HIGH PHOSPHORUS AND POTASSIUM RATES IN A CORN-SOYBEAN ROTATION

1985

G. W. Randall, S. D. Evans, and W. W. Nelson

EXPERIMENTAL PROCEDURES

Ten P and K treatments (Table 1) were applied at three branch experiment stations (Southern Experiment Station, Waseca; Southwest Experiment Station, Lamberton; and West Central Experiment Station, Morris) in Minnesota. A randomized, complete-block design with four replications was used. The 50-pound rates were estimated to be "maintenance" rates, and the 0, 100, and 150-pound rates provide the response curves for each element. Treatments 5 and 8 receive P and K, respectively, every third year for the duration of the experiment. Treatments 9 and 10, applied in the fall of 1973, did not receive P and K again until the fall of 1978 when the treatments were resumed at Waseca because P appeared to be limiting. These two treatments were resumed at Morris in 1979 for the same reason. All other treatments have been applied annually. In 1982, soybeans were planted at Morris and Waseca after 8 years of continuous corn to begin a long-term corn-soybean rotation phase of this experiment.

Table 1. Phosphorus and potassium treatments applied in the high P and K rate study.

Trt. No.	Application Year (Fall) 1973,'76,'79,'82	1974,'75,'77,'78,'80,'81,'83,'84
	lb P_2O_5 + K_2O/A	
1	0 + 0	0 + 0
2	0 + 100	0 + 100
3	50 + 100	50 + 100
4	100 + 100	100 + 100
5	150 + 100	0 + 100
6	100 + 0	100 + 0
7	100 + 50	100 + 50
8	100 + 150	100 + 0
9 1/	150 2/ + 100	0 + 100 3/ 5/
10 1/	100 + 150 2/	100 + 0 4/ 6/

1/ Neither P nor K was applied in 1976.

2/ The 150-lb rate was not applied at Lamberton or Waseca in 1979 but was applied at Morris.

3/ 150 + 100 applied at Waseca in 1978.

4/ 100 + 150 applied at Waseca in 1978.

5/ 0 + 100 was applied at all locations from 1980 through 1984.

6/ 100 + 0 was applied at all locations from 1980 through 1984.

The P and K materials were broadcast on soybean residue and chiseled in at all locations in the fall of 1984. Phosphorus was applied as CSP (0-46-0) and K as muriate of potash (0-0-60). Starter fertilizer was not used.

Specific experimental procedures used for corn at each of the stations are presented in Table 2. Management practices providing for optimum yields were employed at each location.

At Lamberton each of the plots was split with the east half planted to soybeans and the west half to corn. Soybeans (Corsey 79) were planted in 30" rows at a rate of 9 seeds/foot on May 7. Weeds were controlled with a ppi application of Treflan. Plant tissue samples were not taken. Soybeans were harvested October 21.

Please refer to title page of this publication for information regarding application and use of this article.

Planting in 1983 went smoothly due to the warm and dry conditions in late April and during May. Although some moisture stress occurred at Waseca during July, conditions were generally very good for exceptional yields at all three locations. Weed and insect control were excellent at all locations.

Table 2. Experimental procedures for the high P and K rate study on continuous corn at the three branch stations in 1985.

Variable	Branch Station		
	Lamberton	Morris	Waseca
Planting date	5/7	5/1	5/1
Row spacing	30"	30"	30"
Planting rate	26,000	27,800	31,000
Hybrid	Pioneer 3732	Pioneer 3901	Pioneer 3732
Nitrogen rate	150#	140#	160#
Herbicide	3# Lasso + 2# Bladex/A ppi	3# Lasso + 2.2# Bladex/A preemerge	3½# Lasso + 3½# Bladex/A preemerge
Insecticide	Counter 1 lb/A	Counter 1.8 lb/A	None
Harvest date	10/2	10/14	10/16

RESULTS AND DISCUSSION

Soil samples taken at the end of the 1985 growing season indicate significant differences in Bray P_1 extractable P and exchangeable K at all locations (Table 3). There appeared to be a good linear response between extractable Bray P_1 and P application rate. Soil test P was always lowest with treatments 1 and 2, which received no P. Intermediate P levels were found with treatment 3 (50-lb P_2O_5 annually) and treatment 5 (150-lb P_2O_5 every third year). Highest soil test P values were associated with the annual 100-lb P_2O_5 treatments at all locations. Soil test P values at all locations were quite similar to those obtained in 1984. Soil test K values were approximately 25% lower than in 1984 at Lamberton, 15% higher at Morris and remained the same at Waseca. Soil P values obtained with Olsen's $NaHCO_3$ test on the calcareous soil at Morris were slightly but consistently lower than the values from the Bray P_1 test (1:10 ratio).

Table 3. Soil test values as influenced by 12 years' application of P and K treatments at Lamberton, Morris, and Waseca.[1/]

Treatment		pH			P				K		
No.	Description	La	Mo	Wa	L_{10}	M_{10}	M_{OL}	W_{10}	La	Mo	Wa
	lb P_2O_5+K_2O/A[2/]				lb/A						
1	0 + 0	5.7	7.8	6.5	51	9	6	17	242	396	239
2	0 + 100	5.7	7.8	6.7	39	9	6	12	368	557	281
3	50 + 100	6.1	7.7	6.5	73	43	37	44	337	489	275
4	100 + 100	5.6	7.7	6.6	106	85	79	79	308	499	288
5	0 + 100	5.8	7.7	6.7	68	26	22	37	328	500	301
6	100 + 0	5.6	7.6	6.7	104	86	77	75	237	373	249
7	100 + 50	5.7	7.7	6.7	106	81	72	72	302	454	257
8	100 + 0	5.8	7.6	6.4	90	96	86	81	267	426	246
9	0 + 100	5.9	7.7	6.7	44	21	14	18	305	448	272
10	100 + 0	5.7	7.8	6.6	74	37	33	61	258	405	248
Signif. Level (%):		45	94	74	99	99	99	99	99	99	90
BLSD (.05),(.10)*:			.2		22	18	14	12	34	45	46*
CV (%) :		5.2	1.2	2.7	21.	26.	24.	16.	8.5	7.	9.6

1/ Samples were taken in September before the 1985 treatments were applied.
2/ Rates applied in fall of 1984 for 1985 crop.

Soil test K was influenced (P = 90% level) by the K applications at all locations in 1985 (Table 3). The response to annual K applications was not as pronounced as with P. Highest soil test K values were associated with the annual application of 100 lb K_2O/A. Soil pH was not related to the P and K treatments.

Soil samples were taken from both the corn and soybean areas in 1985 (Table 4). Consistent differences in soil pH, extractable P or exchangeable K were not found between the corn and soybean crops regardless of past fertilizer treatment.

Table 4. Soil test values as influenced by the crop grown at Lamberton.[1/]

Treatment[2/]	Corn pH	Corn P	Corn K	Soybeans pH	Soybeans P	Soybeans K
lb P_2O_5+K_2O/A		-- lb/A --			-- lb/A --	
0 + 0	5.7	51	242	5.8	58	228
100 + 100	5.6	106	308	5.7	102	315

1/ Samples taken in September before the 1985 treatments were applied.
2/ Twelve-year annual application rate.

To determine the depth of accumulation of P and K from the long-term fertilizer additions, soil samples were taken in 6-inch increments to a depth of 36 inches from both the continuous check and annual 100-lb P_2O_5 and K_2O rates (Table 5). Soil pH was unaffected at both locations by the treatments. Fertilizer P accumulated almost entirely in the top 12 inches at both locations. Potassium also accumulated in the top 12 inches at Lamberton. At Waseca there was some indication of accumulation of soil K to a depth of 30" with the annual 100 + 100 treatment.

Table 5. Influence of 12 years' fertilizer P and K additions on the accumulation of P and K in the soil profile at Lamberton and Waseca.

Depth.	Trt.[1/]: Soil pH 0 + 0	Soil pH 100 + 100	Soil P 0 + 0	Soil P 100 + 100	Soil K 0 + 0	Soil K 100 + 100
inches			---------- lb/A ----------			
			Lamberton			
0-6	6.1	5.8	40	95	280	418
6-12	5.9	5.9	33	80	258	363
12-18	6.6	6.6	4	8	194	207
18-24	7.2	7.2	2	2	154	162
24-30	7.8	7.8	2	2	122	132
30-36	8.0	8.0	2	2	124	134
			Waseca			
0-6	6.7	6.8	13	82	215	298
6-12	6.7	6.8	7	47	219	281
12-18	6.8	7.2	3	7	223	308
18-24	7.1	7.5	3	4	218	315
24-30	7.4	7.7	3	3	210	290
30-36	7.5	7.7	3	3	212	228

1/ Twelve-year annual application rate of pounds P_2O_5 and K_2O/A.

Approximately 5 to 6 weeks after planting, ten plants were selected randomly from each plot, measured, harvested, dried and weighted to determine early plant growth. Early weight and height of the corn were increased significantly by the treatments at all three locations (Table 6). Both early plant weight and height were lowest with the check treatment (no. 1). At Morris and Waseca, both early plant height and weight were increased by the 50 and 100-lb P_2O_5 rates over the 0 - P_2O_5 rate (trt. no. 2). At Waseca, plant weight and height were increased by 25 and 10%, respectively, with the 100-lb K_2O treatment over the 0-lb K_2O rate. Responses to K were not found at the other two locations.

Table 6. Early plant growth as influenced by high P and K rates at the three experimental sites in 1985.

Treatment		Weight			Height (Extended)		
No.	Description	La	Mo	Wa	La	Mo	Wa
	lb P_2O_5+K_2O/A	-- g/dry plant --			------ cm -----		
1	0 + 0	2.7	2.6	3.9	36	48	52
2	0 + 100	3.0	3.1	4.8	38	50	59
3	50 + 100	3.0	4.2	5.7	40	59	63
4	100 + 100	3.8	4.5	6.4	43	61	67
5	0 + 100	2.8	4.1	5.2	38	57	62
6	100 + 0	3.5	4.4	5.1	40	58	61
7	100 + 50	3.2	4.5	5.6	42	60	64
8	100 + 0	3.7	4.9	5.6	42	63	62
9	0 + 100	2.7	3.5	4.6	36	55	58
10	100 + 0	3.2	4.2	5.6	41	57	61
Signif. Level (%):		99	99	99	97	99	99
BLSD (.05)	:	0.5	0.7	0.7	5	5	3
CV (%)	:	10.	12.	8.4	7.8	6.3	3.0

The leaf opposite and below the ear was sampled at all locations in 1985 and was submitted for analysis (Table 7). At Lamberton, leaf K concentrations were increased significantly from 1.14% K to about 1.8% with the 100-lb K_2O rate. Concomitant decreases in leaf Ca, Mg, Mn, and Zn were found with the higher leaf K concentrations. Leaf P was not affected by the P treatements.

At Morris and Waseca, the 50 and 100-lb P_2O_5 treatements increased leaf P, Ca, Mg, and Fe above the 0-lb rates and decreased leaf Zn (Table 7).

Although soil test K was very high at Morris, the K treatments increased leaf K and decreased leaf Ca, Mg, and Cu. Leaf K concentrations at Waseca were extremely low (ca 0.80%) when no K was added. The 100-lb K_2O rate almost doubled the K concentrations while the 50-lb rate had a slight effect. Leaf Ca, Mg, and Mn concentrations were reduced by the 50 and 100-lb K_2O rates.

Final plant population was not affected by the P and K treatments at Morris and Waseca (Table 8). For some unexplainable reason, differences were found at Lamberton.

Slight but inconsistent differences in ear moisture were found at harvest at Lamberton (Table 8). Grain moisture was reduced significantly by the P treatments at Morris and to some extent at Waseca. The K treatments had no effect on grain moisture.

Silage yields were increased by about 30% with the 50 and 100-lb P_2O_5 treatments at Morris (Table 9). Although silage yields at Waseca were approximately 10% higher with the 100-lb K_2O treatments, this was only significant at the P=77% level. Silage and grain yields were not affected at Lamberton.

Grain yields were increased by about 30 and 15% with the 50 and 100-lb P_2O_5 rates at Morris and Waseca, respectively (Table 9). Yields were not increased with the 100-lb rate over the 50-lb rate. The K treatments did not affect yields at Morris, but did result in slight yield increases at Waseca. Considering the very low leaf K concentrations at silking, it is surprising that larger grain yield responses were not found.

Soybean yields at Lamberton were affected significantly (P=91% level) (Table 10). Lowest yields were associated with the 0-lb K_2O treatments and were increased rather consistently with the 100-lb K_2O rate. Soybean height was not influenced by the treatments.

Table 7. Effect of high P and K rates on the nutrient concentrations in the corn leaf at Lamberton Morris, and Waseca in 1985.

Treatment No.	Treatment Description	Nutrient P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	lb P_2O_5+K_2O/A	%				ppm				
				Lamberton						
1	0 + 0	.25	1.14	.51	.56	130	67	38	5.9	9.8
2	0 + 100	.24	1.78	.44	.33	120	43	29	6.1	11.2
3	50 + 100	.26	1.84	.46	.35	124	49	27	6.5	10.3
4	100 + 100	.26	1.76	.46	.34	128	46	26	5.7	9.3
5	0 + 100	.24	1.82	.44	.36	121	54	28	6.8	10.2
6	100 + 0	.26	1.14	.54	.56	128	67	33	4.6	10.1
7	100 + 50	.26	1.62	.47	.39	128	53	31	5.6	9.6
8	100 + 0	.26	1.51	.48	.42	130	55	26	6.2	8.9
9	0 + 100	.26	1.75	.46	.38	126	51	30	6.2	10.5
10	100 + 0	.25	1.25	.52	.52	126	54	29	5.0	11.4
	Signif. Level (%):	88	99	99	99	93	97	97	98	57
	BLSD (.05),(.10)*:		.20	.06	.06	8*	17	8	1.3	
	CV (%) :	3.7	9.3	7.6	11.	3.9	18.	16.	13.	15.
				Morris						
1	0 + 0	.20	1.60	.55	.51	198	96	38	8.2	6.8
2	0 + 100	.20	1.90	.51	.37	208	95	41	6.2	5.5
3	50 + 100	.28	1.95	.68	.44	266	112	28	6.4	9.2
4	100 + 100	.29	2.04	.64	.42	248	113	25	6.3	6.7
5	0 + 100	.28	2.10	.58	.42	244	99	30	6.1	8.4
6	100 + 0	.29	1.53	.74	.65	261	126	23	7.1	6.8
7	100 + 50	.30	1.90	.66	.50	247	109	23	6.1	8.6
8	100 + 0	.29	1.77	.74	.53	285	119	24	7.8	4.8
9	0 + 100	.27	1.73	.65	.55	250	106	33	6.4	8.8
10	100 + 0	.28	1.70	.69	.55	259	121	30	8.2	9.1
	Signif. Level (%):	99	99	99	99	99	99	99	99	87
	BLSD (.05) :	.03	.20	.11	.06	45	20	4	1.1	
	CV (%) :	9.2	7.7	11.	9.5	11.	11.	11.	11.	32.
				Waseca						
1	0 + 0	.21	.84	.58	.76	110	44	39	6.5	10.3
2	0 + 100	.19	1.52	.47	.46	108	37	38	7.2	10.9
3	50 + 100	.23	1.53	.50	.48	115	39	31	6.5	9.9
4	100 + 100	.25	1.43	.57	.52	117	42	27	5.7	9.7
5	0 + 100	.25	1.43	.52	.51	116	41	32	5.9	10.5
6	100 + 0	.27	.77	.67	.83	113	48	26	5.0	9.4
7	100 + 50	.25	1.14	.60	.63	119	41	26	5.1	10.1
8	100 + 0	.25	1.04	.59	.63	118	47	28	5.3	10.1
9	0 + 100	.22	1.38	.50	.52	108	37	32	6.3	10.0
10	100 + 0	.26	.80	.63	.75	110	46	28	5.0	9.5
	Signif. Level (%):	99	99	99	99	93	74	99	99	30
	BLSD (.05),(.10)*:	.02	.12	.05	.06	8.6*		5	1.2	
	CV (%) :	4.6	6.8	5.8	6.6	4.3	14.	9.7	11.	9.6

Table 8. Population and moisture at harvest as influenced by high P and K rates in 1985.

Treatment No.	Treatment Description	Final Population La	Final Population Mo	Final Population Wa	Ear Moisture La	Grain Moisture Mo	Grain Moisture Wa
	lb P_2O_5+K_2O/A	plants/A x 10^{-3}			---------- %		---------
1	0 + 0	23.1	25.8	27.7	39.7	31.9	31.1
2	0 + 100	24.7	27.9	27.2	40.3	33.4	31.7
3	50 + 100	26.2	26.9	27.0	39.9	28.6	30.1
4	100 + 100	27.2	27.6	26.1	40.8	28.0	30.0
5	0 + 100	25.1	27.7	27.7	40.4	29.1	30.2
6	100 + 0	25.7	28.0	27.6	40.0	25.8	27.1
7	100 + 50	28.5	27.8	27.6	40.4	28.5	29.4
8	100 + 0	24.9	27.3	27.7	39.2	27.2	28.1
9	0 + 100	23.7	27.4	24.5	40.0	29.2	30.0
10	100 + 0	25.3	26.8	27.3	39.4	27.4	27.4
Signif. Level (%):		97	67	32	96	99	99
BLSD (.05) :		3.5			1.1	1.8	1.5
CV (%) :		7.8	4.1	7.6	1.6	4.4	3.1

Table 9. Corn silage and grain yields as influenced by high P and K rates in 1985.

Treatment No.	Treatment Description	Silage Yield La	Silage Yield Mo	Silage Yield Wa	Grain Yield La	Grain Yield Mo	Grain Yield Wa
	lb P_2O_5+K_2O/A	---- T DM/A -----			------- bu/A -------		
1	0 + 0	7.53	6.32	6.56	162.2	108.4	143.6
2	0 + 100	7.90	6.57	7.20	171.4	115.3	153.9
3	50 + 100	8.04	8.14	7.19	171.8	148.5	184.4
4	100 + 100	8.10	8.41	7.62	172.5	152.8	174.7
5	0 + 100	8.05	7.85	7.68	166.3	152.3	184.3
6	100 + 0	7.77	7.45	7.06	166.5	150.2	165.6
7	100 + 50	7.85	7.85	7.46	169.4	154.1	173.4
8	100 + 0	7.82	7.74	7.67	171.1	156.6	170.0
9	0 + 100	7.51	7.34	7.72	160.9	153.2	161.5
10	100 + 0	7.82	7.45	6.89	172.1	151.3	168.1
Signif. Level (%):		74	99	77	85	98	99
BLSD (.05) :			1.19			33.8	10.0
CV (%) :		4.5	9.4	7.7	3.9	13.	3.7

Table 10. Soybean plant height and yields at Lamberton as influenced by high P and K rates in 1985.

Treatment No.	Treatment Description	Height at Maturity	Yield
	lb P_2O_5+K_2O/A	inches	bu/A
1	0 + 0	39.7	40.8
2	0 + 100	38.2	46.4
3	50 + 100	40.2	42.6
4	100 + 100	39.5	46.0
5	0 + 100	41.5	45.5
6	100 + 0	40.7	39.7
7	100 + 50	41.0	41.6
8	100 + 0	40.0	40.7
9	0 + 100	40.5	42.4
10	100 + 0	40.0	41.8
Signif. Level (%):		19	91
BLSD (.10) :		--	6.4
CV (%) :		5.9	8.0

SUMMARY - 1985

These data were quite similar to past years in that yield responses were found with P at Morris and Waseca. However, slight yield responses to K were found at Waseca with corn and at Lamberton with soybeans. Concentrations of K in the earleaf were extremely deficient with the 0-lb treatment at Waseca. This is the first time in 12 years that a consistent yield response has been found to either P or K at Lamberton. Triennial applications of the 150-lb rates of P_2O_5 and K_2O appear to be equal to annual applications at the 50-lb rate.

12-YEAR SUMMARY

Corn and soybean yields for the 12-year period since the initiation of the study are presented in Tables 11 and 12 for Lamberton, Table 13 for Morris, and Table 14 for Waseca.

At Lamberton significant corn yield differences among the P and K treatments occurred in only 1 of 12 years; and in that year (1979) no relationship to either P or K was found. With soybeans, statistical yield differences were noted in 2 of 5 years with no consistent effect of either P or K in one of those two years. In the other year (1985) there was a fairly consistent response to K. Soil tests at that site have not dropped below 40 lb P/A and 240 lb K/A (Table 3) even without added P or K. Consequently the limited response to P and K over the 12-year period.

Table 11. Long-term corn yields as affected by P and K treatments at Lamberton.

	Years[1/]												12-Yr.
Trt. No.	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	Avg.
	bu/A												
1	79.7	64.5	16.7	130.5	111.5	118.0	80.8	110.8	146.9	51.2	132.8	162.3	100.5
2	69.5	55.7	8.9	121.8	112.7	112.8	87.6	111.6	147.5	48.9	138.9	171.4	98.9
3	62.5	50.3	16.8	119.5	114.7	106.5	85.7	113.9	151.5	50.0	131.4	171.8	97.9
4	74.8	69.7	15.2	136.2	113.5	117.6	87.0	117.1	149.0	48.5	140.6	172.5	103.5
5	76.7	48.2	14.3	119.5	115.6	108.0	86.6	111.2	151.4	47.9	122.0	166.4	97.3
6	80.4	69.0	15.1	114.5	116.9	124.1	88.1	114.6	146.4	54.2	134.1	166.5	102.0
7	77.9	58.9	17.5	128.1	112.8	120.9	81.7	104.7	155.3	55.7	130.0	169.4	101.1
8	80.1	59.4	11.6	125.2	114.6	126.6	89.4	113.4	150.7	57.3	144.6	171.1	103.7
9	69.7	46.6	12.6	122.2	115.8	119.2	81.0	108.8	150.4	57.3	136.8	160.9	98.4
10	74.5	65.8	11.2	122.4	118.3	120.7	94.2	111.5	148.9	63.2	137.2	172.1	103.3
Signif(%)[2/]:	+	NS	NS	NS	NS	*	NS	80	34	59	82	85	
BLSD (.05) :						13.8							
CV (%) :	11.	30.	39.	11.	4.3	6.8	10.	5.0	4.1	18.	7.5	13.1	

1/ Continuous corn from 1974 to 1981. Corn following soybeans from 1982 to 1985.
2/ * and + are significant at the 95 and 90% levels, respectively. NS = not significant at the 90% level. Since 1981 all significance shown as a probability level.

Table 12. Long-term soybean yields as affected by P and K treatments at Lamberton.

	Years[1/]					5-Yr.
Trt. No.	1981	1982	1983	1984	1985	Avg.
	bu/A					
1	47.7	51.2	34.4	39.8	40.8	42.8
2	46.0	47.8	34.9	43.1	46.3	43.6
3	49.5	50.0	34.4	45.8	42.6	44.5
4	48.6	49.9	38.2	41.0	46.0	44.7
5	45.9	48.9	35.0	43.5	45.5	43.8
6	44.5	51.4	32.4	41.7	39.7	41.9
7	46.5	49.8	37.8	42.9	41.6	43.7
8	45.5	48.3	35.4	45.4	40.7	43.1
9	44.6	49.0	35.8	42.4	42.4	42.8
10	46.3	49.3	33.8	40.5	41.8	42.3
Signif. Level (%):	15	95	32	48	97	
BLSD (.05) :		2.8			6.4	
CV (%) :	9.8	3.1	11.7	9.7	8.0	

1/ Soybeans following corn for all years.

The most consistent yield responses have occurred at Morris (Table 13). Significant corn and soybean yield responses to the 50-lb P_2O_5 rate have occurred in 7 out of 12 years and in 6 of the last 7 years. The effect of the 0-lb P_2O_5 rate on soil test P shown in Figure 1 indicates a loss of 1 lb soil test P/A/year over the 12-year period. Since 1978 (5th year of the study) soil test P has averaged 10 lb P/A or less and thus, consistent yield responses have occurred. Yield responses have not occurred with the 100-lb P_2O_5 rate over the 50-lb rate and with any of the K_2O rates. Soil test K has varied considerably over the 12-yr period and does not show a statistical relationship to K application rate (Fig. 2). Based on the best fit linear regression lines (Fig.'s 1 and 2) soil test P values were changed by -1.0, +1.3, and +5.3 lb P/A/yr with the 0, 50, and 100-lb P_2O_5 rates, respectively (Table 15). Soil test K changes were positive regardless of K application rate (Table 15).

Table 13. Long-term corn and soybean yields as affected by P and K treatments at Morris.

Trt.	Years[1/]												Yield Avg.	
													10-Yr	2-Yr
No.	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	Corn	Sb
	bu/A													
1	92.9	118.2	29.0	102.4	113.6	90.9	107.1	120.5	47.1	106.5	38.3	108.4	98.9	42.7
2	89.6	125.9	23.4	98.4	113.1	90.7	108.5	115.2	45.6	105.1	36.3	115.3	98.5	40.9
3	91.9	125.8	26.4	101.4	119.7	99.6	123.8	130.5	53.0	129.0	44.6	148.5	109.7	48.8
4	94.6	127.1	35.8	98.0	124.6	110.5	127.0	136.1	56.3	128.2	45.3	152.8	113.5	50.8
5	98.6	127.4	31.0	97.2	119.8	110.6	120.8	132.0	54.6	128.3	43.2	152.3	111.8	48.9
6	91.3	125.6	33.4	94.1	121.4	113.3	127.3	130.1	56.7	126.6	46.1	150.2	111.1	51.4
7	95.5	126.3	33.6	97.4	123.3	105.7	126.7	132.1	54.7	133.6	46.8	154.1	112.8	50.7
8	93.1	124.5	24.3	98.4	124.7	107.9	121.5	129.4	57.8	125.7	45.0	156.6	110.6	51.4
9	97.8	128.0	32.6	99.8	119.5	102.8	120.1	128.3	57.6	124.7	45.1	153.2	110.7	51.4
10	101.2	141.4	30.6	102.8	120.1	101.0	126.1	129.8	53.1	127.6	45.4	151.3	113.2	49.2
Signif:	NS	*	NS	NS	NS	*	NS	**	99	94	99	98		
BLSD(.05):		12.1				17.5		11.1	4.8	19.0	4.2	33.8		
CV(%) :		3.	28.	6.	5.3	9.9	9.0	5.3	6.3	9.9	6.6	13.4		

1/ Continuous corn from 1974-1981; soybeans in 1982 and 1984; corn in 1983 and 1985.
2/ ** and * are significant at the 99 and 95% level, respectively. NS = not significant at the 90% level. Since 1982 all significance shown as a probability level.

At Waseca, corn and soybeans responded to the 50-lb P_2O_5 rate in 5 of 12 years with a slight response to K_2O in one year (1985) (Table 14). Similar to Morris, responses to P have been more frequent in the last 5 yrs when soil test values dropped below 20 lb P/A on the 0-lb P_2O_5 treatments (Fig. 3). Soil test P has been maintained with the 50-lb P_2O_5 rate and increased substantially with the 100-lb rate. Yield responses have not occurred over the 50-lb rate, however, with the 100-lb rate of application. Similar to Morris, soil test K varied considerably over the 12-yr period and did not relate well to K application rate (Fig. 4). Based on the best fit linear regression lines (Fig.'s 3 and 4) soil test P values were changed by -2.3, +0.6, and +3.7 lb soil P/A/yr with the 0, 50, and 100-lb P_2O_5/A rates, respectively (Table 15). For reasons not apparent at this time, soil test K was increased with all rates of K.

Because of frequent yield responses to P at Morris and Waseca, the relationship between yield response and soil test P level was examined (Fig's 5 and 6). The percent yield response for the 50-lb vs. 0-lb, 100-lb vs. 50-lb, and 150-lb (every 3rd year) vs. 0-lb rates were plotted and related to soil test each year. This resulted in 33 comparisons at Morris and 34 at Waseca (yields from 1976 at Morris and two outliers at Waseca were omitted). A highly significant negative relationship between percent yield response and soil test was found at both sites.

Based on the regression lines the percent yield response for a given soil test was calculated (Table 16). At Morris a 14% yield response can be expected with broadcast P when soil test P is 10 lb P/A while at Waseca a 10% yield response can be expected. Yield response continued to decrease at both locations as soil test P increased. At soil test P values greater than 30 lb P/A, yield responses of less than 4% can be expected with the broadcast application of P. These results emphasize the fact that continued application of P to soils testing higher than 40 lb Bray P_1/A does not result in a consistent economical return even under higher levels of management.

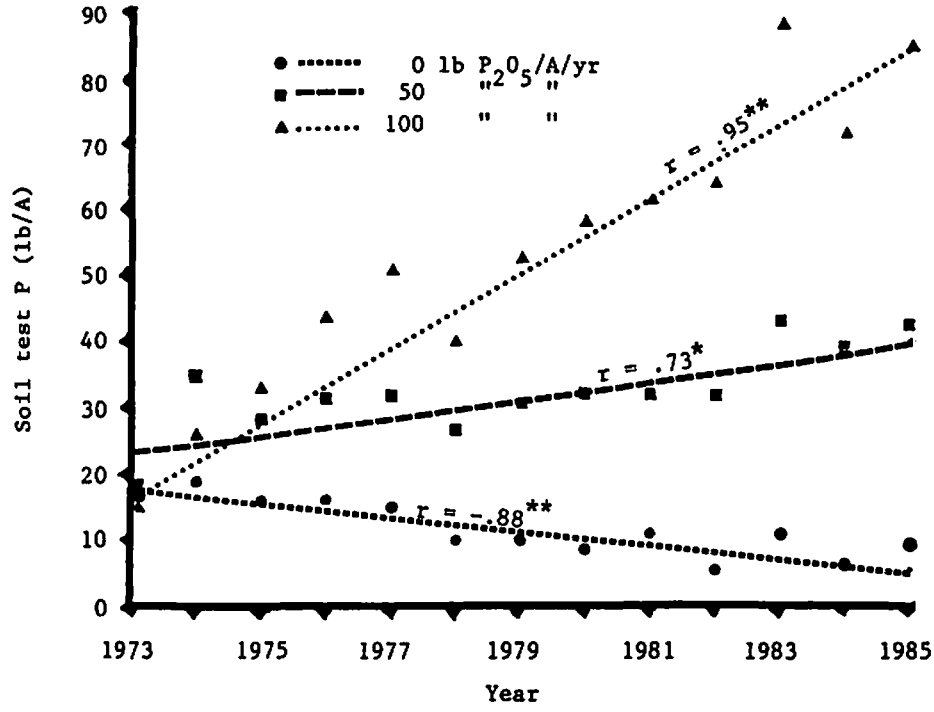

Fig. 1. Linear relationship between the amount of P applied and soil test P for the 13-yr period at Morris.

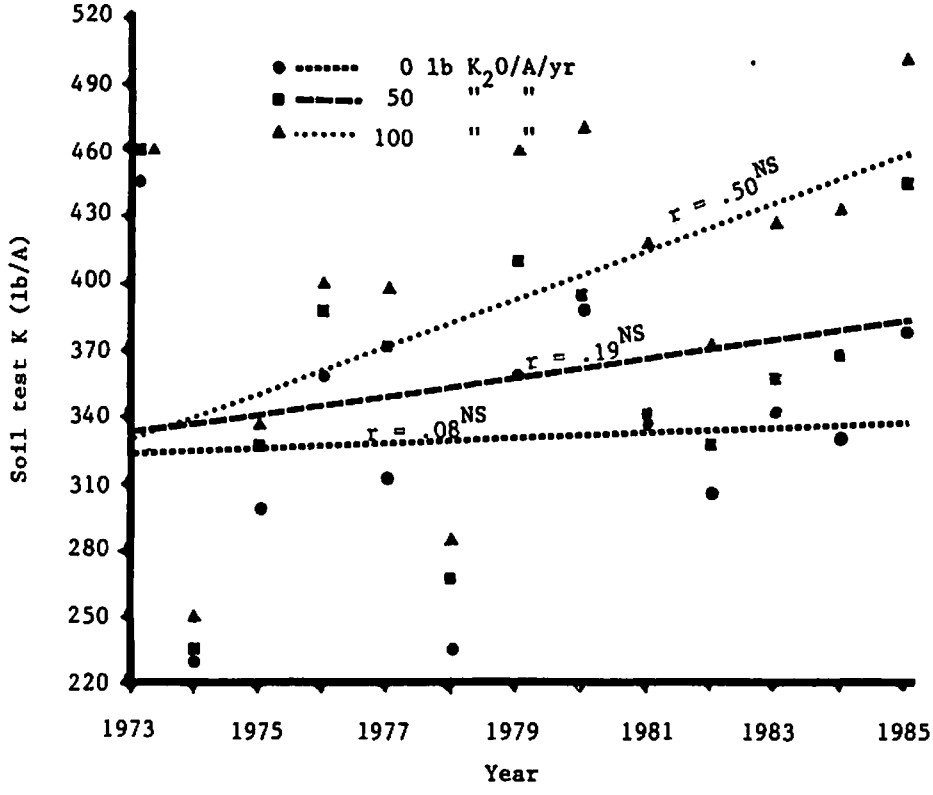

Fig. 2. Linear relationship between the amount of K applied and soil test K for the 13-yr period at Morris.

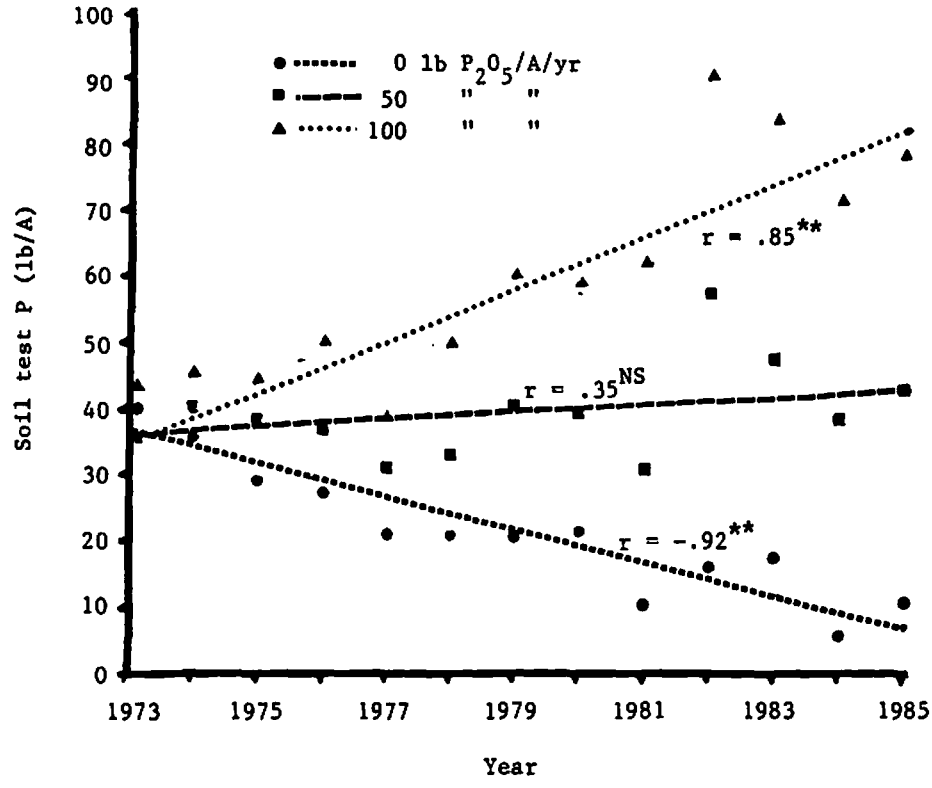

Fig. 3. Linear relationship between the amount of P applied and soil test P for the 13-yr period at Waseca.

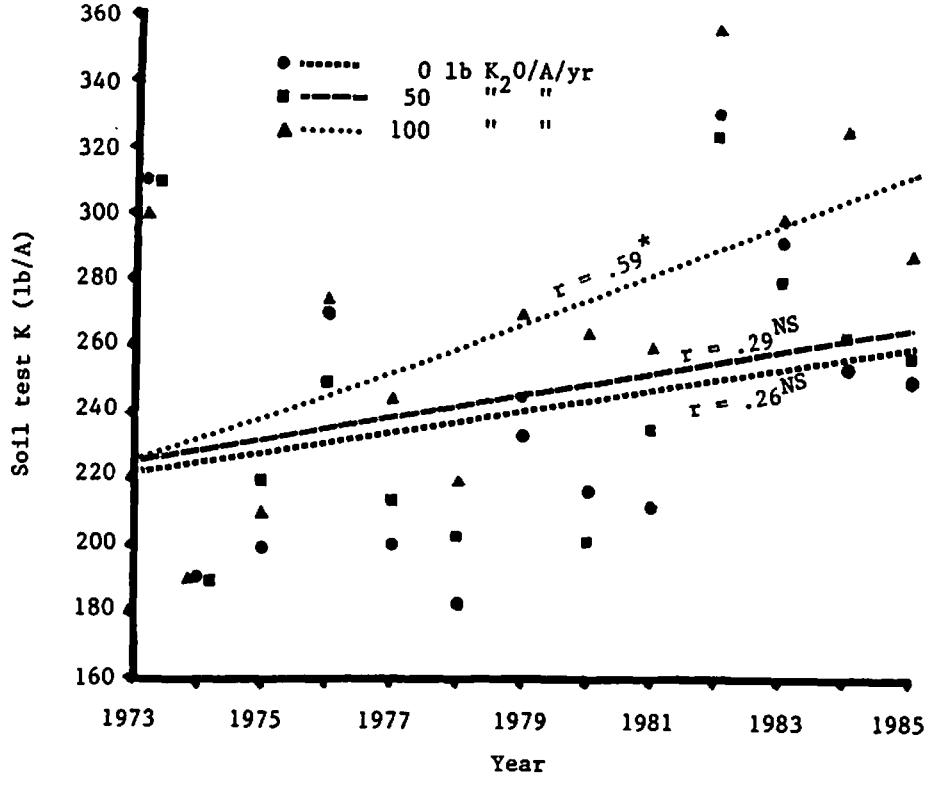

Fig. 4. Linear relationship between the amount K applied and soil K for the 13-yr period at Waseca.

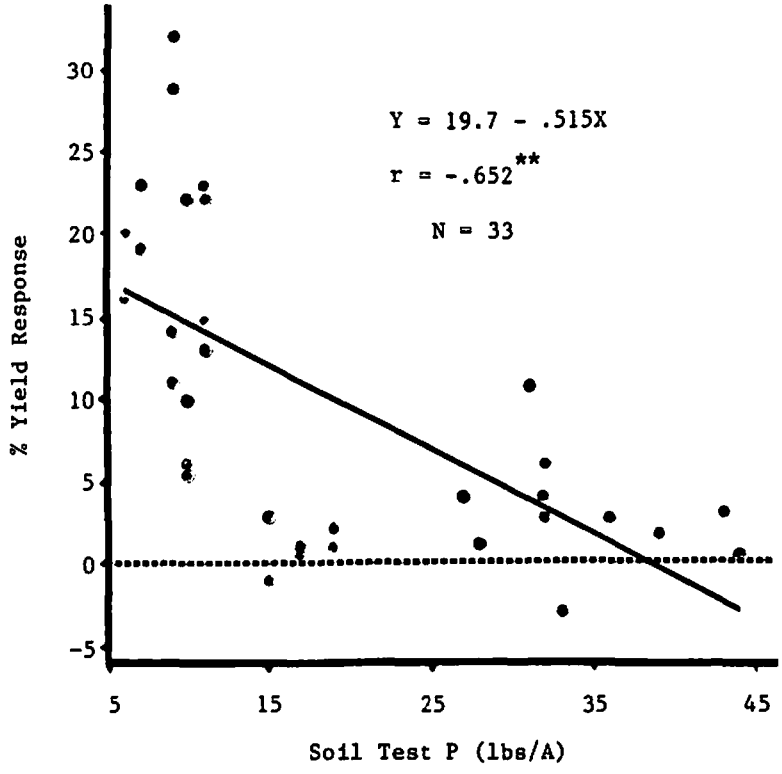

Fig. 5. Yield response as influenced by soil test P at Morris from 1974-1985.

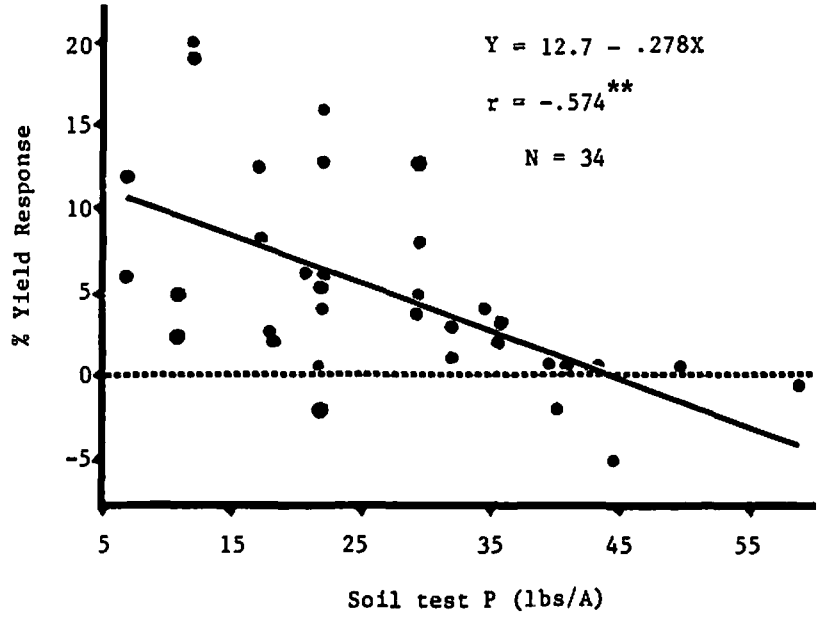

Fig. 6. Yield response as influenced by soil test P at Waseca from 1974-1985.

Table 14. Long-term corn and soybean yields as affected by P and K treatments at Waseca.

Trt. No.	Years 1/ 1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	Yield Avg. 10-Yr Corn	Yield Avg. 2-Yr Sb
	bu/A													
1	124.8	103.2	74.7	148.7	160.2	163.6	136.8	182.9	53.3	128.1	44.2	143.5	136.6	48.7
2	125.9	105.1	97.9	159.0	160.5	164.8	129.9	181.2	51.5	126.9	44.3	153.9	140.5	47.9
3	128.6	118.7	101.9	155.6	170.5	175.5	146.4	190.4	58.4	130.1	47.1	184.4	150.2	52.7
4	127.9	87.3	86.4	157.7	177.8	176.6	143.8	195.7	57.9	129.8	47.5	174.7	145.8	52.7
5	129.6	110.4	105.5	159.9	167.6	174.0	150.8	185.7	55.9	130.5	49.5	184.3	149.8	52.7
6	129.6	104.4	93.7	158.4	167.8	171.2	137.4	188.2	57.7	134.7	46.9	165.6	145.1	52.3
7	132.0	108.3	118.0	158.1	173.9	172.6	145.7	199.3	58.0	125.8	47.8	173.4	150.7	52.9
8	125.7	109.9	98.6	160.2	173.5	176.6	143.0	194.6	55.9	137.0	48.0	170.0	148.9	51.9
9	131.8	102.1	98.5	157.6	164.6	167.6	143.1	193.5	55.1	127.6	44.9	161.5	144.8	50.0
10	125.7	92.6	91.7	156.6	156.7	171.2	146.9	194.1	56.0	128.3	44.2	168.1	143.2	50.1
Signif:	NS	NS	*	NS	**	NS	NS	99	99	06	76	99		
BLSD(.05):			24.8		11.9			7.8	3.2			10.0		
CV (%):	4.	14.	15.	5.	4.4	5.2	9.3	2.8	3.8	7.7	5.9	3.7		

1/ Continuous corn from 1974-1981; soybeans in 1982 and 1984; corn in 1983 and 1985.
2/ ** and * are significant at the 99 and 95% levels, respectively. NS = not significant at the 90% level. Since 1982 all significance shown as a probability level.

Table 15. Change in soil test P and K/year over the 12-yr period as influenced by annual P and K rates.

Annual P_2O_5 or K_2O rate	P Morris	P Waseca	K Morris	K Waseca
lb/A	-- lb soil P/A/yr --		-- lb soil K/A/yr --	
0	-1.0	-2.3	+1.3	+3.1
50	+1.3	+0.6	+3.2	+3.1
100	+5.3	+3.7	+9.4	+7.0

Table 16. Percent yield response to broadcast P as influenced by soil test at Morris and Waseca.

Soil P Test	Location: Morris	Location: Waseca
lb P/A	-- % Yield Response --	
10	14	10
20	9	7
25	7	6
30	4	4
35	2	3
40	0	2

ACKNOWLEDGEMENT

Sincere appreciation is extended to the Tennessee Valley Authority-National Fertilizer Development Center for their financial assistance in this project.

EVALUATION OF THE RELATIONSHIP BETWEEN TILLAGE AND PLACEMENT OF P AND K IN A CORN-SOYBEAN ROTATION

G.W. Rehm, S.D. Evans, W.W. Nelson, and G.W. Randall
University of Minnesota

Background:

Until recently, farmers had few choices with respect to placement of P and/or K for corn and soybean production. They could either broadcast and incorporate before planting, apply it in a band to the side of and below the seed at planting (starter fertilizer) or use a combination of both of these methods.

Our thinking about placement of P and/or K has changed substantially in recent years. Two factors are primarily responsible for this change. One factor is the increased popularity of the adoption of conservation tillage production systems. Without some form of primary tillage, P and K (both immobile nutrients) remain relatively close to the soil surface if broadcast applications are used. This may or may not be a disadvantage for broadcast applications.

Secondly, Dr. Stan Barber demonstrated that fertilizer banded on the soil surface and subsequently plowed under produced corn yields that were higher than yields produced by the broadcast application of similar rates. Therefore, this study was initiated to evaluate the effect of placement of P and K on corn and soybean production under two tillage systems where the soil test values for P and K vary over a wide range.

Experimental Procedure:

This study was initiated at the branch experiment stations in Morris, Lamberton, and Waseca in the fall of 1983. Relevant soil properties for the experimental sites are listed in Table 1.

Four factors (tillage system, rate of P_2O_5 and K_2O, placement of these nutrients, and starter fertilizer use) are being evaluated at both low and high fertility sites at the Waseca location. At Morris, there is no low fertility site. Space was limiting at the Lamberton location, so rate of applied P_2O_5 and K_2O is not considered. Both low and high fertility sites are used, however, at the Lamberton location. A randomized complete block design with 4 replications is used at all locations.

Treatments were repeated in late October and early November of 1984 at Waseca and Lamberton. Treatments were applied in late May of 1985 at the Morris location. For the fall chisel system, treatments are applied before the fall tillage operation. Fall tillage is not needed for the ridge-till system. The plots were chisel plowed in late May of 1985 at the Morris location.

The rates of P_2O_5 and K_2O used are either 44 + 87 or 66 + 131. A 4-12-24 suspension material is used to supply the P_2O_5 and K_2O.

The rates of P_2O_5 and $K_2O$are 1) broadcast on the soil surface, 2) applied in a band on the soil surface. Distance between band in 30 inches 3) applied in a subsurface bands at a depth of 6-8 inches. The distance between subsurface bands is 30 inches.

The starter fertilizer was 100 lb. 7-21-7 per acre at Waseca and Lamberton and 110 lb. 10-34-0 per acre at the Morris site. The starter fertilizer was placed to the side of and below seed level at all sites.

Whole plant samples were collected at 4 to 5 weeks after emergence, dried, and weighed. Ear leaf samples were collected at silking. All plant samples were analyzed for P and K. Uptake by young plants of these two nutrients was computed by multiplying plant weight by nutrient concentration.

Please refer to title page of this publication for information regarding application and use of this article.

Grain yields were measured with plot combines at all locations and were corrected to a 15.5% moisture basis before reporting. Standard analysis of variance procedures were used for separation of treatment means.

Table 1. Selected soil properties for the experimental sites.

Soil Property	Location and Fertility Level				
	Waseca		Lamberton		Morris
	High	Low	High	Low	High
pH	6.6	6.1	5.8	6.0	7.5
P, lb./acre (Bray & Kurtz #1)	48	14	33	14	39
K, lb./acre (1 N $NH_4C_2H_3O_2$)	433	190	305	222	259
organic matter, %	3.5	3.5+	3.0	3.0	3.5+
Texture	clay loam	clay loam	clay loam	clay loam	silt loam

Tillage Effects:

The effect of tillage system on the variables measured in this study is summarized in Table 2. Except for the Morris site, average yield was higher when the ridge-till system was used. Excessively wet conditions hampered planting operations for the ridge till system at Morris causing a reduction in stand. The stand reduction is the most obvious explanation for the lower yields in the ridge till-system at this site.

Early plant growth in the ridge-till system was also reduced by the excessively wet planting conditions at Morris. In contrast, early plant growth at both the high and low fertility sites at Waseca was enhanced in the ridge-till system.

Tillage system used had no effect on the P concentration of young plants at all locations. The K concentration of these plants, however, was higher when the chisel system was used.

In general, the placement X rate interaction was not significant and, likewise, the rate X starter interaction. The tillage X placement and tillage X starter interactions, however, were significant in many cases. Therefore, these variables will be shown in the interaction tables that follow.

Morris Results

A combination of late planting because of excessive moisture and an early frost prevented harvest of grain at Morris. Considering total dry matter yield, there were some 3-way interactions that were significant. There is no ready explanation for the interactions. Since main effects were not significant, these significant interactions might be considered to be artifacts of the statistical analysis. In general, 3-way interactions were not significant at other locations.

The P concentration of young plants at Morris was increased by the use of the starter fertilizer (Table 3) and this increased concentration was also reflected in P uptake (data not shown). The same observation was noted for the K concentration of young plants (data not shown). The practical significance of this observation is questioned because the soil has a very high level of soil test K.

Table 2. Effect of tillage system on variables measured in 1985.

Location	Variable	Ridge Till	Chisel
Morris	Yield (ton DM/acre)	5.56	6.03*
Morris	Early Growth, g/6 plants	5.9	7.5*
Morris	P Conc - Whole Plant, %	.482	.488
Morris	K Conc - Whole Plant, %	3.20	3.77*
Morris	P Uptake, mg/6 plants	28.7	37.2*
Morris	K Uptake, mg/6 plants	189.3	283.3*
Lamberton, low fertility	Yield, bu./acre	134.0	120.2*
Lamberton, low fertility	Early Growth, g/6 plants	17.9	16.6
Lamberton, low fertility	P Conc. Whole Plant, %	.409	.410
Lamberton, low fertility	K Conc. Whole Plant, %	3.14	3.35*
Lamberton, low fertility	P Uptake, mg/6 plants	74.8	68.2
Lamberton, low fertility	K Uptake, mg/6 plants	566.8	555.1
Lamberton, low fertility	P Conc - Ear Lear, %	.230	.240*
Lamberton, low fertility	K Conc - Ear Leaf, %	1.55	1.66*
Lamberton, low fertility	Yield, bu./acre	137.5	133.3*
Lamberton, low fertility	Early Growth, g/6 plants	22.2	21.3
Lamberton, low fertility	P Conc. Whole Plant, %	.438	.426
Lamberton, low fertility	K Conc. Whole Plant, %	3.74	3.79
Lamberton, low fertility	P Uptake, mg/6 plants	96.8	89.4
Lamberton, low fertility	K Uptake, mg/6 plants	831.9	799.4
Lamberton, low fertility	P Conc - Ear Leaf, %	.280	.276
Lamberton, low fertility	K Conc - Ear Leaf, %	1.93	1.95
Waseca, low fertility	Yield, bu./acre	124.6	119.2*
Waseca, low fertility	Early Growth, g/6 plants	21.4	17.0*
Waseca, low fertility	P Conc - Whole Plant, %	.383	.376
Waseca, low fertility	K Conc - Whole Plant, %	2.26	2.70*
Waseca, low fertility	P Uptake, mg/6 plants	81.8	64.6*
Waseca, low fertility	K Uptake, mg/6 plants	492.9	475.4
Waseca, low fertility	P Conc - Ear Leaf, %	.175	.193*
Waseca, low fertility	K Conc - Ear Leaf, %	.897	.923
Waseca, high fertility	Yield, bu./acre	154.8	148.6*
Waseca, high fertility	Early Growth, g/6 plants	29.9	25.2*
Waseca, high fertility	P Conc - Whole Plant, %	.434	.439
Waseca, high fertility	K Conc - Whole Plant, %	3.83	4.02
Waseca, high fertility	P Uptake, mg/6 plants	130.0	111.2*
Waseca, high fertility	K Uptake, mg/6 plants	1139.3	1010.4*
Waseca, high fertility	P Conc - Ear Leaf, %	.270	.264
Waseca, high fertility	K Conc - Ear Leaf, %	1.75	1.72

*Difference between names is significant at PR>F = .10 or lower.

Table 3. Effect of tillage system, fertilizer placement and starter fertilizer use on the P concentration of young corn plants. Morris. 1985.

	Tillage System					
	Ridge-Till			Chisel		
Placement	With Starter	No Starter	Ave.	With Starter	No Starter	Ave.
	% P					
----	.490	.468	.479	.504	.478	.491
Broadcast	.485	.468	.477	.511	.482	.497
Surface Band	.505	.465	.485	.520	.452	.486
Subsurface Band	.494	.471	.483	.486	.479	.483
	.494	.468		.505	.473	

Use of the starter fertilizer produced the largest increase in P concentration when additional P_2O_5 and K_2O were applied in a surface band. This was true for both tillage systems. When soil test P levels are in the low range, increases in P uptake by young plants can lead to enhanced early growth and ultimately higher yields.

Lamberton Results

Grain yields at the low fertility site at Lamberton were influenced by both tillage system and starter fertilizer use. Placement of P_2O_5 and K_2O had no effect on yield (Table 4). Use of the starter in addition to 44 lb. P_2O_5 and 87 lb. K_2O/acre applied by some other method produced a 6 bu./acre increase with the ridge-till system and a 12 bu./acre increase with the chisel system.

Table 4. Effect of tillage system, fertilizer placement and starter fertilizer use on the grain yield at the low fertilizer site at Lamberton. 1985.

	Tillage System					
	Ridge-Till			Chisel		
Placement	With Starter	No Starter	Ave.	With Starter	No Starter	Ave.
	bu./acre					
----	---	105.9	---	----	97.9	---
Broadcast	135.2	131.0	131.1	125.5	112.5	119.5
Surface Band	138.0	127.4	132.7	131.2	118.1	124.7
Subsurface Band	137.8	134.4	136.1	122.2	111.5	116.9
	137.0	130.9		126.3	114.0	

Use of the starter fertilizer also increased grain yield at the Lamberton high fertility site (Table 5). When averaged over other placement methods, the increase was 9 bu./acre for the ridge-till system and 7 bu./acre for the chisel system. The positive response to starter fertilizer at this location in 1985 demonstrates the importance of starter fertilizer as a management tool for corn production with all tillage systems under Minnesota planting conditions.

Table 5. Effect of tillage system, fertilizer placement and starter fertilizer use on the grain yield at the high fertility site at Lamberton, 1985.

	Tillage System					
	Ridge-Till			Chisel		
Placement	With Starter	No Starter	Ave.	With Starter	No Starter	Ave.
	bu./acre					
---	---	133.8	--	---	124.2	--
Broadcast	139.9	136.4	138.2	135.3	131.5	133.4
Surface Band	143.5	134.0	138.8	142.5	125.8	134.2
Subsurface Band	141.2	129.8	135.5	134.0	131.1	132.6
	141.5	133.4		137.3	129.5	

Early growth at the Lamberton low fertility site was also improved by the use of a starter fertilizer. When averaged over all other factors, six plants weighed 11 gm when no starter was used. This weight increased to 23.5 gm when the starter was applied. Early growth was also increased by starter use at the high fertility site. When averaged over other factors studied, 6 plants weighed 17.6 gm when no starter was used and the weight increased to 25.7 gm when the starter was applied. The stimulation of early plant growth by the starter was reflected in yield.

The use of the starter fertilizer was the only factor that influenced the P concentration in young corn plants at the low fertility site. When averaged over other factors the P concentration increased from .398% to .421% when the starter was used. The use of the starter had no effect on P concentration in young corn plants at the high fertility site.

Tillage was the only factor to affect the K concentration in young plants at the low fertility site. None of the factors used had any effect on the K concentration in young plants at the high fertility site. The effects of tillage system, placement, and starter use on uptake of P and K by young plants reflect the effects of these factors on early plant growth.

The K concentration in the ear leaf samples collected from the low fertility site was significantly influenced by tillage system, fertilizer placement and starter use (Table 6). The tillage X placement interaction was significant. With the ridge-till planting system, the K concentration was higher when subsurface bands were used. The reduction in K concentration with the use of the starter fertilizer cannot be explained at this time. The K concentration in the ear leaf samples collected from the high fertility site was not significantly affected by any of the factors used in the study.

Table 6. Effect of tillage system, fertilizer placement and starter fertilizer use on the K concentration in ear leaf tissue at the Lamberton low fertilizer site. 1985.

	Tillage System					
	Ridge-Till			Chisel		
Placement	With Starter	No Starter	Ave.	With Starter	No Starter	Ave.
	% K					
---	---	1.35	--	---	1.39	--
Broadcast	1.48	1.58	1.53	1.70	1.81	1.76
Surface Band	1.43	1.54	1.49	1.62	1.60	1.61
Subsurface Band	1.56	1.68	1.62	1.61	1.64	1.63
	1.49	1.60		1.64	1.68	

The P concentration in the ear leaf samples collected from the low fertility site was influenced by fertilizer placement and there was a significant placement x tillage interaction (Table 7). Starter fertilizer use, however, had no effect on the percentage of P in the ear leaf tissue from this site. For both tillage systems, the P concentration was highest when the P_2O_5 was broadcast. The P concentration was lowest when the P_2O_5 was applied in a surface band with the chisel system.

The P concentration in the ear leaf was also influenced by P_2O_5 placement at the high fertility site but there was no tillage by placement interaction. When averaged over all other factors, the P concentration was highest when the P_2O_5 was broadcast and lowest when it was placed in a subsurface band. Examination of the data for P and K concentrations in the ear leaf tissue indicates that there is no strong relationship between these values and grain yield.

Table 7. Effect of tillage system, fertilizer placement and starter fertilizer use on the P concentration in the ear leaf tissue at the Lamberton low fertility site in 1985.

	Tillage System					
	Ridge-Till			Chisel		
Placement	With Starter	No Starter	Ave.	With Starter	No Starter	Ave.
	% P					
---	---	.173	--	---	.178	--
Broadcast	.234	.243	.239	.241	.263	.240
Surface Band	.225	.222	.224	.240	.239	.240
Subsurface Band	.232	.225	.229	.229	.225	.227
	.230	.230		.237	.242	

Waseca Results

Tillage system was the major factor that had a significant effect on the variables measured at the high fertility site at Waseca. Grain yields from this site are summarized in Table 8. Neither placement, rate of P_2O_5 and K_2O used, nor starter fertilizer use had any significant effect on yield.

Table 8. Effect of tillage system, fertilizer placement and starter fertilizer use on the yield of corn at Waseca high fertility site. 1985.

	Tillage System					
	Ridge-Till			Chisel		
Placement	With Starter	No Starter	Ave.	With Starter	No Starter	Ave.
	bu./acre					
---	144.8	154.3	149.6	153.9	138.1	146.0
Broadcast	147.6	157.5	152.6	147.9	147.9	147.9
Surface Band	157.5	150.9	154.2	152.0	148.2	150.1
Subsurface Band	159.1	158.4	158.8	153.9	154.1	154.0
	154.7	155.6		151.3	150.1	

Tillage system also had a significant effect on early plant growth at the high fertility site (Table 2). When averaged over all factors, the weight of 6 plants was 25.2 gm in the chisel planting system and 29.9 gm in the ridge-till planting system. This effect on early growth was also reflected in uptake of P and K by the young plants.

The P concentration of whole plants at this site was significantly increased only by rate applied. The K concentration in these plants was significantly influenced by tillage system and rate of K_2O applied. There was also a significant tillage X fertilizer placement interaction (Table 9). In the ridge-till system, K concentration in the whole plant tissue was highest when the fertilizer was broadcast. In the chisel system, the highest K concentration resulted from the use of the subsurface band.

The P concentration in the ear leaf at the high fertility site was influenced only by the tillage system used (Table 2). The K concentration was only influenced by placement. When averaged over other factors, the percentage of K was 1.71, 1.67, and 1.83 when the K_2O was broadcast, applied in a surface band, and applied in a subsurface band respectively. A significant increase resulted from the placement in the subsurface band.

Table 9. Effect of tillage system, fertilizer placement and starter fertilizer on the K concentration in young corn plants at the Waseca high fertility site. 1985.

	Tillage System					
	Ridge-Till			Chisel		
Placement	With Starter	No Starter	Ave.	With Starter	No Starter	Ave.
	% K					
---	3.53	3.32	3.43	3.73	3.64	3.69
Broadcast	3.74	3.80	3.77	3.95	3.68	3.82
Surface Band	3.87	3.64	3.76	3.90	4.01	3.96
Subsurface Band	3.69	3.60	3.65	4.34	4.06	4.20
	3.77	3.68		4.06	3.92	

Grain yield at the low fertility site at Waseca was significantly influenced by all factors studied. There was also a significant tillage by fertilizer placement interaction. The effects of tillage system, fertilizer placement and starter use measured in 1985 were consistent with results measured at this site in 1984.

At a rate of 44 lb. P_2O_5 and 87 lb. K_2O per acre, the use of the subsurface band produced the highest yield for both tillage systems (Table 10). With the ridge-till system, the broadcast application of this rate of P_2O_5 and K_2O produced the lowest yield. The use of the surface band produced the lowest yield when the chisel system was used.

Table 10. Effect of tillage system fertilizer placement and starter fertilizer use on the grain yield at the Waseca low fertility site. 1985.

	Tillage System					
	Ridge-Till			Chisel		
Placement	With Starter	No Starter	Ave.	With Starter	No Starter	Ave.
	bu./acre					
---	93.1	83.8	88.5	87.1	79.3	83.2
Broadcast	115.1	114.1	114.6	118.0	119.4	118.7
Surface Band	126.3	117.1	121.7	105.8	105.1	105.5
Subsurface Band	135.1	124.7	129.5	129.1	120.5	124.6
	125.5	118.6		117.6	115.0	

The use of the starter fertilizer in addition to the P_2O_5 and K_2O applied by some other method increased yields by 7 bu./acre with the ridge-till system and 3 bu./acre with the chisel system.

These were no significant interactions between rate and the other factors studied. When averaged over all other factors, the rate of 44 lb. P_2O_5 and 87 lb. K_2O per acre produced 119.2 bu./acre. The yield from the use of 66 lb. P_2O_5 and 131 lb. K_2O per acre averaged 124.6 bu./acre.

The effects of tillage system, fertilizer placement, fertilizer rate, and starter use on early growth were consistent with the effects of these factors on grain yield. The increase in early growth at this site was measured in final grain yield.

The P concentration in young plants was not significantly influenced by the factors used in this study. Because of the large differences in early plant growth, P concentration could have been influenced by plant dilution effects.

Use of a starter fertilizer increased the K concentration in young plants for both tillage systems (Table 11). Fertilizer placement also influenced K concentration in the tissue and there was a significant interaction with tillage system. The use of the subsurface band produced the highest concentration for the chisel system. In the ridge-till system, however, the surface band produced the highest concentration. These results indicate that young plants can utilize the K_2O applied on the soil surface. This would be expected where the surface band is incorporated with the chisel operation. There is, however, no incorporation of the surface band in the ridge-till system. There must be some downward movement of applied K between the time of application in the fall and corn emergence the following spring.

Table 11. Effect of tillage system, fertilizer placement and starter fertilizer use on the K concentration in young plants at the Waseca low fertility site. 1985.

	Tillage System					
	Ridge-Till			Chisel		
Placement	With Starter	No Starter	Ave.	With Starter	No Starter	Ave.
	% K					
---	1.30	1.23	1.27	1.47	1.44	1.46
Broadcast	1.91	1.71	1.81	2.44	2.41	2.43
Surface Band	2.55	2.49	2.52	2.35	2.13	2.24
Subsurface Band	2.20	1.95	2.08	3.26	2.34	2.60
	2.22	2.05		2.68	2.29	

The effects of the four factors on P uptake by young plants parallel the effects of these factors on early plant growth. Uptake of K by young plants, however, was influenced only by rate of P_2O_5 and K_2O applied and starter fertilizer use.

The P concentration in the ear leaf tissue was significantly influenced by tillage system, fertilizer placement, fertilizer rate and starter fertilizer use. This is consistent with the effects of these 4 factors on the P concentration in young plants. Use of the starter increased the P concentration for the ridge-till system only (Table 12).

Table 12. Effect of tillage system, fertilizer placement and starter fertilizer use on the P concentration in the ear leaf tissue at the Waseca low fertility site. 1985.

	Tillage System					
	Ridge-Till			Chisel		
Placement	With Starter	No Starter	Ave.	With Starter	No Starter	Ave.
	% P					
---	.169	.142	.156	.173	.155	.164
Broadcast	.176	.168	.172	.205	.194	.200
Surface Band	.158	.155	.157	.167	.164	.166
Subsurface Band	.186	.176	.181	.192	.200	.196
	.173	.166		.188	.186	

The broadcast placement produced the highest P concentration for the chisel system. Placement in a subsurface band produced the highest P concentration in the ridge-till system. The surface band produced the lowest P concentration for both planting systems. The use of a subsurface band without a starter fertilizer resulted in P concentrations that were almost equal to the P concentration in ear leaves of the control treatment. These results suggest that mobility of the applied P is slight.

In addition to the treatments needed to complete the factorial, others were added at the Waseca and Morris sites to provide for several comparisons of interest. The "t" test was used to separate means in these added comparisons. The results of these comparisons at the Waseca low fertility site are discussed in the following paragraphs. At the time of this writing "t" tests had not been completed for the variables measured at the Waseca high fertility site and the Morris site.

The use of 100 lb. 7-21-7 per acre produced a significant increase in 6 of the 8 variables measured (Table 13). The amount of K_2O applied in the starter was apparently not sufficient to increase the K concentration in young corn plants as well as the amount of K absorbed by these plants. Interpretation of the data is not changed if tillage systems are analyzed separately. So, data from both systems were combined for the averages shown in Table 13. Considering the low soil test values at this site, the positive response to the use of the starter fertilizer was expected.

The "t" test was also used to determine if small amounts of P_2O_5 and K_2O applied in a starter fertilizer were equal to larger amounts applied in some other way without the addition of a starter. Grain yields were higher when higher amounts were broadcast, applied in a surface band, or used in a subsurface band (t = 6.74***, 6.13***, 3.07** respectively). As would be expected, P and K concentrations in the plant tissue at the 2 stages sampled were also significantly higher when the higher amounts of P_2O_5 and K_2O were used.

In the fall of 1983, a single application of 440 lb. P_2O_5 and 870 lb. K_2O was applied at a depth of 12 inches either directly below the corn row or in the middle between two rows. In addition to the fertilizer applied in 1983, both treatments received an annual subsurface band of 44 lb. P_2O_5 and 87 lb. K_2O per acre. A starter was also used each year. Grain yield in 1984 when the fertilizer was applied below the row was 150.5 bu./acre. When the fertilizer was applied between the rows, the yield was 145.6 bu./acre. This difference in yield was not significant (t = 1.42).

Table 13. Effect of the use of starter only when compared to the control on the variables recorded the Waseca low fertility site. 1985.

Variable	Control	Starter Use Only
Yield, bu./acre	81.6	90.1*
Early Plant Growth, g/6 plants	13.0	15.2**
P Conc. Whole Plant, %	.350	.380**
K Conc. Whole Plant, %	1.33	1.38
P Uptake, mg/6 plants	46.0	57.8**
K Uptake, mg/6 plants	175.0	212.0
P Conc.-Ear Leaf, %	.150	.170**
K Conc.-Ear Leaf, %	.52	.56***

*,**,*** Treatment means are significantly different at the .10, .05, and .01 confidence levels respectively.

The annual application of the subsurface band did not improve yields when the high rates were applied in 1983. When the high rates was applied between the rows and a subsurface band used each year, the yield was 145.6 bu./acre. The yield from the same placement of high rates without the annual application was 147.3 bu./acre. The difference was not significant (t = .40).

The 1985 grain yields were improved by the application of the high rates of P_2O_5 and K_2O in 1983. However, yields will have to be recorded for a number of years before the benefit of the use of high rates placed at a depth of 12 inches can be accurately assessed.

EFFECT OF POTASSIUM PLACEMENT ON CORN PRODUCTION IN HIGH YIELD ENVIRONMENTS IN SOUTHEAST MINNESOTA

G. Rehm, M. O'Leary, G. Cremers, and B. Anderson

The interest in the use of conservation tillage systems for corn production continues to increase in southeastern Minnesota. Soil test values for K are usually medium to low for the majority of soils in this region. These low soil test values create several questions that relate to management of K fertilizers. This study is designed to evaluate the effect of rate and placement of fertilizer K with and without the use of K in a starter fertilizer on corn production with two tillage systems.

Experimental Procedure:

This study was initiated in the spring in 1984 in a farmer's field in Wabasha County. Treatments were reapplied in the spring of 1985. The soil is classified as a Fayette silt loam and is characteristic of soils in the region. The pH was 6.5. The Bray and Kurtz #1 test showed 72 lb. P/acre while the 1 N $NH_4C_2H_3O_2$ extraction showed 219 lb. K/acre.

Tillage system (no till, chisel), rate of applied K (0, 40, 80, 120 lb./acre) placement (broadcast, subsurface band), and starter with and without K are the factors included in the study. A randomized complete block design is used with 4 replications.

In 1985, treatments were applied in late April. The K source for subsurface and broadcast application was 0-0-60. A 7-21-7 fluid fertilizer at a rate of 195 lb./acre was used to supply K in the starter. The fluid product, 10-34-0 (128 lb./acre) was used as a starter for plots that did not receive K in the starter.

All plots received a preplant application of 180 lb. N/acre supplied as 28-0-0. Corn was planted on May 14, 1985 at a population of 25,400 plants per acre in 38 in. rows. The variety was Pioneer 3737. Counter was used for corn rootworm control and the Lasso - Bladex combination (applied preemergence) was used for weed control. Corn was cultivated once in mid June. This cultivation was used to build ridges in the no-till system so that corn would be planted on ridges in 1986.

Whole plant samples (4 plants/plot) were taken 4 weeks after emergence. Ear leaf samples were collected at silking. Dry matter production was measured at physiological maturity and whole plant samples were collected at this time. All plant samples were dried, weighed when appropriate and analyzed for K. Grain yields were harvested in late October and corrected to 15.5% moisture.

Results and Discussion:

In 1985, there were no significant interactions among the variables used for any of the parameters measured in this study. Therefore, main effects will be summarized in the tables that follow.

Before discussing the data, it's important to emphasize that rainfall was very limited during the first half of the growing season. Little effective rainfall was recorded between planting and July 24. There were small showers during this period but amounts received in each shower were small. Therefore, the corn was stressed during the first two weeks in July and this stress will explain, in part, the low yields.

The effect of tillage system on corn growth and yield, K concentration in the plant tissue, and K uptake by corn is summarized in Table 1. Early plant growth was greater when the chisel system was used. This improved early growth was reflected in both grain yield and total dry matter production.

Except for the mature plant at physiological maturity, the K concentration in the tissue was higher when the chisel system was used. Consequently K uptake was high when corn was grown in the chisel system. These results are consistent with data reported from other studies in Minnesota.

Please refer to title page of this publication for information regarding application and use of this article.

Table 1. Effect of tillage system used on early growth, corn yield, K concentration in the tissue and K uptake. 1985.

	Tillage System	
	Chisel	No-Till
early growth, weight of 4 plants, g	32.5	17.3
yield, bu./acre	119.5	90.1
dry matter yield, ton/acre	4.90	3.74
K concentration, young plants, %	3.55	3.05
K concentration, ear leaf, %	1.84	1.67
K concentration, mature plant, %	.92	1.03
K uptake, young plants, mg/4 plants	1148.7	525.2
K uptake, mature plants, lb./acre	90.1	77.1

Problems were encountered with the no-till planting system in 1985. Consequently, soil to seed contact was poor. This reduced stand and subsequently caused a reduction in both dry matter and grain yield.

The influence of rate of K applied was inconsistent (Table 2). In the chisel system, grain yield was increased by the use of 40 lb. K/acre with additional K producing no further increases in yield. The K concentration in the young plants and the ear leaf tissue was also significantly increased by the initial 40 lb. K/acre increment. Rate of K applied had no significant effect on K uptake by young plants and total K uptake by mature corn.

The rate of fertilizer K applied affected the K concentration in the young plants and ear leaf tissue when corn was planted in the no-till system (Table 2). Because of the planting problems described above, however, there was a large amount of variability in the data. Therefore, it is difficult to attach a large amount of importance to data collected from the no-till system in 1985. The grain yields from the no-till system were especially low. With a medium K test in the soil, the soil itself was apparently able to supply adequate K for these low yields.

Placement of fertilizer K had a significant effect on grain yield was well as the concentration of K in plant tissue when corn was planted in the chisel system (Table 3). Placement of the fertilizer K in a subsurface band was superior to a broadcast application. These results are analagous to results of studies where subsurface application of fertilizer P has been superior for small grain production.

Table 2. Effect of rate of applied K on early growth, corn yield, K concentration in the tissue, and K uptake by corn. 1985.

	K Applied (lb./acre)			
	0	40	80	120
Chisel System:				
early growth, weight of 4 plants, g	34.0	32.2	33.8	31.4
yield, bu./acre	115.9	119.0	119.2	120.3
dry matter yield, ton/acre	4.86	5.03	4.80	4.87
K conc. young plants, %	2.96	3.47	3.51	3.68
K conc. ear leaf, %	1.67	1.82	1.82	1.87
K conc. mature plant, %	.88	.90	.94	.92
K uptake, young plants, mg/4 plants	1010	1109	1181	1157
K uptake, mature plants, lb./acre	86.0	90.8	90.2	89.2
No-Till System:				
early growth, weight of 4 plants, g	18.0	16.2	17.8	17.9
yield, bu./acre	89.0	87.0	92.5	90.7
dry matter yield, ton/acre	3.36	3.71	3.73	3.77
K conc. young plants, %	2.51	2.95	3.04	3.14
K conc. ear leaf, %	1.49	1.61	1.65	1.75
K conc. mature plant, %	.96	1.00	1.04	1.05
K uptake, young plants, mg/4 plants	454	472	539	565
K uptake, mature plants, lb./acre	64.6	74.4	77.3	79.4

Table 3. Effect of K placement on early growth, corn yield, K concentration in the tissue, and K uptake by corn. 1985.

	Placement	
	Broadcast	Subsurface Band
Chisel System:		
early growth, weight of 4 plants, g	32.9	32.0
yield, bu./acre	116.9	122.0**
dry matter yield, ton/acre	4.97	4.83
K conc. young plants, %	3.39	3.71**
K conc. ear leaf, %	1.81	1.86
K conc. mature plant, %	.89	.95**
K uptake, young plants, mg/4 plants	1111	1187
K uptake, mature plants, lb./acre	88.5	91.7
No-Till System:		
early growth, weight of 4 plants, g	17.3	17.3
yield, bu./acre	91.0	89.2
dry matter yield, ton/acre	3.70	3.77
K conc. young plants, %	2.64	3.45**
K conc. ear leaf, %	1.63	1.70*
K conc. mature plant, %	1.04	1.02
K uptake, young plants, mg/4 plants	458	591**
K uptake, mature plants, lb./acre	77.3	76.8

*,** Difference between means is significant at the .05 and .01 confidence levels respectively.

With subsurface placement, the K was placed where soil was moist while broadcast applications were incorporated in dry soil. The subsurface application would have placed the fertilizer K in a more active portion of the root zone.

For the no-till system, placement had no significant effect on yield. With no significant response to rate of applied K, this result would be expected. Placement of fertilizer K did have a significant effect on the K concentration in the plant tissue. The concentration was higher in the young plants and the ear leaf tissue when K was applied below the soil surface rather than broadcast. With no incorporation of broadcast K in the tillage system, this result would be expected. This is especially true in a dry year.

Except for the K concentration in the ear leaf tissue from the no-till planting system, there was no significant effect of the use of K in a starter fertilizer in 1985 (Table 4). Because of the warm, dry conditions in spring and early summer, these results would be expected when averaged over all rates of applied K and both methods of placement. In 1985, the starter fertilizer would have been placed in soil that was relatively dry. Consequently, plant use of K applied in this way was probably low.

Table 4. Effect of K applied in a starter fertilizer on early growth, corn yield, K concentration in the tissue, and K uptake by corn. 1985.

	K Applied in the Starter	
	Yes	No
Chisel System:		
early growth, weight of 4 plants, g	31.8	33.2
yield, bu./acre	119.4	119.6
dry matter yield, ton/acre	4.88	4.92
K conc. young plants, %	3.60	3.51
K conc. ear leaf, %	1.85	1.82
K conc. mature plant, %	.93	.91
K uptake, young plants, mg/4 plants	1146	1152
K uptake, mature plants, lb./acre	90.4	89.7
No-Till System:		
early growth, weight of 4 plants, g	16.8	17.8
yield, bu./acre	91.2	89.0
dry matter yield, ton/acre	3.79	3.68
K conc. young plants, %	3.07	3.01
K conc. ear leaf, %	1.70	1.64+
K conc. mature plant, %	1.03	1.03
K uptake, young plants, mg/4 plants	509	542
K uptake, mature plants, lb./acre	77.8	76.2

+, Difference between treatment means in significantly different at the .10 confidence level.

CAULIFLOWER RESPONSE TO GYPSUM ON A COARSE-TEXTURED SOIL - 1985

C. J. ROSEN AND H. J. BUCHITE

Interest in growing freshmarket vegetables in north central Minnesota has increased over the past few years. Many of the soils in this area tend to be coarse-textured and low in exchangeable Ca. Cauliflower grown on these soils often develop a disorder known as "tipburn" which is characterized by tip necrosis of the young leaves surrounding the curd. Because younger leaves are not separated from the curd at harvest, tipburned leaves can lower the quality of marketable heads. Previous studies have suggested a correlation between tipburn and low leaf tissue calcium. The objective of the present study was to determine the effects of gypsum on cauliflower yield, tipburn and postharvest qualities.

Materials and Methods:

This experiment was located in Princeton, MN on a Hubbard loamy sand. Soil chemical properties (0-24 inches) before gypsum application were as follows:

	---------Soil Depth---------			
	0-3"	3-6"	6-12"	12-24"
P (lb/A)	52	50	40	55
K (lb/A)	88	82	113	211
Ca (lb/A)	256	331	456	904
S (lb/A)	6	5	9	30
pH	5.4	5.3	5.3	5.3

Treaments included a control and three rates of gypsum (500, 1000, and 2000 lb/A) and were applied on 1 July. Two methods of incorporation were used: disked and moldboard plow. A split plot randomized complete block design was used with 4 replications. Main plots were tillage method and subplots were the gypsum treatments. Cauliflower (cv. 'Snowcrown') transplants were planted on 8 July and banded with 50 lb/A N, 50 lb/A P_2O_5, 150 lb/A K_2O, 1/2 lb/A B, 30 lb/A S, and 40 lb/A Mg. Additional N was sidedressed at the rate of 50 lb/A three and 8 weeks after planting. Plant spacing was 16 inches within the row and 40 inches between row centers. Soil samples were collected on 11 September. Leaves immediately surrounding the head (immature leaves) and fully expanded leaves (mature leaves) were sampled on 6 September. Nutrient composition of dried leaf samples was determined using a Kjeldahl/conductimetric procedure for N and an inductively coupled plasma (ICP) spectrometer for the other elements. Each plot was observed for development of leaf tipburn. Two center rows of each plot were harvested on 6 dates from 3 September to 26 September. Measurements included total yield and curd size.

Results:

Gypsum treatments had no significant effect on cauliflower yield or head diameter (Table 1). Incorporation of gypsum by disking resulted in a larger curd size compared to incorporation by plowing. The reasons for this increase in curd size due to tillage are not clear from the present experiment.

Soil calcium levels increased with increasing gypsum rates (Table 2). It is interesting to note that in this soil, calcium levels increased at the 12-24 inch depth which indicates a downward movement of calcium over the growing season. Soil sulfur followed the same pattern as soil calcium (Table 3). For both nutrients, method of gypsum incorporation had little effect on extractable levels.

Gypsum treatments increased concentrations of sulfur and tended to decrease concentrations of nitrogen, magnesium and boron in recently matured leaves (Tables 4 and 5). In younger leaves gypsum increased concentrations of calcium and sulfur but decreased concentrations of magnesium (Tables 6 and 7). Levels of tissue calcium and sulfur were greater in the disked treatment compared to the moldboard plow treatment. This indicates that on these sandy soils, incorporation by disking is adequate for increasing tissue levels of calcium and sulfur in shallow rooted crops such as

Please refer to title page of this publication for information regarding application and use of this article.

cauliflower. Despite the fact that gypsum increased tissue calcium, plants from all plots developed the tipburn symptom. This indicates that more than soil calcium is involved in the tipburn disorder. It it possible that the cultivar used in this study has an inefficient calcium translocating system. Although this field was well irrigated, slight water stress coupled with high temperatures may also be involved. For both mature and immature leaf samples molybdenum values are presented, however because most values were below the detection limit of the ICP only the means are provided. In general, molybdenum concentrations decreased with gypsum applications.

General Conclusions:

Calcium and sulfur soil levels increased with increasing gypsum application. During the growing season, calcium and sulfur tended to leach through the soil profile. Although gypsum treatments significantly increased soil and tissue levels of calcium and sulfur, there was no significant effect of these treatments on cauliflower tipburn incidence, final yield or postharvest quality. It is possible that the cultivar 'Snowcrown' is susceptible to this disorder and that a different cultivar may be better suited for these coarse-textured soils.

The cooperation of Dr. Roger C. Gibson, U. S. Gypsum Corporation, during the course of this research is gratefully acknowledged.

Table 1. Influence of gypsum on yield and head diameter of cauliflower.

Gypsum Treatment	Yield D[1]	Yield MB	Head Diameter D	Head Diameter MB
Lb/A	------T/A-------		-----inches----	
0	5.72	4.31	9.2	8.2
500	5.00	5.49	9.0	8.9
1000	5.23	4.50	9.2	8.5
2000	4.58	5.20	8.8	8.8

Statistics	Significance[2]	
Tillage	NS	**
Gypsum	NS	NS
Linear	NS	NS
Quadratic	NS	NS
Gyp X Till	**	*

[1]D = Disked, MB = Moldboard plow
[2]+ = .2, ++ = .1, * = .05, ** = .01

Table 2. Influence of gypsum treatments on ammonium acetate extractable Ca at various depths.

Gypsum Treatment	Soil Depth 0 - 3" D[1]	0 - 3" MB	3 - 6" D	3 - 6" MB	6 - 12" D	6 - 12" MB	12 - 24" D	12 - 24" MB	0 - 24" D	0 - 24" MB
lb/A	lb/A									
0	209	287	229	198	463	395	840	680	1740	1561
500	370	328	283	259	558	400	1115	840	2325	1835
1000	426	310	261	279	413	553	1065	1060	2174	2201
2000	333	340	351	411	505	585	1200	1100	2389	2436

Statistics	Significance[2]				
Tillage	NS	NS	NS	++	NS
Gypsum	++	*	NS	*	**
Linear	+	**	++	**	**
Quadratic	*	NS	NS	+	+
Gyp X Till	NS	NS	+	NS	NS

[1]D = Disked, MB = Moldboard plow.
[2]+ = .2, ++ = .1, * = .05, ** = .01

Table 3. Influence of gypsum on monocalcium phosphate extractable sulfur at various depths.

Gypsum Treatment	Soil Depth 0 - 3" D[1]	0 - 3" MB	3 - 6" D	3 - 6" MB	6 - 12" D	6 - 12" MB	12 - 24" D	12 - 24" MB	0 - 24" D	0 - 24" MB
lb/A	lb/A									
0	5	4	3	2	7	5	18	18	32	27
500	4	4	5	3	9	7	23	23	40	38
1000	6	5	3	25	11	22	37	41	56	91
2000	6	17	12	57	26	44	82	51	125	168

Statistics	Significance[2]				
Tillage	NS	++	NS	NS	NS
Gypsum	++	*	*	**	**
Linear	*	**	**	**	**
Quadratic	NS	NS	NS	NS	NS
Gyp X Till	++	+	NS	+	NS

[1]D = Disked, MB = Moldboard plow.
[2]+ = .2, ++ = .1, * = .05, ** = .01

Table 4. Macronutrient concentrations in recently mature cauliflower leaves as affected by gypsum.

Gypsum Treatment	N		P		K		Ca		S		Mg	
	D[1]	MB	D	MB	D	MB	D	MB	D	MB	D	MB
lb/acre	%											
0	4.05	4.21	0.50	0.49	3.45	3.08	0.81	0.87	0.76	0.63	0.27	0.28
500	3.79	3.74	0.46	0.50	3.64	3.35	1.01	0.90	0.91	0.81	0.25	0.28
1000	4.03	3.76	0.47	0.49	3.51	3.40	0.93	0.84	0.94	0.79	0.24	0.24
2000	3.72	3.80	0.49	0.47	3.29	3.41	0.97	0.93	0.91	0.91	0.24	0.21

Statistics	Significance[2]					
Tillage	NS	NS	+	NS	**	NS
Gypsum	+	NS	NS	NS	**	++
Linear	++	NS	NS	NS	**	*
Quadratic	NS	NS	+	NS	**	NS
Gyp X Till	NS	NS	NS	NS	+	NS

[1]D = Disked, MB = Moldboard plow.
[2]+ = .2, ++ = .1, * = .05, ** = .01

Table 5. Micronutrient concentrations in recently mature cauliflower leaves as affected by gypsum.

Gypsum Treatment	Fe		Mn		Zn		Cu		B		Mo	
	D[1]	MB	D	MB	D	MB	D	MB	D	MB	D	MB
lb/acre	ppm											
0	60	62	98	101	47	49	4	5	51	35	.7	.5
500	54	57	97	65	48	41	4	5	42	30	.4	.8
1000	57	56	109	75	52	52	4	4	44	32	.6	.2
2000	57	59	84	83	47	47	4	4	34	32	.4	.2

Statistics	Significance[2]				
Tillage	NS	*	NS	+	**
Gypsum	NS	NS	+	NS	+
Linear	NS	NS	NS	NS	*
Quadratic	NS	NS	NS	NS	NS
Gyp X Till	NS	+	NS	NS	NS

[1]D = Disked, MB = Moldboard plow.
[2]+ = .2, ++ = .1, * = .05, ** = .01

Table 6. Macronutrient concentrations in immature cauliflower leaves as influenced by gypsum.

Gypsum Treatment	N		P		K		Ca		S		Mg	
	D[1]	MB	D	MB	D	MB	D	MB	D	MB	D	MB
lb/acre	%											
0	4.03	3.85	0.54	0.51	3.54	3.19	0.36	0.34	0.72	0.63	0.24	0.24
500	3.90	3.59	0.50	0.52	3.51	3.33	0.42	0.42	0.80	0.77	0.23	0.24
1000	3.97	3.81	0.52	0.51	3.46	3.42	0.46	0.39	0.89	0.77	0.23	0.23
2000	3.90	3.67	0.52	0.49	3.46	3.41	0.50	0.44	0.89	0.82	0.22	0.22

Statistics	Significance[2]					
Tillage	*	NS	*	*	**	NS
Gypsum	NS	NS	NS	**	**	+
Linear	NS	NS	NS	**	**	**
Quadratic	NS	NS	NS	NS	**	NS
Gyp X Till	NS	NS	NS	NS	+	NS

[1]D = Disked, MB = Moldboard plow.
[2]+ = .2, ++ = .1, * = .05, ** = .01

Table 7. Micronutrient concentrations in immature cauliflower leaves as influenced by gypsum.

Gypsum Treatment	Fe		Mn		Zn		Cu		B		Mo	
	D[1]	MB	D	MB	D	MB	D	MB	D	MB	D	MB
lb/acre	ppm											
0	66	63	68	56	52	49	4	5	39	29	.6	.6
500	65	61	65	50	54	46	4	4	32	28	.2	.5
1000	64	59	77	54	57	55	5	4	34	27	.3	.6
2000	66	64	79	59	53	50	4	4	35	27	.3	.3

Statistics	Significance[2]				
Tillage	+	**	++	NS	**
Gypsum	NS	NS	NS	NS	NS
Linear	NS	+	NS	NS	NS
Quadratic	NS	NS	+	NS	+
Gyp X Till	NS	NS	NS	++	NS

[1]D = Disked, MB = Moldboard plow.
[2]+ = .2, ++ = .1, * = .05, ** = .01

INFLUENCE OF SEED INOCULATION, SOIL APPLIED NITROGEN AND FOLIAR APPLIED NITROGEN ON PRODUCTIVITY OF PROCESSING PEAS

C. J. ROSEN, C. KAHRMANN, H. J. BUCHITE AND J. B. HEBEL

Minnesota usually ranks second or third nationally in the production of processing peas. Despite relatively large acreages, little attention has been given to nitrogen response by peas. The objectives of the present study were to : 1) determine the effect of inoculation on pea productivity in a coarse and a fine textured soil, 2) characterize pea response to soil applied nitrogen and 3) evaluate the use of a foliar nitrogen source on pea productivity.

Materials and Methods:

The experiment was conducted at two sites: Southern Experiment Station in Waseca, MN and the Sand Plains Research Farm in Becker, MN. Prior to planting and fertilizer application, soil at the Waseca site - Nicollet clay loam, and at the Becker site - Hubbard loamy sand, had the following test values:

	Becker	Waseca
pH (0-6")	6.3	7.4
P lb/A, (0-6")	53	34
K lb/A, (0-6")	185	436
N lb/A (0-12")	16	25

The previous crop at Waseca was corn and at Becker was rye. There were six N treatments which included 1) a control, 2) 40 lb N/A (preplant soil applied), 3) 80 lb N/A (preplant soil applied), 4) 30 lb N/A as a foliar (15 lb at flowering, and 15 lb during pod formation), 5) 60 lb N/A as a foliar (30 lb at flowering, 30 lb during pod formation), 6) 40 lb N/A (preplant soil applied) and 30 lb N/A as a foliar (15 lb N/A at flowering and 15 lb N/A during pod formation). The nitrogen source for all soil applications was ammonium nitrate and the source for foliar nitrogen was Formolene (30-0-2). The Formolene was mixed with water (10:1) and applied with WEX a surfactant.

Two pea varieties, 'Target' and 'Venus' were planted at Becker on 14 April and at Waseca on 19 April. Plant populations were appoximately 500,000/A. A split plot design with 4 replications was used where variety and inoculation were whole plots and N treatments were subplots. The Waseca plot was nonirrigated. At Becker, rainfall was supplemented with irrigation to supply approximately 1" of water per week. Whole plant samples were collected 4 weeks after planting for N determination (prior to foliar N applications). At Becker 'Target' was harvested 19 June and 'Venus' 24 June. At Waseca 'Target was harvested 21 June and 'Venus' 24 June. Harvested vines and pods were placed in a viner to separate the peas from the shell and vine plant material. Subsamples of peas were obtained for tenderometer reading, N determination and % moisture. Subsamples of the vines plus shells were taken for N determination and % moisture. Orthogonal contrasts were used to detect N treatment differences over inoculation and variety. High N vs Low N compares treatments 3, 5, and 6 to treatments 1, 2, and 4. Soil vs foliar compares treatments 2 and 3 to treatments 4 and 5. Linear and quadratic responses are for treatments 1, 2, and 3.

Results and Discussion:

Pea yields at both locations increased with soil applied nitrogen (Table 1). The nitrogen response at Becker was linear compared to a quadratic reponse (maximum yield at 40 lb N/A) at Waseca. Foliar applied N tended to depress yields at both locations. Inoculation had no significant effect on yields at either site; however, at Becker, yields tended to increase in the inoculated plots when supplemental N was not provided, the opposite response was observed at Waseca. Nodule weight per plant was significantly increased with inoculation at Becker (Table 2). Soil applied nitrogen significantly depressed nodule weight. 'Target' appeared to nodulate better than 'Venus'. Although detailed measurements were not obtained at Waseca, visual examination of the plants indicated that all plants were well nodulated.

Please refer to title page of this publication for information regarding application and use of this article.

Fresh weight of vines and shells increased with soil applied N at Waseca but response was inconsistent at Becker (Table 3). Inoculation increased vines and shells at Becker, whereas a decrease was recorded at Waseca. The reasons for these differences are not clear from this experiment.

Tenderometer readings (a measure of maturity at harvest) were not significantly affected by any of the treatments (Table 4). This was not expected since N applications generally are believed to delay maturity.

Nitrogen concentrations in whole plants samples collected 4 weeks after planting significantly increased with soil applied N (Table 5). Inoculation had an inconsistent effect and appeared to depend on variety. Because foliar N treatments were not applied for another 2 weeks, the comparison between foliar and soil applied N is not valid at this sampling time. Nitrogen concentrations in peas at harvest tended to increase with foliar application (Table 6), however, this was not related to yield. Inoculation had no effect on N concentrations in peas. In general, soil applied N decreased pea N concentrations. Similarly, N concentrations in vines and shells at harvest tended to decrease with increasing soil applied N (Table 7). The lower N concentrations in both vines + shells and peas with higher soil applied N is difficult to explain at this time. Application of foliar N significantly increased N concentrations in vines and shells.

Nitrogen content in peas was about one third that in the vines and shells (Tables 8 and 9). The nitrogen content in the vines and shells (80 - 140 lb/A) could be a significant N contribution for subsequent crops if incorporated after harvest. The effects of soil applied N on N content in peas generally followed pea yields. Inoculation did not significantly affect pea N content. Nitrogen content in vines and shells was not affected by inoculation at Becker and depended on variety at Waseca. High rates of soil and foliar applied N increased N content of vines and shells at Becker.

General Comments:

Pea yields at both sites were generally increased with soil applied N. A greater response was observed at Becker than at Waseca. Future experiments using smaller increments of soil applied N are necessary to refine N response by peas. Yield increases with applied N may not be desirable if vine production is too great. Inoculation of pea seed had no effect on production at Waseca (nonirrigated, fine textured soil), but a trend of increased yields with inoculation was observed in the control plot at Becker (irrigated, coarse textured soil). At Becker nodulation was dependent on inoculation, soil applied N, and pea variety. Foliar N fertilizer increased N concentrations in peas as well as in vines and shells; however, this did not correlate to an increase in yield. Because processing peas are harvested at a physiologically immature stage of growth, the applications of foliar N may have been too late to be of any benefit to yield.

Table 1. Influence of soil applied nitrogen, foliar applied nitrogen, and seed inoculation on pea yields.

Treatment	Becker				Waseca			
	Venus		Target		Venus		Target	
	NI[1]	I	NI	I	NI	I	NI	I
lb N/A	T/A							
0	1.65	1.84	1.27	1.64	2.42	2.35	1.95	1.84
40 Soil	2.37	1.92	1.24	1.39	2.79	2.59	1.98	1.91
80 Soil	2.07	2.43	1.55	1.19	2.43	2.44	1.98	1.84
30 Foliar	1.97	1.75	1.12	1.48	2.39	2.50	1.76	1.98
60 Foliar	1.78	2.05	1.09	1.35	2.44	2.30	1.89	1.84
40 S + 30 F[2]	1.79	1.88	1.26	1.32	2.44	2.39	1.80	1.89

[1]NI = noninoculated, I = inoculated. [2]S = Soil, F = Foliar

Statistics	P>F	P>F
Inoculation	0.2541	0.3921
Variety	0.0001	0.0001
Nitrogen	0.3792	0.1830
High N vs. Low N	0.9418	0.1814
Soil vs. Foliar	0.0565	0.0734
N rate linear	0.1446	0.6977
N rate quadratic	0.8165	0.0288
Nitrogen x Inoculation	0.6581	0.5008
Nitrogen x Variety	0.3380	0.7035
Inoculation x Variety	0.5363	0.5712
Nitrogen x Inoculation x Variety	0.2098	0.9290

Table 2. Influence of soil applied nitrogen, foliar applied nitrogen and seed inoculation on nodule dry weight at harvest.

Treatment	Becker			
	Venus		Target	
	NI[1]	I	NI	I
lb N/A	mg/plant			
0	40	49	78	100
40 Soil	27	60	46	75
80 Soil	31	54	23	42
30 Foliar	36	66	20	126
60 Foliar	29	26	9	82
40 S + 30 F[2]	31	68	28	107

[1]NI = noninoculated, I = inoculated. [2]S = Soil, F = Foliar

Statistics	P>F
Inoculation	0.0002
Variety	0.0191
Nitrogen	0.3623
High N vs. Low N	0.1087
Soil vs. Foliar	0.7037
N rate linear	0.0893
N rate quadratic	0.9716
Nitrogen x Inoculation	0.6053
Nitrogen x Variety	0.7719
Inoculation x Variety	0.0299
Nitrogen x Inoculation x Variety	0.7150

Table 3. Influence of soil applied nitrogen, foliar applied nitrogen, and seed inoculation on vine and shell yield.

	Becker				Waseca			
	Venus		Target		Venus		Target	
Treatment	NI[1]	I	NI	I	NI	I	NI	I
lb N/A	T/A							
0	12.36	13.79	13.25	13.23	11.68	13.45	12.30	10.91
40 Soil	14.42	12.44	11.91	11.15	14.31	12.31	12.15	11.75
80 Soil	12.90	15.27	12.81	12.87	14.12	13.07	13.20	12.18
30 Foliar	12.84	13.88	12.28	12.78	14.16	12.85	12.60	12.40
60 Foliar	12.83	13.13	12.91	13.92	12.51	12.34	12.28	11.34
40 S + 30 F[2]	14.37	16.28	12.74	13.25	11.40	12.31	13.34	11.67

[1]NI = noninoculated, I = inoculated. [2]S = Soil, F = Foliar

Statistics	P>F	P>F
Inoculation	0.0325	0.0286
Variety	0.0934	0.0454
Nitrogen	0.3666	0.1065
High N vs. Low N	0.0909	0.9452
Soil vs. Foliar	0.8512	0.1696
N rate linear	0.6846	0.0197
N rate quadratic	0.2083	0.9632
Nitrogen x Inoculation	0.5490	0.5666
Nitrogen x Variety	0.3881	0.3127
Inoculation x Variety	0.5519	0.3870
Nitrogen x Inoculation x Variety	0.8415	0.0211

Table 4. Influence of soil applied nitrogen, foliar applied nitrogen, and seed inoculation on tenderometer readings.

	Becker				Waseca			
	Venus		Target		Venus		Target	
Treatment	NI[1]	I	NI	I	NI	I	NI	I
lb N/A	TD							
0	94.8	91.0	84.0	83.8	80.5	78.6	86.1	90.1
40 Soil	97.3	94.0	82.0	83.8	80.6	80.4	88.5	88.4
80 Soil	97.3	94.5	85.3	81.0	81.4	80.3	86.6	86.0
30 Foliar	96.0	90.0	81.0	85.0	78.6	81.1	87.4	88.3
60 Foliar	97.0	96.3	82.0	83.5	80.3	80.8	86.0	88.9
40 S + 30 F[2]	86.5	88.5	82.5	83.0	81.6	80.8	86.0	87.5

[1]NI = noninoculated, I = inoculated. [2]S = Soil, F = Foliar

Statistics	P>F	P>F
Inoculation	0.5323	0.4716
Variety	0.0001	0.0001
Nitrogen	0.0841	0.9653
High N vs. Low N	0.6536	0.6998
Soil vs. Foliar	0.6563	0.8748
N rate linear	0.5056	0.7746
N rate quadratic	0.8306	0.3696
Nitrogen x Inoculation	0.7735	0.7244
Nitrogen x Variety	0.0875	0.4965
Inoculation x Variety	0.3323	0.3524
Nitrogen x Inoculation x Variety	0.5314	0.5084

Table 5. Influence of applied soil nitrogen, foliar applied nitrogen, and seed inoculation on nitrogen concentration in whole plants sampled 4 weeks after planting.

	Becker				Waseca			
	Venus		Target		Venus		Target	
Treatment	NI[1]	I	NI	I	NI	I	NI	I
lb N/A	% N							
0	3.22	3.26	3.71	3.89	3.72	2.80	3.40	3.29
40 Soil	3.86	3.46	4.28	4.26	3.57	3.90	3.88	3.73
80 Soil	4.46	4.42	4.45	4.86	4.01	3.68	4.19	4.61
30 Foliar	3.04	2.97	2.95	3.27	3.01	3.49	3.49	3.57
60 Foliar	2.99	3.05	3.07	3.78	3.11	2.79	3.36	2.96
40 S + 30 F[2]	3.93	4.22	4.41	4.51	3.94	3.66	3.83	3.68

[1]NI = noninoculated, I = inoculated. [2]S = Soil, F = Foliar

Statistics	P>F	P>F
Inoculation	0.0726	0.2939
Variety	0.0002	0.0873
Nitrogen	0.0001	0.0001
High N vs. Low N	0.0001	0.0475
Soil vs. Foliar	0.0001	0.0001
N rate linear	0.0001	0.0001
N rate quadratic	0.5008	0.6470
Nitrogen x Inoculation	0.2276	0.0715
Nitrogen x Variety	0.2358	0.3534
Inoculation x Variety	0.0422	0.5795
Nitrogen x Inoculation x Variety	0.5656	0.1139

Table 6. Influence of soil applied nitrogen, foliar applied nitrogen, and seed inoculation on nitrogen concentrations in peas sampled at harvest.

	Becker				Waseca			
	Venus		Target		Venus		Target	
Treatment	NI[1]	I	NI	I	NI	I	NI	I
lb N/A	% N							
0	4.42	4.49	4.10	4.03	3.82	3.79	4.04	4.03
40 Soil	4.32	4.54	4.09	3.87	3.84	3.82	4.17	4.13
80 Soil	4.32	4.41	3.89	3.99	3.73	3.77	4.13	3.99
30 Foliar	4.44	4.47	4.14	3.89	3.90	3.77	4.20	4.18
60 Foliar	4.48	4.48	4.09	4.03	3.88	3.83	4.12	4.23
40 S + 30 F[2]	4.52	4.40	3.88	4.04	3.89	3.93	3.98	3.16

[1]NI = noninoculated, I = inoculated. [2]S = Soil, F = Foliar

Statistics	P>F	P>F
Inoculation	0.9773	0.7898
Variety	0.0001	0.0001
Nitrogen	0.3832	0.1060
High N vs. Low N	0.4906	0.8285
Soil vs. Foliar	0.0810	0.0648
N rate linear	0.0700	0.7407
N rate quadratic	0.9508	0.0677
Nitrogen x Inoculation	0.6686	0.4949
Nitrogen x Variety	0.9525	0.3925
Inoculation x Variety	0.3854	0.5506
Nitrogen x Inoculation x Variety	0.0616	0.4793

Table 7. Influence of soil applied nitrogen, foliar applied nitrogen, and seed inoculation on nitrogen concentrations in vines and shells sampled at harvest.

	Becker				Waseca			
	Venus		Target		Venus		Target	
Treatment	NI[1]	I	NI	I	NI	I	NI	I
lb N/A	% N							
0	2.04	2.67	2.48	2.36	2.20	2.42	2.61	2.51
40 Soil	1.95	2.00	2.66	2.17	2.54	2.46	2.28	2.52
80 Soil	1.91	1.73	2.11	2.30	2.04	2.23	2.29	2.48
30 Foliar	2.20	2.09	2.83	2.57	2.19	2.35	2.78	2.53
60 Foliar	2.44	2.42	3.07	2.93	2.45	2.37	2.88	2.37
40 S + 30 F[2]	2.27	2.35	2.52	2.69	2.22	2.48	2.73	2.64

[1]NI = noninoculated, I = inoculated. [2]S = Soil, F = Foliar

Statistics	P>F	P>F
Inoculation	0.3344	0.8658
Variety	0.0001	0.0185
Nitrogen	0.0001	0.0258
High N vs. Low N	0.1259	0.6689
Soil vs. Foliar	0.0001	0.0226
N rate linear	0.0093	0.0352
N rate quadratic	0.6116	0.1389
Nitrogen x Inoculation	0.5148	0.0752
Nitrogen x Variety	0.5942	0.0717
Inoculation x Variety	0.2619	0.2353
Nitrogen x Inoculation x Variety	0.3139	0.1656

Table 8. Total nitrogen removed in peas as influenced by soil applied nitrogen, foliar applied nitrogen and seed inoculation.

	Becker				Waseca			
	Venus		Target		Venus		Target	
Treatment	NI[1]	I	NI	I	NI	I	NI	I
lb N/A	lbs N/A							
0	29.4	33.2	19.3	26.2	35.3	35.6	26.6	26.7
40 Soil	42.9	35.5	19.3	21.5	40.5	38.6	28.8	27.8
80 Soil	36.6	44.2	23.5	18.1	34.7	35.2	28.3	25.8
30 Foliar	36.1	31.6	17.4	22.3	35.4	36.4	25.8	28.4
60 Foliar	32.4	37.2	16.5	21.0	36.6	34.6	27.8	26.5
40 S + 30 F[2]	32.7	30.4	18.9	19.9	37.6	36.6	25.8	27.4

[1]NI = noninoculated, I = inoculated. [2]S = Soil, F = Foliar

Statistics	P>F	P>F
Inoculation	0.3865	0.3359
Variety	0.0001	0.0001
Nitrogen	0.3750	0.2250
High N vs. Low N	0.8570	0.1952
Soil vs. Foliar	0.0798	0.2448
N rate linear	0.1899	0.6487
N rate quadratic	0.6652	0.0163
Nitrogen x Inoculation	0.6595	0.7299
Nitrogen x Variety	0.3103	0.6728
Inoculation x Variety	0.5186	0.9312
Nitrogen x Inoculation x Variety	0.3220	0.8524

Table 9. Total nitrogen uptake by vines and shells as influenced by soil applied nitrogen, foliar applied nitrogen and seed inoculation.

	Becker				Waseca			
	Venus		Target		Venus		Target	
Treatment	NI[1]	I	NI	I	NI	I	NI	I
lb N/A	lbs N/A							
0	96.8	116.6	121.4	122.1	84.7	104.4	104.8	89.9
40 Soil	111.4	101.5	110.5	92.9	118.5	101.4	90.1	95.3
80 Soil	89.9	105.0	108.2	109.0	95.8	96.9	101.6	96.1
30 Foliar	105.2	105.5	125.7	117.6	105.1	90.1	110.0	97.2
60 Foliar	120.0	124.7	138.6	140.4	104.3	97.4	112.9	87.9
40 S + 30 F[2]	120.3	125.1	122.6	131.7	85.8	104.0	112.9	92.6

[1]NI = noninoculated, I = inoculated. [2]S = Soil, F = Foliar

Statistics	P>F	P>F
Inoculation	0.6936	0.0662
Variety	0.0495	0.9567
Nitrogen	0.0071	0.8790
High N vs. Low N	0.0659	0.9071
Soil vs. Foliar	0.0024	0.7239
N rate linear	0.1833	0.7780
N rate quadratic	0.5317	0.2914
Nitrogen x Inoculation	0.7094	0.4033
Nitrogen x Variety	0.7575	0.1773
Inoculation x Variety	0.3812	0.0654
Nitrogen x Inoculation x Variety	0.9845	0.0352

RESPONSE OF POTATO GROWN UNDER LONG ROTATIONS TO CALCIUM AND MAGNESIUM AMENDMENTS ON A COARSE-TEXTURED SOIL - 1985

C. J. ROSEN and H. J. BUCHITE

Soil management practices for potato production differ from those used for most other agricultural crops in that liming of low pH soils is avoided. The reason for not raising soil pH is due to the potential for increasing the incidence of common scab when the soil pH is above 5.2. Approximately 30% of potatoes grown in Minnesota are on irrigated coarse-textured soils. Because recommendations are not to lime, soil calcium, magnesium and pH have dropped to low ranges. The potential for Al and Mn toxicity also exists due to the increased solubilities of these elements with low pH. Over the past 10-15 years, yields of potatoes grown on these coarse-textured soils have generally declined. Part of this problem may be due to lack of proper rotation coupled with an imbalanced soil fertility.

In a study conducted at this site in 1984, calcium and magnesium applied as fine dolomitic lime or as sulfate salts tended to increase potato yields. However, potatoes died back early (due to Verticillium wilt) which resulted in low yields in all treatments. In this study disease problems appeared to be an overriding factor. The objective of the present study was to determine the influence of Ca/Mg amendments and fumigation on potato production on a coarse-textured soil with a history of continuous potatoes.

Materials and Methods:

The experimental site was located in Cambridge, MN on an Anoka loamy sand. Soil chemical properties before treatment application were as follows:

Soil Depth --inches--	pH	P	K	Ca	Mg
		-------lb/A-------			
0 - 6	4.9	519	306	298	66
6 - 12	4.6	476	233	290	60
12 - 24	4.7	255	455	532	130

Potatoes had been grown on this site for the past 10 - 15 years. Treatments included:

1) Check
2) 2.0 T/A Lime
3) 4.0 T/A Lime
4) 6.0 T/A Lime
5) Check
6) 1.8 T/A Gypsum + 2.1 T/A Epsom Salts
7) 3.6 T/A Gypsum + 4.2 T/A Epsom Salts
8) 5.4 T/A Gypsum + 6.3 T/A Epsom Salts

All amendments were applied 12 November 1984 as a broadcast and disked in. The liming material used was a 100 mesh dolomitic limestone. The gypsum/Epsom salt combination was used to provide an equal amount of Ca and Mg as a non-lime source. The following spring the entire field was plowed to a depth of 8 - 10". On 18 April 1985 strips of the field were fumigated with Telone C (injected to a depth of 6") at a rate of 50 gal/A. An equal area was left unfumigated. The field was then packed after injection. Potatoes, cv. 'Norland', were planted on 5 May 1985. Spacing used was 3 feet between row centers. At planting, 120 lb N/A, 70 lb P_2O_5/A, 280 lb K_2O/A and 90 lb S/A was banded. An additional 60 lb N/A was applied at emergence and at hilling. Soil samples were collected on 10 May 1985 and 28 August 1985. Plant tissue samples consisting of the most recently matured whole leaf (blade and petiole) were collected 58 (at flowering) and 81 (onset of dieback) days after planting. Two center 15' rows from each plot were harvested on 12 September 1985 with the following measurements recorded: total yield, A-Size (greater than 2") B-Size (less than 2") and scab ratings. A split plot design with 4 replications was used. Fumigation was the main plot and Ca/Mg treatments were the subplots. Orthogonal contrasts were used to determine linear and quadratic responses to lime (treatments 1, 2, 3, and 4) and gypsum plus Epsom salts (treatments 5, 6, 7, and 8). Lime vs. gypsum plus Epsom salts compares treatments 2, 3, and 4 to treatments 6, 7, and 8.

Please refer to title page of this publication for information regarding application and use of this article.

Results and Discussion:

Potato yields were significantly increased with addition of calcium and magnesium amendments (Table 1). Yield increases were due primarily to increases in A-size potatoes. There was a linear response to lime applications compared to a more quadratic response to gypsum plus Epsom salts. Potato yields were low in all treatments due to early dieback. Fumigation had no effect on dieback incidence and in general depressed yields. This negative effect on yield may have been due to toxicity of the fumigant on potato growth. Had the fumigant been applied the previous fall or at lower rates in the spring, toxicity may not have occurred. The reason why fumigation had no effect on early dieback cannot be determined from this study. However, Verticillium wilt did not appear to be the major cause of dieback this year.

At the begining of the season soil Ca increased linearly with increasing gypsum application at the 0-6" and 6-12" depths (Table 2). Lime treatments had no significant effect on soil Ca at this time. Neither amendment affected soil Ca at the 12-24" depth. Late in the growing season, soil Ca increased linearly with gypsum application at all depths while lime amendments increased Ca at the 0-6" and 6-12" depths (Table 3). Because of higher solubility of gypsum compared to dolomitic lime, soil Ca levels were greater with the gypsum source. Soil Mg increased linearly with increasing lime and Epsom salt applications (Table 4). As with Ca, the sulfate salt was more soluble than the lime source. This resulted in higher Mg levels with Epsom salts compared to lime. At the end of the growing season, soil Mg trends were similar to those at the begining of the season with higher levels resulting from the Epsom salt source (Table 5). Soil pH increased linearly with increasing lime application at the begining and end of the growing season (Tables 6 and 7). Even with relatively large applications of lime (6T/A), soil pH incresed less than one-half a pH unit. Liming did not have any effect on scab incidence (data not presented). However, soil pH was less than 5.2 in all treatments which is below the range considered optimum for scab development. Because of the low solubility of lime, it is possible that soil pH will increase in subsequent years. In contrast to lime, gypsum and Epsom salts significantly decreased soil pH at the begining of the season, however, the effect was not as pronounced by the end of the season. Soil pH levels were greater when the soil was fumigated, possibly because of decreased nitrification.

Leaf tissue macro and micronutrient levels during flowering are presented in Tables 8 and 9. Lime applications increased concentrations of N, Mg, and Ca and decreased concentrations of Mn and B. Gypsum and Epsom salt applications increased concentrations of N, Mg, and Fe and decreased concentrations of Mn and B. Fumigation increased concentrations of P and decreased concentrations of Ca, Mg, and Mn. At the onset of dieback, lime applications increased tissue levels of N, Ca, Mg, and Zn and decreased levels of Mn and B (Tables 10 and 11). Gypsum and Epsom salt applications increased concentrations of Ca, Mg, and Fe and decreased concentrations of K and Mn. Fumigation increased concentrations of N, P, and B and decreased concentrations of Ca, Mg, and Mn. It is interesting to note that although soil levels of Ca and Mg were higher with gypsum and Epsom salts compared to lime, tissue levels of these nutrients were similar for both amendment sources. Fumigation effects on nutrient composition may possibly be due to stunting of plant growth (concentrating N and P) and a reduction in transpiration rate (depressing Ca and Mg uptake).

General Conclusions:

Potato yields increased with applications of calcium/magnesium amendments. Because of higher solubility of the sulfate sources, lower rates can be applied compared to the lime sources. Although scab incidence was not increased by liming in this experiment, the sulfate salts would be the safer source to use if scab is a problem. Dolomitic lime would be a suitable source of Ca and Mg if soil pH is less than 5.0 and scab resistant varieties are used. None of the amendments or fumigation had any effect on early dieback problems. Rotating potatoes with other crops may be the only solution to prevent potato yields from declining in this area.

Table 1. A-size, B-size, and total yield as influenced by calcium-magnesium amendments and fumigation.

Treatment[1]	B-size +Fum	B-size -Fum	A-size +Fum	A-size -Fum	Total +Fum	Total -Fum
	CWT/A					
Check	40.2	33.9	78.4	105.5	118.6	139.4
1X Lime	41.1	31.9	99.2	118.1	139.9	150.1
2X Lime	41.1	38.7	123.4	137.0	164.1	175.7
3X Lime	41.1	39.7	117.1	160.2	158.3	200.4
Check	40.2	36.3	92.9	109.9	131.1	146.2
1X G + E[2]	37.3	38.7	118.1	148.6	155.4	186.9
2X G + E	34.9	40.2	123.4	143.8	158.3	184.0
3X G + E	33.9	35.3	105.5	137.0	139.4	171.8

Statistics	Significance[3] B-size	A-size	Total
Fumigation	NS	NS	+
Treatment	NS	**	**
Linear Lime	NS	**	**
Quad Lime	NS	NS	NS
Linear G + E	NS	++	+
Quad G + E	NS	**	**
Lime vs G + E	NS	NS	NS
Tmt X Fum	NS	NS	NS

[1]See Materials and Methods section for actual rates.
[2]G + E = Gypsum + Epson Salts.
[3]NS = >.2, + = .1-.2, ++ = .05-.1, * = .01-.05, ** = <.01.

Table 2. Influence of calcium-magnesium amendments and fumigation on ammonium acetate extractable Ca at various depths, 10 May.

	Depth (inches)							
	0-6		6-12		12-24		0-24	
	(lb/A)							
Treatment[1]	+Fum	-Fum	+Fum	-Fum	+Fum	-Fum	+Fum	-Fum
Check	283	299	277	291	372	257	1302	1103
1X Lime	313	311	277	307	339	303	1267	1224
2X Lime	426	367	354	341	329	289	1438	1285
3X Lime	380	369	327	421	302	520	1312	1830
Check	286	278	273	276	330	373	1220	1298
1X G + E[2]	338	417	477	578	367	349	1549	1693
2X G + E	406	528	860	903	378	387	2020	2205
3X G + E	514	1059	800	994	416	460	2145	2971

Statistics	Significance[3]			
	0-6	6-12	12-24	0-24
Fumigation	+	+	NS	NS
Treatment	**	**	NS	**
Linear Lime	NS	NS	NS	+
Quad Lime	NS	NS	NS	NS
Linear G + E	**	**	NS	**
Quad G + E	+	++	NS	NS
Lime vs G + E	*	**	NS	**
Tmt X Fum	NS	NS	NS	NS

Table 3. Influence of calcium-magnesium amendments and fumigation on ammonium acetate extactable Ca at various depths, 28 August.

	Depth (inches)							
	0-6		6-12		12-24		0-24	
	(lb/A)							
Treatment[1]	+Fum	-Fum	+Fum	-Fum	+Fum	-Fum	+Fum	-Fum
Check	370	329	371	384	414	389	1569	1492
1X Lime	452	376	439	414	392	507	1675	1636
2X Lime	420	385	487	419	443	427	1793	1657
3X Lime	460	538	525	568	352	488	1690	2082
Check	350	341	426	334	381	401	1539	1477
1X G + E[2]	476	505	603	556	616	489	2061	2038
2X G + E	462	532	664	786	538	563	2202	2444
3X G + E	840	563	913	1078	685	648	3123	2936

Statistics	Significance[3]			
	0-6	6-12	12-24	0-24
Fumigation	NS	NS	NS	NS
Treatment	**	**	**	**
Linear Lime	*	+	NS	*
Quad Lime	NS	NS	NS	NS
Linear G + E	**	**	**	**
Quad G + E	NS	NS	NS	NS
Lime vs G + E	**	**	**	**
Tmt X Fum	NS	NS	NS	NS

[1]See Materials and Methods for actual rates.
[2]G + E = Gypsum + Epsom Salts.
[3]NS = >.2, + = .1-.2, ++ = .05-.1, * = .01-.05, ** = <.01.

Table 4. Influence of calcium-magnesium amendments and fumigation on ammonium acetate extractable Mg at various depths, 10 May.

	Depth (inches)							
	0-6		6-12		12-24		0-24	
	(lb/A)							
Treatment[1]	+Fum	-Fum	+Fum	-Fum	+Fum	-Fum	+Fum	-Fum
Check	61	68	62	64	88	55	298	242
1X Lime	77	75	71	82	77	78	302	313
2X Lime	104	106	105	105	77	63	362	337
3X Lime	108	98	92	128	76	115	352	454
Check	57	61	69	56	74	72	273	262
1X G + E[2]	116	121	121	137	171	188	579	635
2X G + E	144	158	171	207	218	271	750	906
3X G + E	166	178	192	180	346	293	1050	944

Statistics	Significance[3]			
	0-6	6-12	12-24	0-24
Fumigation	NS	NS	NS	NS
Treatment	**	**	**	**
Linear Lime	**	**	NS	++
Quad Lime	NS	NS	NS	NS
Linear G + E	**	**	**	**
Quad G + E	*	**	NS	+
Lime vs G + E	**	**	**	**
Tmt X Fum	NS	NS	NS	NS

Table 5. Influence of calcium-magnesium amendments and fumigation on ammonium acetate extractable Mg at various depths, 28 August.

	Depth (inches)							
	0-6		6-12		12-24		0-24	
	(lb/A)							
Treatment[1]	+Fum	-Fum	+Fum	-Fum	+Fum	-Fum	+Fum	-Fum
Check	47	41	42	49	74	58	237	206
1X Lime	80	64	91	79	77	116	325	374
2X Lime	86	62	99	79	84	102	353	344
3X Lime	95	87	127	127	72	110	366	434
Check	53	49	62	39	63	51	240	190
1X G + E[2]	76	86	52	74	91	94	309	348
2X G + E	98	95	65	73	116	178	393	524
3X G + E	81	76	91	61	140	98	451	333

Statistics	Significance[3]			
	0-24	6-12	12-24	0-24
Fumigation	NS	NS	NS	NS
Treatment	**	**	**	**
Linear Lime	**	**	NS	++
Quad Lime	NS	NS	NS	NS
Linear G + E	*	++	**	**
Quad G + E	*	NS	*	NS
Lime vs G + E	NS	**	++	**
Tmt X Fum	NS	NS	+	NS

[1]See Materials and Methods for actual rates.
[2]G + E = Gypsum + Epsom Salts.
[3]NS = >.2, + = .1-.2, ++ = .05-.1, * = .01-.05, ** = <.01.

Table 6. Influence of calcium-magnesium amendments and fumigation on soil pH (1:1 soil - water) at various depths, 10 May.

	Depth (inches)					
	0-6		6-12		12-24	
Treatment	+Fum	-Fum	+Fum	-Fum	+Fum	-Fum
Check	4.9	4.9	4.6	4.7	4.8	4.8
1X Lime	4.9	4.9	4.7	4.9	4.8	4.8
2X Lime	5.3	5.2	5.1	5.0	4.9	4.9
3X Lime	5.3	5.0	5.0	5.1	4.9	4.9
Check	5.0	4.8	4.9	4.7	4.8	4.7
1X G + E[2]	4.6	4.7	4.5	4.4	4.4	4.4
2X G + E	4.5	4.5	4.4	4.5	4.4	4.4
3X G + E	4.5	4.4	4.4	4.5	4.5	4.4

Statistics	Significance[3]		
	0-6	6-12	12-24
Fumigation	++	NS	NS
Treatment	**	**	**
Linear Lime	**	**	++
Quad Lime	NS	NS	NS
Linear G + E	**	**	**
Quad G + E	+	**	**
Lime vs G + E	**	**	**
Tmt X Fum	NS	+	NS

Table 7. Influence of calcium-magnesium amendments and fumigation on soil pH (1:1 soil - water) at various depths, 28 Aug.

	Depth (inches)					
	0-6		6-12		12-24	
Treatment	+Fum	-Fum	+Fum	-Fum	+Fum	-Fum
Check	4.7	4.5	4.7	4.6	4.5	4.4
1X Lime	4.9	4.7	5.0	4.6	4.6	4.6
2X Lime	5.1	4.7	5.0	4.6	4.7	4.4
3X Lime	5.1	5.0	5.3	5.1	4.7	4.6
Check	4.8	4.5	4.9	4.4	4.5	4.4
1X G + E[2]	4.7	4.6	4.7	4.4	4.4	4.4
2X G + E	4.7	4.5	4.5	4.3	4.5	4.3
3X G + E	4.6	4.5	4.6	4.3	4.5	4.3

Statistics	Significance[3]		
	0-6	6-12	12-24
Fumigation	++	*	NS
Treatment	**	**	**
Linear Lime	**	**	NS
Quad Lime	NS	NS	NS
Linear G + E	NS	+	**
Quad G + E	NS	NS	NS
Lime vs G + E	**	**	**
Tmt X Fum	NS	NS	NS

[1]See Materials and Methods for actual rates.
[2]G + E = Gypsum + Epsom Salts.
[3]NS = >.2, + = .1-.2, ++ = .05-.1, * = .01-.05, ** = <.01.

Table 8. Macronutrient levels in recently mature leaves 58 days after planting as influenced by calcium-magnesium amendments and fumigation.

	N		P		K		Ca		Mg	
	%									
Treatment[1]	+Fum	-Fum	+Fum	-Fum	+Fum	-Fum	+Fum	-Fum	+Fum	-Fum
Check	4.94	4.47	0.43	0.36	4.76	4.87	0.39	0.53	0.35	0.36
1X Lime	4.97	4.85	0.41	0.37	4.75	5.08	0.48	0.51	0.38	0.40
2X Lime	5.05	4.93	0.42	0.41	5.01	4.93	0.46	0.61	0.38	0.45
3X Lime	5.01	5.20	0.43	0.37	4.79	4.95	0.44	0.63	0.38	0.48
Check	4.77	4.89	0.43	0.36	4.70	5.13	0.40	0.53	0.29	0.38
1X G + E[2]	5.11	5.10	0.44	0.38	4.91	4.85	0.47	0.60	0.41	0.47
2X G + E	5.38	4.99	0.43	0.40	4.84	4.85	0.47	0.53	0.42	0.50
3X G + E	5.19	5.17	0.47	0.38	4.80	4.98	0.40	0.60	0.36	0.54

Statistics	Significance[3]				
	N	P	K	Ca	Mg
Fumigation	NS	**	NS	**	*
Treatment	*	NS	NS	NS	**
Linear Lime	*	NS	NS	+	*
Quad Lime	NS	NS	NS	NS	NS
Linear G + E	*	+	NS	NS	**
Lime vs G + E	++	+	NS	NS	+
Tmt X Fum	NS	NS	NS	NS	NS

Table 9. Micronutrient levels in recently mature leaves 58 days after planting as influenced by calcium-magnesium amendments and fumigation.

	Fe		Mn		Zn		B	
	ppm							
Treatment	+Fum	-Fum	+Fum	-Fum	+Fum	-Fum	+Fum	-Fum
Check	155	161	326	431	39	31	32	30
1X Lime	173	195	339	417	34	34	29	30
2X Lime	150	179	267	361	33	35	29	28
3X Lime	171	153	278	342	35	40	28	29
Check	159	184	382	475	39	33	31	34
1X G + E[2]	256	226	365	445	41	37	30	30
2X G + E	215	267	296	411	40	40	29	30
3X G + E	255	281	346	380	43	40	30	33

Statistics	Significance[3]			
	Fe	Mn	Zn	B
Fumigation	NS	+	NS	NS
Treatment	**	+	+	**
Linear Lime	NS	++	NS	**
Quad Lime	NS	NS	NS	NS
Linear G + E	**	++	++	NS
Quad G + E	NS	NS	NS	**
Lime vs G + E	**	++	*	**
Tmt X Fum	NS	NS	NS	++

[1]See Materials and Methods for actual rates.
[2]G + E = Gypsum + Epsom Salts.
[3]NS = >.2, + = .1-.2, ++ = .05-.1, * = .01-.05, ** = <.01.

Table 10. Macronutrient levels in recently mature leaves 81 days after planting as influenced by calcium-magnesium amendments and fumigation.

	N		P		K		Ca		Mg	
	%									
Treatment[1]	+Fum	-Fum	+Fum	-Fum	+Fum	-Fum	+Fum	-Fum	+Fum	-Fum
Check	4.65	4.28	0.29	0.24	5.25	5.21	0.67	1.06	0.32	0.44
1X Lime	4.77	4.66	0.28	0.24	4.87	5.33	0.89	1.24	0.45	0.65
2X Lime	5.06	4.72	0.29	0.26	5.04	5.26	0.93	1.29	0.52	0.67
3X Lime	4.78	4.74	0.28	0.24	5.00	5.27	0.92	1.31	0.52	0.73
Check	4.72	4.36	0.34	0.23	5.36	5.29	0.71	0.99	0.34	0.39
1X G + E[2]	5.56	4.77	0.29	0.25	5.06	4.95	0.77	1.16	0.46	0.62
2X G + E	5.01	4.59	0.30	0.24	5.19	4.93	1.06	1.27	0.61	0.72
3X G + E	4.87	4.94	0.31	0.26	4.78	4.73	0.83	1.24	0.58	0.77

Statistics	Significance[3]				
	N	P	K	Ca	Mg
Fumigation	*	*	NS	**	*
Treatment	++	NS	*	**	**
Linear Lime	+	NS	NS	**	**
Quad Lime	NS	NS	NS	++	*
Linear G + E	NS	NS	**	**	**
Lime vs G + E	NS	++	+	NS	NS
Tmt X Fum	NS	++	NS	NS	NS

Table 11. Micronutrient levels in recently mature leaves 81 days after planting as influenced by calcium-magnesium amendments and fumigation.

	Fe		Mn		Zn		B	
	ppm							
Treatment[1]	+Fum	-Fum	+Fum	-Fum	+Fum	-Fum	+Fum	-Fum
Check	184	201	609	729	25	24	58	53
1X Lime	199	221	594	783	31	26	60	52
2X Lime	185	192	450	664	29	29	55	52
3X Lime	176	189	517	582	24	23	53	48
Check	194	208	613	800	30	22	57	55
1X G + E[2]	212	233	451	707	27	26	54	52
2X G + E	237	336	537	774	30	31	60	57
3X G + E	306	334	518	623	29	29	57	60

Statistics	Significance[3]			
	Fe	Mn	Zn	B
Fumigation	NS	+	NS	+
Treatment	**	+	**	++
Linear Lime	NS	*	NS	*
Quad Lime	NS	NS	**	NS
Linear G + E	**	+	*	+
Quad G + E	NS	NS	NS	NS
Lime vs G + E	**	NS	++	*
Tmt X Fum	NS	NS	NS	NS

[1]See Materials and Methods for actual rates.
[2]G + E = Gypsum + Epsom Salts.
[3]NS = >.2, + = .1-.2, ++ = .05-.1, * = .01-.05, ** = <.01.

EVALUATION OF FOLIAR FERTILIZERS FOR STRAWBERRY PRODUCTION - 1985

C. J. Rosen, H. J. Buchite, E. E. Hoover, and J. J. Luby

Foliar fertilizers have been promoted in recent years to improve yield and quality of many horticultural crops. The basic idea behind foliar feeding is that applied nutrients may be more immediately available for metabolic processes compared to conventional soil applications. In most cases, instructions are to apply foliar fertilizers during "critical" growth periods to alleviate any nutrient stress that may be occurring at that time. The objective of this experiment was to determine the influence of foliar fertilizer rate and application time on strawberry yield and quality.

Materials and Methods:

Treatments were applied to a third year planting (second fruiting season) of 'Earliglow' strawberries on a Gotham loamy sand. A soil sample (0-6") was collected before treatments were applied in 1985 and had the following test values: P (lb/A), 119; K (lb/A), 238; pH, 5.1. A randomized complete block design was used with 4 replications. The planting system was a matted row with 4 feet between row centers. Each plot consisted of a 20 ft row. The treatments included:

Treatment number:

1. Control - soil applied fertilizer, 1984, after renovation.

2. 16-4-4 applied before (9 May 1985) and during (16 May 1985) flowering, 3.2 gal/A per application.

3. 16-4-4 applied during fruit maturation (23 May 1985 and 30 May 1985), 3.2 gal/A per application.

4. 16-4-4 applied before (9 May 1985) and during (16 May 1985) flowering, and during fruit maturation (23 May 1985 and 30 May 1985), 1.6 gal/A per application.

5. 16-4-4 applied during flowering (16 May 1985) and during fruit maturation (30 May 1985), 6.4 gal/A per application.

6. 16-4-4 applied during flower initiation (6 September and 20 September 1984), 1.6 gal/A per application.

7. 16-4-4 applied before (9 May 1985) and during (16 May 1985) flowering and during fruit maturation (23 May 1985 and 30 May 1985), 3.2 gal/A per application.

8. 16-4-4 same as treatment 7 except that fertilizer was applied directly to the soil in the row.

9. 9-18-9 applied before (9 May 1985) and during (16 May 1985) flowering and during fruit maturation (23 May 1985 and 30 May 1985), 2.5 gal/A per application.

10. 9-18-9 same as treatment 9 except 5.0 gal/A per application.

The rates were selected so that 1.6 gal/A 16-4-4 and 2.5 gal/A 9-18-9 provided 2.5 lb N/A. All plots received the same rates of soil applied fertilizer after renovation in 1984 (according to U of M recommendations). Foliar fertilizer treatments were applied with a CO_2 sprayer fit with two fan type nozzles. The spray pattern covered approximately a 36 inch width. The foliar fertilizers were applied with 12 gal water/A at 40 psi. All treatments included WEX, a surfactant, at the rate of 3 ml/gal. Yield measurements were recorded on the following harvest dates: 7, 12, 17, 21, and 26 June 1985. Berry wieghts and percent soluble solids

---

Please refer to title page of this publication for information regarding application and use of this article.

were determined on subsamples from each plot at each harvest. Nutrient concentrations were determined in the most recently mature leaves (leaflets + petiole) sampled on 12 June 1985.

Results and Discussion:

There were no significant differences due to treatment in total yield, or yield at any of the individual harvest dates (Table 1). However, there was a tendency for the foliar fertilizer treatments to delay maturity compared to the control. Berry weight decreased with harvest date for all treatments (Table 2). There was no significant positive increase in berry weight due to foliar fertilizer, although at the final harvest there was a tendency for foliar fertilized plots to have a larger berry size. Percent soluble solids in ripe berries was not significantly affected by treatment (Table 3). Nutrient concentrations in strawberry leaves sampled during harvest are presented in Table 4. Because samples were collected two weeks after the last foliar application and leaf samples were rinsed thoroughly in distilled water before drying, it was assumed that most of the nutrients were inside the leaf tissue and not on the surface. Leaf N concentrations were highest in the spring soil applied treatment (treatment #8) and lowest in the control. Foliar fertilizer treatments tended to increase leaf N compared to the contol. There were no significant differences in leaf P concentrations which may be due to the relatively high soil P levels. Leaf K concentrations were lowest in the control. Foliar fertilizer and spring soil applications tended to increase leaf K. Although significant differences in leaf Fe and Cu were detected, these were not related to treatment. Leaf Zn was lowest in the control plot, and highest in the spring soil applied teatment. Reasons for low leaf Zn in the control plot cannot be explained from the present study.

Conclusions:

The foliar fertilizers used in this study did not significantly increase strawberry yield or quality. Applications of foliar fertilizers did increase leaf concentrations of N and K. This indicates that foliar fertilizers could be used to temporarily correct nutrient deficiencies of these elements. Provided that soil fertility is managed properly, foliar fertilizers appear to have minimal effects on strawberry production.

Table 1. Influence of foliar fertilizers on strawberry yield.

Treatment Number and Fertilizer[1]	Harvest Date					Total
	6 June	12 June	17 June	21 June	26 June	Yield
	T/A					
1. Control	0.47	1.26	1.20	1.20	1.03	5.16
2. 16-4-4	0.19	0.96	1.17	1.22	1.46	5.00
3. 16-4-4	0.19	0.83	1.37	1.46	1.53	5.38
4. 16-4-4	0.25	0.97	1.47	1.38	1.54	5.62
5. 16-4-4	0.25	0.91	1.07	1.15	1.17	4.41
6. 16-4-4	0.30	1.01	1.43	1.22	1.32	5.29
7. 16-4-4	0.32	1.16	1.22	1.38	1.35	5.42
8. 16-4-4 (Soil)	0.36	1.04	1.27	1.20	1.27	5.14
9. 9-18-9	0.37	1.18	1.34	1.19	1.69	5.76
10. 9-18-9	0.31	1.19	1.22	1.44	1.76	5.91
Pr > F	.349	.638	.747	.266	.430	.505

[1]See Materials and Methods for rates and times of applications.

Table 2. Influence of foliar fertilizers on berry weights.

Treatment Number and Fertilizer[1]	Harvest Date 6 June	12 June	17 June	21 June	26 June	Average Weight[2]
	grams/berry					
1. Control	16.6	14.5	10.7	8.2	6.5	10.7
2. 16-4-4	16.0	14.3	12.8	9.6	8.0	11.0
3. 16-4-4	14.9	14.6	12.7	10.2	8.2	11.1
4. 16-4-4	15.1	13.7	12.7	10.4	7.2	10.9
5. 16-4-4	15.6	13.4	10.2	8.7	7.4	10.3
6. 16-4-4	18.2	14.9	11.6	8.3	7.1	10.7
7. 16-4-4	16.5	14.4	10.7	9.7	7.3	10.7
8. 16-4-4 (Soil)	17.9	13.9	13.1	8.8	7.5	11.2
9. 9-18-9	16.8	13.9	12.1	9.4	8.2	11.1
10. 9-18-9	17.7	15.8	12.0	9.8	8.1	11.4
Pr > F	.023	.692	.068	.625	.429	.211
BLSD (0.10)	2.4	--	2.6	--	--	--

[1]See Materials and Methods for rates and times of applications.
[2]Averages are adjusted to yield

Table 3. Influence of foliar fertilizers on percent soluble solids in ripe berries.

Treatment Number and Fertilizer[1]	Harvest Date 6 June	12 June	17 June	21 June	26 June
	%				
1. Control	9.66	9.17	9.40	9.09	9.01
2. 16-4-4	9.17	9.35	8.89	8.57	8.75
3. 16-4-4	9.64	9.45	8.27	8.78	8.68
4. 16-4-4	9.16	9.79	9.25	8.83	8.80
5. 16-4-4	9.32	9.48	8.71	8.57	8.36
6. 16-4-4	9.61	9.56	9.25	9.17	9.20
7. 16-4-4	9.64	9.12	9.35	8.65	8.04
8. 16-4-4 (Soil)	9.69	9.35	9.46	8.84	8.99
9. 9-18-9	9.32	9.60	9.25	8.27	9.04
10. 9-18-9	9.38	9.50	9.20	7.92	8.32
Pr > F	.126	.813	.393	.157	.221

[1]See Materials and Methods for rates and times of application.

Table 4. Influence of foliar fertilizers on elemental concentrations in strawberry leaves (leaflets + petiole) sampled on 12 June during harvest.

Treatment Number and Fertilizer[1]	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	%					ppm				
1. Control	1.74	0.26	1.87	1.10	0.34	78	307	18	7	40
2. 16-4-4	1.94	0.27	2.25	0.86	0.31	72	327	21	8	37
3. 16-4-4	1.92	0.26	2.14	1.07	0.35	76	305	21	7	46
4. 16-4-4	1.85	0.26	2.03	0.99	0.33	72	326	19	7	39
5. 16-4-4	1.93	0.25	2.13	0.96	0.32	74	327	19	7	38
6. 16-4-4	1.82	0.26	2.13	1.04	0.34	89	304	20	7	39
7. 16-4-4	1.98	0.27	2.15	0.97	0.33	73	315	21	7	42
8. 16-4-4 (Soil)	2.12	0.25	2.16	0.96	0.33	83	368	22	7	40
9. 9-18-9	1.93	0.28	2.28	0.97	0.33	78	350	21	7	45
10. 9-18-9	1.91	0.28	2.05	1.08	0.34	79	342	20	6	40
Pr > F	.084	.111	.058	.304	.589	.029	.429	.016	.094	.678
BLSD (0.10)	0.27	--	0.28	--	--	12	--	2	1	--

[1]See Materials and Methods for rates and times of applications.

NITROGEN MANAGEMENT FOR PROCESSING SWEET CORN ON IRRIGATED COARSE-TEXTURED AND NONIRRIGATED FINE-TEXTURED SOILS -1985

C. J. ROSEN, H. J. BUCHITE AND J. B. HEBEL

Management of fertilizer nitrogen is highly dependent on soil and climatic conditions. With excessive rainfall, coarse-textured soils are subject to excessive drainage which can increase nitrate-nitrogen losses from the root zone. In fine-textured soils under these same conditions, nitrate can be lost through denitrification and/or leaching processes. Because of potential nitrogen loss during the growing season which may detrimentally affect yield and groundwater quality, the practice of sidedressing or use of nitrification inhibitors have become issues of concern for sweet corn growers. Although many studies dealing with nitrogen management have been conducted with field corn, the differences in growing season and harvested product make it difficult to extrapolate the data from these studies to processing sweet corn. The objectives of this on going study were to: 1) characterize the response of sweet corn to nitrogen when grown on a coarse-textured irrigated soil and a fine-textured nonirrigated soil, and 2) evaluate the effectiveness of split nitrogen applications and a nitrification inhibitor on sweet corn production under these contrasting conditions.

Experimental Procedures:

This experiment was conducted at two locations: Sand Plains Research Farm in Becker, MN (Hubbard Loamy Sand) and the Southern Experiment Station in Waseca, MN (Nicollet Clay Loam). Soil chemical properties before fertilizer application are listed below:

	Becker	Waseca
pH (0-6)	6.5	7.6
P (lb/A, 0-6")	73	34
K (lb/A, 0-6")	245	436
N (lb/A, 0-12")	14	20

Phosphorus and K (150 lb/A 0-14-30) were banded at Becker at planting. No supplemental P or K was provided at Waseca. There were nine treatments which included a control, 4 nitrogen rates (50, 100, 150, 200 lb N/A) 100 lb N/A plus N-serve (0.5 lb ai/A), 150 lb N/A plus N-Serve (0.5 lb ai/A), 100 lb N/A split (1/2 preplant, 1/2 6-8 leaf stage), 150 lb N/A split (1/3 preplant, 1/3 6-8 leaf stage, 1/3 12 leaf stage). All preplant nitrogen was with anhydrous ammonia. For the split treatments ammonium nitrate was used as the nitrogen source. Two hybrids, Code 5 (early maturing) and Jubilee (mid-season maturing) were planted on 30 April at Waseca and 1 May at Becker. Stands were thinned to populations of approximately 26,000. Spacing was set at 2.5 ft between rows. A split plot randomized complete block design with 4 replications was used at each location. Nitrogen treatment was the main plot and hybrid the subplot.

Whole plant samples collected at the 6-8 leaf stage (before any sidedress application) and leaf samples from opposite and above ear at mid-silking were dried and ground for total N determination. Concentrations of other nutrients were determined on leaf samples from the 100 lb N/A and 150 lb N/A treatment with and without inhibitor.

Total yield (green - ear and husk), husked yield, and stover yield were obtained by harvesting two 15 ft center rows within each plot. Subsamples of ears, husk and stover were taken to determine % moisture for nitrogen uptake calculations. The following quality measurements were also made: ear length, % moisture in kernels, and % useable ears (5.5 inches or greater with unfilled tip removed - COC eligible).

From May through July precipitation at Waseca totaled 6.9 inches and at Becker totaled 11.7 inches. Approximately 6.4 inches of water was supplied by an overhead irrigation system at Becker. Code 5 was harvested 2 August at Waseca and 5 August at Becker; Jubilee was harvested 8 August at Waseca and 12 August at Becker.

Please refer to title page of this pubication for information regarding application and use of this article.

Results were statistically analyzed by comparing means within a hybrid and by using factorial combinations for the 100 lb N/A and 150 lb N/A rate preplant with and without inhibitor and these same rates preplant and split applied.

Results and Discussion:

Becker:

Response to preplant nitrogen was apparent in both hybrids up to 200 lb N/A (Table 1). Quality factors such as ear length, and % useable ears were also improved with nitrogen rates up to 200 lb N/A. The use of inhibitor did not significantly increase yield for either variety when compared to the preplant rate without inhibitor. However, there was a trend for Code 5 to yield more with the inhibitor than without the inhibitor. No trend was observed for Jubilee. Differences in ammonium utilization by the hybrids may play a role in the inhibitor effect. Further experiments are needed to study this aspect of nitrification inhibitors. The percentage of useable ears was greater for both hybrids when inhibitor was used indicating that the inhibitor treatment improved ear fill. Split application at 100 lb N/A was inferior to the same rate preplant. Sidedressed N was applied as ammonium nitrate and several rainfall events occured 1-2 weeks after application. Most of the nitrate probably leached out of the root zone. The second sidedress of N (150 split) was apparently enough to maintain yields. However, this split application did not significantly increase yields compared to the same rate preplant. Higher nitrogen rates, use of inhibitor and split applications tended to be associated with higher moisture content of the kernals.

Nitrogen concentrations in whole plant samples collected at the 4-6 leaf stage were not affected by the various N treatments although plants from the control plot tended to be the lowest in N concentration for both hybrids (Table 2 and 3). Concentrations of N in mid-silk leaf samples increased with increasing preplant N application. Inhibitor tended to increase mid-silk leaf N concentrations while split applications had a negative effect. Concentration of N in the ears was not consistently related to treatments, although 150 split application, 200 lb N/A preplant, and inhibitor were associated with higher N concentrations. Husk and stover N concentrations followed similar trends to that of mid-silk leaf sample. Total N removal was greatest for the high N treatments. Inhibitor increased N uptake in Code 5 but had no effect on uptake by Jubilee. Split applications increased N uptake at the 150 lb N/A rate but not at the 100 lb N/A rate. The effect of inhibitor and N rate (100 and 150 lb N/A) on mid-silk leaf elemental concentrations is presented in Table 4. In general, inhibitor increased leaf N and P, and decreased leaf Mg concentrations. Increasing N rate increased leaf concentrations of N, P, Ca, Mg, Fe, Mn, Zn, and Cu.

Waseca:

Limited precipitation during June and July at Waseca had a negative effect on yield and quality of the sweetcorn. The effect was more pronounced with Code 5 compared to Jubilee. This difference was primarily due to a late July rainfall which came too late for Code 5 (early maturing) but early enough to improve yield and quality of Jubilee (midseason maturing). Increasing rates of preplant nitrogen increased yield and quality of both hybrids (Table 5). Preplant N with inhibitor had no effect on yield or quality of sweetcorn compared to the same rates without inhibitor. Because of the extremely dry conditions, this is not surprising. Split applications of N, in general, had a negetive effect on yield compared to the same preplant rates. The lack of response to the split applied N was due to lack of rainfall to transport the N to the roots. Most of the sidedressed N was on the soil surface until the end of July. Response may have occurred had the N been injected rather than applied to the soil surface.

Nitrogen concentrations in whole plant samples (6-8 leaf) were generally related to whether N had been applied at planting (Tables 6 and 7). Plants from the control plot consistently had the lowest N concentrations. Plants from plots that received at least 50 lb N/A preplant generally had similar N concentrations. Concentrations of N in leaves sampled at mid-silking increased with N applications. Inhibitor had no effect on leaf N concentrations and split applied N had a negative effect. Ear, husk, and stover N concentrations generally followed the same trend as mid-silk leaf

sample. Total N uptake by the above ground portions of the plant followed yield and rate of N application. The influence of inhibitor and N rate (100 and 150 lb N/A) on elemental concentrations in leaves sampled at mid-silking is presented in Table 8. Inhibitor had no significant effect on leaf elemental concentrations while increasing N rate increased leaf concentrations of N, Mg, Mn, and Cu.

General Comments:

These two contrasting locations clearly show how soil and climate affect N management for sweet corn production. At the Becker location (irrigated sandy soil), at least 150 lb N/A was necessary for optimum yields and quality. Split applications or inhibitor at 100 lb N/A did not approach yields and quality of higher rates. Split applications or inhibitor at 150 lb N/A had statistically similar yields to preplant 150 and 200 lb N/A. Use of inhibitor tended to increase ear fill. Conversely, no response to inhibitor and a negative response to split N applications were observed on the nonirrigated clay loam soil under dry conditions at Waseca. Response to preplant N at Waseca was much higher than expected. This may have been due to the high plant populations used coupled with the exceedingly dry soil conditions.