Treatment Information

	Check	PK	NK	NP	NPK	NPK+ M.E.
Yield	68	71	69	55	57	
Population	12,300	12,300	13,100	12,500	13,300	
Number Barren Stalks	300	900	1,500	1,800	3,200	
Number Lodged Stalks	100	100	0	100	200	

	Increase	Decrease
Yield difference due to N =		14 bu.
" " " " P =		12 "
" " " " K =	2 bu.	

	Check	PK	NK	NP	NPK	NPK+ M.E.
Yield	77	55	55	62	44	53
Population	17,300	16,500	17,000	17,300	17,000	17,300
Number Barren Stalks	1,500	3,500	3,500	2,900	7,100	5,500
Number Lodged Stalks	400	200	300	400	200	400

	Increase	Decrease
Yield difference due to N =		11 bu.
" " " " P =		11 "
" " " " K =		18 "
" " " " M.E =	9 bu.	

	Check	PK	NK	NP	NPK	NPK+ M.E.
Yield	46	87	29	89	90	
Population	18,300	17,800	17,800	23,300	16,500	
Number Barren Stalks	4,300	1,600	5,400	2,100	2,200	
Number Lodged Stalks	2,300	2,000	1,200	2,700	2,000	

	Increase	Decrease
Yield difference due to N =	3 bu.	
" " " " P =	61 "	
" " " " K =	1 "	

	Check	PK	NK	NP	NPK	NPK+ M.E.
Yield	101	112	100	112	118	
Population	15,200	15,400	14,900	15,700	15,400	
Number Barren Stalks	300	200	600	400	200	
Number Lodged Stalks	1,600	2,200	800	1,800	1,300	

	Increase	Decrease
Yield difference due to N =	6 bu.	
" " " " P =	18 "	
" " " " K =	6 "	

	Check	PK	NK	NP	NPK	NPK+ M.E.
Yield	106	92	102	99	98	
Population	15,700	16,500	16,700	16,700	17,000	
Number Barren Stalks	1,600	2,600	2,300	2,500	2,200	
Number Lodged Stalks	800	500	1,000	1,300	1,600	

	Increase	Decrease
Yield difference due to N =	6 bu.	
" " " " P =		4 bu.
" " " " K =		1 "

Minnesota Subsoil Fertility Study (1956-1959)[1)]

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Introduction

Difficulties are frequently encountered by making lime and fertilizer recommendations on basis of soil tests on surface samples alone without information of the subsoil fertility. Although farmers are encouraged to obtain subsoil samples for testing purposes, their response has not been adequate. Since subsoil sampling is both time comsuming as well as inconvenient to the average farmer, it is doubtful whether the practice can be successfully established as an integral part of a soil sampling and testing program. However, if the nutrient levels in the subsoil of individual soil series were known and were reasonably uniform within each series, sampling of the plow layer would be adequate if the soil weries were known.

For this purpose a cooperative study on subsoil fertility of Minnesota's major soil series was initiated in 1956. The cooperating agencies are the Department of Soils of the University of Minnesota and the Soil Conservation Service. The purpose of this report is to describe briefly the procedure which is followed in this study, and, with the help of a few examples, to illustrate the possibilities of a study such as this.

Procedure

Profile samples are obtained by S.C.S. area soil scientists in connection with their regular soil survey work. Some profiles are taken from fields that have been included in the "Soil Productivity Study" conducted in cooperation with the Department of Soils. It is expected that 20 to 50 profiles of each major soil series will be collected. However, the choice of profiles within a given soil series is left entirely to the soil scientists. Sometimes samples are submitted to the laboratory for chemical and/or mechanical analysis where the identification by regular field methods seems to be insufficient.

Duplicate, one pint samples of each horizon are taken, put in plastic bags, sealed, labeled and placed in carboard containers. Samples and soil description forms (S.C.S. Form 232C) are mailed or brought to the Soil Testing Laboratory. File numbers are given to each profile as well as individual horizon samples. Samples, after being air-dried, crushed and screened, are tested by regular soil testing procedures. These include determinations for pH, organic matter, phosphorus and potassium. The pH is determined with a Beckman pH meter on a soil-water paste. Organic matter is determined by employing the potassium dichromate and sulfuric acid method. The color differences are measured by means of a colorimeter. Extractable phosphorus is determined colorimetrically by the Bray's No. 1 method. Exchangeable potassium is determined on a neutral 1N ammonium acetate extract using the Perkin-Elmer flame photometer. The contents of phosphorus and potassium are expressed in parts per two million. (One part per two million of phosphorus or potassium is equivalent to one pound per acre assuming the sample represents a 6 inch layer or 2 million pounds of soil).

1) In cooperation with the S.C.S.

After the completion of the analyses, test results are recorded and a copy is sent to the S.C.S. Soil Scientist, who had submitted the samples. Samples are saved with the intention of undertaking additional determinations on soil physical, mechanical and chemical properties as resources will permit.

During last year it became apparent that, because of lack of funds, it will be possible to investigate more thoroughly only a limited number of profiles. For that purpose "modal" profiles of 27 soil series were selected. Mechanical and chemical analyses on these samples are now nearly completed.

Results

A total of 2608 samples from 503 profiles have been submitted for this study. Tables 1 and 2 show the number of profiles obtained from each S.C.S. area since the establishment of this study. A list of profiles obtained from major soil series is also included.

Tables 3 to 11 show results of mechanical and chemical analyses which have been completed on nine profiles considered as "modal" for the Lester, LeSueur, Clarion, Kranzburg, Aastad, Flom, Bearden, Ulen and Hubbard series.

Previous studies on soils of Iowa, Wisconsin and Minnesota have indicated that exchangeable potassium content may be considerably higher in air-dry samples, especially in subsoil, in comparison to that determined on field moist soil. On coarse textured soils which are rather low in clay content, such drying effect is much less pronounced. The data of Figures 1 to 9 illustrate the effect of sample drying upon the exchangeable potassium content on nine different Minnesota soils.

Conclusions

The information already obtained indicates that this study can greatly contribute to our knowledge of the subsoil fertility status of soils of Minnesota. It should lead to a better understanding of various soil series in respect to problems concerning liming, fertilization and overall management.

Table 1. NUMBER OF SOIL PROFILES RECEIVED ANNUALLY FOR THE SUBSOIL FERTILITY STUDY, 1956 to 1959

YEAR	NUMBER OF PROFILES	NUMBER OF SAMPLES
1956	55	333
1957	185	984
1958	162	804
1959	101	487
Four Year Total	503	2608

Table 2. NUMBER OF SOIL PROFILES OBTAINED FOR MINNESOTA'S SUBSOIL FERTILITY STUDY BY COUNTIES AND S.C.S. AREAS, 1956 to 1959.

AREA I.		AREA II.		AREA III.		AREA IV.		AREA V.		AREA VI.		AREA VII.	
						S.C.S. Soil Scientists: Edwards, Diedrick, Sutton, Lueth, Munter, Nyberg							
Scilley, Ravenholt, Barron		Erickson, Lewis		Grimes, Ziebell, Chamberlain				Hokanson, Lorenzen		Cummins		Harms, Poch	
Kittson	3	Douglas	3	Aitkin	4	Carver	29	Lincoln	10	Blue Earth	3	Wabasha	17
Lake of the Woods	8	Ottertail	4	Benton	3	Chippewa	17	Lyon	9	Brown	19	Mower	1
Marshall	1	Stevens	1	Chisago	3	Kandiyohi	16	Murray	13	Freeborn	21	Dodge	1
Norman	6	Grant	5	Kanabec	1	Meeker	22	Nobles	20	LeSueur	15	Goodhue	3
Red Lake	1			Mille Lacs	4	Renville	13	Pipestone	6	Martin	6		
Beltrami	8			Sherburne	17	Sibley	15	Redwood	3	Rice	36		
Pennington	3			Stearns	4	Swift	21	Jackson	1	Steele	41		
Polk	3					Wright	1	Rock	1	Watonwan	10		
Clearwater	3					Bigstone	12	Yellow Medicine	2	Waseca	20		
Koochiching	2					Pope	12						
Area Total	38		13		36		158		65		171		22

State Total 503

LIST OF PROFILES OBTAINED FROM MAJOR SOIL SERIES FOR MINNESOTA'S SUBSOIL FERTILITY STUDY, 1956-1959

FD Fayette - Dubuque	
Fayette	5
Dubuque	2
Bertrand	2
TD Tama - Downs	
Tama	5
Downs	4
LH Lester - Hayden	
Dundas	8
Hayden	29
CL Clarion - Lester	
Lester	31
LeSueur	16
HB Hayden - Bluffton	
Bluffton	2
Nessel	1
Ames	1
OKF Ostrander - Kenyon - Floyd	
Ostrander	3
Kenyon	3
Floyd	3
Racine	1
Taopi	3
Varco	1
Lerdahl	3
SK Skyberg - Kasson	
Skyberg	1
CNW Clarion - Nicollet - Webster	
Storden	5
Lakeville	1
Clarion	23
Nicollet	29
Webster (Timbered)	6
Webster	16
Webster, Calc. Var.	18
Harpster	2
Glencoe	7
Blue Earth	1
Truman	1
Kinston	4
Madelia	5
Marna	8
Laura	4
Beauford	4

CNW	
Terril	1
Comfrey	1
Fieldon	1
Arlington	4
Rolfe	1
Thurman	1
MKU Moody - Kranzburg - Vienna	
Kranzburg	10
Moody	1
Primghar	1
Marcus	1
Afton	1
Vienna	2
Lismore	2
Leota	1
BA Barnes - Aastad	
Buse	9
Barnes	17
Aastad	10
Flom	7
Parnell	6
Hamerly	7
Vallers	6
Alcester	1
Arco	2
Sverdrup	3
Hendricks	1
Tetonka	1
Pierce	1
WB Waukon - Barnes	
Waukon	3
Gonvich	1
FB Fargo - Bearden	
Fargo	2

FB

Bearden	4
Colvin	3
Sletten	1
Borup	2

UST Ulen - Sioux - Tanberg

Ulen	2
Sioux	2
Grimstad	1
Mavie	1

MW McIntosh - Winger

McIntosh	1
Winger	1

NR Nebish - Rockwood

Nebish	3
Beltrami	1
Shooks	2
Brickton	2

RKP Rocksbury - Kittson - Peat

Kittson	1
Rockwell	3

TGP Taylor - Grygla - Peat

Baudette	2
Hiwood	2
Chilgren	3
Grygla	1
Wildwood	1
Indus	1

MBH Milaca - Brainerd - Hibbing

Freon	3
Freer	1
Milaca	1
Mora	1
Bock	1
Flak	2

ZIP Zimmerman - Isanti - Peat

Zimmerman	4
Nymore	2
Lino	2
Isanti	2

M Menahga

Menahga	3
Redby	1

WH Wadena - Hubbard and Terrace Soils

Hubbard	13
Wadena	4
Estherville (BA group)	9
Fairhaven (CNW group)	4
Litchfield	1
Biscay	3
Kasota	1
Kato	1
Bixby	2
Waukegan	2
Estilline	1
Central	3

Table 3. Soil Type Lester Loam Location Carver County

Legal Description SW¼ of SW¼ Sec. 1 Benton Twp. R 25 W T 115 N

Sampled by R. J. Edwards Laboratory No. 106:1-6

Depth Inches	Horizon	Per cent			Texture		pH Paste	Organic matter %	Extractable P p.p.2m.	Exchangeable K p.p.2m.		Extractable Cations m.e./100 g. soil				$CaCO_3$ Equivalent %	Electrical Conductivity EC x 10^3 Millimhos per CM @ 25° C
		Sand	Silt	Clay	Field method	Mechan. Anal.				Field moist	Air-dry	Ca	Mg	K	Na		
0-6	A_1	46.1	32.3	21.6	h.l	l	6.9	7.7	64	634	547	19.3	6.4	0.70	0.10	-	-
6-8	A_2	48.7	30.8	20.5	l	l	7.0	2.2	45	289	321	11.9	3.4	0.41	0.06	-	-
8-14	B_1	40.8	28.8	30.4	cl	cl	7.0	1.6	37	186	375	14.3	5.7	0.48	0.09	-	-
14-23	B_{21}	39.9	30.6	29.5	cl	cl	6.9	1.0	15	77	321	13.7	6.8	0.41	0.18	-	-
23-30	B_{22}	40.0	32.0	28.0	h.cl	cl	6.8	0.6	18	77	313	12.8	6.5	0.40	0.24	-	-
30-42+	C	37.0	39.2	23.0	cl	l	7.8	0.3	3	66	274	11.5	5.0	0.35	0.23	17.1	0.5

Table 4. Soil Type LeSueur Silty Clay Loam Location Carver County

Legal Description NE¼ of NW¼ Sec. 5. San Francisco Twp.

Sampled by R.O. Lueth Laboratory No. 402:1-8

Depth Inches	Horizon	Per cent Sand	Per cent Silt	Per cent Clay	Texture Field method	Texture Mechan. Anal.	pH Paste	Organic matter %	Extractable P p.p.2m.	Exchangeable K p.p.2m. Field moist	Exchangeable K p.p.2m. Air-dry	Extractable Cations m.e./100g. soil Ca	Mg	K	Na	$CaCO_3$ Equivalent %	Electrical Conductivity EC x 10^3 Millimhos per CM @ 25°C
0-7	A_1	11.1	51.9	37.0	lt.cl	si.cl	7.0	7.8	11	231	360	27.0	9.4	0.46	0.11	-	-
7-9	AB	11.8	50.4	37.8	cl	si.cl	6.7	6.9	37	162	328	20.2	7.4	0.42	0.10	-	-
9-14	B_1	9.1	49.2	41.7	cl	si.c	6.2	3.6	25	117	399	20.2	8.1	0.51	0.11	-	-
14-18	B_{21}	10.0	37.7	52.3	h.cl	c	5.1	1.9	4	103	587	19.9	8.2	0.75	0.22	-	-
18-28	B_{22}	17.1	35.3	47.6	vh.cl	c	4.5	1.0	3	82	485	14.9	7.3	0.62	0.22	-	-
28-34	B_3	18.3	40.5	41.2	cl	si.c	6.4	0.6	7	87	493	20.2	10.3	0.63	0.39	-	-
34-39	C_1	33.2	38.0	28.8	cl	cl	7.1	0.4	3	83	415	16.4	6.1	0.53	0.37	4.9	0.5
39+	C_2	-	-	-	cl	-	7.5	0.2	3	87	297	11.1	4.0	0.38	0.37	9.2	0.5

Table 5. Soil type Clarion clay loam Location Brown county
Legal description SE¼ SE¼ Sec. 26 Home township R 32 W T 110 N
Sampled by J. F. Cummins Laboratory No. 367:1-5

Depth Inches	Horizon	Per cent			Texture		pH Paste	Organic matter %	Extractable P p.p.2m.	Exchangeable K p.p.2m.		Extractable Cations				$CaCO_3$ Equivalent %	Electrical Conductivity EC x 10^3 Millimhos per CM @ 25° C.
		Sand	Silt	Clay	Field method	Mechan. anal.				Field moist	Air-dry	Ca	Mg	K	Na		
												m.e./100 g. soil					
0-8	A_p	35.8	33.8	30.4	cl	cl	5.6	4.6	14	277	399	13.4	6.0	0.51	0.09	-	-
8-13	A_1	37.1	32.8	30.1	cl	cl	5.6	4.4	8	193	360	13.4	5.9	0.46	0.09	-	-
13-23	B_1	38.2	31.9	29.9	cl	cl	6.1	1.0	2	99	344	13.7	6.7	0.44	0.17	-	-
23-32	B_2	40.0	33.4	26.6	cl	l	6.4	0.7	3	99	328	13.4	6.4	0.42	0.20	-	-
32-36	C_1	40.4	33.5	26.1	cl	l	8.0	0.3	3	101	282	10.9	4.0	0.36	0.20	15.2	0.5

Table 6. Soil Type Kranzburg Silty Clay Loam Location Nobles County

Legal Description NE¼ Sec. 15. Grand Prairie Twp. R43 W T 101 N.
Sampled by F. D. Lorenzen Laboratory No. 298:1-6

Depth Inches	Horizon	Per Cent			Texture		pH Paste	Organic matter %	Extractable P p.p.2m.	Exchangeable K p.p.2m.		Extractable Cations			
		Sand	Silt	Clay	Field Method	Mechan. Anal.				Field Moist	Air-Dry	Ca	Mg	K	Na
0-7	A_{1p}	5.8	64.1	29.9	si.l	si.cl.	6.5	4.6	10	206	266	15.2	7.1	0.34	0.08
7-12	AB	4.8	63.5	31.7	si.l	si.cl.	6.6	4.5	11	245	305	14.9	7.3	0.39	0.08
12-16	B_{21}	2.9	64.3	32.8	si.l	si.cl.	6.2	3.1	7	128	297	14.9	7.3	0.38	0.11
16-21	B_{22}	2.9	62.7	34.4	si.l	si.cl.	6.0	2.1	5	63	313	15.5	8.2	0.40	0.12
21-32	C	4.7	69.7	25.6	si.l	si.l	6.3	1.2	11	53	313	12.8	7.4	0.40	0.16
32+	D	33.9	45.8	20.3	calc. till	l	6.4	0.7	9	56	289	11.9	7.5	0.37	0.14

Table 7. Soil type Aastad loam Location Swift county
Legal description NW¼ NW¼ Sec. 16, Hayes township
Sampled by R. T. Diedrick Laboratory No. 308:1-5

Depth Inches	Horizon	Per cent Sand	Per cent Silt	Per cent Clay	Texture Field method	Texture Mechan. anal.	pH Paste	Organic matter %	Extractable P p.p.2m.	Exchangeable K p.p.2m. Field moist	Exchangeable K p.p.2m. Air-dry	Extractable Cations Ca (m.e./100 g. soil)	Extractable Cations Mg (m.e./100 g. soil)	Extractable Cations K (m.e./100 g. soil)	Extractable Cations Na (m.e./100 g. soil)	$CaCO_3$ Equivalent %	Electrical Conductivity EC x 10^3 Millimhos per CM @ 25° C
0-6	A_p	41.0	36.6	22.4	lt.cl	1	7.4	5.4	10	138	219	18.9	4.6	0.28	0.12	-	0.8
6-14	A_1	30.1	42.8	25.1	lt.cl	1	7.1	5.3	8	108	211	19.9	4.8	0.27	0.12	-	0.4
14-19	B_{21}	28.2	47.0	24.8	cl	1	6.7	3.6	6	63	227	14.6	5.5	0.29	0.09	-	-
19-24	B_{22}	27.2	47.5	25.3	cl	1	6.5	2.1	3	77	266	13.4	5.2	0.34	0.09	-	-
24-27	B_{23}	-	-	-	scl	-	-	-	-	-	-	-	-	-	-	-	-
27-52+	C_1	24.2	50.2	25.6	cl	sil	6.4	2.0	5	70	282	14.0	5.5	0.36	0.11	-	-

Table 8. Soil type Flom silty clay loam Location Swift county
Legal description NW¼ NW¼ Sec. 16 Hayes township
Sampled by R. T. Diedrick Laboratory No. 182:1-5

Depth Inches	Horizon	Texture Field Method	pH Paste	Organic matter %	Extractable P p.p.2m.	Exchangeable K p.p.2m.		Extractable cations				$CaCO_3$ Equivalent %	Electrical Conductivity EC x 10^3 Millimhos per CM @ 25° C.
						Field Moist	Air-dry	Ca	Mg	K	Na		
								m.e./100 g. soil					
0-6	A_p	lt.sicl	7.7	6.9	9	285	469	27.5	14.0	0.60	0.11	2.2	1.0
6-14	A_1	lt.sicl	7.7	5.9	5	149	328	24.7	15.7	0.42	0.11	1.6	0.5
14-18	B_{21}	sicl	8.2	1.9	3	54	274	10.2	17.5	0.35	0.13	8.1	0.5
18-22	B_{22}	sicl	8.4	0.9	2	48	203	6.2	14.3	0.26	0.13	13.4	0.5
22-30	C_1	cl	8.4	0.3	2	54	164	3.7	10.4	0.21	0.16	17.3	0.5

Table 9. Soil Type Bearden Silty Clay Loam Location Chippewa County

Legal Description NE¼ NE¼ Sec. 3. Grace Twp.

Sampled By R. T. Diedrick Laboratory No. 183:1-5

Depth Inches	Horizon	Per Cent Sand	Per Cent Silt	Per Cent Clay	Texture Field method	Texture Mechan. Anal.	pH Paste	Organic matter %	Extractable P p.p.2m.	Exchangeable K p.p.2m. Field moist	Exchangeable K p.p.2m. Air-dry	Extractable Cations Ca m.e./100 g. soil	Extractable Cations Mg m.e./100 g. soil	Extractable Cations K m.e./100 g. soil	Extractable Cations Na m.e./100 g. soil	$CaCO_3$ Equivalent %	Electrical Conductivity EC x 10^3 Millimhos per CM @ 25° C
0-7	A_p	6.5	56.9	36.6	si.l	si.cl.	7.7	8.1	8	320	422	31.9	6.9	0.54	0.26	11.6	1.3
7-11	A_1	6.4	57.1	36.5	si.l	si.cl.	7.8	7.6	8	345	422	34.2	6.9	0.54	0.24	12.3	1.2
11-14	A_{1Ca}	6.7	55.6	38.7	si.l	si.cl.	8.0	4.7	3	134	305	24.5	6.9	0.39	0.17	19.0	1.0
14-20	B_2	7.2	58.6	34.2	si.cl.	si.cl.	7.7	1.8	3	101	321	16.7	6.4	0.41	0.18	21.2	0.8
20-33	C	12.0	52.7	35.3	si.cl.	si.cl.	7.5	0.4	3	127	360	17.4	4.0	0.46	0.29	18.0	2.4

Table 10. Soil Type Ulen Loam Location Kittson County

Legal Description NE corner Sec. 36. Jupiter Twp. R47 W T 160 N.

Sampled by F. M. Scilley Laboratory No. 213: 1-4

Depth inches	Horizon	Texture: Field Method	Texture: pH Paste	Organic matter %	Extractable P p.p.2m.	Exchangeable K p.p.2m.: Field Moist	Exchangeable K p.p.2m.: Air-Dry	Extractable Cations m.e./100 g. soil: Ca	Mg	K	Na	$CaCO_3$ Equivalent %	Electical Conductivity EC x 10^3 Millimhos per CM @ 25° C
0-8	A_p & A_1	lt.l	8.3	4.0	5	134	125	12.0	4.9	0.16	0.06	8.5	0.8
8-17	A_3 Ca	lt.sl	8.3	3.1	2	30	70	10.8	4.7	0.09	0.10	11.8	0.8
17-25	C_1 Ca	f.s.	8.1	0.8	1	18	39	5.4	1.6	0.05	0.07	17.1	1.1
25-40	C_2 Ca	f.s.	8.5	0.4	1	11	16	1.8	0.8	0.02	0.04	17.2	0.3

Table 11. Soil type Hubbard loamy coarse sand Location Sherburne county
Legal description SW¼, SW¼, Sec. 33, Haven township
Sampled by M. F. Grimes Laboratory No. 301:1-5

Depth Inches	Horizon	Particle Size Distribution (in mm) (per cent)								Texture	
		Very coarse sand 2-1	Coarse sand 1-0.5	Medium sand 0.5-0.25	Fine sand 0.25-0.10	Very fine sand 0.10-0.05	Total sands	Total silts	Total clays	Field method	Mechan. analysis
0-8	A_{1p}	3.5	38.3	18.8	20.2	1.5	82.3	11.4	6.3	l s	l c s
8-14	A_{12}	4.8	38.7	23.0	13.4	1.4	81.3	11.7	7.0	l s	l c s
14-24	A-B	9.9	41.1	19.9	17.9	1.2	90.0	6.4	3.6	l s	c s
24-40	B	1.4	50.4	31.8	14.1	0.6	98.3	1.0	0.7	s	c s
40-72	C_1	7.9	61.7	19.1	9.8	0.3	98.8	1.2	0	s	c s

Depth Inches	pH Paste	Organic Matter %	Extractable P p.p.2m.	Exchangeable K p.p.2m.		Extractable Cations			
				Field Moist	Air-Dry	Ca	Mg	K	Na
						m.e./100 g.			
0-8	6.2	2.8	38	45	47	4.4	1.8	0.06	0.04
8-14	5.7	1.6	7	13	39	4.4	0.8	0.05	0.03
14-24	5.7	0.8	12	12	16	1.8	0.5	0.02	0.03
24-40	6.1	0.1	9	21	16	0.9	0.2	0.02	0.03
40-72	6.2	0.0	13	15	16	0.6	0.4	0.02	0.02

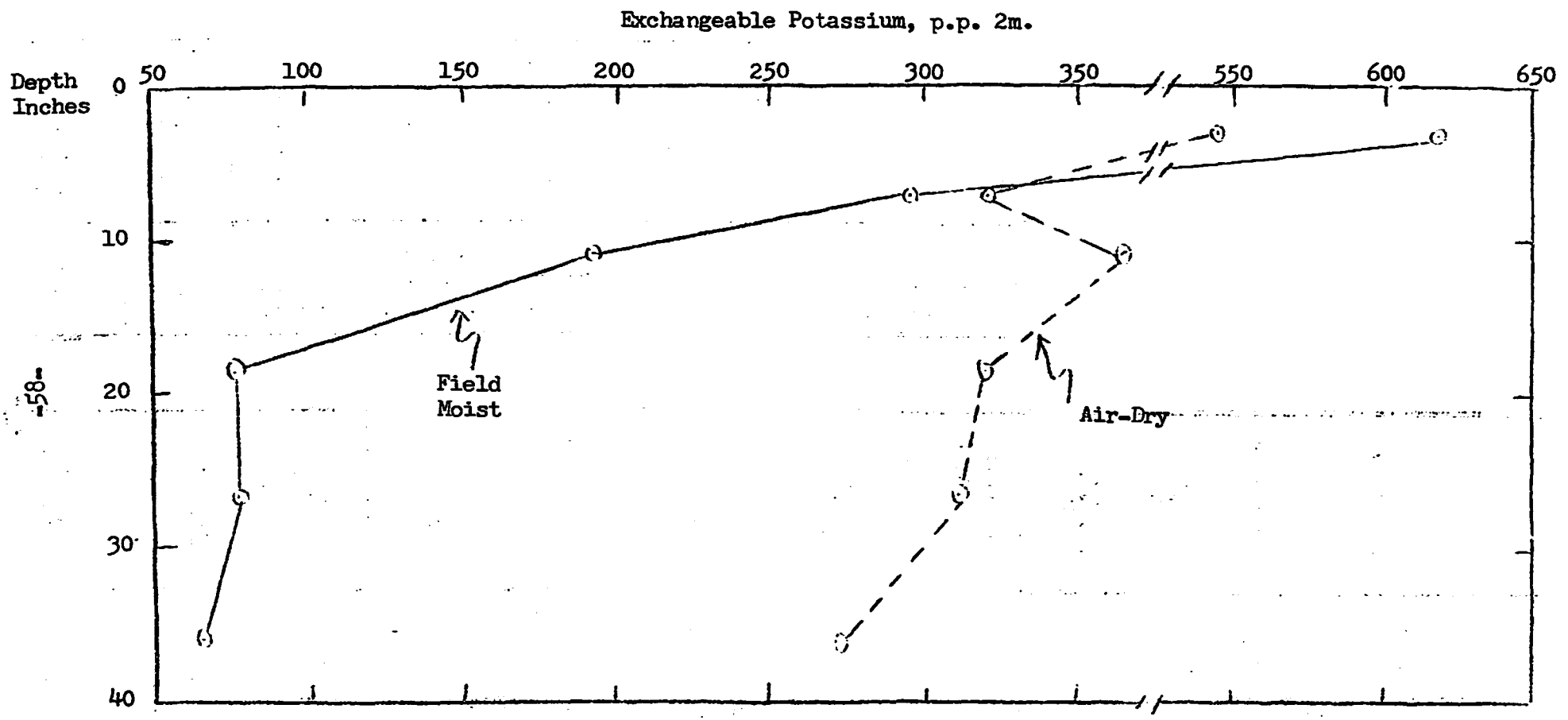

Fig. 1. Effect of drying upon the content of exchangeable potassium in Lester Loam, Carver County.

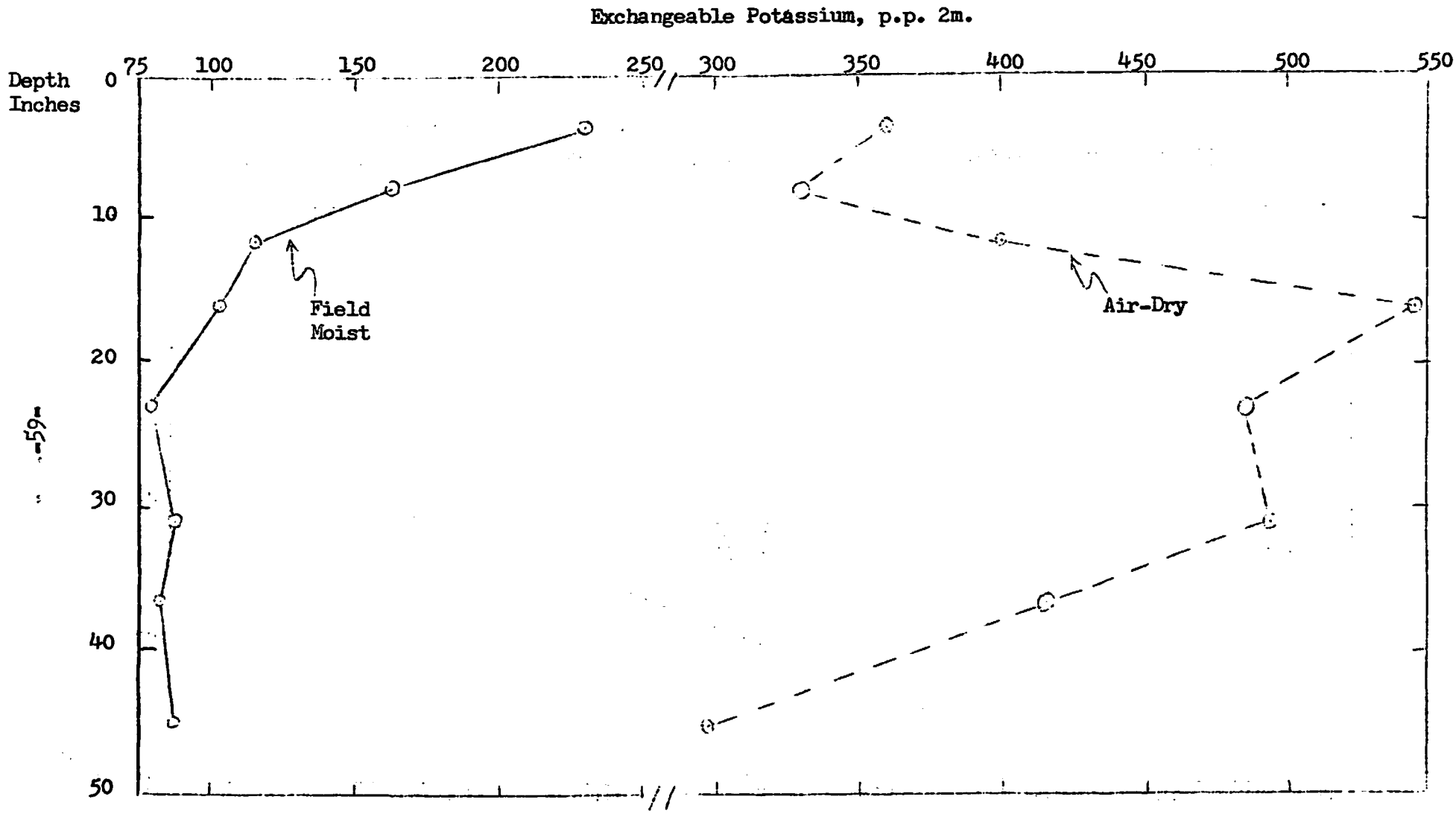

Fig. 2. Effect of drying upon the content of exchangeable potassium in Le Sueur Silty Clay Loam, Carver County.

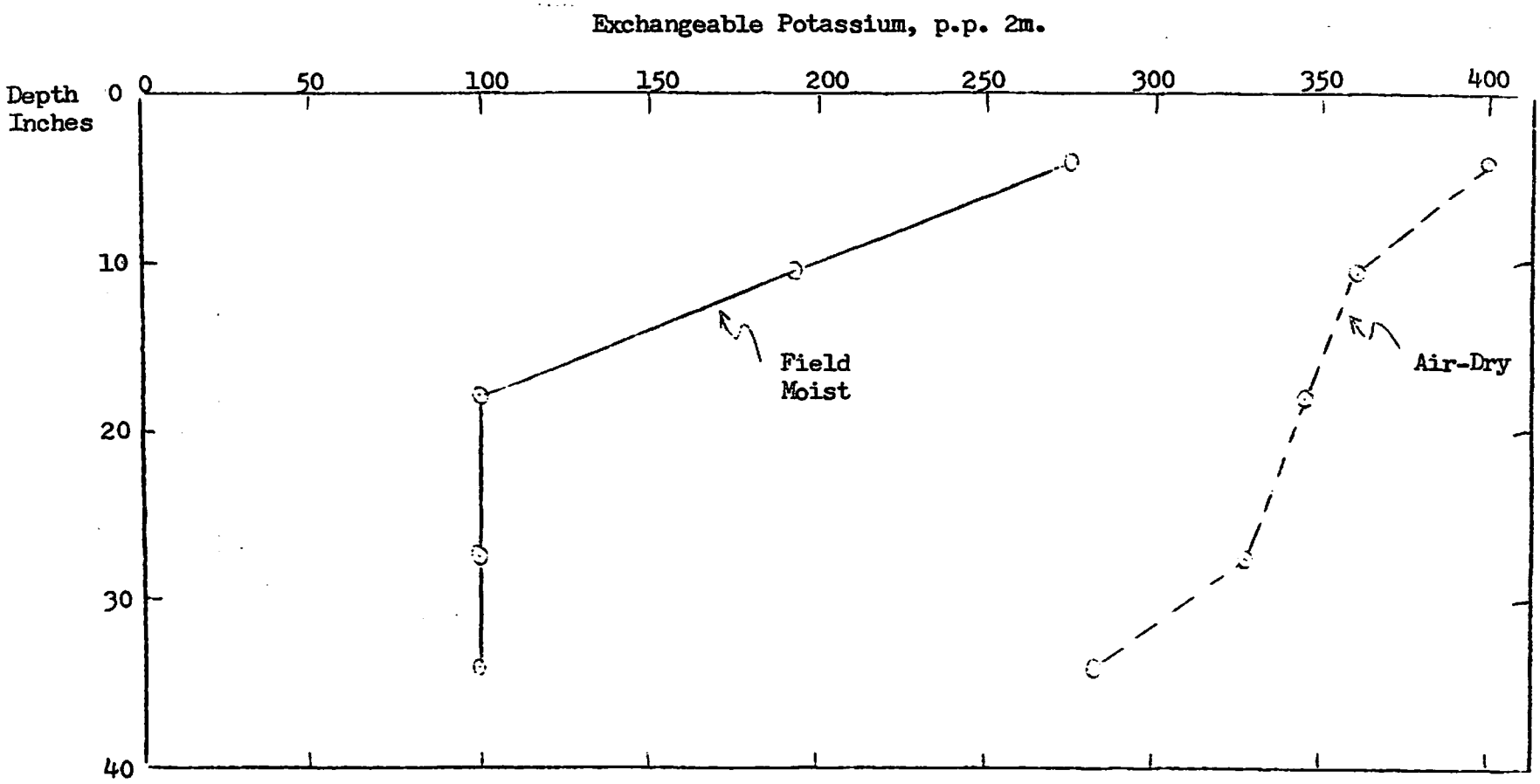

Fig. 3. Effect of drying upon the content of exchangeable potassium content in Clarion Clay Loam, Brown County.

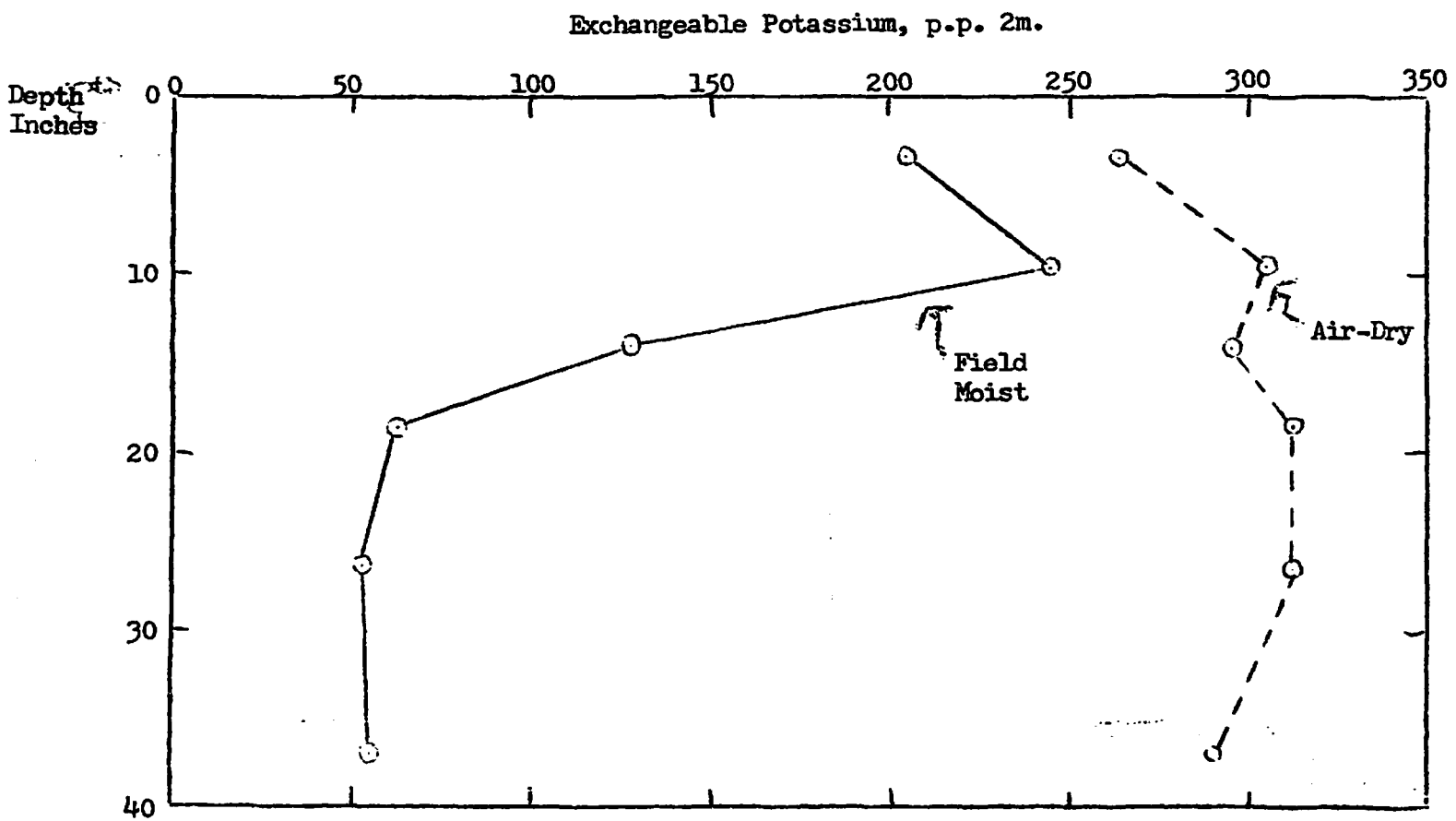

Fig. 4. Effect of drying upon the content of exchangeable potassium in Kranzburg Silty Clay Loam, Nobles County.

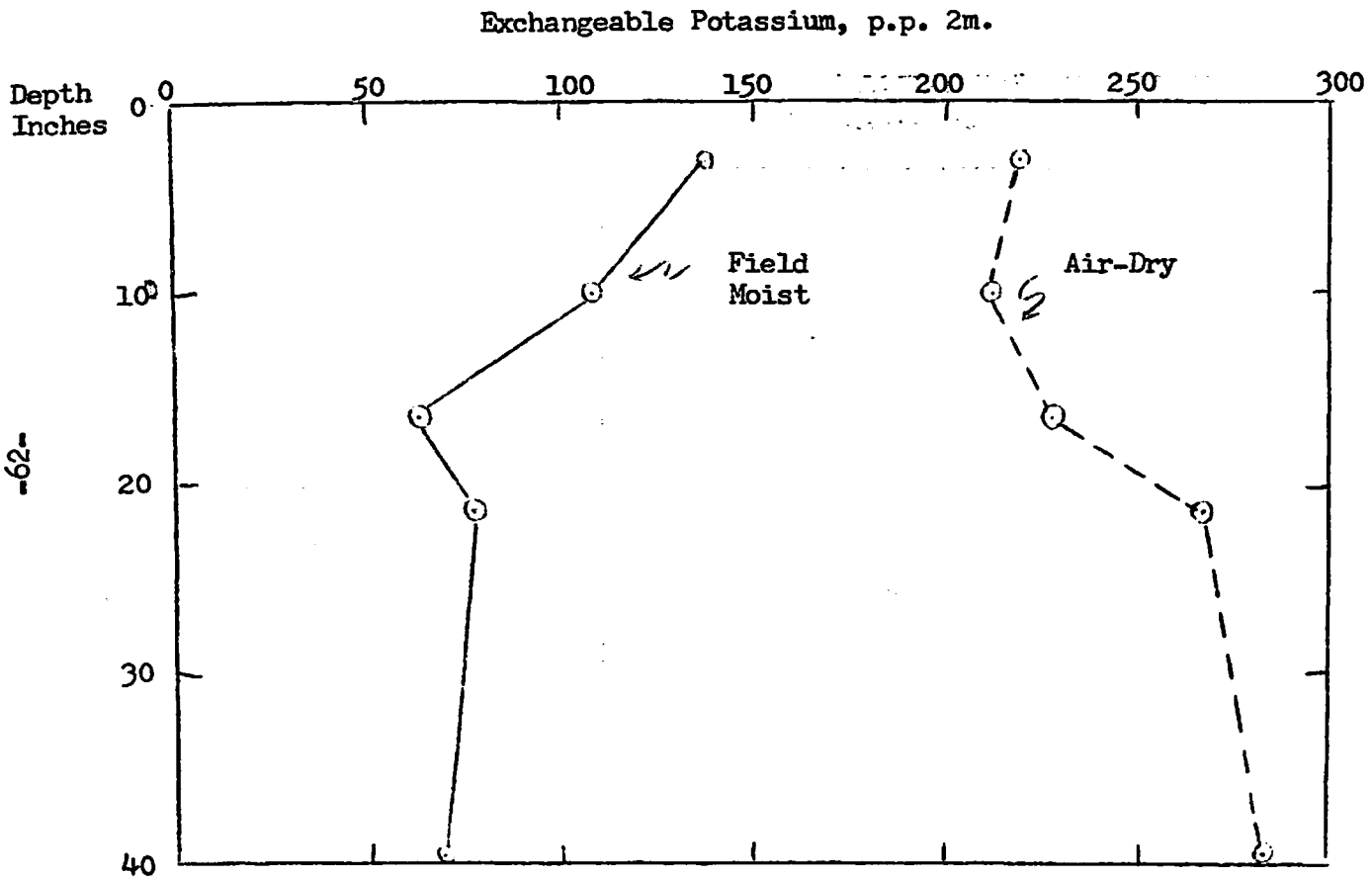

Fig. 5. Effect of drying upon the content of exchangeable potassium in Aastad Loam, Swift County.

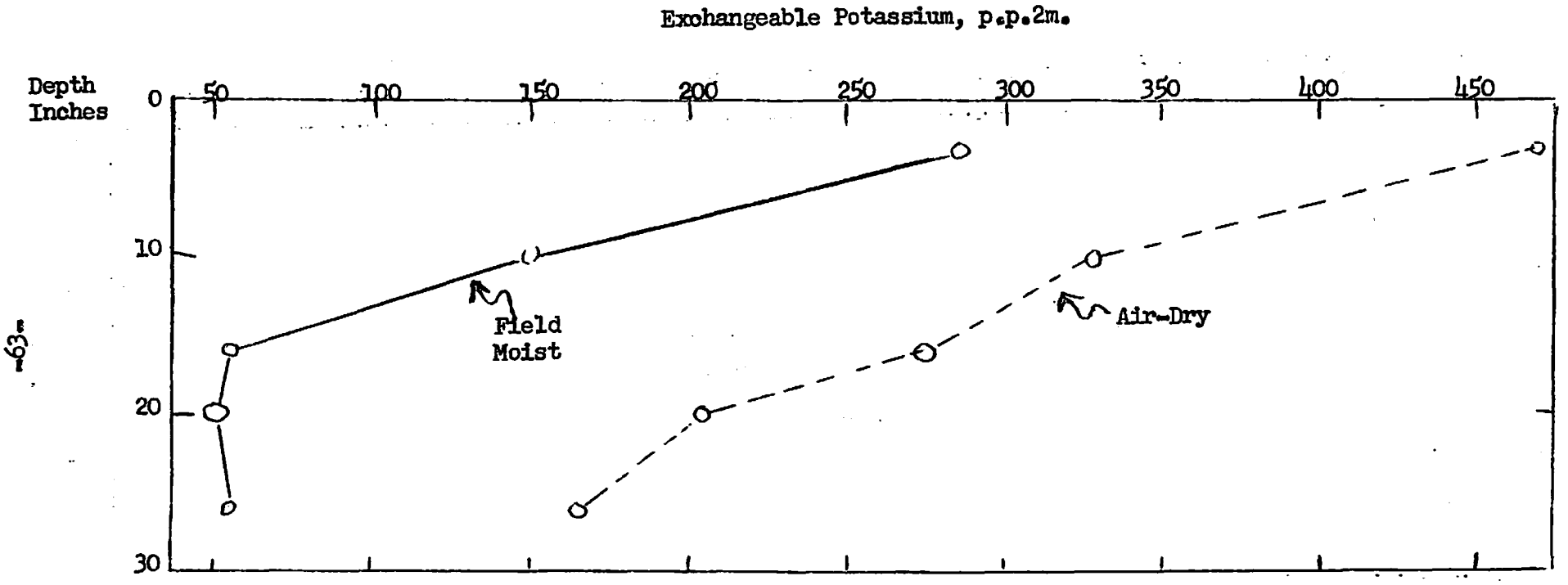

Fig. 6. Effect of drying upon the content of exchangeable potassium in Flom Silty Clay Loam. Swift County.

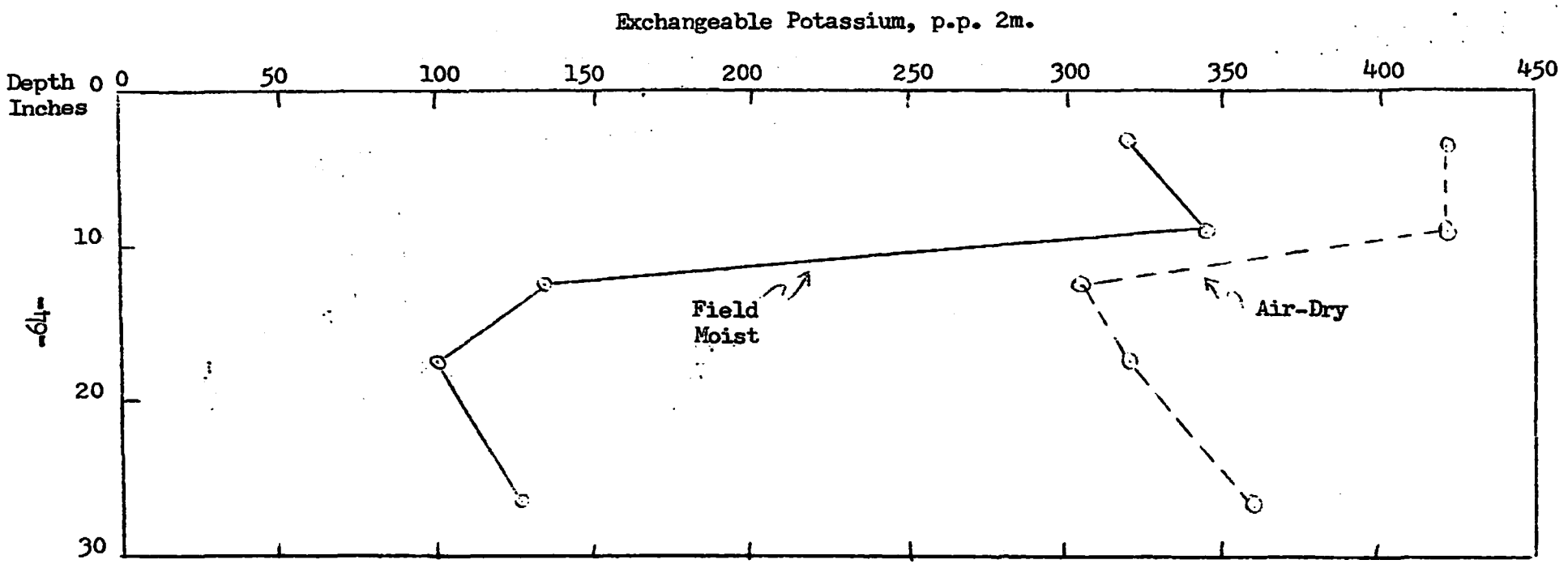

Fig. 7. Effect of drying upon the content of exchangeable potassium in Bearden Silt Loam, Chippewa County.

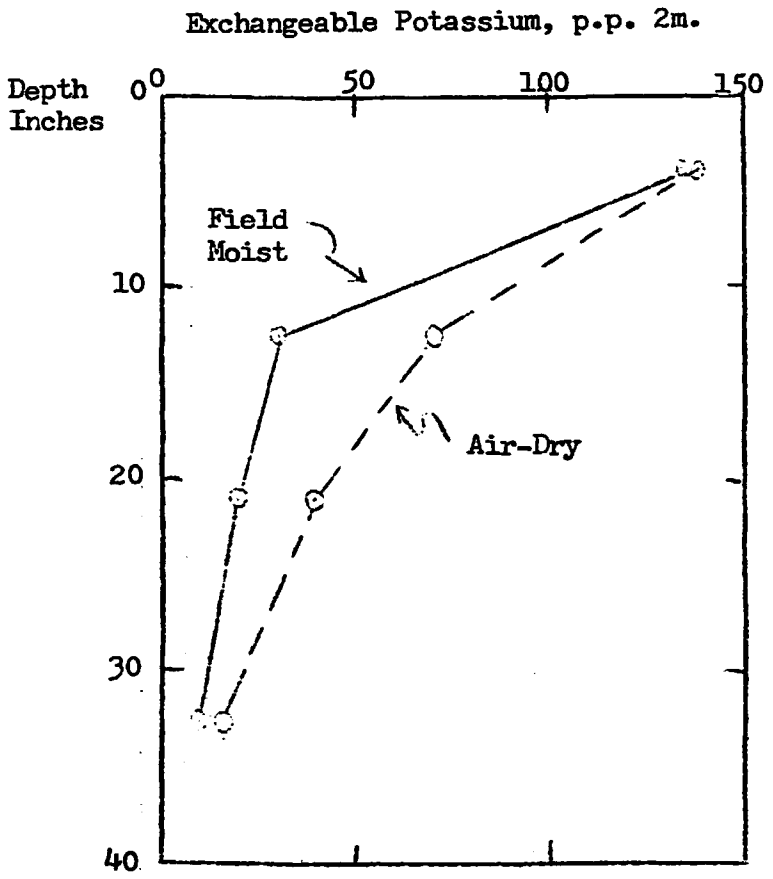

Fig. 8. Effect of drying upon the content of exchangeable potassium in Ulen Loam, Kittson County.

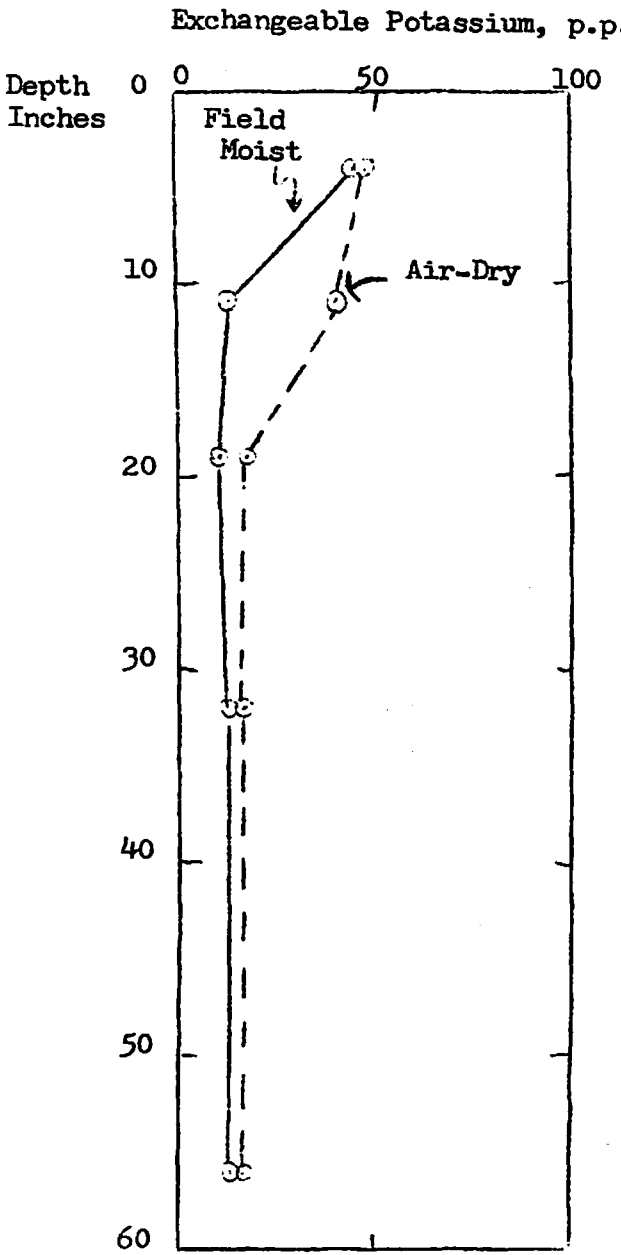

Fig. 9. Effect of drying upon the content of exchangeable potassium in Hubbard Loamy Coarse Sand, Sherburne County.

Nitrogen Losses to the Atmosphere

J. M. MacGregor

Soil investigators have always been unable to balance the nitrogen economy of soils, and it has long been suspected that nitrogen losses not accountable were being lost to the air as NH_3, N_2, N_2O and possibly as N_2O_2.

Recent laboratory investigations in the Department of Soils, using infra-red and mass spectrometric procedures, have shown that wet soils lose appreciable amounts of some fertilizer nitrogen in the air. These losses were most serious where nitrogen was applied in large amounts as the nitrate form, with little loss where applied as urea or as ammonium chloride.

However, under drier soil conditions, when urea was broadcast on the surface of a fine textured soil (Nicollet silty clay loam), at the rate of 100 pounds of N per acre, about 3% was lost as ammonia to the atmosphere over a four week period. Where the same amount of urea was broadcast on a sandy soil, 6% of the nitrogen was lost to the air in 14 days. Covering the urea with a half inch of the sandy soil reduced the loss to half of that of the surface application (3%). Some field experiments have indicated a slightly greater use of the nitrate nitrogen by corn plants, but this varies with different soil and weather conditions.

It must be kept in mind that nitrogen is not a mineral element, but can revert to gaseous forms and be lost from the soil in this way. Good results have been obtained with all of our commonly used nitrogen fertilizers - and more research is essential to increase this nitrogen efficiency in crop production even more.

Comparison of Sources of Phosphate (Goodhue County, 1959)

A. C. Caldwell and J. Kline

An experiment comparing sources of phosphate was established on an alfalfa field on the Augustine brothers farm in the spring of 1959. This soil is a Fayette silt loam testing medium in available P and neutral in reaction. Fertilizer treatments consisted of tunisian rock, Florida rock, concentrated superphosphate, calcium metaphosphate, and monodicalcium phosphate. Two samples of alfalfa were taken for yields, and one (the first) for P analysis. Results are given in the following tables.

Yield results show that responses to phosphorus were small (which was somewhat contrary to what might have been expected on the basis of soil test). All materials brought about a small increase in alfalfa yields, none differing significantly from another.

All phosphorus materials increased the phosphorus content of alfalfa. The more available forms of phosphorus had greater effects than the rock phosphates, however Tunisian rock supplied more phosphorus to plants than did Florida rock.

Effect of phosphate source on the yield and phosphorus content of alfalfa (Augustine Bros. Farm, Goodhue County, 1959).

Treatment	Alfalfa Yield T/A 1st cutting	Alfalfa Yield T/A 2nd cutting	% P 1st cutting
None	1.9	1.1	0.233
Conc. super - 80# P_2O_5/ac	2.1	1.2	0.287
" " -160 " "	2.2	1.4	0.335
Cal. meta - 80 " "	2.2	1.3	0.296
" 160 " "	2.0	1.3	0.281
Monodical - 80 " "	2.0	1.1	0.269
" 160 " "	2.0	1.4	0.312
Florida rock - 1000 #material/ac	2.0	1.2	0.249
Tunisian rock - 1000 # " "	2.2	1.3	0.257
" 500# " "	2.1	1.2	0.263

Phosphorus Source Experiment
A. C. Caldwell and J. Kline

A phosphate source experiment was established at Rosemount in 1951. Twelve treatments of various phosphate materials were replicated four times across a regular rotation of corn, wheat alfalfa, and alfalfa.

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

Table 2 shows the effects of the various phosphorus treatments on the extractable phosphorus content of the soil as determined by the Soil Testing Laboratory. The readily available forms of phosphorus more than doubled the extractable phosphorus content of the soil, while rock phosphorus forms had no significant effect.

Yield results for 1959 are included in Table 3. No significant yield increases resulted on any of the crops by any of the phosphate sources. Close observation of the data, however, shows that the yields of corn, wheat, and alfalfa are nearly always larger on plots receiving phosphorus as opposed to those receiving none. This does indicate a response to phosphorus, in general, on this soil.

Table 2. The effect of various phosphate treatments on the extractable phosphorus content of a Port Byron silt loam soil (Rosemount Experiment Station, 1959).

Treatments	lbs. P_2O_5/A/yr.	Bray's # 1 Phosphorus lbs./A	diff. from Check
Check	-	12	---
Ord. super phos.	40	31	19
Conc. super phos.	40	32	20
Ca. meta phos.	40	30	18
H_3PO_4	40	29	17
Fused tri Ca.	40	21	9
Fla. rock (lt.)	100	14	2
Fla. rock + Ord. super	20 + 20	20	8
	lbs. material/A./4 yrs.		
Fla. rock (hvy.)	1000	17	5
West rock	1000	14	2
Col. clay rock	1000	12	0
Tunis rock	1000	17	5

LSD (F_{95}) = 10.5

Because of the large variation in the experiment, over all yield results showed no significant differences due to the residual fertilizer, Table 4. By selecting out a factorial design of 23 and 97 pounds per acre N, P_2O_5, and K_2O some interesting results were obtained. Residual potassium was found to have had significant effects on corn yield at the 10% level. Interaction effects of residual N and K, and P and K were found to be significant at the 5% level.

The best yields for the entire experiment resulted on plots that has received all three nutrients.

Table 3. The effect of various phosphate treatments on the yield of corn, soybeans, wheat, and alfalfa in a rotation, 1959.

Treatments	lbs. P_2O_5/A./yr.	Corn[1] bu./A	Corn[1] diff.	Soybeans bu./A	Soybeans diff.	Wheat bu./A	Wheat diff.	Alfalfa[2] tons/A	Alfalfa[2] diff.
1. Check	--	118	--	31.9	---	24.7	---	1.54	---
2. Ord. super phos.	40	119	1	32.2	0.3	28.7	4.0	2.05	0.51
3. Conc. super phos.	40	124	6	31.7	-0.2	27.1	2.4	2.17	0.63
4. Ca. meta phos.	40	123	5	31.8	-0.1	32.7	8.0	1.90	0.36
5. H_3PO_4	40	127	9	31.5	-0.4	30.4	5.7	1.83	0.29
6. Fused tri Ca.	40	126	8	33.4	1.5	29.6	4.9	2.39	0.85
7. Fla. rock + Ord. super	20 + 20	127	9	31.6	-0.3	28.7	4.0	1.69	0.15
8. Fla. rock (lt.)	100	130	12	31.5	-0.4	23.2	-1.5	1.70	0.16
	lbs. material/A/4 yrs.								
9. Fla. rock (hvy.)	1000	117	-1	32.1	0.2	27.7	3.0	2.47	0.93
10. West rock	1000	137	19	31.5	-0.4	28.0	3.3	1.80	0.26
11. Col. Clay rock	1000	126	8	31.3	-0.6	26.4	1.7	1.81	0.27
12. Tunis rock	1000	140	22	32.5	0.6	25.3	0.6	2.06	0.52

No significant differences.

[1] @ 15% moisture

[2] Dry weight

The effect of lime on the yield of corn, soybeans, oats, and alfalfa in a rotation, 1959

A. C. Caldwell

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

In 1959, it was decided to study the effect of lime on soybeans also, so the rotation was changed to corn, soybeans, oats, and alfalfa. Another change which was made at the same time included an application of five ounces of $(NH_4)_2 MoO_4$ per acre on one-half of a check plot in each replication.

Yield results from the four crops for 1959 are included in Table 1. Corn yields were substantially better on the three and six ton per acre rates of lime as compared with the plots receiving no lime. The higher rates of lime, however, did not continue the trend of increased yield.

Soybean yields were not significantly affected by the lime application.

Table 1. The effect of lime on the yield of corn, soybeans, oats, and alfalfa in a rotation, 1959.

Treatment	Soil pH	Yields: Corn[1] bu/A	Corn[1] diff.	Soybeans bu/A	Soybeans diff.	Oats bu/A	Oats diff.	Alfalfa[2] tons/A	Alfalfa[2] diff.
0, tons lime/A	5.8	114	---	33.4	---	33	---	1.35	---
3, tons lime/A	6.1	144	30	32.6	-0.8	38	5	2.71	1.36
6, tons lime/A	6.6	156	42	33.3	-0.1	42	9	3.25	1.90
12, tons lime/A	6.6	123	9	32.2	-1.1	43	10	3.03	1.68
24, tons lime/A	7.1	118	4	34.3	0.9	38	5	3.16	1.81
0[3] tons lime/A	5.8	131	---	34.4	---	38	---	1.68	---
5 oz. $(NH_4)_2MoO_4$/A	5.8	128	-3	34.1	-0.3	33	-5	2.06	0.38
LSD(F_{95}) =			13.0		NS		8.75		.473

1 15% moisture
2 Dry weight
3 Boarder effects limit the use of this check plot to comparisons with the molybdenum treatment only.

Oat yields were increased significantly by the six and twelve ton per acre rates of lime, but the three and 24 ton rates were not significantly different.

Alfalfa yields were very significantly affected by the lime applications. The largest yield increase of 1.9 tons per acre resulted on the plots receiving six tons per acre of lime.

The molybdenum treatment had no significant effects on the yields of any of the four crops.

Included in the table are the soil pH values corresponding to the various treatments. The soil pH has increased with increased lime applied. This trend has remained constant for the past several years.

farm and home

FACT SHEET

SOILS
NO. 5

Sulfur for Minnesota Soils

C. J. OVERDAHL AND A. C. CALDWELL

Sulfur is an essential element for plant growth and is a constituent of the proteins. It is also found in important plant hormones. Consequently inadequate supplies of soil sulfur may seriously affect crop yields.

Legumes suffering from lack of sulfur can be recognized by their light yellow to almost white leaves. The entire leaf area including the veins is affected with this discoloration. Sulfur is associated with plant nitrogen metabolism in protein formation. Thus when sulfur is absent there is low nitrate assimilation which makes the plant appear to be nitrogen deficient. When adequate nitrogen is present, oats and other nonlegume crops may benefit from sulfur fertilization. A recent publication (Station Bulletin 444) by Rost, Evans, and Kramer, presents data in this regard. At present, however, the major emphasis is on supplying sulfur for legumes.

Sulfur deficiency restricts yields, principally of legumes, in many of the northern Minnesota counties. These areas are not well defined but see the map for the tentative boundaries. The most prominent soils where the deficiencies occur are usually sandy in texture and were originally covered with forest.

Sources of Soil Sulfur

Sulfur problems in Minnesota are not new. Research dates back to the very early days of soil's research in the state. F. J. Alway, former head of the Department of Soils, was a pioneer in this field. He carefully studied the effect of sulfur added to soils by rains and by direct soil-air contact, and even direct uptake by leaves of sulfur from the atmosphere.

Alway found that large industrial areas create a sufficient supply of sulfur for soils in the immediate area. Coal, natural gas, petroleum, and refinery sludge when burned give off sulfur to the air.

The sulfur from precipitation was measured at various locations in Minnesota for 12 months in 1936 and 9 months in 1937. The figures from three locations in pounds per acre of sulfur for the year 1936 are as follows:

Minneapolis	197
St. Paul Campus	26
Bemidji	3

For the 9-month period in 1937, 4.5 pounds was measured at Bemidji, but it seems safe to say that the annual accumulation from precipitation in areas quite remote from industrial centers will be 5 pounds per acre or less.

Direct absorption of sulfur from the atmosphere by plants was found to be very low. Therefore in low sulfur areas away from industral centers the natural supply from the atmosphere cannot maintain an adequate level in the soil.

Sulfur Bearing Materials

Gypsum is the chief source of sulfur for sulfur deficient soils. Most gypsum materials will contain about 18 percent sulfur. There are, however, other important sources such as in commercial fertilizers like ammonium sulfate and potassium sulfate.

The sulfur content of fertilizers has been measured and averages have been reported from many sources and manufacturers. It is important

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that users of fertilizers in sulfur deficient areas understand the tremendous variation in the sulfur content of various fertilizers. The following figures show the percent sulfur content of fertilizer, manure, and soil amendments commonly available in northern Minnesota.

Material	Percent sulfur
Gypsum	18.0
Ammonium sulfate (21-0-0)	23.9
Barnyard manure	0.1
Potassium chloride (0-0-60)	0.4
Potassium sulfate (0-0-50)	17.6
Sul-Po-Mag	22.7
Superphosphate (0-20-0)	11.5
Concentrated super (0-47-0)	0.7
Limestone	0.04
5-20-20	3.1

Sulfur Removal by Crops

The removal of sulfur by crops has been determined by analyzing the plants. Some of the average yields and the sulfur removed are as follows:

Crop	Yield per acre	Sulfur removed
		Lbs/acre
Alfalfa	2 tons	12
Red clover	1½ tons	9
Corn	50 bushels	8
Potatoes	300 bushels	24

The efficiency of use of sulfur is never 100 percent, hence approximately 20 pounds of sulfur or an application of about 100 pounds of gypsum per year would be a minimum necessary to offset the annual crop removal. It would appear that higher rates would be necessary for crops such as potatoes unless yields are much less than 300 bushels.

Leaching Losses

Figures on losses of sulfur by internal drainage are not available in Minnesota. However, there have been experiments on leaching losses conducted in other states. Data in literature from several states indicates large losses of sulfur on sandy soils by leaching. The Experiment Station at Cornell University reports losses of more than half of the applied sulfur. These losses in the drainage water depend upon the amount of sand, the sulfur content to begin with, the quantity added, and even the soil temperature.

Recommendations

There is no soil test for sulfur made in the Minnesota Soil Testing Laboratory. Plant analysis shows promise, but correlation studies are necessary. Evaluation of sulfur needs must be based on observing sulfur deficiency symptoms and on knowing the soil area. If potassium, phosphorus, and lime have been adequately supplied in the past, but legume growth is still poor, then sulfur should be added.

Since the price of gypsum is reasonable, material should be applied wherever a deficiency is suspected. Check strips can be left to see if yields have been improved. Apply gypsum at 300 pounds per acre or an equal amount of sulfur-bearing material. Apply about once every three years.

Gypsum is not a substitute for lime, crops on acid soils will still need lime applications.

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ST. PAUL 1, MINNESOTA

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3-59

THE NICOLLET COUNTY PLOTS

SOIL FERTILITY AND CROP PRODUCTION STUDIES ON THE WEBSTER SOILS OF SOUTHERN MINNESOTA

Webster and the closely related Nicollet soil series make up nearly 10% of the total land area of Minnesota or nearly 5 million acres. The soils are productive, almost level in topography, and erosion is not a serious problem but drainage is often necessary.

The Nicollet Soils Experimental Field was established by the Department in 1948 under the direction of Prof. C. O. Rost. The field is located on the Sidney Johnson farm, northwest of St. Peter in Nicollet County. Results obtained from 1949 through 1954 were published as Minn. Agr. Exp. Sta. Bul. 438, April 1957, under the authorship of Prof. Rost and Senior Plot Supervisor H. W. Kramer. Leadership of the project was passed on to W. P. Martin, upon Prof. Rost's retirement in 1954. Establishment and care of the plots would not have been possible without the close collaboration of Fred Wetherill, Nicollet County Agent. Prof. Paul Burson has also provided helpful suggestions as have others in the soil fertility and including Soil Extension group.

Cropping Systems:

Three cropping systems were initially used: (1) corn-oats, (2) corn-oats with clover* as a green manure crop, and (3) a 4-year rotation of oats-hay**-corn-corn.

In the corn-oats rotation, these two crops were grown in alternate years. Clover was seeded in oats and it was plowed down as a green manure in the fall of the same year. Each crop appeared each year in replicated plots. No manure was used in the 2-year rotations, but nutrients were supplied with commercial fertilizers. The 4-year rotation included barnyard manure for first-year corn (commonly used in the area) plus commercial fertilizer treatments.

In 1958, the 4-year rotation was extended to five years with the inclusion of soybeans in the rotation between the two corn crops. The 5-year rotation is now: oats-hay**-corn-soybeans-corn. Fertility treatments and use of barnyard manure remain about the same.

In 1954 a continuous corn program was instituted with fertility treatments to evaluate interactions with amount and time of application of nitrogen. In 1955, these plots were planted to oats to evaluate nitrogen residuals. Since 1956, these plots have been in continuous corn.

*Originally sweetclover. In 1959 shifted to southern alfalfa mixed with mammouth red clover.

**In 1959, in addition to the vernal alfalfa, some red clover, alsike and timothy were added to assure stand if season dry.

Fertilizer Treatments: (Four replications in all exp.)

Corn-Oats (with or without clover*)

1. Check (untreated)
2. 135 lbs. 33-0-0 broadcast for oats.
3. Same as 2 + 150 lbs 0-46-0 broadcast for oats.
4. Same as 3 + 100 lbs 0-0-60 broadcast for oats.
5. 150 lbs 0-46-0 broadcast for oats.
6. 175 lbs 6-24-12 in hill for corn.
7. 200 lbs 33-0-0 broadcast for corn planting time.
8. 200 lbs 33-0-0 broadcast for corn 1st cultivation.

Regular fertilization (approx. plant food application; see under "heavy fertilization" for actual application rates.)

6. check (no treatment)
1. 0-40-0 for oats
2. 0-40-40 for oats
7. 40-40-0 for oats
3. 40-40-40 for oats
10. 0-40-0 for oats and 0-40-0 broadcast 1st yr. corn
9. 0-60-0 broadcast 2nd yr. corn
4. 8 tons manure 1st yr. corn
5. 8 tons manure 1st yr. corn + 10-40-20 hill 2nd yr. corn
8. 8 tons manure 1st yr. corn + 10-40-20 hill 1st yr. corn

Heavy fertilization

During early years of experiment it was noted that yields were not approaching potential with ordinary treatments. Consequently plots were split in half and heavier treatments made. Though emphasis was on fertilization of corn, some treatments were included for all crops in the rotation.

1. 100 lbs 0-46-0 broadcast for oats.
1X Same as 1 + 150 lbs 0-46-0 top-dressed on hay in spring.

2. 200 lbs. 0-20-20 broadcast for oats.
2X Same as 2 + 300 lbs 0-20-20 top-dressed for hay in spring.

3. 135 lbs. 33-0-0 + 200 lbs 0-20-20 broadcast for oats.
3X Same as 3 + 300 lbs 0-20-20 broadcast on sod before plowing + 200 lbs 33-0-0 broadcast 1st yr. corn at planting.

4. 8 tons manure 1st yr. corn
4X Same as 4 + 8 tons manure plowed under 2nd yr. corn.

5. 8 tons manure 1st yr. corn + 175 lbs. 6-24-12 in hill 2nd yr. corn.
5X Same as 5 + 8 tons manure plowed under 2nd yr. corn + 175 lbs. 6-24-12 in hill 1st yr. corn.

6. Check, no treatment

6X 1000 lbs 10-10-10, on sod, fall-plowed for corn.+
175 lbs 6-24-12 in hill 1st yr. corn+
" " " 2nd yr. corn+
200 lbs 33-0-0 side-dress 2nd yr. corn 1st cultivation+
135 lbs 33-0-0 + 100 lbs 0-46-0 broadcast for oats+
100 lbs 0-0-60 topdress for hay in spring.

7. 135 lbs 33-0-0 + 100 lbs 0-46-0 broadcast for oats
7X Same as 7 + 100 lbs 0-0-60 topdress for hay in spring.

8. 8 tons manure 1st yr. corn + 175 lbs 6-24-12 in hill.
8X Same as 8 + 8 tons manure plowed under 2nd yr. corn + 175 lbs 6-24-12 in hill 2nd yr. corn.

9. 150 lbs 0-46-0 broadcast 2nd yr. corn
9X Same as 9 + 135 lbs 33-0-0 broadcast for oats + 200 lbs 0-20-20

10. 100 lbs 0-46-0 broadcast for oats + 100 lbs 0-46-0 broadcast 1st yr. corn.
10X Same as 10 + 0-0-60 topdress for hay in spring + 200 lbs 33-0-0 broadcast 2nd yr. corn.

Continuous corn-nitrogen interaction:

Rate and time of nitrogen application: (broadcast)

	Planting	1st cult.	2nd cult.	Total N applied (lbs.)
1.	0	0	0	0
2.	40	0	0	40
3.	40	40	0	80
4.	40	40	40	120
5.	40	0	40	80
6.	0	40	40	80
7.	0	0	40	40
8.	0	40	0	40
9.	80	0	0	80
10.	120	0	0	120

All plots received 175 lbs. 6-24-12 in the row at planting. North half of each plot received in addition 300 lbs. 0-20-20 in the hill.

Soil Test

Phosphorus: 5-17 lbs (low to very low) surface soil
2-18 lbs " sub-surface soil

Potassium: 110-315 lbs (medium) surface soil
90-220 lbs " sub-surface soil

NICOLLET COUNTY RESIDUAL EFFECT OF NITROGEN FOR OATS
IN 1955

APPLIED ON CORN IN 1954

Treatments

Total N Applied	Planting Time	First Cultivation	Second Cultivation	Ave. Yields in Bu./A.
0	0	0	0	55
		Increase over check		
40	40	0	0	+12
80	40	40	0	+19
120	40	40	40	+39
80	40	0	40	+30
80	0	40	40	+19
40	0	0	40	+10
40	0	40	0	+21
80	80	0	0	+29
120	120	0	0	+41

At planting time on corn in 1954 a starter fertilizer (5-20-20) was used at 150 lbs. per acre.

Nitrogen is in lbs. of N per acre applied as Am. Nitrate.

Continuous Corn

(Rate and time of nitrogen application)

Treatment*		Yield**	
Total N	Time applied*	(Bu/Ac.)	+PK Starter
None	0-0-0	58	
None	0-0-0	Increase over check	0
40 lbs	1-0-0	+ 5	+11
80	1-1-0	+ 4	+19
120	1-1-1	+ 6	+17
80	1-0-1	+ 9	+18
80	0-1-1	+ 4	+18
40	0-0-1	+ 7	+18
40	0-1-0	+ 8	+21
80	2-0-0	+ 8	+18
120	3-0-0	+ 8	+17

*0-0-0 refers to time of application, i.e. planting time-1st cultivation-2nd cultivation.
1 = 40 lbs. N as ammonium nitrate
2 = 80 lbs. N as ammonium nitrate
3 = 120 lbs. N as ammonium nitrate

**Yields damaged because 2,4-D decreased stand.

NICOLLET COUNTY SOIL FERTILITY AND CROP PRODUCTION PLOTS - 1959 YIELDS

TREATMENTS (regular)	Corn (1) Reg.	Corn (1) Extra*	Soybeans Reg.	Soybeans Extra*	Corn[1] (2) Reg.	Corn[1] (2) Extra*	Oats Reg.	Oats Extra*	Hay Reg.	Hay Extra*
6. Check (untreated)	109 bu.	+18	44 bu.	+10	138 bu.	+4	87 bu.	+18	2.80 T	+2.24
1. P for oats	+15	+ 3	+ 1	+ 3	- 2	+8	+22	+ 4	+1.08	+1.23
2. PK for oats	+11	+ 8	+ 1	+ 3	+ 3	-1	+15	0	+1.38	+1.07
7. NP for oats	+11	0	+ 1	+ 3	+ 5	-7	+27	+ 1	+1.09	+0.83
3. NPK for oats	+ 7	+13	+ 3	+ 6	- 4	+9	+23	+ 1	+1.06	+1.08
10. P for oats & corn	+14	+ 4	0	+ 7	- 1	+9	+14	+13	+1.40	+ .30
9. P for corn	+13	0	+ 1	+ 2	- 2	+5	+18	+ 5	+1.46	+ .75
4. Manure for corn	+21	+ 1	+ 7	+ 2	0	+7	+18	+13	+ .52	+1.06
8. Manure & P for corn	+17	+ 5	+ 9	+ 2	- 2	0	+17	+10	+1.07	+1.19
5. Manure & NPK for corn	+20	+ 1	+ 6	+ 3	0	-2	+13	+15	+1.21	+1.21
L.S.D.	10	10	4	7	39	14	15.1	13.7	0.82	.74

Note: See earlier outline of actual fertilizer treatments. *Extra column refers to heavy fertilization treatments; results given as increases over regular treatments. Corn damaged somewhat from heavy wind following 2,4-D treatment. Oats damaged by red leaf transported by aphids (green bug) particularly on outside series.

[1]Corn in Series XI and XII, two years removed from alfalfa hay.

	Corn	(With Legume)	Oats*	(With legume)
1. Check (untreated)	71 bu.	---	40 bu.	---
		Increase over check		
1. Legume with oats	---	+18	---	0
2. N for oats	+17	+37	+ 6	+ 7
3. NP for oats	+22	+39	+58	+60
4. NPK for oats	+20	+40	+58	+53
5. P for oats	+ 3	+53	+12	+35
6. NPK in hill for corn	+17	+32	+12	+23
7. N plowdown for corn	+35	+46	- 5	- 9
8. N sidedress corn 1st cult.	+29	+20	+11	+ 1
L.S.D.	15.9	13.6	19.2	17.6

*Red leaf noted to be worse with N and not as bad with P.
Matt Moore - Dept. Plant Path.

NICOLLET COUNTY SOIL FERTILITY AND ROTATION PLOTS — 1958 YIELD RESULTS

TREATMENTS	Corn (1) Reg.	Corn (1) Plus*	Soybeans Reg.	Soybeans Plus	Corn (2) Reg.	Corn (2) Plus	Oats Reg.	Oats Plus	Hay Reg.	Hay Plus
6. Check	80bu.	103bu.	28bu.	—	52bu.	81bu.	61bu.	118bu.	2.7t.	3.5t.
1. P on oats	86	94	33		62	70	75	94	4.6	5.3
2. PK on oats	90	98	34		58	68	75	99	4.6	4.8
3. NPK on oats	80	102	34		62	74	96	113	3.5	3.8
4. Manure on corn	94	97	—		79	91	73	112	4.0	4.2
5. Manure & NPK on corn	100	104	—		81	89	88	118	3.8	4.2
7. NP on oats	82	91	35		61	69	92	107	3.3	4.2
8. Manure & P on corn	100	107	—		78	88	79	128	4.4	4.7
9. P on corn	81	98	—		65	73	73	105	4.6	4.8
10. P on oats & corn	90	95	33		64	71	76	97	4.4	4.8

Plus* Supplementary treatments, i.e. 6x = 1000 lbs 10-10-10 on sod in fall; 175 lbs. 6-24-12 on 1st & on 2nd year corn; 200 lbs 33-0-0 sidedress on corn; 135 lbs 33-0-0 & 100 lbs 0-43-0 on oats; 100 lbs. 0-0-60 topdress hay in spring.

	Corn Reg.	Corn With legume	Oats Reg.	Oats With legume
1. Check	56bu.	61bu.	48bu.	56bu.
2. N on oats	59	70	63	63
3. NP on oats	73	83	94	100
4. NPK on oats	77	87	85	89
5. P plowdown	68	77	58	73
6. NPK in hill	73	93	54	67
7. N plowdown	63	60	46	48
8. N sidedress	79	69	71	59

Corn yields with time of N application: 1-0-0 = N at planting; 0-1-0 = N at 1st cultivation; 0-0-1 = N at 2nd cultivation

	0-0-0	0-0-1	0-1-0	1-0-0	0-1-1	1-1-0	1-0-1	1-1-1	2-0-0	3-0-3
N alone	35bu.	53	52	53	55	60	52	54	53	58
N + 6-24-12 hill	44	62	61	62	57	66	57	62	61	64

Note: 1958 dry year (13" ppc. below normal). Excellent yields for county.

Fertilizer Rotation Studies

A.C. Caldwell and J. Kline

(A report on 1959 fertilizer experiments)

In 1956 a fertilizer rotation study was designed and established at the Waseca, Morris, and Crookston experiment stations. These studies were begun with the object of evaluating the effect of fertilizer treatment and crop rotation on soil properties and crop response. The fertilizer treatments in this experiment are a complete factorial of the nutrients nitrogen, phosphorus, and potassium. The rates of application of these nutrients are chosen appropriate to the crop and soil type under study. All fertilizers are applied in the spring as a broadcast application with the exception of a small portion for corn which is applied in the hill at planting time. All experiments are replicated three times.

The crops at Waseca and Morris are in a five year rotation plus continuous corn. The cropping sequence for these stations are as shown below:

Waseca	Morris
Corn	Corn
Corn	Corn
Soybeans	Soybeans
Oats	Flax
Alfalfa	Alfalfa
Continuous Corn	Continuous Corn
(not in rotation)	(not in rotation)

The Crookston experiment consists of two separate rotations. The three year rotation has the crop sequence of sugar beets, wheat and sweet clover fallow, while the four year sequence consists of corn, soybeans, wheat and alfalfa.

In addition to the fertilizer treatments outlined each crop is fertilized with an additional heavy treatment called NPK+ which is not analyzed statistically with the experiment but is used only for comparative purposes.

Discussion of Results

Waseca

Corn

Continuous corn yields at Waseca ranged from 91 to 125 bushels per acre in 1959 although this was the second year with less than normal precipitation. Fertilizer treatments resulted in general yield decreases with respect to non-treated plots. Nitrogen and potash treatments both caused significant decreases in corn yields amounting to 17 to 18 bushels per acre (table 1).

Similar results were obtained with first and second year corn with fertilizer treatments resulting in generally lower corn yields. Potash applications resulted in a significantly lower corn yield on first year corn. The positive and significant PK interaction on first and second year corn (table 2 and 3) should not be interpreted to mean that PK combinations resulted in yield increases. The PK interaction in this case means that while potash alone resulted in yield decreases, this effect was minimized by the application of phosphate along with potash.

Soybeans
Soybean yields were generally good, ranging from 33 to 37.4 bushels per acre. As is usually the case, no fertilizer response was found on soybeans in 1959.

Corn Forage
Forage samples were taken from the continuous corn and first year corn. The forage yields ranged from 16.5 to 21.3 tons per acre on continuous corn and from 19.3 to 23.1 tons per acre on first year corn. No significant positive or negative fertilizer effects were found for forage yields.

Oats Grain
The yield of oats ranged from 54.9 to 78.1 bushels per acre. Nitrogen treatments resulted in lodging and a significant reduction in yield. Phosphate and potash treatments had no effect on oats yield.

Oats Forage
Samples of oats for forage were taken when the grain was in the dough stage. The yields ranged from 5.8 to 8.5 tons per acre and a significant positive response was found due to phosphate application. The significant PK interaction (table 8) may be interpreted to mean in this case that phosphate and potash together were more beneficial to yields than either one alone.

Alfalfa
Two cuttings of alfalfa were obtained from the Waseca plots in 1959. The yields ranged from 1.8 to 2.8 tons per acre. A significant positive response was found showing that 80 pounds P_2O_5 per acre resulted in yield increases over plots not treated with phosphate.

Morris

Corn
The rainfall during the period from April to August was three inches below the long time average at Morris in 1959. Only four inches of precipitation were received during the fall of 1958 and winter of 1959. The low rainfall resulted in almost total corn failure at the Morris station. There were few fertilizer effects, however, the position in the rotation did influence yields. Second year corn was the highest in over-all yield with an average of 36.8 bushels per acre. Continuous corn was next with an average of 30.6 bushels per acre and first year corn following alfalfa resulted in complete failure with an average of only 14.6 bushels per acre.

Soybeans
Soybean yields were generally low ranging from 13.6 to about 19 bushels per acre. Fertilizers had no beneficial effect on yield. The significant NK interaction shown on table 13 does not mean that these nutrients improved soybean yields. It means only that nitrogen modified somewhat the negative effects of potash on yields.

Flax
Yields of flax were poor ranging from 6.7 to 15.1 bushels per acre. A significant reduction in flax yields wax observed due to the application of 40 pounds P_2O_5 per acre. Although nitrogen is usually beneficial to flax no such effect was found in 1959.

Alfalfa
Two cuttings of alfalfa were obtained from the Morris plots in 1959. As in previous years a strong positive response to 80 pounds P_2O_5 per acre was found. In

addition a significant NP interaction was found which can be interpreted to mean that nitrogen and phosphorus together resulted in lower yields than when phosphorus was used alone.

Crookston

Corn (Four year rotation)
Corn yields at the Crookston station ranged from 66.3 to 93.4 bushels per acre and were generally superior to yields of previous years. Forty pounds P_2O_5 per acre was found to increase yields by 18.6 bushels per acre.

Soybeans (Four year rotation)
In 1959 soybeans were planted instead of barley in the four year rotation. The yields ranged from 23.8 to 30.8 bushels per acre and a significant phosphate response amounting to three bushels per acre was found.

Wheat (Four year rotation)
Wheat yields were significantly increased by the application of both nitrogen and phosphorus. Nitrogen resulted in a 13 bushel increase and phosphorus in an 8.6 bushel increase (table 18). In addition a significant NP interaction was found showing that nitrogen and phosphorus together resulted in greater yields than either one alone. This interaction is shown below.

	No N	40 lbs. N
No P	23.2 bu/A	31.0 bu/A
40 lbs. P	26.6 bu/A	44.9 bu/A

Alfalfa (Four year rotation)
Alfalfa yields were very low; ranging from 0.4 to 1.34 tons per acre. Forty pounds P_2O_5 per acre resulted in an increased yield of about 0.4 tons per acre.

Sugar Beets (Three year rotation)
Yield of sugar beets was increased by the application of both nitrogen and potash but sugar percentage was decreased to a significant degree by nitrogen applications. The yield of sugar as shown on table 22 indicates that fertilization had neither a positive nor negative effect on the total sugar produced per acre.

Wheat (Three year rotation)
Wheat yields on the 3-year rotation were not influenced by nitrogen application. A significant increase amounting to about 6.8 bushels per acre was found due to the application of 40 pounds P_2O_5 per acre.

Fertilizer Rotation Experiment

Table 1. Continuous Corn (15% moisture). Waseca, 1959

Treatment	lbs/ac $N-P_2O_5-K_2O$	Average Yield bu/ac	Diff.	Treatment effect [1]
None	0-0-0	125	-	
N	160-0-0	116	- 9	-17.8*
P	0-160-0	135	10	- 9.6
K	0-0-160	113	-12	-18.6*
NP	160-160-0	91	-34	- 4.6
NK	160-0-160	95	-32	8.8
PK	0-160-160	93	-30	- 1.8
NPK	160-160-160	92	-33	
NPK+	320-320-320	113	-12	

* Significant at 95% level.

** Significant at 99% level.

Table 2. First year corn. Waseca, 1959

Treatment	lbs/ac $N-P_2O_5-K_2O$	Average Yield bu/ac	Diff.	Treatment effect[1]
None	0-0-0	141		
N	40-0-0	142	1	- 6.5
P	0-80-0	137	-4	- 0.7
K	0-0-80	121	-20	-10.8*
NP	40-80-0	112	-29	- 0.3
NK	40-0-80	108	-33	5.5
PK	0-80-80	124	-17	16.0**
NPK	40-80-80	135	- 6	
NPK+	80-160-160	142	1	

Table 3. Second Year Corn. Waseca, 1959

Treatment	lbs/ac $N-P_2O_5-K_2O$	Average Yield bu/ac	Diff.	Treatment effect
None	0-0-0	137		
N	80-0-0	118	-19	- 5.6
P	0-80-0	126	-11	7.1
K	0-0-80	90	-47	-11.6
NP	80-80-0	102	-35	- 0.9
NK	80-0-80	100	-37	16.1
PK	0-80-80	117	-20	20.4*
NPK	80-80-80	128	- 9	
NPK+	160-160-160	121	-16	

Table 4. Soybeans Waseca, 1959

Treatment	lbs/A $N-P_2O_5-K_2O$	Average Yield bu/A	Diff.	Treatment effect
None	0-0-0	36.0		
N	20-0-0	35.2	-0.8	0
P	0-40-0	36.3	0.3	0.39
L	0-0-40	33.0	-3.0	-0.62
NP	20-40-0	34.5	-1.5	-1.0
NK	20-0-40	35.9	-0.1	1.27
PK	0-40-40	35.5	-0.5	0.51
NPK	20-40-40	35.1	-0.9	
NPK+	40-80-80	37.4	1.4	

Table 5. Continuous Corn Forage* Waseca, 1959

Treatment	lbs/A $N-P_2O_5-K_2O$	Average Yield Tons/A	Diff.	Treatment effect
None	0-0-0	18.1		
N	160-0-0	21.3	3.2	1.44 Sig. at 94%
P	0-160-0	18.1	0.0	-0.84
K	0-0-160	17.3	-0.8	-0.94
NP	160-160-0	17.3	-0.8	-0.42
NK	160-0-160	17.8	-0.3	0.24
PK	0-160-160	16.5	-1.6	1.16
NPK	160-160-160	19.3	1.2	
NPK+	320-320-320	20.8	2.7	

*Field weight 74% moisture.

Table 6. First Year Corn Forage Waseca, 1959

None	0-0-0	20.8		
N	40-0-0	21.1	0.3	-0.99
P	0-80-0	20.9	0.1	-0.71
K	0-0-80	22.3	1.5	0.66
NP	40-80-0	19.3	-1.5	-0.26
NK	40-0-80	20.6	-0.2	-0.29
PK	0-80-80	21.3	0.5	+0.13
NPK	40-80-80	20.5	-0.3	
NPK+	80-160-160	23.1	2.3	

Table 7. Oats Grain Waseca, 1959

Treatments	lbs/A $N-P_2O_5-K_2O$	Average Yield bu/A	Diff.	Treatment Effect
None	0-0-0	77.0		
N	80-0-0	67.3	-9.7	-18.9**
P	0-80-0	84.9	7.9	1.5
K	0-0-80	77.5	0.5	- 4.7
NP	80-80-0	59.9	-17.1	- 2.8
NK	80-0-80	54.9	-21.1	- 1.6
PK	0-80-80	78.1	1.1	1.2
NPK	80-80-80	59.7	-17.3	
NPK+	120-160-160	64.0	-13.0	

Table 8. Oats Forage * Waseca, 1959

Treatment	lbs/A $N-P_2O_5-K_2O$	Average Yield Tons/A	Diff.	Treatment effect
None	0-0-0	6.67		
N	80-0-0	6.32	-0.35	-0.62
P	0-80-0	6.56	-0.11	0.73*
K	0-0-80	5.81	-0.86	0.32
NP	80-80-0	6.11	-0.56	-0.56
NK	80-0-80	6.03	-0.64	-0.22
PK	0-80-80	8.50	1.83	0.89*
NPK	80-80-80	6.59	-0.08	
NPK+	120-160-160	7.56	0.89	

*59% H_2O

Table 9. Alfalfa (2 cuttings)* Waseca, 1959

Treatment	lbs/A $N-P_2O_5-K_2O$	Average Yield Tons/A	Diff.	Treatment effect
None	0-0-0	1.83		
N	20-0-0	2.20	0.37	0.04
P	0-80-0	2.49	0.66	0.62**
K	0-0-80	2.06	0.23	0.16
NP	20-80-0	2.36	0.53	-0.07
NK	20-0-80	1.89	0.06	-0.09
PK	0-80-80	2.76	0.93	0.20
NPK	20-80-80	2.83	1.00	
NPK+	20-160-160	2.58	0.75	

* 15% Moisture.

Table 10. Continuous Corn* Morris, 1959

Treatment	lbs/A $N-P_2O_5-K_2O$	Average Yield Bushels/A	Diff.	Treatment effect
None	0-0-0	32.5		
N	160-0-0	37.9	5.4	7.7*
P	0-160-0	23.2	-9.3	-4.1
K	0-0-40	31.0	-1.5	0.2
NP	160-160-0	33.1	.6	3.6
NK	160-0-40	33.9	1.4	0.1
PK	0-160-40	24.9	-7.6	2.9
NPK	160-160-160	37.7	5.2	
NPK+	320-320-80	21.8	-10.7	