Table 8. Analyses of Corn Stover.

Treatment	N	P	K	Ca	Mg	Mn	Zn	B
	%					ppm		
1	1.2	.17	1.2	.20	.14	34	25	6.2
2	1.1	.16	1.2	.21	.13	33	20	5.4
3	1.2	.19	1.2	.19	.15	31	20	5.2
5	1.2	.18	1.3	.21	.15	36	21	6.6

Table 9. Soybean Leaf Analyses at Initiation of Blossom.

Treatment	S	P	K	Ca	Mg	Mn	Zn	B
	%						ppm	
4	.36	.46	2.7	1.1	.42	.01	68	54
6	.35	.46	2.8	1.0	.42	.01	56	52

Table 10. Soybean Stem Nutrient Analyses, 1986

Treatment	S	P	K	Ca	Mg	Mn	Zn	B
	%					ppm		
4	.16	.38	5.5	1.3	.47	53	34	42
6	.13	.39	5.5	1.2	.48	50	28	42

Table 11. Soybean Seed Nutrient Analyses, 1986

Treatment	S	P	K	Ca	Mg	Mn	Zn	Cu	B
	%					ppm			
4	.42	.69	2.2	.14	.27	27	34	8.5	42
6	.41	.69	2.2	.14	.27	30	54	8.2	34

Table 12. Soybean Seed Nutrient Removal, lb/A, 1986

Treatment	S	P	K	Ca	Mg	Mn	Zn	Cu	B
	lb/A								
4	12.4	20	64	4.0	7.8	.08	.17	.02	.10
6	13.1	22	69	4.3	8.5	.10	.17	.03	.11

Table 13. Yield of Soybeans, bu/A Summary.

1982	1983	1984	1985	1986	1986
47.0	47.0	37.6	36.4	49.2[1]	53.0[2]

[1] 1st year soybean following corn
[2] 2nd year soybean following corn

LUPIN BEAN STUDY

H.L. Meredith and M. Wiens[1]

Lupinus alba (white lupin) studies were initiated at the Staples Station in 1984 and these studies continue. Lupins grow best on well drained, slightly acidic soils. The plant is cold tolerant thereby allowing seeding with the earliest spring planted crops. Lupins have the potential for high yields; they are highly palatable and are high in protein.

Yields from studies conducted to date appear in Table 1.

Table 1. Ultra Lupin Yields at the Staples Station, Staples, Minnesota, 1984-86. Yields are based on 13.5 Moisture Basis and Bushel Weight of 60 lbs.

	Yield, bu/A			
Treatment	1984[2]	1985[3]	1986[3]	
			Exp. #1	Exp. #2
1. No fertilizer	39.1	71.4	40.6	32.0
2. 100# 8-32-16 [4]	39.4	64.1	41.8	37.4 [5]
3. 25# sulfur	43.2	71.2	44.0	31.7
4. 300# K_2O	40.5	63.8	40.6	43.3
5. PKS + 60# P_2O_5	39.4	68.8	39.2	40.2
6. PKS + 60# N [6]	41.5	64.9	33.8	32.8
Avg.	40.5	67.4	40.0	36.0

No significant difference in yield as a result of any fertility treatments was observed. Yield differences were attributed to population variables and weed competition, especially in 1986.

Experiment #1 is continuous lupins while Experiment #2 is rotated with a cereal crop. Long term studies are designed to determine if diseases are intensified in the continuous plot.

A Review of the 1986 Growing Season:

Lupin yields were quite disappointing in 1986 for more than one reason. We feel that we understand most of the reasons.

The fall of 1985 was considered a poor environment for development and growth of seed quality. The cool

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1 A special thanks for the assistance and interest shown by Dr. George Rehm, Brian Anderson, and Greg Cremers.

2 30-inch row spacing

3 6-inch grain drill

4 Changed to 160 # N split application in 1985, no fertilizer in 1986

5 Boron + SKPZn

6 N deleted in 1986, 10 lb. zinc (Zn) added.

(cold) wet weather prevented maturation. Normally harvest is accomplished in late August-early September. In 1985 harvest could not be initiated prior to a hard freeze in mid to late October. Even then lupins contained excessive moisture in many cases. We believe "poor" seed quality resulted even though germination testing at room temperature (90%) indicated good, viable seed. However, given the soil environment in mid April when lupins should be planted, a germination temperature more in line with soil temperatures would be more meaningful, such as 50-60°F.

Soil preparation: Sandy soils become quite "fluffy" when spring plowed. Grain drills have tension on disks to push downward only and seed depth is not uniform. The result is excessively deep seed placement. Especially where seed viability was suspect, deep placed seed likely resulted in poor populations. We believe this accounted for the poor stands experienced in 1986.

Weed competition: Lupins are poor competitors with weeds. Especially where lupin populations were low, late germinating weeds were rampant. Ragweeds and wild buckwheat were perhaps the most troublesome weeds. The year was also one of high rainfall and the excessive moisture likely played a heavy role in the premature dissipation of herbicides in the profile permitting a heavy infestation of weeds.

Flowering temperatures: Seed set occurred for the most part from the primary flowers and only partially from the secondary flowers. High temperatures during this stage prevented pod set thereby limiting yield.

Plans for 1987 to offset potential problems: Soils where lupins are to be planted will not be plowed in the spring. Soils will receive a double disking and smoothed prior to planting.

A cold temperature (50-60°F) germination test will be administered prior to planting to test seed viability. The seed quality in 1986 should be excellent owing to the near ideal weather at maturation.

Experimental plots will be seeded at a heavy rate (200 lb/A or more) to ensure uniform population. Long season herbicides are essential. To date Lasso, Dual, Prowl, and Lorox have been used on lupins with success.

Fertility response: Poor stands, severe weed competition, and high temperatures during flowering put a lid on yields. Yields of this magnitude harvested in 1986 represent less than half the potential yield for this crop. The lupin plant is a vigorous forager of plant nutrients. To date, no yield increases have been attributed to any fertilizer nutrient. Only when high yields are harvested from uniform populations free of weed competition will a nutrient response be more likely to occur.

Although yields varied from one fertilizer treatment to another, this should not be attributed to a fertility response. Population variability and weed competition likely accounted for all of the variables in yield observed.

Sulfur: Note that the sulfur concentration in the lupin bean increased rather dramatically with the addition of 25 pounds of sulfur (S) per acre. The three sulfur containing amino acids, methionine, cysteine and cystine, require adequate sulfur be available in the soil medium. From a nutritional aspect, methionine becomes the first limiting amino acid in rations containing a high proportion of lupins or soybean meal. Therefore, it is essential that sufficient sulfur be present throughout the growth of the plant, but especially during the formation of the bean. It is of interest to note that one-sixth of the methionine requirement may be replaced with cystine in studies with rats. It is likely all three amino acids are enhanced in the presence of sufficient sulfur. Casein is a standard for methionine. Soybean meal requires the addition of 0.1% supplementation with methionine, whereas lupins would require 0.3% addition of methionine to make it equivalent to casein.

Sequence of Events in 1986

4/8 - Area plowed
4/16 - Area disked and fertilizer applied
4/16 - Lupins planted @ 190 lb/A, variety ultra
4/22 - Lasso applied @ 3 pt/A
5/3 - Lupin emerging
5/28 - Leaf and petiole sampling
6/4 - Flowering begins, plants 6-10 inches tall
6/23 - Pod set begins
7/3 - Second leaf and petiole sampling
7/21 - Third leaf and petiole sampling
7/31 - First leaf drop
8/16 - Plants 21-25 inches, flowering
8/19 - 90% of pods are brown, readily shatter on contact
9/5 - Harvest (could have harvested earlier as beans were at or below 14% and shattered easily)

4/15 - 8/15 Rainfall = 17.8; supplemental irrigation = 2.8"

Weeds: Wild buckwheat, ragweed and lambsquarters.

Moisture Requirements: The lupin plant is very practical in regards to soil moisture. At flowering the plant reads the soil moisture status. If it is dry or inadequate moisture is available the plant will deliver a low pod set. Likewise, moisture stress along with temperature and/or wind stress or any combinations which trigger a perceived moisture stress will result in low pod set. Where irrigation is available it is imperative that the moisture status be monitored at least on a daily basis. Slightly excessive moisture at this stage would be in preference to any moisture stress.

In 1986 the primary pod set was excellent but the secondary pod set was essentially absent. Note that yields were decreased about 40% over the previous year. Other factors along with moisture and temperature were responsible for the low yields. But, it should be duly noted that there was little to no pod set beyond the primary stage. Ideally, a heavy primary and secondary pod set is desired. Solid stands are the best bet for ensuring that pod set occurs predominately from the primary and secondary flowering.

Excessively high temperatures are known to cause abortion/poor pod set. Generally temperatures beyond 85°F would be detrimental at flowering.

Discussion: It is noted that 2.8" of irrigation water was supplied. Table 8 lists 32 days when the maximum temperature reached 80°F or above, 17 days were 85°F or above and four days were 90°F or above.

The period May 27-31 was critical as flowering was initiated on June 4. During this five-day period no precipitation was recorded, pan evaporation was 1.85 inches of water and the relative humidity ranged from 32-37 percent, temperature maximum averaged 86.4°F. Truly a stressful period. Supplemental irrigation at this stage would be absolutely essential. When temperatures reach 85°F it would be advantages to sprinkle irrigate to cool the canopy and provide moisture for evaporation to aid in the cooling process (539 calories of heat required to vaporize one gram of water).

Table 2. Nutrient Content of Lupin Beans, Staples Station, Staples, MN 1986. Experiment #1, Continuous lupins.

Treatment	N	S	P	K	Ca	Mg	Mn	Zn	Cu	B
	%							ppm		
1	5.6	.23	.45	1.2	.26	.20	.12	38	4.0	15
2	5.5	.22	.45	1.2	.24	.19	.12	36	4.0	15
3	5.6	.28	.42	1.2	.26	.19	.12	38	4.5	14
4	5.5	.29	.41	1.3	.26	.19	.10	39	4.0	14
5	5.6	.30	.49	1.4	.26	.21	.11	36	4.2	11
6	5.6	.31	.49	1.4	.26	.21	.12	45	5.0	14

Table 3. Nutrient Content of Lupin Beans, Staples, Staples, MN 1986. Experiment #2 (1st year lupins).

Treatment	N	S	P	K	Ca	Mg	Mn	Zn	Cu	B
	%							ppm		
1	5.4	.24	.49	1.2	.26	.20	.16	45	5.7	23
2	5.5	.28	.48	1.2	.26	.20	.14	48	5.1	21
3	5.3	.28	.47	1.3	.26	.20	.13	44	4.9	18
4	5.1	.28	.51	1.3	.27	.20	.15	46	5.5	18
5	5.4	.28	.48	1.4	.24	.20	.13	49	5.3	19
6	5.4	.29	.49	1.3	.25	.20	.13	49	5.2	28

Table 4. Lupin Bean (Grain) Nutrient Removal, Staples Station, Staples, MN 1986. Experiment #1, Continuous lupin.

Treatment	N	S	P	K	Ca	Mg	Mn	Zn	Cu	B
	lb/A							ppm		
1	120	4.9	9.8	25	5.6	4.3	2.6	.08	.01	.03
2	122	4.8	10.0	26	5.4	4.3	2.7	.08	.01	.03
3	130	6.7	9.8	28	6.2	4.5	2.7	.09	.01	.03
4	120	6.2	8.9	28	5.6	4.2	2.2	.09	.01	.03
5	118	6.2	10.0	29	5.3	4.4	2.3	.07	.01	.02
6	101	5.6	8.8	25	4.6	3.7	2.1	.08	.01	.03
Avg.	118	5.7	9.6	27	5.4	4.2	2.4	.08	.01	.03
lb/bu	3.0	.14	0.24	.67	.14	.10	.06	.002	-	-
Ratio: N = X		21	12.0	4.5	21	30	50	1500		

Table 5. Lupin Bean (Grain) Nutrient Removal, Staples Station, Staples, MN 1986. Experiment #2 (1st year lupins).

Treatment	N	S	P	K	Ca	Mg	Mn	Zn	Cu	B
	lb/A							ppm		
1	91	4.0	8.2	20	4.4	3.3	2.6	.08	.01	.04
2	93	4.8	8.0	20	4.4	3.4	2.4	.08	.01	.04
3	123	6.5	11	30	6.0	4.6	3.1	.10	.01	.04
4	108	6.1	11	28	5.8	4.3	3.1	.10	.01	.04
5	94	5.0	8.3	23	4.3	3.5	2.3	.08	.01	.03
6	105	5.6	10	26	5.0	3.9	2.6	.10	.01	.05
Avg.	102	5.3	9.4	29	5.0	3.8	2.7	.09	.01	.04
lb/bu	2.8	.15	0.26	.8	.15	.10	.07	.002	-	-
Ratio: N - X		19	11	3.5	19	28	40	1400		

Table 6. Soil Test Data, Staples Station, Staples, MN 1986. Experiment #1, Continuous Lupins.

	First Sampling					Second Sampling		
Treatment	Soil Texture	Organic Matter	Soil pH	Bray P lb/A	K lb/A	Soil pH	Bray P lb/A	K lb/A
1	SL	M	7.0	79	123	6.9	70	129
2	SL	M	7.1	87	128	7.1	70	111
3	SL	M	6.9	82	110	7.0	83	128
4	SL	M	7.1	73	288	7.2	68	192
5	SL	M	7.1	111	330	7.1	96	289
6	SL	M	6.8	109	249	6.7	97	218

Table 7. Soil Test Data, Staples Station, Staples, MN 1986. Experiment #2, Continuous Lupins.

	First Sampling					Second Sampling		
Treatment	Soil Texture	Organic Matter	Soil pH	Bray P lb/A	K lb/A	Soil pH	Bray P lb/A	K lb/A
1	SL	M	6.4	72	132	6.8	69	98
2	SL	M	7.0	71	89	69	65	87
3	SL	M	6.9	90	149	6.8	90	139
4	SL	M	6.3	98	154	6.3	95	162
5	SL	M	6.7	70	171	6.8	81	160
6	SL	M	6.5	80	177	6.5	76	125

Table 8. Maximum Air Temperature (above 80°F), Pan Evaporation, Precipitation, Relative Humidity, Wind Speed and Leaf Wetness, Staples Station, Staples, MN 1986.

	May				
	27	28	29	30	31
Max. Air Temp. °F	82	82	89	89	90
Pan Evaporation Water, inches/day	.29	.27	.17	.57	55
Precipitation, inches/day	0	0	0	0	0
Relative Humidity, Minimum %	37	37	33	32	34
Wind Speed, mean, miles/hr	2.6	3.2	1.3	5.8	10.4
Leaf Wetness 0 - dry 100 - wet % of day wet	30	35	28	2	0

	June								
	3	18	19	20	21	25	26	27	28
Max. Air Temp. °F	91	85	91	83	88	89	86	80	81
Pan Evaporation Water, inches/day	.25	.21	.26	.30	.38	.28	.18	.34	.26
Precipitation, inches/day	.23	.02	0	0	1.06	0	0	0	0
Relative Humidity, Minimum %	37	66	59	75	66	56	65	32	43
Wind Speed, Mean, miles/hr	9.5	7.4	3.9	8.1	3.9	8.6	8.4	5.6	4.2
Leaf Wetness 0 - dry 100 - wet % of day wet	20	40	13	4	64	0	4	27	9

	July																	
	3	4	5	7	9	15	16	17	18	19	22	23	24	25	27	28	29	30
Max. Air Temp. °F	83	91	85	85	83	80	84	88	87	81	86	86	85	81	84	81	84	81
Pan Evaporation Water, inches/day	.38	.27	.27	.31	.25	.14	.26	.13	.37	.37	.24	.51	.02	.20	.24	.20	.24	.31
Precipitation, inches/day	.63	.11	0	0	0	.64	0	0	.99	0	0	.15	.01	0	0	.47	.06	0
Relative Humidity, Minimum %	46	55	62	38	46	70	79	68	62	52	52	66	51	40	59	72	62	45
Wind Speed, mean, miles/hr	8.9	5.8	10.8	3.5	2.3	4.5	6.5	5.8	4.4	7.8	4.3	11.4	5.2	3.5	3.8	3.4	5.4	7.0
Leaf Wetness 0 - dry 100 - wet % of day wet	29	36	5	15	44	59	42	44	50	32	28	2	27	40	50	54	36	21

Table 9. Leaf and Petiole Samples of Lupins sampled on 5/28. Staples (sampled from Exp. #1).

Treatment	P	K	Ca	Mg	Mn	Zn	Cu	B
	--------- % -------					-- ppm --		
1	.32	2.8	.89	.21	.11	13	2.4	9.5
6	.29	1.7	1.18	.26	.11	15	2.8	12

Table 10. Leaf and Petiole Samples of Lupins sampled 5/28/86, Staples (sampled from Exp. #2).

Treatment	P	K	Ca	Mg	Mn	Zn	Cu	B
	---------- % --------					---- ppm ----		
1	.29	2.8	.99	.21	.11	12	2.2	11
2	.33	1.7	1.1	.31	.12	14	2.7	13
3	.31	2.0	1.1	.27	.12	14	2.4	12
4	.34	1.9	1.2	.26	.11	18	2.9	14
5	.36	3.1	.99	.22	.11	16	2.4	11
6	.30	2.9	.97	.27	.13	14	2.6	10

Table 11. Leaf Samples of Lupins sampled 5/28/86, Staples (sampled from Exp. #2) Plants Eight Inches Tall.

Treatment	P	K	Ca	Mg	Mn	Zn	Cu	B
	--------- % -------					-- ppm --		
1	.33	1.6	1.15	.31	.12	20	3.1	27
2	.34	1.4	1.36	.37	.12	21	2.9	16
3	.38	2.0	1.02	.20	.09	19	2.9	18
4	.40	1.7	1.12	.22	.10	22	2.9	21
5	.34	2.0	.96	.24	.11	21	3.0	25
6	.37	2.0	1.09	.19	.10	20	3.1	16

Table 12. Lupin Plant Samples, Top Four Inches When Plant Eight Inches Tall. 5/28, Staples

Treatment	P	K	Ca	Mg	Mn	Zn	Cu	B
	---------- % --------					---- ppm ----		
1	.37	2.4	.85	.27	.11	26	2.7	24
2	.35	1.8	1.08	.33	.11	32	2.9	18
3	.38	2.5	.96	.19	.09	30	3.1	20
4	.44	2.4	.93	.22	.10	30	2.9	18
5	.39	3.1	.82	.23	.11	26	3.3	20
6	.44	2.1	.93	.19	.11	26	3.3	20

TRITICALE - RYE STUDY

H. Meredith and M. Weins

Triticale is a synthetic grain derived from durum wheat x rye. Although the crop has been around for sometime, only recently has the crop received new emphasis.

New varieties have been released and this study is intended to evaluate these varieties. Three new winter varieties were planted in the fall of 1986 and one new spring variety will be planted in 1987. Additionally a new rye variety was planted in the fall of 1986 and this variety will be evaluated against the triticale varieties.

The data below lists limited data on the varieties harvested in 1986 at the Staples Station, Staples, MN.

Table 1. Composition of Whole Plant Harvested on 5/28/86 Just Prior to Heading.

Variety	N	S	P	K	Ca	Mg	Mn	Zn	Cu	B
	%						ppm			
Rymin Rye	2.2	.17	.30	2.7	.33	.16	47	28	2.2	3.8
Triticale I-18	2.4	.18	.35	3.3	.38	.13	73	30	2.1	3.0
Triticale 239	2.3	.20	.37	3.5	.36	.14	80	34	2.4	3.4
T-Double Crop	2.2	.19	.35	3.4	.40	.14	80	35	2.4	3.1

Table 2. Flag Leaf Harvested on 5/28/86 Just Prior to Heading.

Variety	P	K	Ca	Mg	Mn	Zn	Cu	B
	%				ppm			
Rymin Rye	.27	1.6	-	.23	55	19	2.4	-
Triticale I-18	.33	2.3	-	.15	61	29	2.2	4.8
Triticale 239	.34	2.3	.29	.14	52	34	2.5	6.5
T-Double Crop	.40	2.4	.23	.14	46	43	3.0	5.2

Table 3. Composition of Whole Plant at Forage Harvest.

Variety	N	S	P	K	Ca	Mg	Mn	Zn	Cu	B
	%						ppm			
Rymin Rye	1.2	.10	.22	2.0	.24	.13	25	14	5	4
Triticale I-18	1.5	.10	.22	2.2	.25	.12	40	24	5	4
Triticale 239	1.4	.10	.23	2.3	.21	.12	37	26	6	4
T-Double Crop	1.5	.10	.25	2.5	.26	.12	42	36	6	5

Table 4. Yield of Rye and Triticale, Grain and Forage.

Variety	Bu/A	Tons/A (DM)
Rymin Rye	53.8[1]	3.22
Triticale I-18	59.3[2]	2.72
Triticale 239	39.2[2]	2.91
Triticale Double Crop	30.1[1]	2.87
Spring Triticale	34.2[2]	-

[1] Average of 2 replications

[2] Average of 3 replications

Table 5. Composition of Triticale and Rye Grain

Variety	N	S	P	K	Ca	Mg	Mn	Zn	Cu	B
	%						ppm			
Rymin Rye	2.1	.16	.46	.58	.53	.17	52	51	1.3	1.2
Triticale I-18	2.0	.16	.46	.60	.60	.18	63	52	1.7	1.2
Triticale 239	2.3	.17	.48	.62	.62	.19	63	59	1.8	1.1
T-Double Crop	2.4	.17	.47	.62	.64	.18	69	63	1.9	1.2
Spring Triticale	2.5	.18	.55	.68	.62	.21	70	63	1.5	1.6

Table 6. Composition of Triticale and Rye Straw After Harvest.

Variety	N	S	P	K	Ca	Mg	Mn	Zn	Cu	B
	%						ppm			
Rymin Rye	.33	.08	.07	1.2	.21	.04	42	14	1.1	1.6
Triticale I-18	.67	.09	.10	1.0	.23	.06	30	16	1.6	1.7
Triticale 239	.43	.08	.10	1.2	.20	.06	44	16	1.2	1.9
T-Double Crop	.61	.09	.15	1.4	.24	.07	45	23	1.3	1.8
T-Spring	.35	.08	.10	1.4	.18	.04	39	10	1.3	1.4

SOUTHERN EXPERIMENT STATION
WASECA, MINNESOTA

WEATHER DATA - 1986

Month	Period	Precipitation 1986	Precipitation Normal 1/	Avg. Air Temp. 1986	Avg. Air Temp. Normal 1/	Growing Degree Days 1986	Growing Degree Days Normal 1/
		---- inches ----		------ °F -----			
January	1-31	0.89	0.84	14.5	10.0		
February	1-28	0.52	0.99	13.4	16.4		
March	1-31	2.18	1.99	31.4	27.6		
April	1-30	4.13	2.64	48.4	44.7		
May	1-10	0.95		56.4		97.5	
	11-20	2.04		56.4		84.5	
	21-31	0.77		62.2		145.5	
	Total	3.76	3.76	58.4	57.7	327.5	334
June	1-10	0.91		66.5		165.0	
	11-20	1.77		68.8		186.5	
	20-30	5.21		70.9		204.0	
	Total	7.89	4.48	68.7	67.1	555.5	518
July	1-10	1.51		69.8		196.0	
	11-20	1.87		72.9		222.5	
	21-31	0.52		72.9		251.5	
	Total	3.90	4.02	71.9	71.2	670.0	641
August	1-10	0.11		67.2		173.5	
	11-20	0.40		66.6		170.0	
	21-31	1.90		61.2		136.5	
	Total	2.41	3.99	64.9	68.8	480.0	579
September	1-30	5.57	3.36	59.8	59.8	340.5	311
October	1-31	2.83	2.08	48.3	48.9	37.0	38
November	1-30	1.42	1.43	25.6	32.5		
December	1-31	0.35	1.02	21.6	18.0		
Year	Jan-Dec	35.85	30.60	44.1	43.6	2410.5 2/	2421
Growing Season	May-Sep	23.53	19.61	64.7	64.9	2373.5	2383

1/ 30-year normal from 1951 - 1980.
2/ 50 to 86°F base, May 1 until first fall frost.

Notes:
1) Highest temperature on June 20 and July 19 -- 92°.
2) Highest 24-hour precipitation on June 21 -- 2.46".
3) Highest 48-hour precipitation on June 21-22 -- 4.64".
4) Last spring frost -- April 22.
5) First fall frost -- October 6.

ROTATION NITROGEN STUDY

Waseca, 1986

G. W. Randall, P. L. Kelly, and M. P. Russelle

Increasing the efficiency of fertilizer N along with fine-tuning fertilizer N recommendations by improved diagnostic techniques, symbiotic N fixation, crop rotation, etc. are goals which are gaining widespread research support throughout the United States. The adoption of crop rotations or sequences may play a vital role in the conservation of N. The purpose of this study is to determine the N needs of continuous corn (removed for grain), corn removed for silage, second year corn following soybeans, corn following soybeans, and corn following wheat.

EXPERIMENTAL PROCEDURES

Four crop sequences (continuous corn, corn-soybean, corn-wheat, and corn-wheat + alfalfa) were begun in 1974 on a Webster clay loam. Each N plot within each crop sequence is 15' wide (6 rows) by 50' long. Rates of N (0, 40, 80, 120, 160, and 200 lb N/A) have been applied annually to corn.

The corn-wheat + alfalfa sequence was dropped in 1981 in favor of a continuous corn system where all of the corn was removed as silage the preceding year. This gives us a comparison of the N needs between grain removal only compared to total above-ground biomass removal. In 1982, a C-C-Sb rotation was introduced to examine the N needs of second-year corn following soybeans. All plots are replicated five times in a split-split plot design with crop sequences as the main plot, which is split into six N rates with each N plot split into two corn hybrids.

In 1986, anhydrous ammonia was applied on April 23 to all corn plots. All plots were moldboard plowed in the fall of 1985 and field cultivated on April 25, 1986.

Each corn plot was split lengthwise and two corn hybrids (Pioneer 3732 and Pioneer 3906) were planted in 30" rows at 30800 ppA on May 3. Counter was applied to all corn plots at 1 lb/A to control rootworms. Weeds were chemically controlled along with one cultivation of the corn. A combination of 3½ qt Lasso plus 3½ lb Bladex/A was applied preemergence to corn. No starter fertilizer or broadcast P and K was used because of high soil test P and K levels.

Corn leaf samples were taken at silking from rows 2 and 3 (Hybrid A) and from rows 4 and 5 (Hybrid B) of each 6-row plot. Corn yields were taken by mechanically harvesting the same rows. Grain moisture and grain N data were obtained on the harvested samples.

After the 1985 harvest and again in the spring of 1986 prior to N application, soil samples were taken to a depth of 5' from the 0 and 160-lb N treatments which were applied to the continuous corn (grain) and continuous corn (silage) rotations. Soil samples were also taken from the 0-lb N treatments in the plots where soybeans and wheat were the 1985 crops. Two cores were taken/plot, divided into 1-foot increments, composited/rep, dried, crushed, and analyzed for NO_3-N by the University of Minnesota Soil Testing Laboratory.

RESULTS

Nitrate-N levels remaining in the soil profile after the 1985 crop, which was available to the 1986 corn, are presented in Table 1. When no fertilizer N was applied in 1985 (except the blanket 50-lb rate to wheat) very little difference in residual NO_3-N remaining in October appeared among the five crop sequences.

Samples taken from these 0-N plots the following spring showed marked decreases (33 to 58%) in NO_3-N compared to the fall sampling except following soybeans where NO_3 levels were reduced by only 22%. From 40 to 75% of the residual NO_3-N was found in the top foot of the 5-foot profile with all four crops. When the 160-lb rate of N was applied to continuous corn (grain and silage), a significant amount of residual N was found throughout the 5-foot profile in the fall. Samples taken the following April from these same plots showed approximately a 20% decline in NO_3-N throughout the profile. Reasons for these decreases are thought to be due to either denitrification or leaching.

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

Table 1. Effect of N rate applied to corn and crop sequence on residual NO_3-N remaining in the 0-5' profile in the fall of 1985 and at the beginning of the 1986 growing season.

	October, 1985				April 1, 1986			
	1985 Crop							
Profile depth	Corn (grain)	Corn (silage)	Soybeans	Wheat	Corn (grain)	Corn (silage)	Soybeans	Wheat
feet	lb NO_3-N/foot							
	0 lb N/A							
0-1	19	21	24	17	20	17	21	20
1-2	2	10	14	12	6	1	12	6
2-3	8	7	13	10	1	1	8	5
3-4	7	5	8	8	1	2	7	3
4-5	7	9	9	8	2	1	5	3
Total(lb NO_3-N/5')	53	52	68	55	30	22	53	37
	160 lb N/A							
0-1	27	23			24	23		
1-2	27	18			17	15		
2-3	24	19			19	19		
3-4	20	18			13	17		
4-5	21	19			15	12		
Total(lb NO_3-N/5')	119	97			88	86		

Corn grain yield, leaf N, grain N, grain N removed, and grain moisture at harvest are shown in Table 2 for each of the treatments. All data are an average of five replications. Averages and statistical interpretations for each of the main factors and the two-way interactions are shown in Table 3.

Grain yield

Corn yields were excellent in 1986 considering the moisture stress encountered from mid-July until mid-August. As in previous years crop sequence had a substantial effect on corn yield. Yields following soybeans or wheat were significantly higher (18 to 35 bu/A) than when following continuous corn (either for grain or silage) when averaged over N rates and hybrids. Second year corn yields following soybeans were not different from continuous corn. When averaged over N rates and hybrids, corn yields following soybeans were significantly higher than when following wheat. Yields were economically maximized with the 200-lb N rate when averaged over crop sequence and hybrids; however, the sequence x N rate interaction was highly significant. Yields from the two hybrids were identical when averaged over sequence and N rates.

Closer examination of the interactions reveals additional information. The sequence x N rate interaction was highly significant (P = 99% level) when averaged across hybrids. For the CC(g), CC(s), C-Sb, C-W, and Sb-C-C systems, highest yields were obtained statistically at the 160, 160, 120, 120, and 160-lb N rates, respectively, and were economically maximized at the 200, 200, 200, 160, and 200-lb rates, respectively. Yield responses of 84.7, 92.5, 72.0, 90.1, and 96.6 bu/A were obtained with the maximum economic rate of N for each of the respective crop sequences. Yields with the 0-lb N rate were lowest with the CC(g), CC(s) and Sb-C-C systems, intermediate with the C-W system, and highest with the C-Sb system. These data indicate that the higher amounts of plant residue incorporated from the 1985 CC(g) and Sb-C-C systems probably immobilized greater amounts of N than from the lower residue crop systems. Also, corn yield responses in all crop sequences to N rates of either 160 or 200 lb/A is not consistent with past years and indicates that the very wet June may have caused losses of fertilizer N.

Similar to 1985, the sequence x hybrid interaction was not significant indicating that the two hybrids behaved identically across all sequences. On the other hand, a significant N rate x hybrid interaction was found. At the 0- and 40-lb N rates, P3732 yields were 4.9 and 3.9 bu/A higher, respectively, than P3906. Yields were identical between the two hybrids at the 80-, 120- and 160-lb rates. At the 200-lb rate P3906 yielded 4.0 bu/A better than P3732 when averaged over sequences. No three-factor interaction was found.

Corn yield responses to N with each of the sequences did not appear to show any consistent relationship to the residual soil NO_3-N levels shown in Table 1. This is consistent with past years.

Table 2. Corn grain yield, leaf N, grain N, grain N removed, and grain moisture as influenced by previous crop, N rate and hybrid at Waseca, 1986.

Previous Crop	Hybrid	N rate (lb/A) 0	40	80	120	160	200
		Yield (bu/A)					
Cont. Corn (grain)	3906	68.3	94.4	112.1	131.7	148.8	160.0
	3732	75.8	97.8	111.8	135.6	153.0	153.6
Cont. Corn (silage)	3906	69.2	93.7	118.5	147.3	148.2	170.6
	3732	76.8	96.7	115.9	141.8	144.4	160.5
Soybeans	3906	108.0	134.2	147.8	166.0	174.1	177.7
	3732	106.0	141.8	145.8	169.0	175.0	180.3
Wheat	3906	80.7	111.1	143.4	169.4	170.3	172.3
	3732	85.3	111.9	141.5	165.0	174.1	174.0
Corn after soybeans	3906	56.4	84.1	104.9	139.8	153.1	160.6
	3732	63.2	89.1	110.9	138.3	148.1	152.3
		Leaf N (%)					
Cont. Corn (grain)	3906	1.30	1.39	1.77	2.07	2.27	2.42
	3732	1.33	1.48	1.77	2.20	2.54	2.62
Cont. Corn (silage)	3906	1.30	1.49	1.68	2.30	2.51	2.51
	3732	1.29	1.51	1.78	2.21	2.38	2.67
Soybeans	3906	1.45	1.84	2.28	2.63	2.57	2.84
	3732	1.55	2.01	2.27	2.62	2.73	2.80
Wheat	3906	1.34	1.76	2.07	2.35	2.74	2.65
	3732	1.43	1.67	2.07	2.65	2.75	2.89
Corn after soybeans	3906	1.16	1.38	1.60	2.12	2.43	2.60
	3732	1.18	1.41	1.81	2.29	2.34	2.66
		Grain N (%)					
Cont. Corn (grain)	3906	1.20	1.14	1.21	1.25	1.32	1.46
	3732	1.07	.96	1.01	1.09	1.18	1.25
Cont. Corn (silage)	3906	1.14	1.14	1.16	1.29	1.29	1.39
	3732	1.00	.96	.96	1.07	1.14	1.23
Soybeans	3906	1.13	1.19	1.22	1.33	1.36	1.49
	3732	.96	1.00	1.07	1.23	1.23	1.30
Wheat	3906	1.13	1.10	1.16	1.31	1.37	1.43
	3732	.96	.97	1.04	1.14	1.21	1.32
Corn after soybeans	3906	1.14	1.10	1.10	1.25	1.29	1.46
	3732	.97	.91	.97	1.08	1.13	1.24
		Grain N Removed (lb/A)					
Cont. Corn (grain)	3906	38.8	51.1	64.6	78.2	93.1	109.9
	3732	38.7	44.6	53.5	70.5	85.0	90.6
Cont. Corn (silage)	3906	37.2	50.4	65.0	90.1	90.7	112.2
	3732	36.7	44.0	52.6	71.8	78.0	93.2
Soybeans	3906	58.3	76.0	85.5	104.6	112.1	125.1
	3732	48.2	67.7	74.0	98.9	102.2	110.3
Wheat	3906	43.0	57.8	78.4	105.3	110.7	116.7
	3732	38.7	51.2	69.3	88.9	99.3	108.2
Corn after soybeans	3906	30.4	43.8	54.6	82.8	93.5	110.7
	3732	29.1	38.5	51.2	70.7	79.2	89.5
		Grain Moisture (%)					
Cont. Corn (grain)	3906	23.6	22.9	22.9	22.1	21.3	21.4
	3732	28.6	26.0	24.6	23.3	22.5	22.8
Cont. Corn (silage)	3906	24.0	23.2	22.8	22.1	21.9	21.4
	3732	28.9	26.1	25.1	24.1	23.3	22.8
Soybeans	3906	23.2	22.8	22.2	22.0	21.9	21.6
	3732	26.3	24.9	23.7	22.0	23.4	22.7
Wheat	3906	24.5	23.3	22.6	22.5	22.0	22.3
	3732	27.7	26.2	23.9	23.1	22.7	23.6
Corn after soybeans	3906	23.8	23.4	23.1	22.3	21.8	21.1
	3732	28.1	26.0	24.2	23.2	22.7	22.0

Table 3. Main factor and two-factor interaction averages for corn yield, grain moisture, grain N, grain N removal and leaf N in 1986.

Source		Grain Yield	Grain Moisture	Grain N	Grain N removed	Leaf N
		bu/A	------- %	--------	lb/A	%
MAIN FACTORS						
Sequence						
Cont. corn (grain)		120.2	23.5	1.18	68.2	1.93
Cont. corn (silage)		123.6	23.8	1.15	68.5	1.97
Sb-C		152.1	23.1	1.21	88.6	2.30
Wht-C		141.6	23.7	1.18	80.6	2.20
Sb-C-C*		116.7	23.5	1.14	64.5	1.91
Signif. Level (%):		99	55	96	99	99
BLSD (.05) :		7.9	--	.05	6.6	.10
N Rate (lb/A)						
0		79.0	25.9	1.07	39.9	1.33
40		105.5	24.5	1.05	52.5	1.59
80		125.3	23.5	1.09	64.9	1.91
120		150.4	22.8	1.21	86.2	2.34
160		158.9	22.4	1.25	94.4	2.53
200		166.2	22.2	1.36	106.6	2.67
Signif. Level (%):		99	99	99	99	99
BLSD (.05) :		4.8	0.3	0.03	2.9	0.08
Hybrid						
P 3906		130.6	22.5	1.25	79.0	2.03
P 3732		131.2	24.5	1.09	69.1	2.10
Signif. Level (%):		51	99	99	99	99
INTERACTIONS						
Sequence x N Rate						
CC(g)	0	72.1	26.1	1.13	38.7	1.32
	40	96.1	24.5	1.05	47.9	1.43
	80	111.9	23.8	1.11	59.1	1.77
	120	133.6	22.7	1.17	74.3	2.13
	160	150.9	21.9	1.25	89.1	2.40
	200	156.8	22.1	1.35	100.3	2.52
CC(s)	0	73.0	26.4	1.07	36.9	1.30
	40	95.2	24.7	1.05	47.2	1.50
	80	117.2	24.0	1.06	58.8	1.73
	120	144.6	23.1	1.18	81.0	2.26
	160	146.3	22.6	1.21	84.4	2.45
	200	165.5	22.1	1.31	102.7	2.59
Sb-C	0	107.0	24.8	1.04	53.2	1.50
	40	138.0	23.8	1.10	71.8	1.92
	80	146.8	22.9	1.15	79.7	2.28
	120	167.5	22.5	1.28	101.8	2.62
	160	174.6	22.7	1.30	107.2	2.65
	200	179.0	22.2	1.39	117.7	2.82
Wht-C	0	83.0	26.1	1.04	40.8	1.38
	40	111.5	24.7	1.03	54.5	1.72
	80	142.5	23.2	1.10	73.9	2.07
	120	167.2	22.8	1.23	97.1	2.50
	160	172.2	22.4	1.29	105.0	2.74
	200	173.1	22.9	1.37	112.4	2.77

Source		Yield	Grain Moisture	N	Grain N removed	Leaf N
		bu/A	------- % --------		lb/A	%
Sb-C-C*	0	59.8	25.9	1.05	29.7	1.17
	40	86.6	24.7	1.00	41.2	1.39
	80	107.9	23.6	1.04	52.9	1.71
	120	139.1	22.7	1.17	76.7	2.20
	160	150.6	22.2	1.21	86.4	2.38
	200	156.4	21.6	1.35	100.1	2.63
Signif. Level (%):		99	90	94	96	69
BLSD (.05) :		15.6	--	--	10.4	--
BLSD (.10) :		13.2	1.1	0.09	8.8	--
Sequence x Hybrid						
CC(g)	3906	119.2	22.4	1.26	72.6	1.87
	3732	121.2	24.6	1.09	63.8	1.99
CC(s)	3906	124.6	22.6	1.23	74.3	1.97
	3732	122.7	25.0	1.06	62.7	1.97
Sb-C	3906	151.3	22.3	1.29	93.6	2.27
	3732	153.0	24.0	1.13	83.6	2.33
Wht-C	3906	141.2	22.9	1.25	85.3	2.15
	3732	141.9	24.5	1.10	75.9	2.24
Sb-C-C*	3906	116.5	22.6	1.22	69.3	1.88
	3732	117.0	24.4	1.05	59.7	1.95
Signif. Level (%):		34	94	40	23	59
BLSD (.10) :		--	0.3	--	--	--
N rate x Hybrid						
0	3606	76.5	23.8	1.15	41.5	1.31
	3732	81.4	27.9	.99	38.3	1.36
40	3906	103.5	23.1	1.13	55.8	1.57
	3732	107.4	25.8	.96	49.2	1.61
80	3906	125.3	22.7	1.17	69.6	1.88
	3732	125.2	24.3	1.01	60.1	1.94
120	3906	150.8	22.2	1.29	92.2	2.29
	3732	150.0	23.3	1.12	80.1	2.39
160	3906	158.9	21.8	1.33	100.0	2.50
	3732	158.9	22.9	1.18	88.7	2.55
200	2906	168.2	21.6	1.44	114.9	2.61
	3732	164.2	22.8	1.27	98.4	2.73
Signif. Level (%):		96	99	23	99	28
BLSD (.05) :		4.2	0.5	--	3.2	--
Seq. x N rate x Hybrid						
Signif. Level (%):		29	4	39	74	90
BLSD (.10) :						.25
CV (%) :		5.8	3.8	4.8	8.0	7.7

* = Position in sequence for which measurements taken.

In summary, corn yields (averaged over hybrids) from the 200-lb rate were approximately 9% higher when following either soybeans or wheat compared to continuous corn (grain or silage). This advantage was slightly below the advantages shown in previous dry years. Also, contrary to reports from Purdue University, P3732 continued to respond to increasing N rates to 200 lb N/A. This same N rate also maximized the P3906 yield when averaged over sequences.

Grain Moisture

Grain moisture at harvest was unaffected by crop sequence but was reduced significantly by each N rate up through 160 lb/A. The shorter season hybrid (P3906) had significantly less moisture.

Interactions between crop sequence and N rate or hybrid were not significant at the 95% level. The highly significant interaction between N rate and hybrid was due to the greater difference in grain moisture betwwen the two hybrids at the low N rates (4.1 and 2.7 points at the 0 and 40-lb rates, respectively) compared to a 1.1 point difference at N rates ≥120 lb/A.

Grain N

Grain N concentrations were influenced by the crop sequence when averaged over N rates and hybrids. Highest N concentrations were found when corn followed soybeans while lowest levels occurred with second year corn after soybeans and CC(s). Grain N concentrations were increased by N rates up through 200 lb/A. The P3906 hybrid averaged 0.16% higher grain N or 1.0% higher protein than P3732 when averaged over sequence and N rate. The significant sequence by N rate interaction was due to the higher concentrations of N at N rates of ≥120 lb/A when corn followed soybeans or wheat compared to corn. At the low N rates, grain N concentrations were quite similar among the crop sequences except for CC(g) at the 0-lb rate. Interactions between sequence and hybrid and between N rate and hybrid were not found.

Grain N removed

Nitrogen removed in the grain crop was closely associated with both grain yield and grain N concentration. Highest grain N removal was when soybeans or wheat was the previous crop, when the 200-lb N rate was applied, and when P3906 was grown.

Nitrogen efficiency, as measured by grain N removed divided by fertilizer application rate, averaged 32, 30, 40, 47 and 35% for the N rates giving the highest yields (statistically) for the CC(g), CC(s), C-Sb, C-W, and Sb-C-C sequences, respectively. At the N rates where yields were maximized economically, the efficiency values were 31, 33, 32, 45, and 35%, respectively. Similar to 1985, N efficiency was highest in the corn-wheat sequence.

Leaf N

Concentrations in the earleaf at silking were significantly higher when corn followed either soybeans or wheat compared to following corn when averaged over N rates and hybrids. Leaf N was increased up through the 200-lb N rate when averaged over sequences and hybrids. Pioneer 3732 contained slightly more N in the earleaf than did P3906. Interactions among sequence, rate and hybrid were not significant (P = 95% level).

Silage production

Measurements were taken from the CC(s) crop sequence to determine fodder yield, fodder N concentration, fodder N uptake, silage yield, and total N uptake. Data shown in Table 4 indicate a significant effect of N up through the 120-lb rate on fodder yield. Similar to previous years, fodder yield of P3732 was significantly greater than P3906. The interaction between N rate and hybrid (P = 94% level) for fodder yield was due to P3906 responding to N rates up through 120 lb/A while P3732 only responded up through 80 lb/A. Fodder N concentration was maximized at the 200-lb rate and contrary to 1985 was significantly higher for P3732. Fodder N uptake was highest at the 200-lb N rate with an advantage for P3732 compared to P3906. The significant interaction between N rate and hybrid for fodder N concentration and uptake can be explained by P3906 maximizing both N concentration and uptake at the 120-lb rate while P3732 maximized both at the 200-lb rate.

Silage yields were increased significantly by N rates up through 160 lb/A and by the P3732 hybrid. Total N removed in the silage was increased with increasing N rates up through 200 lb/A. Equal amounts of N were removed by both hybrids. N efficiency with both hybrids fertilized at the 200-lb rate was 46%.

Summary - 1986

Corn grain yields averaged about 9% higher when corn followed either soybeans or wheat compared to continuous corn (grain or silage). Highest yields with minimum N input were found when corn followed either soybeans or wheat and were maximized at the 120-lb N rate. Yields with both P3732 and P3906 were maximized at the 160-lb N rate with the CC(g), CC(s), and Sb-C-C crop sequences. Grain N concentrations and grain N removal were significantly higher with the P3906 hybrid. Leaf N at silking was maximized at between 2.54% and 2.82% with the 200-lb rate for all crop sequences.

Table 4. Silage production as influenced by N rate and hybrid in a silage corn rotation at Waseca, 1986.

N rate	Hybrid	Fodder Yield	Fodder N	Fodder N Uptake	Silage Yield	Silage N Removal
lb/A		T DM/A	%	lb N/A	T DM/A	lb N/A
0	3906	1.55	.41	12.5	3.36	49.8
	3732	1.82	.42	15.2	3.86	53.6
40	3906	1.98	.34	13.3	4.48	63.9
	3732	2.44	.38	18.4	4.93	61.3
80	3906	2.35	.38	17.9	5.44	82.6
	3732	3.19	.38	24.3	6.41	82.2
120	3906	2.83	.42	23.6	6.53	106.7
	3732	3.18	.46	29.4	6.89	103.0
160	3906	2.90	.44	25.8	7.06	127.9
	3732	3.31	.44	29.5	7.64	127.6
200	3906	2.99	.45	26.9	7.29	142.0
	3732	3.39	.58	39.5	7.79	145.4
MAIN FACTORS						
N rate (lb/A)						
0		1.69	.41	13.9	3.66	51.7
40		2.21	.36	15.8	4.71	62.6
80		2.77	.38	21.1	5.93	82.4
120		3.01	.44	26.5	6.71	104.8
160		3.11	.44	27.6	7.35	127.8
200		3.19	.51	33.2	7.54	143.7
Signif. Level (%)[1/] :		99	99	99	99	99
BLSD (.05) :		.21	.04	3.0	.39	7.2
Hybrid						
3906		2.43	.40	20.0	5.69	95.5
3732		2.89	.44	26.0	6.27	95.5
Signif. Level (%)[1/] :		99	99	99	99	2
INTERACTION			Significance Level (%)[1/]			
N rate x Hybrid		94	99	97	55	11
CV (%) :		7.5	9.	14.	5.7	8.9

[1/] Probability level of significance

TWELVE-YEAR YIELD SUMMARY

Average corn yields over this 12-year period have been optimized with 175, 140, and 140 lb N/A for the continuous corn, corn-soybean, and corn-wheat sequences, respectively. At these N rates, yields for corn following soybeans and wheat where 15 and 13% higher than for continuous corn.

Table 5. Effect of previous crop on corn response to N from 1975-86 at Waseca.

N rate	Previous Crop: Corn(g)	Soybeans	Wheat
lb N/A	bu/A		
0	75	109	104
40	100	134	130
80	115	146	147
120	125	153	151
160	133	158	154
200	136	158	156

SPLIT APPLICATION OF N FOR CORN ON A WEBSTER SOIL

Waseca, 1986

G. W. Randall and P. L. Kelly

Improved nitrogen (N) efficiency is a goal of many corn producers because of the enhanced economic return to their fertilizer dollar. One potential method of improving the efficiency of N is to apply it closer to the period of greatest demand by the plant. For corn this is the period from three weeks prior to three weeks after tasseling. Applying N closer to this period limits the potential for N loss due to leaching or denitrification. Split applications of N have been shown to be quite beneficial on coarse-textured soils where leaching losses are common. The primary purpose of this study was to evaluate split applications of N to a naturally, poorly drained Webster clay loam where leaching is thought not to be a problem.

EXPERIMENTAL PROCEDURES

A poorly drained Webster clay loam soil with lateral tile lines at 75-foot spacings was the experimental site. Corn, which had been fall moldboard plowed, was the previous crop. Soil tests of the site showed a pH = 6.9, OM = High, Bray P_1 = 58 lb/A (VH), and exchangeable K = 358 lb/A (VH).

Sixteen N treatments were applied in a randomized, complete-block design with five replications (Table 1). Each plot measured 10' wide (4 - 30" rows) by 60' long. Split treatments consisted of either a 1/3-rate applied preplant with the remaining 2/3 sidedressed or 2/3 applied preplant and 1/3 sidedressed. Preplant treatments of anhydrous ammonia (AA) and urea-ammonium nitrate solution (UAN) were applied on April 24 and May 5, respectively. Anhydrous ammonia was injected while the UAN was broadcast applied on the soil surface. Immediately after UAN application, the entire experimental area was field cultivated.

Corn (Pioneer 3906) was planted at 30400 ppA on May 7. No starter fertilizer was used. Counter was used at a rate of 1 lb(ai)/A to control rootworms. Weeds were chemically controlled with a preemergence application of Lasso (3½ qt/A) plus Atrazine (3 qt/A). Rootworm and weed control were excellent.

The sidedress portions of the split treatments were applied at the 8-leaf stage (June 19). The AA was injected while the UAN was applied either in bands to the soil surface 6" from the row using a bicycle sprayer with no. 55 orifices or injected 4 to 5" deep using Yetter coulters and thin-profile knives. All plots were cultivated on the following day to incorporate the surface-applied UAN. On June 21 and 22, 2.46 and 2.18 inches of rain, respectively, fell to completely saturate the plots for a 7 to 10-day period.

Five randomly selected whole plants were harvested from the center two rows at the silk initiation stage (July 18 for the 60, 120 and 180-lb N rates and July 21 for the 0-lb rate), were chopped, dried and weighed for dry matter accumulation, and were analyzed for total N concentration. Stover and silage yields were obtained at physiological maturity (PM) (Sept. 8) by hand harvesting 15' of row. Grain yields were determined on October 1 by harvesting the center two rows with a modified JD3300 plot combine. Chemical analyses of the whole plants, stover, and grain were performed by the Research Analytical Laboratory, University of Minnesota.

RESULTS

Whole plant N at silking

Severe N deficiency symptoms were very apparent for the lower N rates at the silking stage. Whole plant N concentrations given in Table 1 show all N treatments with significantly more N than the control. Factorial comparisions of the treatments show a linear response to N rate when averaged over source-time of application. When averaged over N rates significantly less whole plant N was found with the preplant AA and the split applications of 1/3 + 2/3 UAN and 2/3 AA + 1/3 UAN treatments compared to the 1/3 UAN + 2/3 AA treatment.

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Whole plant dry matter at silking

Total dry matter accumulation at silking was increased significantly over the control by all N treatments (Table 1). Factorial comparison of the treatments shows a linear response to N rate when averaged over method of application. Highest DM accumulation occurred with the preplant AA and the 2/3 AA + 1/3 UAN split treatments. These two treatments also showed the lowest N concentrations, probably a result of plant dilution.

Table 1. Whole plant N, stover N, stover yield, and final population as influenced by split applications of N.

Nitrogen			Whole plant at silk		Stover		Final
Rate	Time[1/]	Source[2/]	N	DM	N	Yield	population
lbN/A			%	g/pl	%	TDM/A	ppA x 10^3
0	--	CHECK --	.68	73	.39	1.65	26.5
60	PP	AA	.95	95	.36	2.28	27.2
120	"	"	1.27	98	.42	2.56	28.9
180	"	"	1.37	99	.47	2.95	30.7
60	1/3PP+2/3SD	UAN(PP)+AA(SD)	1.26	89	.39	2.11	27.6
120	"	"	1.36	88	.42	2.30	28.3
180	"	"	1.48	89	.49	2.47	27.3
60	"	UAN(PP)+UAN(Drib.SD)	1.04	88	.36	2.09	27.8
120	"	"	1.26	92	.36	2.26	27.1
180	"	"	1.42	95	.42	2.75	28.4
60	"	UAN(PP)+UAN(Inj.SD)	1.11	85	.33	2.08	26.6
120	"	"	1.36	89	.40	2.46	27.7
180	"	"	1.38	98	.42	2.46	27.7
60	2/3PP+1/3SD	AA(PP)+UAN(Drib.SD)	1.06	91	.38	2.60	27.6
120	"	"	1.27	95	.40	2.54	28.6
180	"	"	1.37	102	.41	2.65	28.9
Signif. Level (%):[3/]			99	99	99	99	99
BLSD (.05) :			.10	7	.06	.28	1.1
CV (%) :			6.5	5.9	11.	8.6	2.9
FACTORIAL COMPARISONS							
Main Factors							
N Rate (lb/A)							
60			1.08	90	.37	2.23	27.4
120			1.30	92	.40	2.42	28.1
180			1.40	97	.44	2.65	28.6
Signif. Level (%):[3/]			99	99	99	99	99
BLSD (.05) :			.05	3	.02	.12	.47
Method (N Time-Source)							
PP - AA			1.20	97	.42	2.60	28.9
PP/SD - UAN/AA			1.37	88	.44	2.29	27.7
PP/SD - UAN/UAN (Dribble)			1.24	92	.38	2.37	27.8
PP/SD - UAN/UAN (Inject)			1.28	91	.38	2.33	27.3
PP/SD - AA/UAN (Dribble)			1.23	96	.40	2.60	28.4
Signif. Level (%):[3/]			99	99	99	99	99
BLSD (.05) :			.06	5	.04	.17	.63
Interaction			Significance Level (%)[3/]				
N Rate x Method			90	49	58	94	99

1/ PP = preplant, SD = sidedress applied at the 8-leaf stage.
2/ AA = anhydrous ammonia, UAN = 28-0-0, Inj = injected 4 to 5" deep, Drib = dribbled in a band next to row.
3/ Probability level of significance.

Stover N

Nitrogen concentrations in the stover at PM were increased linearly by the N rates from 60 to 180 lb/A (Table 1). Only the 180-lb rate of preplant AA and 1/3 UAN (PP) + 2/3 UAN (SD) resulted in stover N concentrations significantly higher than the check. This was probably due to higher yields with all of the N treatments, thus, leading to greater dilution in the stover and translocation of N to the grain. Slight N differences existed among the five methods but none were significantly different from the check.

Stover Yield

Stover yield was increased signficantly over the check by all of the N treatments (Table 1). Highest yields were obtained with the 180-lb rate regardless of source or time of application. Significantly higher yields were found when the preplant (PP) applications consisted of AA compared to UAN. Yield differences were not found between the sidedressed AA and UAN sources or between the method of UAN application (dribble vs injected).

Table 2. Corn grain and silage production as influenced by split applications of N.

Nitrogen			Grain				Silage	Total N
Rate	Time	Source	Yield	H_2O	N	N Removal	Yield	Uptake
lb/A			bu/A	---	% ---	lb/A	TDM/A	lb/A
0	--	CHECK --	50.7	24.1	1.20	28.8	3.21	42.0
60	PP	AA	89.4	23.5	1.17	49.5	4.85	65.7
120	"	"	123.4	22.1	1.34	77.8	6.07	99.6
180	"	"	138.2	21.2	1.54	100.3	6.79	127.8
60	1/3PP+2/3SD	UAN(PP)+AA(SD)	91.4	22.7	1.27	55.0	4.80	71.6
120	"	"	125.6	22.2	1.44	85.4	5.79	105.2
180	"	"	140.7	21.9	1.56	104.0	6.07	128.4
60	"	UAN(PP)+UAN(Drib.SD)	68.8	23.6	1.24	40.4	4.22	55.5
120	"	"	100.8	22.3	1.25	59.5	5.04	75.9
180	"	"	127.2	21.3	1.42	85.6	6.37	108.9
60	"	UAN(PP)+ UAN(Inj.SD)	80.3	22.9	1.24	47.0	4.39	60.7
120	"	"	107.4	22.7	1.31	66.9	5.59	86.6
180	"	"	128.7	21.1	1.49	91.1	5.93	112.0
60	2/3PP+1/3SD	AA(PP)+UAN(Drib.SD)	89.1	22.8	1.20	50.5	5.53	70.5
120	"	"	114.0	21.3	1.35	72.6	5.95	93.0
180	"	"	134.7	21.2	1.49	94.9	6.23	116.6
Signif. Level (%):			99	99	99	99	99	99
BLSD (.05) :			11.2	1.1	.07	7.8	.53	7.1
CV (%) :			8.2	3.5	3.9	8.8	7.6	6.3
FACTORIAL COMPARISONS								
Main Factors								
N Rate (lb/A)								
60			83.8	23.1	1.22	48.5	4.76	64.8
120			114.2	22.1	1.34	72.4	5.69	92.1
180			133.9	21.4	1.50	95.2	6.28	118.7
Signif. Level (%):			99	99	99	99	99	99
BLSD (.05) :			5.1	.5	.03	3.6	.24	3.2
Method (N Time - Source)								
PP - AA			117.0	22.3	1.35	75.9	5.90	97.7
PP/SD - UAN/AA			119.2	22.3	1.42	81.4	5.55	101.7
PP/SD - UAN/UAN (Dribble)			98.9	22.4	1.30	61.8	5.21	80.1
PP/SD - UAN/UAN (Inject)			105.5	22.2	1.35	68.3	5.30	86.4
PP/SD - AA/UAN (Dribble)			112.6	21.8	1.35	72.7	5.90	93.4
Signif. Level (%):			99	67	99	99	99	99
BLSD (.05) :			7.0		.04	4.7	.34	4.3
Interaction			Significance Level (%)					
N Rate x Method			17	67	96	32	96	91

Table 3. Time of N uptake as influenced by rates and split applications of N.

Nitrogen			Stover N Yield[1/]		Grain N Yield at PM			
Rate	Time	Source	Silk	PM	Total	OLD[2/]	NEW[3/]	NEW[3/]
lb/A			lb N/A					% of total
0	--	CHECK --	29.3	13.2	28.8	16.2	12.7	45
60	PP	AA	54.0	16.2	49.5	37.8	11.7	24
120	"	"	79.0	21.8	77.8	57.1	20.7	26
180	"	"	92.4	27.5	100.3	64.8	35.4	35
60	1/3PP+2/3SD	UAN(PP)+AA(SD)	67.6	16.6	55.0	50.9	4.0	6
120	"	"	74.4	19.8	85.4	54.5	30.8	36
180	"	"	79.4	24.4	104.0	55.0	49.0	46
60	"	UAN(PP)+UAN(Drib.SD)	56.3	15.2	40.4	41.1	-0.8	-
120	"	"	69.5	16.4	59.5	53.1	6.4	10
180	"	"	84.1	23.3	85.6	60.8	24.8	29
60	"	UAN(PP)+UAN(Inj.SD)	55.2	13.7	47.0	41.5	5.5	11
120	"	"	74.2	19.7	66.9	54.5	12.4	19
180	"	"	83.0	20.9	91.1	62.0	29.0	32
60	2/3PP+1/3SD	AA(PP)+UAN(Drib.SD)	58.9	20.0	50.5	39.0	11.6	23
120	"	"	76.5	20.4	72.6	56.1	16.5	24
180	"	"	88.4	21.7	94.9	66.8	28.2	29
Signif. Level (%):			99	99	99	99	99	99
BLSD (.05) :			8.5	3.6	7.8	10.0	11.7	15.
CV (%) :			9.4	13.7	8.8	14.9	46.8	45.0
FACTORIAL COMPARISONS								
Main Factors								
N Rate (lb/A)								
60			58.4	16.3	48.5	42.1	6.4	12
120			74.7	19.6	72.4	55.1	17.4	23
180			85.5	23.6	95.2	61.9	33.3	34
Signif. Level (%):			99	99	99	99	99	99
BLSD (.05) :			3.8	1.5	3.6	4.4	5.2	6
Method (N Time - Source)								
PP - AA			75.1	21.8	75.9	53.3	22.6	28
PP/SD - UAN/AA			73.8	20.3	81.4	53.5	28.0	30
PP/SD - UAN/UAN (Dribble)			70.0	18.3	61.8	51.6	10.1	12
PP/SD - UAN/UAN (Inject)			70.8	18.1	68.3	52.7	15.6	21
PP/SD - AA/UAN (Dribble)			74.6	20.7	72.7	53.9	18.8	25
Signif. Level (%):			75	99	99	4	99	99
BLSD (.05) :			-	2.3	4.7	-	7.2	9
Interaction			Significance Level (%)					
N Rate x Method			95	97	32	84	86	92

1/ Silk = silk stage, PM = physiological maturity.

2/ OLD N = N in stover at silk - N in stover at PM; the difference is assumed to be translocated to the grain.

3/ NEW N = Total N in grain - OLD N; the difference is assumed to be absorbed from the soil after silking and/or translocated from the roots.

Final Population

Final populations were higher with increasing rate of N (Table 1). Similar to stover yield, populations were highest with those treatments that received their preplant N as AA compared to UAN. Exact reasons for these relationships and the highly significant N rate x method interaction are not obvious.

Grain Yield

Grain yields were increased significantly over the control by all N treatments (Table 2). Highest yields were obtained at the 180-lb rate for all application methods. When averaged over N rates, there was no difference between the single preplant AA application and the split applications when AA was either applied PP or SD in combination with UAN. However, split applications of N where UAN was the only source produced significantly lower yields. Yields were approximately 5 to 20% lower when UAN was the sidedressed material. Injecting the UAN did not significantly improve grain yields over the dribbled application method. These results indicate that significant losses of N occurred with the sidedressed UAN treatments. It is quite likely that the 4.54" of rain 2 to 3 days after the SD treatments were applied and the subsequent saturated soils may have contributed to denitrification and/or leaching of the N applied as UAN. Under these conditions the AA would have been fixed to the exchange sites and would not have undergone significant nitrification during this period. Thus, it was not susceptible to either denitrification or leaching.

Grain Moisture

Grain moisture at harvest was reduced by all of the 120 and 180-lb N treatments but was not affected significantly by the method of application (Table 2).

Grain N

Grain N was increased significantly over the control by all of the 120- and 180-lb N treatments and increased linearly at N rates from 60 to 180 lb/A when averaged over methods of application (Table 2). Highest N concentration was found with the split application of preplant UAN and sidedressed AA. The split treatment using UAN for both PP and SD applications resulted in significantly lower N concentrations. The highly significant N rate x method interaction was probably due to the small differences between the 60 and 120-lb rates when UAN was the only N source.

Grain N Removal

Grain N removal (product of grain yield times grain N concentration) was increased significantly over the check and linearly by all N rates (Table 2). Highest N removals were associated with the 180-lb rate with the single PP application of AA and the split application where AA was sidedressed. When averaged over N rates, N removal was highest with the split application where AA was SD, intermediate with the single PP application of AA and the split treatment where AA was applied PP, and lowest with the split applications where UAN was the sole source.

Nitrogen efficiency based on grain N removal minus that removed by the check averaged 33, 36, and 37% for the 60, 120, and 180-lb rates, respectively. When averaged over N rates, methods of application ranked according to highest efficiency were: split with UAN + AA (44%), single with preplant AA (39%), split with AA + UAN (37%), split with UAN both PP and SD injected (33%), and split with UAN both PP and SD dribbled (28%).

Silage Yield

Similar to grain yields, silage yields were increased significantly by all N treatments and continued to increase up through the 180-lb N rate (Table 2). Application of AA either all PP or 2/3 PP resulted in yields significantly higher than the other treatments. Lowest silage yields occurred with the split treatments when UAN was the sole N source, regardless of application method.

Total N Uptake

Total N uptake by the corn was calculated by multiplying the stover N concentration times stover yield and adding it to grain N removal. Results of total N uptake were almost identical to those of grain N removal.

Nitrogen efficiency based on total N uptake minus that removed in the check averaged 38, 42, and 43% for the 60, 120, and 180-lb rates, respectively. When averaged over N rates, efficiency was 46, 50, 32, 37 and 43% for the single PP application of AA, split UAN + AA, split UAN + UAN dribble, split UAN + UAN injected, and split AA + UAN, respectively.

Time of N Uptake

To determine the effect of delayed/split applications of N on the time of N uptake relative to silking, whole plants (above-ground portions) were analyzed for total N at the silking stage and at PM (both grain and stover). Nitrogen uptake at the time of silking was increased linearly over the check by all N treatments (Table 3). Method of application did not affect pre-silk N uptake. The significant (P = 95% level) N rate x method interaction was due the minimal affect of N rate with the UAN(PP) + AA(SD) treatment compared to all other treatments.

Stover N yield was increased over the check by all of the 120 and 180-lb rates except the 120-lb UAN(PP) + UAN(Drib.SD) treatment (Table 3). Treatments that contained AA, either PP or SD, generally showed slightly more stover N than those that contained only UAN. The significant interaction between N rate and method was due to the lack of rate effect with the AA(PP) + UAN(SD) treatment in contrast to the significant rate effect with the other treatments. The difference between N yield at silking minus that at PM was assumed to be translocated to the grain and is termed OLD N. The amount of OLD N was increased linearly by N rate but was not affected by method of application (time-source).

NEW N is assumed to be that N taken up into the above-ground portion of the plant after silking and is calculated by substracting the OLD N from the total N in the grain at PM (Table 3). New N as a percent of the total N in the grain averaged 45% from the check treatment. This high amount was primarily due to the low N uptake by the N deficient plants prior to silking. NEW N was increased significantly with increasing rate of application and averaged 12, 23 and 34% with the 60, 120 and 180-lb rates, respectively. The method of application (time-source) had a highly significant effect on the time of N uptake. Averaged over N rates, NEW N ranged from a high of 30% with the UAN(PP) + AA(SD) treatment to a low of 12% with the UAN(PP) + UAN(Drib.SD) treatment. Highest NEW N levels were found with the treatments that contained AA. Injecting the sidedressed UAN resulted in significantly higher levels of NEW N compared to the dribbled application. Split applications of N did not result in greater amounts of late-season N uptake (NEW N) than the preplant AA treatment. These data further substantiate the poor efficiency of the split applications of UAN under these climatic conditions, especially when dribbled on the soil surface.

Residual Soil NO_3-N

Soil samples were taken in 1-foot increments to a depth of 5' from the check plots and all 180-lb N treatments to determine the effect of method (time-source) of N application on the amount of NO_3-N remaining in the soil after harvest. The data shown in Table 4 indicate only 22 to 35 lb/A more NO_3-N in the soil with the 180-lb rates compared to the check. Differences among methods of application were not significant for the total NO_3-N in the 0-5' profile.

Table 4. Residual soil NO_3-N in mid-Oct, 1986 as influenced by N application method.

Profile depth	Check	Application method 1/ Preplant AA	Split UAN+AA	Split UAN+UAN(D)	Split UAN+UAN(I)	Split AA+UAN(D)
feet	lb NO_3-N/A					
0 - 1	20.6	20.6	25.8	22.3	16.7	26.6
1 - 2	14.1	21.4	24.9	17.6	18.6	20.2
2 - 3	12.8	20.8	26.8	26.5	19.0	17.4
3 - 4	12.9	21.4	19.8	24.3	26.3	19.5
4 - 5	17.4	22.4	16.1	19.8	19.2	20.9
Total in 0 - 5' profile	78.	106.	113.	110.	100.	105.

1/ 180 lb N/A

N Recovery

A partial N budget can be obtained by adding the total N uptake shown in Table 2 to the residual NO_3-N shown in Table 4 for each 180-lb treatment, and then subtracting out the uptake plus residual from the check treatment. From this one can calculate the percent recovery at the end of the season by dividing by the rate of N application. At the optimum 180-lb N rate, the percent recovery averaged: preplant AA (63%), UAN + AA (67%), UAN + dribbled UAN (55%), UAN + injected UAN (51%), and AA + dribbled UAN (56%).

CONCLUSIONS

Corn production was not improved in 1986 by split application of N to this Webster soil. Highest yields and greatest efficiency were obtained with the single preplant application of AA and the split application of 1/3 UAN(PP) + 2/3 AA(SD). Poorest yields and N efficiency occurred with the split applications when UAN was the sole N source. Differences between dribbled and injected SD application of UAN generally did not exist. These tesults may have been heavily influenced by the 4+ inches of rain that fell 2 to 3 days after the SD treatments were applied. However, one would have thought that under these wet conditions split applications of N would have performed better than a single preplant application.

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NITROGEN SOURCES FOR CORN WITH CONSERVATION TILLAGE IN SOUTHERN MINNESOTA

1986

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Conservation tillage, which leaves plant residues on the soil surface, is frequently being practiced in southern Minnesota. These residues have been shown to affect N losses. Hence, best management practices, including proper N sources, are necessary to minimize loss of N and maximize economic return. The purpose of this study was to evaluate various N sources for corn production with conservation tillage on two contrasting soils in southern Minnesota.

EXPERIMENTAL PROCEDURES

Two sites which had been ridge-planted in 1985 were seletected for this study. One location was on a Mount Carroll silt loam (Mollic Hapludalf) on the Doug Emerson farm in Goodhue County. This soil represents a large acreage of well-drained, low organic matter, loessial soils cropped to corn in southeastern Minnesota. The other location was at the Southern Experiment Station, University of Minnesota in Waseca County. This Webster clay loam (Typic Haplaquoll) has inherently poor drainage, high organic matter content, and is extensively cropped to corn and soybeans. It represents a large acreage of soils in Southern Minnesota and Northern Iowa.

Soybeans was the previous crop in Goodhue Co. while the Waseca site had been in continuous corn. Soil tests for the Goodhue and Waseca sites follow: pH = 5.7 and 7.1; Bray extractable P_1 = 28 and 42 lb/A (High and Very High); exchangeable K = 222 and 427 lb/A (Med-High and Very High); and extractable SO_4 - S = 8 and 8 ppm (both Medium), respectively, for the two locations. Nitrate-N totaled 48 and 42 lb/A in the 0-5' profile (40 and 35 lb NO_3-N/A in 0-3') profile at the two sites. These were very low residual NO_3 levels. Surface coverage by plant residues averaged 32 and 44% at the two sites, respectively. Ridge height averaged 5.4 inches at the Waseca site.

Sixteen N treatments were replicated four times at the Goodhue site while 13 treatments were replicated four times at the Waseca site. A randomized, complete-block design was used at each site. Each plot measured 10' wide (4 - 30' rows) x 40' long in Goodhue County and 10' wide x 60' long in Waseca County.

Corn (Pioneer 3737) was planted with a John Deere Max-Emerge planter at a population of 27700 plants/acre on May 8 in Goodhue Co. and on May 7 in Waseca Co. Excellent weed and corn rootworm control was obtained with proper chemicals at both sites.

Nitrogen treatments were broadcast applied on the soil surface on May 14 in Goodhue Co. and on May 7 in Waseca Co. Rainfall in the 10-day period following N application in Goodhue Co. totaled 0.30" with .10" on the 1st day and 0.20" on the 10th day following application. At Waseca, 2.99" rain occurred in the 10-day period with .02", .57", .36" 1.38", .11", .53" and .02" on the 1st, 2nd, 3rd, 4th, 6th, 7th and 10th days, respectively, following application. Three quarters of the N (75 lb/A) for the split application was sidedress applied on the soil surface at the 7-leaf stage (June 19) at Goodhue Co. On the next day 1.80" of rain fell to move the AN into the surface soil.

Ten randomly selected leaves opposite and below the ear were taken at silking for N and S analyses. Fodder and grain yields were obtained at physiological maturity by hand harvest techniques at the Goodhue location while plots were combine harvested at Waseca. All stover and grain analyses were conducted on samples gathered at harvest. Chemical analyses were performed by the Research Analytical Laboratory, University of Minnesota.

Soil samples were taken in 1-foot increments to a depth of 3' from the 0, 60, 120, 180, and 240-lb AN treatments on November 11 at the Goodhue Co. site. These samples were dried, ground, and analyzed for NO_3-N to determine the carryover and accumulation of NO_3 in the soil profile.

RESULTS AND DISCUSSION

Rainfall during the 1986 growing season was considerably above normal in Goodhue Co. and slightly above normal in Waseca Co. (Table 1). Conditions were exceptionally dry during the 5-week period

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from mid-July to mid-August at Waseca and resulted in lower yields than expected. Slight amounts of rain occurred on the first day following application at both locations. However, these amounts would not have been sufficient to incorporate the surface-applied N adequately and some volatilization may have occurred. In Goodhue Co. 0.20" and 0.75" of rain fell 10 and 12 days, respectively, after application and should have incorporated the N sufficiently. During the 10-day period following application at Waseca, 2.99" of rain occurred to incorporate the N. Saturated soils did result, however, and may have caused some denitrification.

Table 1. Rainfall during the May thru October growing season in Goodhue and Waseca Counties.

Month	Location	
	Goodhue	Waseca
	inches	
May	3.42	3.76 (0.00)[1/]
June	4.89	7.89 (+3.41)
July	6.61	3.90 (- .12)
August	2.30	2.41 (-1.58)
September	10.54	5.57 (+2.21)
October	2.85	2.83 (+ .75)
TOTAL	30.61	26.36 (+4.67)

1/ Departure from 30-year normal.

Goodhue County

Even though low levels of NO_3 occurred in the soil profile at the beginning of the growing season, the combination of soybeans as the previous crop along with extremely favorable growing conditions during the season resulted in a minimal corn response to the N treatments (Tables 2 and 3). These small differences made it difficult to clearly establish the effects of the N sources and their interaction with rate of N application.

Nitrogen Concentrations

Leaf and grain N concentrations were increased over the control by the 100-lb N/A application rate but generally not by the 50-lb rate (Table 2). When averaged over N rate, differences among the N sources were not significant at the P = 95% level. At the 50-lb rate leaf N was lowest with the urea + AS treatment while grain N was lowest with the UAN treatment. The 100-lb N rate averaged over the six sources increased leaf, stover, and grain N significantly (P = 95% level). Increasing the application rate of AN from 100 to 200-lb N/A increased leaf N significantly but did not influence stover or grain N. The split application of AN did not improve the N concentrations in the plant tissue over the single, preemergence application. Significant (P = 90% level) interactions between N source and N rate were not found for leaf N, stover N, and grain N. Final population was not influenced by N source or rate.

Yields

Stover, silage and grain yields were increased significantly over the check by most of the N treatments, especially the 100-lb N rate (Table 3). Only the 50-lb N rate as urea failed to increase silage and grain yields over the check. When averaged over N rates, highly significant differences were found among the N sources. Stover and silage yields were lowest with urea and highest with the UAN, UAN + S and AS treatments. Grain yields were lowest with the urea + AS treatment and highest with the AS and UAN + S treatments; although differences among the AN, AS, UAN, UAN + S and urea treatments were not significant. Based on these results with AS and UAN + AS, one can speculate as to a S response, although the lower yields with the urea + AS treatment clouds the picture. The 100-lb N rate significantly increased stover, silage and grain yields over the 50-lb rate. Yields were also increased over the 100-lb rate by the 150-lb rate but not by the 200-lb rate or by the split treatment. No interaction between N rate and source was observed.

N Uptake

Uptake of N (product of N concentration times either the grain or grain + stover dry matter yield) was increased significantly over the check by all of the treatments except the 50-lb N rate as urea

or UAN (Table 3). Both grain and total N uptake were consistently lowest with urea when averaged over N rates. Little difference in N uptake was found among the other N sources. Both grain and total plant uptake were increased by the 100-lb rate over the 50-lb rate. Grain and total N uptake were increased over the 100-lb rate by the 150-lb rate as AN but not by the 200-lb rate or the split application. There was no N source x rate interaction. The significant N source by N rate interaction was due to higher grain and total plant uptake at the 120-lb rate with the AS, UAN + S, urea, and urea + AS sources, while with AN and UAN, uptake was not affected by rate. Reasons for this interaction are not known at this time, but may merely reflect the variability in the data.

Table 2. Nitrogen concentration in corn tissue and final population as affected by N source and rate of application in Goodhue Co.

N Treatment		N concentration in			Final
Source[1/]	Rate	Leaf	Stover	Grain	population
	lb N/A	%			ppA x 10^3
CHECK	0	2.63	.51	1.18	21.7
AN	50	2.76	.59	1.27	21.5
"	100	3.02	.63	1.39	20.6
AS	50	2.73	.52	1.22	23.1
"	100	3.01	.57	1.38	23.2
UAN	50	2.76	.54	1.20	22.6
"	100	2.97	.55	1.39	21.1
UAN+S	50	2.84	.55	1.24	22.2
"	100	3.03	.60	1.38	22.3
Urea	50	2.88	.50	1.24	21.6
"	100	2.92	.55	1.30	21.2
½UR+½AS	50	2.72	.54	1.23	22.7
"	100	2.91	.65	1.35	22.4
AN	150	3.00	.64	1.42	23.5
"	200	3.15	.67	1.35	23.7
"	100 split[2/]	3.07	.64	1.39	22.1
Signif. Level (%):		99	96	99	42
BLSD (.05)	:	.18	.14	.07	
CV (%)	:	4.4	13.	4.3	8.6
INDIVIDUAL FACTORS					
N Source (50+100 lb)					
AN		2.89	.61	1.33	21.1
AS		2.87	.55	1.30	23.1
UAN		2.87	.55	1.30	21.9
UAN+S		2.93	.58	1.31	22.2
Urea		2.90	.52	1.27	21.4
½UR+½AS		2.82	.60	1.29	22.6
Signif. Level (%):		54	66	61	72
N Rate (lb/A)					
50		2.78	.54	1.23	22.3
100		2.98	.59	1.37	21.8
Signif. Level (%):		99	97	99	62
INTERACTION			Significance Level (%)		
Source x Rate		68	9	77	5

1/ AN = ammonium nitrate, AS = ammonium sulfate, UAN = urea-ammonium nitrate, UAN + S = UAN + 2% S as AS (25-0-0-2), and UR = urea.

2/ 25 lb at preemergence (May 14) and 75 lb at 7-leaf stage (June 19).

Table 3. Corn yields and N uptake as influenced by N source and rate of application in Goodhue Co.

N Treatment		Yields			Ear	N Uptake	
Source	Rate	Stover	Silage	Grain	Moisture	Grain	Total[1/]
	lb N/A	----- TDM/A -----		bu/A	%	----- lb N/A -----	
CHECK	0	2.36	6.42	152.3	36.8	85.4	109.7
AN	50	2.60	7.26	173.3	36.4	104.2	134.5
"	100	2.65	7.46	179.4	36.8	118.2	151.6
AS	50	2.67	7.46	179.0	36.2	103.4	131.4
"	100	2.93	8.01	188.9	36.4	123.4	156.9
UAN	50	2.53	7.16	173.1	35.9	98.4	126.0
"	100	3.19	8.20	186.5	36.4	122.9	158.2
UAN+S	50	2.82	7.51	175.6	36.3	103.0	134.0
"	100	3.00	8.13	191.6	35.7	125.4	161.8
Urea	50	2.49	6.82	161.6	36.3	94.8	119.9
"	100	2.52	7.15	172.8	35.1	106.6	134.2
½UR+½AS	50	2.72	7.38	174.4	36.7	102.0	131.4
"	100	2.77	7.55	177.7	36.6	113.4	149.5
AN	150	3.13	8.32	193.6	35.9	129.9	170.0
"	200	2.83	7.86	187.4	35.8	119.8	157.1
"	100 split	2.80	7.51	175.1	36.8	115.1	151.1
Signif. Level (%):		99	99	99	29	99	99
BLSD (.05)	:	.39	.67	16.5		12.5	17.1
CV (%)	:	9.2	6.2	6.2	2.9	8.3	8.8
INDIVIDUAL FACTORS							
N Source (50+100 lb)							
AN		2.63	7.36	176.4	36.6	111.2	143.0
AS		2.80	7.73	184.0	36.3	113.4	144.2
UAN		2.86	7.68	179.8	36.2	110.7	142.1
UAN+S		2.91	7.82	183.6	36.0	114.2	147.9
Urea		2.51	6.98	176.1	35.7	100.7	127.1
½UR+½AS		2.74	7.46	167.2	36.6	107.7	140.4
Signif. Level (%):		98	99	98	59	95	95
BLSD (.05)	:	.28	.46	11.7		10.6	15.3
N Rate (lb/A)							
50		2.64	7.27	172.8	36.3	101.0	129.5
100		2.84	7.75	182.8	36.2	118.3	152.1
Signif. Level (%):		99	99	99	34	99	99
INTERACTION				Significance Level (%)			
Source x Rate		88	65	17	47	45	30

1/ Grain + stover

Sulfur Concentrations

Sulfur applications totaled 114, 8, and 57 lb S/A with the AS, UAN + S, and urea + AS treatments, respectively. These amounts of S significantly increased leaf and stover S concentrations and S uptake at the P = 99% level and grain S at the P = 93% level (Table 4). Highest S concentrations and uptake were generally found with the 114-lb rate of S. The 8 lb/A S rate applied with UAN increased leaf S over the UAN alone treatment but did not affect stover or grain S concentrations or S uptake. Nitrogen:S ratios ranged from 10.8 to 14.3 for leaves, 7.6 to 9.7 for stover, and from 13.6 to 14.5 for grain. Lowest N:S ratios were associated with either the 114 or 57-lb S rates.

Table 4. Sulfur concentrations and uptake by corn as influenced by N sources in Goodhue Co.

N Source[1/]	Leaf S	Stover S	Grain S	Sulfur Uptake Grain	Sulfur Uptake Total
	---------- % ----------			----- lb S/A -----	
AN	.213	.065	.096	8.16	11.6
AS	.279	.075	.100	8.89	13.3
UAN	.207	.059	.097	8.56	12.3
UAN+S	.223	.067	.095	8.59	12.6
Urea	.210	.057	.093	7.64	10.5
½UR+½AS	.256	.077	.099	8.36	12.6
Signif. Level (%):	99	99	93	99	99
BLSD (.05) :	.011	.011		.53	1.0
CV (%) :	3.3	11.	3.2	4.1	5.7

1/ 100 lb N/A

Residual Nitrate - N

Samples taken to a 3-foot depth after harvest showed very little relationship between N application rate and the NO_3 remaining in the soil profile (Table 5). Nitrate-N levels were very low. Apparently most of the N not taken up by the plants was leached beyond the 3-foot depth. (Because of extremely wet conditions, it was impossible to get samples below this depth.)

Table 5. Residual soil NO_3-N in the soil profile in November as influenced by N rate in Goodhue Co.

Profile depth	N Application Rate (lb/A) 0	60	120	180	240
feet	---------- lb NO_3-N ----------				
0-1	10	12	15	20	18
1-2	4	4	5	13	11
2-3	4	4	6	9	7
Totals 0-3	18	20	26	42	36

Nitrogen Budget

A partial N budget can be obtained by adding the total N uptake shown in Table 3 to the residual NO_3-N shown in Table 5 for each treatment, and then subtracting out the uptake plus residual from the check treatment. From this one can calculate the percent recovery by dividing by the respective N application rate. Using this method, % recovery totaled 54, 50, 56 and 33% for the 50, 100, 150, and 200-lb N rates, respectively. These low recovery rates indicate that substantial amounts of fertilizer N were lost from the soil or immobilized into the soil organic matter during the 1986 season.

Waseca County

Nitrogen Concentrations

Leaf N was increased significantly over the check by all N treatments (Table 6). Grain N was increased significantly by all of the 150-lb treatments except with the UAN and urea + AS sources. Stover N concentrations were generally not increased over the check by any of the N treatments due to the high variability (CV = 14.0). Leaf, stover, and grain N concentrations with the 150-lb rate averaged 16, 27 and 12% lower at this site than with the 100-lb rate at the Goodhue site.

When averaged over N rates, leaf N was significantly higher with the AA and AS treatments compared to the UAN and UAN + S treatments with the urea treatments being intermediate. Stover N was highest with the AA and AS treatments. Grain N was not affected by source of N. When averaged over the six N sources, leaf and grain N were both increased significantly by the 150-lb N rate. Interactions between N source and N rate were not significant for leaf, stover, or grain N.

Table 6. Nitrogen concentration in corn tissue, final population, and plant height as affected by N source and rate of application in Waseca Co.

N Treatment Source[1/]	Rate	N concentration in Leaf	Stover	Grain	Final population	Plant height
	lb N/A	---------- %	----------	----------	ppA x 10^3	cm
CHECK	0	1.46	.39	1.01	23.7	90
AA	75	2.30	.44	1.05	24.2	103
"	150	2.65	.51	1.21	24.5	103
AS	75	2.15	.45	1.10	24.7	120
"	150	2.59	.44	1.25	24.8	120
UAN	75	1.91	.38	1.02	24.2	109
"	150	2.35	.38	1.14	25.8	114
UAN+S	75	1.75	.39	1.01	24.2	110
"	150	2.45	.43	1.20	24.4	120
Urea	75	2.01	.39	1.06	24.2	115
"	150	2.65	.43	1.21	24.3	112
½UR+½AS	75	2.06	.39	1.11	24.7	118
"	150	2.39	.37	1.15	24.9	119
Signif. Level (%):		99	95	99	26	99
BLSD (.05)	:	.29	.11	.15		6
CV (%)	:	9.7	14.	8.7	4.9	4.2
INDIVIDUAL FACTORS						
N Source						
AA		2.47	.48	1.13	24.4	103
AS		2.37	.45	1.18	24.7	120
UAN		2.13	.38	1.08	25.0	112
UAN+S		2.10	.41	1.11	24.3	115
Urea		2.33	.41	1.13	24.3	114
½UR+½AS		2.23	.38	1.13	24.8	119
Signif. Level (%):		99	99	50	24	99
BLSD (.05)	:	.23	.06			4
N Rate (lb/A)						
75		2.03	.41	1.06	24.3	112
150		2.51	.43	1.20	24.8	115
Signif. Level (%):		99	75	99	80	90
INTERACTION				Significance Level (%)		
Source x Rate		58	35	22	20	90

1/ AA = anhydrous ammonia, AS = ammonium sulfate, UAN = urea-ammonium nitrate, UAN + S = UAN + 2% S as AS(25-0-0-2), and UR = urea.

Final Population and Plant Height

Plant population was not influenced by any of the N treatments (Table 6). Plant height (extended leaves) data taken on June 26 show plants to be 13 to 30 cm (5 to 12") taller with all of the N treatments compared to the check (Table 6). Plants were tallest with the AS and Urea + AS treatments, intermediate with the UAN, UAN + S and urea treatments, and significantly shorter with AA when averaged over N rates. Difference between the two N rates was not significant at the P = 95% level.

Yields

Grain and silage yields were increased over the check by all of the N treatments while stover yields were increased by only the 150-lb treatments (Table 7). Grain moisture was reduced significantly from the check by all of the N treatments.

When averaged over N rate, significant differences (P = 90% level) in stover and silage yields were not found among the N source treatments. Grain yields were highest with the AA and AS treatments and were significantly reduced (about 13%) with the UAN and UAN + S treatments. Stover, silage, and grain yields were all increased significantly by the 150-lb N rate over the 75-lb rate. Interactions between N source and N rate were not significant at the P = 95% level.

Table 7. Corn yields and N uptake as influenced by N source and rate of application in Waseca Co.

N Treatment		Yields			Grain	N Uptake	
Source	Rate	Stover	Silage	Grain	Moisture	Grain	Total[1/]
	lb N/A	----- TDM/A -----		bu/A	%	---- lb N/A ----	
CHECK	0	1.37	3.53	67.4	24.3	32.4	43.2
AA	75	1.94	5.47	121.7	22.0	60.9	78.3
"	150	2.08	6.09	141.0	21.1	80.8	101.5
AS	75	2.36	5.76	120.6	21.5	63.1	84.3
"	150	2.23	6.07	143.2	20.4	84.8	104.2
UAN	75	1.90	5.16	102.9	22.2	49.9	64.4
"	150	2.32	6.05	122.4	20.8	66.2	84.4
UAN+S	75	1.74	4.57	104.4	21.4	50.4	63.9
"	150	2.38	6.34	129.9	21.0	74.7	94.8
Urea	75	1.83	4.88	108.9	22.7	55.0	69.4
"	150	2.61	6.68	143.0	22.2	82.3	104.6
½UR+½AS	75	1.98	5.31	124.4	21.9	66.0	81.4
"	150	2.19	5.85	131.3	20.3	72.0	88.5
Signif. Level (%):		99	99	99	99	99	99
BLSD (.05)	:	.59	.89	19.1	1.3	16.4	20.5
CV (%)	:	18.	12.	12.	4.1	18.	18.
INDIVIDUAL FACTORS							
N Source							
AA		2.01	5.78	131.3	21.5	70.9	89.9
AS		2.29	5.92	131.9	20.9	74.0	94.3
UAN		2.11	5.60	112.7	21.5	58.1	74.4
UAN+S		2.06	5.46	117.1	21.2	62.6	79.3
Urea		2.22	5.78	126.0	22.5	68.6	87.0
½UR+½AS		2.08	5.58	127.9	21.1	69.0	85.0
Signif. Level (%):		46	29	95	98	88	88
BLSD (.05)	:			16.8	.97		
N Rate (lb/A)							
75		1.96	5.19	113.8	21.9	57.5	73.6
150		2.30	6.18	135.1	20.9	76.8	96.4
Signif. Level (%):		99	99	99	99	99	99
INTERACTION				Significance Level (%)			
Source x Rate		91	91	45	26	43	51

1/ Grain + stover

N Uptake

Nitrogen uptake in both the grain and total plant (grain + stover) was increased (P = 95% level) over the check by all treatments (Table 7). When averaged over N rates, differences among N sources were not significant although N uptake was consistently lowest with the UAN and UAN + S treatments. Uptake of N was significantly (P = 99% level) increased by the 150-lb N rate over the 75-lb rate when averaged over N sources. There was no N source by N rate interaction.

Sulfur Concentrations

Sulfur application rates with the AS, UAN + S, and urea + AS treatments totaled 170, 12, and 85 lb S/A, respectively. The 170-lb S rate consistently resulted in highest leaf, stover, and grain S (Table 8). Leaf, stover, and grain S were also increased with the 85-lb rate. The 12-lb rate applied with UAN did not affect leaf S concentrations but did increase stover and grain S slightly. Sulfur uptake in the grain was only increased with the AS treatment (170 lb S/A) while total plant S uptake was increassed with both the 85- and 170-lb S rates. Nitrogen:S ratios ranged from 8.7 to 17.7 for leaves, 4.5 to 10.2 for stover, and 11.7 to 15.1 for grain. In all cases lowest N:S ratios were found with the 85 and 170-lb S rates as AS while highest N:S ratios occurred with the AA treatments. Slight reductions inthe N:S ratio were noted with the UAN + S treatment.

Table 8. Sulfur concentrations and uptake by corn as influenced by N sources in Waseca Co.

N Source[1/]	Leaf S	Stover S	Grain S	Sulfur Uptake Grain	Sulfur Uptake Total
	%			lb S/A	
AA	.150	.050	.080	5.38	7.42
AS	.297	.097	.104	7.07	11.38
UAN	.150	.042	.080	4.68	6.70
UAN+S	.162	.055	.089	5.50	8.04
Urea	.160	.043	.080	5.45	7.72
½UR+½AS	.235	.071	.098	6.13	9.36
Signif. Level (%):	99	99	99	99	99
BLSD (.05) :	.034	.010	.008	1.12	1.59
CV (%) :	13.	12.	6.1	12.	13.

1/ 150 lb N/A

SUMMARY

Although differences did exist among the N sources when averaged over N rates, these differences did not show a consistent advantage for any one particular source. In Goodhue Co. slight advantages appeared with AS and UAN + S while urea and urea + AS resulted in the poorest yields. In Waseca Co., highest yields and N uptake were obtained with AA and AS while UAN and UAN + S resulted in the lowest yields. Corn production was maximized by the 150-lb rate at both locations.

Corn production was not enhanced significantly by the sulfur in the N treatments although S concentrations in the plant and S uptake were increased at both locations. A nitrogen budget calculated from the plant N uptake and residual soil NO_3 data in Goodhue Co. indicated N recovery to range from 33 to 56%, indicating substantial loss of N in 1986. Since SO_4-S is mobile and is easily leached, the extremely wet conditions during the growing season may have accounted for the rather consistent increases in plant S concentrations and S uptake with the 57 and 114-lb rates of S applied as AS.

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NITROGEN LOSS TO TILE LINES AS AFFECTED BY TILLAGE

Waseca, 1986

G. W. Randall and P. L. Kelly

Nitrogen losses to tile lines have been documented in a number of research studies including some conducted at Lamberton and Waseca, Minnesota. These studies primarily showed that N losses were a function of the N application rate and amount of precipitation. To some degree the time of application and crop grown have been shown to influence NO_3-N loss to tile lines. The purpose of this long-term study is to determine if tillage has an effect on N utilization, accumulation of NO_3-N in the soil profile, and the subsequent loss of NO_3-N to tile lines.

EXPERIMENTAL PROCEDURES

A study was initiated in 1975 on a Webster clay loam at Waseca to monitor the movement of N into a tile line installed in each of 12 plots measuring 45' by 50'. Each plot is enclosed with plastic sheeting to a 6' depth. Annual N rates of 0, 100, 200, and 300 lb N/A were applied from 1975-1979. No N was applied for the 1980 and 1981 crops. Residual N from N applied over the 5-year period (75-79) was utilized by the 1980 and 1981 corn crops. Soil samples to 10' and tile water samples taken in late 1981 showed little remaining evidence of the previous treatments.

In the fall of 1981, eight plots with the most uniform tile flow rates over the 1975-81 period were selected. Two tillage treatments (fall moldboard plow and no tillage) were replicated four times and randomized over the previous plot histories. Corn was grown on these plots in 1982 through 1985. The stalks were chopped in October, 1985 and moldboard plots plowed.

On April 22, 180 lb N/A as ammonium nitrate was broadcast applied to the surface of all plots. The moldboard treatment was then field cultivated. Corn (Pioneer 3732) was planted on May 3 at a population of 27700 plants/A with a John Deere Max-Emerge planter equipped with ripple coulters. Starter fertilizer was not used because of the high soil tests. Counter was applied at 1 lb (ai)/A to control rootworms. Weeds were controlled with a preemergence application of Lasso (3½ lb/A) and atrazine (3 lb/A) applied May 15. Weed and insect control was excellent.

The leaf opposite and below the ear was taken from 10 randomly selected plants per plot at silking (Moldboard plow = July 18, No tillage = July 21) and was analyzed for N. Silage and grain yields were taken at physiological maturity by hand harvesting 30 and 60' of row, respectively, from each plot.

Tile lines began flowing in mid March, 1986 and continued to flow intermittently until mid-July. Conditions were extremely dry in late-July and August and no tile flow was recorded during this period. Tile lines commenced flowing again in late September and flowed throughout October. When tile lines were flowing, flow rates were measured daily and samples taken on a Monday, Friday, Wednesday two-week rotation for NO_3 analysis. All analyses were done by the Research Analytical Lab.

Soil NO_3-N in the 0-8' profile was determined from two cores/plot taken in 1-foot increments on October 23, 1986.

RESULTS

Although yields and N removal tended to be consistently higher with the moldboard plow (MP) system compared to the no tillage (NT) system, differences between the two tillage systems were not significant at the P = 90% level (Table 1). Leaf and grain N and final population were not influenced by tillage system. Experimental variability was low as indicated by CV's below 5 for yield. These end-of-season results are markedly different from what was expected in mid-July. At that time, the MP plots exhibited larger corn growth with a dark green color, and advanced maturity compared to the shorter corn that showed N deficiency symptoms on the NT plots.

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

Table 1. Influence of tillage system on corn production and N utilization at Waseca in 1986.

Tillage system	Final population	Leaf N	Silage Yield	Silage N uptake	Grain Yield	Grain N	Grain N removal
	x10^{-3}	%	T DM/A	lb N/A	bu/A	%	lb N/A
Moldboard Plow	27.2	2.38	7.19	129.3	143.4	1.32	90.0
No Tillage	28.2	2.45	7.10	123.5	136.1	1.25	80.6
Signif. Level (%): 1/	81	35	30	43	78	81	81
CV (%) :	2.8	7.8	4.0	10.	4.8	4.7	9.3

1/ Probability level of significance.

Precipitation for April, June and the September-October period was 1.5, 3.3 and 3.0 inches above normal, respectively. Thus, most of the tile flow shown in Table 2 occurred in April, May, June and October. Total tile flow was slightly higher from the NT plots, however, the flow-weighted NO_3-N concentration was slightly lower. Total NO_3-N lost via the tile lines was not different between the two tillage systems. Average NO_3-N concentrations in the tile water continued their upward movement from about 11 mg/L in 1984 to 12 mg/L in 1985 to between 12.8 and 14.0 mg/L in 1986.

Table 2. Influence of tillage system on tile flow, NO_3-N concentration and NO_3-N loss in 1986.

Tillage system	Tile flow	Nitrate-N Concentration 1/	Nitrate-N Loss
	acre inches	mg/L	lb N/A
Moldboard Plow	15.8	14.0	48.2
No Tillage	17.4	12.8	52.0

1/ Flow-weighted

Parameter		Mar	Apr	May	June	July	Sept	Oct	Nov	Total
		Month								
		acre-inches								
Tile Flow	MP	2.32	2.57	3.64	3.82	.34	.76	2.38	.01	15.83
	NT	1.46	3.50	4.29	4.26	.49	.53	2.82	.03	17.38
		mg/L								
NO_3-N Concentration	MP	12.7	13.2	13.3	15.6	14.7	12.6	15.0	15.0	14.0
	NT	9.9	11.1	12.3	17.8	14.0	13.6	13.3	10.8	12.8
		lb N/A								
NO_3-N Loss	MP	6.1	7.7	11.6	13.2	1.2	1.9	7.6	0.02	48.2
	NT	3.4	9.0	11.7	17.9	1.6	1.5	8.2	0.07	52.0

Residual NO_3-N in the soil profile at the end of the 1986 growing season showed about 80 lb/A more N remaining with the NT system (Table 3). Greater amounts of NO_3 were found at each 1-foot increment with the NT system. The largest differences between the two tillage systems occurred below 5' where substantially more NO_3 had accumulated with NT. These results are somewhat different from 1985 when only about 30 lb more N remained under the NT system.

Table 3. Influence of tillage systems on residual NO_3-N in the soil profile in Oct., 1986.

Profile depth	Tillage System	
	Mb. Plow	No Tillage
feet	-------- NO_3-N (lb/A)	--------
0-1	14.2	18.5
1-2	13.2	28.7
2-3	24.2	26.4
3-4	29.0	36.2
4-5	27.2	28.9
5-6	19.3	37.3
6-7	17.4	32.0
7-8	15.8	29.9
Total (lb NO_3-N/A 0-8')	160.3	237.9

FIVE-YEAR SUMMARY

The cumulative totals for the 5-year period (1982-1986) are shown in Table 4. Corn yields over this period have averaged 8 bu/A better with moldboard plow tillage. Approximately 10% more N has been removed in the grain with moldboard plow tillage. This has been due to both higher yields and slightly higher grain N concentrations with the moldboard tillage system some years. Even so, very little difference in applied N removed in the grain exists between the two treatments (48% vs 44% for MP vs NT, respectively). Even though total water flow and NO_3-N lost through the tile lines was about 10% higher with no tillage, this small difference is considered to be insignificant when considering tile flow variability among the eight plots over this 5-year period.

Table 4. Cumulative effects of the two tillage systems over the 5-year period.

Parameter	Tillage System	
	Mb. plow	No tillage
Fert. N applied (lb/A)	900	900
Corn grain removed (bu/A)	673	633
N removed in grain (lb/A)	436	396
N removed in grain as a percent of applied N (%)	48	44
Tile flow (acre inches)	56.9	61.1
Nitrate-N lost in tile (lb/A)	136.6	149.3
N lost via tile lines as a percent of applied N (%)	15	17

STARTER FERTILIZER PLACEMENT EFFECTS ON CORN PRODUCTION

Waseca, 1986

G. W. Randall and P. L. Kelly

Starter fertilizers will increase in popularity as farmers attempt to maximize return from their fertilizer dollar and as reduced tillage becomes more popular. However, with less spring secondary tillage, farmers sometimes encounter problems with the conventional disk opener systems when moist soil is dislodged by them and then sticks to the depth bands on the planter. The result can be uneven seeding depth. To correct this problem, farmers would like to remove the disk opener fertilizer attachment and instead place the starter fertilizer directly with the seed rather than in the conventional 2 x 2" placement. The purpose of this study was to evaluate seed placement versus 2 x 2" placement of three liquid fertilizers on the early growth, final stand, and yield of corn.

Experimental Procedures

A Nicollet clay loam soil planted to corn in 1985, moldboard plowed in the fall, and field cultivated in the spring was the experimental site. The soil tests were: pH = 6.4, OM = High, Bray P_1 = 72 lb/A (VH), and exchangeable K = 390 lb/A (VH).

A randomized, complete block design with four replications was used. Factorial treatments consisting of three liquid starter fertilizers (10-34-0, 9-18-9 and 7-21-7), three rates and two placement methods (directly with the seed and 2" to the side and below) plus a no starter fertilizer check were applied. The 10-34-0 and 7-21-7 were applied at rates of 5, 10 and 15 gal/A while the 9-18-9 was applied at 4, 8, and 12 gal/A to give similar salt rates among all three sources.

Corn (Pioneer 3732) was planted in 30" rows with a JD Max-Emerge planter at 27,700 plants per acre on May 3. The liquid materials were applied either directly on the seed by running the delivery tube between the double disk openers on the planter or in the 2 x 2" position with the starter fertilizer disk opener. Counter (1 lb ai/A) was used as the rootworm insecticide. Chemical weed control consisted of 3½ qt. Lasso and 3½ qt. Bladex/A applied preemergence.

Plant counts to obtain emergence rate and final stand were then taken daily from two rows each 55' long for 12 days beginning on the 9th day after planting. Grain yield was determined by harvesting each plot with a modified JD 3300 plot combine.

Results and Discussion

Growing conditions following planting were excellent for corn germination and emergence. Soil temperature at the 2" depth averaged well above 50°F (Table 1). Soil moisture in the seed zone was slightly below field moist capacity at planting. Six days after planting 0.57" of rain thoroughly wet the seed zone. This was followed by 1.74" on the next two days which more than likely leached much of the salt from the seed zone.

The salt rate ($N+K_2O$) of fertilizers has been shown to be important when applying fertilizer with the seed. Ammonia toxicity and/or salt burn can affect the germination of seedlings. A rule of thumb in Minnesota based on older research is not to apply more than 15 lb of $N+K_2O$/A. The $N+K_2O$ application rates with the various treatments are shown in Table 2. Salt levels are higher for 7-21-7 and 9-18-9 than for 10-34-0 because of the K component. Fifteen gallons of either 10-34-0 or 7-21-7 and 12 gal of 9-18-9 clearly exceeded the 15 lb/A threshold.

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

Table 1. Daily precipitation and average soil temperatures (2" depth) in the 2-week period following planting.

Days after planting	Avg. Soil temperature (2") °F	Precipitation inches
1	60	0
2	69	0
3	70	0
4	65	0
5	61	.02
6	59	.57
7	59	.36
8	56	1.38
9	62	0
10	66	.11
11	53	.53
12	60	0
13	57	T
14	56	.02

Table 2. Salt rate as influenced by starter fertilizer material and rate of application.

Application rate	Liquid fertilizer 7-21-7	10-34-0	9-18-9
gal/A	lb $N+K_2O$/A		
4			7.7
5	7.5	6	
8			15.4
10	15.0	12	
12			23.1
15	22.5	18	

Emergence rate was generally delayed by about 1 day by the seed-placed fertilizers, especially with the high rate of application (Table 3). Application of the high rate of all fertilizer materials with the seed resulted in less than 50% of the plants emerged on the 10th day following planting compared to about 75% with the 2 x 2" placement. Emergence rates did not appear to be affected differently by the three liquid fertilizers. By 14 days after planting emergence had approached 100% regardless of treatment.

Final populations of the starter fertilizer treatments were not significantly lower than the check treatment (Table 4). Factorial analyses (Table 5) showed no population differences among the three liquid fertilizer materials and the three application rates but did show a highly significant difference (P = 99% level) between the two placement positions. However, when averaged over materials and rates, seed placement reduced the final population by only 2% compared to 2 x 2" placement. Interactions between material and rate of application, material and placement, and rate and placement were not significant at the P = 90% level.

Grain yield and moisture were not affected significantly (P = 95% level) by any of the treatments (Tables 4 and 5). A yield response was not obtained over the check yield.

Conclusion

Application of 10-34-0, 7-21-7 and 9-18-9 at the higher rates with the seed resulted in about a 1-day delay in emergence and a 2% reduction in population but did not affect yield. Moist conditions at planting and the 2.33" of rain that occurred from 5 to 8 days after planting more than likely diluted and moved the salts out of the seed zone. To be on the safe side, however, we cannot recommend rates greater than 10 gal/A with these materials when applied with the seed. Rates should be reduced further if soil conditions are very dry at planting and/or soils are lower in organic matter and coarse to medium textured. Application of urea-containing starter fertilizers (9-18-9) is discouraged even at low rates because of potentially severe phytotoxicity of the urea.

Table 3. Influence of liquid starter fertilizer material, application rate, and placement on emergence rate of corn.

Treatment			Days after planting								
Material	Rate	Placement	9	10	11	12	13	14	16	18	20
	gal/A		% of final stand								
None	0	Check	16	72	89	99	99	99	99	100	100
7-21-7	5	Seed	8	59	79	89	95	97	97	98	100
"	"	2 x 2	12	78	91	99	100	100	100	100	100
"	10	Seed	1	35	57	87	95	97	98	99	100
"	"	2 x 2	8	77	92	97	100	100	100	100	100
"	15	Seed	5	48	66	90	97	100	100	100	100
"	"	2 x 2	20	77	91	98	99	100	100	100	100
10-34-0	5	Seed	17	77	91	99	99	99	99	100	100
"	"	2 x 2	20	80	89	97	99	99	100	100	100
"	10	Seed	8	49	69	93	98	98	99	100	100
"	"	2 x 2	15	67	89	98	100	100	100	100	100
"	15	Seed	4	44	61	90	95	99	100	100	100
"	"	2 x 2	10	75	89	98	100	100	100	100	100
9-18-9	4	Seed	11	69	87	95	97	98	99	100	100
"	"	2 x 2	5	69	87	94	95	97	99	100	100
"	8	Seed	5	62	82	93	99	100	100	100	100
"	"	2 x 2	11	68	87	94	99	99	100	100	100
"	12	Seed	6	46	66	85	93	98	97	99	100
"	"	2 x 2	17	79	93	99	99	99	100	100	100

Table 4. Influence of liquid starter fertilizer material, application rate and placement on plant population, grain moisture and corn grain yield.

Material	Rate	Placement	Final population	Corn grain Moisture	Corn grain Yield
	gal/A		ppA x 10^{-3}	%	bu/A
None	0	Check	27.1	22.3	144.6
7-21-7	5	Seed	27.1	21.1	139.3
"	"	2 x 2	26.9	21.7	145.4
"	10	Seed	26.2	21.7	137.3
"	"	2 x 2	27.3	22.3	144.7
"	15	Seed	26.1	21.8	138.9
"	"	2 x 2	27.1	21.4	146.4
10-34-0	5	Seed	26.1	21.4	137.8
"	"	2 x 2	27.7	21.7	141.8
"	10	Seed	27.1	21.9	151.3
"	"	2 x 2	27.0	21.6	147.4
"	15	Seed	26.2	21.6	143.9
"	"	2 x 2	26.6	21.7	143.9
9-18-9	4	Seed	27.1	21.7	143.4
"	"	2 x 2	27.0	22.0	152.3
"	8	Seed	26.2	21.7	142.3
"	"	2 x 2	27.3	22.1	141.5
"	12	Seed	26.4	20.7	144.5
"	"	2 x 2	27.5	21.4	141.6
Signif. Level (%): 1/			99	81	60
BLSD (.05)	:		1.2	-	-
CV (%)	:		2.5	3.0	5.4

1/ Probability level of significance.

Table 5. Factorial analyses of the effect of liquid starter fertilizer material, rate, and placement on corn production parameters.

Factors		Population	Corn grain Moisture	Corn grain Yield
MAIN FACTORS		ppA x 10^{-3}	%	bu/A
Material				
7-21-7		26.8	21.7	142.0
10-34-0		26.8	21.6	144.3
9-18-9		26.9	21.6	144.3
Signif. level (%):		27	8	51
Rate (gal/A)				
5/4		27.0	21.6	143.3
10/8		26.9	21.9	144.1
15/12		26.6	21.4	143.2
Signif. level (%):		75	94	9
Placement				
Seed		26.5	21.5	142.1
2 x 2		27.1	21.8	145.0
Signif. level (%):		99	91	89
INTERACTIONS				
Material x Rate				
7-21-7	5	27.0	21.4	142.3
"	10	26.8	22.0	141.0
"	15	26.6	21.6	142.6
10-34-0	5	26.9	21.5	139.8
"	10	27.1	21.7	149.4
"	15	26.4	21.7	143.9
9-18-9	4	27.0	21.9	147.9
"	8	26.7	21.9	141.9
"	12	27.0	21.1	143.1
Signif. level (%):		53	89	92
Material x Placement				
7-21-7	Seed	26.5	21.6	138.5
"	2 x 2	27.1	21.8	145.5
10-34-0	Seed	26.5	21.6	144.3
"	2 x 2	27.1	21.7	144.4
9-18-9	Seed	26.6	21.4	143.4
"	2 x 2	27.3	21.8	145.1
Signif. level (%):		4	56	73
Rate x Placement				
5/4	Seed	26.8	21.4	140.2
"	2 x 2	27.2	21.8	146.5
10/8	Seed	26.5	21.8	143.6
"	2 x 2	27.2	22.0	144.5
15/12	Seed	26.2	21.4	142.4
"	2 x 2	27.1	21.5	144.0
Signif. level (%):		40	19	58
			Significance level (%)	
Material x Rate x Placement		99	60	26

SOIL TEST COMPARISON STUDY

Waseca, 1986

G. W. Randall and P. L. Kelly

Soil testing is one of the best and most economical methods of ascertaining the nutrient status of the soil. The test then serves as the basis for fertilizer recommendations for crops. Many private and public laboratories provide that service to Corn Belt farmers. The purpose of this study is to compare the soil analyses and fertilizer recommendations given by five regional laboratories for corn production in Southern Minnesota. Working with the laboratories in this comparison study we should be able to improve and standardize fertilizer recommendations for corn and soybean production.

PROCEDURES

Two experimental sites measuring 150' by approximately 300' were selected for sampling in October, 1979. One of the sites had a history of high P and K fertilization while the other had not received P or K since 1974. The soil type in the former is a Nicollet clay loam while that in the latter is primarily Webster clay loam with some Nicollet clay loam. Tile lines spaced at 75' intervals provide excellent drainage at both sites. Neither site can be irrigated.

Four samples consisting of approximately 35 cores each from a 0-7" depth were taken from each site. All samples were oven dried at 95°F, crushed and mixed thoroughly. The samples were then subdivided and sent to five laboratories which test the majority of the soil samples from Southern Minnesota. The laboratories were: A & L Agricultural Laboratories, Inc., Omaha, NE; Harris Laboratories, Inc., Lincoln, NE; Minnesota Valley Testing Laboratories, Inc., New Ulm, MN; AMOCO/Cropmate Co., Reinbeck, IA; and University of Minnesota Soil Testing Laboratory, St., Paul, MN. Soil anslyses requested consisted of pH, OM, extractable P, exchangeable K, extractable S and the micronutrients generally tested by each laboratory. Based on the results from the U of M laboratory these two sites were then classified as being initially "very high" and "medium-high". The fertilizer recommendations given by the five laboratories were then applied as five treatments in the spring of 1980 for corn. An additional check (no fertilizer) treatment was included in the randomized, complete-block design with six replications. Each plot measures 15' wide and 55' long.

After the 1980 crop, soil samples (5 cores/plot times 6 replications yielding 30 cores per treatment) were taken yearly from each treatment and sent to the respective laboratory. This allowed us to follow the buildup or decline of nutrients in the soil as affected by the recommendations of a particular laboratory over time. After 6 years (1980-85) the "very high" fertility site was terminated.

Fertilizer amounts based on the analyses and recommendations from the summer 1985 samples were applied October 31 to the appropriate plots before moldboard plowing. These fertilizer recommendations were based on a soybean yield goal of 55 bu/A following corn. Soybeans (Hardin) were planted in 15" rows on May 22. Chemical weed control consisted of 3½ qt. Lasso and 6 qt. Amiben/A applied preemergence to all plots.

Seed yield and moisture were determined by harvesting each plot with a modified JD 3300 plot combine. Yields were converted to 13.5% moisture.

In August, 1986, 0-7" soil samples were taken from each treatment except Cropmate's and were sent to the laboratory of the respective treatment. (The Cropmate laboratory is no longer in operation.) The recommendations obtained from these samples will be used for the 1987 growing season.

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

Medium-high testing site

The soil test results and the accompanying recommended fertilizer program of each laboratory are shown in Table 1. While the numeric values of the five laboratories were generally similar the corresponding interpretation (whether the soil tested high, low, medium, deficient etc.) varied substantially. Phosphorus and K recommendations among the labs were quite different. Nitrogen was recommended by two of the labs. Also, sulfur and zinc were each recommended by a private lab. Only one of the four private labs recommended liming the soil.

Table 1. Soil test results and the recommended fertilizer program from each laboratory on the medium-high testing site at Waseca in 1986.

Test	Soil Test Laboratory				
	A&L	Harris	MVTL	Cropmate	U of M
	Soil Test Results[1/]				
pH	6.3	6.7	6.3	6.5	6.8
pH (buffer)	6.7	---	7.0	7.0	---
Phosphorus	22 H	24 L	27 VH	36 H	17 H
Potassium	187 M	132 D	135 H	100 L	145 H
Organic matter (%)	4.7 H	4.2 A	4.3 M	5.6	H
Calcium	3200 H	3471 E	4350	2410 H	---
Magnesium	540 VH	440 A	590	363 H	---
Sulfur	8 M	8 A	16 VH	21 H	4 LM
Iron	74 VH	44 E	39 S	---	---
Manganese	31 VH	20 E	16 S	2.1 VH	---
Zinc	3.3 H	1.3 E	1.2 H	1.6 M	1.3 M
Copper	1.5 H	1.0 A	1.1 S	---	---
Boron	1.7 H	---	1.4 S	---	---
ENR (lb/A)	96	---	---	112	---
C.E.C. (meq/100 g)	23.4	21.4	27	15.3	---

1/ All soil test results are stated in ppm unless noted otherwise.

Nutrient	A&L	Harris	MVTL	Cropmate	U of M
	Recommended Fertilizer Program[2/]				
Nitrogen	10	20	0	0	0
Phosphorus (P_2O_5)	25	72[3/]	0	28	20
Potassium (K_2O)	40	215[3/]	43	124[3/]	40
Sulfur	10	--	--	--	--
Iron	--	--	--	--	--
Manganese	--	--	--	--	--
Zinc	--	1.5	--	--	--
Lime (T/A)	1.5	--	--	--	--

2/ All values indicate pounds of nutrients recommended per acre for a yield goal of 55 bushels of soybeans per acre.

3/ Value includes maintenance recommendation, plus 50% of the buildup recommendation which was to be applied over a two-year period.

The treatments that received fertilizer yielded significantly more than the unfertilized check (Table 2). However, there were no significant yield differences among the fertilizer treatments (recommendations).

Table 2. Effect of fertilizer recommendations on soybean seed yield on the medium-high testing site at Waseca in 1986.

Lab	Fertilizer Recommendations lb/A[1/]	Seed Yield bu/A	Seed Moisture %
A&L	10 N + 25 P + 40 K + 10 S	55.8	14.9
Harris	20 N + 72 P + 215 K + 1.5 ZN	57.3	15.0
MVTL	43 K	55.3	14.9
Cropmate	28 P + 124 K	55.1	15.0
U of M	20 P + 40 K	54.7	14.8
Check		48.9	14.7
	Signif. Level (%):[2/]	99	99
	BLSD (.05) :	3.0	.2
	CV (%) :	4.7	1.0

1/ P and K expressed on oxide basis.
2/ Probability level of significance.

SUMMARY - 1986

Substantial differences again existed among the laboratories fertilizer recommendations. High amounts of P were recommended by the Harris lab while high amounts of K were recommended by the Harris and Cropmate Labs. Nitrogen, micronutrients and sulfur were recommended by two of the four private labs.

Differences in grain yield were not observed among the five laboratories' recommendations. Yields were excellent.

Fertilization resulted in highest profit from the MVTL recommendations and no profit from the Harris recommendations (Table 3). Fertilizer costs ranged from $4/A with the MVTL recommendation to $39/A with the Harris recommendation.

Table 3. Effect of fertilizer recommendations on yield, value, fertilizer, cost and economic return on the medium-high testing site at Waseca in 1986.

Lab	Yield bu/A	Value @ 4.57/bu	Fert cost[1/] $/A	Return[2/]
A&L	55.8	255	13	19
Harris	57.3	262	39	0
MVTL	55.3	253	4	26
Cropmate	55.1	252	17	12
U of M	54.7	250	8	10
Check	48.9	223	--	--

1/ Using May, 1986 prices for each nutrient expressed as dollars/lb as follows: N, .18; P_2O_5, .20; K_2O, .09; S, .28; Zn, 1.09.
2/ Return yield value @4.57/bu - (fertilizer cost & value of check trt).

SEVEN-YEAR SUMMARY

Yield responses paid for the fertilizer recommendations made by all five laboratories (Table 4). However, net return was highest with the lowest cost fertilizer recommendations. The higher cost recommendations given by A&L, Harris, and Cropmate resulted in lowest economic return. It is interesting to note the very narrow range in crop value among the five laboratories over this 7-year period (a low of $2409/A to a high of $2421/A).

Table 4. Effect of fertilizer recommendations on total crop value, total fertilizer cost and resulting economics on the medium-high testing site at Waseca from 1980-86.

Lab	7-Yr Total Crop Value[1/]	7-Yr Total Fertilizer cost	Return[2/]
	$/A		
A&L	2409	384	+199
Harris	2421	474	+121
MVTL	2412	287	+299
Cropmate	2411	449	+136
U of M	2415	263	+326
Check	1826	0	---

1/ 3.00, 2.40, 3.00 and $2.07/bu used for corn in 1980, 1981, 1983 and 1985, respectively, and 5.50, 6.00 and $4.57/bu used for soybeans in 1982, 1984 and 1986, respectively, for a seven-year total crop value.

2/ Return over 7-year period = crop value - (fertilizer cost & value of check treatment.

CONSERVATION TILLAGE FOR CORN AND SOYBEAN PRODUCTION

Waseca, 1986

G. W. Randall and J. B. Swan

With increasing emphasis on controlling erosion and minimizing energy requirements (time, labor, and fuel), tillage practices have changed markedly over the last decade. Many of tillage practices have come to be known as "conservation tillage". To fit this definition, a tillage practice must leave 30% of the soil surface covered with residue after planting. The primary purpose of this study is to evaluate five conservation tillage (CT) systems in a long-term corn-soybean sequence. A secondary objective is to determine the value of starter fertilizers in CT systems.

EXPERIMENTAL PROCEDURES

To evaluate some of these CT practices an experiment was started in 1975 with continuous corn grown on a Webster clay loam at the Southern Experiment Station. Five tillage treatments (no tillage, fall moldboard plow, fall chisel plow, ridge-plant and till-plant [flat]) were replicated four times. Each plot was 20' wide by 125' long. Tile lines spaced 75' apart run perpendicular to the rows in all plots. Beginning in 1979 all plots were split into two, 4-row plots -- one with starter fertilizer and the other without.

After 8 years of continuous corn, soybeans were planted in 1983 to begin a long-term corn-soybean rotation. Tillage and starter fertilizer treatments remained the same except the till-plant (flat) treatment was changed to a spring-disk (20" disk blade) treatment (Table 1). Because of increased pressure of the grass weeds in the no tillage treatment, all plots were split so that either the front or rear half received a postemergence application of Poast at a rate of ¼ lb/A with 1 qt of oil concentrate in the years that soybeans were grown.

Ridges for the ridge plant treatment in 1986 were built in June, 1985. After the 1985 soybean harvest, the moldboard and chisel plow treatments were performed. On April 25 the moldboard and chisel plow treatments were field cultivated once and the spring disk treatment was disked twice. Ammonium nitrate was broadcast-applied at a rate of 160 lb N/A immediately before the secondary tillage. Ridges for 1987 soybeans were prepared on June 25.

Corn (Pioneer 3732) was planted in 30" rows at a rate of 30,400 plants/A on May 6. All treatments except no-till were planted with a John Deere 7100 planter equipped with 2" fluted coulters. B&H ridge cleaners were attached to the planter for the ridge-plant (RP) treatment. Because of high surface soil density with no tillage, seeding depth was not adequate with this planter. Thus, a JD 7000 planter was used to get better seeding depth on this tillage treatment. Ten gallons/A of 7-21-7 was used as the starter treatment.

Broadcast P and K were not applied for the 1986 corn crop because of very high soil tests. Soil tests on this site in 1984 averaged: pH = 6.7, $Bray_1$ extractable P = 60 lb/A and exchangeable K = 424 lb/A. Chemical weed control consisted of 3½ lb Lasso and 3½ lb Bladex/A applied preemergence. In order to evaluate the effectiveness of the preemergence herbicide application on weed control, a plastic sheet 18" wide and 6' long was placed between the 4th and 5th rows of each plot during herbicide spraying to prevent the application of herbicide onto the soil surface. Weed counts (grass and broadleaf) were taken on June 3 from sprayed and unsprayed areas. Treatments 2, 3, 4, and 5 were cultivated on June 13. Weed control was excellent on all cultivated plots.

Surface residue coverage was measured by the line-transect method on April 9 prior to spring tillage and on May 27 after planting. Planting depth was determined by cutting off the coleoptile at the soil surface from all the plants in a 10-foot length of row in each tillage plot 33 days after planting. The seeds were then excavated and the length of the coleoptile to the seed was measured. Early plant growth (EPG) was determined by harvesting the above ground portion of 10 random plants per plot 41 days after planting. On June 17 soil samples were taken to a 12" depth from both the starter and no starter portions of the no tillage (NT), moldboard plow (MP), and chisel plow (CP) systems. Eight cores were taken from each plot and after dividing into 0-2, 2-4, 4-6, 6-9, and 9-12" depths were composited. After drying at 100°F they were submitted to the University of Minensota Soil Testing Lab for pH, $Bray_1$ extractable P and exchangeable K analyses.

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

Corn leaf samples were taken on July 16 from all treatments except NT, which was sampled on July 18, by randomly sampling the leaf opposite and below the ear from the starter treatment within each tillage treatment. Yields were taken by combine harvesting the center two rows from each plot with a modified JD 3300 combine. Grain moisture and N concentrations were determined on each of these samples.

RESULTS

Since the 2-way and 3-way interactions at the bottom of Table 1 are non-significant (P = 90% level), the comparison of main effects (tillage, starter fertilizer, and previous Poast treatment) is appropriate.

Significant differences in final population, grain moisture and grain yield were found among the tillage treatments when averaged over starter fertilizer and previous Poast treatments (Table 1). Final population of the NT and RP plots averaged about 2500 plants/A fewer than with the other treatments. Differences in final stand did not exist among the MP, CP and spring disk (SD) treatments. Final population was slightly higher with the starter fertilizer treatments but was not affected by the previous application of Poast.

Grain moisture, an indication of maturity, was significantly higher with the NT treatment compared to the CP, RP and SD treatments (Table 1). This was consistent with previous years when both continuous corn and corn after soybeans were grown. Grain moisture for the MP, CP, RP and SD systems was not significantly different at the P = 95% level. Neither starter fertilizer nor the previous Poast treatments affected grain moisture.

Grain yields were not significantly different (P = 95% level) among the MP, CP, RP and SD systems when averaged over starter fertilizer and Poast treatments (Table 1). The NT yields were closer to those from the other tillage systems this year than in previous years but were still significantly lower than the MP, RP and SD systems. Starter fertilizer gave a highly significant 9.7 bu/A yield increase when averaged across tillage systems. Even though a statistically significant interaction between tillage system and starter fertilizer did not exist (18% level), largest responses to starter were obtained with NT (12.7 bu/A), CP (12.1 bu/A), and RP (10.8 bu/A). Yield response to starter fertilizer averaged only 8.7 and 4.2 bu/A for the SD and MP systems, respectively. The previous Poast treatments did show a 4.5 bu/A yield advantage which was significant at the P = 92% level. This should perhaps be discounted because there was no Poast x tillage interaction and weed control was excellent with all tillage treatments except NT.

Early plant growth was affected significantly by the tillage systems (Table 2). Plants were largest with the RP and CP systems, were intermediate in size with the MP and SD systems and were significantly smaller with NT. Starter fertilizer increased early plant weight by 9% when averaged across tillage systems. The interaction between tillage and starter fertilizer was not significant (57% level). The correlation between EPG and grain yield was not significant when starter fertilizer was used (r = +.397) but was significant at the 99% level when no starter was used (r = +.566). A linear rather than curvilinear relationship was best for each. These relationships agree well with those obtained in 1984.

Grain N was not influenced by tillage or starter fertilizer (Table 2.) However, N removal in the grain (product of grain N concentration and grain yield) was affected significantly by both tillage and starter fertilizer. This effect was due largely to the yield differences among the treatments, which resulted in lowest N removal with the NT system and the plots without starter fertilizer.

Residue measurements taken prior to planting showed significant differences among the treatments for percent of the soil surface covered with residue from the previous crops (Table 3). The treatments ranked NT SD RP = CP MP. After planting, surface residue measurements were taken both within the row and randomly across the plot area. All tillage treatments showed significantly more residue than the MP treatment. However, only the RP and NT systems exceeded 30% and therefore met the definition of "conservation tillage". Within the row measurements showed slightly less residue than random across the plot measurements for all tillage sytems except MP.

Planting depth was not affected significantly by the tillage systems (Table 3). This was not consistent with previous years. The variability in the seeding depth as measured by standard deviation and range in depths indicates least variability with the NT, CP, MP and SD systems and greatest variability with the RP system. Seed placement averaged between 1.6" and 1.8" for the five tillage systems. Even though these differences are less than in previous years with continuous corn, they do point out the need for careful adjustment of the planter even when following soybeans.

Table 1. Influence of tillage methods, starter fertilizer and previous Poast herbicide treatment on corn production at Waseca in 1986.

Treatment					
Tillage	Starter[1/] fert.	Poast[2/] herb.	Final population x 10^3	Grain Moisture %	Grain Yield bu/A
No tillage	S	P	30.1	22.2	151.3
"	S	NP	29.6	22.7	156.8
"	NS	P	26.8	22.8	141.6
"	NS	NP	30.0	23.9	141.1
Fall plow, f. cult.	S	P	32.3	22.3	171.7
" "	S	NP	32.0	22.6	155.4
" "	NS	P	30.8	21.7	158.4
" "	NS	NP	31.3	22.9	160.3
Fall chisel, f. cult.	S	P	32.0	21.7	167.3
" "	S	NP	31.6	21.9	160.6
" "	NS	P	30.4	21.6	154.5
" "	NS	NP	31.4	22.0	149.3
Ridge plant	S	P	30.2	21.8	172.1
" "	S	NP	29.7	21.8	166.1
" "	NS	P	28.8	21.8	164.0
" "	NS	NP	27.6	22.2	152.5
Spring disk	S	P	32.3	21.9	166.7
" "	S	NP	32.4	21.4	173.6
" "	NS	P	30.5	22.1	168.3
" "	NS	NP	30.9	22.2	155.1
INDIVIDUAL FACTORS					
Tillage					
No tillage			29.1	22.9	147.7
Fall plow			31.6	22.4	161.5
Fall chisel			31.4	21.7	157.9
Ridge plant			29.1	21.9	163.7
Spring disk			31.6	21.9	165.9
Significance Level (%):			99	97	95
BLSD (.05) :			1.6	0.8	13.3
Starter Fertilizer (SF)					
Starter			31.2	22.0	164.2
No starter			29.9	22.3	154.5
Significance Level (%):			99	86	99
Poast Herbicide					
Poast			30.4	22.0	161.6
No Poast			30.7	22.4	157.1
Significance Level (%):			41	93	92
Interactions			Significance Levels (%)		
Tillage x SF			3	45	18
Tillage x Poast			36	46	35
SF x Poast			78	76	37
Tillage x SF x Poast			27	3	79
CV (%)			6.4	4.2	7.0

1/ S = starter fertilizer used and NS = no starter fertilizer used.
2/ P = Poast herbicide used and NP = no Poast herbicide used in 1985.