2	1.0	.4
3-4	8.2	3.7	10	90	19.5	5.5	1.0	.4
4-5	8.2	3.5	10	80	20.6	6.3	1.3	.4
5-6	8.3	3.6	9	90	19.7	4.0	1.1	.4
6-8	8.3	3.7	8	80	17.8	8.7	1.0	.4
8-10	8.4	2.6	11	80	10.7	13.1	1.5	.4
10-12	8.5	0.8	4	80	9.0	18.7	-	.5
12-18	8.7	0.6	5	70	7.9	22.5	1.1	.4
18-24	8.8	0.7	5	40	7.2	22.2	1.2	.4

Table 4

Field No. 4 (1964)

Soil Type: Bearden silty clay loam

Location: Roy Kveen, Roseau County
NW¼ of SW¼ Sec. 4, Jadis Twp.

Crop: Timothy, new seeding

Depth Inches	pH (1:1)	Organic Matter	Ex-tract-able P	Ex-change-able K	Total Exchange Capacity	Total Carbo-nates	Sol. Salts (Sat. Extr.)	Ex-change-able Na
		%	pp2m	pp2m.	m.e. per 100 g.	%	mmhos. per cm.	m.e. per 100 g.
0-1	8.1	3.4	27	260	22.1	4.2	1.3	.3
1-2	8.2	3.3	53	100	22.5	4.5	1.0	.5
2-3	8.4	3.3	16	90	21.9	4.7	1.0	.6
3-4	8.4	3.2	14	90	22.4	5.3	1.0	.7
4-5	8.3	3.3	14	100	21.9	5.0	.8	.8
5-6	8.4	3.1	12	90	16.0	4.0	.8	.6
6-8	8.4	1.7	8	100	12.8	11.9	.7	.6
8-10	8.5	1.0	9	70	11.8	24.5	.8	.6
10-12	8.6	1.0	8	70	12.5	32.7	.9	.6
12-18	8.5	1.0	5	80	13.0	24.1	1.0	.6
18-24	8.5	1.0	5	70	10.1	20.1	1.2	.6

Table 5

Field No. 5 (1964)

Soil Type: Bearden silty clay loam

Location: Mary Kveen, Roseau County
NW¼ of NW¼ Sec. 4, Jadis Twp.

Crop: Bluegrass, old stand

Depth Inches	pH (1:1)	Organic Matter	Ex-tract-able P	Ex-change-able K	Total Exchange Capacity	Total Carbo-nates	Sol. Salts (Sat. Extr.)	Ex-change-able Na
		%	pp2m.	pp2m.	m.e. per 100 g.	%	mmhos. per cm.	m.e. per 100 g.
0-1	7.8	4.7	90	180	30.3	0	3.1	1.3
1-2	7.9	4.1	37	110	28.8	0.3	4.0	2.4
2-3	7.7	4.6	44	80	30.2	0.5	4.3	3.0
3-4	7.8	4.4	52	90	30.9	0.7	4.5	3.4
4-5	7.7	4.6	105	110	32.0	1.1	4.5	4.1
5-6	7.7	4.5	34	90	29.2	0.3	4.5	4.1
6-8	7.8	3.0	9	70	24.1	3.9	5.2	3.7
8-10	7.8	1.8	9	60	18.1	7.2	5.0	3.4
10-12	7.9	1.0	7	30	12.7	15.9	4.9	2.3
12-18	8.1	0.9	7	30	9.3	19.2	5.1	2.2
18-24	8.2	0.8	6	40	10.7	20.6	3.7	2.0

Table 6

Field No. 6 (1964)

Soil Type: Viking silty clay to clay

Location: Oliver T. Wold, Roseau County

Crop: Bluegrass, old stand

Depth Inches	p H (1:1)	Organic Matter	Ex-tract-able P	Ex-change-able K	Total Exchange Capacity	Total Carbo-nates	Sol. Salts (Sat. Extr.)	Ex-change-able Na
		%	pp2m.	pp2m.	m.e. per 100 g.	%	mmhos. per cm.	m.e. per 100 g.
0-1	8.0	4.6	15	340	24.2	1.0	1.1	.4
1-2	8.0	3.4	12	280	25.6	1.2	1.1	.4
2-3	8.0	3.9	10	200	21.0	1.1	1.1	.5
3-4	8.0	3.5	9	150	24.8	1.1	.9	.5
4-5	8.0	4.0	7	150	24.8	1.1	1.1	.5
5-6	8.0	4.0	7	130	24.3	1.4	.9	.7
6-8	8.0	2.6	9	120	19.3	1.5	1.0	.7
8-10	8.1	1.2	5	100	11.9	11.4	.8	.5
10-12	8.2	1.1	4	100	13.5	20.2	1.2	.7
12-18	8.2	1.3	4	100	16.8	38.2	1.3	1.0
18-24	8.3	1.0	3	100	14.9	40.3	1.3	1.1

Table 7

Field No. 7 (1964)

Soil Type: Glyndon silt loam

Location: Bjorkman, Roseau County
SE¼ SE¼ Sec. 23, Jadis Twp.

Crop: Bluegrass

Depth Inches	pH (1:1)	Organic Matter	Ex-tract-able P	Ex-change-able K	Total Exchange Capacity	Total Carbo-nates	Sol. Salts (Sat. Extr.)	Ex-change-able Na
		%	pp2m.	pp2m.	m.e. per 100 g.	%	mmhos. per cm.	m.e. per 100 g.
0-1	7.8	5.6	45	140	22.2	1.2	.8	.3
1-2	7.8	5.9	13	90	22.6	1.2	.9	.3
2-3	7.9	5.4	11	90	23.6	1.2	1.0	.6
3-4	7.8	5.3	10	90	23.4	1.5	1.0	.4
4-5	7.9	5.2	9	90	26.0	1.5	1.0	2.1
5-6	7.7	5.0	19	190	25.1	1.8	1.0	.5
6-8	7.8	5.3	19	190	25.8	1.2	1.0	.5
8-10	8.8	2.2	9	110	17.2	3.1	.9	.5
10-12	8.1	1.3	9	80	11.0	17.5	1.3	.3
12-18	8.2	1.0	8	70	8.9	25.2	1.1	.3
18-24	8.4	0.9	6	80	9.9	28.0	.9	.9

Table 8

Field No. 8 (1964)

Soil Type: Glyndon silt loam

Location: Baumgartner, Roseau County
NE$\frac{1}{4}$ SE$\frac{1}{4}$ Sec. 26, Jadis Twp.

Crop: Bluegrass, old, but quite good stand

Depth Inches	pH (1:1)	Organic Matter	Ex-tract-able P	Ex-change-able K	Total Exchange Capacity	Total Carbo-nates	Sol. Salts (Sat. Extr.)	Ex-change-able Na
		%	pp2m.	pp2m.	m.e. per 100 g.	%	mmhos. per cm.	m.e. per 100 g.
0-1	7.8	7.7	80	140	29.4	2.3	1.8	.5
1-2	8.0	8.1	28	70	33.0	2.3	1.6	.7
2-3	7.9	8.1	18	60	32.5	2.2	2.0	1.1
3-4	8.0	8.0	18	50	32.4	2.3	2.1	1.3
4-5	7.9	7.4	23	40	31.7	2.1	2.3	1.2
5-6	7.8	8.1	40	50	34.8	2.2	2.1	1.5
6-8	7.8	7.7	27	50	32.5	2.7	2.2	1.0
8-10	7.9	2.5	15	40	13.5	0.7	2.1	1.0
10-12	8.0	1.0	10	30	10.0	6.3	2.3	.7
12-18	8.3	0.8	5	30	9.9	29.6	1.9	.6
18-24	8.3	0.8	5	30	8.9	36.8	1.7	.5

Table 9

Field No. 11 (1964)

Soil Type: Spooner silt loam

Location: Helmstetter, Lake of the Woods County

Crop: Bluegrass

Depth Inches	pH (1:1)	Organic Matter	Ex-tract-able P	Ex-change-able K	Total Exchange Capacity	Total Carbo-nates	Sol. Salts (Sat. Extr.)	Ex-change-able Na
		%	pp2m.	pp2m.	m.e. per 100 g.	%	mmhos. per cm.	m.e. per 100 g.
0-1	7.9	5.6	80	60	26.4	3.1	1.4	.5
1-2	8.0	5.5	30	40	29.5	3.0	1.7	.4
2-3	8.0	5.5	21	30	28.4	3.1	2.2	.4
3-4	8.0	5.2	18	30	29.3	3.0	2.0	.5
4-5	7.9	5.1	18	40	28.8	3.0	2.4	.6
5-6	8.0	5.2	18	40	26.3	3.0	2.5	.6
6-8	8.0	5.8	21	20	30.0	2.2	2.5	.7
8-10	7.9	5.3	18	30	28.7	2.2	3.5	.6
10-12	8.0	1.7	11	30	17.2	1.4	3.2	.5
12-18	8.1	0.8	6	20	7.1	19.2	2.2	.4
18-24	8.2	0.8	6	10	6.8	21.4	2.8	.3

Table 10

Field No. 9 (1964)

Soil Type: Deep Peat

Location: Charles Habstritt (I), Roseau County
SW¼ SE¼ Sec. 29, T. 163N, R. 39W

Crop: Bluegrass, dense, some lodging

Depth Inches	pH	Extractable P Bray's No. 1	Extractable P Water	Exchangeable K	K	P	Ca	Mg	Na	Si	Mn	Fe	B	Cu	Zn	Al	Sr	Mo	Co	Ba
		pp2m	pp2m	pp2m	%	%	%	%	%	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
0-1	7.6	63	16	110	.24	.20	3.54	.58	.21	.83	301	>840	38	7	29	709	125	>130	1.6	71
1-2	7.6	35	10	40	.20	.16	3.26	.68	.24	.67	300	"	37	6	26	707	117	"	1.5	46
2-3	7.4	28	8	30	.24	.15	3.38	.76	.22	.78	299	"	37	7	26	707	110	"	1.7	50
3-4	7.5	38	12	40	.22	.18	3.78	.89	.30	.99	301	"	41	7	37	711	127	"	2.0	35
4-5	7.3	30	8	20	.32	.18	4.39	.98	.36	1.24	302	"	47	9	43	708	130	"	2.4	32
5-6	7.2	29	9.2	20	.21	.15	3.40	.91	.41	.80	302	"	39	6	42	709	120	"	1.9	28
6-8	6.2	5	7.2	10	.22	.08	2.61	.77	.39	.79	247	"	34	14	13	704	81	"	1.7	20
8-10	5.5	4	7.2	10	.18	.06	2.11	.50	.33	.30	190	"	23	14	11	704	68	8.3	1.2	16
10-12	5.7	3	6	5	.22	.06	2.07	.43	.29	.42	184	"	22	16	12	707	57	8.7	1.2	16
12-18	5.6	3	6	5	.19	.06	1.90	.44	.31	.29	149	"	22	13	11	699	55	8.0	1.5	12
18-24	5.7	4	7.2	10	.19	.06	2.46	.57	.23	1.67	186	"	27	13	14	709	98	>130	1.0	19

Table 11

Field No. 10 (1964)

Soil Type: Deep Peat

Location: Charles Habstritt (II), Roseau County
SE¼ SW¼ Sec. 32, T. 163N, R. 39W

Crop: Bluegrass, older stand

Depth Inches	pH	Extractable P Bray's No. 1	Extractable P Water	Exchangeable K	K	P	Ca	Mg	Na	Si	Mn	Fe	B	Cu	Zn	Al	Sr	Mo	Co	Ba
		pp2m	pp2m	pp2m	%	%	%	%	%	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
0-1	6.9	36	14	70	.26	.15	3.34	.57	.18	1.50	292	>840	41	15	29	703	90	>130	1.8	30
1-2	6.7	34	10	60	.26	.14	3.29	.63	.17	1.14	293	"	41	12	29	709	77	"	1.8	23
2-3	6.5	36	13.2	50	.22	.13	3.04	.65	.26	.85	286	"	40	11	26	708	83	"	1.8	17
3-4	6.4	31	14	60	.24	.12	3.00	.77	.31	.68	291	"	39	10	28	703	79	"	1.9	18
4-5	6.2	26	10	100	.25	.12	2.85	.75	.38	.63	285	"	38	10	26	704	75	"	1.9	18
5-6	5.3	6	8	30	.27	.09	2.75	.68	.40	.34	141	"	32	13	19	704	61	"	1.5	16
6-8	5.1	5	10	20	.20	.07	2.28	.64	.34	.22	120	"	28	14	18	699	59	9.6	1.4	13
8-10	5.0	5	7.2	10	.20	.07	2.29	.59	.29	.22	119	"	29	15	18	699	65	8.6	1.5	13
10-12	5.1	4	8	10	.20	.08	2.52	.57	.25	.23	144	"	33	12	19	695	61	8.5	1.1	16
12-18	5.3	4	8	20	.24	.08	2.33	.49	.33	.23	115	"	33	12	21	701	60	9.9	1.8	11
18-24	5.2	5	7	20	.20	.08	2.22	.48	.27	.26	78	"	32	10	19	699	59	7.8	1.3	10

Table 12. Chemical composition of Kentucky bluegrass and timothy from seed production fields - 1964.

Species, Age of Stand Field No., Soil Type	N	P	K	Ca	Mg	Na	Si	Mn	Fe	B	Cu	Zn	Al	Sr	Mo	Co	Ba
	%	%	%	%	%	%	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
1. Bluegrass																	
a. New Seedings																	
No. 7 Glyndon sil	1.62	.24	1.75	.29	.17	.15	.27	19	73	5	5	15	45	4	.4	.7	10
No. 9 Deep peat	2.97	.36	2.55	.41	.29	.21	.07	37	80	7	4	22	14	11	.5	.7	16
b. Established Stands																	
No. 2 Glyndon fsl	1.65	.30	1.45	.29	.19	.11	.10	27	50	7	6	15	17	3	.3	.5	20
No. 3 Glyndon sicl	1.19	.19	1.21	.27	.21	.10	.15	42	33	7	4	13	10	6	.2	.4	12
No. 8 Glyndon sil	1.50	.23	1.10	.29	.25	.11	.28	23	131	7	5	20	111	4	.4	.6	14
No. 11 Spooner sil (-N)	1.13	.27	1.45	.26	.14	.13	.14	13	34	8	6	16	18	3	.3	.6	13
No. 11 Spooner sil (+N)	1.36	.21	1.04	.34	.23	.12	.10	16	46	9	7	18	20	3	.5	.9	18
No. 10 Deep peat	1.77	.29	1.78	.27	.22	.12	.05	61	49	7	5	38	14	9	.4	.8	28
c. Old Stands																	
No. 6 Viking sic	1.16	.13	.83	.29	.14	.12	.34	48	60	7	5	16	48	3	.4	.6	11
No. 5 Bearden sicl	1.41	.24	1.33	.16	.16	.15	.12	23	58	6	6	15	33	3	.4	.7	9
2. Timothy																	
No. 1 Bearden sicl	1.39	.17	1.65	.38	.17	.14	.47	34	503	8	6	17	605	6	.8	.5	10
No. 4 Bearden sicl	2.16	.22	2.02	.23	.24	.24	.55	25	522	8	8	17	599	6	1.2	.6	17

Nitrogen Fertilization on Turf - 1964

R. S. Farnham

Nitrogen fertilization studies on bluegrass turf on St. Paul Campus were continued in 1964. Objectives of thse studies were as follows:

1) Continue the study with slow release organic and inorganic nitrogen fertilizers on turf grass.
2) Compare the effectiveness of several new resin-coated nitrogen materials and mixed fertilizers with conventional nitrogen fertilizers.

Results and Discussion

Table 1 shows data of total clipping yields for season for turf plots on St. Paul Campus. The coated mixed fertilizer grades 16-8-8 and 20-10-5 and coated $(NH_4)_2SO_4$ applied at the 8 lb. of N/1000 sq. ft. rate produced the highest total clipping yields of any of the treatments. The eight highest yielding plots were all coated fertilizers provided by the Archer Daniels Midland Company, Minneapolis.

These data compare very favorably with data obtained the past three years in that the highest yielding treatments have consistently been coated fertilizer materials. The release of nitrogen throughout the season is made possible by resin coating nitrogenous fertilizers. Periodic clipping yields during the season show this. Even more important as regards the effectiveness of these coated fertilizers on promoting grass growth is that even in late Sept. and October the grass growth on plots receiving these materials is still good although with uncoated materials nitrogen has been depleted.

Table 1. 1964 Turf Plots

Treat No.	Treatment	Rate lbs N/1000 sq. qt.	Total Clippings gms/peat	Rank
3	16-8-8 (5422-20-E) coated	8	539.8	1
6	20-10-5 (5422-20-C) coated	8	534.9	2
29	16-8-8 (5422-18-M) coated	8	533.2	3
16	$(NH_4)_2SO_4$ (19% leach) (c)	8	507.5	4
30	16-8-8 coated ½, organic (Amer. Humates) ½	8	481.1	5
12	NH_4NO_3 (5422-22 W) c	8	472.1	6
14	$(NH_4)_2SO_4$ 2% leach (c)	8	469.0	7
8	NH_4NO_3 (5422-21-U) (c)	8	462.4	8
20	Milorganite (organic)	8	452.1	9
25	Spencer (30-10-0) (c)	8	448.0	10
27	Uramite	8	436.6	11
4	16-8-8 (uncoated)	8	421.6	12
11	Urea (c) with inhibitor	4	417.1	13
28	NH_4NO_3 ½ + $(NH_4)_2SO_4$ + c	8	413.6	14
18	Urea (med. coat)	4	396.5	15
13	$(NH_4)_2SO_4$ coated	4	392.2	16
17	Urea (med. coat)	8	389.3	17
22	Amer. Humates (organic)	8	378.5	18
5	20-10-5 (coated)	4	374.5	19
15	$(NH_4)_2SO_4$ 19% leach (c)	4	373.0	20
1	16-8-8 (coated)	4	360.0	21
19	Milorganite	4	358.9	22
10	NH_4NO_3 (uncoated)	8	356.5	23
7	NH_4NO_3 (coated) 3% leach	4	353.4	24
2	16-8-8 (uncoated)	4	329.3	25
24	Spencer (S-4383)	8	311.7	26
26	Uramite	4	307.0	27

9	NH_4NO_3 (uncoated)	4	305.2	28
21	Amer. Humates (organic)	4	273.5	29
23	Spencer (S4383)	4	273.3	30
31	Check (No N.)	0	151.8	31
32	Check (No N.)	0	129.5	32

CHEMICAL COMPOSITION OF SIXTH CORN LEAF

JOHN GRAVA

The use of plant analysis as a diagnostic tool seems to be a very popular topic in Minnesota these days. This interest apparently was aroused by the occurrence of certain trace element deficiencies in field crops, and the recent establishment of a plant analysis laboratory by the Ohio State University at Wooster.

Actually determination of N, P, K and certain secondary and trace elements in plant material are made frequently on samples from various departmental research projects. However, because of the expense involved in plant analysis, we have depended mainly on soil tests as a diagnostic tool. Soil testing services are inexpensive and readily available to farmers, florists and homeowners. Unfortunately, soil tests for secondary and trace elements are either complicated and time consuming or somewhat unreliable. Thus the use of an instrument which in a few minutes can determine the contents of some 16 elements in plant ash has brought the mass spectrograph into the limelight.

Certain difficulties may be encountered in the use of plant analysis as a diagnostic tool. The two basic problems are: (1) which part of plant, and at what development stage to sample, (2) what nutrient concentration to consider "adequate" for specific plant growth, and yield goal.

Scientists of the University of California, for example, have provided instructions on sampling petioles of sugarbeets and potatoes (5,7). They also have prepared specific guides to critical nutrient concentrations in these two crops. Dr. A. L. Kenworthy, Department of Horticulture, Michigan State University and others have developed similar procedures and guides for foliar analysis of orchard trees. One finds himself in want for similar instructions and guides when the use of plant analysis is contemplated for field crops such as corn, soybeans, small grains, alfalfa and others. This may be especially true of secondary and trace elements.

Most information in professional publications on chemical composition of corn refers to nutrient content of sixth leaf (first one below and opposite the primary ear shoot) collected at silking time. A number of research papers have dealt with the critical levels of N, P and K in corn leaf. Tyner in 1946 (6) defined "critical level" as that concentration of a nutrient which is just adequate for maximum growth. He suggested following critical levels in sixth corn leaf at silking time (on an oven-dry basis): 3.1% N, 0.315% P, 1.4% K. The concept of "critical level" being a point or a narrow range of values has been questioned by several scientists. Nevertheless, the values of N, P and K contents, suggested by Tyner, still are useful as reference points.

However, information pertaining to the contents of secondary and trace elements in corn is rather scarce. Thus there is a serious need for obtaining and accumulating such information on chemical composition of corn and other field crops. With this in mind, 15 samples of plant material from various past field experiments were submitted for spectrographic analysis. The results are given in table 2. Background information concerning the location, soil type, treatment and corn yields of the experiments from which the samples were obtained is given in table 1. Also reported are references in which the experiments have been described more thoroughly.

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Table 1. Location, treatments, corn yields and other information on experiments from which leaf samples were obtained for plant analysis.

Sample No.	Nutrients Applied Lbs./Acre	Treat. & Rep.	Location	Soil Type	Corn Yield Bu./A.	Year	Reference No.
1	110 + 0 + 120	2-II	E. Freeze, Wabasha Co.	Fayette sil	126	1961	1
2	110 + 40R + 120	4-II	" "	" "	116	"	"
3	110 + 40B + 120	5-II	" "	" "	96	"	"
4	110 + 80(40R + 40B) + 120	12-II	" "	" "	125	"	"
5	110 + 80 + 120	12-III	E. Maus, Winona Co.	Fayette sil	133	1961	1
6	120 + 40R + 120	5-III	Nygren Bros., Goodhue Co.	Fayette/Seaton sil	157	1962	2
7	120 + 40 + 120	5-IV	D. Flueger, Goodhue Co.	Fayette sil	155	"	2
8	120 + 40 + 120	5-IV	E. Freeze, Wabasha Co.	" "	136	"	2
9.	0 + 0 + 0	1-I	Rosemount Exp. Sta.	Port Byron sicl	93	1962	4
10	86 + 40 + 40	4-I	" " "	" " "	114	"	"
11	77 + 88 + 136	6-I	" " "	" " "	117	"	"
12	101 + 136 + 236	9-I	" " "	" " "	119	"	"
13.	110 + 32 + 96	4-III	F. Carlson, Isanti Co.	Anoka lvfs	60[1)]	1964	3
14	110 + 64 + 96	11-III	" "	" "	40[1)]	"	"
15	110 + 32 + 96	4-IV	A. Sorteberg, Anoka Co.	Hubbard s	10[2)]	"	3

1) Corn growth and yields affected by moderate drought.

2) Corn growth and yields affected by severe drought.

Table 2. Chemical composition of sixth corn leaf at silking time.

Sample No.	N	P	K	Ca	Mg	Na	Si	Mn	Fe	B	Cu	Zn	Al	Sr	Mo	Co	Ba
	%	%	%	%	%	%	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
1	3.53	.32	1.41	.68	.52	.01	.27	83	160	11	12	21	74	43	1.5	0.0	11
2	3.39	.33	0.97	.77	.63	.01	.28	83	165	13	11	17	76	38	2.0	.1	8
3	3.48	.32	1.18	.68	.51	.01	.19	64	129	10	11	19	36	41	1.2	<.1	9
4	3.54	.39	1.21	.71	.63	.01	.31	75	159	11	10	15	69	39	1.8	.2	7
5	2.93	.34	1.35	.68	.55	.02	.19	82	112	7	8	17	38	38	1.7	.3	7
6	3.24	.35	3.04	.39	.17	.02	.20	38	92	7	8	11	10	21	.3	0.0	5
7	3.31	.33	1.70	.57	.43	.01	.16	44	108	6	9	12	26	23	.8	.1	4
8	3.15	.28	2.11	.35	.24	.02	.13	40	74	6	4	10	12	21	.5	.3	4
9	3.15	.28	1.22	.85	.67	.01	.34	45	110	6	5	24	38	20	1.7	.2	10
10	3.10	.30	2.01	.77	.35	.02	.26	51	108	6	5	20	34	14	1.1	0.0	5
11	2.74	.29	2.39	.70	.32	.02	.19	37	93	6	4	16	29	16	.7	.1	6
12	3.03	.33	2.75	.79	.24	.02	.25	69	132	5	3	19	38	21	.5	0.0	5
13	2.95	.30	2.28	.81	.34	.01	.19	61	147	7	6	14	74	62	.7	<.1	13
14	2.84	.30	1.83	.73	.40	.02	.16	100	124	8	7	23	61	53	.9	<.1	19
15	2.56	.30	1.91	.72	.50	.02	.23	104	133	14	7	29	111	39	1.6	.2	12

Note: The nitrogen determinations were made by the Kjeldahl method at the Department of Soil Science. Determinations of other elements, reported here, were made with an emission spectrograph by the Plant Analysis Laboratory, Wooster, Ohio.

SOIL TESTING IN MINNESOTA DURING 1964

JOHN GRAVA

Currently the University of Minnesota Soil Testing Laboratory processes more than thirty-five thousand samples annually. The following data show the number of various types of samples analyzed in 1964:

Regular farm, garden and lawn samples	33,074
Florist (greenhouse) samples	1,335
Limestone	109
Departmental research samples	1,594
Total	36,112

The monthly distribution of regular soil samples received by the laboratory is shown in table 1.

Table 1. Monthly Distribution of Soil Samples Received by the University of Minnesota Soil Testing Laboratory During 1964.

Month	Number of Samples
January	2988
February	2980
March	3082
April	3784
May	880
June	393
July	507
August	1213
September	2347
October	4959
November	5554
December	4287