On field 11 adjacent to the pasture area Dr. J. M. MacGregor started an experiment on how to fertilize to permanently maintain alfalfa stands on these rolling to steep pasture soils. In his study, running for eleven years (1951-1961), the check plots produced a total of 30.1 tons per acre. This was compared to a basic treatment of 300 lbs. per acre of 0-20-20 (based on soil test) at seeding time where the total increase in yield ranged from zero to 5.4 tons per acre over the check plots. However, when this same basic treatment was used plus an annual topdressed application (applied either fall or spring), the total production per acre for the 11 years was 45.5 tons per acre or 15.4 tons more than the check yields. These same fertilizer treatments (as based on soil test) and time of application have been used on pastures A, B, C, D and E. The basic treatment was 500 lbs. per acre of 0-20-20 applied at time of renovation and seeding as compared to the same basic fertilizer treatment plus an annual topdressed treatment of 200 lbs. per acre of 0-20-20. In 1965 these differences were compared on pastures D and E where the present grazing trials are now being conducted. The basic treatment of 500 lbs. per acre of 0-20-20 was made on pasture D in 1963 and on pasture E in 1961. Each was seeded in their respective years. In 1965 the basic treatments, with no annually topdressed treatment, produced on the alfalfa grass mixture 448.3 lbs. of beef per acre as compared to 544.7 lbs. per acre where the basic plus the annual topdressed treatment was made. This is an increase of 96.3 lbs. per acre for the basic plus annual treatments.

The annual use of fertilizer can and does contribute to the maintaining of a better stand of the legume in the pasture mixture. The alfalfa goes into the winter each year with a better developed root system and more top growth so there is less chance of winter and early spring injury.

In 1966 these same pastures (D and E) were grazed in the same rotation system. However, on the basic fertilizer treatment which had not received a previous annual application treatment of 200 lbs. per acre of 0-20-20 was topdressed. There was an average per acre of 240.0 lbs. of beef produced for both treatments indicating a distinct benefit from the 200 lb. fertilizer rate when applied two to four years after the basic treatment. Some of these variations may be contributed to the amount of topsoil remaining along with the benefit from the fertilizer treatment. Under some soil conditions the 200 lb. rate may not be effective. An additional comparison of the basic and annual fertilizer treatments were made in 1966 where fertilized supplemental sudan pastures were used in the rotational grazing program. The sudan pasture soils are quite uniform in topography and previous management and are typical soils that would be used for cropland on the average farm. The sudan grass was fertilized with 200 lbs. of 0-20-20 and 100 lbs. of N per acre at the time of seeding. With this alfalfa grass mixture plus the fertilized sudan on the basic treatment there was 258.6 lbs. of beef produced per acre as compared to 247.7 lbs. of beef per acre on the basic plus the annual treatment. Here the well fertilized sudan grass pasture with 100 lbs. of N per acre could have offset the differences in fertility levels on the soils in the alfalfa grass mixture. This characteristic difference has occurred other years on pastures B, C and E where the pastures of higher fertility levels tended to make the pastures of lower fertility caused by erosion or a lack of proper nutrient balance to look better than they really were.

These results indicate that all pastures, regardless of kind, should be properly limed and fertilized as to kind, rate and time of fertilizer application if effective beef production is to be obtained the same as any other crop on the land.

Effect of Irrigation, Fertility Level and Plant Population on Corn and Alfalfa at Park Rapids, Minnesota - 1965.

E. C. Seim, A. C. Caldwell, J. Grava, E. R. Allred, J. Eix, J. B. Swan, and G. Rehm.

In 1965 a potential yield study of corn and alfalfa with supplemental irrigation was initiated on a sandy loam soil at the Park Rapids Sulfur Experimental Field. For each crop high fertility practices and high populations were compared with average management practices prevalent in the area. One-half of the plot area was irrigated on a schedule (Table 4). The other half was unirrigated. The one exception was a light irrigation of the alfalfa seeding which was necessary for the survival of the stand.

In the alfalfa experiment, the full treatment plots received 50 lbs./A of P as 0-460, 300 lbs./A of K as 0-0-60, 5 lbs./A B as borax and 50 lbs./A of S as gypsum. The control (average management) plots received gypsum only (50 lbs./A of S). All fertilizer treatments were broadcast and worked in before planting. Ranger alfalfa was inoculated and seeded at the rate of 20 lbs./A. In late July the plots were sprayed with dalapon (2 lbs./A) to control quackgrass. On August 19, the plots were clipped about 8 inches above the ground. No yields were taken from the plots in 1965. Three cuttings were obtained in 1966. Full treatment plots were topdressed after each cutting with 100# K (0-0-60). The control plots were topdressed early in the spring with 200#/acre of 0-20-20.

In the corn experiment, the full treatment plots received 150 lbs./A of N as ammonium nitrate, 25 lbs./A of P as 0-46-0, 200 lbs./A of K as 0-0-60 and 50 lbs./A of S as gypsum. Starter fertilizer, 300 lbs./A of 4-12-24 was applied in a band on each side of the hill. The full treatment plots were sidedressed with 90# of nitrogen per acre as ammonium nitrate. Row width was 36 inches with a hill spacing of 18 inches. Final plant population was 18,300 plants per acre. The control (average management plots received starter fertilizer only (150 lbs./A of 4-12-24). Row spacing was 36 inches, hill spacing 36 inches. Final plant population was 9150 plants per acre. An 85 day corn variety, Minhybrid 805, was used in these trials.

One half of the plots was irrigated on a regular schedule. The other half received no supplemental irrigation. The natural precipitation and supplemental irrigation records for the 1966 season are shown in table 1 for alfalfa and table 2 for corn.

Table 3 presents additional climatic data for the 1966 growing season. In 1966 there were a total of 1934 growth degree days (GDD), about 200 more than the average GDD (1766) accumulated during the average warm season crop period according to Baker and Straub Jr. During the 1965 season when we had very bad luck with corn, the total there was only 1529 GDD.

Table 1. Precipitation and supplemental irrigation during 1966 growing season for alfalfa at Park Rapids, Minnesota.

Date	Hours	Irrigation (inches)	Precipitation
5/1/66 - start of spring growth			
5/11/66			.16
5/13/66			.20
5/15/66			.41
5/19/66			.09
6/5/66			.40
6/13/66			.35
6/19/66			.07
6/21/66			.24
6/22/66	4.0	2.13	
6/24/66			2.18
6/27/66			.13
7/2/66	4.0	2.00	
7/4/66			1.28
7/9/66			.71
7/12/66	4.0	2.00	
7/17/66			.25
7/22/66			.48
7/23/66			.08
7/24/66			.37
7/25/66			2.21
7/31/66			.11
8/1/66			2.37
8/15/66			1.75
8/22/66			1.37
9/13/66			.55
Total		6.13	15.76

Total H_2O (Irr. + Precip) 21.89

Table 2. Precipitation and supplemental irrigation during 1966 growing season for corn at Park Rapids, Minnesota.

Date	Irrigation Hours	Irrigation Amt. applied	Precipitation (inches)
5/21/66-corn planted			
6/5/66			.40
6/6/66	.5	.25	
6/8/66	.5	.37	
6/13/66			.35
6/19/66			.07
6/21/66			.24
6/22/66	4.0	2.13	
6/24/66			2.18
6/27/66			.13
7/2/66	4.0	2.00	
7/4/66			1.28
7/9/66			.71
7/12/66	4.0	2.00	
7/17/66			.25
7/22/66			.48
7/23/66			.08
7/24/66			.37
7/25/66			2.21
7/31/66			.11
8/1/66			2.37
8/15/66			1.75
8/22/66			1.37
9/13/66			.55
Total		6.75	14.90

Total H_2O (Irr. + Precip.) 21.65

Table 3. Rainfall and temperature data for the growing season of 1966, Park Rapids weather station.

Month	Rainfall (inches)		Temperature (of)		Growing Degree Days (G.D.D.)
	Total	Departure from Normal	Average	Departure from Normal	Base Temp. RE= 50°F.
May	1.28	-2.27	50.2	-3.0	116
June	3.57	-0.38	65.1	2.2	453
July	6.31	2.81	72.3	3.1	691
August	6.55	2.52	64.4	-2.3	446
September	0.56	-1.48	57.6	1.5	228
Total	18.27	1.20			1934
Average			61.9	1.5	

* From climatological data, Minnesota, Vol. 72, 1966, U.S. Weather Bureau

The 1966 corn yields are shown in table 4. High fertility plots out-yielded the low fertility low population plots by 43 to 55 bushels. Irrigation was not necessary after July 12th and the earlier irrigation appeared to have no effect on the yield. In this respect however, it must be remembered that drought was so severe in 1965 that unirrigated plot yields were so poor that starter fertilizer and natural fertility may not have been utilized and consequently were made available to the 1966 crop.

Despite, the satisfactory yields recorded; midseason and early fall estimates of the crop were considerably more optimistic than the outcome. Corn in this area always seems to progress slowly from the milk stage through denting to maturity. This may be partially attributed to cool nights and low fall temperature but experimentation with different hybrids may provide a variety more closely adapted to the climatic and management requirements of the area. With irrigation still higher plant populations will be necessary to increase yields. This will require a hybrid which can stand crowding and which will respond well to the heavy fertilization practices required.

Table 4. Effect of irrigation, fertility level and population on corn at Park Rapids, Minnesota

Treatments			% Moisture Ear Corn	Ear Corn Yield	Shelling Percentage
Moisture	Fertility	Population		Bu/Acre	
Irrigated	Low Fert.	Low Pop.	41.9	48.1	77.8
	LF	LP	39.5	53.7	80.1
Average			40.7	50.9	78.95
Irrigated	High Fert.	High Pop.	37.3	100.1	80.1
	HF	HP	39.3	110.6	78.9
Average			38.0	105.4	79.5
Non-irrigated	LF	LP	40.2	68.5	80.0
" "	LF	LP	39.9	76.0	79.8
Average			40.1	72.3	79.9
Non-irrigated	HF	HP	40.2	109.9	81.4
" "	HF	HP	38.4	120.9	79.7
Average			39.1	115.4	80.1

The effect of fertility and irrigation treatments on the yield of alfalfa are shown in Table 5. Despite an extremely late start which decreased the 1st cutting yield (normally the heaviest), 4.5 ton yields were obtained from plots which received the complete management treatment (fertilizer plus water). This is an increase of 2.0 tons over fertility alone or 1.8 tons over water alone.

In the case of alfalfa then water and fertility go hand in hand in increasing yields. Ordinary management practices (50# S as gypsum) without irrigation produced 2.2 tons of alfalfa for the three cuttings. The increases due to irrigation were obtained with only three irrigations supplying 6.13 inches of water.

Soil samples were taken in late August 1966 to determine what effect the fertilizer and water management practices have had on the available P and K, pH and organic matter. The results are shown in Tables 6 and 7.

Table 5. Effect of irrigation and fertility on yield of alfalfa at Park Rapids, Minn.

Treatment		Yield (Tons/A			
Moisture	Fertility	1st cutting	2nd cutting	3rd cutting	Total
Irrigated	Low Fert.	.55	.95	.91	2.41
"	" "	.81	1.30	.78	2.89
	Average	.68	1.13	.85	2.65
Irrigated	High Fert.	1.03	2.33	1.10	4.46
"	" "	.89	2.41	1.15	4.45
	Average	.96	2.37	1.13	4.46
Non-Irrig.	Low Fert.	.45	.54	.97	1.96
" "	" "	.61	.85	.98	2.44
	Average	.53	.70	.97	2.20
Non-Irrig.	High Fert.	.50	.64	1.20	2.34
" "	" "	.53	.90	1.28	2.71
	Average	.52	.77	1.24	2.53

Table 6. Effect of fertilizer and water management practices on pH, organic matter, P & K of a Dorset sandy loam in corn production, (Park Rapids, 1966).

Irrigation Trt.	Fertility Trt.	Population	pH	O.M. %	P lbs/A	K lbs/A
Non-irrig.	High Fert.	High Pop.	5.8	3.0	61	250
			5.8	3.2	50	200
Irrig.	H.F.	H.P.	6.4	3.3	40	200
			6.3	3.7	32	140
Non-irrig.	Low Fert.	Low Pop.	6.4	3.0	36	100
			6.5	3.9	24	70
Irrig.	L.F.	L.P.	6.7	3.9	20	60
			6.7	4.3	18	60

Table 7. Effect of fertilizer and water management practices on pH, organic matter, P, and K of a Dorset sandy loam in alfalfa production. (Park Rapids, 1966)

Non-Irrig.	Alf.	Pot.	Plot	Fert. Trt.	Depth-in.	pH	O.M. %	P lb/A	K lb/a
			1	Heavy					
					0-1	6.1	2.0	55	600
					1-2	6.0	2.0	51	330
					2-3	6.0	2.0	29	220
					3-6	6.0	2.2	23	80
					6-12	6.2	1.5	37	50
"	"	"	3	H					
					0-1	6.3	3.0	61	590
					1-2	6.3	3.0	40	230
					2-3	6.3	1.7	35	200
					3-6	6.2	3.0	30	110
					6-12	6.4	2.3	37	130
Irrig.	"	"	5						
					0-1	6.7	4.6	110	600
					1-2	6.2	4.4	70	260
					2-3	6.0	3.6	33	250
					3-6	6.2	4.4	21	140
					6-12	6.4	2.5	29	80
"	"	"	7						
					0-1	6.7	3.3	36	550
					1-2	6.1	3.6	20	100
					2-3	6.1	3.5	11	60
					3-6	6.3	4.0	15	60
					6-12	6.3	3.2	19	50
Non-Irrig.	"	"	2	Low Fert.					
					0-1	6.0	2.4	34	130
					1-2	6.2	2.6	21	70
					2-3	6.1	2.2	25	70
					3-6	6.1	2.5	29	60
					6-12	6.1	1.7	36	50
"	"	"	4	L					
					0-1	6.3	3.6	19	70
					1-2	6.1	4.1	16	60
					2-3	6.2	5.0	14	50
					3-6	5.9	4.4	13	60
					6-12	6.2	2.7	19	50
Irrig.	"	"	6	Low					
					0-1	6.8	4.3	37	110
					1-2	6.5	3.6	18	80
					2-3	6.4	4.2	18	60
					3-6	6.4	4.5	18	50
					6-12	6.4	2.7	20	40
"	"	"	8	L					
					0-1	6.7	4.1	27	70
					1-2	6.3	4.1	12	60
					2-3	6.2	3.9	11	50
					3-6	6.2	3.5	14	40
					6-12	6.3	2.6	13	40

The Effect of Nitrogen Source, Placement and Time of Application in the Yield and Composition of Continuous Corn on Webster Clay Loam at Lamberton in 1966

J. M. MacGregor, W. W. Nelson and G. Randall

The effect of fertilizer nitrogen, applied either as ammonium nitrate or as urea on continuous corn yield at Lamberton has been studied during the past seven years. The nitrogen content of corn grain and vegetative tissue was determined in the first five years, no analyses were made in 1965, but in 1966, corn sixth leaf samples were analysed by the Ohio State University Spectographic Laboratory for 16 different elements.

From 1960 through 1966, uniformly ample amounts of phosphate and potash fertilizers have been applied to the entire plot area. Three rates of nitrogen, either as ammonium nitrate or as urea were applied, either before, or after plowing in the fall, at the time of seeding, or as a late June sidedressing. All plots were fall plowed. In 1966, for some reason such as hot dry weather during silking, there was an extremely poor kernel set, and many of the ears failed to have a single kernel. This materially reduced 1966 corn yields which were as follows:

Table 1. The Effect of Nitrogen Source, Rate and Time of Application to Webster Clay Loam at Lamberton on Corn Yield in 19 in the Seventh Year of Continuous Corn.

Treatment No.	Time and Method of Application (N in lbs/A)	Avg. ear corn yield @ 15.5% moisture bu/A	Significance[a]
18	160 NH_4NO_3-sidedressed	51.4	a
15	40 urea- "	50.4	ab
12	80 NH_4NO_3-at planting	49.0	abc
17	80 urea-sidedressed	47.3	abe
6	80 NH_4NO_3-plowed down in fall	47.2	abe
16	80 NH_4NO_3-sidedressed	43.8	bed
13	80 Urea-at planting	41.8	ed
14	40 NH_4NO_3-sidedressed	38.6	de
8	160 NH_4NO_3-plowed down in fall	38.5	de
7	80 urea- " " " "	37.8	def
9	160 Urea- " " " "	37.3	def
11	40 Urea-at planting	33.8	efg
5	40 urea-on top of plowing in fall	30.9	fgh
2	40 NH_4NO_3-plowed down in fall	26.8	ghi
4	40 NH_4NO_3-on top of plowing in fall	24.3	hi
10	40 NH_4NO_3-at planting	23.7	i
3	40 Urea-plowed down in fall	19.8	i
1	None	11.0	j

ev = 27.0

The 1966 yields are the lowest of the years of the experiment, and with very late killing frosts, the corn was mature when harvested. The yields during the seven years is shown in the following table.

Table 2. The Effect of Nitrogen Source, Rate, and Time of Application to Webster Clay Loam at Lamberton on Corn Yield from 1960 through 1966 (Average of four replications).

Treatment No.	Time and Application Method N in lbs/A	Yield of ear corn in bu/A @ 15.5% moisture								
		1960	1961	1962	1963	1964	1965	1966	Average	Sig.
9	160 Urea-fall P.U.	79.4	112.5	43.5	152.8	112.4	73.5	37.7	87.4	a
18	160 NH_4NO_3-S.D.	40.7	97.4	77.7	151.7	109.5	77.6	51.4	86.6	a
13	80-Urea at planting	57.7	99.1	40.5	149.3	115.7	84.4	41.8	84.1	ab
17	80-Urea-S.D.	76.9	86.4	48.2	143.8	121.4	64.7	47.3	83.6	abc
8	160 NH_4NO_3-fall P.U.	69.8	97.9	46.7	147.7	100.9	70.8	38.5	81.8	abc
6	80 NH_4NO_3-fall P.U.	67.4	97.9	43.6	149.6	100.8	63.4	47.3	81.4	abc
12	80 NH_4NO_3-at planting	59.3	90.0	32.7	149.2	112.5	74.2	49.0	81.0	abcd
16	80 NH_4NO_3-S.D.	50.4	98.4	46.7	140.7	113.0	68.1	43.8	80.2	abcd
7	80-Urea-fall P.U.	61.7	76.9	36.7	154.5	104.9	73.0	37.8	77.9	abcd
10	40 NH_4NO_3-at planting	66.2	92.0	45.4	152.2	99.8	63.4	23.7	77.5	abcde
14	40 NH_4NO_3-S.D.	63.6	92.6	39.5	148.6	90.4	54.8	38.6	75.4	bcdef
5	40-Urea-fall-top	62.3	101.3	37.0	140.7	84.1	57.4	30.9	73.4	bcdef
15	40-Urea-S.D.	57.7	95.6	24.9	142.3	94.1	48.4	50.4	73.3	bcdef
11	40-Urea-at planting	45.4	91.1	31.4	147.6	100.6	59.8	33.8	72.8	cdef
4	40-NH_4NO_3-fall-top	49.0	96.7	29.6	140.1	101.5	45.6	24.3	69.5	def
3	40-Urea-fall P.U.	55.1	78.2	29.1	148.8	100.3	38.8	19.8	67.2	ef
2	40-NH_4NO_3-fall P.U.	42.3	87.5	30.9	148.6	88.3	34.9	26.8	65.6	f
1	None	49.5	88.2	26.1	132.6	72.9	33.1	11.1	59.1	g

C.V. = 11.4

It is evident that the yields over the seven years are grouped according to the nitrogen rate applied, with less consistent differences as to the source and time at which the nitrogen was applied.

The spectrographic analyses of the sixth corn leaf sampled during 1966 are shown in table no. 3.

Table 3. Spectographic Analyses of Sixth Leaf in 1966 of Continuous Corn Grown under Variable Nitrogen Fertilizer Treatment.

Replicates	Treatment	%				ppm										%	
		P	K	Ca	Mg	Mn	Fe	B	Cu	Zn	Al	Sr	Mo	Co	BA	NA	Si
I and II	No N	.26	1.66	.60	.36	31	114	8	6	25	87	25	1.60	.45	6	.01	.45
III and IV	(1)"	.23	1.81	.59	.28	23	108	6	4	19	75	24	1.18	.25	4	.01	.34
	Avg.	.245	1.74	.60	.32	27	111	7	5	22	81	24	1.39	.35	5	.01	.40
I and II	40 NH_4NO_3PV	.26	1.87	.63	.40	31	102	7	7	22	75	31	1.54	.31	5	.01	.37
III and IV	(2) "	.24	1.77	.60	.35	29	111	7	4	21	65	25	1.37	.22	4	.01	.32
	Avg.	.250	1.82	.62	.38	30	106	7	6	22	70	28	1.45	.26	4	.01	.35
I and II	40 Urea PV	.19	1.28	.45	.29	24	75	5	7	17	53	17	1.17	.24	4	.01	.29
III and IV	(3) "	.22	1.45	.51	.36	28	114	8	4	21	63	24	1.28	.16	4	.01	.26
	Avg.	.205	1.37	.48	.32	26	90	6	6	19	58	20	1.22	.20	4	.01	.28
I and II	40 NH_4NO_3 Top	.19	1.46	.39	.21	17	63	3	3	17	51	19	0.85	.11	4	.01	.29
III and IV	(4) "	.30	1.62	.59	.39	29	116	7	3	21	64	23	1.39	.21	5	.01	.36
	Avg.	.245	1.54	.49	.30	23	90	5	3	19	68	21	1.12	.16	4	.01	.32
I and II	40 Urea Top	.22	1.68	.47	.27	21	77	3	4	18	61	23	1.18	.20	4	.01	.34
III and IV	(5) "	.20	1.24	.50	.31	27	115	7	3	20	40	21	1.15	.22	4	.01	.25
	Avg.	.210	1.46	.48	.29	24	96	5	4	19	50	22	1.16	.21	4	.01	.30
I and II	80 NH_4NO_3 PV	.26	1.67	.55	.36	36	89	7	4	22	56	31	1.46	.21	5	.01	.30
III and IV	(6) "	.26	1.82	.52	.33	44	105	8	7	24	58	27	1.20	.17	5	.01	.30
	Avg.	.260	1.75	.54	.34	40	97	8	6	23	57	29	1.33	.19	5	.01	.30
I and II	80 Urea PV	.28	1.91	.61	.45	45	102	6	6	30	82	26	1.60	.30	6	.01	.38
III and IV	(7) "	.25	1.53	.64	.49	37	102	8	18	25	121	30	1.71	.27	5	.02	.32
	Avg.	.265	1.72	.62	.47	41	102	7	12	28	102	28	1.66	.28	6	.02	.35

Table 3. Analyses of Sixth Leaf(Continued).

Replicates	Treatments	%				ppm										%	
		P	K	CA	Mg	Mn	Fe	B	Cu	Zn	Al	Sr	Mo	Co	Ba	Na	Si
I and II	160NH_4NO_3 PV	.30	1.33	.67	.48	56	102	8	5	26	60	25	1.66	.15	5	.01	.39
III and IV	(8) "	.20	1.24	.43	.35	37	69	4	4	21	36	22	1.16	.16	4	.01	.19
	Avg.	.250	1.28	.55	.41	46	85	6	4	24	48	24	1.41	.16	4	.01	.29
I and II	160 Urea PV	.33	2.38	.70	.44	65	118	9	9	26	92	32	1.62	.30	5	.01	.41
III and IV	(9) "	.19	1.42	.36	.28	27	73	5	3	16	42	22	1.05	.18	3	.01	.17
	Avg.	.260	1.90	.53	.36	46	96	7	6	21	67	27	1.34	.24	4	.01	.29
I and II	40 NH_4NO_3 PL	.31	2.11	.74	.47	35	126	8	8	28	93	38	1.70	.37	5	.01	.36
III and IV	(10) "	.25	1.61	.64	.33	30	97	8	4	20	63	34	1.34	.28	4	.02	.26
	Avg.	.280	1.86	.69	.40	32	112	8	6	24	78	36	1.52	.32	4	.02	.31
I and II	40 Urea PL.	.30	1.87	.67	.37	30	103	7	5	18	60	30	1.42	.17	5	.02	.35
III and IV	(11) "	.23	1.59	.46	.27	22	76	5	3	18	45	19	1.07	.16	4	.01	.26
	Avg.	.265	1.73	.57	.32	26	90	6	4	18	52	25	1.25	.16	4	.02	.30
I and II	80NH_4NO_3 PL.	.25	1.97	.56	.37	34	106	7	4	21	74	35	1.43	.24	4	.02	.25
		.31	1.41	.72	.47	32	109	8	5	21	81	29	1.80	.27	5	.01	.37
	Avg.	.280	1.69	.64	.42	33	108	8	4	21	78	32	1.62	.26	4	.02	.31
I and II	80 Urea PL.	.28	1.59	.64	.39	30	126	7	4	23	81	22	1.62	.38	5	.01	.25
III and IV	(13) "	.28	1.59	.57	.38	35	96	6	7	23	57	23	1.41	.37	5	.01	.28
	Avg.	.280	1.59	.60	.38	32	111	6	6	23	69	22	1.52	.38	5	.01	.26
I and II	40 NH_4NO_3 SD	.22	1.64	.50	.33	23	92	5	5	16	73	24	1.42	.20	4	.01	.22
III and IV	(14 "	.28	1.58	.76	.45	39	108	8	9	21	81	32	1.82	.32	5	.01	.33
	Avg.	.250	1.61	.63	.39	31	100	6	7	18	77	28	1.62	.26	4	.01	.28

Table 3. Analyses of Sixth Leaf(Continued).

Replicates	Treatment	%				ppm										%	
		P	K	Ca	Mg	Mn	Fe	B	Cu	Zn	Al	Sr	Mo	Co	Ba	Na	Si
I and II	40 Urea SD	.26	2.15	.52	.20	25	133	4	4	21	69	26	1.06	.24	5	.02	.26
III and IV	(15) "	.25	1.57	.55	.37	23	91	6	3	18	61	26	1.39	.14	4	.01	.31
	Avg.	.255	1.86	.54	.29	24	112	5	4	20	65	26	1.22	.19	4	.02	.28
I and II	80NH_4NO_3 SD	.26	1.81	.54	.28	28	114	6	4	19	56	26	1.36	.23	4	.01	.23
III and Iv	(16) "	.29	1.90	.59	.38	35	95	9	6	22	76	24	1.50	.22	5	.01	.30
	Avg.	.275	1.85	.56	.33	32	105	8	5	20	66	25	1.42	.22	4	.01	.26
I and II	80 Urea SD	.30	1.70	.81	.48	36	141	8	7	24	99	28	1.85	.29	6	.01	.33
III and IV	(17) "	.30	1.48	.67	.43	42	87	8	4	18	68	22	1.59	.21	4	.01	.31
	Avg.	.300	1.59	.74	.45	39	114	8	6	21	83	25	1.72	.25	5	.01	.32
I and II	160NH_4NO_3 SD	.30	1.67	.70	.52	48	99	8	7	20	62	28	1.94	.28	5	.01	.34
		.26	1.48	.63	.47	50	93	9	4	26	76	29	1.58	.14	4	.01	.31
	Avg.	.280	1.58	.66	.50	49	96	8	6	23	69	28	1.76	.21	4	.01	.32
I and II	Extra	.26	1.70	.57	.38	32	97	8	4	24	53	25	1.38	.25	4	.01	.34
III and IV	(19)	.25	1.84	.55	.39	32	89	7	4	23	74	29	1.39	.18	4	.02	.27
	Avg.	.255	1.77	.56	.38	32	93	8	4	24	64	27	1.38	.22	4	.02	.31
I and II	Extra	.28	2.06	.47	.24	24	93	7	3	22	69	22	1.07	.19	4	.01	.32
III and IV	(20)	.30	2.37	.51	.31	33	110	8	6	22	116	29	1.29	.25	5	.03	.25
	Avg.	.290	2.22	.49	.28	29	101	8	5	22	92	25	1.18	.22	4	.02	.28

The results shown in Table 3 made available for the reader to examine and make his or her own conclusions as to the effect of nitrogen fertilizer in the concentrations of the 16 elements present in the corn leaves.

The Effect of Urea or Ammonium Nitrate Nitrogen on the Nitrate Nitrogen Content of Webster clay loam surface soil and Different Portions of Growing Corn Plants at Lamberton in 1964, 1965, & 1966

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 growth 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 seven 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 entire sampling and analytical procedure was repeated in 1965, but since the corn was not planted until early June, the sampling of soil and leaf tissue for that month was omitted. The 1966 sampling commenced in mid-June as in 1964.

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 Olson's 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 to seven year period, with the relatively large amounts present in mid-June of 1964 or mid-July, 1965 & 1966, 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. Bt mid-July 1964, however, nitrate levels of the leaves were and remained at relatively lowlevels for the remainder of the growing season. Because of the later 1965 planting, the July tissues contained toxic levels in July 1965.

Upper stalks, which were not available for the June 1964 sampling, could be considered relatively safe for feeding during the three months in which these were analyzed. In 1965, all fertilized upper stalks contained toxic amounts of nitrate nitrogen prior to the August sampling.

In the lower stalks, tissues growing on the plots (1964) receiving no

Nitrate Nitrogen Concentrations in 1964, 1965, & 1966 Corn Plants on Webster Clay Loam at Lamberton Fertilized Annually with Ammonium Nitrate or Urea
(Average of 2 replicates)

Lbs N/A annually	Avg. Soil Nitrate-N in ppm				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														
1964	5	2	1	1	0.28	0.23	0.03	0.02	0.06	0.04	0.02	0.03	0.03	0.01
1965	-	6	5	6	--	0.25	0.03	0.02	0.63	0.02	0.03	0.92	0.03	0.02
1966	6	1	2	1	0.18	0.04	0.02	0.02	0.07	0.02	0.02	0.05	0.02	0.02
80/A NH_4NO_3-N (Spring)														
1964	19	5	3	2	0.47t	0.06	0.04	0.02s	0.24	0.07	0.02	0.72t	0.16	0.05
1965	-	29	18	8	--	0.29	0.04	0.02	0.72t	0.04	0.02	1.20t	0.11	0.03
1966	38?	4	1	1	0.24	0.13	0.03	0.02	0.37	0.04	0.02	0.97t	0.12	0.16
80/A Urea-N (spring)														
1964	23	4	4	2	0.44	0.05	0.04	0.03	0.25	0.06	0.03	0.42	0.30	0.17
1965	-	12	20	7	--	0.33	0.01	0.03	0.92t	0.02	0.02	0.81t	0.07	0.02
1966	25	2	2	1	0.24	0.10	0.03	0.02	0.28	0.06	0.02	0.74	0.31	0.05
160/A NH_4NO_3-N (fall)														
1964	46	33	6	4	0.60t	0.11	0.04	0.02	0.39	0.16	0.08	0.80t	0.82t	0.53t
1965	-	9	5	8	--	0.76t	0.03	0.03	0.77t	0.07	0.02	1.12t	0.25	0.21
1966	16	4	2	5	0.30	0.16	0.04	0.03	0.43	0.11	0.06	0.95t	0.44	0.70t
160/A Urea-N (fall)														
1964	36	6	5	2	0.58t	0.14	0.07	0.01	0.43	0.12	0.03	0.67t	0.76t	0.38
1965	-	12	7	16	--	0.26	0.04	0.04	0.75t	0.09	0.05	1.02t	0.60t	0.69t
1966	45	26	2	5	0.31	0.16	0.08	0.03	0.51	0.11	0.01	1.23t	0.60t	0.55t
Manure														
1966	12	4	1	1	0.18	0.05	0.03	0.02	0.10	0.02	0.02	0.11	0.02	0.02
Alfalfa[a]														
1966	13	6	11	5	0.23	0.18	0.06	0.03	0.47t	0.12	0.03	1.04t	0.28	0.66t

[a]By error - 60#/A of NH_4NO_3-N was sidedressed on alfalfa plots in mid-July

t = values exceeding 0.44% NO_3-N are considered to contain toxic concentrations for animal feeding, even in limited quantities.

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. In the July 1965 sampling, the lower stalks of even the unfertilized corn contained toxic concentrations.

The application of farm manure at the rate of 10 tons per acre in the spring of 1966, resulted in little increase in nitrate-N of the corn tissues above that from plots receiving no nitrogen. Apparently this rate of manure application did not materially increase the nitrate content of the corn plants in 1966.

Unfortunately, the 1966 corn planted on alfalfa ground was fertilized with 60 pounds of N per acre in mid-July of 1966. The nitrate-N content of the plants increased and the information obtained was of little value.

This illustrates that heavy nitrogen fertilization and stage of corn growth results in abundant soil nitrate and toxic nitrate levels in some corn tissues grown under the conditions in 1964, 1965 and 1966. It is possible that either legume ground or soils receiving very heavy applications of barnyard manure would result in similar trends, but of lower magnitude. Nitrate nitrogen concentrations present in June, 1964 corn, and in mid July, 1965 and 1966 corn show that growth stage probably has a more important effect on nitrate nitrogen concentrations in corn tissue than N application rates.

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(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, 1964.

Barley - Nitrogen - Protein Study

Northwest Experiment Station, Crookston, 1966
Olaf C. Soine, J. M. MacGregor

This experiment was started in 1964 to study the effect of nitrogen alone and in combinations with phosphate and potash on the yield, bushel weight and protein content of barley. The field work was done by this Station and the protein analysis by the Department of Soil Science.

The 2 nitrogen treatments were broadcast before seeding and the treatments 0-40-0, 10-40-0, 20-40-20, and 20-40-0 were applied in a band at seeding time, alone and in combination with the nitrogen - broadcast. For example, the treatment *10-40-0 means that 10-0-0 was broadcast and *0-40-0 was applied in a band at seeding time on the same plot.

The barley varieties and fertilizer treatments were randomized and replicated 4 times.

Sugarbeets were grown on this land in 1965.

The yield in bushels per acre for Larker, Parkland and Trophy is given in Table 1, with an average for the 3 varieties and Duncan's Range of significance.

The **40-40-20 treatment gave the highest yield for all varieties, and averaged 16 bushels more per acre than the check plot. The first 5 treatments in Table 1, with the broadcast rate of **20-0-0 produced the highest yields and were higher than the next group of treatments with the *10-0-0 broadcast. The treatments without any broadcast were the lowest.

Table 2 gives the bushel weights for the 15 different treatments and shows that Larker has the highest bushel weights followed by Parkland and Trophy respectively.

Table 1. Barley - Nitrogen - Protein Study
Northwest Experiment Station - 1966

Treatment lbs./acre $N-P_2O_5-K_2O$			Yields in bushels per acre Larker	Parkland	Trophy	Ave.	Duncan's Range
**40	40	20	48.7	48.5	48.5	48.58	
**40	40	0	49.8	44.8	43.4	46.01	
**20	0	0	44.9	44.8	46.8	45.48	
**30	40	0	45.0	43.7	46.9	45.20	
**20	40	0	45.6	41.7	45.5	44.26	
*30	40	0	46.4	42.4	42.9	43.90	
*30	40	20	47.0	38.6	44.0	43.20	
*20	40	0	47.3	37.6	39.9	41.59	
*10	40	0	40.7	35.6	41.0	39.11	
*10	0	0	40.4	34.6	39.8	38.29	
20	40	20	38.7	34.9	39.3	37.64	
20	40	0	37.6	35.0	36.8	36.47	
10	40	0	38.4	33.8	37.1	36.41	
0	40	0	34.2	30.0	35.3	33.15	
0	0	0	34.0	29.1	34.6	32.54	

Barley sown: May 5; harvested July 25, 1966.
Treatments *10-0-0 and **20-0-0 broadcast before seeding; remaining treatments applied in a band at seeding with and without the nitrogen broadcast treatments.

Table 2. Barley - Nitrogen - Protein Study
Northwest Experiment Station - 1966

Treatment lbs./acre N-P_2O_5-K_2O			bushel weight Larker	Parkland	Trophy	Average
**40	40	20	47.8	46.0	44.0	45.9
**40	40	0	47.0	46.0	42.8	45.3
**20	0	0	48.3	45.5	43.0	45.6
**30	40	0	47.5	46.8	42.8	45.7
**20	40	0	46.3	45.8	43.5	45.2
*30	40	0	47.5	45.3	43.5	45.4
*30	40	20	47.8	46.3	44.0	46.0
*20	40	0	47.5	46.5	43.8	45.9
*10	40	0	47.8	45.3	43.8	45.6
*10	0	0	48.0	45.3	42.8	45.4
20	40	20	47.5	45.5	44.3	45.9
20	40	0	47.5	46.0	43.3	45.6
10	40	0	47.8	45.8	43.5	45.7
0	40	0	47.8	45.3	43.8	45.6
0	0	0	47.5	45.5	43.0	45.3

The protein data is given in Table 3 for Larker, Parkland and Trophy with an average for the three varieties. The protein content is low for all three varieties and is considerably lower than the 1965 trials. Parkland had the highest protein content of the three varieties.

The higher rates of nitrogen did not influence the protein content when compared to the check. The treatments 0-40-0 and 0-0-0 were equal to, or slightly higher than, the other treatments.

Sugarbeets were grown on this field in 1965 and may in part account for the low protein. The high temperatures during midsummer and the presence of Septoria were also contributing factors.

Table 3. Percent protein in Larker, Parkland and Trophy - 1966

Treatment lbs./acre N-P_2O_5-K_2O			Percent Protein Larker	Parkland	Trophy	Ave.
**40	40	20	10.5	11.2	10.8	10.8
**40	40	0	10.8	11.3	10.6	10.9
**20	0	0	10.7	11.3	10.8	10.9
**30	40	0	10.6	10.7	10.5	10.6
**20	40	0	10.6	10.8	9.9	10.4
*30	40	0	10.4	10.8	10.7	10.6
*30	40	20	10.2	10.9	10.4	10.5
*20	40	0	10.6	11.0	10.2	10.6
*10	40	0	10.6	11.2	10.6	10.8
*10	0	0	10.5	11.3	11.0	10.9
20	40	20	10.6	11.2	10.3	10.7
20	40	0	11.3	11.1	10.2	10.9
10	40	0	10.7	11.1	10.3	10.7
0	40	0	10.8	11.6	10.7	11.0
0	0	0	10.6	10.9	10.8	10.8

Fall vs Spring Nitrogen Fertilization of Small Grains in West Polk County in 1965-66

G.W. Randall, S.L. Bigger and J.M. MacGregor

On October 27, 1965, following the removal of the sugar beet crop, experimental plots were established on two fields in the Crookston area to determine the effect of the time of application of nitrogen fertilizer on the yield of spring wheat. Soils of both fields consisted of a Fargo-Bearden complex, therefore, high clay contents. At this time a randomized block design consisting of five treatments replicated six times was established, and the application of nitrogen on the fall treatments was completed. On May 9, 1966, just prior to seeding, the nitrogen was applied to the spring treatments, all nitrogen being applied as ammonium nitrate. A blanket treatment of 40 lbs. P_2O_5 was also applied by the farmer cooperators. Due to the ensuing weather conditions, one of the fields was seeded to oats rather than to spring wheat.

Climatic conditions for the duration of this experiment are shown in table 1. Temperature data show that January and February were much colder with June and July being warmer than average. The small grain yields, being somewhat lower than expected, may be attributed to the adverse affect of these high temperatures during July. Rainfall during this nine month period was below normal with substantial rainfall only in June.

Table 1. Temperature and precipitation data in the Crookston area during the nine month period November 1, 1965 to August 1, 1966.*

	Temperature		Precipitation	
Month	Average	Departure	Average	Departure
November	25.4	-1.4	.56	-.38
December	18.6	6.1	.71	.13
January	-9.0	-14.2	.16	-.41
February	3.2	-6.0	.23	-.32
March	27.2	4.1	.95	.06
April	36.9	-4.2	1.25	-.11
May	51.0	-3.9	1.31	-1.19
June	65.7	1.9	4.49	.90
July	72.4	2.2	3.17	.22
Total			12.83"	
Average		-1.7°		-1.10"

* Source - Climatological Data, Minnesota, U.S. Dept. of Commerce. Vol. 71. No. 11 - Vol. 72. No. 7.

Visual observations of the spring wheat plot on August 4, (the harvesting date), showed that all plots receiving the 80 pound rate of N to be somewhat lodged. Also,

wheat receiving the spring application of N seemed to have better growth. The treatments and average yields are given in table 2.

Table 2. Nitrogen treatments, average 1966 yields and significance of rate and time of application of N fertilizer to Chris spring wheat on the Gerhard Ross farm (Polk County, Minnesota).

Treatment	Yield (6 rep. Avg.)	Significance[a]
1. None	23.3 bu/A	a
2. 40# N Fall	28.6 "	b
3. 40# N Spring	33.4 "	c
4. 80# N Fall	31.1 "	bc
5. 80# N Spring	33.0 "	c

[a] According to Duncan's Multiple Range Test, those yields with similar letters are not significantly different at the .05 level.

Wheat yields from all four nitrogen treatments were significantly higher than the yields from the check. The 40 and 80 pound spring treatments and the 80 pound fall treatment, (with no significant differences) produced the highest yields. Averaging the 40 and 80 pound N rates, the wheat yield from the spring applications was 33.2 bu/a in comparison to the 29.8 bushel yield from the fall applications. Also, the averages of the combined application times of the 40 and 80 pound N rates were 31.0 and 32.0 bu/acre, respectively.

The oats plot was harvested on August 10. At this time, because of the high rat of N, the oats on almost all 40 pound and on all 80 pound treatments were lodged. A green color of the oats was noticed on the 80 pound treatments, evidence that it may have lodged even before reaching maturity. The check treatment, showing a thinner stand of oats, was still standing. Table 3 shows the treatments and oat yields from this experiment.

Table 3. Nitrogen treatments, average 1966 yields and significance of rate and time of N application for oats on the Ray Eggert farm. (Polk County, Minnesota)

Treatment	Yield (6 rep. avg.)	Significance
1. None	65.8 bu/a	b
2. 40# N Fall	61.1 "	ab
3. 40# N Spring	68.1 "	b
4. 80# N Fall	54.1 "	a
5. 80# N Spring	64.4 "	b

[a] According to Duncan's Multiple Range Test, those yields with similar letters are not significantly different at the .05 level.

Yields from this experiment on oats were obviously affected by the lodging. Combining the 40 and 80 pound treatments, the oat yields of the fall and spring treatments were 57.6 and 66.2 bushels/acre, respectively. Also, with the fall and spring treatments combined, the yields for the 40 and 80 pound treatments were 64.6

and 59.2 bushels/acre, respectively.

It is apparent that spring N application was more effective for increasing wheat yield than the fall treatment, but oat lodging precluded such evidence with oats in 1966.

North Central Experiment Station
Grand Rapids, Minnesota
1966

The Effect of Rate and Split Versus Single Applications of Nitrogen on Yields of Bromegrass

Richard H. Anderson

Results of an experiment conducted in 1964 - 1965 on bromegrass grown on sandy loam soil showed that nitrogen topdressed in the spring was more effective than when applied the previous fall. One hundred pounds (the highest rate) gave the highest yield but not significantly higher than with the 67 pound nitrogen rate. The effect of rate of nitrogen fertilizer was not observable in regrowth following removal of the first crop.

Table 1. Bromegrass yields in response to fall or spring nitrogen application.

Rate of N (lbs)	Fall Application (Tons)	Spring Application (Tons)
0	1.66	1.66
33.5	2.02	2.55
67.0	2.93	3.73
100.0	3.53	3.84

L.S.D. (.05) .414

The 1966 experiment was designed to study:

1. The effect of rate of nitrogen topdressing.
2. The effect of split applications.

Procedure:

1. Four replications were provided with six plots in each measuring 30 inches by 54 feet.
2. The bromegrass to which the nitrogen was applied had been seeded in 1964 as a varietal trial. Fertilizer plots were oriented perpendicular to and crossing all varietal plots.
3. Fertilizer rates selected were, in addition to a check, 50, 100, and 150 lbs of N applied once, and 100 and 150 lbs split in equal parts of 50 + 50 and 75 + 75, respectively, and applied at two dates. The first applications were made on May 6, 1966. The second application of the split treatment was made on June 15.

4. Harvests were taken on June 14 and August 24, 1966. Swaths 15 inches wide were taken over the full length of each plot. Samples were dried to determine moisture content and yields computed in tons per acre. (15% moisture content basis).

Table 2. Bromegrass yields at several levels of nitrogen fertilization.

Nitrogen Rates Lbs N Per/Acre	Yield in Tons Per Acre					
	1st Cutting	Test of Signifi.*	2nd Cutting	Test of Signifi.*	Season Total	Test of Signifi.*
Check	1.15	c	.64	d	1.79	d
50	1.77	b	.68	d	2.45	c
50 + 50	1.78	b	1.53	b	3.31	b
100	2.10	a	.84	cd	2.94	b
75 + 75	1.96	ab	1.93	a	3.89	a
150	2.04	ab	1.01	c	3.05	b

* Duncan's Multiple Range Test. Treatment means with a common letter are not statistically different at the one percent level.

In this test, early season yields (first cutting) are increased by all rates of nitrogen fertilization.

Yields at the lowest rate, 50 lbs N per acre, are not significantly lower than yields at the highest rate, 150 lbs N per acre, in the first cutting.

The split applications, providing a readily available supply of N after the first harvest, result in significantly higher yields in second cutting. Yields of plots receiving 50 lbs and 100 lbs of N at one time were not significantly greater than check plot yields in the second cutting. The rate of 150 lbs N applied at one time apparently contributed something to yield in the second cutting but less than the effect of the second application of N at either the 50 lb. or 75 lb. level.

Split applications of 75 lbs. N before the growing season and 75 lbs. during the growing season produced the highest total season yields. No significant difference existed between yields where100 lbs., 150 lbs., or two 50 lb. applications were made.

Conclusions:

1. On sandy soil, nitrogen applications should be made as near as possible to the time of demand by the crop.

2. An efficient rate of nitrogen topdressing of grasslands appears to fall in a range of 50 lbs. to 100 lbs. of elemental nitrogen applied at any one time.

3. Where amounts of elemental nitrogen in excess of 100 lbs. are to be applied to a crop, significant yield advantages are to be gained by split applications timed to meet the demand of the crop.

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, soybeans, wheat, and alfalfa. Potassium has been applied as required according to soil test. Lime applications were made on two replicates in the fall of 1961. In 1965 and 1966 the corn was sidedressed with 60 and 80 lbs of N/acre respectively.

Table 1
The effect of various phosphate fertilizers on yield of corn, wheat, soybeans and alfalfa. (Port Byron silt loam - Rosemount, 1966).

Treatments	Rate lbs.P_2O_5 A/yr.	Alfalfa 1st cut. Tons/ acre	Alfalfa 2nd cut. Tons/ acre	Alfalfa Total Tons/ acre	Corn 1 bu/ acre	Wheat bu/ acre	Soybean bu/ acre
None	0	1.9	1.4	3.3	90.5	15.5	11.2
Ord. Superphosphate	40	2.6	2.0	4.7	86.3	21.6	7.8
Conc. Superphosphate	40	2.9	2.1	5.0	82.5	24.4	10.0
Calcium Metaphosphate	40	2.4	1.8	4.2	93.9	19.8	9.3
Phosphoric acid	40	2.7	2.0	4.7	88.8	23.2	11.0
Fuzed Tricalcium Phosphate	40	2.5	1.7	4.2	88.8	23.8	12.1
Florida Rock and ord. Super	20+20	2.5	1.8	4.2	91.9	23.1	9.7
Florida Rock Phos.	100	2.8	1.9	4.7	96.2	23.3	12.4
lbs. P_2O_5/A/4yrs.							
Fl. Rock Phosphate	1000	2.8	1.8	4.6	87.5	22.5	10.4
Western Rock Phosphate	1000	2.7	2.1	4.8	92.9	23.1	11.9
Colloidal Clay Rock Phos.	1000	2.2	1.8	4.0	95.3	18.4	11.3
Tunisian Rock Phos.	1000	2.6	1.9	4.6	88.6	18.8	11.1

The 1966 crop yields are shown in table 1 . The most consistent effect of the phosphate treatments has been to increase alfalfa yields. All sources were effective regardless of P solubility. The sidedressed application of Nitrogen to the corn has apparently eliminated effects of the phosphate on corn. Evidently at least part of the effects noted in past years may have been due to benefits derived from the increased vigor and nitrogen fixation by the preceding alfalfa crop. Whea yields have been increased by phosphate treatments in 1966 and in most past years. Generally the more available forms of P have been most effective for this crop. Soybeans have given erratic response in past years as in 1966. There are some indi tions that the level at which potassium is being applied may not be sufficient to supply the needs of all the crops in the rotation. It is also noteworthy to mentio that it has been difficult to maintain good weed control and the content is notably more difficult on the heavily fertilized plots.

Future plans call for reliming and increased applications of N and K to supply the needs of higher corn and bean populations possible with narrow row management practices.

The effect of li e and molybdenum on the yield of alfalfa, oats, corn, and soybean.

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) yields of some common crops, and (2) on the physical and chemical properties of the soil. Treatments of 0, 3, 6, 12, and 24 tons of dolomitic lime per acre were applied on 4 replications in 1951. A rotation of corn, oats, and 2 years of alfalfa was established. Each year corn oats have received 200 lbs. of 5-20-20 per acre. The alfalfa has received P and K as needed according to soil test. Since 1959 soybeans have replaced one year of alfalfa in the rotation. The beans receive 100 lbs. of 5-20-20 starter fertilizer per acre.

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.

In 1966 yields were obtained for alfalfa, oats, corn and soybeans. The 1966 yields are shown in table 1.

Lime significantly increased alfalfa yields in the rotation, but had no significant effect on the yield of corn, oats or soybeans in 1966. In 1965 and 1966 the corn was sidedressed with additional nitrogen (60# Nitrogen 1965, 80# Nitrogen 1966) . This has tended to eliminate any beneficial effect of the lime due to increased nitrogen fixation by the alfalfa on the treated plots.

There is evidence that present fertilization practices may not be supplying adequate levels of K, Mg or some trace elements. Tentative plans are to modify the experiment by maintaining a rotation but establishing continuous corn and alfalfa.

Table 1

Effect of lime and molybdenum on the yield of alfalfa, oats, corn and soybeans. (Port Byron silt loam, Rosemount, 1966).

Lime Treatment Tons/A	Alfalfa 1st cutting	Alfalfa 2nd cutting	Alfalfa Total Tons/acre	Corn Bu/acre	Oats Bu/acre	Soybeans Bu/acre
0	1.09	.75	1.84	79.9	60.9	15.5
3	2.07	1.46	3.53	83.3	60.1	14.8
6	2.45	1.55	4.00	77.7	58.3	14.4
12	2.46	1.67	4.13	86.2	60.2	11.7
24	2.29	1.55	3.84	84.3	61.9	8.87
0 +8.70z. Mo/acre	2.09	1.21	3.30	77.0	62.2	12.8

Comparison of Urea Ammonium Phosphates with Standard Phosphorus Sources
West Central Experiment Station
Samuel D. Evans

Plots were established at the West Central Experiment Station in 1966 to determine the effectiveness of 4 TVA urea ammonium phosphate grades as phosphorus sources for corn. These materials were compared to the standard commercial phosphorus sources.

Table 1. Chemical composition of TVA materials used.

Nominal grade	N % Total	N % NH_3	N % Urea	N % Biuret	P_2O_5 % Citrate avail.	P_2O_5 % Water soluble
29-29-0	29.9	10.4	19.4	0.1	28.5	26.6
25-35-0	24.8	12.1	12.4	0.3	36.5	34.3
34-17-0	37.0	6.3	30.4	0.8	17.7	17.0
33-20-0	33.8	7.2	26.1	0.5	20.4	18.5

Table 2. Soil test values of the experimental area (Doland silt loam)

	Replicate 1	2	3	4	5	6
PH	7.9	7.8	7.8	7.8	7.9	7.9
O.M. %	5.3	5.3	5.0	5.7	6.1	5.9
Ext. P	8	8	9	9	11	7
Exch. K	220	200	170	180	140	200

Table 3. Plant height, grain yield, and ear weight.

Treatments	Plant height July 8, 1966 inches	Yield Bu/A @ 15.5%	Average ear weight @ 15.5%
Check	42.00	107.95	0.434
0-46-0	42.33	108.03	0.435
21-53-0	41.42	107.92	0.437
29-29-0	41.42	108.90	0.435
25-35-0	41.92	109.74	0.443
34-17-0	42.37	105.97	0.426
33-20-0	42.00	105.46	0.428

All plots except the check plot received a broadcast application of the various test materials to give 21.8 lbs. of P per acre. Additional nitrogen

Comparison of Urea Ammonium Phosphates with Standard Phosphorus Sources (continued)

(33 1/2-0-0) was broadcast on all plots to give a total application of 100 lbs. of N per acre. A uniform application of 50 lbs. of 6-24-24 per acre was applied in the row to all plots at planting time.

Table 4. Chemical composition of plant samples taken 6/29/66.

	Check	0-46-0	21-53-0	29-29-0	25-35-0	33-20-0	34-17-0
K %	4.26	4.00	4.04	4.04	4.12	3.96	3.62
P %	.42	.42	.42	.43	.40	.40	.42
Ca %	.58	.60	.59	.59	.59	.61	.58
Mg %	.44	.44	.43	.46	.46	.46	.48
Na %	.04	.04	.03	.04	.04	.03	.02
Si %	.67	.66	.70	.46	.63	.61	.65
Mn ppm	68	58	67	67	62	66	63
Fe ppm	302	304	288	290	239	292	392
Bo ppm	4	4	4	4	4	4	4
Cu ppm	8	8	9	6	7	8	8
Zn ppm	18	18	17	20	16	19	22
Al ppm	282	292	251	202	232	240	260
Sr ppm	21	20	16	18	21	18	12
Mo ppm	1.86	1.95	1.86	1.86	1.90	2.02	2.16
Co ppm	1.89	2.12	1.63	1.69	1.91	1.78	1.68
Ba ppm	7	6	6	8	6	7	8

Table 5. Chemical composition of leaf samples taken 8/1/66.

	Check	0-46-0	21-53-0	29-29-0	25-35-0	33-20-0	34-17-0
K %	2.12	2.23	2.00	1.85	2.22	2.27	2.39
P %	.30	.34	.23	.22	.34	.28	.37
Ca %	.62	.67	.51	.47	.73	.64	.75
Mg %	.51	.50	.41	.39	.54	.49	.55
Na %	.01	.01	.01	.01	.01	.02	.01
Si %	.27	.27	.27	.20	.29	.24	.23
Mn ppm	85	99	71	71	98	89	106
Fe ppm	258	149	144	103	166	231	136
Bo ppm	4	4	3	3	5	3	5
Cu ppm	7	7	7	4	8	6	9
Zn ppm	13	15	12	11	14	15	15
Al ppm	30	35	32	23	48	30	32

Comparison of Urea Ammonium Phosphates with Standard Phosphorus Sources (continued)

Table 5 continued

	Check	0-46-0	21-53-0	29-29-0	25-35-0	33-20-0	34-17-0
Sr ppm	16	16	10	12	18	21	18
Mo ppm	2.06	1.76	1.31	1.47	2.38	1.81	2.09
Co ppm	2.00	1.37	1.20	1.60	3.19	1.58	2.05
Ba ppm	5	5	4	4	5	4	5

Yields and chemical analyses show no apparent difference between the test materials and standard commercial phosphorus sources. In addition, even the small amount of phosphorus applied in the starter (5.2 lbs P/acre) was sufficient for a yield of 107.95 Bu/acre on the check plot.

1966 Phosphorus Placement Study
- Seed Incorporation (Pop Up) -
Southwest Experiment Station

W. W. Nelson and G. W. Randall

An experiment was initiated in the spring of 1966 at Lamberton to determine the effect of small amounts of seed incorporated fertilizer on the 1) early growth of corn, 2) chemical composition of the plant at both an early stage and again at the silking stage and, 3) the yield of corn. The design used was a split plot with four starter treatments and two broadcast treatments all replicated five times. The corn variety planted was DeKalb 3 x 3. Small plants were harvested on June 23. Corn yields were somewhat low, probably due to the hot, dry conditions during pollination.

Plant weights and corn yields as affected by this seed incorporation of fertilizer are shown in the following tables.

Table 1. A description of the starter and broadcast treatments applied to the phosphorus placement experiment.

		Broadcast Treatment*			
		No Broadcast		Broadcast	
Starter Treatment		67+0+0		67+60+30	
Description	Nutrients	Trt. No	Application	Trt. No.	Application
Check	0+0+0	1	67+0+0	5	67+60+30
2 x 2 Band	12+48+24	2	79+48+24	6	79+108+54
Seed Inc.	3+12+6	3	70+12+6	7	70+72+36
2 x 2 Band + Seed Inc.	15+60+30	4	82+60+30	8	82+120+60

*refers to broadcast P_2O_5 and K_2O of 0+60+30.

Table 2. Average weight of 15 small plants and the average corn yield of these eight treatments.

Treatment No.	Plant weight*	Corn Yield**
1	491.8 gms	51.9 bu/A
2	772.6	66.8
3	712.0	58.0
4	973.4	73.2
5	619.8	62.9
6	897.0	67.3
7	853.0	74.2
8	1,075.2	72.6

* weight in grams of 15 small plants harvested June 23
** bushels per acre at 15.5% moisture

For appropriate statistical analysis of this split plot design, the two broadcast treatments have to be combined.

Table 3. The average plant weight and corn yield of the starter treatments with broadcast treatments combined.

Trt. No.	Description	Plant weight	Corn yield
1 (1+5)	Check	555.8 gms	57.4 bu/A
2 (2+6)	2 x 2 Band	834.8	67.0
3 (3+7)	Seed Inc.	782.5	66.1
4 (4+8)	2 x 2 Band + Seed Inc.	1,024.3	72.9

Table 4. The average plant weight and corn yield of the broadcast treatments with the starter treatments combined.

Treatment	Plant weight	Corn yield
No Broadcast	737.4 gms	62.4 bu/A
Broadcast	861.2	69.2

Table 5. Duncan's Multiple Range Test showing which means due to starter fertilizer treatment are significantly different from each other.

Trt. No.	Description	Plant weight	Corn yield
4	2x2 Band + Seed Inc	1,024.3 a*	72.9 a
2	2x2 Band	834.8 b	67.0 ab
3	Seed Inc.	782.5 b	66.1 b
1	Check	555.8 c	57.4 c

* weight and yield figures followed by the same letter belong to the same .05 level population.

Interpretation of Data

Plant weight

The green weights of the 15 small plants were found to vary significantly at the .05 level with the broadcast treatments (F - 9.08) and at the .01 level with the starter treatments (F - 46.87). The broadcasting of 0+60+30 (P_2O_5 amd K_2O) significantly increased the early plant weights from 737 gms to 861 gms. The application of starter fertilizer (Trt. 2) and seed incorporated fertilizer (Trt. 3) also significantly increased the plant weights over the check with no significant difference in weight between Trt. 2 and Trt. 3. The combination of the 2x2 Band and seed incorporated (Trt. 4) significantly increased the plant weights (1,024.3 gms) over the individual application of 2x2 Band (834.9 gms) or seed incorporated (782.5 gms).

Significant differences at the .05 level were not found among the five replications. Also, no interaction was found between the broadcast treatments and the starter treatments.

Corn Yield

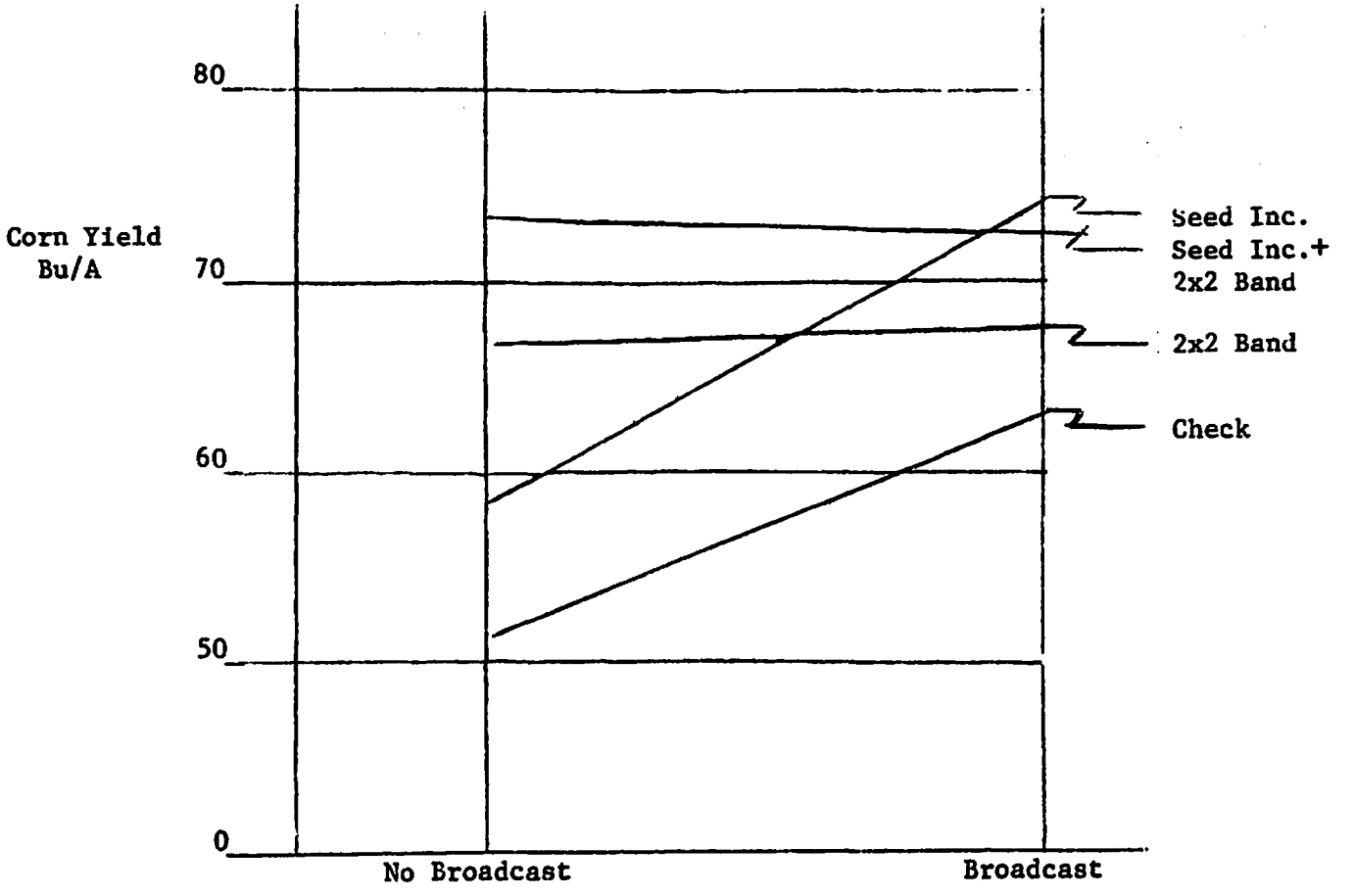
The corn yields were also found to vary significantly at the .05 level with the broadcast treatments (F - 9.52) and at the .01 level with the starter treatments (F - 17.99). The broadcasting of 0+60+30 significantly increased the yields from 62.4 to 69.2 bushels per acre. The application of 2x2 Band fertilizer (Trt. 2) and seed incorporated fertilizer (Trt. 3) also significantly increased the yields over the check with no significant difference between these two treatments. The combination of 2x2 Band and seed incorporated (Trt. 4), producing the highest yield of 72.9 bushels, gave a significant yield increase over the check (57.4 bu.) and over the seed incorporated (66.1 bu.).

The highly significant broadcast x starter interaction indicates that the yields from the check treatment (Trt. 1) and the seed incorporated treatment (Trt. 3) were significantly higher on the broadcast area than on the area where no broadcast treatment was applied. The 2x2 Band treatment (Trt. 2) and the 2x2 Band + seed incorporated treatment (Trt. 4) did not show a significant increase with broadcast fertilization. For illustration see Figure 1.

The coefficients of variability, a measure of the unexplained variation within the experiment, were quite low for both green weights and the corn yields. These values were 11.1 and 7.2, respectively, indicating that this was a very homogeneous experiment.

The linear correlation coefficient between the green plants weights and the corn yields was .645 which was significant at the .01 level.

Figure 1. The effect of the starter treatments with two broadcast treatments (Bdcst x Starter IA) on the yield of corn.



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

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

1966 Yield - Bushels/acre @ 15.5% Moisture

Broadcast Treatment lbs/A \ Row Treatment lbs/A	OP	15P	30P	45P	45P+10Zn	Average
OP	98.69	95.55	93.02	98.96	102.66	97.77
45P	99.38	92.91	95.36	91.77	95.04	94.89
Average	99.04	94.23	94.19	95.36	98.85	

1966 Leaf Sample Analysis
Phosphorus and Zinc*

Broadcast Treatment lbs/A \ Row Treatment lbs/A	OP	15P	30P	45P	45P+10Zn
OP	.19 / 16	.23 / 17	.24 / 16	.28 / 13	.23 / 19
45P	.22 / 13	.23 / 12	.25 / 10	.33 / 14	.25 / 17

* Leaf taken opposite and below ear leaf. Upper value is % phosphorus and lower value is ppm zinc.

Uptake of phosphate by roots and tops of sugarbeets

Northwest Experiment Station
Olaf C. Soine, Soil Scientist

This study was started in 1963 to attempt to measure the uptake of phosphorus by sugarbeet tops and roots by using phosphate alone and in combination with the ammonium form of nitrogen. The literature reports that several workers have noted the increased uptake of phosphorus when it is mixed with the ammonium form of nitrogen.

Three different rates of phosphate alone and in combination with 2 different rates of nitrogen were applied in a band approximately 2 inches to the side and below the seed. The plots were replicated and randomized and were seeded on land which was in black fallow the previous year.

The statistical analysis, sugar, purity, percent total nitrogen, and phosphorus determination were made by the American Crystal Sugar Company, Denver, Colorado.

Samples of the roots and tops were taken four times during the growing season for phosphorus determinations and the analysis was made by the Department of Soil Science, University of Minnesota. On August 17, 1965, samples of tops from five treatments were taken for micronutrient analysis and sent to the Department of Soils at Ohio State University.

Discussion: The data in Table 1 gives the treatment, rate, and yield per acre and percent sucrose, yield of sugar, purity, percent total nitrogen and phosphorus in p.p.m. for 1964-66.

There has been no significant differences in the yield of sugarbeets, sugar per acre, or the percent sucrose over the past 3 years. The percent purity varied slightly but the differences have not been significant. The total nitrogen content increased when phosphate and nitrogen fertilizers were added but the differences were not significant.

There was significant difference in the phosphorus - p.p.m. - between the check plot and the other treatments, but there were no significant differences between these other treatments.

The uptake of phosphorus by the tops and roots in percent for the four different sampling dates is given in tables 2 and 3. The data do not show any large uptake of phosphorus by the tops or roots of beets when nitrogen is added to the phosphate fertilizer. The largest uptake occurred during the early spring but the amount gradually decreased as the growing season progressed. The tops absorbed more phosphorus than the roots.

The micro-nutrient data for the tops are given in table 4 for the five different fertilizer treatments for 1964-65. The results for the two years were very similar. The amount of iron in the 1965 data was lower than in 1964 but the average amount appears to be above the deficiency levels. The cobalt and molybdenum content were higher in 1965 than they were in 1964.

Uptake of phosphate by roots and tops of sugarbeets
(continued)

Table 1. Uptake of phosphorus by sugarbeets - Average 1964-1966.

Treatment	Rate per/acre	Yield tons/acre	Percent sucrose	Yield sugar lbs./acre	Purity percent	%Total nitrogen	Phos p.p.m.
check	----	12.12	14.3	3470	84.7	1.04	543
1 P	40	11.83	14.5	3436	84.9	1.13	625
2 P	80	12.54	14.1	3549	85.0	1.05	623
3 P	120	12.34	14.3	3620	85.7	1.01	625
1 N + 1 P	10 + 40	12.61	14.3	3620	84.5	1.18	590
1 N + 2 P	10 + 80	11.75	14.1	3325	84.7	1.17	603
1 N + 3 P	10 + 120	12.37	14.6	3614	86.2	1.14	608
2 N + 1 P	20 + 40	12.00	14.2	3417	84.5	1.08	585
2 N + 2 P	20 + 80	12.45	14.5	3608	84.8	1.05	675
2 N + 3 P	20 + 120	11.81	14.5	3416	85.2	1.06	662
av. all P- treatments		12.24	14.3	35.35	85.2	1.06	624
av. all 10N + P-treat.		12.24	14.3	35.20	85.1	1.16	600
av. all 20N + P-treat.		12.09	14.4	34.80	84.8	1.06	641

L.S.D.

Page 3
Uptake of phpsphate by roots and tops of sugarbeets
(continued)

Table 2. Uptake of Phosphorus by Sugarbeet Tops 1965

Treatment	Rate	Time of Sampling			
		June 28	July 28	August 31	September
	Lbs./Acre	Per Cent Phosphorus			
Check	-	.530	.370	.298	.260
1P	40	.589	.408	.297	.286
2P	80	.615	.402	.299	.284
3P	120	.603	.384	.288	.292
N + 1P	10 + 40	.589	.352	.285	.288
N + 2P	10 + 80	.593	.399	.290	.291
N + 3P	10 + 120	.605	.401	.296	.296
2N + 1P	20 + 40	.591	.385	.312	.286
2N + 2P	20 + 80	.608	.380	.299	.297
2N + 3P	20 + 120	.614	.418	.289	.297
Av. All P Treatments		.602	.398	.295	.287
Av. All N + P Treatments		.596	.384	.290	.292
Av. All N + P Treatments		.603	.394	.300	.293

Uptake of phosphate by roots and tops of sugarbeets.
(continued)

Table 3. Uptake of Phosphorus by Sugarbeet Roots 1965

Treatment	Rate	Time of Sampling			
		June 28	July 28	August 31	September
	Lbs./Acre	Per Cent Phosphorus			
Check	-	.447	.215	.142	.102
1P	40	.611	.273	.171	.113
2P	80	.600	.280	.163	.122
3P	120	.551	.249	.151	.122
1N + 1P	10 + 40	.508	.227	.147	.105
1N + 2P	10 + 80	.528	.249	.157	.113
1N + 3P	10 + 120	.593	.253	.169	.125
2N + 1P	20 + 40	.562	.247	.169	.130
2N + 2P	20 + 80	.565	.274	.167	.129
2N + 3P	20 + 120	.590	.260	.182	.132
Av. All P Treatments		.587	.267	.162	.119
Av. All N_1 + P Treatments		.543	.243	.158	.114
Av. All N_2 + P Treatments		.572	.260	.173	.130

Uptake of phosphate by roots and tops of sugarbeets.
(continued)

Table 4. Uptake of phosphorus by sugarbeet tops, micro-nutrient analysis. 1964-65.

Treatment	Parts per million										Percent					
	Mn	Fe	B	Cu	Zn	Al	Sr	Mo	Co	Ba	K	P	Ca	Mg.	Na	Si
Check	80	108	50	18	84	99	19	11.8	1.29	6	3.2	.30	.78	1.03	.83	.09
40# P	59	103	46	13	86	93	19	8.9	.78	6	3.0	.26	.55	.82	.90	.08
120# P	61	93	49	15	89	79	17	33.0	1.04	5	2.6	.33	.62	.94	.90	.08
20# N + 40# P	72	127	50	18	92	105	21	34.9	1.07	9	2.9	.33	.76	1.00	1.09	.10
20# N + 120# P	79	96	50	15	79	84	20	30.8	.98	8	3.0	.32	.72	.99	.81	.08

Sugarbeet roots - 1964

Treatment	Parts per million									Percent					
	Mn	Fe	B	Cu	Zn	Al	Sr	Mo	Co	K	P	Ca	Mg	Na	Si
Check	24	19	13	8	29	-1	8	.4	.6	.98	.09	.10	.23	1.38	.05
40# P	20	21	14	7	37	-1	8	.6	.8	.77	.15	.10	.26	1.20	.05
120# P	22	21	13	5	30	-1	3	.4	.5	.74	.18	.10	.24	1.36	.05
20 # N +40# P*	20	17	12	4	18	-1	9	.2	.3	.72	.13	.09	.23	1.30	.05
20# N + 120# P	22	19	13	6	31	-1	8	.5	.6	.96	.15	.10	.23	1.38	.05

*One replicate

SULFUR INVESTIGATIONS ON SOILS AND CROPS

Summary - December 1966

A. C. Caldwell, J. Grava, E. C. Seim, G. W. Rehm
and W. P. Martin

Department of Soil Science

University of Minnesota

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

This report summarizes yield data and analytical studies completed or in progress since July 1966. A brief review of the work in progress and future plans is included.

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

Results and work in progress

In 1966 field studies were again conducted at the Park Rapids, Minnesota sulfur experimental field. Experiments begun in previous years on alfalfa, corn, small grain, and potatoes were continued in 1966. Yields and composition of red clover-brome hay were obtained from trials established in 1965. Supplemental irrigation was practiced on all crops.

In 1966 annual applications of sulfur and gypsum approximately doub-

led the yield of alfalfa. Yields ranged from 2.0 tons to 4.2 tons despite an extremely late start in the spring which delayed and decreased the 1st cutting yield. Elemental sulfur and gypsum were equally effective in increasing yield. All sulfur treatments significantly increased the sulfur content of the tissue.

Sulfur treatment applied in 1962 continued to increase alfalfa yields in 1966. One hundred pounds of elemental sulfur and 1000 lbs of sulfur as gypsum continued to maintain alfalfa yields at near maximum levels. Intermediate rates of sulfur continued to produce yield increases but tissue analysis indicates that sulfur levels in the tissue have fallen to limiting levels. ($<$ 2%).

Similar results were obtained from the yield data and tissue analysis of another study of alfalfa following corn. Adequate sulfur treatments have increased alfalfa yields from 2.1 to 4.7 tons per acre for three cuttings in 1966. Tissue analysis indicates that all residual treatments except 100 lbs. of elemental sulfur per acre are running out. Plots which received sulfur plus trace elements showed no additional benefit beyond what could be attributed to the sulfur supplied.

Yields of small grain were disappointing in 1966 despite an adequate supply of moisture, increased seeding rate, and higher nitrogen application. This is attributed largely to an adverse season. Despite the low yields, 10 lbs. of sulfur increased barley yields by 4 to 11 bushels and significantly increased the sulfur content of the tissue. Sodium sulfate was most effective in increasing yield and sulfur content, followed by elemental sulfur and gypsum.

Oat yields were increased by 4 to 8 bushels per acre by the sulfur treatment with corresponding increases in the sulfur content of the whole

plant tissue.

Increases in wheat yields were smaller (1.7 to 6.0 bushels per acre) and did not show a consistent advantage for any particular sulfur material. The highest mean yield was produced by the gypsum treatment (10 #S/acre). All sulfur treatments increased the sulfur content of the whole plant tissue but it is interesting to note that the sulfur content of the control plants was greater than .2% (.251) which is much higher than the sulfur content of untreated oat and barley plants (.172 and .195% respectively).

In 1966 corn yields of 110-114 bushels were produced with an 85 day hybrid but the 4 bushel increase due to sulfur treatment was not significant at the 5% probability level. Sulfur deficiency symptoms were evident early in the season but were outgrown as the season advanced. Treated corn was consistently drier than the untreated corn.

Red Clover-brome showed significant increases in yield and sulfur content of the hay due to sulfur treatment applied at the time of seeding or to the preceding small grain crop. On untreated plots the red clover was a pale yellowish-green color, was shorter and slower maturing. Treated clover was vigorous and dark-green in color. Sulfur contents of brome and red clover were essentially the same for similar sulfur treatments indicating that both species competed equally for the available sulfur supply.

Yield of Russet Burbank potatoes averaged 543 bushels/acre but there was no significant increase in yield or specific gravity due to sulfur treatment at the 5% probability level. Sulfur content of the petioles at midseason was significantly increased by the sulfur treatment.

The analyses of corn, oat, barley, and wheat grain and potatoe tubers for total sulfur contents are in progress. Plans also provide for a num-

ber of samples to be analyzed for N, P, K, and trace elements.

A survey of pH, organic matter, extractable phosphorus and exchangeable potassium levels on the soils of the experimental plots indicated that annual applications of 100# of sulfur in the elemental form have reduced the pH of the 0-1 and 1-2 inch depths to 4.7 and 5.2 respectively. The pH of the surface two inches of unsulfured plots is 6.8 and 6.2 respectively. As a result of this survey a more extensive sampling of the soil is planned.

The study of the movement of sulfate sulfur in the profile is continuing. Samples were taken at the beginning and end of the 1966 growing season and analyses are nearing completion.

The measurement of sulfur in the rainwater and in the atmosphere is continuing.

New Studies

New studies on the effect of NH_4^+ and NO_3^- on the uptake of the sulfate ion are just getting underway. These studies will involve the use of N^{15} and S^{35} to follow the uptake of N and S into the plants. Studies are also beginning on the absorption of sulfur dioxide and hydrogen sulfide by soil and soil components.

Plans are also being readied to test the effect of several new sulfur-bearing fertilizers at the sulfur experimental field in 1967.

SULFUR INVESTIGATIONS ON SOILS AND CROPS

Report No. 9

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

This report includes 1966 yield data and analytical studies completed or summarized since July 1966. A brief review of the work in progress and future plans is included.

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

Field Research

In 1966 field studies were again conducted at the Park Rapids, Minnesota sulfur experimental field. Experiments begun in previous years on alfalfa corn, small grain and potatoes were continued in 1966. Yield and composition data were obtained for the red clover-brome trials established in 1965. (The potatoes were irrigated on a regular schedule. Other crops received supplemental irrigation when necessary.)

Alfalfa

Two studies with several rates and types of sulfur on alfalfa were established in 1962. One study measures the effect of the various materials applied annually. The other study measures the residual effect of the 1962 sulfur treatments. The experiments compare the effects of three rates of elemental sulfur (25, 50, 100 lbs. S/acre) and a 50 lb. S/acre application of gypsum with a control (0 lbs. S/acre). An additional heavy gypsum application (1000 lbs. S/acre) was included in the residual study. All plots received complete applications of phosphorus and potassium according to soil tests at the beginning of the experiment. Borax (20 lbs/acre) was applied after the 1st cutting in 1962 and after the 2nd cutting in 1965. Additional potassium has been topdressed as needed. The results of previous years have been presented in reports 1-8.

In 1966 three cuttings of alfalfa were taken. The 1966 yield results for the annually applied S treatments are reported in Table 1. Table 2 contains the 1966 yield results for the residual treatments. Total sulfur content of the alfalfa tissue is reported in tables 3 and 4.

Table 1. Effect of annual applications of sulfur-bearing materials on the yield of alfalfa (1966).

Material	Rate lbs S/acre	1st cut tons/acre	2nd cut tons/acre	3rd cut tons/acre	total tons/acre
None	0	.74	.72	.60	2.06
Sulfur	25	1.17	1.55	1.39	4.11
Sulfur	50	1.20	1.42	1.26	3.88
Sulfur	100	1.26	1.43	1.21	3.90
Gypsum	50	1.20	1.65	1.38	4.23
lsd (.05)		.21	.39	.23	.69
(.01)		.29	.54	.32	.94
hsd (.05)		.31	.48	.33	.94
(.01)		.38	.60	.42	1.23

Table 2. Residual effect of sulfur-bearing materials on the yield of alfalfa (1966).

Material	Rate lbs S/acre*	Yield 1st cut tons/acre	2nd cut tons/acre	3rd cut tons/acre	total tons/acre
None	0	.70	.45	.36	1.51
Sulfur	25	1.19	1.03	.78	3.00
Sulfur	50	1.28	1.28	.93	3.49
Sulfur	100	1.40	1.57	1.17	4.14
Gypsum	50	1.13	.99	.68	2.80
Gypsum	1000	1.26	1.47	1.09	3.82
lsd (.05)		.19	.23	.12	.46
(.01)		.25	.30	.16	.62
hsd (.05)		.28	.34	.18	.69
(.01)		.34	.42	.22	.85

*applied in 1962.

Table 3. Effect of annual applications of sulfur-bearing materials on the sulfur content of alfalfa (1966).

Material	Rate lbs. S/acre	Sulfur content of tissue (%) 1st cut	2nd cut	3rd cut
None	0	.158	.189	.208
Sulfur	25	.303	.375	.330
Sulfur	50	.344	.411	.365
Sulfur	100	.381	.440	.389
Gypsum	50	.351	.379	.289
lsd (.05)		.025	.031	.032
(.01)		.035	.042	.043
hsd (.05)		.036	.044	.046
(.01)		.046	.055	.057

Table 4. Residual effect of sulfur-bearing materials on the sulfur content of alfalfa (1966).

Material	Rate lbs. S/acre	Sulfur content of tissue (%) 1st cut	2nd cut	3rd cut
None	0	.146	.171	.206
Sulfur	25	.175	.165	.200
Sulfur	50	.189	.213	.220
Sulfur	100	.242	.250	.261
Gypsum	50	.169	.166	.198
Gypsum P	1000	.343	.327	.329
lsd (.05)		.043	.030	.035
(.01)		.058	.041	.048
hsd (.05)		.064	.045	.053
(.01)		.078	.055	.065

In 1966 annual applications of sulfur and gypsum approximately doubled the yield of alfalfa. Yields ranged from 2.0 tons to 4.2 tons despite an extremely late start in the spring which delayed and decreased the 1st cutting yield. Elemental sulfur and gypsum were equally effective in increasing yield. All sulfur treatments significantly increased the sulfur content of the tissue. (Table 3).

Sulfur treatment applied in 1962 continued to increase alfalfa yields in 1966. One hundred pounds of elemental sulfur and 1000 lbs. of sulfur as gypsum continued to maintain alfalfa yields at near maximum levels (Table 2). Intermediate rates of sulfur continued to produce yield increases but tissue analysis indicates that sulfur levels in the tissue have fallen to levels which are not significantly different from the level in the untreated alfalfa (Table 4) and have fallen below the .3% level necessary for maximum yields. Only the 1000#S application as gypsum continues to supply sulfur at levels sufficient to maintain tissue sulfur at .3% or greater.

The third cutting was taken at a somewhat less mature stage than the first and second cuttings to allow sufficient time for recovery before frost. This probably accounts for the generally higher sulfur content of the tissue from the third cutting plants.

Alfalfa following corn

Alfalfa was seeded in 1963 to an area which had been in corn in 1962. Treatments were modified to include a check; the residual effect of elemental sulfur applied in 1962 at the rate of 25, 50 and 100 lbs. of S per acre; gypsum at 60 lbs. S per acre; the residual effect of 10 lbs. of S per acre as K_2SO_4 and 16-20-0-S applied to the corn; and a sulfur plus trace element treatment that supplied a total of 25 lbs. of sulfur per acre. No additional sulfur was applied in 1964 or 1965. In 1964 only the second cutting was taken