SAND PLAIN EXPERIMENT FIELD

ELK RIVER

WEATHER DATA 1969

Date	Temperature °F Max	Min.	Prec. inches	Date	Temperature °F Max.	Min.	Prec. inches
7	69	57		13	88	66	
8	81	57	1.39	14	85	54	
9	86	66	.02	15	90	58	
10	86	59		16	91	62	
11	89	60		17	93	64	
12	97	65		18	85	58	
13	90	68		19	81	49	
14	90	73	.40	20	87	54	
15	89	70	.22	21	87	51	
16	86	69		22	88	54	
17	77	63		23	87	54	
18	86	57		24	88	53	
19	88	64		25	90	54	
20	78	55		26	90	58	
21	85	53		27	89	64	
22	82	57		28	94	73	
23	80	60		29	95	75	
24	85	53		30	81	55	.10
25	84	60	.22	31	81	53	
26	85	57		9/1	--	50	.36
27	70	51		2	84	--	
28	84	55	2.62	3	84	54	
29	90	59		4	81	60	
30	89	63	.29	5	--	--	.31
31	76	55		6	--	--	
8/1	78	50		7	--	--	
2	87	54		8	64	46	.15
3	87	56		9	65	41	
4	86	63		10	75	40	
5	93	63		11	74	50	
6	91	69		12	88	53	
7	81	60		13	85	56	
8	85	55		14	89	62	
9	80	62		15	81	61	
10	89	56		16	73	50	
11	94	61		17	70	41	
12	94	68		18	64	52	

Denotes Snow*

SAND PLAIN EXPERIMENT FIELD

ELK RIVER

WEATHER DATA 1969

Date	Temperature °F Max.	Min.	Prec. inches
19	73	55	
20	78	48	
21	79	50	
22	70	55	
23	56	45	.05
24	63	34	
25	72	46	.03
26	67	42	
27	64	38	
28	71	32	
29	72	42	.03
30	62	36	
10/1	72	50	
2	77	41	
3	79	48	
4	86	60	
5	65	41	
6	62	39	.15
7	56	41	.03
8	58	36	.01
9	73	45	
10	64	42	
11	51	34	
12	38	32	
13			.57*
14			.02

Data By Month	May	June	July	Aug.	Sept.
Total Prec. "	1.24	3.84	5.36	.10	.93
Mean Max. Temp.	71.6	70.2	83.0	87.6	73.2
Median Max. Temp.	75.5	67.5	83.0	86.5	72.5
Mean Min. Temp.°	45.9	48.7	58.7	58.9	47.7
Median Min. Temp.	48.5	50.0	56.5	62.0	47.0
Mean Temp.°	58.7	59.5	70.8	73.2	60.4
Median Temp.°	63.0	59.0	68.5	72.0	60.5
Max. Temp.°	98	84	97	95	89
Min. Temp.°	28	34	40	50	32

EXPERIMENTS WITH NITROGEN SOURCE, PLACEMENT AND TIME OF NITROGEN APPLICATION TO A WEBSTER-CLAY LOAM AT LAMBERTON FROM 1960 THROUGH 1969

John M. MacGregor, Wallace W. Nelson and Robert G. Munter

A field fertilizer experiment for continuous corn was commenced in the spring of 1960 to determine the relative effectiveness of annually applied N as either ammonium nitrate or as urea. The nitrogen was broadcast and plowed down or simply broadcast and left on the plowed surface over winter, or broadcast in the spring and worked in during the usual seedbed preparation, or broadcast as a sidedressing in late June. Four replications of 18 different annual treatments were applied as a randomized block, each plot being 20 feet wide and 77.5 feet long. A starter fertilizer such as 8-24-12 is applied over the entire field at planting at approximately 175 pounds per acre. The corn seed for several years was drilled lengthwise over each plot at a 40 inch row spacing to obtain about 18,000-20,000 plants per acre, but later the row direction was reversed with a 30 inch row spacing to supply the same population. Many different studies have been made during the ten years of continuous corn growing to N application of this experiment, with results reported each year in Soil Series 76-84. The entire field was tiled in 1963.

The 1969 growing season was extremely wet in early spring with progressively less precipitation as the summer progressed. Soil moisture was very limited in August and September, but no really serious drowth occurred. Ear corn yields during the 10 year period are shown in Table 1.

Each of the nitrogen treatments significantly increased corn yields over the 10 year period, with no significant differences between NH_4NO_3 and urea

nitrogen sources. Where only 40 pounds of nitrogen were applied annually (+ 14 pounds N in the starter fertilizer) spring treatments averaged 95.1 bushels per acre, sidedressing in late June averaged 88.8 bushels, with fall applications averaging 81.4 bushels per acre. The overall 40 pound N treatments averaged 85.3 bushels per acre.

The 80 lb N/A fall treatments averaged 95.7 bushels with similar treatments applied in spring averaging 100.6 bu/A and late June sidedressing producing a 98.0 bu/A. The average of all 80 lb treatments was 98.1 bu/A. The three 160 lb/A rates of N application (or 174 lbs N/A including starter N) produced an average annual yield of 102 bushels per acre.

It is apparent that over the 10 year period, the minimum rate of 40 lbs N/A annually (actually a total of 54 lbs N with starter N) is most effective when applied at planting time and least effective with fall application, being more noticeable in years when corn planting was delayed. Fall application and remaining on the plowed surface over winter (treatments 4 and 5) appear to be equal or possibly better than fall plowdown (Treatments 2 and 3).

As might be expected, smaller differences in corn yield occurred with the 80 or 160 pound N rates in the fall, spring or as a sidedressing.

Table 1. Ten Year Yield of Ear Corn on a Tiled Webster Clay Loam Near Lamberton with Annual Applications of NH_4NO_3 or Urea Nitrogen at Different Rates, Times and Placement.

N applied annually in lbs/A[1]	Years										
	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	Average
	Ear corn yield in bushels per acre										
1) Check	49.5	88.2	26.1	132.6	72.9	33.1	11.1	53.4	102.4	92.8	66.2 a
2) 40 as NH_4NO_3-fall plow down	42.3	87.5	30.9	148.6	88.3	34.9	26.8	75.7	131.6	109.3	77.6 b
3) 40 " urea - " " "	55.1	78.2	29.1	148.8	100.3	38.8	19.8	86.9	132.5	124.5	81.4 bc
4) 40 " NH_4NO_3-fall plow surface	49.0	96.7	29.6	140.1	101.5	45.6	24.3	75.1	135.2	124.6	82.2 bcd
5) 40 " urea - " " "	62.3	101.3	37.0	140.7	84.1	57.4	30.9	87.2	134.0	136.1	84.1 cde
6) 80 " NH_4NO_3- " " down	67.4	97.9	43.6	149.6	100.8	63.4	47.3	114.8	131.2	146.8	96.3 efghi
7) 80 " urea - " " "	61.7	76.9	36.7	154.5	104.9	73.0	37.8	117.2	142.6	144.3	95.0 efghi
8) 160 as NH_4NO_3 " " "	69.8	97.9	46.7	147.7	100.9	70.8	38.5	127.4	140.2	158.7	99.9 fghi
9) 160 " urea - " " "	79.4	112.5	43.5	152.8	112.4	73.5	37.7	121.3	149.9	161.0	104.4 i
10) 40 " NH_4NO_3-spring topdress	66.2	92.0	45.4	152.2	99.8	63.4	23.7	99.8	128.0	142.0	91.3 defg
11) 40 " urea - " "	45.4	91.1	31.4	147.6	100.6	59.8	33.8	95.0	140.5	143.4	88.8 cde
12) 80 " NH_4NO_3- " "	59.3	90.0	32.7	149.2	112.5	74.2	49.0	128.3	144.7	159.5	99.9 ghi
13) 80 " urea - " "	57.7	99.1	40.5	149.3	115.7	84.4	41.8	128.6	138.7	155.9	101.2 hi
14) 40 " NH_4NO_3-sidedress	63.6	92.6	39.5	148.6	90.4	54.8	38.6	96.8	133.4	142.3	90.1 cdefg
15) 40 " urea - "	57.7	95.6	24.9	142.3	94.1	48.4	50.4	86.1	132.2	143.3	87.5 cde
16) 80 " NH_4NO_3- "	50.4	98.4	46.7	140.7	113.0	68.1	43.8	101.6	137.7	140.3	94.1 efgh
17) 80 " urea - "	76.9	86.4	48.2	143.8	121.4	64.7	47.3	117.0	146.9	166.2	101.9 hi
18) 160 " NH_4NO_3- "	40.7	97.4	77.7	151.7	109.5	77.6	51.4	120.2	141.5	148.3	101.6 hi
Average annual corn yield in bu/A	58.6	93.3	39.4	146.7	101.3	60.3	36.3	101.8	135.7	140.9	

[1]The entire area received an additional 14 lbs N/A as starter fertilizer annually (8-24-12 @ 175 lbs/A)

Nitrogen Removal in Corn Grain

The amounts of nitrogen removed per acre in the corn grain is of interest, as well as the increase in percentage N of the corn grain by the different N fertilizer treatments. These are shown in Table 2.

The 40 pound (or a total of 54 pound) rate of N per acre annually had the least effect on N concentration in the corn grain, and increasing rates of N fertilization raised N levels in the grain 40% or more. Increasing corn yields increased nitrogen removal from a low of 18% increase (Treatment 2) to 143% increase (Treatment 9). In general, where less than 100 pounds of N per acre was annually applied, N removal in grain approximates fertilizer N applied. The highest rate of N application resulted in a considerably lower proportion of applied N removal in the corn grain. This is shown in the following section.

The Nitrate-N Content of Soil After Ten Years of N Fertilization

Since this field experiment had been conducted over a 10 year period, in late 1969 all plots were sampled in late October to an 84 inch depth (7 feet) in two 6 inch depths for the surface foot, and in foot increments beyond.

These samples were then analyzed for NO_3-N content and the results are reported in Table 3 in parts per million for each depth. Pounds per acre of nitrate N were computed by assuming that each acre 6 inches of soil weighed approximately 2 million pounds. The average amounts of NO_3-N present in the four replicates of each treatment to a 7 foot depth were then computed to determine nitrate accumulations under the different treatments during the 10 years and their possible relationship to N fertilization and N removal by cropping.

It is obvious that there is little accumulation of NO_3-N to the 7 foot depth with the two lower rates of N fertilization (40 and 80 lbs/A) when applied in the fall one year before sampling. This might be expected by the N removal in the corn grain as shown in Table 2. However, where the 160 lb/A (actually 174 lb/A) annual N application was applied each fall, the NO_3-N content of the soil has been more than doubled, especially where urea was the N source.

Spring N applications at the two lower rates show slightly more NO_3-N in the soil than similar rates applied in the fall, with the late June sidedressing resulting in somewhat more NO_3-N residue remaining. However, the late June sidedressing at the highest rate (Treatment 18) indicates a very large amount of NO_3-N in the 7 foot depth of soils sampled, being largely concentrated in the surface foot. It is evident that fertilization at the rate of 160 lbs N/A (or a total of 174 lbs) annually results in high soil concentrations of NO_3-N, which is unlikely to be completely utilized by the growing corn. Much of this excess N may be removed from the soil in drainage waters of the tiling system, and be lost for crop production. There is also the hazard of needless possible pollution of stream waters draining the area.

To determine the amount of movement of NO_3-N to depths greater than 84 inches, four of the plots (3,7,9, and 13) representing treatments 1,2,6 and 8 were sampled to an 18 foot depth and analyzed for nitrate-nitrogen content. The NO_3-N present in the entire 18 foot depth is shown in Table 4.

It is evident that the plot treated with 54 pounds of N/A annually over the 10 year period has no greater NO_3-N accumulation than soil where the 14 pounds of N was annually applied in starter fertilizer. However, with increasing rates of N application, (94 or 174 lbs of N/A annually) there is an apparent increase in NO_3-N content, especially in the upper 7 foot soil depth (see Table 4).

This would indicate that the percolating water removed by the 48 inch deep tile drainage system is removing considerable amounts of the applied fertilizer nitrogen, but there is some accumulation deep in subsoils where large amounts of N fertilizer have been applied.

The maximum water soluble potassium content of all samples in the 0 to 7 foot depth was 37 ppm, and 42 ppm level was detected in one 13 to 14 foot soil depth.

1969 Concentrations of Nitrate Nitrogen (NO_3-N) and Other Components in Free Soil Water

The experiment described on page 78 of Soil Series 84 was repeated in 1969. As in 1968, the wells were pumped free of all water 24 hours before removing the water samples to be analyzed. This allowed minimum time for the sample to remain in the well with possible chemical change. It was found that some wells failed to hold water because of the rubber stoppers being dislodged.

The spring of 1969 was extremely wet at Lamberton and it was not convenient to reinstate the wells until late in June. Three samplings were made during July and early August (before dry soil conditions eliminated free water accumulations) and the analyses are shown in Table 5(a,b,c and d).

Table 5a indicates a probable lateral movement of NO_3-N at depths of several feet, since the NO_3-N accumulations are somewhat higher than would normally be expected from the application of only 14 lbs of N/A annually, and with a plot width of 20 feet, some of the wells would be only some 8 feet from adjoining plots receiving up to 174 pounds of fertilizer N annually. Also the wells in the roadways (nearer to the tile line) at the end of each

plot (No. 7 and 79) indicate movement of additional NO_3-N toward the tile line at the 42 inch sampling depth.

Nitrate-N (NO_2-N) was low in all samplings but there was considerable variation in the PO_4-P in the well waters at the different depths. Since some 18 pounds of P is applied annually in the starter fertilizer to the surface soil of all plots, it would be reasonable to expect some P accumulation in the waters of the more shallow wells. Moderate quantities of potassium (K) were found at all sampled depths. Electrical conductance (an indicator of soluble salt content) increased with depth as expected.

Table 5b shows water analyses from the wells located on plots receiving 54 and 94 lbs N/A annually for 10 years. Nitrate-N is somewhat higher and the deeper NO_2-N samples considerably higher than in plots receiving less N. The PO_4-P content is less, with K and soluble salt content being considerably higher with higher N treatments.

Table 5c indicates that the annual 174 lb N/A treatment is substantially increasing NO_3-N levels in the free water of these plots with some increase in NO_2-N levels as well. The PO_4-P content is again relatively low (probably because of increasing P removal during higher crop production) with K and soluble salt content being much the same as in Table 5b.

Table 5d shows that some of the wells outside the plots toward the tile in the middle of the uncropped roadway contain waters with high levels of NO_3-N. Some of this accumulation may be attributed to normal nitrate production in the soil and the uncropped and weed-free roadway allows essentially no NO_3-N removal by growing plants. However, it is probable that some of these dissolved nitrates are the result of heavy N fertilization of the adjoining nitrates; PO_4-P, K, and salt concentrations were not remarkable on plots outside these wells.

It must be concluded that heavy N fertilization of continuous corn results in considerable increase in NO_3-N in soil water of the upper 6 feet of the soil profile. The NO_2-N and PO_4-P content of these waters remains relatively low but with a substantial dissolved potassium (K). Soluble salts normally increase with depth on these calcareous soils.

Corn Leaf Zinc and Nitrogen Fertilization

The sixth corn leaves of all treated plots were sampled during silking and analyzed for zinc content to determine if there was any marked effect between continued N fertilization and leaf zinc. The results are shown in Table 6.

Corn leaf zinc varied from 17 to 25 parts per million, with leaves on only the 3 heaviest N treatments containing significantly more zinc than the check treatment.

Since it is known that continued high rates of N fertilization with either ammonium nitrate or urea reduce soil pH, and thus increase soil zinc availability, the pH of each of the four plot-soils where corn had the lowest and highest zinc concentrations was also determined. The averages obtained are shown at the base of Table 6. Although the average soil pH difference is not marked, the trend of lower soil pH and greater zinc concentrations in the corn leaves is apparent.

Table 2. Yield of Dry Shelled Corn, Percentage Nitrogen and Nitrogen Removal in Corn Grain per acre From NH_4NO_3-Urea Treated Continuous Corn on Webster Clay Loam at Lamberton in 1969.

Treatment (lbs N/A)[1]	Dry shelled corn lbs/A 1	2	3	4	% N 1	2	3	4	Average	lbs N removed per acre 1	2	3	4	Average
1) Check	4159	4893	3724	4789	1.09	1.14	0.93	0.99	1.04 a	45.3	55.8	34.6	47.4	45.8 a
2) 40 as NH_4NO_3-fall plow down	5546	5158	4292	5683	1.04	1.02	1.09	1.05	1.05 ab	57.7	52.6	46.8	59.7	54.2 ab
3) 40 " urea - " " "	6171	5906	5096	6384	1.11	1.06	1.11	1.04	1.08 abc	68.5	62.6	56.6	66.4	63.5 bc
4) 40 " NH_4NO_3-" " surface	6407	4595	6152	6431	1.16	1.04	1.08	1.12	1.10 abc	74.3	47.8	66.4	72.0	65.1 bcd
5) 40 " urea - " " "	6066	5352	7216	7126	1.09	0.99	1.12	1.22	1.11 abc	66.1	53.0	80.8	86.9	71.7 cde
6) 80 " NH_4NO_3-" " down	6492	6899	7089	7311	1.05	1.30	1.22	1.23	1.20 cde	68.2	89.7	86.5	89.9	83.6 ef
7) 80 " urea - " " "	5962	7259	6989	7108	1.02	1.30	1.29	1.20	1.20 cde	60.8	94.4	90.2	85.3	82.7 ef
8) 160 " NH_4NO_3-" " "	6809	8139	7604	7481	1.40	1.30	1.39	1.51	1.40 gh	95.3	105.8	105.7	113.0	104.9 hi
9) 160 " urea - " " "	7912	6814	7387	8366	1.37	1.41	1.51	1.55	1.46 h	108.4	96.1	111.5	129.7	111.4 i
10) 40 " NH_4NO_3-spring topdress	5551	7382	6814	7126	1.26	1.12	1.16	1.15	1.17 bcd	69.9	82.7	79.0	82.0	78.4 de
11) 40 " urea - " "	6847	6880	6828	6582	1.22	1.02	1.16	1.33	1.18 bcde	83.5	70.2	79.2	87.5	80.1 ef
12) 80 " NH_4NO_3- " "	7472	7803	6909	8011	1.33	1.33	1.44	1.26	1.34 fgh	99.4	103.8	99.5	100.9	100.9 gh
13) 80 " urea - " "	7112	6630	6942	8820	1.19	1.19	1.34	1.29	1.25 def	84.6	78.9	93.0	113.8	92.6 fgh
14) 40 " NH_4NO_3-sidedress	6928	6535	6630	6847	1.11	1.16	1.26	1.27	1.20 cde	76.9	75.8	83.5	87.0	80.8 ef
15) 40 " urea - "	6890	5958	7585	6691	1.12	1.15	1.26	1.32	1.21 cdef	77.2	68.5	95.6	88.3	82.4 ef
16) 80 " NH_4NO_3- "	6454	5451	6857	7789	1.29	1.13	1.40	1.40	1.31 efg	83.3	61.6	96.0	109.0	87.5 fg
17) 80 " urea - "	8257	7983	8248	6970	1.33	1.40	1.32	1.54	1.40 gh	109.8	111.8	108.9	107.3	109.5 i
18) 160 " NH_4NO_3- "	6932	6256	7992	7320	1.48	1.48	1.43	1.43	1.46 h	102.6	92.6	114.3	104.7	103.6 hi

[1]The entire area received an additional 14 lbs N/A annually as starter fertilizer (8-24-12 @ 175 lbs/A).

Table 3. Nitrate Nitrogen Content of Webster Clay Loam Near Lamberton in November, 1969, Following 10 Years of Continuous Corn Under Different Nitrogen Fertilization.

	Plot nos.	Total N applied/A	Soil depth in inches 0-6	6-12	12-24	24-36	36-48	48-60	60-72	72-84
			ppm NO_3-N							
(1)		Check								
	7	0 + 140# starter	1.3	1.1	1.7	1.1	1.1	2.7	2.0	2.5
	32	" " "	1.7	4.2	1.2	1.5	1.0	2.8	2.8	2.6
	46	" " "	1.0	1.0	1.3	0.9	1.1	1.8	1.2	2.0
	73	" " "	4.4	2.3	1.7	1.1	1.1	1.8	1.4	2.3
		Average ppm	2.1	2.2	1.5	1.2	1.1	2.3	1.9	2.4
		" lbs/A	2.1	2.2	3.0	2.4	2.2	4.6	3.8	4.8
		Total - 25.1 lbs/A								
(2)		40 N - F (PD)								
	3	400 + 140# starter	2.3	1.8	2.3	1.0	1.9	1.0	2.1	2.5
	21	" " "	1.0	2.7	1.7	1.1	3.5	1.5	1.5	1.5
	45	" " "	2.3	1.0	1.5	1.0	0.9	1.3	1.6	1.3
	62	" " "	5.0	3.9	1.7	2.5	1.1	2.3	3.2	1.7
		Average ppm	2.7	2.4	1.8	1.4	1.9	1.5	2.1	1.8
		" lbs N/A	2.7	2.4	3.6	2.8	3.8	3.0	4.2	3.6
		Total - 26.1 lbs/A								
(3)		40 urea F (PD)								
	14	400 + 140# starter	6.6	3.3	2.7	2.4	2.6	3.3	2.6	2.2
	22	" " "	0.8	0.7	1.2	1.4	1.8	3.0	2.3	4.8
	43	" " "	1.2	2.9	1.3	1.1	1.7	1.5	1.3	1.7
	75	" " "	2.3	2.1	0.3	2.1	2.5	2.9	2.8	5.3
		Average ppm	2.7	2.3	1.4	1.8	2.2	2.7	2.3	3.5
		" lbs N/A	2.7	2.3	2.8	3.6	4.4	5.4	4.6	7.0
		Total - 32.8 lbs/A								

(Table 3. continued)

	Plot nos.	Total N applied/A	Soil depth in inches 0-6	6-12	12-24	24-36	36-48	48-60	60-72	72-84
			ppm NO_3-N							
(4)		40 N - F (top)								
	17	400 + 140# starter	5.6	2.5	2.7	2.6	1.9	2.5	3.0	2.5
	27	" " "	2.7	1.8	2.5	1.7	1.3	1.8	3.6	1.8
	48	" " "	2.7	1.8	1.0	1.1	1.2	2.0	1.5	1.3
	61	" " "	3.5	2.1	1.9	1.0	2.3	2.1	3.5	3.0
		Average ppm	3.6	2.1	2.0	1.6	1.7	2.1	2.9	2.2
		" lbs/A	3.6	2.1	4.0	3.2	3.4	4.2	5.8	4.4
		Total - 30.7 lbs/A								
(5)		40 urea F (top)								
	5	400 + 140# starter	2.2	2.2	1.9	1.2	1.5	1.7	2.3	1.9
	36	" " "	1.9	1.4	1.7	1.7	1.2	2.3	2.7	2.3
	55	" " "	2.9	3.6	2.1	3.8	2.8	3.8	2.3	2.8
	69	" " "	5.6	3.3	1.3	1.7	1.7	3.1	1.3	1.9
		Average ppm	3.2	2.6	1.8	2.2	1.8	2.7	2.2	2.2
		" lbs N/A	3.2	2.6	3.6	4.4	3.6	5.4	4.4	4.4
		Total - 31.6 lbs/A								
(6)		80 N - F (PD)								
	9	800 + 140# starter	2.7	1.0	1.9	1.0	1.9	2.6	1.9	2.2
	30	" " "	3.3	1.9	2.1	2.5	2.9	1.9	1.7	1.5
	56	" " "	4.2	2.7	1.9	2.1	4.2	3.2	3.5	3.0
	72	" " "	2.1	1.9	1.3	2.2	2.5	2.8	4.2	5.6
		Average ppm	3.1	1.9	1.8	2.0	2.9	2.6	2.8	3.1
		" lbs N/A	3.1	1.9	3.6	4.0	5.8	5.2	5.6	6.2
		Total - 35.4 lbs/A								
(7)		80 urea F (PD)								
	6	800 + 140# starter	4.4	2.5	1.7	1.2	1.5	1.5	2.1	1.7
	23	" " "	1.1	2.5	1.6	1.9	3.7	4.5	2.9	1.4
	51	" " "	5.3	1.9	2.3	1.5	2.2	3.5	1.3	3.5
	74	" " "	2.4	1.6	1.4	1.7	2.6	2.1	3.6	2.8
		Average ppm	3.3	2.1	1.8	1.6	2.5	2.9	2.5	2.4
		" lbs N/A	3.3	2.1	3.6	3.2	5.0	3.8	5.0	4.8
		Total - 30.8 lbs/A								

(Table 3. continued)

	Plot nos.	Total N applied/A	Soil depth in inches 0-6	6-12	12-24	24-36	36-48	48-60	60-72	72-84
			ppm NO_3-N							
(8)		160 N - F (PD)								
	13	1600 + 140 starter	3.7	1.4	3.6	6.6	8.2	8.4	6.6	3.3
	24	" " "	2.2	2.3	1.0	0.7	1.3	3.0	1.1	6.2
	53	" " "	5.2	6.4	2.9	2.0	3.3	3.2	1.6	2.4
	66	" " "	0.6	2.7	2.6	1.9	10.4	10.1	7.9	10.1
		Average ppm	2.9	3.2	2.5	2.8	5.8	6.2	4.3	5.5
		" lbs N/A	2.9	3.2	5.0	5.6	11.6	12.4	8.6	11.0
		Total - 60.3 lbs/A								
(9)		160 urea F (PD)								
	18	1600 + 140# starter	1.5	3.8	1.2	2.7	4.0	3.0	4.5	4.4
	31	" " "	3.3	3.5	2.2	1.1	8.1	9.2	8.7	8.0
	42	" " "	4.2	5.4	7.4	5.0	4.4	4.4	2.9	4.4
	67	" " "	0.8	3.8	3.7	4.7	19.8	8.8	11.4	13.7
		Average ppm N	2.5	4.1	3.6	3.4	9.1	6.4	6.9	7.6
		" lbs/A N	2.5	4.1	7.2	6.8	18.2	12.8	13.8	15.2
		Total - 80.6 lbs/A								
(10)		40 N - S								
	1	400 + 140# starter	2.9	2.9	2.1	1.9	1.0	1.5	1.7	1.9
	29	" " "	3.1	2.3	1.1	2.8	1.6	1.3	3.1	3.1
	44	" " "	1.2	2.3	0.9	0.9	1.1	2.3	1.5	1.5
	71	" " "	1.2	1.4	1.7	2.9	2.8	2.5	1.6	1.7
		Average ppm N	2.1	2.2	1.5	2.1	1.6	1.9	2.0	2.1
		" lbs/A N	2.1	2.2	3.0	4.2	3.2	3.8	4.0	4.2
		Total - 26.7 lbs/A								
(11)		40 urea S								
	10	400 + 140# starter	8.8	1.9	2.5	2.9	2.1	2.8	2.3	3.7
	35	" " "	3.8	2.9	2.0	2.1	0.9	2.3	1.6	2.3
	59	" " "	2.4	1.0	2.5	3.0	2.1	3.7	1.5	2.8
	64	" " "	3.6	3.5	0.7	2.3	3.9	2.4	3.3	2.4
		Average ppm N	4.7	2.3	1.9	2.6	2.3	2.8	2.2	2.8
		" lbs/A N	4.7	2.3	3.8	5.2	4.6	5.6	4.4	5.6
		Total - 36.2 lbs/A								

(Table 3. continued)

	Plot nos.	Total N applied/A	Soil depth in inches 0-6	6-12	12-24	24-36	36-48	48-60	60-72	72-84
			ppm NO_3-N							
(12)		80 N - S								
	2	800 + 140# starter	2.3	1.9	1.5	1.9	1.7	1.3	1.7	1.6
	25	" " "	1.4	2.9	2.9	1.1	1.5	2.7	1.9	2.8
	60	" " "	2.3	3.5	1.9	3.4	3.7	3.9	1.7	3.7
	78	" " "	3.0	1.9	1.3	1.9	2.1	2.7	2.3	3.4
		Average ppm N	2.3	2.6	1.9	2.1	2.3	2.7	1.9	2.9
		" lbs/A N	2.3	2.6	3.8	4.2	4.6	5.4	3.8	5.8
		Total - 32.5 lbs/A								
(13)		80 urea S								
	16	800 + 140# starter	10.8	3.3	3.2	2.5	2.9	3.0	3.2	3.7
	26	" " "	1.8	2.8	2.3	1.9	2.9	3.6	1.9	2.4
	57	" " "	2.8	2.5	2.9	2.5	3.6	3.8	3.0	2.6
	77	" " "	3.6	7.4	3.4	1.8	3.7	2.7	2.5	1.2
		Average ppm N	4.8	4.0	3.0	2.2	3.3	3.3	2.7	2.5
		" lbs/A N	4.8	4.0	6.0	4.4	6.6	6.6	5.4	5.0
		Total - 42.8 lbs/A								
(14)		40 N - SD								
	15	400 + 140# starter	3.1	2.3	1.9	2.6	2.6	3.0	2.4	3.5
	33	" " "	2.5	1.6	2.0	1.9	1.5	1.9	2.3	2.5
	49	" " "	1.3	1.7	1.7	1.3	2.8	3.6	4.3	1.9
	70	" " "	1.4	2.9	2.1	2.1	2.6	3.4	2.5	1.5
		Average ppm N	2.1	2.1	1.9	2.0	2.4	3.0	2.9	2.4
		" lbs/A N	2.1	2.1	3.8	4.0	4.8	6.0	5.8	4.8
		Total - 33.4 lbs/A								
(15)		40 urea SD								
	19	400 + 140# starter	8.4	2.3	2.3	2.6	3.5	2.4	3.5	2.4
	37	" " "	2.3	1.9	1.9	2.1	1.7	1.9	2.7	1.7
	52	" " "	6.7	2.5	3.2	3.3	5.3	4.6	4.2	1.9
	65	" " "	3.3	5.4	1.0	3.7	3.5	1.9	2.2	1.9
		Average ppm N	5.2	3.0	2.1	2.9	3.5	2.7	3.2	2.0
		" lbs/A N	5.2	3.0	4.2	5.8	7.0	5.4	6.4	4.0
		Total - 41.0 lbs/A								

(Table 3. continued)

	Plot nos.	Total N applied/A	Soil depth in inches 0-6	6-12	12-24	24-36	36-48	48-60	60-72	72-84
			ppm NO_3-N							
(16)		80 N - SD								
	11	800 + 140# starter	6.1	5.6	2.5	2.5	3.0	3.7	4.2	3.1
	38	" " "	10.1	3.7	1.2	2.3	2.7	2.7	1.9	2.3
	58	" " "	3.6	4.2	2.5	1.9	3.2	4.4	3.3	4.2
	63	" " "	8.2	3.7	2.5	2.4	2.4	3.0	3.7	2.4
		Average ppm N	7.0	4.3	2.2	2.3	2.8	3.5	3.3	3.0
		" lbs/A N	7.0	4.3	4.4	4.6	5.6	7.0	6.6	6.0
		Total - 45.5 lbs/A								
(17)		80 urea - SD								
	20	800 + 140# starter	3.1	1.4	2.5	1.7	3.2	2.4	2.7	1.5
	28	" " "	2.0	2.1	1.1	1.3	2.6	2.1	2.2	1.5
	47	" " "	2.7	4.1	2.1	3.6	2.2	2.6	3.1	3.0
	76	" " "	4.1	13.1	6.5	3.6	5.3	5.7	3.4	5.5
		Average ppm N	3.0	5.2	3.1	2.6	3.3	3.2	2.9	2.9
		" lbs/A N	3.0	5.2	6.2	5.2	6.6	6.4	5.8	5.8
		Total - 44.2 lbs/A								
(18)		160 N - SD								
	8	1600 + 140# starter	202.0	13.6	18.4	8.4	2.7	11.1	3.1	2.5
	34	" " "	0.6	4.6	2.3	8.7	4.2	9.9	10.2	6.8
	50	" " "	23.5	61.6	16.0	13.2	10.3	10.9	4.6	6.1
	68	" " "	36.8	80.0	11.5	1.2	5.6	11.5	4.4	10.9
		Average ppm N	65.7	40.0	12.1	7.9	5.7	10.9	5.6	6.6
		" lbs/A N	65.7	40.0	24.2	15.8	11.4	21.8	11.2	13.2
		Total - 203.3 lbs/A								

Table 4. The NO_3-N Content of Webster Clay Loam Near Lamberton Following 10 Years of Continuous Corn and N Fertilization.

Plot No.	7	3	9	13
Treat. No.	1	2	6	8
Lbs N/A in 10 years	140	540	940	1740
Soil depth in feet	NO_3-N in parts per million			
0.5	1.3	2.3	2.7	3.7
0.5 - 1	1.1	1.8	1.0	1.4
1 - 2	1.7	2.3	1.9	3.6
2 - 3	1.1	1.0	1.0	6.6
3 - 4	1.1	1.9	1.9	8.2
4 - 5	2.7	1.0	2.6	8.4
5 - 6	2.0	2.1	1.9	6.6
6 - 7	2.5	2.5	2.2	3.3
7 - 8	2.6	1.3	10.8	2.4
8 - 9	1.3	1.5	1.8	1.5
9 - 10	0.8	1.1	3.1	1.5
10 - 11	0.9	1.3	0.7	1.4
11 - 12	0.8	1.2	3.3	0.9
12 - 13	0.7	0.6	0.8	1.0
13 - 14	1.2	0.8	0.9	1.1
14 - 15	1.4	1.7	0.6	0.8
15 - 16	0.4	1.1	1.7	2.3
16 - 17	2.5	0.9	1.9	1.0
17 - 18	2.3	0.7	1.2	0.7
Total NO_3-N in lbs/A	56.8	50.1	80.3	107.7

Table 5(a)
(N in starter only)

Analyses of Soil Waters Under 1969 Continuous Corn at Lamberton
Tiled Webster clay loam-starter fertilizer of 8-24-12@175#/A.

Plot (yield bu/A)	Depth in feet	lbs N/A annually			NO_3-N in ppm			NO_2-N in ppm			PO_4-P in ppm			K in ppm			Conductance (mmhos/cm)		
		Central	East	West	July 2	July 17	Aug 5	July 2	July 17	Aug 5	July 2	July 17	Aug 5	July 2	July 17	Aug 5	July 2	July 17	Aug 5
(87)																			
4	2	14	54	54	3.1	1.2	1.5	0.2	0.1	1.0	1.08	0.05	0.10	2.76	2.91	1.4	0.34	0.22	0.24
"	3	"	"	"	3.6	-	1.7	0.2	-	0.1	0.17	-	0.03	1.13	-	4.6	0.37	-	0.70
"	4	"	"	"	3.7	1.4	-	0.2	0.1	-	0.11	0.01	-	4.09	1.37	-	1.30	1.38	-
"	5	"	"	"	2.3	1.7	3.2	0.2	0.1	0.2	0.05	0.01	0.01	1.51	1.42	1.4	1.72	1.78	1.80
"	6	"	"	"	3.0	2.1	3.4	0.1	0.1	0.1	0.05	0.03	0.01	1.78	1.42	1.8	1.65	1.65	1.64
(88)																			
7	6	14	94	174	53.0	-	-	0.3	-	-	0.01	-	-	2.29	-	-	2.14	-	-
(103)																			
32	3	14	174	54	6.1	-	-	0.1	-	-	1.06	-	-	1.73	-	-	0.35	-	-
"	4	"	"	"	7.1	5.8	-	0.1	1.0	-	0.23	0.02	-	0.73	0.76	-	0.48	0.78	-
"	5	"	"	"	12.0	4.7	3.7	0.1	0.2	9.0	2.30	0.01	0.01	1.64	2.83	5.9	0.42	0.94	0.86
(101)																			
73	3	14	94	94	3.6	-	1.1	0.5	-	0.1	0.21	-	0.06	6.10	-	5.1	0.96	-	0.58
"	4	"	"	"	7.9	2.5	0.9	0.1	2.0	0.1	0.05	0.01	0.01	1.07	3.63	2.1	0.46	1.40	0.59
"	5	"	"	"	1.0	1.3	-	0.1	0.3	-	0.05	0.18	-	12.0	8.90	-	1.90	1.76	-
								Water outside plots - toward drain tile											
(88)																			
7	3.5	0 (14)	0 (94)	0 (174)	24.4	-	7.9	0.4	-	1.0	0.13	-	0.18	1.56	-	3.8	0.71	-	0.84
(77)																			
79	3.5	0 (14)	0 (94)	0 (14)	8.1	-	-	0.2	-	-	0.01	-	-	1.36	-	-	0.49	-	-

Table 5(b)
54 & 94# N/A

Analyses of Soil Waters Under 1969 Continuous Corn at Lamberton
Tiled Webster clay loam-starter fertilizer of 8-24-12@175#/A

Plot (yield bu/A)	Depth in feet	lbs N/A annually			NO_3-N in ppm			NO_2-N in ppm			PO_4-P in ppm			K in ppm			Conductance (mmhos/cm)		
		Central	East	West	July 2	July 17	Aug 5	July 2	July 17	Aug 5	July 2	July 17	Aug 5	July 2	July 17	Aug 5	July 2	July 17	Aug 5
									Wells within plots										
(130)																			
48	3	54	94	54	4.3	-	-	0.2	-	-	0.06	-	-	1.56	-	-	0.56	-	-
"	4	"	"	"	3.9	-	-	0.1	-	-	0.01	-	-	2.66	-	-	1.20	-	-
(136)																			
11	2	94	54	14	-	3.8	1.5	-	0.1	0.2	-	0.08	0.08	-	5.10	1.6	-	0.98	0.25
"	3	"	"	"	22.9	-	1.9	5.0	-	0.5	0.08	-	0.06	0.94	-	1.3	1.80	-	0.51
"	4	"	"	"	16.0	7.4	-	0.3	8.0	-	0.09	0.01	-	3.14	6.95	-	1.73	2.50	-
"	5	"	"	"	-	-	4.3	-	-	0.5	-	-	0.01	-	-	11.0	-	-	2.58
"	6	"	"	"	-	5.7	7.7	-	4.0	6.0	-	0.01	0.01	-	6.90	6.2	-	3.00	3.00
(115)																			
38	5	94	54	14	-	8.0	11.3	-	0.8	0.7	-	0.01	0.01	-	1.89	2.4	-	0.85	0.98
"	6	"	"	"	-	7.6	11.5	-	2.0	2.0	-	0.01	0.01	-	2.69	5.4	-	1.31	1.35
(145)																			
58	3	94	94	54	14.5	2.9	-	0.4	2.0	-	0.05	0.01	-	3.48	7.30	-	1.66	1.50	-
"	4	"	"	"	6.7	1.2	1.7	2.0	1.0	0.1	0.01	0.01	0.01	8.70	9.05	10.9	3.40	3.50	3.60
"	5	"	"	"	4.3	2.3	2.0	6.0	4.0	0.2	0.04	0.01	0.02	9.10	6.71	10.6	3.25	2.40	3.40
(165)																			
63	3	94	54	54	32.2	-	-	0.1	-	-	0.04	-	-	2.88	-	-	0.84	-	-
"	6	"	"	"	14.9	-	-	0.1	-	-	0.03	-	-	3.05	-	-	2.60	-	-

Table 5(c)
174# N rate

Analyses of Soil Waters Under 1969 Continuous Corn at Lamberton
Tiled Webster clay loam-starter fertilizer of 8-24-12 at 175#/A

Plot (yield bu/A)	Depth in feet	lbs N/A annually			NO_3-N in ppm			NO_2-N in ppm			PO_4-P in ppm			K in ppm			Conductance (mmhos/cm)		
		Central	East	West	July 2	July 17	Aug 5	July 2	July 17	Aug 5	July 2	July 17	Aug 5	July 2	July 17	Aug 5	July 2	July 17	Aug 5
									(Wells within plots)										
(147)																			
8	3	174	14	94	-	27.5	-	-	10.0	-	-	0.03	-	-	4.67	-	-	0.91	-
"	4	"	"	"	-	36.5	-	-	14.0	-	-	0.04	-	-	9.50	-	-	0.62	-
"	5	"	"	"	-	55.0	56.0	-	5.0	0.4	-	0.04	0.01	-	4.28	3.2	-	0.63	3.70
"	6	"	"	"	-	71.0	-	-	0.8	-	-	0.01	-	-	2.26	-	-	0.58	-
(132)																			
34	2	174	54	54	8.8	-	-	0.2	-	-	0.39	-	-	3.98	-	-	0.42	-	-
"	3	"	"	"	11.2	3.6	1.4	0.2	0.1	0.7	0.32	0.09	0.05	1.10	1.13	0.5	0.32	0.28	0.19
"	4	"	"	"	37.2	-	-	0.2	-	-	0.27	-	-	2.40	-	-	0.67	-	-
(156)																			
42	4	174	14	54	-	2.3	-	-	0.4	-	-	0.01	-	-	3.41	-	-	1.62	-
(169)																			
50	2	174	54	94	36.1	-	1.2	0.2	-	0.3	0.08	-	0.05	2.50	-	1.9	0.71	-	0.22
"	3	"	"	"	7.0	11.4	4.2	0.1	0.2	0.2	0.36	0.16	0.04	1.51	5.40	1.3	0.24	1.14	0.35
"	4	"	"	"	35.7	47.0	-	0.2	3.0	-	0.02	0.01	-	3.12	4.72	-	1.84	0.36	-
(146)																			
68	2	174	174	54	11.0	-	-	0.4	-	-	0.08	-	-	4.39	-	-	0.50	-	-
"	3	"	"	"	10.0	-	1.5	0.1	-	0.2	0.07	-	0.03	1.33	-	1.8	0.36	-	0.43
"	4	"	"	"	26.9	14.6	17.9	6.0	6.0	2.0	0.01	0.01	0.02	4.08	5.60	1.2	2.40	1.97	1.60
"	5	"	"	"	30.8	33.2	-	0.2	0.8	-	0.03	0.01	-	1.60	1.56	-	1.53	1.08	-
"	6	"	"	"	44.5	62.0	47.7	4.0	5.0	10.0	0.05	0.01	0.01	7.60	6.15	7.2	2.17	0.37	2.28

Table 5(d)
Wells outside plots

Analyses of Soil Waters Under 1969 Continuous Corn at Lamberton
Tiled Webster clay loam-starter fertilizer of 8-24-12 at 175#/A

Plot (yield bu/A)	Depth in feet	lbs N/A annually			NO_3-N in ppm			NO_2-N in ppm			PO_4-P in ppm			K in ppm			Conductance (mmhos/cm)		
		Central	East	West	July 2	July 17	Aug 5	July 2	July 17	Aug 5	July 2	July 17	Aug 5	July 2	July 17	Aug 5	July 2	July 17	Aug 5
								Wells outside plots (12' from tile line)											
(88)		0	0	0															
7	3.5	14	94	174	24.4	-	1.3	0.4	-	0.1	0.13	-	0.02	1.56	-	6.4	0.71	-	0.84
(77)		0	0	0															
79	3.5	14	94	14	8.1	-	-	0.2	-	-	0.01	-	-	1.36	-	-	0.49	-	-
(146)		0	0	0															
15	3.5	54	54	94	19.2	-	-	0.2	-	-	0.05	-	-	0.98	-	-	0.43	-	-
(138)		0	0	0															
33	3.5	54	14	174	19.2	-	-	0.1	-	-	0.06	-	-	0.51	-	-	0.30	-	-
(145)		0	0	0															
70	3.5	54	54	54	4.7	-	-	0.1	-	-	0.04	-	-	0.79	-	-	0.26	-	-
(115)		0	0	0															
38	3.5	94	54	14	-	9.6	-	-	0.5	-	-	0.01	-	-	0.80	-	-	0.44	-
(145)		0	0	0															
58	3.5	94	94	54	19.3	-	-	0.1	-	-	0.05	-	-	0.96	-	-	0.72	-	-
(147)		0	0	0															
8	3.5	174	14	94	107.0	-	7.9	0.3	-	1.0	0.20	-	0.18	5.60	-	3.8	1.45	-	0.84

(Table 5d. continued)

Plot (yield bu/A)	Depth in feet	lbs N/A annually			NO_3-N in ppm			NO_2-N in ppm			PO_4-P in ppm			K in ppm			Conductance (mmhos/cm)		
		Central	East	West	July 2	July 17	Aug 5	July 2	July 17	Aug 5	July 2	July 17	Aug 5	July 2	July 17	Aug 5	July 2	July 17	Aug 5
					Wells outside plots (12' from tile line)														
(132)		0	0	0															
34	3.5	174	54	54	11.7	-	-	0.1	-	-	0.08	-	-	0.27	-	-	0.23	-	-
(146)		0	0	0															
68	3.5	174	174	54	23.8	8.7	-	0.2	0.1	-	0.05	0.01	-	1.34	5.10	-	0.43	0.67	-

Table 6. Zinc Concentrations of the Sixth Corn Leaf at Silking in 1969 in the Tenth Year of Continuous Corn and Different N Fertilization of a Webster Clay Loam at Lamberton.

	[1] Zinc in leaves as ppm				
Annual N (lbs/A)	1	2	3	4	Average
1) Check	24.7	21.7	15.2	17.2	19.7 abc
2) 40 as NH_4NO_3-fall plow down	18.8	15.9	16.5	17.5	17.2 ab
3) 40 " urea - " " "	19.4	21.7	22.0	15.0	19.5 abc
4) 40 " NH_4NO_3-fall plow surface	17.1	20.1	16.7	15.7	17.4 ab
5) 40 " urea - " " "	20.1	14.9	21.9	16.4	18.3 abc
6) 80 " NH_4NO_3-" " down	21.1	20.1	17.8	20.3	19.8 abc
7) 80 " urea - " " "	23.2	21.4	23.7	18.1	21.6 bcd
8) 160 as NH_4NO_3-" " "	22.4	-	36.2	17.4	25.4 d
9) 160 " urea - " " "	18.6	28.3	24.3	20.7	23.0 cd
10) 40 " NH_4NO_3-spring topdress	21.1	21.0	17.8	18.1	19.5 abd
11) 40 " urea - " "	22.1	14.8	16.4	15.5	17.2 ab
12) 80 " NH_4NO_3- " "	23.1	20.2	18.1	15.2	19.2 abc
13) 80 " urea - " "	20.4	18.3	24.1	15.0	19.5 abc
14) 40 " NH_4NO_3-sidedress	19.6	18.4	17.6	19.1	18.7 abc
15) 40 " urea - "	17.1	16.3	17.8	16.7	17.0 a
16) 80 " NH_4NO_3- "	23.0	17.5	19.6	16.6	19.2 abc
17) 80 " urea - "	18.1	18.9	18.7	18.1	18.5 abc
18) 160 " NH_4NO_3- "	23.4	21.1	21.5	19.1	21.3 bcd

[1] The entire area received an additional 14 lbs N/A annually as starter fertilizer (8-24-12@175 lbs/A).

Average soil pH of treatment 15(lowest leaf zinc) = 6.2
" " " " " 8(highest " ") = 5.8